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Research on Energy-saving Technology of Air-conditioning Water Cooling Storage

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Abstract: Cold storage air-conditioning is widely used in daily life. Generally, it refers to turning on the chiller at night when electricity is low to store cold, and when there is a lot of electricity during the day, the stored cold source at night is released into the system. This article introduces the water-storage energy-saving technology of air-conditioning, including a brief introduction to the water-storage technology, working principles, benefits, technical improvements and its application prospects.

Keywords Air conditioning; Water storage; Energy saving technology; Application

INTRODUCTION

With the rapid growth of my country's economy and the continuous improvement of people's living standards, in recent years, especially the demand for air-conditioning terminals caused by the hot summer effect has continued to increase, and air-conditioning has increasingly become one of the necessities of people's lives. As of 2020, after nearly 30 years of development in the domestic air-conditioning industry, the industry has moved from an incremental market to a stage of stock competition, and due to the impact of the new crown epidemic on the economy and people's daily lives, people are paying more and more attention to the energy-saving and environmental protection performance of air-conditioners. The impact on human health, how to reduce the power consumption of air-conditioning under the premise of ensuring indoor air quality, so as to save electricity costs has become a hot topic of research. Air-conditioning water and cold storage technology [Fang, *et. al.*, 2016] is increasingly favored by people due to its good energy-saving and environmental protection functions. This technology mainly uses the principle similar to batteries, when the electricity consumption is low, the air conditioner is stored for cold storage, and when the electricity consumption is high, the accumulated energy is released. Therefore, the air-conditioning water and cold storage technology has extremely important strategic significance for peak shaving, valley filling, load adjustment and power saving.

In the air-conditioning system, the water-storage energy-saving technology is one of the important measures to solve the extremely imbalance between the minimum and maximum usage during operation. The working principle of the air-conditioning water cold storage technology is: when the power is used at low load at night, the accumulated cold energy is stored for use by the white sky when the electricity peak is used, so as to achieve the effect of balancing the operating time of the refrigeration equipment. In addition, air-conditioning water cold storage technology can reduce the installed capacity of chillers, reduce the installed capacity of auxiliary equipment (such as water pumps, cooling towers, transformers, etc.), so that refrigeration equipment can operate at full load and efficiently, and it can also balance grid load. The cold storage technology of air conditioner mainly includes two kinds, one is water cold storage, the other is ice cold storage. We mainly discuss the water cold storage energy-saving technology.

BASIC CHARACTERISTICS OF WATER STORAGE TECHNOLOGY

The composition of the cold water storage system and their respective functions

Refrigeration units, circulating water pumps, pipes, terminal equipment, cooling towers, etc. form a water cold storage system. The chilled water temperature is generally 7℃/12℃, which is the same as the summer cooling of household air conditioners. The outdoor unit is a condenser to provide outside air. Heat dissipation, the room is an evaporator, used to absorb the excess heat in the room, and is realized by the evaporation and condensation of the refrigerant. In the chilled water system (generally the load is relatively large), chilled water is used as a medium and sent to the end air pan (including the coil and the fan). The fan makes the indoor air circulate through the coil and exchange heat with the chilled water to achieve the cooling effect. After the heat

exchange, the temperature of the chilled water rises from 7℃ to 12℃, and the temperature at the evaporator side of the refrigeration unit drops to 7℃ to reach the cycle. The condenser side of the refrigeration unit releases heat. Generally, the cooling tower is used to release the heat. Water is also required as a medium to take away the heat. Here, the water is called cooling water. Disperse to the air, cool down, and then return to the condenser. The transfer of heat and cold of the refrigeration unit depends on the refrigerant.

Cooling method

There are two cooling methods, one is that the refrigerator operates in the original way, and the other is the cold storage tank. The two cooling modes can be used in combination. During the day, part of the cooling capacity is provided by the refrigerator and part of the cooling capacity is provided by the cold storage tank.

Characteristics of water storage technology

1. The total number of boot hours per year is less than that of conventional systems;
2. When storing cold at night, the temperature will decrease, and the cooling effect will be improved to a certain extent. The unit is in an efficient operation state, and the efficiency can be increased by nearly 5-7%. The total power saving rate of the air-conditioning system is not less than 11%.
3. The electricity price difference of the time-sharing power supply policy is obtained from this. "Sell high and buy low", which can also save a lot of electricity bills and save electricity.

PRINCIPLES AND DESIGN PRINCIPLES OF WATER STORAGE TECHNOLOGY

Design principle

The design principle of energy-saving air-conditioning water storage system [6] is to use the equipment unit to work when the power consumption is low at night to cool the water into chilled water, and then release it during the day to be used for the cooling of the air-conditioning water storage system, so that it can be reduced. The purpose of peak filling. It can be simplified to charge cold at night and let it cool during the day. The schematic diagrams of charging cold at night and releasing cold during the day are shown in Figure 1 and Figure 2, and the schematic diagram of the cold water storage system is shown in Figure 3 [Liu, et. al., 2013].

Design principles

There are many factors to be considered in the design of cold storage water, including various factors that affect the initial investment and operating costs. Study the relationship between electricity consumption, electricity price and total electricity fee as much as possible, and the peak and low electricity consumption. Factors such as the electricity price structure, thereby achieving the most satisfactory economic benefits, reducing the initial investment while reducing electricity consumption, in order to achieve the effect of reducing electricity bills.

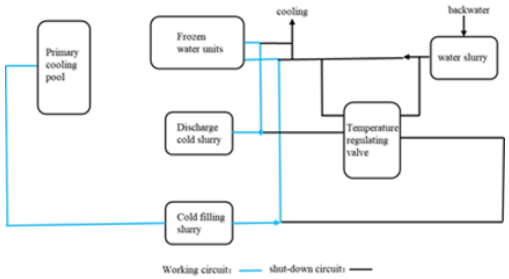

Figure 1 Schematic diagram of charging and cooling at night

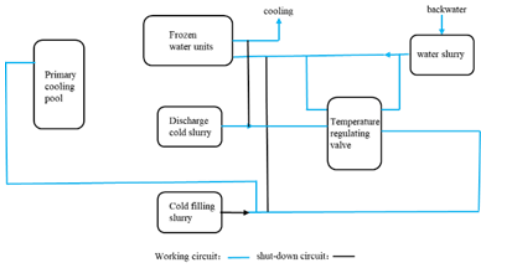

Figure 2 Schematic diagram of cooling down during the day

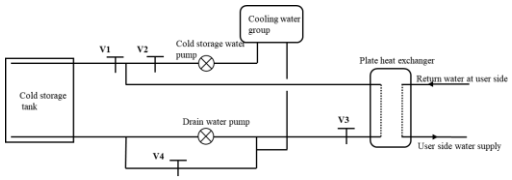

Figure 3 Schematic diagram of water storage system

If the energy-saving design of water storage is carried out, accurate analysis of the characteristics of building air-conditioning load is an indispensable step. We need to understand the changes in the electricity consumption of electricity-consuming buildings over time. With reference to this relationship function, we can select the system type more accurately and know how to control the system. This is to better design the space occupied by the object, ensure the efficiency of the host and reduce energy consumption on the basis of meeting the work requirements.

When we design an air-conditioning system using water-storage energy-saving technology, we must consider many factors, such as the matching performance and operating conditions of the equipment units. When designing with mathematical modeling, it is ensured that the work task can be completed, the electricity consumption is the least, and the consumption is the least.

THE FORM OF COLD WATER STORAGE

Diaphragm method

The water storage tank for cold storage applications is equipped with a movable flexible membrane or hard plate. This partition or membrane is used to separate the water of different temperatures in the storage tank. Most of this partition or membrane is horizontal. , So you can't use the diffuser, thereby reducing costs. However, the disadvantage of this method is that both the flexible membrane and the partition require costly maintenance. Compared with the diffuser, it does not show its own advantages in terms of operation and maintenance.

Natural layered water storage

Natural stratified water storage is the simplest and most effective and most affordable water storage method. This method does not cause the problem of water flow. Compared with the partition method, there is no partition maintenance cost. The rationally designed natural stratified water storage efficiency can reach 87%-96%. This method must use a tool for drainage, that is, a diffuser. Due to the different densities of different liquids, gravity flow is generated with the help of the difference in density, which then produces a smaller limit of hot and cold water not mixing, and the thickness is also as thin as possible. This method needs to pay attention to the reasonable control of the water flow velocity of gravity flow, and also need to weaken the disturbance of the thermocline layer to avoid its destruction of the water flow velocity. This method is suitable for upright flat-bottomed cylindrical water storage tanks.

Maze Method

As shown in Figure 4, this method uses partitions to divide the water tank into multiple small units, so that the water flow can cross each unit in turn according to the designed route. This method can effectively prevent the mixing of hot and cold water. In the labyrinth method, hot water enters from the bottom inlet and cold water enters from the top inlet during the cold storage and release process. This design will cause the cold water and hot water to mix under the action of buoyancy and gravity. Too high a flow rate of hot and cold water will cause the mixing speed of hot and cold water to exceed expectations, which will cause the water flow to be blocked and reduce the capacity of the cold storage system.

In summary, the above three methods have their own advantages and disadvantages, but in general, natural layered water storage is the most beneficial water storage method.

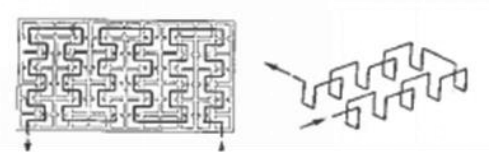

Figure 4 Road map of water flow in labyrinth cold storage tank

TYPES OF WATER STORAGE

Centralized energy storage is a commonly used method in energy-saving technologies for cold storage and air conditioning. Under normal circumstances, the total cold storage capacity is 25500RT. On the basis of making full use of peak and valley electricity prices and saving operating costs, water storage cold storage can play the role of "cutting peaks and filling valleys", thereby solving the problem of power shortage to a certain extent. Studies have shown that the water storage cold storage is expected to save 2% of operating costs, which can save 345 million yuan per year compared with traditional refrigeration technology.

Labyrinth type

Generally speaking, if the cold storage space is too small, the labyrinth type will be used. Countries like Japan with many earthquakes and small area often adopt cold storage technology with a small space when designing buildings, that is, using this labyrinth-type water storage technology. Generally not often used in earth buildings.

Single slot, multi slot type

Different from the labyrinth type, the limitation of this type is that the height is limited, and the single groove type is not easy to control and difficult to be reliable. Rigid partitions are often installed to assist in use.

Multi-slots are connected in series. Rigid baffles are required to be set just like single-slots, but several should be set according to the number.

Naturally layered type

Its core feature is that the natural gravitational stratification is formed by water of different densities and different temperatures, and the thermocline formed by the mixture of hot and cold water is the separation layer between the hot and cold water areas.

In summary, the above three types of water storage [10] have their own advantages and disadvantages, which can be selected and used according to different actual conditions, but the most commonly used is the natural layered type of water storage.

In addition to the water storage technology, the current commonly used cold storage technology is also ice storage technology. Its ice storage system uses electric refrigeration and water-cooled air-conditioning as the main mechanism of ice, and uses preferential electricity prices to store ice in the period of low power consumption and low load. In ice storage equipment. During the day when the power load is high, avoid peak electricity prices, stop or intermittently operate the electric refrigeration host and water-cooled air conditioner, and release the ice storage capacity storage device to meet the needs of the water-cooled air conditioner load. The performance comparison between ice storage technology and water storage technology is shown in Table 1. In terms of power consumption, ice storage air conditioning consumes more power than water storage air conditioning; compared with investment, ice storage air conditioning has higher investment than water storage air conditioning , Compared with the form of energy storage, water storage is comparable to ice storage; in terms of after-sales maintenance costs, ice storage is 6-10 times higher than water storage. It can be seen from Table 1 that the water storage method has the advantages of low power consumption of the chiller, low initial investment of the cold storage system, convenient source of the cold source of the system, low technical requirements, low operating cost and high coefficient of refrigeration performance. However, there is also the disadvantage of large volume of the cold tank. If the cold storage pool and the fire-fighting pool are used in combination, the disadvantages of this shortcoming will be infinitely reduced.

Table 1: Performance comparison between ice storage system and water storage system

project	Ice storage system	Water storage system
Cold storage tank volume	Small (only 10%-35% of the water storage system)	Big
Cold machine chilled water outlet temperature	1-3℃	4-6 ℃
Cooling machine power consumption	Higher	Lower
Investment in cold storage system	Higher	Lower
Cold storage cold source	Need to be able to operate independently of the ice machine to form a dual working condition cooler	Can use existing system cold source
Design and operation	High technical requirements and high operating costs	Low technical requirements and low operating costs
Coefficient of refrigeration performance COP	Low (10%-20% lower than water storage)	Higher
Other uses	without	Can be used in conjunction with existing building spaces such, and can be used as a heat storage system in winter

CALCULATION OF COLD STORAGE CAPACITY AND MAXIMUM COOLING RATE OF WATER STORAGE AIR CONDITIONING

According to the literature [10,11], the calculation formula for the volume V of the cold storage tank is:

$$V = 3600 \times (\frac{Q}{Q_t}) \times \rho \times C \times \mathrm{FOM} \times a \qquad (1)$$

Constant: ρ= (1000kg/m3);

C= Specific heat capacity of cold water (4.18kJ/kg* ℃);

Variable: Q= Cold storage capacity (RT);

Q_t = The temperature difference between cooling and storage;

FOM= Insulation efficiency of cold storage tank;

a= The volumetric efficiency of the cold storage tank.

The use of water-storage air-conditioning technology needs to determine the maximum cold storage capacity and maximum cooling rate of the water-storage air conditioning.

Assuming that the rated cooling capacity is $q_1(KW)$, the energy supply time is $t_1(h)$, R is the proportional factor between the cold storage time and the working time, and the cold storage time $t_x(h)$, then:

$$\begin{aligned} S_1 &= S - S_1 = S_2 + S_x \\ &= q_1 t_1 + R q_1 t_x = q_1 (t_1 + R t_x) \end{aligned} \qquad (2)$$

where S_1 = Design circuitous cooling capacity after deducting the cooling capacity of the basic equipment;

S = Objects are cold loaded for 24 hours;

S_1 = Basic equipment provides cold load;

S_2 = Cooling load capacity of the refrigeration unit;

S_x = Device releases cooling capacity.

The rated cooling capacity of the available refrigerator air conditioner:

$$S_1 = S_2 t_1 - R t_x \quad (3)$$

Among them: the cold storage capacity of the refrigerator $\geq q_1$.

Assumed system cold storage rate $a = \frac{S_x}{S} = S_x / (S_1 + S)$, From the formula (3), it can be seen that $S \geq 0$, the maximum cold storage rate of the air conditioner can be determined as:

$$a = S_{\max} = S_x S_1 = R q_1 t_x q_1 (t_1 + R t_x) = R t_x t_1 + R f_{x'} \quad (4)$$

It can be seen from formula (4) that a is related to $t_1(h)$, R, and cold storage time $t_x(h)$. The larger R, the smaller the capacity, and the greater the maximum cold storage rate.

THE BENEFITS OF AIR CONDITIONING WATER AND COLD STORAGE ENERGY-SAVING TECHNOLOGY

It can be seen from the above that the water-storage energy-saving technology can not only make full use of the large gap between the day and night due to the time of electricity use for cold storage and energy storage, and thus achieve the purpose of saving electricity, but also can continue to promote technological innovation, which is important for China's rapid economic growth. In terms of it, it is undoubtedly a great project. For individual applications, after the host device uses the water-storage energy-saving technology, its cooling efficiency can be increased by 6% to 8% during energy storage operation, and the total power saving rate of the air-conditioning system is about 10% [12]. When individual users are expanding their capacity or want to install a new refrigeration and air-conditioning system, they can choose water-storage air-conditioning, which uses the difference in electricity time to freeze water at night, and releases the stored chilled water to provide cooling during the daytime peak power consumption. Then it alleviates the situation of excessive electricity consumption, and to a certain extent makes up for the shortcomings caused by the peak electricity consumption. It not only reduces the electricity consumption of users, reduces electricity bills, but also relieves the pressure on the national grid. Water storage air conditioners, in short, store cold energy when there are few electricity users. On the whole, its energy-saving effect is more significant [13]. Taking Shandong Province as an example, in 2020 Shandong Province will consume 551.37 billion kilowatt-hours of electricity, of which thermal power will be 5067.2 kilowatt-hours, accounting for about 91.9% of the total electricity consumption. If the cold water storage technology is adopted, the initial investment can be reduced by 1,500 yuan for every 1kW peak load transferred. This shows that the cold water storage technology can greatly save investment.

APPLICATION PROSPECT AND DIRECTION OF WATER STORAGE TECHNOLOGY

The use of water-storage energy-saving technology can not only alleviate the time difference in power consumption, but also ease the contradiction between power construction and new power consumption to a certain extent, which is one of the effective means to solve this contradiction [14]. Therefore, various policies to promote the vigorous development of water-storage air-conditioning energy-saving technologies have also been introduced in various provinces and cities to support the popularization and development of water-storage air-conditioning technologies. Not only new projects are suitable for the application of water storage technology, but also renovation projects are suitable for the application of this energy-saving technology.

In our country, the water tank volume can be reduced by increasing the working temperature difference of the water storage air conditioner, thereby reducing the cost and heat loss, and the energy consumption of liquid transmission will also be reduced. The water storage capacity exceeds a certain limit, and the establishment of water storage tanks in the open space or the full use of existing pools can bring great benefits. In addition, if the water-storage energy-saving technology is used in an area with a suitable latitude and a heat pump system, it can be used for winter heat storage and summer cold storage. This use method can improve the utilization efficiency of cold storage tanks, and in certain The degree is more economical.

At the early stage of the development of water-cooling technology, some areas of my country adopted water-cooling energy-saving technology when installing air conditioners on some stadium buildings, because the inlet temperature of

conventional air conditioners was 7℃ and the outlet water temperature was 12℃. Under such constraints, The working temperature of the cold-carrying body has only increased by 5℃, which makes the volume of the cold storage pool larger, and the floor space, cost, and cold loss during the cold storage process are correspondingly increased, so it is difficult to popularize this technology. In recent years, many researchers in our country have conducted a lot of exploration and research on the improvement of air-conditioning water storage technology. After a series of case studies [15], the working temperature difference of the cold carrier has been extended to 8~10℃, even Beyond this range, the cold storage density has also increased from the original 5000 kcal/m3 to 10000 kcal/m3. The improvement of cold water storage technology has greatly reduced the volume of cold storage tanks, and the project cost, heat transfer loss and power consumption of cold carrier transportation will be reduced to a certain extent, which greatly promotes the promotion and application of this technology .

CONCLUDING REMARKS

This article introduces the composition, design principles, working methods, etc. of the cold water storage system, and can understand the user benefits and social benefits it brings, master the calculation of cold storage capacity and cold storage rate, and understand the methods to improve water cold storage energy-saving technology. However, since this article only conducts theoretical research on cold water storage technology, and has not conducted actual field application and testing, further field research and design are needed in order to better promote cold water storage technology.

REFERENCES

Duan Yi Example analysis of the application of water storage technology in the data center[J]. Refrigeration and Air Conditioning,2015,15 (9):81-86

Fang Guiyin, Yu Lin, Yang Fan The current situation and development trend of air-conditioning technology[J]. Refrigeration and air conditioning,2006 (1):1-5

Gao Xiaohui Research and selection of refrigeration station transformation scheme in the western part of Capital International Airport[D]. Beijing: North China Electric Power University,2017

He Jiangming, Cui Chengxuan Application of water storage and energy saving in central air conditioning system[J]. Telecommunications,2008 (8):41-43

Liu K J，Zhang Q L，Li D Y. Application Analysis of Chilled Water Storage Technology in the Transformation of Central Air Conditioning System[J]. Advanced Materials Research，2013，608-609：1097-1105.

Hu Qianlong The application of water storage and cooling technology in the waterway multi-link unit is studied[J].Daily Appliances,2018 (6):46-50

Polaris Power Network News Center. In 2020, the economy and electricity growth rate of all provinces will be the highest in the country[J/OL]. https://news.bjx.com.cn/html/20210210/1135944.shtml，2021-02-10.

Su Gang, Wang Jun, Zhang Minhua Application of water storage and cooling technology in the air conditioning transformation project of a factory[J]. Clean and air conditioning technology,2019 (02): 80-85

Sun Tie . Water storage can be used in energy-saving applications in air conditioning systems[D]. Chongqing: Chongqing University,2018

Teng Shixing Analysis of water storage cooling schemes in high-density data centers[J]. Building Electric,2019,38 (1):29-34

Wei Yiping The design and application of water storage technology in general hospitals[J]. Shanghai Construction Technology,2020 (1):29-31

Xu Mingming Analysis of the scheme of heat and cooling system for waste heat in an industrial area of Shanghai[J].Shanghai Energy Saving,2021 (5):499-507

Zhang Naifeng, Xu Helin, Wu Wenfei Water storage technology is used in the design and application of air conditioning cold source[J].Bautou College of Steel,Journal, 1998 (4):75-78

Zhang Weili, Li Heng, Ren Fengyan Application of water storage and cooling technology in an engineering[J].Hebei Industrial Technology,2015,32 (2):155-160.