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Study of Chilled Water Storage System in Subway Engineering: A Case Study of a Subway Station in Guangzhou

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Abstract: Based on the distribution of cooling load at a subway station and the peak-valley electricity price in Guangzhou, a chilled water storage system is reserved in the ample space above the station's distribution area. This study proposes a design scheme and operational strategy for a chilled water storage system suitable for subway engineering, based on calculating the cooling load and designing a chilled water storage system in a subway station. Additionally, it proposes calculation coefficients of hourly cooling load suitable for subway engineering and convenient for estimation of hourly cooling load. Furthermore, an economic analysis is conducted by combining hourly cooling load with time-of-use electricity prices. This study provides a reference for the design and application of chilled water storage systems in subsequent subway projects.

Keywords: Chilled water storage; Subway station; Hourly cooling load; Peak-valley electricity price

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1. Introduction

The transportation sector has become the dominant user of energy consumption and carbon emissions in China, with the continuous enhancement of urbanization level and the diversification of transportation logistics and travel demands [1]. In 2020, the Chinese government announced at the United Nations Assembly, its commitment to achieving carbon peak by 2030 and carbon neutrality by 2060. Urban rail transit, as a crucial component of urban public transportation, is widely regarded as a significant means to alleviate traffic congestion and achieve energy conservation and emission reduction due to its characteristics of high speed and large capacity. According to statistics, as of 2023, 59 cities in China had opened 338 urban rail transit lines, with a total operating line length of 11,224.54 km. In the same year, the total passenger traffic reached 29.466 billion trips, with a total electricity consumption of 24.977 billion kWh [2]. The ventilation and air conditioning system, as a crucial component of energy consumption and environmental protection, accounts for approximately 25%–35% of the total energy consumption in subways [3], and in humid and hot regions such as Guangzhou, this proportion can even reach 40% [4–6].

The rapid increase in air conditioning load has become the primary cause of seasonal power shortages, leading to a widening peak-valley difference in the power grid and compromising grid safety. Cold storage technology takes advantage of sensible heat, latent heat, or the heat of chemical reaction during the phase change of a working medium to store cold energy [7]. Specifically, during periods of low electricity demand, the cold produced by a chiller unit is stored in a cold storage device, and during periods of high electricity demand, the cold is retrieved from the device to meet the user's needs [8]. On the one hand, it can reduce the peak load on the power grid, achieve the goal of "peak load shifting," [9] and improve the efficiency and stability of the grid. On the other hand, it can leverage the difference in peak and valley electricity prices to generate considerable economic benefits for users [10].

In the 1930s, cold storage technology was first applied in large and medium-sized buildings such as factories and theaters in the United States [11]. China introduced cold storage technology in the 1990s, and currently, over a thousand cold storage projects have been built and put into use [12]. Researchers have extensively explored the theory and practice of cold storage technology [13]. However, failure cases of cold storage applications are not uncommon, especially in special fields such as subway engineering construction.

Currently, the design process and calculation methods for cold storage in subway engineering remain unclear. The calculation of cooling load serves as a crucial basis for the design of the cold storage system. In the early stage of design, the coefficient method is commonly used to estimate the hourly cold load on the design day, to construct the cold storage system, and to obtain approximate parameters. However, there is currently a lack of default coefficients for subway stations [14]. Additionally, the cold storage time in subway stations is shorter than that in general buildings, and equipment rooms require continuous cooling 24 hours a day [15]. The current load calculation methods cannot accurately reflect the actual load distribution characteristics of subway stations, and the typical hourly load cannot fully represent the actual load distribution throughout the year, resulting in significant deviations between calculated results and actual data.

In response to the aforementioned issues, this paper systematically investigates the design methods and calculation procedures suitable for chilled water storage systems in subway stations. By adopting a partial load storage cooling approach, the chiller unit stores cold water while supplying cooling during valley electricity pricing periods, while during peak electricity pricing periods, priority is given to supplying cooling from the cold water storage tank, with any insufficient cooling capacity being supplied by the chiller unit. A monthly load coefficient model and an hourly load coefficient model have been established. A method combining hourly cooling capacity with time-of-use electricity pricing is adopted to calculate the static investment recovery period during the whole air-conditioning season, providing an economic analysis of the chilled water storage scheme for subway stations.

2. Methods and case study

2.1. Project overview

The project is located in Guangzhou, China. It involves the construction of an underground two-level island platform station. The total length of the station is 423 m, with a standard section width of 23.5 m. The total area of the station is 24,899 m^2. The station hall above the track area possesses ample space, which is suitable for the consideration of implementing chilled water storage technology applications.

2.2. Conventional water system design scheme

The design cooling load of the station is 1,369 kW, with a large system design cooling load of 768 kW and a small system cooling load of 601 kW. The conventional water system design scheme uses a primary pump variable flow system. The supply/return water temperature for the chilled water system is calculated at 7°C/14°C, while the supply/return water temperature for the cooling water system is calculated at 32°C/37°C.

2.3. Water cooling storage system design scheme

Currently, the primary cold storage media used in air conditioning systems include water, ice, and eutectic salts. Compared to the other two cold storage systems, the chilled water storage system boasts a relatively lower initial investment and more lenient requirements for terminal equipment. It can utilize conventional chiller units, offering high operational efficiency. However, its disadvantage lies in the smaller volumetric heat capacity, necessitating a larger footprint for the cold water storage tank [16]. Given the substantial cooling demand of this subway station and the ample space available in the station hall above the track area, it is suitable to adopt a chilled water storage system. In this project, the liquid level in the expansion tank and the cold water storage tank can be designed to exceed the highest point of the chilled water system's water pipes during the cold storage process. Taking into account the need to minimize the impact on the structural load-bearing capacity of the station, heat exchange losses, and economic considerations, the high-position cold water storage tank open-loop direct supply system scheme is selected [17,18].

2.4. Water cooling storage system load calculation

The ventilation and air conditioning system in the public area of subway stations (large system) primarily consists of seven components: heat dissipation and moisture dissipation from passenger flow, fresh air load of the ventilation and air conditioning system, heat dissipation from lighting, elevators, ticket machines, and communication equipment, heat dissipation and moisture dissipation from the station maintenance structure, fresh air infiltration load at station entrances and exits, and other loads caused by ventilation in the station tunnels [19]. The ventilation and air conditioning system in subway station equipment and management rooms (small system) is influenced by factors such as equipment heating capacity, fresh air load of the ventilation and air conditioning system, number of staff, heating capacity of lighting equipment, heat dissipation and moisture dissipation from walls [20]. Currently, designers have conducted in-depth research on the design cooling load of subway stations and have formed a relatively mature calculation model.

Given that the design cooling load for the large system is 768 kW, the design cooling load for the personnel management room system is 136 kW, and the design cooling load for the equipment management room system is 465 kW, the air conditioning season spans from March to November. The station operates from 06:00 to 00:00 (midnight).

(1) Step 1: Calculation of design cooling load

$$Q_s = Q_d + Q_x \tag{1}$$

In **Equation (1)**: Q_s = Design cooling load, kW; Q_d = Design cooling load of the large system, kW; Q_x = Design cooling load of the small system, kW. Where Q_d is calculated based on existing design methodologies, taking into account factors such as the civil engineering conditions of the station, indoor and outdoor air calculation parameters, and forecasted long-term peak passenger flow volumes; Q_x is calculated using **Equation (2)**.

$$Q_x = Q_{xr} + Q_{xs} \tag{2}$$

In **Equation (2)**: Q_x = Design cooling load of the small system, kW; Q_{xr} = Design cooling load for personnel management rooms, kW; Q_{xs} = Design cooling load for equipment management rooms, kW. Where Q_{xr} and Q_{xs} are calculated are conducted based on existing design methodologies, taking into account factors such as the environmental requirements of personnel management rooms, the heat dissipation and operational environment requirements of equipment management rooms, and indoor and outdoor air calculation parameters.

In this case, Q_s = 768 + 136 + 465 = 1,369 kW.

(2) Step 2: Calculation of monthly load factor

$$K_{m(n)} = \frac{Q_{m(n)}}{\max(Q_{m(n)})} \tag{3}$$

In **Equation (3)**: $K_{m(n)}$ = Monthly load factor, where n is the month of the air conditioning season; $Q_{m(n)}$ = Monthly cooling load, kW, where n is the month of the air conditioning season. Where $Q_{m(n)}$ is calculated based on the average temperature and humidity of each month during the air conditioning season, utilizing existing design methodologies. Calculations are conducted based on the station, the results are shown in **Table 1**.

Table 1. Monthly load factor estimation table

Month	1	2	3	4	5	6	7	8	9	10	11	12
$K_{m(n)}$	0.26	0.33	0.44	0.63	0.82	0.94	1.00	0.99	0.89	0.69	0.48	0.31

Note: According to data from the Central Meteorological Observatory of China, the monthly average temperature and humidity in Guangzhou over 30 years (1991–2020)

Stations in other regions may refer to or make adjustments based on these data.

(3) Step 3: Calculation of hourly load factor

$$K_{td(t)} = \begin{cases} \frac{Q_{td(t)}}{\max(Q_{td(t)})} & (t_s \le t \le t_e) \\ 0 & (t_e < t < t_s) \end{cases} \tag{4}$$

In **Equation (4)**: $K_{td(t)}$ = Hourly load factor of the large system, where t is the time; $Q_{td(t)}$ = Hourly cooling load of the large system, kW, where t is the time; t_s = Station start operation time; t_e = Station end operation time. Where $Q_{td(t)}$ is calculated based on typical daily passenger flow, outdoor air calculation parameters, and other information according to existing design methodologies. The hourly load factor for the large system is calculated based on the station, the results are shown in **Table 2**.

Table 2. Hourly load factor estimation table

Moment	0–5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
$K_{td(t)}$	0	0.64	0.88	0.91	0.80	0.81	0.82	0.81	0.81	0.85	0.86	0.86	1	0.96	0.78	0.76	0.76	0.72	0.62

Note: Based on the calculations conducted at a station in Guangzhou, stations in other regions may refer to or make adjustments based on these data

$$K_{txr(t)} = \begin{cases} 1 \ (t_s \le t \le t_e) \\ 0 \ (t_e < t < t_s) \end{cases} \tag{5}$$

In **Equation (5)**: $K_{txr(t)}$ = Hourly load factor for personnel management room systems, where t is the time; t_s = Station start operation time; t_e = Station end operation time.

$$K_{txs(t)} = 1 \tag{6}$$

In **Equation (6)**: $K_{txs(t)}$ = Hourly load factor for equipment management room systems, where t is the time. For this case, $K_{txr(t)} = \begin{cases} 1 \ (6 \le t \le 24) \\ 0 \ (0 < t < 6) \end{cases}$; $K_{txs(t)} = 1$.

(4) Step 4: Calculation of hourly cooling load for each month

$$Q_{z(n,t)} = K_f \times K_{m(n)} \times \left(K_{td(t)} \times Q_d + K_{txr(t)} \times Q_{xr} + K_{txs(t)} \times Q_{xs}\right) \tag{7}$$

In **Equation (7)**: $Q_{z(n,t)}$ = Hourly cooling load, kW, where n is the month of the air conditioning season and t is the time; Q_d = Design cooling load of the large system, kW; Q_{xr} = Design cooling load for personnel management rooms, kW; Q_{xs} = Design cooling load for equipment management rooms, kW; K_f = Additional coefficient considering ineffective capacity and cooling losses of the cooling storage device, generally taken as 1.05 to 1.1; $K_{m(n)}$ = Monthly load factor, where n is the month of the air conditioning season; $K_{td(t)}$ = Hourly load factor of the large system, where t is the time; $K_{txr(t)}$ = Hourly load factor for personnel management room systems, where t is the time; $K_{txs(t)}$ = Hourly load factor for equipment management room systems, where t is the time. In this case, taking 08:00 on a certain day in June as an example, $Q_{z(6,8)} = 1.05 \times 0.94 \times (0.91 \times 768 + 1 \times 136 + 1 \times 465) =$ 1,282.98 kW.

(5) Step 5: Calculation of daily cooling load

$$Q_{d(n)} = \sum_{t=0}^{t=23} Q_{z(n,t)} \tag{8}$$

In **Equation (8)**: $Q_{d(n)}$ = Daily cooling load, kWh, where n is the month of the air conditioning season; $Q_{z(n,t)}$ = Hourly cooling load, kW, where n is the month of the air conditioning season and t is the time. In this case, taking a certain day in June as an example, $Q_{d(6)} = \sum_{t=0}^{t=23} Q_{z(6,t)}$ = 24,536.03 kWh.

(6) Step 6: Calculation of daily cold storage capacity of the chiller units

$$Q_{g(n)} = \sum_{t=t_{g1}}^{t=t_{g2}} (Q_s - Q_{z(n,t)}) \tag{9}$$

In **Equation (9)**: $Q_{g(n)}$ = Daily cold storage capacity of chiller units, kWh, where n is the month of the air conditioning season; $Q_{z(n,t)}$ = Hourly cooling load, kW, where n is the month of the air conditioning season and t is the time; t_{g1} = Start time of the valley electricity pricing; t_{g2} = End time of the valley electricity pricing. In this case, taking a certain day in June as an example, $Q_{g(6)} = \sum_{t=0}^{t=7} (1369 - Q_{z(6,t)})$ = 5,859.71 kWh.

(7) Step 7: Calculation of cooling capacity of the cooling storage tank

$$Q_x = \min (Q_{g(n)}) \tag{10}$$

In **Equation (10)**: Q_x = Cooling capacity of the cooling storage tank, kWh; $Q_{g(n)}$ = Daily cold storage capacity of chiller units, kWh, where n is the month of the air conditioning season. In this case, $Q_x = \min(Q_{g(n)}) = Q_{g(7)} =$ 5,534.67 kWh.

(8) Step 8: Calculation of the cool storage rate

$$i = \frac{Q_x}{\max (Q_{d(n)})} \tag{11}$$

In **Equation (11)**: i = Cool storage rate; $Q_{d(n)}$ = Daily cooling load, kW, where n is the month of the air conditioning season. In this case, $i = \frac{Q_x}{\max (Q_{d(n)})} = \frac{Q_x}{Q_{d(7)}} = \frac{5534.67}{26102.16}$ = 21%.

(9) Step 9: Calculation of effective volume of the cooling storage tank

$$V = \frac{3600 \times Q_x}{\eta \times \rho \times c \times \Delta t} \tag{12}$$

In **Equation (12)**: V = Effective volume of the cooling storage tank, m^3; Q_x = Cooling capacity of the cooling storage tank, kWh; η = Ratio of actual output to theoretically available energy during the energy storage period, generally taken as 0.85 to 0.90; ρ = Density of water, kg/m^3; c = Specific heat capacity of water, kJ/(kg·K); Δt = Temperature difference between supply and return water, °C, generally not less than 7°C. In this case, $V = \frac{3600 \times Q_x}{\eta \times \rho \times c \times \Delta t} = \frac{3600 \times 5534.67}{0.85 \times 1000 \times 4.2 \times 7}$ = 797.31 m^3.

(10) Step 10: Calculation of hourly cooling capacity of chiller units for each month

The chilled water storage system operation strategy involves storing cold during the valley electricity pricing period, releasing cold during the peak and flat electricity pricing periods, with priority given to releasing cold during the peak electricity pricing period.

(i) Cold storage stage (valley electricity pricing period)

$$Q_{j(n,t)} = \begin{cases} Q_s \ (if Q_x \geq \sum_{t=g1}^{t} (Q_s - Q_{z(n,t)})) \\ \max\{Q_x - \sum_{t=t_{g1}}^{t=t-1} (Q_s - Q_{z(n,t)}), 0\} + Q_{z(n,t)} \ (if Q_x < \sum_{t=t_{g1}}^{t} (Q_s - Q_{z(n,t)})) \end{cases} \quad (13)$$

In **Equation (13)**: $Q_{j(n,t)}$ = Hourly cooling capacity of chiller units, kW, where n is the month of the air conditioning season and t is the time, $t_{p1} < t < t_{p2}$; Q_x = Cooling capacity of the cooling storage tank, kWh; Q_s = Design cooling load; $Q_{z(n,t)}$ = Hourly cooling load, kW, where n is the month of the air conditioning season and t is the time; t_{g1} = Start time of the valley electricity pricing; t_{g2} = End time of the valley electricity pricing.

(ii) Cold release stage (peak electricity pricing period)

$$Q_{j(n,t)} = \begin{cases} 0 \ (if Q_x \geq \sum_{t=t_{f1}}^{t} Q_{z(n,t)}) \\ Q_{z(n,t)} - \max\{Q_x - \sum_{t=t_{f1}}^{t=t-1} Q_{z(n,t)}, 0\} \ (if Q_x < \sum_{t=t_{f1}}^{t} Q_{z(n,t)}) \end{cases} \quad (14)$$

In **Equation (14)**: $Q_{j(n,t)}$ = Hourly cooling capacity of chiller units, kW, where n is the month of the air conditioning season and t is the time, $t_{p1} < t < t_{p2}$; Q_x = Cooling capacity of the cooling storage tank, kWh; $Q_{z(n,t)}$ = Hourly cooling load, kW, where n is the month of the air conditioning season and t is the time; t_{f1} = Start time of the peak electricity pricing; t_{f2} = End time of the peak electricity pricing.

(iii) Cold release stage (flat electricity pricing period)

$$Q_{j(n,t)} = \begin{cases} 0 \ (if Q_x \geq \sum_{t=t_{f1}}^{t=t_{f2}} Q_{z(n,t)} + \sum_{t=t_{p1}}^{t} Q_{z(n,t)}) \\ Q_{z(n,t)} - \max\{Q_x - \sum_{t=t_{f1}}^{t=t_{f2}} Q_{z(n,t)} - \sum_{t=t_p}^{t=t-1} Q_{z(n,t)}, 0) \ (if Q_x < \sum_{t=t_{f1}}^{t=t_{f2}} Q_{z(n,t)} + \sum_{t=t_{p1}}^{t} Q_{z(n,t)}) \end{cases} \quad (15)$$

In **Equation (15)**: $Q_{j(n,t)}$ = Hourly cooling capacity of chiller units, kW, where n is the month of the air conditioning season and t is the time, $t_{p1} < t < t_{p2}$; Q_x = Cooling capacity of the cooling storage tank, kWh; Q_s = Design cooling load; $Q_{z(n,t)}$ = Hourly cooling load, kW, where n is the month of the air conditioning season and t is the time; t_{f1} = Start time of the peak electricity pricing; t_{f2} = End time of the peak electricity pricing; t_{p1} = Start time of the flat electricity pricing; t_{p2} = End time of the flat electricity pricing.

Table 3. Time-of-use electricity prices

Time period	Electricity price (RMB/kWh)
Valley electricity price: 00:00–08:00	0.28
Peak electricity price: 10:00–12:00; 14:00–19:00	1.17
Flat electricity price: 08:00–10:00; 12:00–14:00; 19:00–00:00	0.70

In this case, it has been found that similar projects in Guangzhou which are proposed to implement a time-of-use electricity pricing system in the future by investigation, time-of-use electricity prices are shown in **Table 3**.

(i) Cold storage stage (valley electricity pricing period)

Taking 07:00 on a certain day in June as an example, $Q_{j(6,7)} = max\{5534.67 - \sum_{t=t_0}^{t=6}(1369 - Q_{z(6,t)}), 0\} + Q_{z(6,7)}$ 1,260.24 kWh.

(ii) Cold release stage (peak electricity pricing period)

Taking 10:00 on a certain day in June as an example, $Q_{j(6,10)} = 0$ kWh.

(iii) Cold release stage (flat electricity pricing period)

Taking 13:00 on a certain day in June as an example, $Q_{j(6,13)} = Q_{z(6,13)} - max\,(5513.2 - \sum_{t=10}^{t=11} Q_{z(6,t)} - \sum_{t=14}^{t=18} Q_{z(6,t)} - \sum_{t=12}^{t=12} Q_{z(n,t)}, 0) = 1{,}207.18$ kWh

The effect of the chilled water system for each month can be ascertained by calculation. The effect of the chilled water system for June is shown in **Figure 1**.

Figure 1. The effect of the chilled water system in June

(11) Step 11: Calculation of static payback time

$$C_s = \sum_{n=1}^{n=12} \{ \sum_{t=0}^{t=23} (\frac{Q_{z(n,t)}}{K_f \times COP} \times C_{(t)}) \times N_{(n)} \} \quad (16)$$

In **Equation (16)**: C_s = Annual electricity cost of the conventional design scheme, RMB; $Q_{z(n,t)}$ = Hourly cooling load, kW, where n is the month of the air conditioning season and t is the time; K_f = Additional coefficient considering ineffective capacity and cooling losses of the cooling storage device, generally taken as 1.05 to 1.1; COP = Coefficient of performance of the chiller unit; $C_{(t)}$ = Time-of-use electricity price, RMB; $N_{(n)}$ = Number of days in the air conditioning season month, where n is the month of the air conditioning season. In this case, $C_s = \sum_{n=1}^{n=12} \{ \sum_{t=0}^{t=23} (\frac{Q_{z(n,t)}}{1.05 \times 5} \times C_{(t)}) \times N_{(n)} \}$ = 818,600 RMB.

$$C_x = \sum_{n=1}^{n=12} \{ \sum_{t=0}^{t=23} (\frac{Q_{j(n,t)}}{COP} \times C_{(t)}) \times N_{(n)} \} \quad (17)$$

In **Equation (17)**: C_s = Annual electricity cost of the chilled water storage scheme, RMB; $Q_{j(n,t)}$ = Hourly cooling capacity of chiller units, kW, where n is the month of the air conditioning season and t is the time; COP = Coefficient of performance of the chiller unit; $C_{(t)}$- Time-of-use electricity price, RMB; $N_{(n)}$ = Number of days in the air conditioning season month, where n is the month of the air conditioning season. In this case, $C_x = \sum_{n=1}^{n=12} \{ \sum_{t=0}^{t=23} (\frac{Q_{j(n,t)}}{5} \times C_{(t)}) \times N_{(n)} \}$ = 596,400 RMB.

$$A = \frac{C_c}{C_s - C_x} \quad (18)$$

In **Equation (18)**: A = Static investment payback period, years; C_c = Initial investment in the chilled water storage system, RMB; C_s = Annual electricity cost of the conventional design scheme, RMB; C_x = Annual electricity cost of the chilled water storage scheme, RMB. In this case, the initial investment for this scale of chilled water storage system is estimated to be 1,500,000 RMB by investigation. $A = \frac{150}{81.86-59.64}$ = 6.75 years.

3. Conclusion

This study presents the design methods and calculation steps for a chilled water storage system applicable to subway stations comprehensively and systematically for the first time, based on a subway station in Guangzhou. The monthly and hourly load coefficient models have been established by adopting a partial load storage cooling approach. Furthermore, the estimation tables for monthly and hourly load coefficients suitable for subway engineering have been proposed based on actual project cases, filling the gap in hourly load coefficients for subway station-type buildings and making the estimation of hourly loads in subway stations more convenient and accurate. The calculations determined the required volume of the cooling storage tank for this project is 797.31 m^3, the cooling storage rate of this project is about 21%, and the effect of the chilled water system for each month has been analyzed. The static payback time is calculated by combining hourly cooling capacity with time-of-use electricity pricing throughout the entire air conditioning cycle, making economic analysis of the chilled water storage system more accurate. The calculation shows that the static payback time of the chilled water storage system in this project is approximately 6 years.

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References

[1] Lulu Z, Qiong T, 2023, Research on the Effectiveness of Urban Low-Carbon Transportation under the Construction of Dual-Carbon Goals Based on the Perspective of Fuzzy Evaluation. Journal of Highway and Transportation Research and Development (English Edition), 17(3).

[2] China Urban Rail Transit Association, 2024, Annual Statistical and Analysis Report of Urban Rail Transit in 2023. China Urban Rail Transit Association, 2024(3): 1, 46.

[3] Zhu J, Sun Z,2015, New Perspectives on Subway Ventilation and Air Conditioning Systems. HVAC, 45(7): 1–5, 27.

[4] Zhang J, Tan Z, Tan M, et al., 2020, Investigation and Analysis of the Current Operation Status and Energy Consumption of Subway Ventilation and Air Conditioning Systems. Installation, 2020(4): 52–55.

[5] Su Z, Li X, 2021, Research on the Principle Model and Simplification of Sub item Energy Consumption in Subway Stations. HVAC, 51(09): 18–23.

[6] Cao H, 2022, Research on Energy Consumption Prediction and Energy saving Measures of Subway Ventilation and Air Conditioning System. Enterprise Technology and Development, 2022(11): 128–130.

[7] Zhang X, 2006, Air Conditioning Cold and Heat Storage Technology. Dalian Maritime University Press, Dalian.

[8] Jia Y, 2018, Analysis of Water Storage Cooling Systems Based on Actual Measurements and Research on Water Storage Tanks, thesis, Xi'an University of Engineering.

[9] Li Y, 2014, Benefit Analysis of Water Storage Cooling in Peak Shaving and Valley Filling. Demand Side Management of Electric Power, 16(02): 30–33.

[10] China Academy of Building Research, 2012, Code Description of Civil Building Heating, Ventilation, and Air Conditioning Design Standard GB50736-2012. China Building Industry Press, 2012: 172–175.

[11] Jan V, Michael B, 2012, Cost Optional Analysis and Load Shifting Potentials of Cold Storage Equipment. Energy and Buildings, 49: 226–234.

[12] Sun ZY, 2015, Energy & TES situation in China. China, Japan and Korea TES Workshop and Expert Meeting, Korea.
[13] Xu W, Sun Z, Li J, et al, 2016, Investigation and Analysis of Cold Storage Engineering Applications in China. HVAC, 46(7): 75–80.
[14] China Academy of Architectural Design and Research Co. Ltd., 2022, Unified Technical Measures for HVAC Design of Civil Buildings 2022. China Architecture&Building Press, Beijing.
[15] Zhu M, Chen L, 2023, Application of Water Storage Cooling Technology in Energy Conservation of Subway Stations. Energy Conservation, 42(05): 58–60.
[16] Parson R, 2008, ASHRAE Handbook. S50 SI-Thermal Storage. Atlanta (USA): ASHRAE Inc., 2008: 50.4.
[17] Ren J, Wu X, 2013, Design and Construction Debugging Analysis of Open Water Storage Air Conditioning System. HVAC, 43(10): 83–85.
[18] Chen L, 2016, A Preliminary Discussion on Open and Closed Systems. Building Thermal Energy Ventilation and Air Conditioning, 35(01): 60–63.
[19] Wu W, Peng J, Liu Y, et al., 2010, Discussion on Air Conditioning Design for Public Areas of Subway Platform Screen Doors. Refrigeration and Air Conditioning, 10(6): 94–101.
[20] Zhu P, Ding D, Xu L, 2008, Dynamic Simulation and Analysis of Air Conditioning Loads in Subway Small Systems. HVAC, 38(11): 21–24.

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