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Central Air Conditioning Engineering Design for an Office Building in Shenyang

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Abstract: Located in Shenyang (Cold Zone C), this office building is a high-rise structure consisting of 1 basement floor and 9 above-ground floors, with a total height of 48.15 meters and a building area of 28,616.2 m^2. It serves as an enterprise office building. The design aims to maintain an indoor temperature of 26 ℃ (60% relative humidity) in summer and 18 ℃ (50% relative humidity) in winter. Using Tianzheng HVAC calculations, the total cooling load is determined to be 1,501.09 kW (with an index of 113.32 W/m^2), and the total heating load is 1,454.72 kW (with an index of 109.8 W/m^2). System scheme: The ventilation system utilizes fresh air ducts to transport fresh air. Offices and similar spaces employ fan coil units combined with an independent fresh air system (with square diffusers for air supply from above and return air from below, and single-layer louvered return air outlets). Lobbies, ball game rooms, and similar spaces utilize an all-air system (with swirl air outlets for air supply and single-layer louvered return air outlets for return air). The water system in this design employs a closed, return-flow, two-pipe, primary pump system. The cold source equipment is selected as two water-cooled screw chillers (LS850H), while the heat source is connected to the municipal heat network (110/60℃) and exchanges heat through a BR0.2 heat exchanger. Equipment selection includes: chilled water pump ISG-125-200B, cooling water pump IS100-65-315C, and hot water pump IS100-65-315; the pressure maintaining and water replenishing equipment adopts a pressure tank V2-500-460 and a water replenishing pump ISG40-250; the water treatment equipment includes a softened water tank FRP-1.6, a DH-1 type softened water processor, etc. Energy conservation and protection: Equipment is equipped with soft hoses and shock absorbers for noise and vibration reduction; pipelines are insulated with foam rubber or centrifugal glass wool, and air ducts are protected against corrosion with epoxy zinc-rich primer and polyurethane topcoat. Condensate water pipes are protected against corrosion with PVC plastic pipes.

Keywords: Shenyang; Office building; Central air conditioning; Design

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1. Introduction

Currently, some central air conditioning systems in office buildings in Shenyang face issues such as high energy consumption, insufficient system compatibility, and low heating efficiency in winter, making it difficult to balance energy conservation and comfort requirements [1]. Against this backdrop, combining the climatic characteristics of Shenyang with the functional requirements of office buildings, conducting research on central air conditioning engineering design, optimizing system selection and design schemes, is of great practical significance for reducing building energy consumption, improving the quality of the office environment, and promoting regional building energy conservation development. It also provides a reference for the design of central air conditioning systems in similar cold regions.

2. Project overview

The building is located in Shenyang, which falls within the cold zone of the thermal engineering division, specifically the severe cold (C) zone. The winter cold period is relatively long, while the summer period is shorter. The building type is a high-rise structure with a fire resistance rating of Grade I. The building serves as an enterprise office building, with the main rooms being offices, followed by archives rooms, conference rooms, and other such spaces. The total land area of the project is 19,998.57 m^2; the total construction area of the office building is 28,616.2 m^2, including 20,582.62 m^2 of aboveground construction area and 8,033.58 m^2 of underground construction area. The building has one basement floor, nine aboveground floors, and two podium floors, with a total height of 48.15 meters [2].

The cold and heat sources for this design utilize the municipal heating network and chiller units. The air conditioning system scheme for the designed area employs a fan coil unit plus fresh air system and an all-air system. The cold and heat source room is located in an independent room on the basement floor, while the cooling tower is situated on the roof.

3. Air conditioning system design

3.1. Air conditioning design parameters

3.1.1. Outdoor meteorological parameters

Table 1. Outdoor calculation parameters for air conditioning in Shenyang

Outdoor environmental design	Parameters
Calculated daily average temperature for outdoor air conditioning in summer	27.5 ℃
Calculated dry bulb temperature for outdoor air conditioning in summer	31.5 ℃
Calculated wet bulb temperature for outdoor air conditioning in summer	25.3 ℃
Average outdoor relative humidity in summer	65%
Outdoor atmospheric pressure in summer	100090 pa
Maximum wind direction and average wind speed in summer	2.6 m/s
Calculated temperature for outdoor heating in winter	-5.2 ℃
Calculated temperature for outdoor air conditioning in winter	-20.7 ℃
Calculated temperature for outdoor ventilation in winter	-11 ℃
Average outdoor relative humidity in winter	60%
Outdoor atmospheric pressure in winter	102080 pa
Maximum wind direction and average wind speed in winter	2.6 m/s

3.1.2. Indoor design parameters

The design temperature for indoor air conditioning in summer is set at 26 ℃, while in winter, it is set at 18 ℃. The design humidity for indoor air conditioning in summer is set at 60%, and in winter, the design relative humidity is set at 50%. The minimum fresh air volume for each room is set at 30 m^3/h. The values for indoor lighting power density, per capita area, and equipment power density of air conditioning are selected based on relevant design specifications such as the "Standard for Lighting Design of Buildings" GB50034-2013 and the "Standard for Electrical Design of Civil Buildings" GB 51348-2019, combined with common sense.

This office building primarily involves light labor, and it includes a tennis activity room and an activity fitness room where people engage in heavy labor. The working hours of this building are from 8:00 to 18:00, a total of 10 hours. The specific parameters of various types of rooms in this building are shown in **Tables 2**, **3** and **4**.

Table 2. Lighting power density values (W/m^2)

Building category	Room category	Lighting power density (W/m^2)
Corporate office building	Ordinary office	15
	High-end office	18
	Meeting room	11
	Corridor	5
	Hall	15
	Gym	11
	Reception room	15
	Lounge	15
	Private rooms and dining area	13
	Reading room	8

Table 3. Per capita occupied area of different types of rooms (m^2/Person)

Building category	Room category	Per capita area occupied (m^2/person)
Corporate office building	Ordinary office	4
	High-end office	8
	Meeting room	2.5
	Corridor	50
	Hall	2.5
	Gym	8
	Reception room	2.5
	Lounge	2.5

Table 4. Equipment power density of different types of rooms (W/m^2)

Building category	Room category	Power density of electrical equipment usage (W/m^2)
Corporate office building	Ordinary office	15
	High-end office	15
	Meeting room	11
	Corridor	-
	Hall	15
	Gym	10
	Reception room	15
	Lounge	15
	Private rooms and dining area	18
	Reading room	8

3.2. Air conditioning cold and heat source design

Due to the fact that this building is an office building, the total cooling load of the project is 1501.09 kw and the total heating load of the project is 1454.72 kw. Through searching relevant literature and combining with the actual project, four schemes have been preliminarily selected.

After a technical and economic analysis, it is evident that while the cost of year-round air conditioning operation using a chiller unit combined with the urban heat network is relatively high, the initial investment for a ground source heat pump is the greatest, necessitating extensive underground construction. Given that the groundwater level in Shenyang is relatively deep (16–18 meters), this may increase the difficulty and cost of drilling. Shenyang is located in a severely cold region, where the heating efficiency of air source heat pumps decreases significantly as the outdoor temperature drops in winter. Various components of the heat pump system are prone to damage under long-term operation, leading to increased maintenance costs. Considering economic efficiency, the combination of a chiller unit and urban heat network proves to be the most optimal. Therefore, based on a comprehensive comparison, it is recommended to adopt the chiller unit combined with municipal heat sources.

3.3. Air conditioning water system design

For this design, the air conditioning water system employs a closed two-pipe primary pump variable water volume system. An electric two-way valve is installed on the return water branch of the fan coil unit. The system achieves an imbalance rate within 15% between systems by adding balance valves and changing the pipe diameters, and then adjusts through the regulating valves installed on each loop. A flow meter is set up on each floor of the air conditioning water system, and flow meters are also installed on each supply and return pipe of the sub-collector in the refrigeration room. Water hammer prevention measures are implemented between the supply and return pipes of the water pump in the machine room.

Automatic exhaust valves are installed at the highest points and convex bends of the air conditioning water circuit system, while drain valves for cleaning and waterproofing are installed at the lowest points and the bottom of the riser. A whole-process water treatment device is installed on the main pipe of the air conditioning cooling return water system. The air conditioning chilled water and cooling water systems are laid without slope, with a condensate water slope of not less than 3%. Cleanout openings are provided on the condensate water pipes. The pressure bearing capacity of the cooling water and chilled water system pipes and valves should not be less than 1.6 MPa. The refrigeration station is located in the refrigeration room on the basement floor, and the cooling tower is located in the green space at the northwest corner of the building, with one cooling tower corresponding to one chiller unit.

3.4. Air conditioning system design

This design directly selects fan coil units combined with fresh air handling units. The fresh air handling units process outdoor air through cooling, dehumidification, heating, and other processes, ensuring that the enthalpy value of the fresh air entering the unit is equal to that of the indoor air. The fresh air is moved from the outdoor state point W to the indoor state point on the isenthalpic line, where its temperature and humidity parameters are equal to those at point L. At this point, the relative humidity at point L is approximately 90% of the dew point of the machine.

For the lobby on the first floor, the ball activity room and large conference room on the second floor, an all-air system with a primary return air system is adopted.

4. Selection of cold sources and related equipment

4.1. Determination of the refrigeration room

The architectural engineering project designed this time has the available conditions for a basement. Based on the design principles of saving building space and optimizing layout, after comprehensive argumentation, the refrigeration and heat exchange room is located on the first basement floor [3].

When selecting a refrigeration unit, it is necessary to comprehensively consider the purpose of the building, the characteristics of various refrigeration machines, and factors such as local water sources, power sources, and heat sources. The initial investment and operating costs of various types of refrigeration units should be compared through comprehensive technical and economic calculations. In this design scheme, a screw-type chiller unit is selected.

The total installed capacity of the refrigeration machine should encompass the actual cooling capacity required by the user, as well as the cold loss incurred by both the refrigeration system itself and the refrigeration system. Generally, it can be calculated based on the added value. The cold loss is typically 5% to 7% for direct refrigeration systems and 7% to 15% for indirect refrigeration systems. The actual cooling capacity required by the user represents the maximum cooling load for the entire building. Since this building belongs to the indirect cooling system, the added value of cold loss is set at 10%. Therefore, two LS850H refrigeration units are chosen.

4.2. Selection of cooling tower model and quantity

The number of cooling towers should correspond one-to-one with the number of chiller units, and the selection of cooling towers should be based on the cooling water flow rate [4]. Then, the number of cooling towers should be determined based on the calculated cooling water volume and system regulation methods mentioned above. Furthermore, the cooling towers are connected by cooling water pumps, and the number of cooling towers should correspond one-to-one with the number of refrigeration units, with backups being negligible. Therefore, the number of cooling towers selected is two. According to the "Jinri Counterflow Environmental Protection Sheet Metal Cooling Tower Selection Manual", the model of the cooling tower selected for this project is 10102-GLL.

4.3. Selection of chilled water pumps and cooling water pumps

Select three chilled water pumps with model ISG-125-200B, using them in parallel, with two in operation and one as standby.

Three chilled water pumps of model IS100-65-315C was selected, connected in parallel for use, with two in operation and one as standby.

4.4. Selection of constant pressure water replenishment equipment

This building is a high-rise structure, hence the constant pressure water replenishment device in this design employs a constant pressure device consisting of a pressure tank and a water replenishment pump. Its principle is to maintain the original pressure through volume changes of the pressure tank. The device is composed of a pressure tank, a water replenishment pump, a softened water tank, a softened water equipment, a safety valve, an electromagnetic valve, etc., combined through a piping system, which constitutes the pressure tank constant pressure device. In this design, two water replenishment pumps of model ISG40-250 were selected, with their performance parameters shown in the table below. They were used in parallel, one in operation and one as standby. During water replenishment during the off-season or emergency water replenishment, both pumps operated simultaneously [5].

4.5. Selection and calculation of water treatment equipment

Installing a softened water tank is one of the key measures to optimize the operation of the air conditioning water system. When determining the effective volume of the softened water tank, it is recommended to refer to the flow rate of the make-up water pump for 0.5 to 1.0 hours. According to the previous calculations, the make-up water volume for this system is 1.61 m^3. The make-up water storage volume Vb of the tank was calculated based on the flow rate of the make-up water pump for 1 hour. The pressure relief and drainage capacity of the upper part of the make-up water tank or softened water tank should be able to accommodate a volume equivalent to the maximum expansion of the system.

Check the relevant models of the softened water tank. The selected model was FRP-1.6, and the dimensions of the softened water tank were 1800 × 1200 × 750 (length × width × height).

The fully automatic water softening treatment equipment was selected based on the system's water replenishment volume, and the chosen model was the DH-1 type fully automatic water softener.

Utilizing various complex technologies such as filtration and electrochemistry, it addresses common issues in circulating water systems, including scaling, corrosion, microbial proliferation, and suspended solids pollution. It possesses functions such as scale prevention and removal, sterilization and algaecide, as well as inhibition of microbial proliferation. The comprehensive water treatment device was installed on the main pipes for cooling and chilled water.

In heating, ventilation, and air conditioning (HVAC) systems, solid impurity particles posed a potential threat to equipment, leading to failures such as wear of pump impellers, valve jamming, and blockage of heat exchanger tube bundles. These issues can result in system efficiency degradation at the least, and even downtime accidents at the most severe. Y-type filters precisely filter impurities generated during system operation, such as welding slag, rust, sediment, metal debris, fibers, and colloidal particles, thereby reducing equipment wear and failure, lowering operation and maintenance costs, optimizing system operation efficiency, ensuring stable operating conditions of chillers, stable air conditioning terminal equipment, stable automatic control valves, and stable work efficiency. During system operation, water filters were installed on the inlet pipelines of pumps, heat exchange equipment, and thermal metering devices in air conditioning cold water and cooling water systems to prevent impurities from entering the water system, polluting or blocking these devices. When selecting the model of water filter, the actual diameter of the corresponding pipe section should be considered to ensure a perfect fit between the filter and the pipeline system, achieving the best filtering effect.

5. Selection of heat sources and related equipment

According to the principles of heat exchanger selection, when one heat exchanger stops working, the design heat exchange capacity of the remaining heat exchangers should not be less than 65% of the design heating capacity in cold regions, and should not be less than 70% in severe cold regions. Therefore, the heat exchange capacity of each heat exchanger should not be less than 1120.1 kw. In this design, two BR0.2 heat exchangers are selected, with one in operation and one as standby.

For this design, three hot water pumps with model IS100-65-315, flow rate of 50 m^3/h, and head of 32 mH_2O can be selected and connected in parallel for use, with two in operation and one as standby.

6. Noise elimination, shock absorption, thermal insulation, and corrosion prevention

In every air duct system (including the inlet and outlet of air handling equipment), canvas hoses are installed, with seams fixed using sealant. The water pipe system (chilled water, cooling water) is equipped with rubber flexible connectors, with a length of ≥ 150 mm, and both ends are equipped with limit devices to prevent pulling off. The rigid connection between the cutting equipment and the pipeline is cut off to reduce vibration transmission (vibration isolation efficiency can reach over 80%).

The water pump utilizes an inertial base (with a concrete block weighing 2 to 3 times the equipment) combined with rubber vibration isolators. A 20 mm-thick rubber pad is placed between the base and the ground to further reduce aerodynamic noise and mechanical noise. A series of measures can be taken, such as reducing airflow velocity, selecting low-noise water pumps, and applying sound-absorbing materials

Apply resistive mufflers, reactive mufflers, resonant mufflers, and other types of mufflers, and set up noise reduction plenum boxes (with a size of twice the cross-sectional area of the air duct) at the air supply outlets to reduce airflow noise; add a fiber sound absorption layer at the return air inlet. The fan coil unit adopts a suspended damping spring vibration isolator (with a spring compression of 25 mm), and a rubber pad is added at the connection between the suspension rod and the floor. The condensate water pipe adopts a flexible rubber connecting pipe, and elastic sealing materials are filled at the place where it passes through the floor.

The combination of spring vibration isolator and inertia base is adopted. Inertia base: The thickness of the concrete base is ≥ 500 mm, and its weight is 2 to 3 times that of the unit. The interior is equipped with a steel mesh to lower the center of gravity and evenly distribute the load. Spring vibration isolator: A low-frequency damping spring vibration isolator (natural frequency ≤ 3Hz) is selected. The load capacity of a single vibration isolator is evenly distributed according to the weight of the unit. During installation, it is necessary to level it to ensure even stress distribution.

Flexible foam rubber is selected as the insulation material for small-diameter pipelines, while centrifugal glass wool is chosen for cooling water pipelines and air conditioning ducts.

For air conditioning ducts in civil buildings, a coating scheme consisting of a double-layer epoxy zinc-rich primer and acrylic polyurethane topcoat can be adopted. Freezing water pipes often suffer from condensation due to damaged insulation layers, leading to corrosion. Therefore, plastic-lined steel pipes can be used to replace traditional galvanized steel pipes, effectively isolating moisture from contact with metal. Condensate water pipes, which are in long-term contact with condensate water, are prone to microbial growth and corrosion of the pipes. Therefore, PVC plastic pipes can be selected.

7. Conclusion

This article focuses on the research of the central air conditioning engineering design for an office building in Shenyang. Taking into account the climate characteristics of the severe cold region in Shenyang and the usage requirements of the office building, the core tasks such as system selection, load calculation, equipment layout, and pipeline design have been completed.

During the design process, both energy efficiency and practicality were taken into account, and the parameters of the air conditioning system were optimized. This addressed the pain points of low heating efficiency and high energy consumption in severe cold regions during winter, ensuring that the system meets the comfort requirements of office areas while reducing operating costs. The design scheme presented in this paper is tailored to the actual project and can be directly applied to engineering practice. It also provides a concise and feasible reference for the design of central air conditioning systems in office buildings in Shenyang and similar severe cold regions, successfully fulfilling the research objectives of the thesis.

Disclosure statement

The authors declare no conflict of interest.

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