Empirical Study on Temperature and Humidity Stability of Archive Exhibition Hall

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Abstract. With the diverse cultural demands of the public, in recent years, some large and medium-sized archives in China have integrated various archive resources and held various types of fixed exhibitions. The air conditioning system has always been the main part of energy consumption in buildings, especially public buildings. The selection and design of airflow organization are particularly important for the energy-saving and green archive construction of air conditioning systems. In order to explore the stability design of temperature and humidity in the exhibition hall of the archives, the method of analyzing measured data was adopted. By calculating the qualified distribution percentage of temperature and humidity at the measured points, it was explained how the exhibition hall of the archives should do a good job in preventive protection of archives while maintaining the comfort of visitors, and achieve effective control of temperature and humidity.

Keywords: Archives; Exhibition Hall; Temperature and humidity regulation, Empirical evidence.

1 Introduction

With the diverse cultural demands of the public, in recent years, some large and medium-sized archives in China have integrated various archive resources and held various types of fixed exhibitions. At the same time, the security of archives and the comfort of exhibitors in exhibitions have become one of the issues of great concern to archives. Building air conditioning systems need to meet people's requirements for indoor thermal and humidity comfort on the basis of energy conservation, and the same applies to exhibition halls. Air conditioning airflow organization refers to the reasonable arrangement of air supply and return ports in air-conditioned rooms, so that purified and heat-treated air is sent into the room through the air supply ports, and in the process of diffusion and mixing, indoor waste heat and humidity are uniformly eliminated, thereby forming a relatively uniform and stable temperature, humidity, and airflow velocity in the working area to meet the requirements of indoor temperature and humidity.

In order to ensure the stability of temperature and humidity in the exhibition hall of archives, the archives industry has issued standards such as *the Code for Design of*

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Archives Buildings (JGJ25-2010) [1]and t*he Code for Design of Archives Air Conditioning Systems* (DA/T87-2021)[2], which specify the temperature and humidity requirements and air system design requirements for exhibition halls. According to regulatory requirements, the temperature of the exhibition hall should be maintained within the range of 18-28 ℃, with a relative humidity of 45-60%, a fresh air volume of 20m3/h per person, and a ventilation rate of 1-2 times/h. Proper temperature and humidity control in exhibition halls with large spaces is an important task for successfully hosting exhibitions[3].

On the one hand, the reason is that archives have left the environment of the long-term adapted collection preservation site, and suddenly face different climatic environments in the exhibition site, which can easily cause damage due to drastic changes in the environment; On the other hand, the secondary deepening design of the archive exhibition hall will change the flow of the exhibition hall, especially for high-rise exhibition halls, there may be the addition of mezzanines, resulting in uneven temperature and humidity environments in some parts of the exhibition hall. The third aspect is that the exhibition hall is a relatively open space, and the stability of temperature and humidity will be affected by the use of adjacent rooms and temperature and humidity control, which can easily lead to the actual controlled temperature being lower or higher than the set suitable temperature. In such a situation, the archives should strengthen their attention to temperature and humidity control in the exhibition hall, establish a solid safety bottom line for archives, and take into account the comfort of exhibitors. Among all environmental factors, temperature and humidity are one of the most commonly concerned environmental indicators. Therefore, it is necessary to conduct research on the comfort and energy efficiency of air conditioning airflow organization in exhibition halls in combination with the actual needs of archives, based on the great importance attached to archival research work by China and archives departments.

About 40 years ago, a large amount of research on indoor temperature and humidity control began abroad. In order to meet the requirements of autonomy and control optimization for solar greenhouse control systems, Song Huang [4] developed an intelligent greenhouse temperature and humidity control system based on the single neuron proportional integral derivative (SNPID) algorithm. The results indicate that the designed solar greenhouse temperature and humidity control system has significant advantages in autonomy and control optimization, providing an efficient and economical solution for environmental management of solar greenhouses. This system has important practical application prospects in promoting sustainable development, highlighting its wide-ranging impact and potential significance. Ma Longkai [5] believes through research that a reasonable air distribution in air-conditioned rooms will create a comfortable indoor thermal environment, which is conducive to the physical and mental health of personnel and efficient work. At the same time, it can effectively reduce the initial investment and operational energy consumption of equipment, achieving building energy efficiency. The design of indoor air distribution cannot be a single, isolated project. It is necessary to conduct a comprehensive analysis based on the environmental thermal comfort requirements of each station in the work area, in order to reduce the energy

consumption of air conditioning operation and achieve the goal of building energy conservation. For existing buildings and large space buildings, corresponding air distribution design schemes should be designed reasonably.

In China, in the 1960s, the National Science and Technology Commission formed a special research group to tackle the problem of constant temperature and humidity, and achieved some results. In recent years, Shen Binbin [6] has conducted research on the design of air conditioning systems for high-rise spaces in a certain office building, introducing common forms of air conditioning systems for high-rise spaces in office buildings, and elaborating on the concept of layered air conditioning in high-rise spaces and the method of calculating layered air conditioning loads. Through field testing and data analysis of a certain project's air conditioning design case, the theoretical methods of layered air conditioning systems are verified, providing reference for similar engineering designs. Wang Yongquan [7] analyzed the deficiencies in the airflow organization of the original air conditioning system in the silk processing workshop, and transformed two sets of upper air conditioning systems on the side walls into lower air conditioning systems, while retaining one set in the center of the workshop as a backup. Combined with the workshop roof ventilator for exhaust. After the renovation, the comfort and energy efficiency of the workshop environment have significantly improved.

2 Model Introduction

2.1 Actual Location Model

Taking the exhibition hall of a high-rise archive as an example, the air outlets are fan coil unit air supply outlets and swirl air supply outlets. The airflow organization form is upper air supply and upper return air. The layout of the air supply outlets is shown in Figure 1.

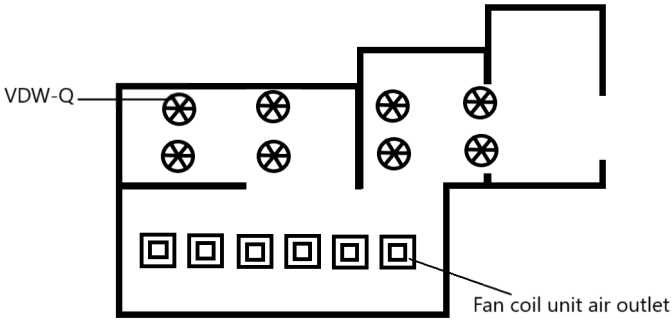

Fig. 1. Actual measurement of the airflow organization form in the exhibition hall.

The overall size of the model is 33.6m × 17.6m × 5.9m. There are a total of 6 air supply outlets for the fan coil unit, each with a size of 0.25m × 0.25m. There are 8 swirl air outlets, each with a size of 0.63m. The air supply outlets and swirl air outlets for the fan coil unit are on the same plane, with a top distance of 0.4m from the roof.

2.2 Selection and Illustration of Actual Measurement Points

The distribution of temperature and humidity detection points is closely related to the exhibition hall area, overall layout, display cabinet placement, and return air vents. According to the "Code for Indoor Environmental Pollution Control of Civil Building Engineering" (GB50325) and "Indoor Air Quality Standards" (GB/T18883), when the usable area of a room is greater than 100 square meters, five or more detection points should be set up, evenly distributed on the diagonal or in a plum blossom pattern. The sampling point should avoid open air vents and be more than 0.5m away from the wall. The height of the sampling point should be consistent with the height of the human breathing zone, with a relative height set between 0.5 and 1.5 meters.

Based on the actual situation of the exhibition's large space, six testing points are planned to be selected. Select relatively enclosed exhibition sections and exhibition locations with special exhibits to set up temperature and humidity detection points. At the same time, the corners of the exhibition hall are generally areas where airflow organization is prone to short circuits, and monitoring points need to be arranged. The overall layout style of the tested model is shown in Figure 2. To simplify the calculation, without considering the influence of heat sources and equipment in the exhibition hall, the distribution law of temperature and humidity in the exhibition hall is studied by comparing the temperature and humidity at different measured points.

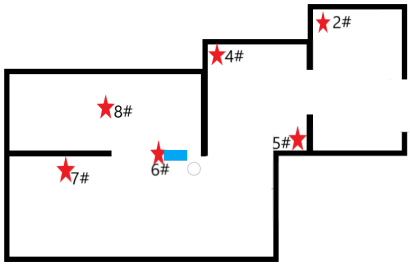

Fig. 2. Overall layout style diagram of the tested model.

When analyzing the measured data, the influence of solar radiation and floor heat transfer is ignored. Assuming that the upper and lower sides of the room are insulated, in order to simplify the simulation study, the interior walls are set as insulated; The export boundary satisfies the overall conservation of mass correction.

3 Comparison of Measured Data

3.1 Climate Conditions

In October 2023, the temperature at the location of the archive exhibition hall in the constituency was approximately between 22 ℃. The average highest temperature during the day is about 26 ℃, and the average highest temperature is 22.13 ℃. The lowest

temperature at night is 5 ℃, with an average lowest temperature of 9.84 ℃.The maximum and minimum outdoor temperatures in October are shown in Figure 3

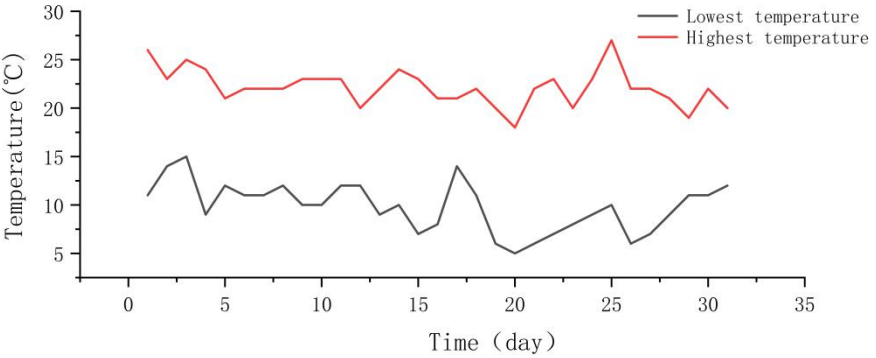

Fig. 3. Daily Temperature Variation Chart for October 2023.

3.2 Comparison and Analysis of Temperature and Humidity Data at Actual Measurement Points

Selection of Measurement Points. To measure the effectiveness of temperature and humidity control in exhibitions, this study selected temperature and humidity data from six locations to evaluate the temperature and humidity control results of the exhibition hall on the comfort of exhibition objects and personnel. Select three public areas 2 #, 3 # -8 # to evaluate the regulatory effect on general protected objects.

In this study, the measured data was collected using a portable temperature and humidity recorder that does not require a power source. It can be placed at the measuring point location to ensure that it does not affect personnel visits or the aesthetics of the exhibition hall. The instrument itself has no noise and collects data every 10 minutes. The temperature range is -20 ℃ -+80 ℃, with an accuracy of ± 0.5 ℃; The humidity measurement range is 0-90% RH, with an accuracy of ± 3% RH.

Analysis of Measured Point Results. As shown in Figure 4 and Figure 5,according to statistics, the temperature in public areas during the exhibition period ranges from 21.3 ℃ to 25.6 ℃, with an average temperature of 23.8 ℃, which basically meets the temperature requirements for exhibition halls specified in the "Design Specification for Air Conditioning Systems in Archives" (DA/T87-2021). Through the control of the air conditioning system, the relative humidity distribution range in the public areas during the exhibition is 22.3% -57.6%, with an average relative humidity of 44.7%. Most of the time, the relative humidity is controlled below 50%, but further analysis reveals that the relative humidity briefly rose above 50% on October 24th and 28th. The reason is that the entire venue has carried out line maintenance in the past two days, and the dehumidification equipment of the air conditioning system has not been running, which has affected the rapid increase in humidity in the public areas of the exhibition hall.

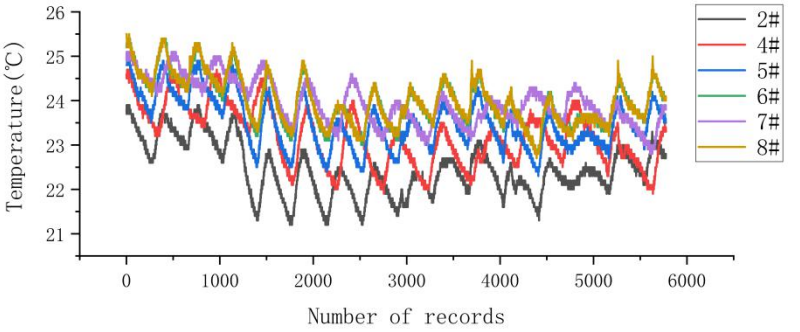

Fig. 4. Temperature changes at actual measurement points in the exhibition hall during the October exhibition period.

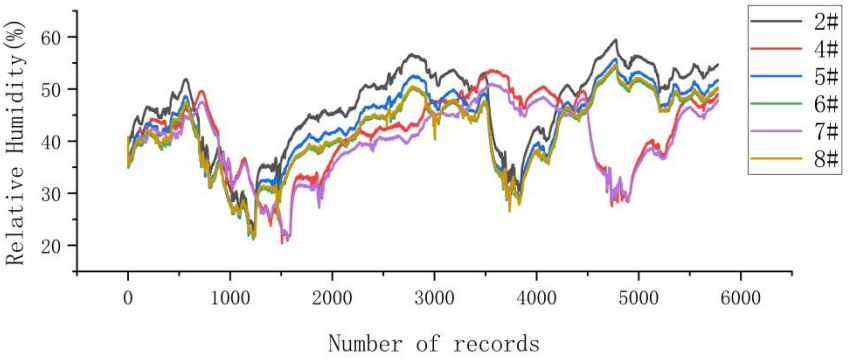

Fig. 5. Changes in relative humidity measured at exhibition hall locations during the October exhibition period.

3.3 Evaluation Formula Setting

For a large amount of monitoring data, people often evaluate it based on simple averages and maximum/minimum values. Although this can also explain many problems, averages mask the differences between various detection values; The separate evaluation of temperature and humidity artificially severs the coupling between temperature and humidity. Therefore, the suitability indicators for temperature and humidity regulation at each measured point are determined by the temperature and humidity qualification rate (P) and the percentage of temperature and humidity distribution, while the overall regulation effect is evaluated by the qualification index (PI).

$$\text{P (measured point control qualification rate)}= \frac{\text{number of data that simultaneously meet temperature and humidity requirements}}{\text{total data volume}} / \times 100\% \quad (1)$$

$$\text{PI(overall control effect)} = \frac{\text{Tested the qualification rate of regulation at esch point}}{\text{Sum of measured point positions}} \times 100\% \quad (2)$$

3.4 Calculation and Analysis Results

To evaluate the overall effectiveness of temperature and humidity regulation in the exhibition hall, point 4 # is selected as an example for detailed explanation. The temperature and humidity of the measured point are shown in Table 1.

Table 1. 4 # Percentage of Temperature and Humidity Distribution Controlled by Actual Measurement Points.

range	<18℃	18—28℃	>28℃
<45%	0.00%	22.41%	0.00%
45—60%	0.00%	77.59%	0.00%
>60%	0.00%	0.00%	0.00%

The data from the measured points 2 #, 4 # -8 # shows that the qualified rate of temperature and humidity in the public areas of the exhibition hall is around 80%. If temperature factors are not considered, the qualified rate will reach 92.15%, indicating that the temperature and humidity control effect of the entire exhibition hall is significant. According to the formula (PI), the overall regulation effect is calculated, and the temperature and humidity qualification index (PI) is above 83.46%, indicating that the overall regulation effect is good and the expected regulation goals have been achieved. Especially during the exhibition period, the temperature and humidity in the area where the exhibition is located fluctuate greatly, and the influence of external climate is more prominent than before.

4 Conclusion and Suggestions

For a considerable period of time in the past, archives generally prioritized limited resources to meet basic display requirements, resulting in insufficient infrastructure, hardware resources, and especially a lack of cultural relic protection measures for temporary exhibition halls in current museums. Specifically, this is reflected in the fact that most existing air conditioners in archives are comfort air conditioners designed for the audience. Although these comfort air conditioners can cool down, they do not have the function of regulating relative humidity, and their air volume is small and the wind speed is low, which cannot form an overall airflow circulation. Secondly, for temporary exhibitions, due to the irregular replacement of exhibitions and frequent adjustment of physical exhibition locations, the protection requirements of each exhibition are different, making it difficult for some relatively fixed air vents and control equipment to be effective in practical applications. In air conditioning and ventilation systems, swirl vents can be used for high air volume and large temperature difference air supply to reduce the number of vents. They are installed on ceilings or ceilings and can be used for low spaces within 3 meters, as well as for large-area air supply at two different heights, even up to 10 meters or more. In the exhibition arrangement, full consideration should be given to the types and exhibition methods of exhibition archives arranged

under the swirl air outlet, in order to better utilize the controllability of the swirl air outlet. Finally, some exhibitions may display archives of various materials, including paper archives, physical archives, etc., which often cannot be differentiated and controlled by a single control device.

The research and practice of exhibitions is a significant and practical issue for archives. A good exhibition not only requires high-quality form design to showcase the value of the exhibits and create aesthetic enjoyment for the audience, but also needs to review the scientific concept and requirements of archive protection against the design plan, so that the concept of protection runs through the entire plan. Therefore, the design plan for the archive preservation environment in the exhibition hall should not only be part of the formal design, but also relatively independent of it. The connection lies in the fact that the regulatory measures adopted should try not to affect the effectiveness of the audience's visit as much as possible; Relative independence requires adhering to the principle of "protection first", ensuring the smooth implementation of protective measures, and not overly pursuing absolute perfection in formal design.

A comprehensive design plan covers many factors, and this study mainly focuses on temperature and humidity control in exhibition halls as an example.

Firstly, protect the object. At the beginning of the design, it is necessary to clarify the types of archives planned to be exhibited in this exhibition, as well as the new media equipment and physical objects to be used. It is also important to specify the size, weight, and protection requirements of the exhibits, so that sufficient preparation and arrangement can be made before they are in place. Technicians should understand the materials, quantities, and preciousness of the exhibits, comprehensively sort out precious archives and environmentally sensitive physical archives, distinguish whether there are special protected objects or physical archives on display, facilitate targeted control measures in the later stage, and avoid hidden dangers to the safety of archives.

Secondly, regulatory objectives. The archive proposes temperature and humidity parameters for the exhibition hall in different seasons based on the requirements for preserving exhibition archives and the temperature and humidity conditions in the area where the archive is located. Technicians should comprehensively collect data from local exhibition halls during the same period, evaluate the goals that the exhibition can achieve, and consider possible abnormal situations. The control measures for general exhibition halls are designed based on the local climate characteristics, and relying solely on existing control equipment may not preserve environmental conditions in some special climates. Therefore, when redesigning exhibition halls, archives should raise potential extreme issues with the design party and jointly negotiate achievable temperature and humidity control targets. If the exhibition venue and space are limited and several archives of different materials are stored in the same display cabinet, the control targets should be determined based on the cultural relics that are most sensitive to the preservation environment.

Thirdly, the direction of regulation. The fixed exhibition will experience seasonal changes in climate within a year, but the overall temperature change will not undergo fundamental changes, so the temperature and humidity control of the exhibition hall is one-way. In practical work, analyze the relationship between the environmental re-

quirements for archive preservation and the climatic characteristics during the exhibition period, identify the contradictions between the two, and clarify the direction of regulation as humidification or dehumidification, heating or cooling.

Fourth, regulatory measures. After clarifying the direction of exhibition control, professional control measures should be selected based on the control requirements of different archives. If there are physical paper archives, physical archives or other exhibits that are particularly sensitive to the environment during the exhibition, they should be placed in well sealed display cabinets, equipped with independently controlled humidity control equipment, and ensured to work continuously for 24 hours through an intelligent control system. If necessary, humidity control materials can also be placed in the display cabinets. It should be noted that the installation position and method of the control equipment should not affect the overall display effect, but also facilitate daily equipment maintenance, data reading, and equipment dismantling. For some essential control equipment and control materials, a portion of the funds will be gradually increased in the exhibition. At present, there are many brands and models of various control equipment. Based on past usage experience, the equipment brands and models suitable for this exhibition should be selected, and the actual quantity should be determined according to the effective control area and exhibition area. Currently, many archives have established environmental monitoring systems, but the existing dehumidifiers cannot achieve automatic data transmission, let alone remote control. Further research and development are needed for more user-friendly functions.

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