Study on Temperature and Humidity Distribution and Monitor Arrangement in Tobacco Aging Warehouse

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Abstract. In the process of tobacco storage and conservation, the temperature and humidity are monitored in the aging warehouse. Due to the large number of warehouses, the equipment investment and maintenance cost are high. So the arrangement of monitor is optimized, which can not only reduce the equipment investment, but also comprehensively and accurately monitor the temperature and humidity. The temperature and humidity monitors ware used to collect data through NB-IoT. After the experimental analysis, the results show that: (1) The hierarchical distribution in the vertical direction of temperature and humidity in the warehouse is significant. (2) The horizontal distribution of temperature and humidity is more significant in the lower layer, but less significant in the higher layer, especially in the upper layer. According to the vertical and horizontal distribution characteristics of temperature and humidity in tobacco aging warehouse, the representative monitoring points are selected at each layer. These monitoring points are evenly distributed in the low temperature and high humidity areas of the warehouse, and the location is simple and easy to use.

Keywords: Tobacco aging; Warehouse; Temperature and humidity distribution; Monitor arrangement; Representative monitoring point.

1 Introduction

The aging quality of tobacco leaves is mainly affected by the temperature and humidity of the warehouse during storage and curing[1]. With the development of technology, the automatic monitoring method of the Internet of Things technology such as ZigBee[2-6] and NB-IoT[7-10] solves the problem of a large amount of labor in the manual monitoring method, ensures the timeliness of temperature and humidity regulation, and can also arrange the monitoring point to the place where personnel cannot reach, improving the accuracy of data. However, the number of the warehouses is large, and a large number of monitoring systems and equipment need to be invested. The investment and maintenance costs are high. Therefore, it is considered that in the same warehouse, according to the distribution rule of temperature and humidity, as little as possible to arrange the monitor. So as to reduce the Investment of monitoring equipment, and comprehensively monitor the temperature and humidity of the tobacco aging warehouse.

IEDM 2024, February 23-25, Kuala Lumpur, Malaysia

DOI 10.4108/eai.23-2-2024.2345889

2 Materials and methods

2.1 Materials

Experimental warehouse. The tobacco aging warehouse for Length × width × height: 36m×27m×7m. Layout of the monitor: 6 temperature and humidity monitoring points were selected at 4 corners and 2 long side midpoints at a height of 0.3m from the ground. Another 6 monitoring points are taken at the vertical elevation of 3m and 6m respectively. A total of 18 temperature and humidity monitors are installed at the above monitoring points, and the distance between the monitor and the column is more than 0.3m, and the distance between the door and window is more than 1m. As shown in Figure 1.

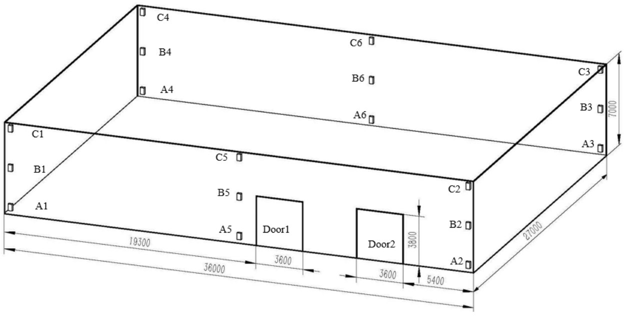

Fig. 1. Schematic diagram of monitor arrangement in tobacco aging experimental warehouse.

Monitoring system composition. The system consists of three parts: monitoring and sensing layer, network communication layer and analysis and display layer. The monitoring and sensing layer mainly includes temperature and humidity sensors and other control devices. The network communication layer includes sensor, measurement and control device, management device and other equipment. The analysis and display layer includes computer, mobile phone, monitoring and management software, etc. As shown in Figure 2.

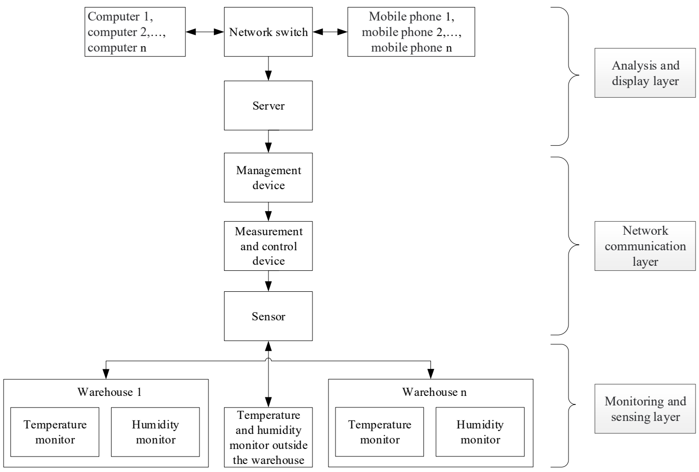

Fig. 2. Block diagram of monitoring system.

2.2 Methods

Guarantee of data integrity. Based on the communication protocol of NB-IoT, a two-way authentication data protocol was designed. Firstly, the node applied for the status of the background, and sent the environmental parameter data when the node received the background status information and confirmed that the whole network was smooth. Secondly, when the background successfully receives the parameter information, it will send a confirmation message to the foreground node. Only after the node confirms, the system considers the data transmission successful. If the network is abnormal, the monitor automatically stores the data, and the next time node network is normal Send it[11].

Data acquisition. The automatic monitor obtains the temperature and humidity of the warehouse every hour, and records the data through wireless transmission to the terminal computer. Each monitor obtains 356 pairs of temperature and humidity data. Each monitor loses packets for 1-3 times. The data recorded by the monitor is normal.

Data processing. (1) For the different monitoring values of the same type of instruments in the same room, after analyzing the reasons for the data differences and excluding the anomalies, the average value of the same type of data is used to represent the monitoring values.(2) When comparing the significance of temperature and humidity differences, parametric tests (such as ANOVA) are used if all the data are normally distributed, and non-parametric tests (such as median tests) are used if any of the data are not normally distributed.(3) If the difference between temperature and humidity is not significant, or the regional distribution of temperature and humidity is inconsistent, then cluster analysis is used.

3 Results and analysis

3.1 Analysis of stratified distribution of temperature and humidity in vertical direction

Temperature stratified distribution verification. The average temperature of 6 monitoring points in layers A, B and C at the same time was calculated. 3 sets of average temperature data of each layer were tested for normality respectively. The data were all non-normal distribution during the sampling period, and the median test was performed. The results showed that the average temperature of layers A, B and C was significantly different (95% confidence interval $P < 0.05$). As shown in Table 1.

Table 1. Median test results of mean temperature at each layer.

Comparative item	N≤	N>	Median/°C
A layer average temperature	251	97	20.40
B layer average temperature	176	174	21.25
C layer average temperature	99	252	22.28
Overall media = 21.25			
Chi-Square= 134.85 DF = 2 P = 0.000			

Time series plot of temperature. The differences in the temperatures of layers A, B, and C are also relatively obvious, with fewer crossings. As shown in Figure 3.

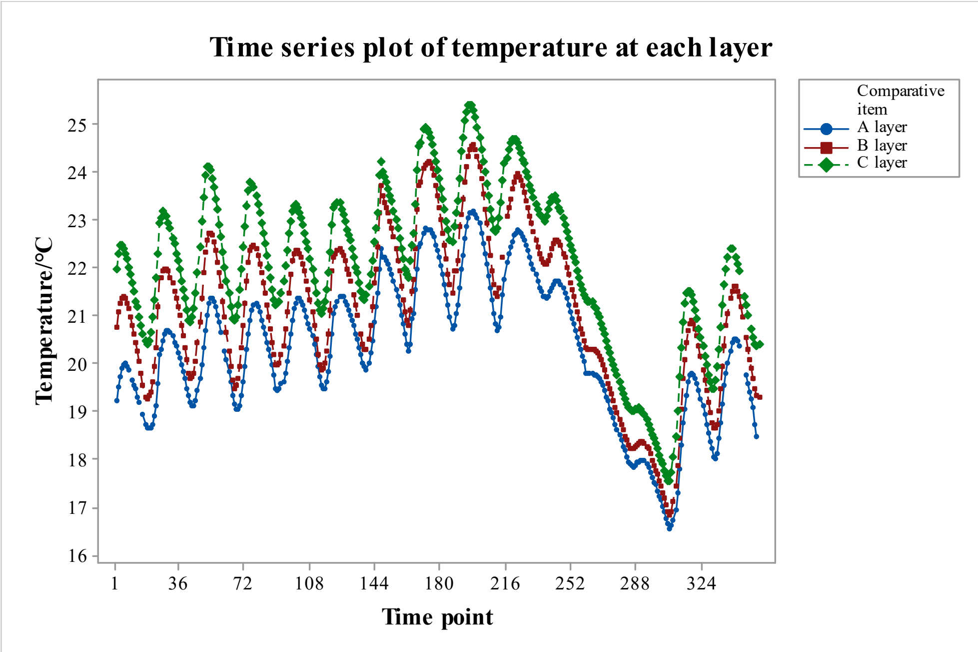

Fig. 3. Time series plot of temperature at each layer.

Humidity stratified distribution verification. Similarly, the average humidity of layers A, B and C was not normally distributed during the sampling period, and the median test was performed. The results showed that the average humidity of layers A, B and C was significantly different. As shown in Table 2.

Table 2. Median test results of the average humidity at each layer.

Comparative item	N≤	N>	Median/%
A layer average humidity	150	198	44.92
B layer average humidity	180	170	43.27
C layer average humidity	195	156	40.87
Overall media = 43.90			
Chi-Square = 11.24 DF = 2 P = 0.004			

Time series plot of humidity. The differences in the humidity of layers A, B, and C are also relatively obvious, with fewer crossings. As shown in Figure 4.

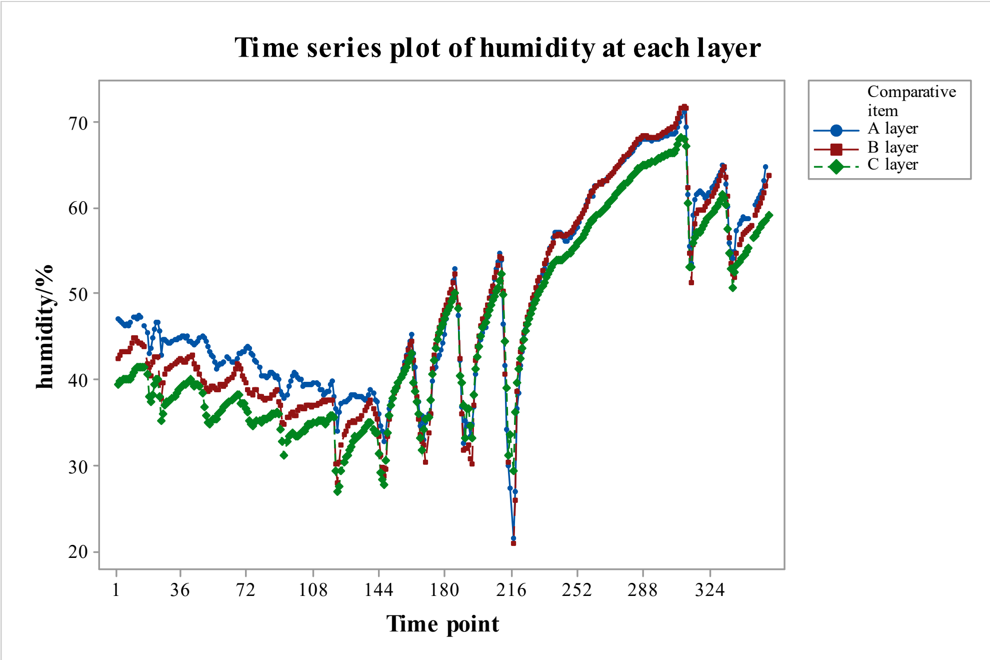

Fig. 4. Time series plot of humidity at each layer.

Summary I. In tobacco aging warehouse, the stratified distribution of temperature and humidity in the vertical direction is significant, so it is feasible to select a representative monitoring point in each layer when deploying the monitor.

3.2 Analysis of temperature and humidity distribution in horizontal direction

Significance analysis. (1)In layer A, the temperature distribution analysis was carried out. 6 sets of temperature data from A1 to A6 monitoring points were mostly non-normal distribution during the sampling period, and the median test was performed. The results show that the temperature of each point from A1 to A6 is significantly different, among which, the temperature of A1, A4 and A6 is smaller, and A2, A3 and A5 is larger. (2) In layer A, the humidity distribution is analyzed. Similarly, the results showed that the humidity of each point from A1 to A6 was significantly different. Among them, the humidity of A2 and A5 is smaller, and A1, A4 and A6 are larger. (3) It can be seen that in layer A, the distribution of low temperature and high humidity areas is consistent, while the distribution of high temperature and low humidity areas is inconsistent. (4) Similarly, the temperature and humidity distribution analysis is carried out in layer B and C. The analysis of the median temperature and humidity test results of each layer is shown in Table 3.

Table 3. Analysis of median test results of temperature and humidity at each layer.

Layer	Median temperature P value	Low temperature region	High temperature region	Median humidity P value	Low humidity region	High humidity region	Consistency of temperature and humidity region
A layer	P=0＜0.05	A1、A4、A6	A2、A3、A5	P=0＜0.05	A2、A5	A1、A4、A6	The distribution of low temperature and high humidity is consistent; high temperature and low humidity is inconsistent
B layer	P=0＜0.05	B1、B2	B3、B4、B6	P=0＜0.05	B6	B4、B5	Inconsistent
C layer	P=0＜0.05	C4	C5	P=0.051＞0.05	No significant	No significant	Indistinguishable region

Summary II. In tobacco aging warehouse, the temperature and humidity distribution in the horizontal direction is more significant at the lower level, but less significant at the higher level, and the difference of humidity at the higher level is particularly insignificant.

Cluster analysis of the distribution of temperature and humidity. Compared with the horizontal distribution of temperature and humidity in each layer, the distribution area is not completely consistent. Therefore, the method of temperature and humidity region consistency cannot be used to select representative monitoring points. The median temperature and humidity were considered for cluster analysis. It can be seen that each layer has a significantly different distribution area. Including low temperature and high humidity areas, and high temperature and low humidity areas. Among them, layer B (middle layer) also has significantly different high temperature and high humidity areas. As shown in Table 4.

Table 4. Results of temperature and humidity cluster analysis at each layer

Layer	Low temperature and high humidity region	High temperature and low humidity region	High temperature and high humidity region
A layer	A1、A4、A6	A2、A3、A5	-
B layer	B1、B2、B3、B5	B6	B4
C layer	C2、C3、C4、C6	C1、C5	-

Summary III. According to Figure 1, the low temperature and high humidity area is located at the far door of the lower level, the back door of the middle level and the near door of the upper level. Tobacco are prone to mildew under low temperature and high humidity conditions, which is an area that needs to be monitored.

3.3 Tobacco aging warehouse temperature and humidity monitor scheme

Arrangement of temperature and humidity monitor. First, according to the stratified significance of temperature and humidity in the vertical direction, a representative monitoring point is selected in each layer. Secondly, according to the distribution characteristics of temperature and humidity in the horizontal direction, a monitoring point is selected from the low temperature and high humidity area of each layer. Third, the location of the selected monitoring points in the warehouse has a simple and easy-to-use regularity. The core of the above principles is to select temperature and humidity monitoring points from low temperature and high humidity areas. The distribution characteristics are the far door of the low level, the back door of the middle level, and the near door of the high level.

As shown in Figure 5. If two monitoring points need to be arranged in the warehouse, the X, Y point is preferred, and the two points are located on the diagonal of the far door of the lower level and the near door of the high level. If 3 monitoring points need to be arranged, the X, Y, Z point is preferred, and the third point is located at the above diagonal midpoint projected on the back door. If 4 monitoring points need to be arranged, the X, Y, Z1, Z2 point is preferred, the third point is located at the lower level of the above diagonal third and projected on the back door, and the fourth point is located at the upper level of the above diagonal third and projected on the opposite door end. According to the standard[12], when the warehouse area exceeds 1000 m^2, no less than 1 monitoring point shall be added for every 500 m^2. When the height of the warehouse exceeds 10m, at least 1 monitoring point can be arranged because the difference in temperature and humidity on the upper layer is not significant.

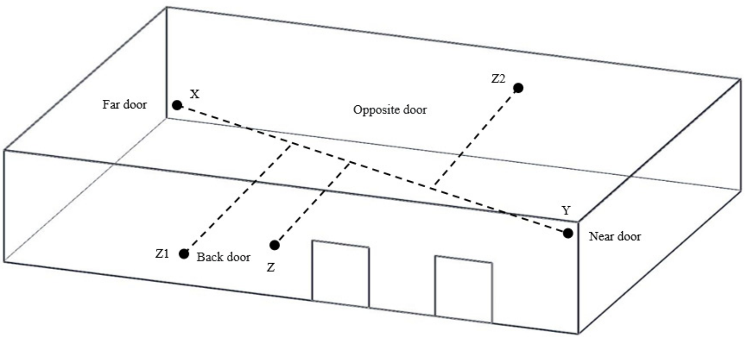

Fig. 5. Scheme of temperature and humidity monitor in tobacco aging warehouse.

4 Conclusions

When considering optimizing the temperature and humidity monitoring system of tobacco leaves warehouse, we need to make comprehensive evaluation and decision from many aspects. Firstly, according to the temperature and humidity distribution characteristics of the warehouse, the monitoring points are arranged in layers in the vertical direction, and the distribution characteristics of the low andhigh floors are selected in the horizontal direction. Secondly, choose a temperature and humidity monitor with long-term stability, high precision and low energy consumption, and ensure the ease of use and maintenance of the equipment. In addition, the data collection frequency is set reasonably, and the data analysis and application are carried out regularly to better understand the temperature anchumidity change law of the warehouse. ln terms of economic benefits, it is necessary to consider factorssuch as equipment investment, return, maintenance costs and long-term benefits. At the same time, pay attention to security and reliability considerations, take necessary security measures to ensure datasecurity and privacy protection. Technical feasibility assessment needs to consider the current level of technology and future development trend, environmental and social impact assessment needs to pay attention to the impact on the environment and society, and formulate corresponding coping strategies and implementation plans. Finally, the comprehensive evaluation of various factors provides specific and actionable suggestions and decision-making basis for decision makers, and constantly improves and optimizes the program to improve its implementation effect and sustainability.

Acknowledgments. The research is supported by the following funds: 2018 State Tobacco Monopoly Administration standard project *Monitoring guide for basic environmental parameters of tobacco aging warehouse*. Project number: 2018B001.

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