Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Environmental Sciences 12 (2012) 354 – 358

Procedia Environmental Sciences

2011 International Conference on Environmental Science and Engineering (ICESE 2011)

Analysis of Refrigeration System for Quasi-Low Temperature Warehouse

Yin Liu[1], Jing Ma[2]

[1]*School of Energy & Environment Zhongyuan University of Technology Zhengzhou, China*
[2]*School of Civil and Architecture Henan University of Technology Zhengzhou, China*
hvacr@126.com,mjja@163.com

Abstract

As the economy continues to develop, the continuous improvement of living standards, quality requirements for food is also rising, food storage requirements continue to increase. Quasi-low temperature storage of grains is a scientific method and it can keep food fresh, which has wide application prospects and practical values. This paper has discussed the advantages of quasi-low temperature grains storage and the basic parameters. Combined with a design example, the calculation of refrigeration load, refrigeration equipment configuration and ventilation system design of the quasi-low temperature storage system of bulk brown rice have been described.

Keywords: Refrigeration system; Quasi-low temperature; Storage; Grains warehouse

1. Introduction

As the economy continues to develop, the continuous improvement of living standards, quality requirements for food is also rising; food storage requirements continue to increase. Quasi-low temperature storage of grains is a scientific method and it can keep food fresh, which has wide application prospects and practical values. This paper take Shanghai Waigaoqiao Quasi-low temperature storage of grains as example to discussed the advantages of quasi-low temperature grains storage and the basic parameters. Shanghai Waigaoqiao grains storage warehouse is located in the Yangtze River delta, Yangtze River west bank of Shanghai Pudong new area, near the sea entrance of Yangtze River. The land part of the project covers about 69,000 m2. The total construction area of the proposed project is 170,000m2, and the total

 doi:10.1016/j.proenv.2012.01.289

investment is about 1.5 billion Yuan. Grains storage constructions include grain silos and horizontal warehouse. Some horizontal warehouses have been designed as quasi-low-temperature warehouse.

2. The Basic Parameters of Quasi-low Temperature Wharfhouse

Quasi-low temperature grains storage is to keep grains at a relatively low temperature with the premise of reasonable water contents with natural or mechanical ventilation cooling, mechanical refrigeration or other measures. Its main purpose is to delay grain quality deterioration, and control harmful microbes or pests. The temperature of quasi-low temperature warehouse is controlled within 15~20℃ [1]. Quasi-low temperature warehousing has been adopted by Shanghai Waigaoqiao grains warehouse to deposit bulk brown rice by the mechanical refrigeration method.

2.1 Characteristics of Brown Rice

Brown rice is the particles after the husk of the paddies has been wiped off. Since brown rice has different nutrient composition with the paddies, different storage methods have been used. Brown rice includes pericarp and plantule, which is germinable. Under high temperature and humidification, brown rice easily fever and mildew. Brown rice includes abundant hydrophilic substances which easily adsorbed water content and resulted in mildew. The fatty acid in the husk and the plantule of brown rice easily increased if improper storage method has been adopted. Under high temperature and high humidification condition fatty acid may further decompose and release an unpleasant odor [2]. Quasi-low temperature storage can maintain the quality of brown rice in the maximal degree.

2.2 Design Parameters of Quasi-Low Temperature Brown Rice Warehouse

The Shanghai Waigaoqiao quasi-low temperature grain storage warehouse is a bulk brown rice horizontal warehouse. The total storage areas are 3,276 m2 and it has been separated into four houses. The bulk brown rice horizontal warehouse is 11m high and the grain bulk is 8m high.

According to the characteristics of brown rice, combined with the relevant state standards and the requirements of quasi-low temperature grains storage, the warehouse design temperature is 15-20℃ and relative humidity is 70% in summer.

3. Cooling Load Calculation

To maintain a low temperature condition, heat must be taken out of the granary. The heat taken out of the warehouse per hour called "cooling load". The refrigeration equipment selection has been based on the maximum "cooling load"[3]. The cooling load of quasi-low temperature brown rice warehouse included building envelope cooling consumption Q_1, brown rice cooling consumption Q_2, brown rice storage breath cooling consumption Q_3, ventilation cooling consumption Q_4, fan cooling consumption Q_5 and operation cooling consumption Q_6. The total cooling consumption:

$$Q = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6 \qquad (1)$$

3.1 Building Envelope Cooling Consumption

Building envelope cooling consumption include the cooling load of wall and roof, the cooling load of solar radiation and the cooling load of ground. The calculation formula is:

$$Q_1 = q_q + q_y + q_d \quad (2)$$

Where

$$q_q = K_q F_q (t_w - t_n) \cdot n = nK_q F_q \Delta t_q \quad (3)$$

$$q_y = K_y F_y \Delta t_y \quad (4)$$

$$q_d = (t_w - t_n) \sum K_{df} F_d \quad (5)$$

Where Q_1 is building envelope cooling consumption q_q is cooling load of wall and roof(W), q_y is cooling load of solar radiation (W), q_d is cooling load of ground (W), K_q is heat transfer coefficient of building envelope(W/(m^2·℃)), F_q is surface area of building envelope (m^2), t_w is outdoor temperature(℃), t_n is indoor temperature (℃), n is correction coefficient of indoor and outdoor temperature difference, $\triangle t$ is temperature difference of indoor and outdoor(℃), q_y is cooling load of solar radiation (W), $\triangle t_y$ is under the influence of solar radiation average equivalent temperature difference between day and night (℃), F_y is surface area by solar radiation (m^2), F_d is ub-surface area (m2), K_{df} is flooring sectional assumed heat transfer coefficient, determined by the distance from the external walls (W/(m^2·℃)).

3.2 Brown Rice Cooling Consumption

Brown rice cooling consumption was decided by brown rice storage volume, specific heat, cooling degree, and the time to cool down. The calculation formula is:

$$Q_2 = \frac{G \cdot c \cdot \Delta t}{z} = \frac{G(i_n - i_w)}{z} \quad (6)$$

Where Q_2 is brown rice cooling consumption, G is brown stock (kg), c is specific heat of brown (kJ/kg·℃), z is cooling time (h), i_n is warehouses enthalpy (kJ/kg), i_w is outside enthalpy (kJ/kg), $\triangle t$ is temperature difference of indoor and outdoor (℃).

3.3 Brown Rice Storage Breath Cooling Consumption

The brown rice will breathe and release heat. The higher the temperature, the stronger the respiration is and the more heat will be released. The brown rice storage breath cooling consumption calculation formula is:

$$Q_3 = G \cdot q \quad (7)$$

Where Q_3 is brown rice storage breath cooling consumption, G is brown stock (kg), q is respiratory heat of brown (W/kg).

3.4 Ventilation Cooling Consumption

To maintain the quality of brown rice, the air in brown warehouses should be replaced frequently. The ventilation cooling consumption calculation formula is:

$$Q_4 = (i_w - i_n)G / m = (i_w - i_n)nV\gamma / m \quad (8)$$

Where Q_4 ventilation cooling consumption, G is brown stock (kg), i_n is warehouses enthalpy (kJ/kg), i_w is outside enthalpy (kJ/kg), G is brown stock (kg), m is fan operation time for replacement of fresh air day and night, n is the number of fresh air replacement day and night, V is granary cubage, N is fan motor power, γ is air density (kg/m^3).

3.5 Fan Cooling Consumption

Fans in the air-conditioning unit will produce heat when working. It is the part of the total cooling consumption. The fans cooling consumption calculation formula is

$$Q_5 = N \cdot \eta \qquad (9)$$

Where Q_5 is fan cooling consumption, N is fan motor power, η is motor effective coefficient.

3.6 Operation Cooling Consumption

The cooling consumption of operation and management included lighting equipment cooling consumption, the consumption of cold of the doors and windows open and other operational workers. It can be calculate by design manual.

3.7 Total Cooling Consumption

When refrigeration equipments have been configured, the total cooling consumption should multiply safety factor. Generally, the safety factor is from 1.1 to 1.3. In accordance with the request of design, the brown temperature drop 1℃ for per 16 hours, and the total cooling consumption is 215kW of one part.

4. System Design

4.1 Cold Source Selection

According to the operations of brown rice entrancing warehouse, usually it is impossible to carry out the operation for the four part of the warehouse at the same time. Brown rice must be entranced into the four parts of the warehouse one bye one. The quasi-low temperature warehouse cooling consumption should be determined by the brown entrance steps. After one part operation end and the temperature drop to 15℃, then another operation and so on. It can prevent redundant equipment and excessive investment.

Based on the above factors, two screw chillers were selected with the refrigeration capacity 232kW. According to the quasi-low temperature warehouses required to maintain in 15℃ to 20℃. The temperature of the out water which from the screw chillers was designed at 5℃ and the return water temperature is 10℃.

4.2 Wind System

The quasi-low temperature warehouse air-conditioning system is all air system. Air handling used air handling unit. The air handling unit includes mixing section, the early results of the filters section, cooling section, maintenance section, heating section, humidifying section, fans section and supply air section. It will select cycle wind system in summer, and using the 10~100% of fresh air at the transitional season and winter according to the ambient temperature. To prevent condensation at brown rice surface, supply air temperature should not be higher than the lowest temperature of brown rice. When the outdoor air was supplied, the double speed axial fans and the electric windows should be opened. The working numbers of the double speed axial fans and the opening of the electric windows were determined by the air volume entering the warehouses. It should maintain the positive pressure and ensure pressure balance in warehouses.

The quasi-low temperature bulk brown warehouse of Shanghai Waigaoqiao Grain Reserve Depot was advised to use the forced ventilation system [4]. The air distribution form of the ventilation system is bottom supply and upper return. The air is distributed by the trench under the floor and back air handing unit by the pipe on the top of the warehouse. According to the requirement of grain store, the indoor wall should keep smoothing, and prevent the accumulation of stale long-term. Therefore, the system of vertical pipes has been embedded in the wall of the warehouses.

4.3 Out of Warehouses Brown When Cold-Storage Areas of Design

For the low temperature grain storage, it should avoid frequently opening the warehouse doors or moving the brown into and out of the warehouses. It can prevent the hot air entering the warehouses and the cooling loss. The brown rice into or out of the warehouses should be done during night, maybe little cold could be loss.

The cooling saving should be fully considered at the time of the brown out of the warehouse when the quasi-low temperature warehouse has been designed. The air curtains with high static pressure were set on the top of each door. The air curtains can hold back the air exchange between indoor and outdoor and it can reduce the cold loss. At the same time, when the brown entered the warehouse at high temperature season, the air curtains can pre-cool the brown.

5. Conclusion

The design emphasis of the quasi-low temperature refrigeration system was based on the grain storage technology requirements and grain characteristics, calculating cooling load reasonable, selecting cooling source and distributing cooling into warehouse. Shanghai Waigaoqiao grain reserve depot quasi-low temperature warehouse design fully considered the in above factors, and it provides a reference to similar low temperature grain reserve system.

6. Acknowledgment

This work was supported by the Young Key Teacher Foundation of Zhongyuan University of Technology.

References

[1]Q. Y. Lu, Food and Oil Storage Study, China: China Financial and Economic Press, 1999, 230-231.

[2]Y. SH. Guan, Low Temperature Storage Grain, China: Agriculture Press, 1982,149-154.

[3]Logistics Management Division of the State Grain Reserve Bureau, China's Grain Storage Volumes, China: Chongqing University Press, 1994,112-113.

[4]L. Yang, Low Temperature Storage Grain and Preservation Technology, China: Shaanxi Science and Technology Press, 1985,64-66.