Application Availability of Insulation Heat of the Terrace in a Rebuilt Refrigerator

Chunmin Qu Yong Sun Zhonghai Chen
Associate Professor Master Master Professor
City Construction Department, Hebei Institute of Architecture Civil Energy, China, 075024
qucm@yahoo.com.cn

Abstract: Dealing with the terrace in rebuilt refrigerators influences the performance characteristics, performance safety and construction costs. This paper researches the heat transfer of the terrace of the rebuilt refrigerator by the numerical method, analyzes the temperature distribution of the terrace, and supplies guidance for rebuilding refrigerators.

Keywords: rebuilding refrigerator; insulation heat; saving energy

1. INTRODUCTION

The homoiothermal refrigerators that are built early day need be rebuilt to the cryogenic refrigerators along with the development continuously of market economy. The matching of refrigeration system and preventing frostbite of the terrace are considered in the process of rebuilding. The matching of refrigeration system is solved by enlarging the refrigeration equipments by the thermodynamics calculation that only is a cost. But there are some difficulties on the preventing frostbite of the terrace. At first, the influence achieved by the building need be considered for preventing frostbite of the terrace due to the base, the terrace are designed according to the primary designing. Secondly, the cost effectiveness of different projects of frostbite of the terrace need be considered.

The methods of preventing frostbite of the terrace in engineering have the basement method, the ventilation method, and sleeper wall half-overhead method, the oil pipe preventing frostbite method and the electric heating method [1]. But there are some projects that are applied due to the structure of original build, investment and the cost of performance in the process of rebuilding. There is important practical significance researching on the temperature distribution of the terrace. The paper researches the application availability of the method of insulation heat in the process of rebuilding.

2. PHYSICAL MODELS

There is a refrigerator whose area is 1666.10 m^2, including three floors. First floor that is homoiothermal need rebuild to cryogenic refrigerator. There are five cooling room. The area of No.1，No.2，No.4，No.5 is 17.29 m ×14.68 m . The area of No.3 is 23.7 m ×11.04 m . The conventional methods of preventing frostbite are not available due to the first floor is homoiothermal, the terrace is not be dealt. The method of insulation heat will be applied to preventing frostbite by analyzing.

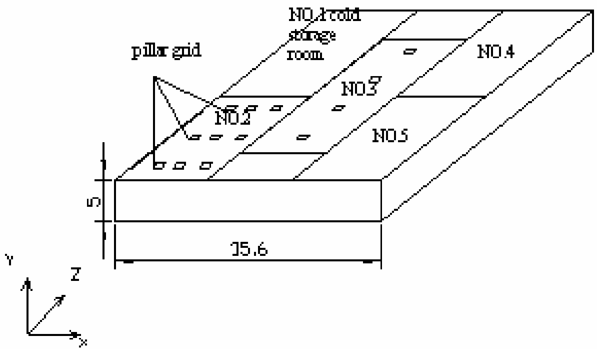

Fig.1 Physical model of refrigerator terrace

Commonly the insulation heat layer possessed some thickness is laid on the terrace of the refrigerator. But the insulation heat layer can not prevent heat transfer absolutely, can but reduce the velocity of heat transfer. The major difference of temperature comes into being between the room and soil layer of the terrace when the temperature of the refrigerator is reduced. The temperature of the soil layer reduces as a result of the heat transferring from the soil layer to the room. The situation of freezing line gradually descends along with the temperature of soil layer reducing if the soil layer can not gained heat [2]. Finally the terrace or the ground work will be frozen, expanded. This is very harmful to the safety of the architectural structure of the refrigerator. So the preventing frostbite of the terrace of the refrigerator plays an important role in the process of the rebuilding.

The simulation research of the temperature distribution is doing for the terrace of the refrigerator before dealt and after dealt. The terrace of the refrigerator is simplified so that the research is convenient. The terrace below the floor of the refrigerator $5m$ looks as the researching object. Every cold storage room has the grid of pillar $0.6m \times 0.6m$, the distance of the bottom of pillar to the terrace is $2m$. The reference frame is given as Fig.1.

3. MATHEMATICAL MODELS

Some hypotheses are done for researching simply in the process of building models.

(1) The environmental temperature holds constant. It is under the average temperature of the whole year2℃－3℃;

(2) The cooling bridge are dealt correctly, the heat transfer of the cooling bridge is neglected.

(3) The inner environmental temperature of the refrigerator holds constant;

(4) The material characteristic of the terrace, the insulating material are constant.

3.1 Control Equations

The process of heat transfer is an astable conduction process by analyzing the process of heat transfer of the terrace. The controlling equation that states the process is given as follows [3].

$$\frac{\partial(\rho c_p T)}{\partial t} + div(\rho U T) = div(\lambda grad T) + S_T$$

Here

Source item $S_T = 0$

Convective term $div(\rho U T) = 0$

The controlling equation simplifies:

$$\frac{\partial T}{\partial t} = \frac{\lambda}{\rho c}\left(\frac{\partial^2 T}{\partial^2 x} + \frac{\partial^2 T}{\partial^2 y} + \frac{\partial^2 T}{\partial^2 z}\right)$$

Here

T —temperature, ℃

t—time, s

λ —thermal conductivity, $W/(m.℃)$

ρ —density, Kg/m^3

c —specific heat, $J/(kg.K)$

3.2 Boundary Conditions

The floor of the refrigerator looks as the top surface of the physical model: $T_s = -18℃$

The rest surface: $7℃ - 2℃ = 5℃$

3.3 Solving Controlling Equations

Discretion of the equation applies the method of control volume. The method of control volume is a popular numerical way. The discretion of the area applies the method of inner node viz. the continuously space is replaced by the finite discrete dot. The diagram of the controlling volume is stated by Fig.2. The diagram of the grid system is stated by Fig.3. The break line expresses the line of boundary, the capitals show the node, and the small letter shows the boundary. The equations are given for the planar form, but it is easy to extend the three-dimensional form.

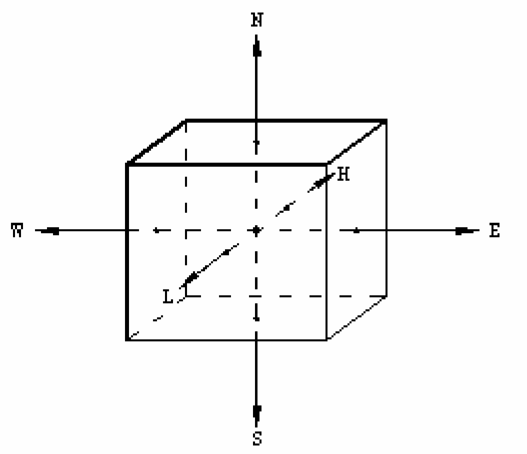

Fig.2 Diagram of the control volume

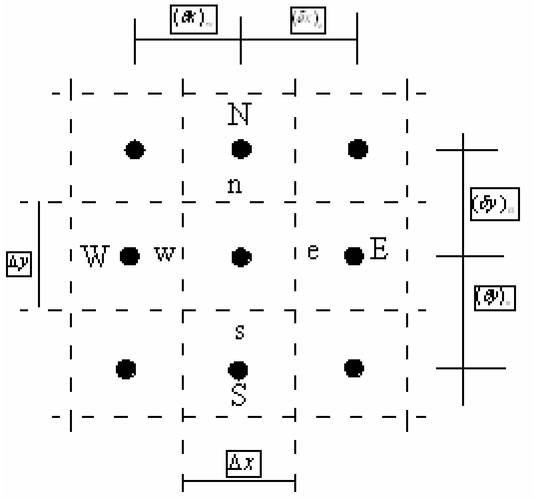

Fig.3 Diagram of the grids system

The discrete equation

$$a_p T_p = \sum a_{nb} T_{nb} + b$$

4. RESULTS

The temperature distribution of the terrace of the refrigerator is simulated by the program according to the physical model and the mathematical model. There are two projects, NO.1 project is that the terrace is only conventional dealt and the NO.2 project is that the terrace is dealt by the polyurethane heat preservation expect the conventional dealing. The results are shown as follows.

Because the temperature change of the section of XY is less and it is major on the section of XZ, the analysis is based on the section of XZ. The variation of the situation of freezing dot vs. the time is shown in Fig.4. From the Fig.4, the situation of the freezing dot is at the situation of about 1.75 m for the NO.1 project. Furthermore the situation of the freezing dot goes down along with the time. The velocity of descending reduces largely after six years and goes to a balanced state. The situation of freezing dot is about 0.6 m to the floor of the refrigerator when the refrigerator operators about one year for the NO.2 project. It is about 0.7 m to the floor of the refrigerator after operating six years and goes to a state of balanced state. The situation of freezing dot goes down continuously, but the velocity is slow.

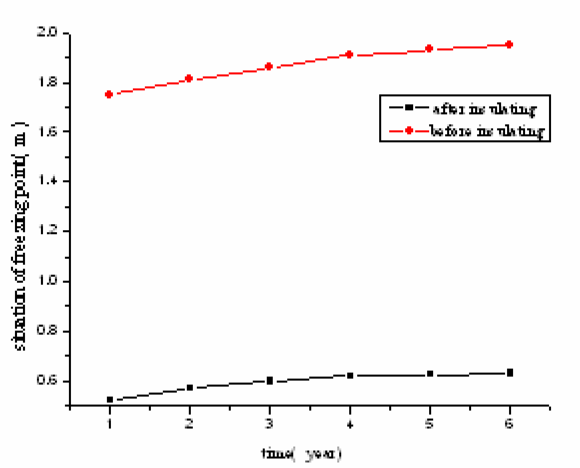

Fig.4 Variation of the freezing point with respect to the time at $Y = 3.56m$

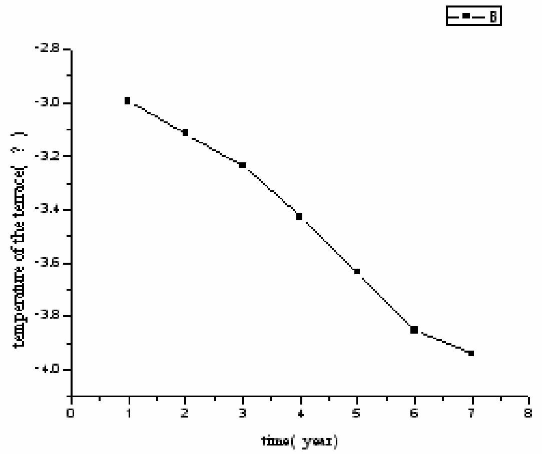

Fig.5 Variation of the temperature of terrace with respect to the time at $Z = 2m$

The variations of the temperature of different level of the terrace with respect to the time are shown in Fig.5 and Fig.6. From the above, the temperature of the terrace goes down along with the time, and it goes to a balanced state after operating six years. The velocity is slow gradually.

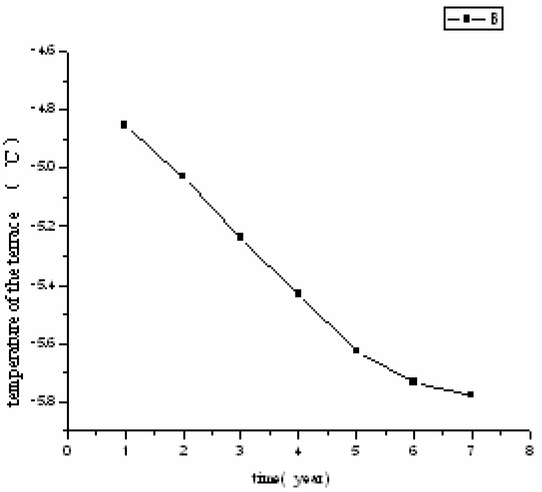

Fig.6 Variation of the temperature of terrace with respect to the time at $Z = 1.87m$

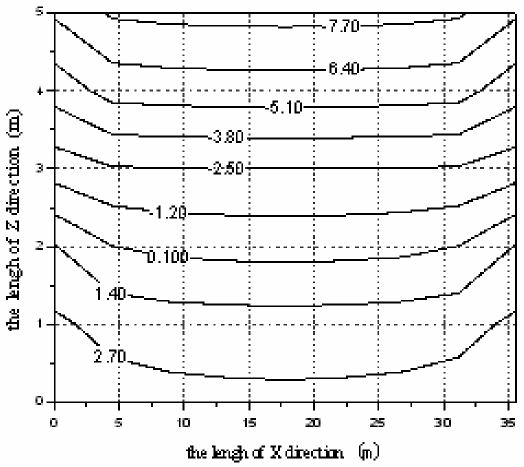

Fig.7 Temperature distribution before insulating at section of XZ

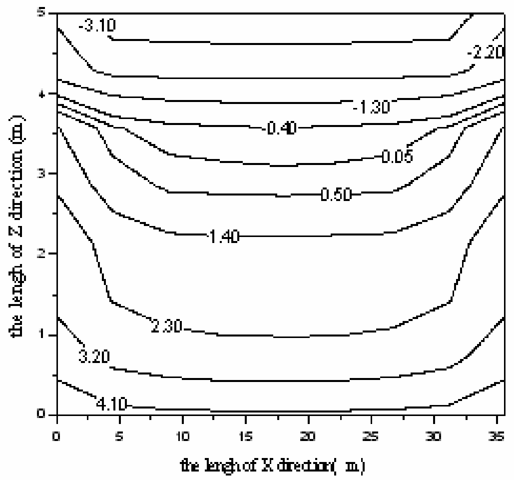

Fig.8 Temperature distribution after insulating at the section of XZ

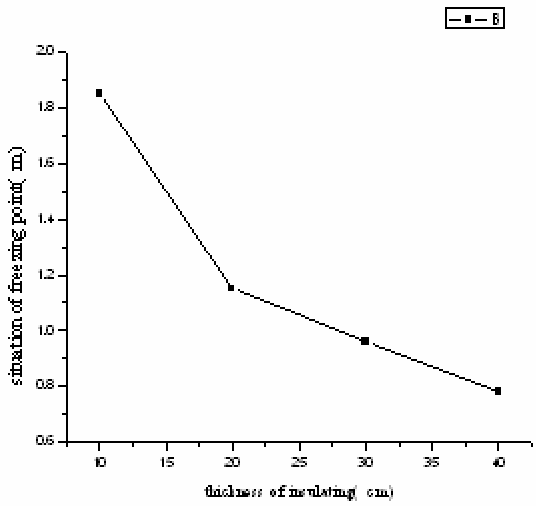

Fig.9 Variation of the situation of freezing point with respect to the thickness of insulating

The temperature distributions of XZ section are referred to Fig.7, Fig.8. From above figures, the situation of freezing line is 2 m under the floor of the refrigerator for NO.1 project. The situation of freezing line is 1 m under the floor of the refrigerator when the refrigerator operating 10 years for NO.2 project.

The variation of situation of the freezing line with respect to the time under different thickness of insulating layer when the terrace is dealt by insulation heat is referred to Fig.9. The situation of freezing dot changes quickly when the thickness of insulating layer is $10cm - 20cm$. It changes slowly along with increasing of the insulating layer.

5. CONCLUSIONS

The preventing frostbite is a key in the process of the homoiothermal refrigerator rebuilding to a cryogenic. It is a better method that applying heat insulation. There are some conclusions bythe simulating the temperature distribution of the terrace of the refrigerator.

(1) The mathematic model and physical model of the terrace of the refrigerator are built, and the controlling equations are solved by the method of controlling volume.

(2) The research states that the situation of freezing dot is 1.75 m to the floor of the refrigerator if the floor is not dealt by insulating heat about one year. And the situation of freezing dot descends along

with operating time. The velocity of descending reduces largely six years, and it goes to a balanced state.

(3) The insulating heat can prevent frostbite in the process of rebuilding. It is preferred that the thickness of insulating layer is 30 cm.

(4) The simulation results state that the method of insulating heat is a better way for the preventing frostbite of the terrace of refrigerator. The results supply the theoretical guide for saving energy rebuilding and saving energy operating of the refrigerator.

REFERENCES

[1] Jianhua Li, Chun Wang. Design of cold store [M], China Machine Press, 2003, 37-39(In Chinese)

[2] Code for design of cold store (GB50072—2001) [M]. China Planning Press, 2001 (In Chinese)

[3] Wenquan Tao. Numerical heat transfer (second edition) [M], Xi'an, Xi'an Jiao Tong University Press, 2001, 5: 89—245(In Chinese)