A study on using heat pipe technology for lowering temperature for storing up grain

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Abstract
This paper deals with the application of heat pipe technology for safely storing up grain and the possibility of lowering temperature of grain heap for minimizing or eliminating mildew. Some analysis data and detailed demonstration examples are given in this paper.

Foreword
In the cold season, because grain’s function performance of heat loss is no good, the temperature of lower strata grain is 10°C higher or even more higher than the temperature of the upper’s. Thanks to physical condition of store up grain and grain’s breathing, it often leads to local grain the temperature elevate of gather. Because heat can not reject in time, grain goes mouldy. For this reason, the higher temperature of store up grain is one key factor to interfere with safety of storing up grain.

If heat can be rejected, and the temperature difference can be reduced possibly. It is very favourable with preventing from going and storing safely up grain.

Heat pipe technology had been used some sixties. It is a new technology of storing safely up grain

Heat pipe’s structure, principles and characteristics
The standard heat pipe is composed of: the wall of a container and core of absorbs liquid and working medium. See figure 1.

There are three working part in the heat pipe, evaporate part, adiabatic part and condensate part. Its working principle is when heating evaporate part, the working medium evaporated by heat absorb, the steam and latent heat transported give condensate part. It is condensate become the liquid returning evaporate part by capillarity, it there are closed work order of six. see figure 2.

In a word, the heat pipe can high-speed transport quantity of heat, by using medium’s phase transition under given state. It there are not anything mechanical movement in all working process. And it is simple of structure, work reliable, a small volume, lighter weight. Its use life-span is number year or number ten year under rational design and better technological of assemble.

The main characteristics
1. Higher ability of heat transfer. The heat pipe’s heat transfer speed is 200m/s or higher. It is several hundreds times faster than that of steel pipe at the same temperature.
2. The better performance of isothermal. The longer isothermal zone’s forms, because its heat drag is very little in heat pipe, by temperature difference only have 1-3°C.
3. It has the performance of one-way only heat condition.
4. The direction’s reversibility of heat transfer. Either of two is heated, it become evaporate part, and other end become condensate part. When heat pipe under zero-gravity state or lay aside of horizontal.
5. The alterability of thermal current density: The heat pipe may be designed straight pipe, annular, bobbin and etc according to using demand. The area of different heat transfer can change the thermal current density. The scope of heat pipe’s adapting temperature is -200°C -2200°C.

It may be divided into high-temperature heat pipes (over 350°C), mesotherm heat pipes (50°C - 350°C), low temperature heat pipes (under 50°C) etc three scope of working temperature.

The heat pipes technology’s development
Thanks to heat pipe’s specific property of heat transfer fast and isothermal, it is used in many engineering and sciences realm. For example 1: A warplane runway can not be used after accumulated snow in winter, Siberia Russian country. For solving the question, There are more than four thousand and four hundred low temperature heat pipes of more than 10 meter and L kind, have been installed under the warplane runway. The quantity of heat in soil have been transported to over warplane runway, it have been used to
melt snow. It had been used less than 40 years.

For example 2: avoiding the spontaneous ignition of coal heap and reducing worsen of coal quality. They have seen testing and studying by Nanjing college of chemical industry and Dongnan university. They used heat pipe of low temperature to lower swiftly coal heap's temperature, from 70°C to 55°C and the region may lower to under than 40°C after five days. Experiment has proved that heat pipes for heat loss is a better measure for coal heap's store of long time in China.

![Fig.1. Heat pipe's composition structure sketch map](image1)

![Fig.2. The principle of heat pipe's work](image2)

The theory and summary of heat pipe's technology are deepening and developing in many territory. The heat pipes of each types and different function are emerging. The heat pipe's expend, especially at small-sized micromonomoture (φ10 – 500μm, L = 10 – 30mm) and large-scale very-large-scale (φ300mm, L = 100M). Thanks to Energy saving are getting universal follow with interest and an urgent need in present world. The heat pipe technology will further get good graces, and it will facilitate the developing of correlation technology.

**The design and application of the heat pipe for storing up grain**

The practicality of the heat pipe to give off heat for storing up grain

In our province, grain reserves are largely in the form of depot of room deposit, in new building depot, especially the newly-built ones. We also have other forms to store up grain such as the trampet deposit, the deposit of Soviet Union style, the old temples and underground deposit.

The climate of Shanxi varies greatly. The average temperature is between 4°C to 14°C. The frost season is comparatively long, usually between 140 to 240 days every year and it is decreased progressively from the north to the south. The average underground temperature from 4 to 20 meters deep is around 11°C to 16°C. Figure 3 shows the regulation of the grain temperature change in room deposit.

From the analysis we can see that the basic regulation of the grain temperature change in a year is as follow: The temperature in the upper layer of grain varies greatly in accordance with the temperature of the day. Its difference is around 28°C. The temperature in the middle and bottom layers vary slightly. The difference is about 9°C. The grain temperature changes a month later than the air temperature does. During winter and early spring seasons, the grain temperature in the bottom layer is higher than that of the upper layer. The average difference is 10°C. In the summer season the grain temperature in the bottom layer is lower than that of the upper layer. Its average difference is 10°C.

In autumn and early winter seasons the grain temperature in the middle layer is comparatively high. The temperature difference of the upper layer is around 10°C, and the
numerical value of the temperature difference for storing up grain varies accordingly with the changes of temperature in different places.

![Temperature Graph]

**Fig. 3.** The curves of grain temperature changes in four seasons

Explain: 1 Curve A: The temperature of the barn
Curve B: The grain temperature of the upper layer
Curve C: The grain temperature of the middle layer
Curve D: The grain temperature of the bottom layer

2 The map is based on the No. 7 National barn storage in Linfen, Shanxi. The grain temperature was measured from the wheat storage (the third class) in 1995.

3 The map was drawn in April, 1997. Drawer: Zhu Zhi-ang

During the storage, the local heat of grain can occur in certain places storing up grain owing to the low conduction of the heat (usually about 0.1 - 0.2kcal/m·h·°C). When the grain temperature reaches 35°C to 40°C, the change of colors in the grain can be seen accompanied with mold. When the grain temperature rises to 50°C to 55°C, poor quality of grain was to occur thus the grain loss can not be avoided.

By adopting the heat pipe with low temperature, the heat in the grain deposit can be eliminated through the pipe with help of the utility of the temperature differences between climate and grain in cold season so that the temperature in grain deposit can be maintained as low as we expect. As for the heaps of again with higher temperature, it is necessary to insert the heat pipe timely to eliminate the heat, meanwhile the condensate agent is also adopted with the use of temperature differences between the climate and the grain in summer so as to reduce the loss of grain in storage.

**The designing shapes of the heat pipe**

The heat pipe of low temperature with gravity is designed and made with carbon steel and ammonia. Its diameter is between 20 to 120 mm. And its length around 1.5 to 4.5 m. The installation of the heat absorption and the heat loss is also necessary in the condensate part of the pipe.

This kind of heat pipe possesses the one-way heat conduction. It is very useful to store up energy. Through using its gravity, the chimney effect of condensing agent in evaporating part is greatly enhanced. Owing to the high pressure head, the structure of the inside of the pipe can be made simple to simplify the structure of the whole heat pipe and increase the heat conduction.

**The demands of storing up grain by the heat pipe**

Inside the room deposit, the best way to lay the heat pipe is vertical installation (β = 90°, see figure 4), usually the angle should not be less than 50° (see figure 4). The height above surface of the grain heap should be around 500 mm. The place and the distance for the installation of the heat pipe depend on the local temperature and the regulation of temperature changes accordingly.

Outside the room deposit, the installation of the heat pipe should be 1.5 m away from the wall and 3 - 10 meters deep in the ground, usually install the pipe 5 meters away from the south wall. If necessary put each from both east and west walls. The forms of the pipe can be made in L form or in an umbrella from. Water proof and leakage should be paid much attention to. In the area with longer cold weather the outside pipes can be put in small numbers or none.
In the underground barn and cave dwelling barn it is necessary to choose the most suitable to install the heat pipe according to the local conditions.

If the grain storage is in summer, we propose to install heat pipes in the grain timely and take them out when the grain temperature becomes low.

For those with high temperature, insert heat pipes with different length to eliminate the heat. In summer, it is better to use condensate agent to control the rising of the grain temperature in the condensate part of the heat pipe.

The illustration of primarily correlated factors

In grain storage the number and the distance of the heat pipes installed should depend mainly on different weather in the areas and different situations for storing up the grain.

To those with local heat of grain, install the pipes at the beginning and observe the temperature changes timely to avoid the high temperature difference in very short time.

To those with installed pipes, it is better to open the windows and doors of the room in cold and dry season, so as to eliminate the heat through the pipes and from the upper layer of the grain. The grain temperature is lowered gradually and the dew can be avoid.

To make sure that the grain is stored up in low temperature, the roofs of the barns should be designed properly and the materials used for the walls to keep the temperature should be suitable. With proper conditions the heat pipe can be installed in the ground, for the cold temperature accumulated in the soil in winter can be given off during summer to prolong the delaying time of grain temperature change so that the grain temperature of storing up the grain can be kept low.

The Analysis Of The Economic Accounting

The cost of the materials

- raw material: 40 steel pipe 114 yuan/per piece.
- Supplementary material: fillings (replacements), rainsmg liquid 30 yuan/per piece
- cost of production: (making and assembling) 80 yuan/per piece
- total production cost: 224 yuan/per piece

Economic analysis

For a barn of 2500 thousand kg, ten pieces of pipes are needed. The total cost will be 3000 yuan (each costs 300 yuan). For the barn of 50 million kg, the total cost is 68 thousand yuan, including 8000 yuan for reserve use.

This investment is about 0.002 yuan per kg. of grain on average. The heat pipes can be used at least 10 years or longer. By using heat pipe we can control the rising temperature of the grain heap so that there is no need for us.
to rotate the grain and turn over the grain in the sun shine. Thus we can save the mechanical fees for ventilating the barns. By using the heat pipe we can also reduce the loss of grain so as to assure the credibility of storing up grain safely.

**Conclusion and Discussion**

**Conclusion**

Adopting the heat pipe of low temperature with gravity can conduct large quantities of heat so that it is feasible to give off the heat from the barns and keep the barns in low temperature. During the whole storage period there is no need to consume any form of energy so as to avoid the air pollution. So it is a technological and economical measure to store up grains safely.

**Discussion**

Design and make still better heat pipes if the conditions for storing up grain allow. Considering the different moisture and temperature in the grain, and test the time of giving off heat by pipes, its influenced areas and the rate of lowering the temperature in order to decide the proper distance to install the heat pipe in different weather and conditions.

**References**

Chang Rang, etc. 1996. The Techniques of Storing up Gram. Grain Bureau of Shanxi Province, Taiyuan, China, 490p.


