0417

# Research into the Pest Prevention of Stored Grain in Underground Warehouse with New Earth – Structure

Zhang Longchuan*, Sun Yuhua and Wang Guoli

**Abstract**: Make use of natural low temperature, low moisture, air tightness of the underground warehouse and take effective eco – methods to keep grain all the year round in the environment of low temperature, low moisture and low oxygen. Without chemical antiseptic and preventative, we've prevented pests and mildew and realized safe storage.

**Key words**: underground warehouse, stored grain, pest prevention, safe storage

## Introduction

With the development of society and improvement of people's living standard, the demand is becoming higher that people should reduce the harmful remainders in grain and grain produce. Safety, sanitation, environmental protection and saving energy have become a necessary choice about the storage of grain. According to the demand-higher quality, more nutrition, more benefit, less loss, less pollution, lower cost-for the development of storage skills, since 2004 we've conducted the experiment with stored grain in the underground warehouse, in which we use eco-methods to prevent pests and mildew. We've made much progress.

Yuanbaoshan State Grain Warehouse lies in the dry area between Inner Mongolia and Xinjiang, where there is little rain and low temperature——the monthly average temperature is below zero centigrade for more than five months, and it has low water level. The water content in the top ten-meter earth-layer is only 11.8%. The whole underground warehouse is water-proof, moisture-proof and airtight. The platform at the top of the warehouse is hardened with concrete. The warehouse also has complete drainage equipment. The whole warehouse is deeply buried under the ground and its top is covered with an more than 4 – meter – deep layer of earth. So all the year round the temperature of the warehouse remains 8 – 12℃ and the warehouse air relative humidity remains 40 – 50%, which forms an ideal grain storage environment with low temperature, low air humidity, airtightness and no oxygen.

## 1 Materials

### 1.1 Experimental Warehouse

No. 51 warehouse was the one used for the experiment, was built in 1998. The roof is like part of a spheroid with an arch height of 3.6 meters and reinforced steel concrete structure. In order to prevent moisture, we spread, three layers of asphalt, each separated by a layer of felt, covering a layer of dry brick. The roof is covered with a four-meter thick layer of earth. The main storage compartment is like the frustum of a cone; its top diamete is 18 meters and bottom diameter is 12 meters. The storage compartment height is 15 meters, made of brick. In order to prevent moisture, we spread two layers of felt between three layers of asphalt like the roof. The bottom of the silo is like a cauldron whose depth is one meter. It's also made of brick, with two layers of felt between three layers of asphalt to seal out ground moisture. There are two openings in the underground silo, one at the top and the other at the bottom. The roof inlet is a hollow cylinder, one meter inside diameter and its height is 3.5 meters. The bottom outlet is a door with 2 meters in height by 1.2 meters in width. The door is made of metal and it's airtight. On the door is a grain discharge opening where grain slides out into an unload conveyor. The capacity of the warehouse is 2 500 ton (90 000 bushels).

### 1.2 Facility Test Instruments

One electrical oxygen-measuring machine; one carbon dioxide-measuring machine, one electrical instrument for measuring grain moisture and temperature.

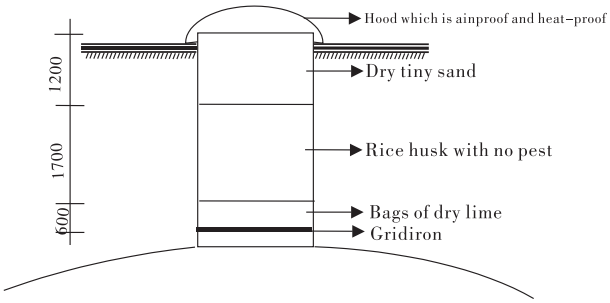
*Yuanbaoshan State Grain Storeage, Chifeng, Inner Mongolia*, 024070

### 1.3 Experimental Grain Seed Storage

Experimental or research seed corn which was locally produced in 2003 was stored in this high quality storage center because of the high standard and demand to maintain safe seed moisture content and temperature.

## 2 Research Methods

2.1 Make best use of natural low temperatures, low air moisture, and air tightness of the underground warehouse, and take storing methods of low temperature and airtightness, rather than applying chemicals and aerating to cool the grain for safe, insect free storage. Use the biotic factors in this hermetic storeage silo to consume oxygen by the physiological activities (storage insects and grain respiration) which reduced the oxygen and increased the carbon dioxide to control pests and prevent mildew.




2.2 The top outlet filler material is supported by a strucutural steel gridiron. Once the silo has been filled, the 1 meter diameter inlet is filled in proper sequence with bags of dry lime, sterilized rice husk with no insects, and dry fine sand. After compacting these three insulating products, we covered it with a rainproof, heat resistant hood then sealed it to make it airtight.

2.3 In order to make the warehouse more airtight, the grain discharge opening at the bottom outlet is sealed up by thin polyethylene film and pressed hard to seal it uniformly. The steel door has rubber gasketing all around to make it airtight.

2.4 Grain condition is examined totally by an electrical monitoring system which provides 24 – hour monitering of the grain temperature and moisture content at selected sampling points every day. In order to improve the accuracy of examining and increase the number of temperature-monitoring points, the whole warehouse is fixed with 17 cables, 3 circles, making a total of 119 temperature monitoring points and 2 sensors for measuring air humidity.

2.5 Dry the experimental grain to reduce grain moisture and disinfest pests and bacteria. Grain goes though the drier which opoerates at a plenum temperature between 100 – 120℃ to dry the grain to safe moisture contents. While drying the moisture, the high temperature will also kill pest eggs and mildew on the grain.

2.6 Chill the experimental grain to temper, and killing insect pests and mildew in low temperatures. After grain is dried, put it into a shed with a hood to make it cool and freeze slowly. Make sure that the grain temperature is lower and lay the foundations of killing pests and mildew by heating, then by freezing. .

2.7 Sterilize the empty warehouse and keep it cool. Sanitize and sterilize the warehouse according to the state grain storage warehouse rules before the grain is loaded into it. Open the top outlet and the bottom outlet on a cold day. With a large axial-flow ventilator blowing cold air downward through the top inlet, give the whole warehouse a non-stop 48 – hour mechanical ventilation to get rid of excess heat and air moisture so that the whole warehouse can be in a state of low temperature and low moisture, which is good for filling with grain.

2.8 Cool the grain a second time while loading it into the warehouse. The loading is all-weather and non-stop. Foreign substance is removed by a slide sifter before entering the warehouse. At the same time, use a ventilator to blow high velocity airflow into the grain slide sifter in the direction opposite of grain flow to remove trash and foreign substances and cool the grain.

## 3 Experiment in Underground Warehouse

On January, 13, 2004 the empty warehouse was aerated non – stop for 48 hours to remove excess heat and air moisture, when the temperature was 14.7℃ and the air humidity was 38%. After 48 hours, we loaded the whole storehouse with the grain. During the course of loading, we smoothed out the surface every one meter of the loaded grain to guarantee the grain was well-distributed and reduce particle size separation and self-grading. We non-stop loaded 2 347 tons of grain in 24 hours. During the course of it, the two outlets were sealed up on time so that the whole warehouse had an airtight and independent storing environment. And we installed the grain-examining equipment. Then the stored grain got in the normal charge. Having loaded the warehouse with grain, we determined the level of oxygen in the warehouse was 20.8%, carbon dioxide 0.03%, and the ware-

house temperature was 5℃, the grain temperature was 2℃ while the air temperature was 16.5℃ when the grain was loaded. All the grain in the warehouse had no pests. Six months later, we determined the level of oxygen in it was 16.3%, carbon dioxide 4.2%.

| Rank | Capacity g/L | Foreign Substance % | Moisture % | Defects % | | Color, Odor | Pests |
|---|---|---|---|---|---|---|---|
| | | | | Total | Musty Grain | | |
| 1 | 716 | 0.4 | 14.2 | 3.8 | 0.1 | normal | no |

The normal arrangement of stored grain is carefully and systematically carried out according to the system of grain storage. Grain condition is tightly monitored and controlled by the electrical examining system for grain condition. Make a good collection and analysis of the data of the grain temperature and grain moisture. Strengthen the examination in pests and mold and strengthen the appraisal of the quality so as to ensure the storage is safe. In March, 2007, the experimental corn left the warehouse, when the level of oxygen in it was 11%, carbon dioxide 10% and there was no pest in the whole warehouse.

| Rank | Capacityg/L | Foreign substance % | Moisture % | Defects % | Fatty acid value (KOH) mg/g | Taste evaluation | Color, odor | Pests |
|---|---|---|---|---|---|---|---|---|
| | | | | Total | Musty grain | | | |
| No | 715 | 0.3 | 14.1 | 4.1 | 0.2 | 35.3 | 81 | Normal |

## 4 Result and Analysis

4.1 The Grain temperature changes a little, and grain condition is stable. During the 38 month storage, the grain temperature was generally kept 6 – 11℃. The grain temperature has a little change, grain condition is stable and we didn't have to turn the grain because the temperature need dropping or the grain quality need adjusting.

4.2 There is no pest case. Judging from the grain condition, grain temperature is generally kept 6 – 11℃, the moisture is 40 – 50%. The whole warehouse is effectively sealed to cut off the influence on it from outside air temperature and moisture. Before loading, use high temperature to heat and cold temperatures to freeze and kill worm eggs and mold sticking to grains. The whole warehouse is sealed to form a condition of low temperature and humidity. Use the biotic factors of stored grain respiration to reduce the level of oxygen in the warehouse and increase the level of carbon dioxide. Destroy the environment in which insects and mold live and reproduce, so that there is no pest case. So we don't need chemical protection and prevention.

4.3 The quality of stored grain is good. Stored grain is in the airtight environment of low temperature, low moisture and low oxygen, so its activities are limited, it lies dormant, and it has little change in quality. We've realized the goal – keep stored grain fresh and guarantee the quality.

## 5 Conclusion

Use the natural low temperature, low moisture and natural cold source, cool and clean the grain while loading the warehouse, use the special features of the underground warehouse that it has few doors and no windows to strengthen sealing of the warehouse. Reduce the level of oxygen in the warehouse by eco – methods. Leave the stored grain in the environment of natural low temperature, low moisture, low oxygen and airtight store for long periods. Don't put any chemical antiseptic or preventative in the warehouse to control the growth and reproduction of insects and molds. Guarantee the quality, keep it fresh and store safely.

| Month | 2004 | | | 2005 | | | 2006 | | |
|---|---|---|---|---|---|---|---|---|---|
| Juanuary | Top grain Temperature ℃ | 3.1 | Moisture % | Top grain Temperature ℃ | 6.5 | Moisture% | Top grain Temperature ℃ | 8.8 | Moisture% |
| | Middle grain Temperature ℃ | 2.8 | 39 | Middle grain Temperature ℃ | 5.2 | 41 | Middle grain Temperature ℃ | 6.7 | 42 |
| | Bottom grain Temperature ℃ | 1.9 | | Bottom grain Temperature ℃ | 4.8 | | Bottom grain Temperature ℃ | 6.5 | |

| Month | 2004 | | | 2005 | | | 2006 | | |
|---|---|---|---|---|---|---|---|---|---|
| February | Top grain Temperature ℃ | 3.1 | Moisture % | Top grain Temperature ℃ | 6.7 | | Top grain Temperature ℃ | 8.9 | Moisture% |
| | Middle grain Temperature ℃ | 2.9 | 39 | Middle grain Temperature ℃ | 5.2 | 43 | Middle grain Temperature ℃ | 6.7 | 44 |
| | Bottom grain Temperature ℃ | 2.1 | | Bottom grain Temperature ℃ | 4.9 | | Bottom grain Temperature ℃ | 6.5 | |
| March | Top grain Temperature ℃ | 3.1 | Moisture % | Top grain Temperature ℃ | 6.7 | Moisture% | Top grain Temperature ℃ | 8.9 | Moisture% |
| | Middle grain Temperature ℃ | 2.8 | 40 | Middle grain Temperature ℃ | 5.3 | 42 | Middle grain Temperature ℃ | 6.8 | 43 |
| | Bottom grain Temperature ℃ | 2.1 | | Bottom grain Temperature ℃ | 4.9 | | Bottom grain Temperature ℃ | 6.7 | |
| April | Top grain Temperature ℃ | 3.5 | Moisture% | Top grain Temperature ℃ | 6.7 | Moisture% | Top grain Temperature ℃ | 8.9 | Moisture% |
| | Middle grain Temperature ℃ | 2.8 | 42 | Middle grain Temperature ℃ | 5.4 | 44 | Middle grain Temperature ℃ | 6.8 | 45 |
| | Bottom grain Temperature ℃ | 2.4 | | Bottom grain Temperature ℃ | 4.8 | | Bottom grain Temperature ℃ | 6.6 | |
| May | Top grain Temperature ℃ | 3.8 | Moisture % | Top grain Temperature ℃ | 6.9 | Moisture% | Top grain Temperature ℃ | 9.4 | Moisture% |
| | Middle grain Temperature ℃ | 3.1 | 42 | Middle grain Temperature ℃ | 5.5 | 44 | Middle grain Temperature ℃ | 7.1 | 47 |
| | Bottom grain Temperature ℃ | 2.8 | | Bottom grain Temperature ℃ | 5.1 | | Bottom grain Temperature ℃ | 6.6 | |
| June | Top grain Temperature ℃ | 4.1 | Moisture% | Top grain Temperature ℃ | 6.9 | Moisture% | Top grain Temperature ℃ | 9.8 | Moisture% |
| | Middle grain Temperature ℃ | 3.4 | 45 | Middle grain Temperature ℃ | 5.7 | 47 | Middle grain Temperature ℃ | 7.2 | 49 |
| | Bottom grain Temperature ℃ | 3.1 | | Bottom grain Temperature ℃ | 5.3 | | Bottom grain Temperature ℃ | 6.5 | |
| July | Top grain Temperature ℃ | 4.8 | Moisture % | Top grain Temperature ℃ | 7.1 | Moisture% | Top grain Temperature ℃ | 10.2 | Moisture% |
| | Middle grain Temperature ℃ | 4.1 | 47 | Middle grain Temperature ℃ | 5.9 | 49 | Middle grain Temperature ℃ | 7.3 | 48 |
| | Bottom grain Temperature ℃ | 3.7 | | Bottom grain Temperature ℃ | 5.5 | | Bottom grain Temperature ℃ | 6.4 | |

| Month | 2004 | | | 2005 | | | 2006 | | |
|---|---|---|---|---|---|---|---|---|---|
| August | Top grain Temperature ℃ | 5.2 | Moisture % | Top grain Temperature ℃ | 7.3 | Moisture% | Top grain Temperature ℃ | 10.4 | Moisture% |
| | Middle grain Temperature ℃ | 4.5 | 49 | Middle grain Temperature ℃ | 6.2 | 48 | Middle grain Temperature ℃ | 7.3 | 9 |
| | Bottom grain Temperature ℃ | 4.1 | | Bottom grain Temperature ℃ | 5.7 | | Bottom grain Temperature ℃ | 6.3 | |
| September | Top grain Temperature ℃ | 6.1 | Moisture % | Top grain Temperature ℃ | 8.1 | Moisture% | Top grain Temperature ℃ | 10.7 | Moisture% |
| | Middle grain Temperature ℃ | 4.7 | 48 | Middle grain Temperature ℃ | 6.5 | 47 | Middle grain Temperature ℃ | 7.2 | 47 |
| | Bottom grain Temperature ℃ | 4.3 | | Bottom grain Temperature ℃ | 6.1 | | Bottom grain Temperature ℃ | 6.5 | |
| October | Top grain Temperature ℃ | 6.3 | Moisture % | Top grain Temperature ℃ | 8.4 | Moisture% | Top grain Temperature ℃ | 10.7 | Moisture% |
| | Middle grain Temperature ℃ | 4.7 | 45 | Middle grain Temperature ℃ | 6.7 | 46 | Middle grain Temperature ℃ | 7.3 | 45 |
| | Bottom grain Temperature ℃ | 4.5 | | Bottom grain Temperature ℃ | 6.3 | | Bottom grain Temperature ℃ | 6.4 | |
| November | Top grain Temperature ℃ | 6.4 | Moisture % | Top grain Temperature ℃ | 8.7 | Moisture% | Top grain Temperature ℃ | 10.8 | Moisture% |
| | Middle grain Temperature ℃ | 4.8 | 42 | Middle grain Temperature ℃ | 6.6 | 44 | Middle grain Temperature ℃ | 7.3 | 43 |
| | Bottom grain Temperature ℃ | 4.7 | | Bottom grain Temperature ℃ | 6.4 | | Bottom grain Temperature ℃ | 6.3 | |
| December | Top grain Temperature ℃ | 6.5 | Moisture % | Top grain Temperature ℃ | 8.8 | Moisture% | Top grain Temperature ℃ | 10.7 | Moisture% |
| | Middle grain Temperature ℃ | 5.1 | 42 | Middle grain Temperature ℃ | 6.5 | 43 | Middle grain Temperature ℃ | 7.2 | 42 |
| | Bottom grain Temperature ℃ | 4.8 | | Bottom grain Temperature ℃ | 6.5 | | Bottom grain Temperature ℃ | 6.4 | |

## References


[1] Edited by State Bureau of Grain Storage, The Total of Grain Storage of China

[2] Edited by Personnel Department of State Bureau of Grain Storage, Warehouse Housemen in Grain and Oil

[3] Lin Zaiyun, Wu Lina, Underground Grain Storage Project, an essay from the 7th international-conference about the protection of stored produce

[4] Wang Zilin, Experiment Report for Safe Storage of Grain in Underground Wwarehouse, an essay from the 7th international conference about the protection of stored produce

[5] Zhang Longchuan, Sun Yuhua, Wang Guoli, Primary Research into Green Storage of Wheat in Underground Warehouse, Grain Storage 2007 (1)53