# Using aeration and insulation to reduce grain temperature in China grain warehouses

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Abstract

Reducing grain temperature is a safe, effective and economic way to minimize damage to grain. It suppresses the activity of all life forms in a grain storage ecosystem. As a result, it stabilizes the grain during storage, reduces loss and keeps freshness. We conducted trials on grain storage facilities (2800-8000 t) in Tianjin, China. The technologies are based on the following factors: the characteristics of local climate (cold dry winters and hot humid summers), large scale storage structure and grain special requirements. Based on these factors, the researchers devised comprehensive and targeted solutions. For example, the insulation of existing large flat top storage was increased, by using various insulation materials in exterior roofing, interior ceiling, walls, vents, windows and doors, using efficient yet economic insulation material in new storage construction. In winter, we used ventilation by natural and forced aeration to maintain low temperatures. In summer, we used insulation and cooling to achieve temperature control. The technology can effectively reduce grain losses and maintain quality by reducing grain respiration, insect and microbial activities. At the same time, it reduces and avoids chemical pollution, protects the grain and the environment from pollution. It achieves low grain loss, low environmental impact, lower cost; high grain quality, high grain nutrient and high efficiency. It is becoming a new direction in scientific grain storage.

Keywords: Temperature controlled grain storage, Tianjin, China

## *1. Introduction*

Temperature is a key factor in preserving grain. The current study of temperature controlled grain storage technology was based on the following factors: the climate of Tianjin, improvement of storage structure insulation, aeration cooling in winter, temperature control in the summer. It is designed to maintain low temperature throughout the storage period, to reduce losses due to grain respiration, moulds and insects. Temperature controlled grain storage technology is safe, economic, environmentally-friendly and effective (Fields, 1992; Mason and Strait, 1998; Burks et al., 2000). It has been a trend in grain storage technology.

We were interested in looking at low temperature grain storage technology for the following reasons. Pests include insects, microorganisms can greatly damage the grain. Pests are active within certain temperature range. Controlling storage temperature can effectively suppress pest growth and reproduction, and as a result, it maintains grain quality during storage. Temperature greatly influences the grain ecosystem. High temperature will accelerate grain respiration, end-use quality degradation and dry weight loss. Controlled temperature grain storage technology can reduce grain respiration and other activity. As a result, it maintains grain quality during storage.

Storage facilities should have good thermal insulation and temperature control, which protects the grain from external heat. Various insulation materials were retrofitted to the existing facilities to control temperature. The climate: Tianjin (39° 8' 32" N / 117° 10' 36" E) has long, cold, dry winter. It lasts approximately 160 days. Air temperature is around -8 to 6°C. There are around 100 days below 0ºC. In summer, it is hot and humid. Air temperature is around 20 to 34ºC. There are around 50 days above 30ºC. There are approximately 80 days above 80% r.h. Based on this climate, the facilities use aeration cooling in winter and air conditioning in summer to control temperature.

*2. Case studies*

Four studies were conducted; 1: aeration cooling; 2: large sandwich panel insulation; 3: magnesium board insulation; 4: self cooling. All studies were performed in close to Tianjin, China.

*2.1. Case study 1: Aeration*

Two methods or aeration cooling were used: natural aeration and forced aeration with fans. Natural aeration cooling took advantage of the cold climate in winters, maintained low temperature without using additional powered ventilation system. Specifically, it controlled temperature by opening, closing the windows and vents using timers. Ventilation was operated between 13 October 2006 and 29 January 2007 (Table 1).

**Table 1** The effect of aeration, natural and forced aeration (centrifugal fan) on large flat wheat storages in China, Study 1. Warehouses had walls made of brick and concrete (500 mm thick), and concrete roofs.

| Method | Location Storage Facility Storage number | Building length, width (m) | Flow rate ($m^3$/h) | Pressure (pa) | Power (kW) | Duration of aeration (days, total hours) | Wheat Grade | Size of grain bulk (t) | Average moisture content (%) | Average Temperature before aeration Level | (°C) | Average Temperature After Aeration Level | (°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Natural aeration cooling | Hangu district DongFeng #81 | 30, 21 | NA | NA | NA | 100, 1000 | 3 | 3069 | 12.5 | Upper | 21.7 | Upper | 5.3 |
| | | | | | | | | | | Middle | 17.1 | Middle | 9.9 |
| | | | | | | | | | | Mid 2nd | 14.0 | Mid 2nd | 8.8 |
| | | | | | | | | | | Lower | 14.4 | Lower | 8.0 |
| Forced aeration cooling | Tanggu National Grain Reserve #17 | 54, 24 | 3420-4020 | 1340-2040 | 5.5 | 8, 168 | 3 | 5015 | 12.5 | Upper | 5.9 | Upper | 5.8 |
| | | | | | | | | | | Middle | 20.0 | Middle | 5.7 |
| | | | | | | | | | | Mid 2nd | 21.0 | Mid 2nd | 5.2 |
| | | | | | | | | | | Lower | 16.0 | Lower | 5.8 |

The forced aeration cooling used mobile centrifugal fans mounted to external lower vents of the warehouse. The compressed air traveled from centrifugal fans through lower vent, ducts, to grain, then exited through upper vents. The study was conducted from mid to late December 2005, approximately 20 h/d, 168 h total. Four fans were used. The unit ventilation rate is calculated as $m^3$h/t of grain. The result showed significant improvement in both natural and force aeration.

*2.2. Case study 2: Sandwich panel insulation*

Large insulated sandwich panels were used to insulate the storage from warm outside summer temperatures to maintain low grain temperature. The insulated site was National Grain Reserve, Tianjin Tanggu district, #2 storage. The storage is 54 m long, 24 m wide. Load bearing structures are steel beams, columns and trusses. The roof and walls are double layered composite sandwich panels, with heat insulating fiber glass wool core. The roof panel: 0.8 mm thick external skin, 0.6 mm internal skin, 150 mm fiber glass fiber wool core. External-internal wall panel: 0.5 mm skin, 75 mm thick fiber glass wool core. The uninsulated facility was National Grain Reserve, Tianjin Tanggu district, Yujiabao #8 storage. It is 50 m long, 20 m wide. The walls were constructed of 370 mm thick prefabricated concrete frames and bricks. The roof was concrete construction.

Grain information for case studies are shown in Table 2. Temperatures were taken periodically during the study. In summer, the warehouse insulated with large sandwich panel construction storage had room air temperatures from 3º to 6 ºC lower (Fig. 1) and grain temperatures from 2ºC to 5ºC lower (Fig. 2) than uninsulated conventional storage. The insulation had significant benefits.

**Table 2** Conditions of storage of storage facilities, temperatures given in figures.

| Study | Storage facility number | Aeration | Insulation added | Wheat grade | Size of grain bulk (t) | Grain moisture content (%) |
|---|---|---|---|---|---|---|
| 2 | 2 | No | Yes | 3 | 3800 | 12.2 |
| 2 | 8 | No | No | 3 | 2800 | 12.0 |
| 3 | 16 | No | Yes | - | 8299 | 12.5 |
| 3 | 7 | No | No | - | 7202 | 11.0 |
| 4 | 64 | Yes | Yes | 2 | 6140 | 12.4 |
| 4 | 38 | No | No | 2 | 3017 | 11.4 |

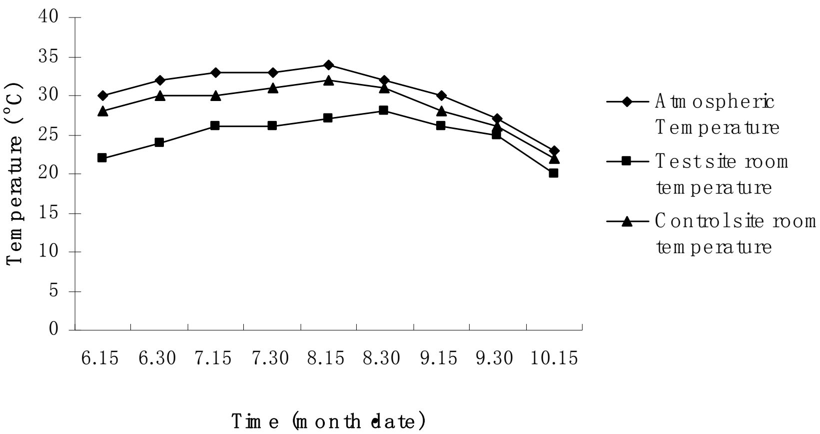


**Figure 1** Air temperature compared to test (insulated) and control (uninsulated) grain, Study 2.

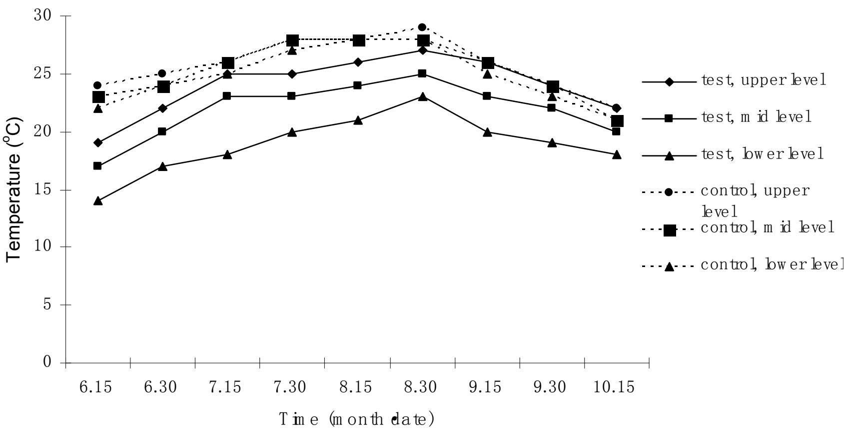


**Figure 2** Grain temperatures by level for test (insulated) and control (uninsulated) grain, Study 2.

### *2.3. Case study 3: Magnesium board insulation*

Magnesium board insulation was used to lower the temperature in large flat top storage. The insulated site was Central Grain Reserve, Tianjin Ji County storage. It was 54 m long, 30 m wide. The warehouse was constructed of brick and concrete. The wall was 500 mm thick. In summer, due to the lack of insulation from the concrete roof, the upper level room temperature can reach as high as 31ºC. The upper level grain temperature can reach between 28º and 31ºC. This had an adverse effect on the grain. Insulation improvements were made to #16 storage by installing magnesium composite insulation boards. First, the exterior of the storage was water sealed with 4 mm SBS layer. Scaffold was built on the exterior of the storage using waterproof magnesium trusses (60 mm X 80 mm X 2400 mm). The magnesium insulation boards (30 mm X 900 mm X 1800 mm) were glued to the scaffold. The scaffolding between the roof and the insulation board forms a gap, promoting ventilation cooling by natural aeration. The insulation boards were painted with white protective paint. It reflects light and repels water. The uninsulated site, #7 storage, was 48 m long, 30 m wide.

Compared to the uninsulated, the insulated storage, room temperature was 5º to 6.4ºC lower (Fig. 3), upper level grain temperature was 4.2º to 6.7ºC lower; mid and lower level grain temperature was 2.2 to 3.1ºC lower (Fig. 4). The insulation improvement had a significant effect on the temperature.

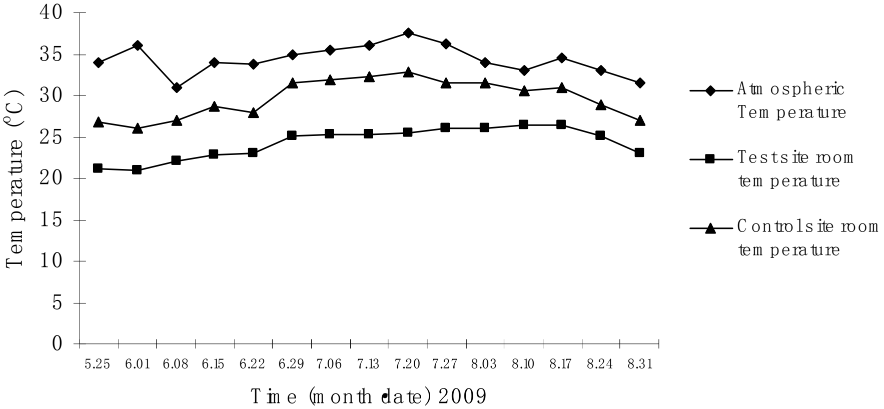


**Figure 3** Air temperature compared to test (insulated) and control (uninsulated) grain, Study 3.

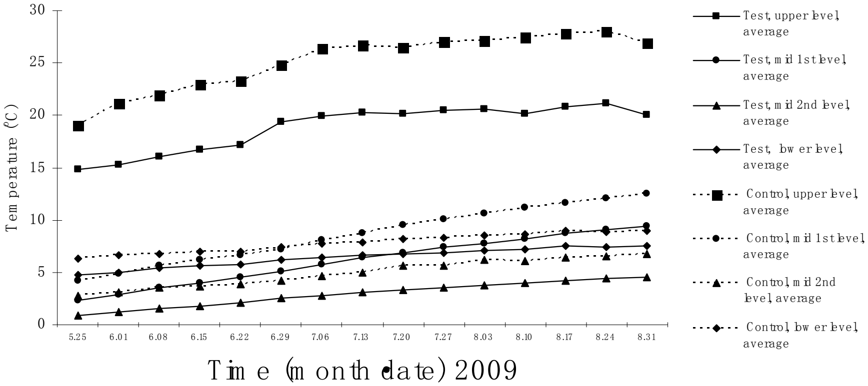


**Figure 4** Temperatures by level for test (insulated) and control (uninsulated) grain, Study 3.

*2.4. Case study 4: Self cooling*

The self cooling study, the lower level cooler grain in the large flat top storage was used as a cold source to lower the temperature of the upper level grain. The aerated and insulated site was Central Grain Reserve at Tianjin Ninghe County. It was brick and concrete construction with 500 mm thick wall. The aerated site, #64 storage was 54 m long, 23 m wide. The following insulation improvements were made. Insulation sandwich panels were suspended from the interior ceiling. The panels were 75 mm thick with steel skins and polystyrene thermal plastic foam core. The external of the storage was covered 46mm thick polystyrene thermal plastic foam panels. Storage doors, windows and vents were sealed with the same material.

In large flat top storage, open air circulation in winter can reduce the grain temperature to between 0 and 5ºC during winter. During summer, the upper level grain temperature can reach between 28º and 30ºC. However, the mid/lower level grain temperature was between 2º and 15ºC. This technique utilized the cooler grain at the mid/lower level to lower the upper level temperature. Methods: From mid June to mid September, two to four air blowers were setup at the upper level. The air intake was 4 to 5 m below the grain surface. It was used to circulate the mid/lower level cool air to the top. Depending on the temperature condition, 2 to 4 blowers were operated 8 to10 h/d, a total of 264 blower/operations, equivalent of 2090 operating hours. The fan was a JW8X1 model, with a flow rate of 630 $m^3/h$, a pressure of 1400 Pa and used 0.55 kW. The unaerated and uninsulated site was #38 storage. It was 23 m long, 27 m wide.

The result of the study 4 showed that the maximum room temperature in summer was below 23ºC. The maximum grain temperature was below 22ºC. It was between 4º to 7ºC lower than the unaerated and uninsulated warehouse. The maximum grain temperature was 7°C lower in the upper level, 9ºC lower in the mid/lower level. There was a significant reduction in temperature.

The following techniques were also experimented and achieved good results: Pressure seal the storage, water spray cooling on the roof, external wall, windows and door shading.

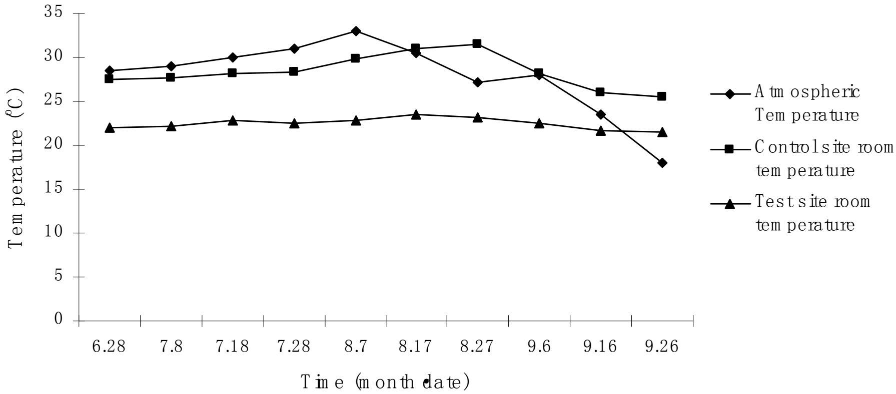


**Figure 5** Air temperature compared to test (aerated and insulated) and control (unaerated and uninsulated) grain, Study 4.

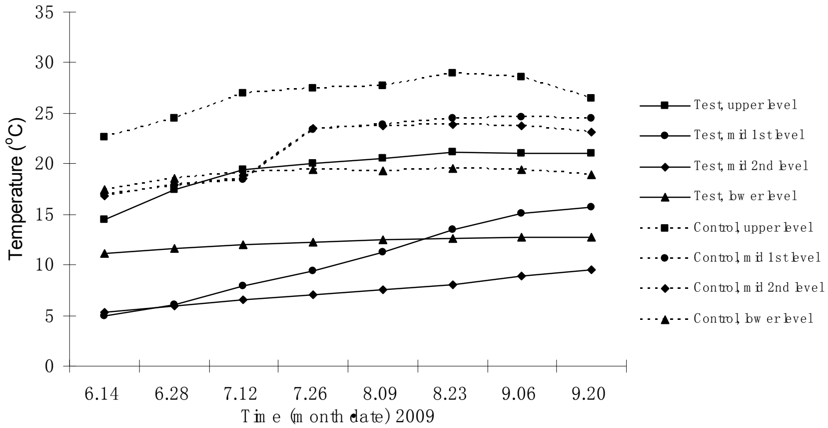


**Figure 6** Temperatures by level for test (aerated and insulated) and control (unaerated and uninsulated) grain, Study 4

## *3. Conclusions*

Using aeration and insulation to reduce grain temperatures can effectively suppress pest activity, such as the reproductive activity of insects and microorganisms. It can control grain respiration, reduce solid matter loss. Based on the climate, grain condition, ventilation cooling by natural and forced aeration can be used. The grain storages should be built or remodeled with insulation materials that are strong, durable, economic, environmental friendly, to achieve the cooling effect. An optimum solution should be designed with the consideration of climate, storage condition/specification and grain condition. Temperature controlled grain storage technology has proven to be safe, economic, environmentally-friendly and effective. It should be widely applied to storages with similar conditions.

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