0508

Effect of Sealing Treatment for Warehouse and Grain Surface in High Flat Warehouse on Natural Oxygen Reducing

Gu Wenyi[1], Zou Wei[2], Liu Hongyan[3], Mo Dailiang[2], Chen Jibin[2], Niu Quan[2] and Cao Yang[4]

Abstract: The tested warehouse was the No. 8 warehouse of Beihai Grain Depot, State Grain Reserves, the reference warehouse was the No. 6 warehouse of Beihai Grain Depot, State Grain Reserves, the walls of the warehouses were brick-concrete structure and the thickness was 0.7m, the roof of the warehouse was steel roof truss structure, the length of warehouse was 56m, the width was 21 m, the height of grain pile was 6m; the warehouses have been equipped with grain temperature detection system and external fixed recirculation fumigation system. The sealing treatment process for warehouse and grain surface was as follows: performed repairing for cracks on terrace, wall surface and at wall corners with "two cloth and three times coating" method before warehouse-entry of corns; filled and sealed the gaps between vents of ventilating ducts and walls and crevices on wall-passing openings of cables; soft rubber gaskets were changed in the vents of ventilating ducts; after grain loading, performed sealing between the door of the warehouse and grain blocking plate and sealing for grain surface with "double-slot and double-film" and "double-slot and one-film" separately, the grain film was five-layer nylon co-extrusion film. After sealing, performed field airtightness test by negative pressure method with airtightness tester, the average 300Pa half-life was 275s. The average 280Pa half-life of the reference warehouse was 53.7s; it showed that the airtightness of the grain pile after treatment has been improved obviously. Sealed the grain pile of the tested warehouse for 45 days, and the concentration of oxygen in the grain pile was reduced from 20.5% to 9.7%, while the concentration of carbon dioxide increased to 4%. However, for the reference warehouse which has been also sealed for 45 days, the concentration of oxygen was only reduced to 16.1%. It showed that under the conditions of higher grain temperature and better airtightness, the corns produced that year and a higher pest density (23pcs/kg), the respirations of various organisms in the grain pile could reduce the concentration of oxygen in the grain pile and increased the concentration of carbon dioxide obviously. Although it could not kill the pests and microorganisms completely, it could have certain inhibition for growth of entomomycete. This research provides reference for application of low oxygen pest controlling and killing technology.

Key words: grain storage, corn, sealing, airtightness, low oxygen

Preface

With the extended applications of the green grain storage technologies such as gas adjustment and temperature controlling, the airtightness improving technologies for warehouse and grain piles which can ensure that former technologies achieve the best effect and the new technologies of heat insulation have been highly concerned. The existing researches show that ensuring the airtightness of the warehouse is the important condition for ensuring the safety and success of grain storage by gas adjustment[1].

Generally, the airtightness of the warehouse is tested by the pressure decay experiment (Pt experiment) at home and abroad, the "pressure half-life" tested under certain pressure in the Pt experiment can present the airtightness of the warehouse or grain pile; generally, in the same conditions, the longer pressure half-life, the better airtightness of the warehouse[2]. And then set the standards for pest killing by fumigation and gas adjustment according to the pressure half-life tested by the Pt experiment. As specified in the national "Technical procedure for PH_3 recirculation fumigation (trial implementation)", test the airtightness of the warehouse by positive pressure method, the pressure half-life reducing from 500Pa to 250Pa in the empty warehouse should be not less than 40s, and the pressure half-life of the low round warehouse under the same conditions should be not less than 60s[3]. In Australia, it is specified that for the first class warehouse, the time for

1. *Guangxi Branch of China Grain Reserves Corporetin, Nanning*, 530022
2. *Beihai Grain Depot, State Grain Reserves, Beihai*, 536000
3. *Grain and Food College, Henan University of Technology, Zhengzhou*, 450052
4. *Academy of State Administration of Grain, Beijing*, 100037, *cy@ chinagrain. org*

pressure reducing from 2500 Pa to 1500 Pa in the empty warehouse should be not less than 5 min[4].

In order to obtain the better effects of fumigation and gas adjustment, the grain depots in many areas of our country have performed a large number of researches and tests for airtightness improving technology of warehouse and grain pile. For the status that the effects of doors and windows in horizontal warehouses and the effects of grain loading inlets, manholes, vents, ports of temperature measuring cables, terraces and walls in low round warehouses and silos on the integral airtightness of the warehouse were bigger, some grain depots has performed airtightness improving on these places with clear target[5-13]. The CBH company in Australia performed airtightness improvements in the "gas adjustment research" project (CAP), it covered the grain piles with air tight films, sealed the vents with slots and performed spray coating of polyurethane foaming materials on cracks of doors, windows and terraces and crevices of vents in the tested silos, then performed Pt experiment after improvements, the pressure half life reducing from 200Pa to 100Pa was more than 12 min[14].

The standard of airtightness for PH_3 recirculation fumigation of our country has been established to ensure the application effects of chemical fumigation medicines in grain warehouses [15] and provide basic conditions for the effect of fumigation and prevention and killing of drug-resistance pests; however, in aspect of prevention and killing of pests by gas adjustment, the requirement for airtightness of warehouse and grain pile is much higher; for example, the standard of airtightness for pest killing by CO_2 gas adjustment is that the 500Pa half-life should be more than 300s[16]. In order to perform the application demonstration of low oxygen pest killing and controlling technology in Beihai Grain Depot, State Grain Reserves, according to the actual status of grain warehouse in the depot, we performed airtightness improvement for the tested warehouse (No. 8 high flat warehouse), and tested the airtightness of grain pile after sealing, thus creating good conditions for performing the demonstration experiment. We report the process and result of the airtightness improving herein to provide reference for other depots.

1 Materials and Method

1.1 Materials

1.1.1 Tested grains and warehouses

We chose the No. 8 warehouse (corn) of Beihai Grain Depot, State Grain Reserves as the tested warehouse and No. 6 warehouse (corn) of Beihai Grain Depot, State Grain Reserves as the reference warehouse. See table 1 below for the status of the grains.

The tested warehouse was the high flat warehouse built in 1997 of which length was 56m, width was 21m and the designed height of pile was 6m; the walls of the warehouse were brick-concrete structure, with thickness of 0.7 m; the roof of the warehouse was steel roof truss structure and heat insulating materials was used on the surface of the warehouse. The ventilating system was three-set geosyncline ventilating net (one machine and three ways) which has been equipped with three 11kW centrifugal blowers; there were four axial flow fans of which powers were 0.55kW has been equipped on gable walls and bilateral walls; and it was equipped with complete test system for status of grain, and external fixed recirculation pipe network was installed on south side of walls and heat insulation treatment has been performed on these recirculation pipes.

When the warehouses were empty, we could see several obvious cracks on the walls and terraces of the warehouses: the cracks on the walls were relatively small and many of them were caused by empty plump of the rendering layers; there was one bigger crack of which width was 10mm and length was 2 - 4m in the middle of terrace, on the wall surface and at the junction of terrace separately; these cracks were caused by settlement of the ground; In the original design, the vent used rubber mat as the sealing material mostly, and its airtightness could meet the requirement at the beginning basically, but with the prolongation of the using time and increasing of the dismounting times of the cover boards during the ventilating process, the rubber mat became aging, damaged and no elasticity. The filling materials in the joint seams between vents and walls exposed to air for long time, so there were efflorescence and cracking-off phenomenon; and the sealing slots on the grain surface and doors had aging and damaged phenomenon.

1.1.2 Airtightness improving and sealing material for grain surface

Slots, plastic films, sealing plates and seal

Table 1. The status of grain in the tested warehouse

Bin №	kind	Quantity (t)	Stored time	Moirsture (%)	Impurity (%)
6	Yellow	4960	2006.4	13.3	1.0
8	corn	4938	2007.8	13.4	0.9

ants used for airtightness improving of the warehouse

Film sealing slot: made by rigid PVC; specification: 6 – 9mm; produced by Xinliang Storage Equipment Factory, Luqiao, Taizhou, Zhejiang.

Film sealing pipe: made by PVC of which size can match with the slot. Produced by Xinliang Storage Equipment Factory, Luqiao, Taizhou, Zhejiang.

Plastic film: five-layer nylon co-extrusion film; width: 2 – 16m; thickness: 0.08 – 0.12mm; specific gravity: 0.95g/cm^3; oxygen transmissibility: 56mL/m2 · 24h; manufacturer: Hengchang Plastic Factory, Suzhou, Anhui.

Gas sampling tube: PVC soft tube of which inner diameter is 5 × 7 mm; manufacturer: Guangdong Lianjiang Building Materials Factory.

Seam filling materials: sealant, concrete, lime powder, glue and etc. Mainly used for treating various joint seams to ensure the airtightness.

1.1.3 Instruments and equipments for test

Test instrument for airtightness: produced by Henan Future Mechanism & Electron Co., Ltd.; type: CQMY; rated voltage: 380V; air volume: 2 670 – 5 270 m^3/h; total pressure: 990 – 1 580 Pa; main shaft speed: 2900 r/min; power of motor: 3kw; other instruments: U-pressure gauge, stop watch and etc.

Tester for oxygen concentration: PGM – 2000 oxygen concentration tester, range: oxygen concentration 0 – 25%, used for test of the oxygen concentration in the warehouse. Manufacturer: RAE Systems (Shanghai) Inc.

Orsat gas analyzer[17]; QF190 Orsat gas analyzer. Manufacturer: Shanghai Yatai Glass Apparatus Co., Ltd. Used for adjustment of instruments and test of CO_2 concentration.

One set of other assistant tools such as stopwatch.

1.2 Method

1.2.1 Test method for pressure half-life:

Connect CQMY airtightness tester with U-pressure gauge and vent, start the equipment, and when the pressure in the tested warehouse reaches to – 350pa, stop the equipment and close the butterfly valves; begin to time when the pressure is – 300pa and record the time from – 300pa to – 150pa, repeat for 3 times and calculate the average pressure half-life.

1.2.2 Arrangement of gas sampling points

Perform blocking prevention treatment on one end of the gas sampling tube, then fix it on the iron rod which has screw threads on both head and end, and insert it into related depth of the grain pile. Another end of the gas sampling tube is introduced to the external gas tester. Seal the mouth of pipe with rubber. The locations of the gas sampling tubes in the grain pile are shown in figure 1 below; there are three depths for each gas sampling point, i. e. 1m, 3m and 5m away from the grain surface. There are totally 15 test points for gas concentration.

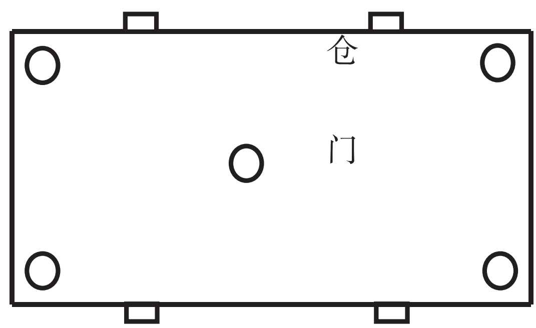

Fig. 1 Arrangement of the gas sampling points in the grain pile

1.2.3 Test method for oxygen concentration

Connect the PGM – 2000 oxygen concentration tester with the gas sampling tube in the gas testing box, start and run the tester until there is no change of concentration, test three times for each point and record the results.

1.2.4 Test method of CO_2

Take the gas from the gas sampling tube with 50mL of 3-way injector, do not take the first ten times, then inject it into Orsat gas analyzer from the 11th time and test the CO_2 concentration in the sample, perform sampling for three times for each sampling tube and take the average value.

1.2.5 Data treatment method

Use Microsoft Excel to perform the date analysis.

2 Result and Analysis

2.1 Technical Process of the Airtightness Improving for the Warehouse

2.1.1 Treatment for seams of terraces,

walls, wall corners and junctions.

First, cleaned the extend the cracks of terraces, walls, wall corners and junctions, then poured concrete and perform rendering and leveling with cement mortar. After drying of mortar, performed repairing with "two cloth and three times coating" method, i. e. brushed one layer of waterproof coating, stuck one layer of fiber cloth, after drying, brushed one layer of waterproof coating and stuck one layer of fiber cloth again, finally, brushed one layer of waterproof coating on the surface of the fiber cloth, the width of fiber cloth was about 500mm. The treatment process was the same as that reported by Chen Yuanzhu basically.[12]

2.1.2 Treatment of the vent

Performed de-scaling treatment for about 20cm on inner wall of the external end of the ventilating duct vent with sand paper to let it to be smooth. Then applied the adhesion agent on the places which have been de-scaled on the inner wall of ventilating duct vent; the width was about 3cm. Stuck silicon rubber mats which have been cut well onto them and compacted them uniformly, and performed curing for more than 24h.

2.1.3 Sealing treatment for grain surface

After grain loading, performed leveling of grain surface and then pressed glued board (arc shape at the wall corners) of which width was 10cm and thickness was 5mm into the wall which was 10cm above the grain storage line of 6m (the original slot was at 2cm above the grain storage line), then fixed the slot in the center of glued board with nails, finally, added the glue into lime powder and mixed them to mash, then performed filling of seams with the mash; the thickness which can just cover the glued board was better and made its surface to be smooth and flat. Performed curing for more than 48h. When performed sealing after complete curing, pressed the five-layer nylon co-extrusion film of which thickness was 0.12mm and the plastic pipe matched with slot into the slot. This formed the sealing of "double-slot and one film" on the grain surface.

2.1.4 Treatment for doorway

Dug a slot of which depth was 3cm and width was 5cm with tools at 5cm near the grain blocking plate on offside of the grain blocking plate and on the wall which was 5cm near the door separately, installed the sealing slots into them and sealed the mouths with lime and cement. The film pressing method was as above. These two slots and two films formed the sealing of "double-slot and double-film". In order to let the films stick to the plate tightly under the positive and negative pressure to relieve the pressure, installed wood plate between two layers of plastic films to fix them.

2.2 The Airtightness of the Tested Warehouse and the Reference Warehouse

Through a series of sealing treatments for walls, doors, vents and inlets of cables in the No. 8 warehouse, performed field test of airtightness by negative pressure method with airtightness tester; see table 2 for the results. The first tested pressure half-life was only 82s, at that time, the voice of air leakage could be heard at the door and the vent obviously, therefore, the intensive problem need to be resolved in the first stage was the sealing treatments for the door and vent. Tested the pressure half-life after improvements of door and vent, the result reached to nearly 200s, 116s higher than that of the first time, however, the airtightness was still not ideal at that time, then changed to use positive pressure, and inspected air leakage places with the soapy water coating method; during the process, we found small part of sealing pipes scaled off from the slot and we organized storekeepers to perform slot pressing treatment for sealing pipes; performed checking and repairing of leaks for sealing slots and sealing films of grain surface, after that, tested the pressure half-life for the third time and the half-life increased to 275s, 3.3 times bigger than that of the first time (82s).

The door and grain surface of the No. 6 warehouse were sealed with single plastic film. Since the airtightness of the installed sealing slots and hoses were not good at the building period of the warehouse and some parts were aged and damaged, when performed negative pressure test with the airtightness tester, the max. negative pressure only could reach to 280Pa (see table 2), and the time for pressure reducing to 140Pa was 53.7s.

The airtightness of the tested warehouse was better than that of the reference warehouse obviously.

Table 2. Test results of the airtightness

No	Date	Range (Pa)	Half-life(s)	Average half-life (s)	Remark
8	10.13	-300 - -150	90 79 77	82.0 ±4.0	Major air leakage places were doors and vents
8	10.15	-300 - -150	202 196 198	198.7 ±1.8	Cushion of the vent was replaced to soft rubber; used sealing of "double-film and double-slot" for doors.
8	10.16	+200 - +100	95	-	Inspected leaks with the soapy water coating method and found that the joint of airtightness tester and vent was not good, then treated with sealant
8	10.19	+200 - +100	43	-	Sealing films for grain surface and doors scaled off from slots
8	10.22	-300 - -150	277 276 273	275.3 ±1.2	Sealed and pressed slots for sealing films for grain surface and doors again, repaired leaks of films for grain surface
6	10.18	-280 - -140	56 53 52	53.7 ±1.2	As to reference warehouse, the increasing time of the pressure was very short and the max. Pressure only could reach to 280Pa, and the airtightness was bad

2.3 Natural Oxygen Reducing Result after the Sealing of Grain Pile

From table 3, we can see that after 45 days sealing of grain pile for the No. 8 warehouse, the oxygen concentration in the grain pile was reduced from 20.6% to 9.7% and the CO_2 concentration increased from 1.0% to 4.0%. Through analysis, the reasons may be:

1) Relatively higher density of pests. In the air tight environment, the breath of pests will consume oxygen gradually and accumulate CO_2 at the same time. From the sampling and testing, we found that the density of pests reached to 23pcs/kg, in which, *Cryptolestes pusillus* (Schonherr): 7; *Sitophilus zeamais* Motschulsky: 1; *Tribolium castaneum* (Herbst): 2; *Cryptolestes ferrugineus* (Stephens): 10; larva of *Plodia interpunctella* (Hubner): 3.

2) There was certain quantity of microorganisms in the corns obtained that year, and through the breath, microorganisms could reduce the oxygen in sealed grain pile. Some researches show that, microorganisms have excellent oxygen reducing effect[18].

3) The corns obtained that year had relatively stronger breath effect. Since the characteristics such as bigger embryo of corn, both new grain and old grain had very strong oxygen reducing effect[18].

We can see that good airtightness of the grain pile can reduce the oxygen concentration obviously.

Table 3. Changes of concentrations of oxygen and CO_2 in the tested warehouse under the air tight condition

Date[1]	AOC[2] (%)	ACO$_2$C[3] (%)	TW[4] (℃)	ATW[5] (℃)	T[6] (℃)
Sep. 15, 2007	20.6	0.5	27.5	18.0	27.6
Oct. 15, 2007	14.8	1.0	26.2	21.2	24.0
Oct. 22, 2007	12.3	2.9	25.7	21.8	22.8
Oct. 29, 2007	10.2	3.6	27.1	22.4	22.7
Oct. 30, 2007	9.7	4.0	25.1	22.6	17.6

Note: 1 Test time on 9:00 am; 2 Average oxygen concentration; 3 Average CO_2 concentration; 4 Temperature of warehouse; 5 Average temperature of warehouse; 6 Temperature

From table 4, the No. 6 reference warehouse was also sealed for 45 days and the oxygen concentration in the grain pile was reduced form 20.6% to 16.1% which was 6.4% higher than that of the tested warehouse; it showed that the oxygen concentration was reduced, but the range of reducing was smaller than that of the tested warehouse. Through analysis, the reasons may be:

The airtightness of the reference warehouse was much worse than that of the tested warehouse, the diffusion of the gas concentration could reduce the oxygen concentration in the warehouse;

1) The density of pests in the reference warehouse was lower. Through sampling and testing of the grain pile, the density of pests was 2/kg;

2) Through low temperature storage of the stored grain in the reference warehouse for a period of time, it inhibited growth of partial microorganisms.

Table 4. Change of oxygen concentration in the reference warehouse (No. 6 warehouse) under the air tight condition

Test time (9:00am)	Average oxygen concentration(%)
May 21, 2007	20.6
May 31, 2007	19.9
June 10, 2007	18.6
June 20, 2007	17.2
June 30, 2007	16.5
July 5, 2007	16.1

3 Discussion

Although the origin of film sealing technology for grain pile is relatively earlier and it has been used extensively, the reports of airtightness testing after sealing and reducing degree of oxygen are few, and it is lack of strong support for this film sealing technology, however, this technology can ensure the effective implementation for green low oxygen stored grain, it is the precondition for effective inhibiting of growth and reproduction of pests and microorganisms under low oxygen condition. Luotian depot in Hubei has performed related research[18]; for the wheat of which water content was 12.2%, performed natural oxygen reducing for 55 days under the status that there were pests detected (24/kg), and the oxygen concentration was reduced to 12% around. In 1970s, Xiamen, Fujian performed test on paddy with low water content, performed five-face sealing for 1 million kgs of early paddy of which water content was 12.3%, after storage for a period of time, the content of oxygen in the grain pile was stable at 2% - 6%; through testing, we found that the quantity of pests in the warehouse was inhibited. At the same period, Taicang, Jiangsu and other areas performed oxygen-reducing storage test over summer for late japonica rice, after sealing with PVC films on grain pile for a period of time, the oxygen content in grain pile was stable at 2% - 5%, and there was no pest through test[18]. These results were compatible with this research basically, except they did not test the airtightness of the grain pile and thus detailed comparison between the result of this research and that of them could not be performed. We suggest that in future researches and experiments, it would be better if each experimental organization can test the airtightness of the grain pile and warehouse after sealing to obtain a large number of data which can be used for reference and comparison, and establish the basis for gas adjustment and fumigation technologies.

This test also shows that through natural oxygen reducing, the oxygen concentration in the grain pile of which airtightness is relatively good also can be reduced to less than 10%. Although pests and microorganisms can not be killed completely, it has certain inhibition for growth of entomomycete, and provides better conditions for applications of pest controlling and killing by gas adjustment and fumigation technologies and establishes base for the next manual and mechanical oxygen reducing experiment. However, the further experiments and researches are still needed for the inhibiting effect of natural oxygen reducing on stored grain pests and mold.

References

[1] Kong Xiaoling. Development and application of the tested warehouse for stored grain pest controlling by CO_2 gas adjustment. Transactions of the Chinese Society for Agricultural Machinery. 2006(8):73 - 77

[2] Shu Zaixi. Discussion on effect of the airtightness of warehouse on safety of the stored grain. Grain Distribution Technology, 2001 (5):33 - 35

[3] Technical procedure for PH_3 recirculation fumigation (trial implementation). State Grain Reserves. LIANGYOU CANGCHU KEJI TONGXUN. 2001 (1):24 - 25

[4] Liang Quan. Basic research progress and application of PH_3 fumigation. Grain storage, 1994 (2 - 3, added) 23, 1992 (5) 356 - 361

[5] Jiang Jin'an. Airtightness improvement for high flat warehouse. Grain Science and Technology and Economy. 2004 (5):37 - 45

[6] Huang Man. Applied technology for airtightness improvement of silo. Grain Distribution Technology. 2004(1):16 - 18

[7] Zhao Yingjie et al. Simple discussion on fumiga-

tion method for silo and airtightness requirement of silo. Grain Distribution Technology. 1998 (2):30 – 37

[8] Li Min et al. Initial exploration of airtightness difference among various low round warehouses. Grain Distribution Technology. 2005 (4): 21 – 33

[9] Deng Lanqing, Simple discussion on application of gas controlled storage in stored grain. Grain storage. 2006 (3):28

[10] Gao Yuchen. Simple discussion on airtightness of gas adjustment warehouses. Grain storage. 2006 (6):23

[11] Shen Zonghai. Grain storage [M]. Beijing: China Financial & Economic Publishing House, 1998

[12] Chen Yuanzhu. Exploration of improvement on airtightness by local improvement in high flat warehouse. Grain storage machinery and warehouse building. 2004 (32):51

[13] Yu Jian et al. Technical research on safety grain storage technology by CO_2 in brick silo. Grain storage. 2001 (1)

[14] R. H. (Jack) Burton. 1998. Sealing permanent storages for fumigation using. Australian Postharvest Technical Conference

[15] Wang Dianxuan. Relativity between airtightness of warehouse and dosage and concentration of medicine used in PH_3 recirculation fumigation. Grain storage. 2002 (4):11 – 14

[16] Ma Zhongping, Ma Honglin, He Qile et al. Overview of the application status of CO_2 adjustment grain storage technology in our depot. Grain storage 2006 Vol. 35 No. 3 P. 13 – 16

[17] Shen Zonghai. Grain storage [M]. Beijing: China Financial & Economic Publishing House, 1998

[18] Storage and management administration, State Grain Reserves. China grain storage . Chongqing: Chongqing University Press, 1994. 130 – 16