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## Test on Recirculation Fumigation under Plastic Sheet in Squat Silo

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**Abstract:** To improve the sealing performance of squat silos, an experiment on recirculation fumigation under plastic sheet in squat silo was made at Daminggong Grain Depot. Comparing with the common recirculation fumigation technologies, it has more advantages, such as the fumigant concentration balance being reached in shorter time, maintaining a high enough dosage for sufficient time, good cost-benefit and the chance of infesting insects again being reduced.

**Key words:** squat silo, recirculation fumigation under plastic sheet

### Introduction

Silos with ratio of height to diameter of less than 1.5 have often been called “squat” silos. As squat silo has such advantages as large storage capability, small floor area, easy automatic implementation, good aeration and recirculation fumigation systems, ease of loading and unloading with several silos in-line, in the late 1990s, starting in 1998, when the project of construction twenty-five thousands million kilogram warehouse was put into practice, a number of squat silos were built for state grain reserve storage. To improve the sealing performance, grain mass surface should be sealed by plastic sheet, under the impulse of recirculation blower, the technology of recirculation fumigation under plastic sheet can make phosphine circulated through circle ducts and other ventilating ducts equipped in advance.

In recent years, along with this technology was put into production in some large warehouses and squat silos, it has created many difficulties, such as phosphine infiltrating slowly by gravity in high and large grain masses (like the new 30 × 60m warehouses and 30 m diameter squats), uneven gas distribution, resulting in poor insecticidal control effects, labors intensity and other negative issues. But in the new construction at state grain depots since 1998, recir-

ulation fumigation has been frequently used. The technology had some choke points, such as strictly required warehouse sealing performance, high non-effective dosage rates in the procession of fumigation implementation, phosphine losing excessively, storages being quickly infested with insects again shortly after fumigation. In addition, in the process of implementation in squat silos, the silo roof ventilation hole was very difficult to seal. Therefore, to conquer some disadvantages in the procession of the common recirculation fumigation, the research on recirculation fumigation under plastic sheet in squat silo had been made at Daminggong Grain Depot State Grain Reserves, in Shaanxi province. Many good effects have been achieved by this experiment.

## 1 Materials and Methods

### 1.1 Materials

#### 1.1.1 Testing warehouse

No. 11 squat silo was chosen as the testing warehouse. It was built in 1998, designed for a capacity of 8750 tons and whole volume of 12410.9 cubic meters. It has equipped with immobile recirculation fumigation system. The wheat for testing was loaded in the squat silo in 2005. The specific qualities and pests of storage grain are listed in Table 1.

**Table 1. The specific qualities and pests of storage sweat at No. 11 squat silo**

Amount (ton)	Grain moisture (%)	Average temperature of grain mass (°C)	Species of main pests	Pests density (No./kg)	Height of grain mass (m)	Volume of grain mass (m <sup>3</sup> )	Type of recirculation fumigation device
7772.945	11.5	20.6	Rusty grain beetle	5	13.9	9820.35	Built-in piping with recirculation blower

### 1.1.2 Chemicals and Its dose

Aluminium Phosphide ( 56% ), carbon dioxide, application concentration of  $1.22 \text{ g/m}^3$  with chemicals, with the total dose of 12 kg, at the volume ratio of carbon dioxide to phosphine of 98:2. delivered from fixed phosphine generator.

### 1.1.3 Phosphine Recirculation Device

YYWF7122 type of recirculation fumigation fan; quantity of ventilation of  $600 \text{ m}^3/\text{h}$ , pressure of ventilation of 1000 Pa, power of 0.55 kW; moveable recirculation ducts under PVC plastic surface sheet; Polyvinyl Chloride (PVC) tube with diameter of 110 millimeters and 4 meters long; as well as recirculation fumigation ducts outside the silo.

### 1.1.4 Phosphine Provider

LM - KF3608 - V type of mobile fixed fumigation device outside of warehouse.

### 1.1.5 Device for Detection

DST - 01D type of phosphine monitor, DST - 01A type of phosphine alarm apparatus.

### 1.1.6 Ventilation Ducts

Underground conduit with pectinate ventilation ducts and six ventilation hole, equipped at both south and north sides of squat silo.

## 1.2 Methods

### 1.2.1 Equipment with Recirculation Fumigation Ducts under Sheet

Connect one port of the PVC flexible duct,  $\Phi 110 \text{ mm}$  diameter and 4 m long, with the upper recirculation gas suction hole in squat silo, embed another port 10 cm under grain mass surface.

### 1.2.2 Make Grain Mass and Ducts Sealed

After completing equipping of recirculation fumigation ducts under sheet, cover grain mass with PVC film in squat silo, and joint the connection place of PVC film with bonding machine, then connect PVC film with thermometric cables and walls respectively by scotch tape, at the end, seal with scotch tape again at the edge of ventilation ducts.

### 1.2.3 Gas Tightness Test

After having sealed grain mass and ventilation holes, the half life of pressure, which it takes in rising the pressure of silo from -500Pa to -250Pa, would be tested as a piece of parameter of silo tightness.

### 1.2.4 Equip Devices

Connect recirculation ducts with the scavenge port of LM - KF3608 - V type of mobile out-warehouse fumigation device, and the high-pressure soft duct of  $\text{CO}_2$  cylinder with the in-

take port of out-warehouse fumigation device.

### 1.2.5 Gas-leaking Test

By operating the recirculation fumigation fans and generator unit of mixed phosphine and carbon dioxide, check whether working smoothly, and check for gas-leakage by soap bubble test.

### 1.2.6 Application with Chemicals

Put 12 kg Aluminium Phosphide ( AIP ) prepared before into pot storage for chemicals, and then open the valve of  $\text{CO}_2$  cylinder and make the gas pressure keep the level of 0.2 MPa. 5 minutes later, the recirculation ducts have been cleaned by  $\text{CO}_2$ , and provide chemicals at the rate of 45 g per minute.

### 1.2.7 Recirculation

At the early stage of providing chemicals, open the device for recirculation, it would not finish until the concentration of phosphine in both sides of south and north was in balance approximately ( the minimum to maximum  $\geq 0.6$  ).

### 1.2.8 Measurement for Phosphine Concentration

Since 4 hours after recirculation, phosphine concentration has been detected once by phosphine monitor everyday. It should not end until finished.

### 1.2.9 Inspection on Pests Control

After fumigation was over, the residue should continue to aerate properly. Inspection on pests control should not be carried on by grain sampling until chemicals scattered out.

## 2 Results

### 2.1 Airtight Quality of the Squat Silo

It has been shown that the half life of pressure of No 11 squat silo was 110 seconds by gas tightness test.

### 2.2 Phosphine Concentration Alteration

It has been shown from phosphine concentration determination that the phosphine concentration in grain mass would be in balance approximately 24 hours after fumigation, and it would reach the maximum value one hour later, and then began to decrease gradually, till about 30 hours after fumigation, the ratio of the minimum concentration to the maximum one has become 0.75, the uniformity of phosphine concentration in grain mass has kept the level of 80%. 28 days later, the average phosphine concentration in grain mass still could keep  $70 \text{ mL/m}^3$  upwards. The total concentration-time product (CT) could be beyond  $180 \text{ mg} \cdot \text{h/m}^3$ .

## 2.3 Effects on Pests Control

After having cultured the sampling pests for 14 days, none of them was found to keep alive and the mortality was 100%.

## 3 Analyses and Discussion

As the same as the common recirculation fumigation, comparing with the common fumigation, recirculation fumigation under sheet have more advantages, including decreasing the application quantity of chemicals, being easy to phosphine distributing evenly as soon as possible, convenient to add chemicals and safeguarding workers healthy etc. . Therefore, emphasis on comparing with the common recirculation fumigation will be listed as follows.

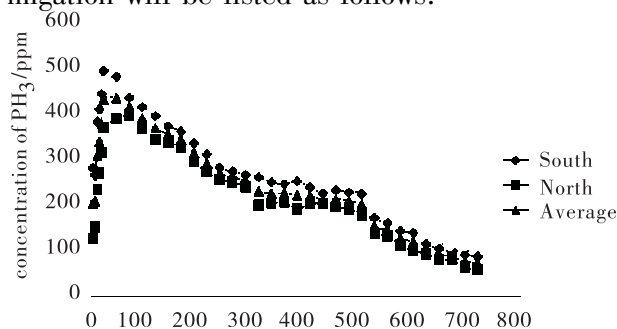


Fig. 1 Relationship between PH<sub>3</sub> concentration with fumigation hours in No. 11 squat silo

**3.1 By recirculation fumigation under sheet, the effective fumigation concentration would be reached in shorter time around the whole silo, and a high enough dosage could be maintained for sufficient time. Thereby, the effect of fumigation would be improved**

3.1.1 Its airtight quality be superior to one while the common recirculation fumigation

From the results of gas tightness test, its airtight quality was 110 seconds, however, while the same squat silo was carried on the common recirculation fumigation in 2000, its airtight quality measured was 75 seconds, obviously, its airtight quality while it carried on recirculation fumigation under sheet was superior to one while the common recirculation fumigation.

3.1.2 Phosphine uniformity in grain mass be superior to one while the common recirculation fumigation

As the gas volume circulated which recirculation fumigation under sheet needs was less than that the common recirculation fumigation needs, the times gas exchanged per second became more frequent, and it took less time for phosphine concentration coming into balance than the common recirculation fumigation, and

less time for gas circulating. Moreover, at recirculation fumigation under sheet, after concentration into balance, the ratio of the minimum concentration to the maximum concentration always kept 0.7 upwards. From the figure on PH<sub>3</sub> concentration fumigation hours, it seems smooth and the phosphine concentration decreased on an even keel.

3.1.3 Maintain a high enough dosage for sufficient time by recirculation fumigation under sheet

In the first 30 days after fumigation, PH<sub>3</sub> concentration in No. 11 squat silo decreased at the rate of 2.87%. After being sealed, phosphine concentration inside still could keep 100 mL/m<sup>3</sup> upwards for 26 days to kill all life stages of the infesting insects. However, at the common recirculation fumigation, phosphine concentration decayed at much greater speed, according to the paper reported<sup>[1]</sup>, 5.7 hours later the common recirculation fumigation, the maximum average concentration reached the level of 791.0 mL/m<sup>3</sup>, however, 113 hours later, phosphine concentration in grain mass arrived at 102.5 mL/m<sup>3</sup>, 140 hours later, it only left at 31.1 mL/m<sup>3</sup>, therefore, in the first 6 days after fumigation completed, phosphine decreased at the rate of 16% everyday, which was 4 times than recirculation fumigation under sheet. In addition, at recirculation fumigation under sheet, It would took 14 days for phosphine concentration decreasing from 400 mL/m<sup>3</sup> to 100 mL/m<sup>3</sup>, and at common recirculation fumigation, it would only took 4 days. Therefore, to reach a certain CT value, it would need to apply chemicals at the common recirculation fumigation with over 2 times than at recirculation fumigation under sheet. From these standpoints, during recirculation fumigation under sheet, it would not only save non-effect application quantity under the sheet, and also decrease the total chemicals application quantity.

**3.2 Good Cost – benefits at Recirculation Fumigation Under Sheet**

Comparing with the common recirculation fumigation, as no chemicals application in the empty space, the volume of fumigation became less, and less dosage would be provided, moreover, it took less time on recirculation, and needed less electrical consumption, so it had better economical benefits, ecological benefits and social benefits. While fumigation expenditure under sheet per ton grain in No 11 squat silo was 0.123 RMB, the one of common recirculation

fumigation was 0.317 RMB. So it could save 60% upwards once. In addition, as the small possibility of infested insects again after recirculation fumigation, grain could be stored safely

by carrying on low oxygen and no chemicals, and then grain contamination and environment pollution also decreased further.

**Table 2. expenditure table on recirculation fumigation under sheet**

Aluminium Phosphide			Carbon Dioxide			Electrical Consumption by Fumigation Device		
Dosage (kg)	Price (RMB/kg)	total (RMB)	Dosage (kg)	Price (RMB/kg)	total (RMB)	Time(h)	Power(kW)	Fees(RMB)
12	30	360	200	2	400	3.5	5.2	12.7
Electrical Consumption by Recirculation Ventilator			Health Care for Fumigation Workers(RMB)			Expenditure Each Ton Grain(RMB/t)		
Time(h)	Power(kW)	Fees(RMB)						
80	0.55	32.6	150			0.123		

**3.3 At Recirculation Fumigation under Sheet, Safety Should Be in Care**

Though gas tightness quality was better at recirculation fumigation under sheet, still could little phosphine leak outside, so in case of checking inside in the implementation process of fumigation, workers should be careful and wear Full Face Canister Respirator well.

**3.4 Prevent from Dewfall of Grain Mass in the Implementation Process of Fumigation**

As the squat silo was higher, stack effect came into being easily. Under the promotion of stack effect and recirculation ventilator, the moisture in grain mass would go upward, if the moisture gone upward could not scatter out, it would be easy to produce dewfall on the surface

of grain mass. So while carrying on fumigation under sheet, check and inspection should be taken frequently to ensure grain storage safety.

In a word, recirculation fumigation under sheet, with broad application prospects, will be the first alternative technology for grain storage fumigation in the future.

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