Technical study of controlled atmosphere with carbon dioxide in brick silo for safe storage of wheat

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Abstract

Carbon dioxide was piped into a sealed brick silo until well distributed in the grain mass. The silo atmosphere was recirculated until there was an even distribution of 70% carbon dioxide in the grain mass. Fourteen days after ventilation was stopped, over 35% CO_2 still remained in the grain mass. Using this method, wheat free of insect and moulds can be safely stored.

Introduction

In 1971 Pujidao Grain Storage, Tianjin carried out the first CO_2 treatment of bulk paddy rice in China. The method involved treatment of the bulk under tarpaulins. It has been in use since then on bulk grain. The technical study described here aimed to provide information on treatment with CO_2 of grain held in brick silo bins. This had not been investigated previously in China. The study was carried out using two bins known as the 'test' and 'control' bins. The test bin was extensively modified and the control bin was sealed but not modified. Information from Australia on similar treatments was not directly applicable as it referred to much larger-scale applications.

Work started in 1990 to make the test silo bin sealed and to equip it with a multifunctional gas ducting system. In both the trial and control bins, CO_2 was applied through the duct at the base of the bin, forcing the air out of the bin, until the concentration was over 70%. The study, completed in 1992, met the assessment criteria of a panel of scientists and fulfilled the Chinese requirements for grain stores.

Materials and Methods

Structure of the silo bins

Figure 1 gives a general view of the silo bins at Junliangchen Mill. The brick silo bins are 14 m high, 6.63 m inside diameter and 7.45 m outside diameter. They are equipped with steel bottom cones with a 0.3 m diameter grain outlet. The bin roof is of concrete with a rectangular manhole, 0.56 × 0.57 m, and an aeration vent of 0.46 m diameter. The ductwork fitted was multifunctional, allowing recirculation of fumigant, aeration and fumigant application.

In the sealing trial the inner wall of the test bin was rendered with two coats of a mixture of sand, hydrated lime and cement. Three further coats were applied using a mixture of cement with a little sand. The control bin was coated, inside and out, with two layers of the latter mixture. The outer wall of the test bin was also rendered with two coats of this mixture. The holes in the roof were all fitted with easily removable steel plates (0.005 m thickness) bedded onto 0.03 m thick silicone rubber and secured with nuts.

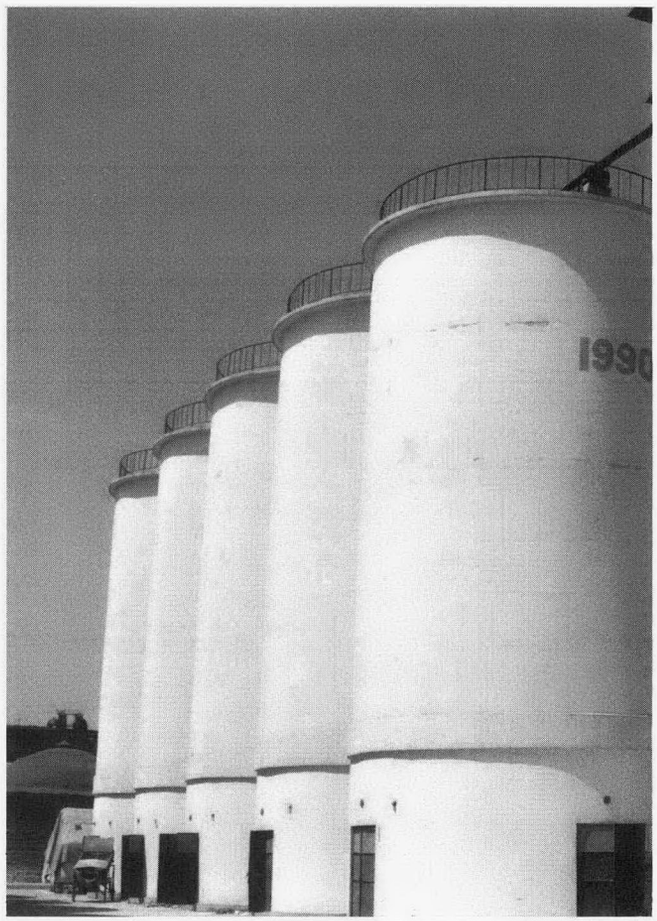

Fig. 1. Brick silos in Junliangchen Mill.

Testing for gastightness

Table 1 gives the results of the gastightness tests after sealing.

Grain

The test bin contained 220 t hard red wheat, 11.0% m.c., inloaded on 4 August 1992. The control bin contained 220 t soft red wheat, 11.0% m.c., inloaded on 5 August 1992.

Test equipment used

Centrifugal blower (CQ18–I), multifunctional duct system (see Figure 2), CO_2 gas detector (CYES–IIO2), Air sampler (CD–I).

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Table 1. Test results, pressure tests to determine gastightness.

	Initial pressure (mm H_2O)	Pressure limits (mm H_2O)	Decay time (seconds)
Test bin	302	200–100	103
	302	100–50	98
	302	50–25	99
Control bin	288	200–100	67
	288	100–50	56
	288	50–25	58

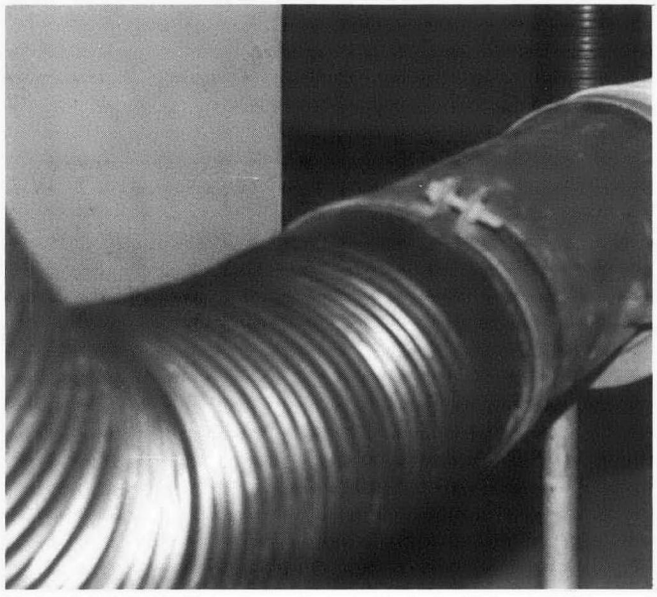

Fig. 2. A part of the multifunctional duct system.

CO_2 addition

After aeration using the duct system, CO_2 was introduced into the base of each bin, displacing the bin atmosphere gradually through the aeration vent in the roof. It was planned to seal the gas inlet and outlet when the concentration in the bin reached 70% CO_2.

In the test silo bin 422.5 kg was introduced on 8 August 1992 at a rate of 0.73 kg/min. When the 7 sampling points detected an average CO_2 level of >80% the inlet and outlet were sealed. After 120 hours the CO_2 level had dropped below 35% at some points. Supplementary CO_2 was added into the headspace on 15 August (109.5 kg). On 21 August (218 kg) was added with recirculation to keep the CO_2 concentration above 35% for 14 days.

In the control silo bin, 586.5 kg of CO_2 was added on 7 August into the duct at the base of the bin at a rate of 0.79 kg/min, with the bin sealed when the average of the 7 sampling points exceeding 80%. After 38 hours the CO_2 concentration had dropped below 35% at (250 kg) was added on 9 August. Because of the rate of loss of CO_2, no further gas was added.

Results and Analysis

The results of CO_2 analysis in summary (Table 2) showed that the Australian standard for CO_2 Controlled Atmosphere (CA) was met in the test bin (i.e. 70% or greater initially, with no less than 35% 10–14 days later).

Results from the control bin in Table 2 showed that this bin could not reach the Australian standard.

Details of CO_2 levels at the 7 sampling points in the test bin are given in Table 3. In this bin the highest concentration was 90.7% and the lowest 82.3% after purging, a difference of 8.4%. The concentrations in the control bin (Table 4) were less even with 93% and 81% as highest and lowest concentration after purging, a difference of 12%.

Table 3, test bin results, showed that when the average at the 7 sampling points was over 35% the maximum was 67.2%, the minimum was 24.6% and the difference 42.6%. The corresponding values for the control bin (Table 4) were 85.6%, 20.6% and 65.0% respectively. This shows that there was a more even distribution of CO_2 in the test bin than in the control bin.

The quantity of CO_2 lost from the control bin was high at high CO_2 concentration (43.5%) and lower at low concentration (31%). Corresponding figures for the test bin were 30.4% and 9.1% respectively. This shows that it is important not to add CO_2 to give too high a concentration initially.

Recirculation was very important as indicated by data in Table 3 for before and after recirculation.

CO_2-based CA can safely protect grain without grain or environmental contamination.

With CO_2-based CA applied to 30 silo bins, avoiding downgrading of the grain, it is calculated that ¥144 000 per year can be saved.

The reason why the trial silo bin retained CO_2 better than the control one, as shown by results given above, is because it was better sealed. The difference, caused by the high density of CO_2 relative to air, was more apparent at low CO_2 concentrations than at high concentrations.

Conclusions

Brick silos with a pressure half life of 103 seconds and equipped with sealing and ductwork as described can be used to store grain with CO_2 CA technology.

Table 2. Summary of CO_2 treatment and results.

Bin	Sealing treatment		First CO_2 addition		Second CO_2 addition		Third CO_2 addition	
	Render on inner and outer walls—number of coats	Extra render on inner wall—number of coats	Quantity (kg)	Average CO_2 concentration (%)	Quantity (kg)	Average CO_2 concentration (%)	Quantity (kg)	Average CO_2 concentration (%)
Test bin	2	3	422.5 (8 Aug)	87.0	109.5 (15 Aug)	42.1	218	42.4
				69.9 after 26 hours		34.3 after 72 hours	(21 Aug)	36.5 after 43 hours
				47.5 after 96 hours				
Control bin	2	0	586 (7 Aug)	87.1	250 (9 Aug)	68.7	–	–
				62.9 after 24 hours	(9 Aug)	35.2 after 70 hours		
				49.1 after 48 hours				

Table 3. CO_2 concentrations (%) in test and control bins.

Time	Sampling point							
	1	2	3	4	5	6	7	Average
				Test bin				
1500, 8 Aug. 1992	83.1	89.8	90.1	90.7	83.4	82.4	89.8	87.02
1700, 9 Aug. 1992	48.3	67.2	91.8	90.4	46.0	65.3	80.0	69.85
1500, 10 Aug. 1992	33.8	53.3	88.1	90.1	33.1	53.2	72.0	60.51
1500, 11 Aug. 1992	27.5	43.3	81.0	86.1	27.2	43.3	67.2	53.65
1500, 12 Aug. 1992	21.6	36.7	74.7	84.2	19.7	36.2	59.5	47.51
1500, 13 Aug. 1992	18.5	31.9	69.3	78.7	18.2	32.0	54.1	43.24
1500, 15 Aug. 1992[a]	13.3	23.7	69.4	82.3	33.0	23.1	31.9	42.10
1500, 16 Aug. 1992	28.5	30.2	62.4	71.9	26.9	28.7	39.4	41.14
1500, 17 Aug. 1992	24.7	29.0	56.3	67.2	24.6	26.9	39.3	38.28
1500, 18 Aug. 1992	21.7	24.4	51.2	63.5	19.0	24.4	36.7	34.30
1500, 19 Aug. 1992	9.5	24.2	49.4	61.5	15.1	23.4	32.9	32.78
1500, 20 Aug. 1992	17.0	21.8	45.5	52.9	17.2	22.0	33.9	30.02
0800, 21 Aug. 1992	15.7	21.0	45.2	52.5	15.8	20.9	32.2	29.04
1000, 21 Aug. 1992	20.2	19.5	20.7	50.9	19.0	19.0	18.0	23.90
1500, 21 Aug. 1992[b]	19.9	20.1	93.3	93.7	17.6	18.0	93.0	50.80
1900, 21 Aug. 1992	38.5	38.6	35.2	73.7	41.5	35.8	33.8	42.44
1000, 22 Aug. 1992	35.6	38.5	38.5	59.2	36.5	33.1	36.8	39.74
1000, 23 Aug. 1992	32.5	33.9	40.8	48.3	31.4	33.0	35.8	36.52
1000, 24 Aug. 1992	28.0	31.5	39.7	44.4	28.6	30.1	34.4	33.81
1000, 25 Aug. 1992	24.5	28.9	38.7	42.3	24.1	27.9	32.9	31.32
[a]109.5 kg added into headspace								
[b]Reading after 218 kg addition and 2 hours recirculation								
				Control bin				
1500, 7 Aug. 1992	81.0	88.0	92.0	93.0	86.0	83.5	86.0	87.07
1500, 8 Aug. 1992	47.8	61.5	74.3	90.3	60.2	48.1	58.1	62.90
1500, 9 Aug. 1992	38.0	35.4	67.4	91.3	45.5	29.7	36.5	49.11
1700, 9 Aug. 1992[a]	42.5	5.0	92.3	90.0	70.8	44.6	67.3	68.71
1500, 10 Aug. 1992	34.1	45.9	77.1	2.1	46.1	34.0	44.3	55.37
1500, 11 Aug. 1992	25.6	33.8	60.2	91.3	33.2	25.4	33.0	43.21
1500, 12 Aug. 1992	21.4	23.9	49.0	85.6	23.6	20.6	22.5	35.22
1500, 13 Aug. 1992	18.5	17.9	39.4	78.5	17.6	18.2	18.4	29.78
1500, 14 Aug. 1992	16.1	15.9	33.0	71.6	15.7	16.3	15.9	26.30
1500, 15 Aug. 1992	13.2	13.4	29.3	67.7	12.5	13.6	13.3	23.28
1500, 16 Aug. 1992	4.3	13.0	12.4	62.1	12.5	12.3	12.3	18.41
1500, 17 Aug. 1992	3.0	10.5	22.6	56.8	10.4	11.0	11.0	17.90
1500, 18 Aug. 1992	6.4	8.7	19.2	49.4	10.0	10.4	10.2	16.32
1500, 20 Aug. 1992	2.6	8.5	14.6	38.2	8.8	9.2	9.2	13.01
1500, 22 Aug. 1992	1.3	8.0	15.4	35.5	7.4	7.6	7.5	11.81
1000, 23 Aug. 1992	1.1	7.3	14.1	33.1	6.7	7.0	7.0	10.90
[a]250 kg CO_2 added into headspace								

The study showed that the test bin achieved >70% CO_2 and still had >35% CO_2 after 14 days. The study cost ¥22010 for materials and ¥2200 for labour.

References

Grain and oil storage edition group. 1987. China National Financial and Economics, Grain and Oil Storage, 226–253.

Rui Sun, Lianghua Guan, Chengguang Zhang, Chunhe Liu and Jianhua Lui. 1993. Ducting systems for silo fumigations in Tianjin municipality, China. In: Navarro, S. and Donahaye E., ed., Proceedings of an International Conference on Controlled Atmospheres and Fumigation in Grain Storages. Winnipeg, Canada, June 1992. Caspit Press Ltd., Jerusalem, 343–351.

Zhou Jing-Xing and Jiang Yong-Jia. 1985. Grain storage technology. Peoples Republic of China, Zheng Zhou Grains College Library, 85–87.