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Evaluation of 'Closed Loop Fumigation' in Large Steel Unsealed Silos in Western Australia

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Abstract: Many large bolted silos with a capacity greater than 500 m are constructed unsealed in Australia unless full sealing is specified by the client. These silos may have a sealing compound inserted between each wall sheet and the base concrete but have open eaves, no sealing between the roof lap joints and unsealed access ports.

The fumigant phosphine is used routinely to control stored grain insects in this type of silo. The efficacy of these fumigations is questionable and gas may be lost before all life stages of the insect are controlled and with the potential to select for phosphine resistance. To control all life stages of the target species the gas must be retained within the grain for the period specified in the protocol.

To achieve full control of insects in these silos sealing is recommended but it is a more complicated and costly procedure to seal after construction. The addition of a recirculation (Closed Loop) system in conjunction with additional joint sealing and sealing of access ports may enhance distribution of gas throughout the grain profile.

This paper reports on an investigation into fumigations in bolted steel silos ranging from 835 m to 1 729 m^3, ambient weather effects on the gas values and the impact of direction of airflow within the silo.

Fumigation results varied according to the ambient conditions and the air flow direction created by the recirculation fan.

A protocol of 100 ppm for seven days for susceptible grain beetles was reached in some storage under low ambient wind conditions but failed to reach this protocol under high wind conditions.

Fumigant loss was high when the gas was blown into the headspace and there was improved retention when the gas was extracted from the headspace and blown into the base.

Key words: closed loop fumigation, phosphine

Introduction

In very large squat sealed grain stores (height is less than twice the width) gas applied to the surface will diffuse over time to the lower parts of the silo. Friemel (1983 [6]) reported on the work by Allen et al (1979 [1]) on the surface application of Detia bag blankets to a 14 000 m squat welded silo in the USA. Phosphine concentrations > 100 ppm were achieved by day 8 in all parts of the silo.

To predict a successful fumigation the gas must be contained within a storage structure with minimal gas loss such as a sealed silo. A sealed structure is determined by a pressure halving test (P) of greater than five minutes from an initial pressure of 25 mm of water gauge for (i) an empty or part full silo and (ii) three minutes for a full silo. (Andrews et al 1994 [2])

In an unsealed silo, surface application of phosphine will more likely result in a greater part of the gas being lost to the atmosphere from a venturi effect (Reed 2006 [8]) created by wind blowing over the silo and causing a low pressure zone above the silo. The air/gas mixture within the silo will rise and leak from open joints before it can penetrate to the lowest parts of the silo.

In Australia a large number of squat grain silos > 500 m capacity have been constructed over the last 20 years. A majority of these silos were not constructed to the suggested sealed standard although the walls may have had a sealant product applied as the sheets were bolted together. The roof sheets and wall to roof joint are generally close coupled in the more recent constructions while older silos have open eave venting. These silos do not constitute a sealed storage and in terms of a successful fumigation are considered to be unable to reach a criteria suggested by Banks (1984 [3]) that "an average concentration greater than the minimum effective against insects be present at the end of

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the exposure period". In Western Australia the protocol for farm based fumigations is > 100 ppm for at least seven days >25℃ and 10 days <25℃. (Newman 2008 [5]).

Many of these large unsealed silos are regularly dosed with phosphine by the grain manager, most often by surface application of tablets and sometimes through aeration ducts if fitted. Many novel and informal methods are adopted by grain managers to reduce the numbers of visible insects during the storage period according to Andrews in 1994. This type of repeated fumigation can be considered a control failure because it has not eliminated all insect stages and has the potential to select insects for resistance to phosphine. In the absence of strictly policed regulations it would be useful to be able to recommend a technology that would assist a more effective fumigation.

Evidence from grain storage engineers in the USA has shown fumigations in large unsealed silos can be successful if the structure is fitted with recirculation ductwork and low power blower providing at least six air changes within the silo per day and minimising gas loss by sealing open joints, hatches and aeration ports. (Noyes, 1994 [7])

Method and Materials

This paper reports on work carried out to gauge the effectiveness of closed loop fumigations, the impact of recirculation direction and the effect of ambient heat on the concentration values at different times of the day in large unsealed silos in Western Australia (WA).

Ambient Wind Effect on Fumigations

The trial was conducted at Wongan Hills (WA) on 835 m 10 year old silos which had sealant applied to the vertical and horizontal lap joints and the concrete base during construction, the side entry door and the roof side hatch were fitted with rubber seals. The top hatch is attached to a permanent gravity tube sealed to the hatch during construction but remains open for grain flow allowing air leakage. The roof-to-wall joint and the roof sheet joints are close mated but not sealed. A 0.375 kW powered blower attached to the side of the silo draws the air/gas mixture from the headspace through a 100 mm PVC pipe which re-enters the silo through the lower wall. (Fig. 1)

The first fumigation in the summer of March 2006 was conducted under hot conditions of 26 – 36℃ with winds gusting between 23 – 30 kph. The silo contained barley at 75% fill and 9.3% moisture content. Blanket formulation of Quickphos aluminium phosphide at 1.19g/m^3 was laid on top of the grain and the recirculation fan was operated for the first three days of the fumigation period.

Fig. 1 Recirculation system fitted to 835m silo

A second fumigation was conducted in May 2006 under more moderate winds in an adjacent silo of the same capacity with the same construction and sealing techniques, 85% filled with wheat at 9.3% moisture content. Fumigant and fan operation was identical to the first fumigation.

Observations and discussion

Gas values were recorded with a Canary Company Silo Chek' and in the first fumigation (Fig. 2) increased rapidly in all monitored points reaching a peak of about 500 ppm by the second day.

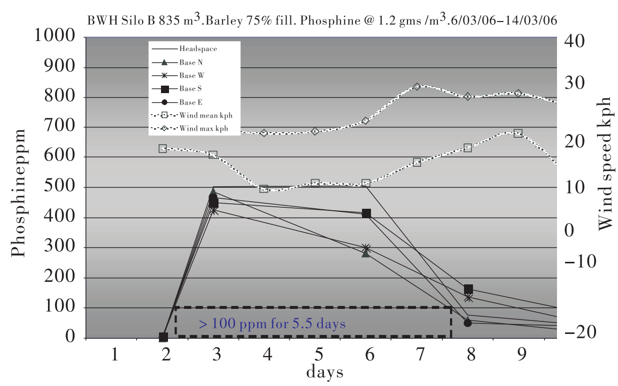

Fig. 2 Record of gas concentrations under high wind conditions

The gas values were trending downwards in line with the usual decay pattern seen in phosphine fumigation until day 5 when the wind speed increased, gusting up to 30 kph creating a venturi effect which drew the gas out of leak points in the silo. The result of 5.5 days > 100ppm is most likely to have been considered a success by the manager because there would be no insects visible in the grain. It is unlikely eggs and pupae were killed by this treatment and the grain would have required re-fumigation when adult insects became visible.

In the second fumigation (Fig. 3) under

lighter wind conditions (5 – 25 kph) gas values rose more slowly but reached 100 ppm in all parts of the silo except Base N in <44 hrs. Values remained above 100 ppm in all monitored points in the silo for seven days. Base N furthest from where the gas was blown in reached 100 ppm later but remained above it for >7 days. The fumigation period was considered successful according to Bank's criteria (1984 [4]) and corresponded with DAFWA recommendations (Newman 2008[5]).

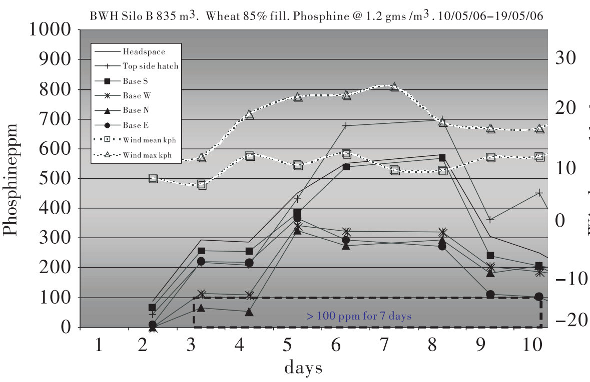

Fig. 3 Record of gas concentrations under low wind conditions

Effect of Airflow Direction within an Unsealed Silo

A trial on an unsealed 1 729 m silo loaded to 85% with Oats at 11% mc and 28℃ commenced in January 2007 at Wagin, WA.. The wall had been sealed during construction and additional sealing with polyurethane adhesive sealant was applied to the base joint, to the wall and roof joint internally, the roof seams externally and to the peak loading port. The roof top auger hopper was covered with a double layer of PVC sheeting, the bottom unloading auger was fitted with a seal plate and the auger void under the silo was blanked off at both ends. A dedicated fumigation hatch was created in the roof and equipped with hooks onto which to suspend the phosphine blankets. A low pressure fan (unknown capacity) was connected to a 100mm PVC pipe, entering the silo in the headspace and the auger void beneath the silo. Initially air was drawn from the auger void and blown into the headspace but re-configured during the fumigation to reverse the flow.

Observations and Discussion

Fumigation commenced by suspending two Quickphos blankets ($1.16 g/m^3$) of AlP in the fumigation hatch (Fig 4) and switching on the recirculation fan. Phosphine gas values rose in all points in the silo reaching 630 ppm in the headspace and 100 ppm at the base. (Fig 5)

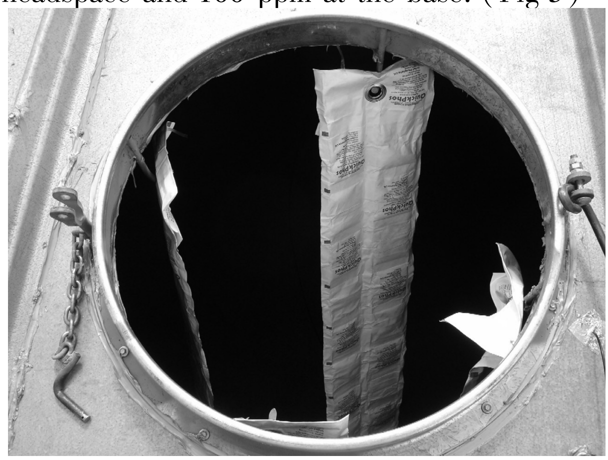

Fig. 4 Phosphine blankets suspended in fumigation hatch

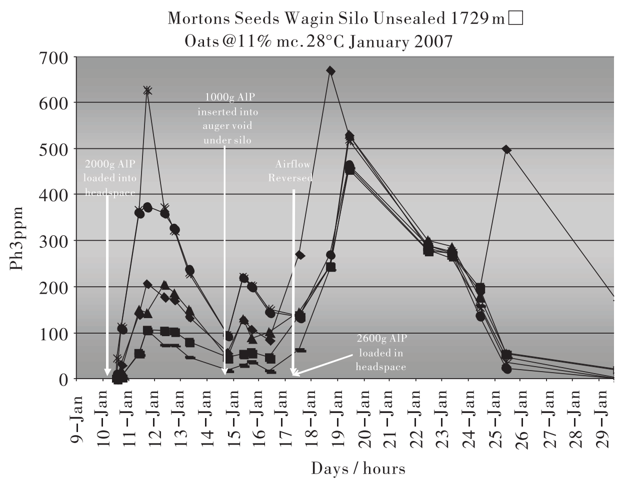

Fig. 5 Chart of fumigation showing the effect of redosing the headspace after reversing recirculation flow.

Gas concentrations were boosted by inserting 1 000g AlP tablets into the auger void when it was < 20ppm, producing a short-lived elevation of gas values to a maximum of 220ppm in the headspace before falling rapidly.

The PVC pipe work was modified to reverse the direction of the air movement drawing from the headspace and injected into the auger void. With the recirculation fan off the headspace was re-charged with 2 600g of AlP in blanket and Bagchain formulations and gas values escalated rapidly at all points remaining above 100 ppm for 7 days reaching a peak of 670ppm at the SE base monitoring point.

Solar radiation effect on gas values Adjacent to the Wall in Steel Silos

The fumigation at Wagin produced slight evidence of gas movement attributed to the heating by the sun on the south east side of the silo and rapid movement of air up the inside of the wall drawing gas across the floor recording a high value at the base monitoring point. This wall heating effect was observed in a CLF on 1 171 m unsealed silos at Cunderdin WA. (Fig. 6)

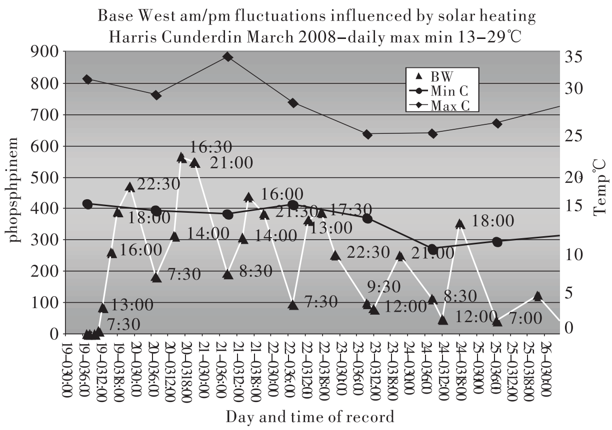

Fig. 6 Effect of wall heating on phosphine gas values, high diurnal temperatures

The monitoring was more frequent enabling more precise observations and it can be seen that the morning readings on the shaded west side (BW) were lower on average than the readings at the same point later in the day when the sun was heating that side. The effect was stronger when the ambient temperature varied between 13 – 29℃ then a month later when the daily average ranged between 11 and 25℃. (Fig. 7)

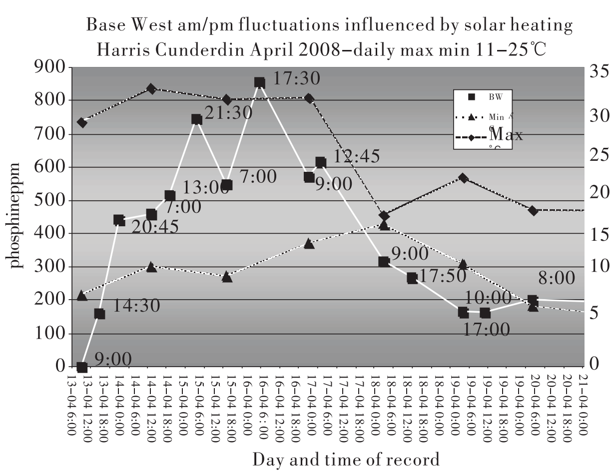

Fig. 7 Effect of wall heating on phosphine gas values, medium diurnal temperatures

This has implications for the timing of the reading suggesting the manager be aware of this effect during hotter periods. One reading a day could provide an incorrect measure of the fumigation. In this type of fumigation it is suggested there should be multiple readings taken to more effectively manage the gas loss and provide a clear indication of fumigation success or failure.

Conclusions

From these experiments it appears that fumigation in unsealed silos can be assisted with recirculation but ambient wind conditions will have a direct bearing on the success or failure of the fumigation. It is recommended by DAFWA to fumigate soon after harvest when high wind conditions are most likely. However in unsealed silos it may be more appropriate to manage the insects initially by reducing the grain temperature with aeration to prevent rapid population development and timing the end point of fumigation to coincide with extraction and sale of the grain.

Gas values achieved in the most successful of the fumigations were insufficient to control phosphine resistant insects had there been any present. Fumigators must be aware of the resistance status of the insects in their grain before considering a fumigation of this nature.

In the Wongan hill silo gas loss was recorded at a lower wall entrance hatch with a Silo Chek at up to 70 ppm while the fan was switched on and from the peak of the silo when the fan was switched off. Additional sealing would improve the result of future fumigations

This technique is not compatible with good grain storage practice and is contrary to recommendations promulgated in documents since the 1980's but this information has not prevented fumigation in unsealed silos. Further investigation would be valuable to make recommendations on reducing gas loss by fumigation timing, identifying common leak points sealing techniques and developing air systems to balance recirculating airflow around the silo.

While it is acknowledged that full sealing is the most appropriate method for control of grain insects, recommendations to retro-seal has had limited success, most likely because of the cost. Recommendations to add a recirculation system and apply sealing at critical points may be more acceptable and assist to improve the standard of fumigation in these silos. Part of such recommendations should include a benefit cost analysis to encourage the sealing of large squat silos during construction.

The observations of air direction effect in unsealed bolted steel silos shows that the roof is a vulnerable area most likely to leak gas and any additional pressure applied by a fan will exacerbate the gas loss.

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References

[1] Allen, J. R. and Snider, C., 1979. The Detia bag blankets, a new fumigation technique. A publication by: Research Products Company, Salina, USA

[2] Andrews, A. S., Annis, P. C., and Newman, C. R. 1994. Sealed storage technology on Australian farms.. In: Highley, E., Wright, E. J. Banks, H. J., and Champ B. R., ed. *Stored Product Protection*, Proceedings of 6th International Working Conference on Stored – product Protection. Canberra, Australia, 17 – 23 April 1994. CAB International, Wallingford, Oxon, UK 27 – 36

[3] Banks, H. J. and Annis, P. C. 1984. On criteria for success of phosphine fumigations based on observation of gas distribution patterns. In: Ripp, B. E. et al., ed., Controlled atmosphere and fumigation in grain storages. Proceedings of an international symposium, 11 – 22 April 1983, Perth, Australia, 1984, Amsterdam, Elsevier, 327 – 341

[4] Cook, J. S. 1984. The use of controlled air to increase the effectiveness of fumigation of stationary grain storages. In: Ripp, B. E. et al., ed., Controlled atmosphere and fumigation in grain storages. Proceedings of an international symposium, 11 – 22 April 1983, Perth, Australia, 1984, Amsterdam, Elsevier, 419 – 430

[5] Newman, C. R. 2008. Department of Agriculture and Food Western Australia, Farmnote 307 Grain storage: Insect control. http://www.agric.wa.gov.au/content/FCP/FN GSInsectCont 08.pdf

[6] Friemel, W. 1983. The Detia bag blanket, its use and application. In: Ripp, B. E. et al., ed., Controlled atmosphere and fumigation in grain storages. Proceedings of an international symposium, 11 – 22 April 1983, Perth, Australia, 1984, Amsterdam, Elsevier, 359 – 367

[7] Noyes, R. T., and Kenkel, P. 1994. Closed loop fumigation systems in the south western United States. In: Highley, E., Wright, E. J. Banks, H. J., and Champ B. R., ed*Stored Product Protection*, Proceedings of 6th International Working Conference on Stored – product Protection. Canberra, Australia, 17 – 23 April 1994. CAB International, Wallingford, Oxon, UK 335 – 341

[8] Reed, C. R., 2006, Managing Stored Grain to Preserve Quality and Value. AACC International. www.aaccnet.org ISBN 1 – 891127 – 47 – 0