Effectiveness of SIROFLO® in horizontal storages

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Abstract

Recent trials have evaluated SIROFLO® in unsealed horizontal storages. Early trials of this technique in horizontal storages indicated that levels of sealing had to be achieved that approached the specifications of gastightness for a sealed storage. Moreover, there was some evidence to support the view that a more economical option in these structures would have been to seal them and offset the higher capital cost by the cheaper methods of application available in sealed horizontal storages.

The results of the recent trials indicate that SIROFLO® can now be applied effectively and economically in some horizontal storages. Some of the gas distribution profiles obtained in a recent trial at Shepherd's Siding, New South Wales are presented. There was evidence to suggest that chimney forces influenced gas concentration profiles in the vicinity of the walls. Although the efficacy of Dryacide® as a gas barrier was evaluated, the results obtained did not provide evidence of improved concentrations of phosphine in the surface layers of the bulk as had been shown previously in uncapped vertical storages.

Introduction

Horizontal storages (sheds) have been widely adopted in Australia for storing grain. In Western Australia for example, they are the predominant form of storage. Although most sheds are cheaper to build on a cost/t basis, the cost benefit is quickly eroded in unsealed sheds if grade segregation is required and when insect control measures other than grain protectants have to be applied. Today, with many markets demanding low residue or residue free grain and with the many grades that characterise marketing requirements, sheds pose difficult problems for pest control strategies.

Sheds built in the past were constructed with open eaves to ventilate the structures and to minimise problems associated with moisture condensation. Some of the more recent sheds are equipped with aeration facilities which are a useful adjunct to the use of grain protectants in that cooler grain reduces the rate of decay of the grain protectants. However, all of these ventilated or aerated sheds are inherently unsuitable for conventional fumigation.

Over the years, attempts to fumigate grain in sheds have included such methods as:

- probing and sheeting infested portions of the bulk,
- completely probing and sheeting the entire grain surface,
- laying aluminium phosphide blankets over the surface of the grain and again completely sheeting the entire grain surface,
- sheeting the entire shed and then adding fumigant,
- sealing the sheds to a gas-tightness standard and then using surface application methods.

Only the last 2 methods offer any real hope of achieving a successful fumigation. However, sheeting the entire structure is costly, difficult to put in place and difficult to maintain. Retro-sealing sheds to the gas-tightness standard is costly but is more durable. Industry sources have quoted costs for retro-sealing of sheds from between about $4.50/t to over $11/t with some reports as high as $19/t.

Soon after the implementation of SIROFLO® in vertical silos in Australia, attempts were made to implement the technique in sheds (Winks, R.G., Waterford, C.J. and Russell, G.F., unpublished data). SIROFLO® is a patented, flow-through fumigation process that enhances the distribution of gas through grain and, in vertical storages, is designed to overcome such forces as the 'chimney effect' that can give rise to rapid gas loss in leaky storages.

During the early trials of SIROFLO® in horizontal storages, the grain was mostly uncovered. To achieve adequate phosphine concentrations throughout the grain it was necessary to seal all but the lap-joints in the roof. With the grain uncovered it was necessary to achieve minimum concentrations in the headspace that, via convection, were carried back into the grain. Following the use of Dryacide® as a gas barrier in vertical silos by the New South Wales Grain Corporation and in trials (Winks, R.G., Waterford, C.J. and Russell, G.F., unpublished data), and a preliminary trial by the New South Wales Grain Corporation with this material in a small high-walled shed, a full-scale SIROFLO® trial was implemented in a 15000 tonne shed at Shepherd's Siding, New South Wales (NSW). The purpose of the trial was to evaluate SIROFLO® in a shed in which the walls had been adequately sealed and in which the grain had been covered with a layer of Dryacide®, an amorphous silica dust. Some of the results of that trial are described.

Materials and Methods

The shed at Shepherd's Siding is a high-wall, aerated, steel framed shed with metal cladding. The shed is 96 m long × 24.4 m wide and 5.5 m to the eaves and has a capacity of 15000 t of wheat. During the SIROFLO® trial it contained 13800 t of wheat. Prior to this trial this shed had been fitted with above-floor, transverse aeration ducts. These ducts present problems for the handling authority and many are damaged during the outloading of such sheds. Although aeration ducts can provide excellent gas distribution ducts, they were replaced for this trial by the grain handling authority, with a purpose-built gas distribution system designed to eliminate the problems perceived with aeration ducts. The vertical wall joints of the shed were sealed with fibreglass mesh and sprayed with flexible acrylic paint. The eaves were left open and the roof lap-joints left unsealed. The

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total cost of sealing the walls and installing SIROFLO® in this shed was $2 per tonne (based on the capacity of the shed) which represents a considerable saving over quoted costs for retro-sealing this type of storage to the gastightness standard which specifies, as a minimum, that an increased or decreased pressure in the fumigation enclosure will decay to half the initial value in not less than 5 minutes with the enclosure filled to its normal capacity.

Phosphine was supplied to the SIROFLO® manifold from cylinders of Phosfume a 2% w/w mixture of phosphine in carbon dioxide manufactured by Commonwealth Industrial Gases Ltd, Sydney. Phosphine was added to the airstream of the SIROFLO® system into the shed to produce a concentration of 35 ppm.

Forty-three gas sampling lines were located in various positions throughout the grain mass and a further four were located in the free air space above the grain and one was located in the SIROFLO® inlet duct to the storage. The sampling lines were of 1/8 in hard-wall nylon tubing. Sampling lines were run to a mobile laboratory equipped with a micro-processor controlled, sample selection manifold so that samples of gas could be drawn from each sampling point in turn and injected into a gas chromatograph. The sampling procedure provided a 2 minute line flushing phase before the sample was injected. One sampling sequence of the 48 points took 233 minutes whereupon the cycle was repeated for the duration of the trial. Phosphine concentrations were measured from the response of a flame photometric detector calibrated automatically during the sampling sequence from a standard gas mixture containing phosphine in nitrogen.

The velocity and direction of wind during this trial was obtained from the nearby meteorological station at Wagga Wagga, NSW.

This paper reports the phosphine concentration profiles obtained from 6 of the 48 sampling lines located within the grain mass both before (Trial 1) and after the application of Dryacide® (Trial 2). The locations of these points are given in Figure 1. Dryacide® was applied as a dust, at a rate of 100 g/m2, from a venturi air gun supplied with compressed air at 100 psi.

Results

Before Dryacide®—Trial 1

Gas concentration profiles during Trial 1, at a number of locations within the grain mass, are given in Figures 2–6. These represent the data obtained at floor level, 1 m below the grain surface and at 150 mm below the grain surface and represent the extremes of variability obtained both in terms of overall variability and in terms of diurnal fluctuations. The fumigation was turned off on day 5 and the decay of phosphine concentrations, due to natural ventilation, monitored for several days afterwards.

Wind velocities during the same period ranged up to 17 knots with most days characterised by a light to moderate breeze. During the evenings the wind dropped and most evenings were calm. Wind direction was variable but mostly from the east for the first 3 days and then from the west. The longitudinal axis of the Shepherd's Siding shed is approximately east west.

With Dryacide® —Trial 2

Following the application of Dryacide® to the grain surface, the same inlet concentration of phosphine and air flow, as applied during Trial 1 (without Dryacide®), were applied to the storage. Gas concentrations, at the same five locations within the grain mass, were monitored and are given in Figures 7–11.

Wind velocities for the same period ranged up to about 16 knots and as with Trial 1, most evenings were calm. However, overall, the wind was lighter during this trial compared with Trial 1 and was almost entirely from an easterly direction.

Temperature data were also collected during this trial. Ambient temperatures and those recorded in the grain at a point along the south wall are given in Figure 12. While the grain temperature remained at about 24°C, the ambient temperature fluctuated from about 12°C to about 25°C.

Discussion

Gas concentration profiles obtained both before and after Dryacide® application were generally satisfactory but there appeared to be greater diurnal variation at some locations after Dryacide® had been applied. It is notable however, that where this occurred, the concentrations dropped during the night when conditions were calm and ambient temperatures lower, which would suggest that 'chimney forces' were the cause of the apparent ingress of air. As warm intergranular air rose out of the centre of the grain mass, cold air presumably flowed in through the open eaves and down through the grain adjacent to the walls. During the warmer daylight hours, the flow down the walls reversed and adequate gas concentrations were re-established. At point *J*, however, air could have entered through the hopper valve if it had not been adequately sealed. With conventional methods of application of this fumigant in this shed, from aluminium phosphide formulations, this process leading to air ingress and fumigant loss would have led to the rapid decay of concentrations, particularly around the edges of the bulk.

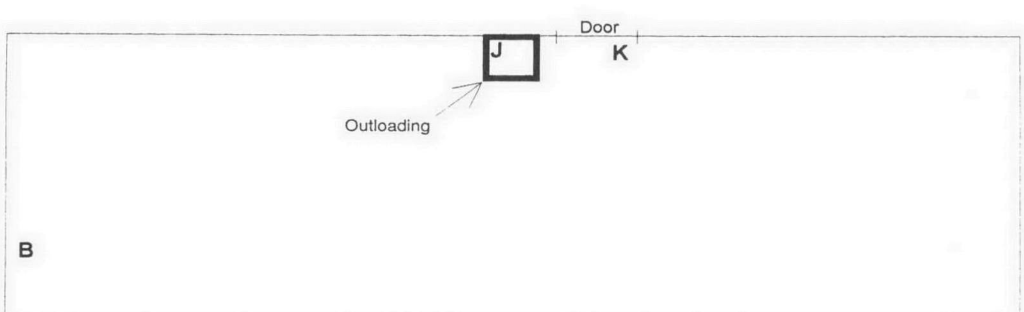

Fig. 1. Plan view of 15000 tonne horizontal storage at Shepherd's Siding, New South Wales showing the location of sampling points *B*, *J* and *K* during the SIROFLO® phosphine fumigation trial in 1993.

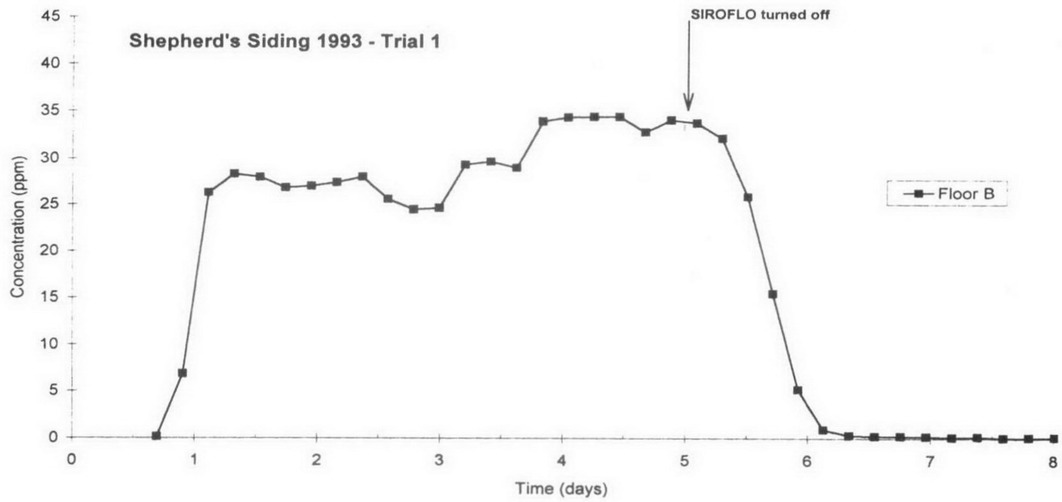

Fig. 2. Phosphine concentration profile on the floor at point *B* in a horizontal storage at Shepherd's Siding, NSW during a SIROFLO® fumigation trial, before Dryacide® was applied to the grain surface.

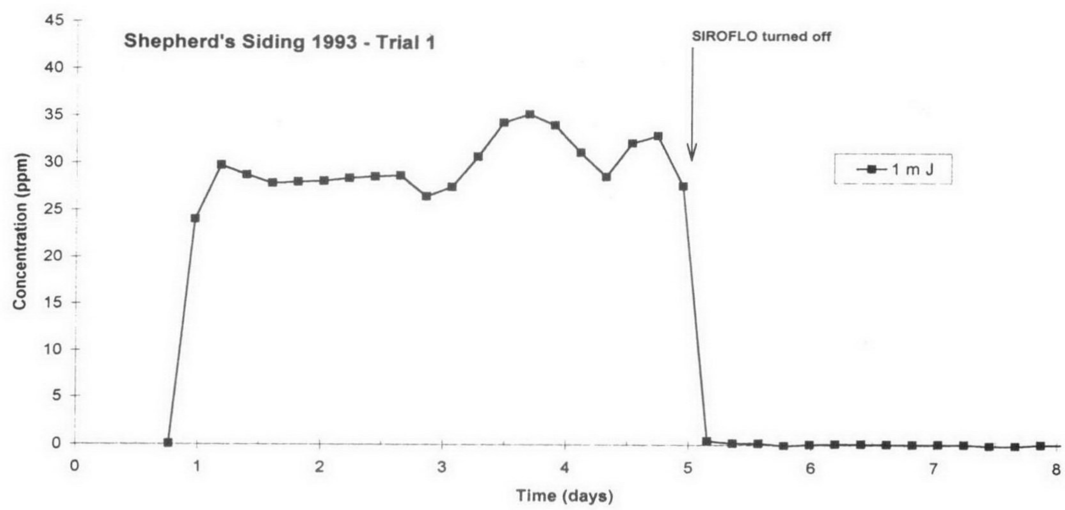

Fig. 3. Phosphine concentration profile at point *J*, 1 m below the surface of the grain in a horizontal storage at Shepherd's Siding, NSW during a SIROFLO® fumigation trial, before Dryacide® was applied to the grain surface.

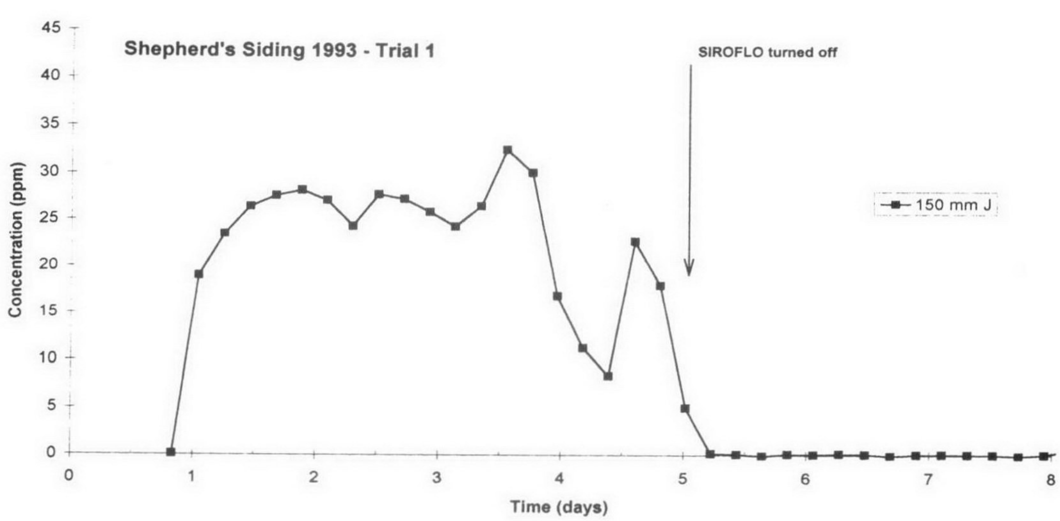

Fig. 4. Phosphine concentration profile at point *J*, 150 mm below the surface of the grain in a horizontal storage at Shepherd's Siding, NSW during a SIROFLO® fumigation trial, before Dryacide® was applied to the grain surface.

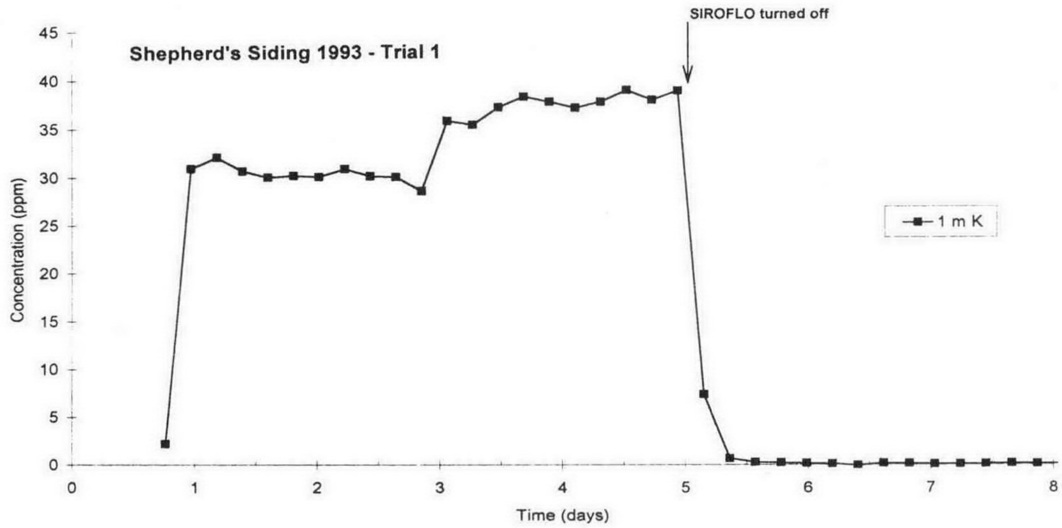

Fig. 5. Phosphine concentration profile at point *K*, 1 m below the surface of the grain in a horizontal storage at Shepherd's Siding, NSW during a SIROFLO® fumigation trial, before Dryacide® was applied to the grain surface.

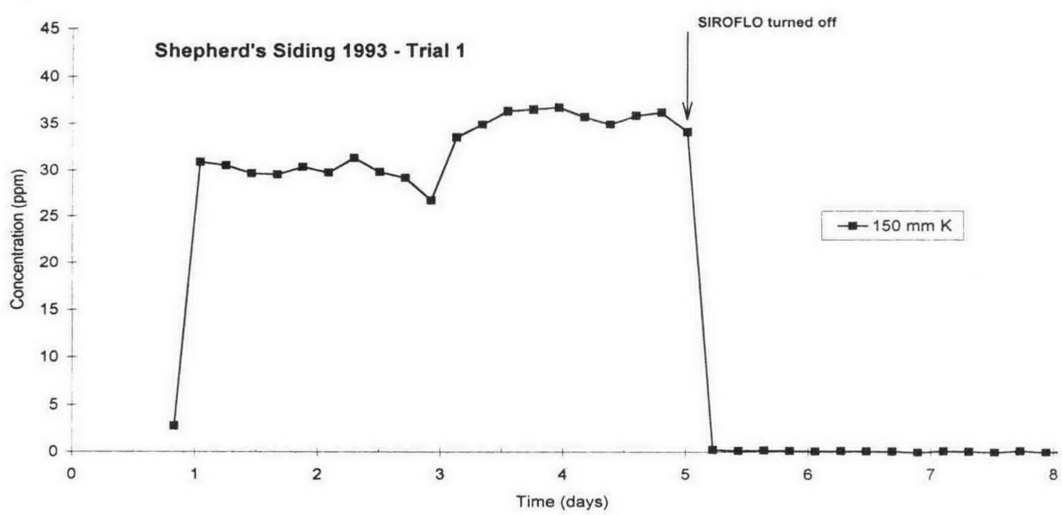

Fig. 6. Phosphine concentration profile at point *K*, 150 mm below the surface of the grain in a horizontal storage at Shepherd's Siding, NSW during a SIROFLO® fumigation trial, before Dryacide® was applied to the grain surface.

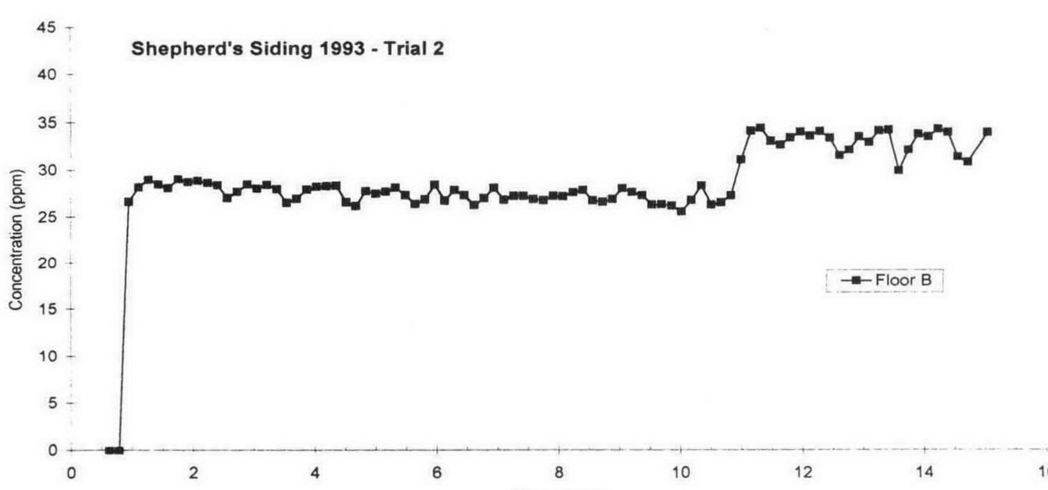

Fig. 7. Phosphine concentration profile on the floor at point *B* in a horizontal storage at Shepherd's Siding, NSW during a SIROFLO® fumigation trial, after Dryacide® was applied to the grain surface.

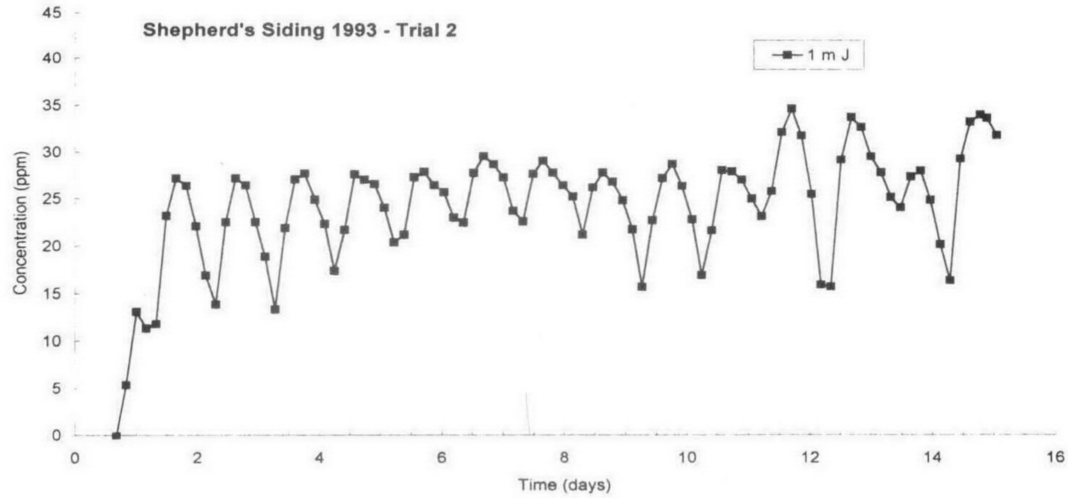

Fig. 8. Phosphine concentration profile at point *J*, 1 m below the surface of the grain in a horizontal storage at Shepherd's Siding, NSW during a SIROFLO® fumigation trial, after Dryacide® was applied to the grain surface.

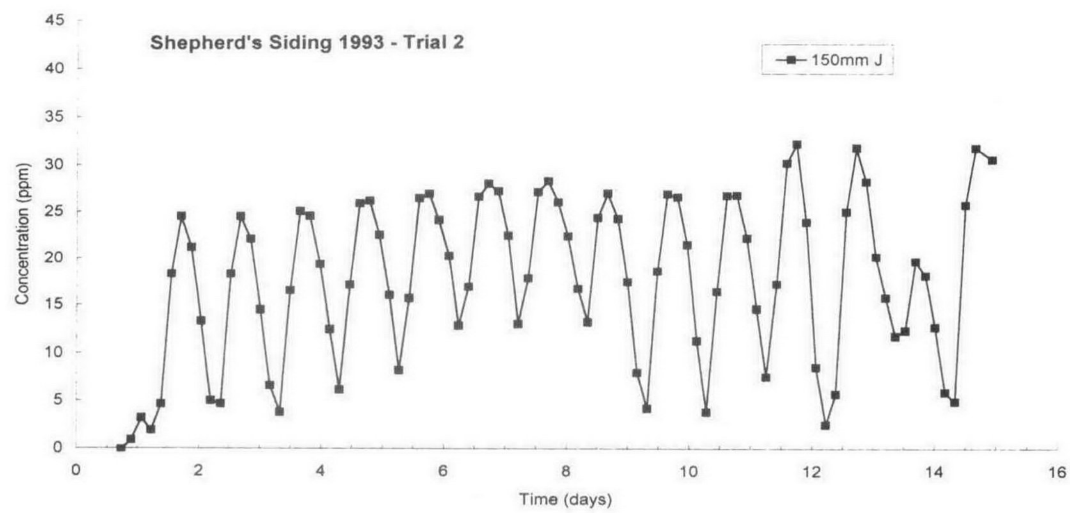

Fig. 9. Phosphine concentration profile at point *J*, 150 mm below the surface of the grain in a horizontal storage at Shepherd's Siding, NSW during a SIROFLO® fumigation trial, after Dryacide® was applied to the grain surface.

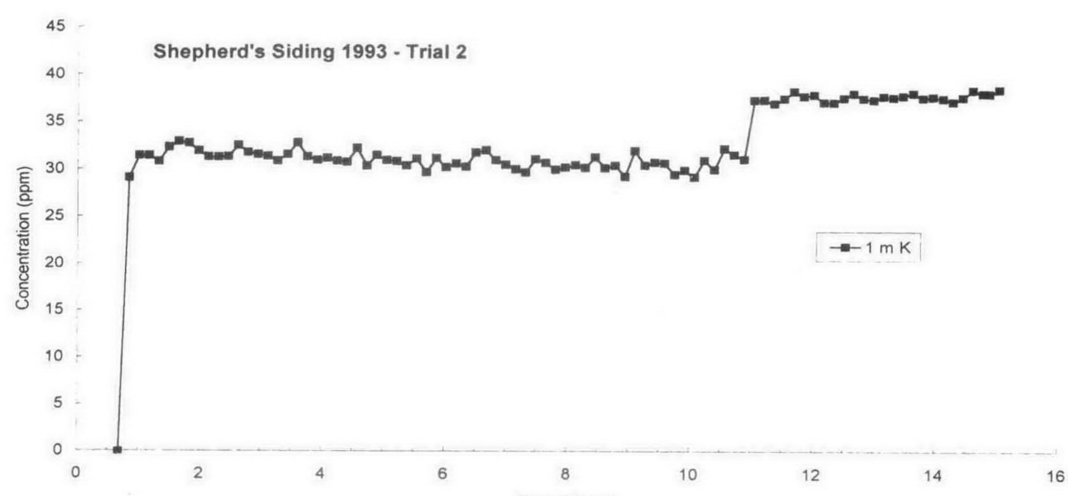

Fig. 10. Phosphine concentration profile at point *K*, 1 m below the surface of the grain in a horizontal storage at Shepherd's Siding, NSW during a SIROFLO® fumigation trial, after Dryacide® was applied to the grain surface.

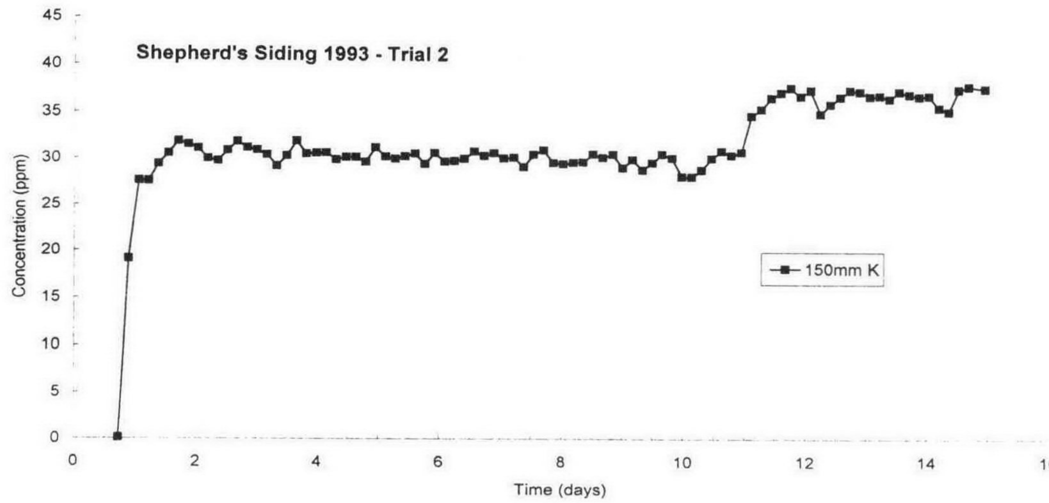

Fig. 11. Phosphine concentration profile at point *K*, 150 mm below the surface of the grain in a horizontal storage at Shepherd's Siding, NSW during a SIROFLO® fumigation trial, after Dryacide® was applied to the grain surface.

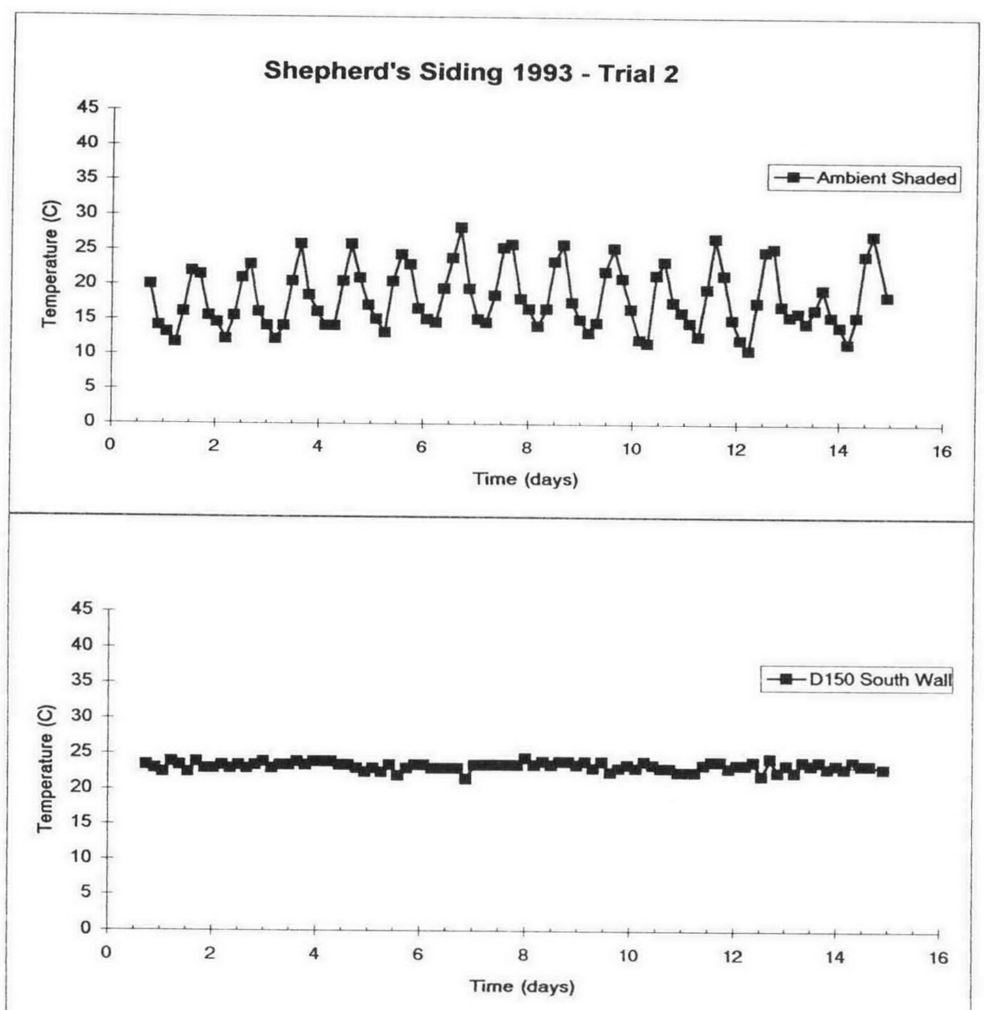

Fig. 12. Temperature profiles in the grain along the south wall and outside a horizontal storage at Shepherd's Siding, NSW during a SIROFLO® fumigation after the application of Dryacide® to the surface of the grain

With oscillating concentrations, the question arises as to whether they are as efficacious as a constant concentration, i.e., whether it is the total *Ct* product that is the critical parameter or the total time period. If the *Ct* product were the critical parameter it would suggest that the insects were capable of rapidly detoxifying phosphine during the periods when concentrations were low or absent. However, evidence suggests that recovery of adults of *Tribolium confusum* and *T. castaneum* from sublethal doses of phosphine takes up to 12 days (Bond and Upitis, 1973; Winks 1973). Moreover, the effects of a second sublethal dose of phosphine applied 24 hours later, to adults of *T. castaneum*, was cumulative and resulted in 82% mortality (Hobbs and Bond, 1989). This evidence suggests that exposure time is the critical parameter rather than the total *Ct* product. However, a study is in progress that is specifically aimed at determining the efficacy of oscillating concentrations and particularly their effects on other species.

Most concentration profiles measured at the 43 sampling points in the grain, resembled those obtained at point *K* but, overall, it cannot be argued that Dryacide® significantly improved the gas concentration profiles obtained. This is in contrast to the benefits that have been observed when this material has been applied to the surface of grain in open-topped vertical silos. Although similar methods of application are used in both structures, the larger surface area of the horizontal storage is thought to have led to greater variation in the evenness of application with some areas of the surface receiving too little Dryacide® to be effective. Methods of application of Dryacide® are still being developed particularly in the context of large grain bulks in sheds.

In the gas concentration profiles for Trials 1 and 2, the data show a rise in concentration towards the end of the trial period. This rise is a characteristic of the gas source, Phosfume, 2% w/w phosphine in liquid carbon dioxide, and occurs when all of the liquid in the cylinders has been vaporised.

The data of Trial 1 in Figures 2–6 show that concentrations in the grain mass decay rapidly after the gas and fan have been turned off or the cylinders have emptied and the grain allowed to ventilate naturally. From these data, the storage could be entered safely for outloading purposes 24 hours after the end of the fumigation period.

Conclusions

The trials in this storage demonstrated that effective fumigations with SIROFLO® can be carried out in this type of structure. The sealing of the walls is believed to have been a major factor in this regard. The results before and after Dryacide® were not conclusive and it could not be argued that the layer of this material, in this instance, achieved the benefits that have been demonstrated elsewhere.

Although some fluctuations in concentration were observed, the benefit of this method of application is that the concentrations can be restored after periods of air ingress and the treatment period maintained for as long as necessary, particularly if laboratory studies show that, at least for some species, the total *Ct* product is the critical parameter.

References

Bond, E.J. and Upitis, E. 1973. Response of three insects to sublethal doses of phosphine. Journal of Stored Products Research, 8, 307–313.

Hobbs, S.K. and Bond, E.J. (1989. Response of *Tribolium castaneum* (Herbst)(Coleoptera: Tenebrionidae) to sublethal treatments with phosphine. Journal of Stored Products Research, 25, 137-146.

Winks, R.G. 1973. Some aspects of the response of *Tribolium castaneum* (Herbst) to phosphine. PhD Thesis, University of London.