From: E.J. Wright, M.C. Webb and E. Highley, ed., Stored grain in Australia 2003. Proceedings of the Australian Postharvest Technical Conference, Canberra, 25–27 June 2003. CSIRO Stored Grain Research Laboratory, Canberra.

Grain-dust suppression by spraying water on grain

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Abstract. A trial has been carried out at the Newcastle port grain terminal to address an environmental problem of grain dust becoming airborne when ships are loaded with grain consignments for export. Dusty feed barley was sprayed with water at 2 L/t at the transfer point from an under-bin reclaim belt conveyor to a transverse belt conveyor delivering grain from the reclaim conveyors to the elevator boots at the Newcastle port terminal. The spraying of water substantially reduced the amount of dust becoming airborne at the last point of transfer to a storage bin and in the bin headspace. Applying the water to both the upper and lower surfaces of the grain stream, with a larger proportion of water directed to the lower surface, appeared to target the grain dust more effectively and delivered a better result than applying all the water to the upper or lower grain surface only. This is a new concept and there seems to be scope for further refinement. The increase in the grain moisture content as a result of the water application appeared to be negligible and within the limits of normal variation in grain moisture content under industrial conditions in a grain export terminal. To verify our conclusions, a further trial is required while grain is being loaded on board a ship.

Introduction

Grain dust has been the subject of much deliberation worldwide, particularly since the large-scale handling and storage of grain in bulk started. A series of grain-dust explosions in the 1970s destroyed a number of grain storages and caused the loss of several lives, which sparked intense research interest in grain-dust management. International conferences to determine and address the causes were held, such as the International Symposium on Grain Dust in October 1979 in Manhattan, Kansas. Health hazards related to grain dust have been a research subject for a long time (e.g. Wright 1940; Chan-Yeung et al. 1979; Lacey 1990). As a result, aspiration systems for grain-dust removal received greater prominence since the 1970s, but the costs of maintenance and of the disposal of collected dust (Schnake 1981) ensured continued research effort being invested in alternative approaches to grain-dust management. Mineral and vegetable oil and oil and water sprays applied to grain to suppress grain dust were visited and revisited over many years (e.g. Jones and Parnell 1985). In Australia, Annis and Bridgeman (1994) carried out trials using a 1 in 4 oil/water emulsion. As a result of all these efforts, dust explosions are now mostly limited to relatively small events, such as occasional dust explosions inside bucket elevators, while health problems are under control.

At the Newcastle export grain terminal, all of these earlier dust-related problems are generally satisfactorily addressed and the current problem is of a different nature. Here, like at several other older Australian seaports, residential property development taking place in the previously industrial harbour area has raised the levels of public awareness about environmental pollution by grain dust. Visible dust in particular, such as the dust billowing from a ship's hold when grain is being dumped into the hold for export, and dust that might pollute the water or surrounding properties, is of particular concern. As a result, the terminal is experiencing increased pressure from environmental authorities to address these issues. Various solutions are possible, mostly fairly costly. Some of these are nonetheless in the process of being implemented, such as upgrading the dust-aspiration facilities in the truck-unloading area. However, a quick, inexpensive solution is also sought. The trial described here was the second of two recent trials at the Newcastle port grain terminal carried out to investigate an inexpensive way of addressing the problem of grain dust becoming airborne when ships are loaded with grain consignments for export.

Earlier, our own observations at grain elevators have revealed that, on a conveyor belt, insects, grain dust and other fine materials tend to settle towards the bottom of the grain. This is probably a result of the vertical motions of the grain stream and the belt as the belt travels across the idlers supporting it (Figure 1). Thus, grain dust is not optimally targeted where water and oil sprays are applied to the top surface of the grain stream on a conveyor. Our approach was to direct various ratios of the total volume of water applied to both the underside of the grain stream and the upper grain surface. This is easily achieved where the grain stream has to travel through the air, such as at a transfer point from belt to a chute, or to another belt.

Materials and methods

Grain was sprayed with water at the transfer point from conveyor C52 to conveyor C54 of the Newcastle port terminal. Conveyor C52 is one of several parallel under-bin reclaim belt conveyors that carry grain outloaded from storage bins to the elevator house. Conveyor C54 is a transverse belt conveyor delivering grain from the reclaim conveyors to the elevator boot of any one of four bucket elevators. The grain capacity of these conveyors is about 500 t/h for wheat.

Dusty feed barley was available for the trial, and was stored in a number of bins spread throughout the facility. For the purpose of the test, barley was outloaded from a bin on the C52 conveyor line, sprayed with water at the C52/C54 transfer point, elevated and loaded into a suitable empty bin. The effects of treatments on grain dust becoming suspended in air were assessed at the over-bin conveyor and in the bin headspace of the bin into which the treated barley was loaded. Available empty bins were also spread throughout the elevator; hence from time to time this required the use of different over-bin conveyors and trippers. This required us to move our observation equipment to a new position and affected the readings obtained. However, the spray position remained fixed throughout the trial.

At the spray position, two spray points were installed: the first to spray water onto the lower surface of the grain stream where the grain travelled over the gap between the grain chute and the belt where grain was fed from C52 onto C54; and the second to spray water onto the upper grain surface on C54, immediately beyond the dust hood where the grain was fed onto the belt. Water was applied at a total rate of 2 L/t (or a total of 9.6 L/min at 290 t/h). Appropriately sized flat spray TeeJets® were used to deliver the desired volume. Pressure and flow meters allowed accurate control over the delivery rate. The distance between the spray tip and the grain stream was adjusted so that the spray pattern covered about three-quarters of the width of the grain stream. The upper and lower grain surfaces were sprayed at the ratios shown in Table 1, with the actual grain flow rate for barley at about 290 t/h.

All spray treatments except one were matched with two control treatments (no water sprayed)—one immediately before the spray treatment, and one immediately after, with all three 'treatments' on the same continuous 'run' of grain, i.e. grain outloaded from the same bin and loaded into the same (initially empty) bin (see Table 2). The exceptional treatment set with only one control was the one where an equal quantity of water was sprayed on each of the lower and upper grain surfaces. For every treatment run, which included the spray treatment and the two controls, the grain flow was continuous to eliminate variations in dust conditions due to stopping and starting of the grain flow. For every treatment run, the grain for the two controls and the spray treatment came from the same bin and was loaded into the same receiving bin to reduce variations in dust conditions as far as practically possible. Spraying was started or stopped as required to effect the spray treatments and the control treatments. Thus, observations on any particular set of treatments (the spray treatment and the two controls) were made in a single location, using the same tripper and equipment settings, and on a grain stream as homogeneous with regard to dust content as can possibly be achieved under industrial conditions.

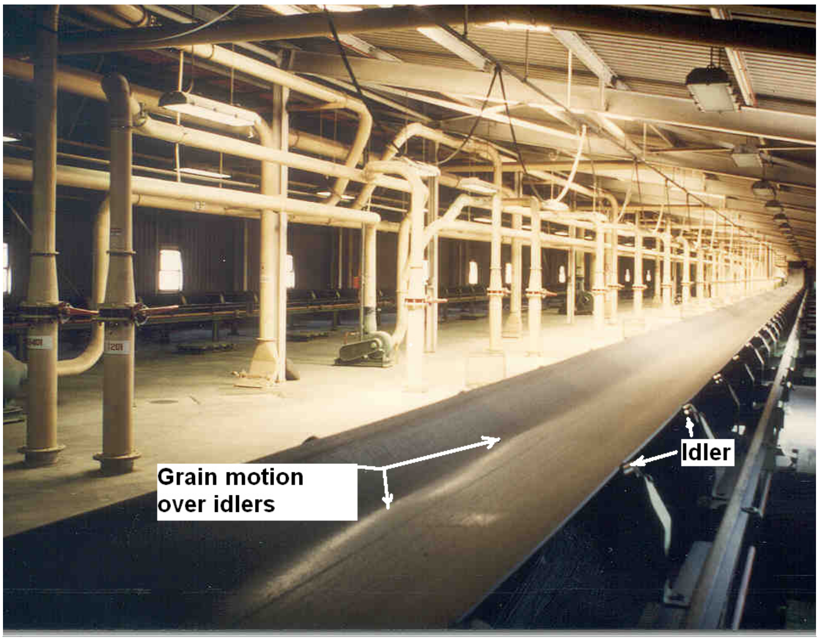

Figure 1. Grain on a conveyor belt as it travels over the idlers. The motion of the conveyor belt and the grain on the belt as the belt travels over the idlers causes grain dust to settle towards the bottom of the grain stream on the belt.

Table 1. Details of the volume of water sprayed onto feed barley during a trial at the Newcastle grain terminal at a barley flow rate of about 290 t/h.

Water spray treatment		Spray volumes					
No.	L/t	%		L/min		L/t	
		Lower	Upper	Lower	Upper	Lower	Upper
1	2.0	100	0	0	9.7	2.0	0
2	2.0	65	35	6.3	3.4	1.3	0.7
3	2.0	35	65	3.4	6.3	0.7	1.3
4	2.0	0	100	0	9.7	0	2.0
5	2.0	50	50	4.8	4.8	1.0	1.0
	Controls	0	0	0	0	0	0

To assess the effects of the spray treatments, two sets of observations were made. A Casella optical dust-measuring instrument was used at the over-bin conveyor around the tripper to measure the dust concentration in the air in mg of dust/m^3 of air. An industrial vacuum cleaner was used to collect dust suspended in the air in the head-space of the bin into which the grain was loaded over a specified time.

The observation probe of the Casella instrument was taped in a standard position to the tripper, close to the joint between the tripper chute and the bin chute, where grain dust normally escapes to greater or lesser extent, depending on the particular tripper and bin combination, and on the amount of dust ejected from the grain. The readings were recorded at intervals of 61 seconds over the observation period using a data recorder. The average of all readings was calculated for each spray or control treatment.

The amount of grain dust suspended in air in the bin headspace during inloading was determined using an industrial vacuum cleaner equipped with brushless motor and static-free accessories. Use of this equipment eliminated the danger of a dust explosion. The vacuum hose was simply dangled about 2 m into the bin into which the grain was being loaded. To allow conditions inside the bin to stabilise before dust collection started, the motor was switched on about five minutes after a control or spray treatment started and was allowed to run for as long as sprayed or control grain was being loaded into the bin. The vacuum cleaner was equipped with paper dust-collection bags, which were weighed before and after each control or spray run. The weight of dust collected and the time over which it was collected were recorded. Initially, each observation period stretched over about an hour, but later about 30 minutes was considered to be sufficient, as the quantity of dust collected was large enough to demonstrate differences between treatments. The data were recalculated to a standard 60 minutes.

For moisture tests on the grain, the grain stream was sampled with an automatic sampler on a continuous basis and the composite sample thus obtained for each spray and control treatment was used for a near infrared moisture test. The moisture content of the dust collected by vacuum cleaner from the bin headspace was also determined, using the standard oven test for fine materials.

The percentage reduction of dust suspended in air at the tripper as well as in the bin headspace was calculated using the following formula:

$$100[0.5(C1 + C2) - S]/0.5(C1 + C2) \quad (1)$$

where

C1 = dust reading of the control preceding the spray treatment

C2 = dust reading of the control following the spray treatment

S = dust reading of the spray treatment.

Results and discussion

Dust suspended in air at the final grain transfer point

The results are summarised in Table 2 and evaluations of the results are presented in Tables 3 and 4.

Tables 2 and 3 show that spraying water onto grain caused substantial reductions in the amount of dust becoming airborne at the point where the grain was returned to a storage bin. The reductions in the bin head-space were smaller than around the tripper, the reason for which is unclear. However, with the exception of spray ratio no. 2 (see Table 3), there is good agreement in the rankings (ranked from highest to lowest values) of the two sets of observations, with the rank either the same, or not differing by more than 1. Spray treatments where half or more of the water was sprayed onto the lower grain surface were more effective than spray treatments where all or most of the water was sprayed onto the upper grain surface. This indicates that our assumption at the onset of these trials, namely that much of the dust in the grain becomes more or less concentrated towards the lower part of the grain stream as it moves along its route, is probably correct. Fine material concentrating towards the bottom of the grain stream forms the spoutline in bulk grain. Spraying most of the water onto the lower grain surface therefore targets the dust more specifically and achieves the better result.

Table 2. The effects of water spray treatments (at 2 L/t) applied at different ratios to the lower and upper surfaces of a grain stream on the amount of airborne dust at the tripper and in the headspace of the bin into which the treated grain was loaded, and on the moisture content of grain and grain dust.

Treatment	Airborne dust		Moisture content (%)	
	Tripper (g/m^3)	Bin headspace (g/h)	Grain dust	Grain
Control	45.3	129.4	–	11.7
Lower 1 L/t; upper 1 L/t	5.9	91.9	–	12.0
Control	46.5	150.9	–	–
Control	118.4	188.9	9.3	11.8
Lower 0; upper 2 L/t	57.1	113.4	10.6	11.4
Control	114.7	162.4	8.6	11.3
Control	16.3	134.8	8.8	11.3
Lower 2 L/t; upper 0	5.5	64.6	11.4	11.5
Control	31.6	171.5	9.1	11.1
Lower 1 L/t; upper 1 L/t	3.5	93.6	10.8	11.1
Control	115.5	152.8	9.9	11.6
Control	115.5	152.8	9.9	11.6
Lower 1.3 L/t; upper 0.7 L/t	26.7	61.1	11.6	11.7
Control	137.5	139.0	10.2	11.3
Control	137.5	139.0	10.2	11.3
Lower 0.7 L/t; upper 1.3 L/t	32.1	63.5	12.0	11.3
Control	126.0	128.7	10.7	–

Table 3. Percentage reduction, compared to the controls, in dust becoming airborne at the grain tripper and in the bin headspace achieved by various spray ratios of water applied to the lower and upper surfaces of the grain stream before the grain enters a bucket elevator.

Spray rate	Tripper		Bin headspace		Total rank
	% reduction	Rank	% reduction	Rank	
1. Lower 2 L/t; upper 0 L/t	77	3	58	2	5
2. Lower 1 L/t; upper 1 L/t	89	1	45	4	5
3. Lower 1.3 L/t; upper 0.7 L/t	79	2	58	1	3
4. Lower 0.7 L/t; upper 1.3 L/t	76	4	53	3	7
5. Lower 0 L/t; upper 2 L/t	51	5	35	5	10

Spraying 1.3 L/t (65%) of water onto the lower, and 0.7 L/t (35%) onto the upper surface of the grain stream (spray ratio no. 3) achieved the best overall effect—i.e. the lowest value for total rank (Table 3), or the highest percentage reduction of dust suspended in the air when the treatment is compared with the controls immediately before and after treatment.

However, it is also clear that not all the grain dust occurs in the lower part of the grain stream on the conveyor, because spraying all the water onto the lower grain surface appears to be less effective than spraying some of it onto the upper grain surface as well. The idlers at the Newcastle grain terminal are particularly evenly adjusted and the conveyor belts travel particularly evenly, with minimal vertical motion. In addition, the belt tensions are maintained at optimum level, with minimal sagging between idlers, which further reduces vertical motion as the belts travel over the idlers. Therefore, the concept of targeting the dust more specifically could probably be developed further. For example, it may be possible to concentrate the dust even more towards the bottom by adjusting the belt idlers so as to provide more vertical motion as the belt moves over them, and to form the belt into a deeper, narrower trough over a particular section of the conveyor. To do this most effectively, it would be necessary to investigate in depth the dust distribution within the grain stream as it moves through the facility, and the effects of grain transfers at various points on the conformation of the grain stream and the dust distribution within the grain stream.

Moisture content of the grain and of grain dust

The moisture contents of composite grain samples, and of grain dust from the bin headspace collected during the various spray and control treatments, are presented in Table 4.

Table 4. Percentage increase in the moisture content of grain dust from the bin headspace and of grain as a result of spraying the grain with water, compared to unsprayed grain.

Spray rate	Grain dust		Grain	
	% increase	Rank	% increase	Rank
1. Lower 2 L/t; upper 0 L/t	27.4	1	2.7	1
2. Lower 1 L/t; upper 1 L/t	18.7	2	0	5.5
3. Lower 1.3 L/t; upper 0.7 L/t	15.4	4	2.2	2
4. Lower 0.7 L/t; upper 1.3 L/t	14.8	5	0	5.5
5. Lower 0 L/t; upper 2 L/t	18.4	3	1.3	3

The nominal expected increase in the moisture content of grain sprayed with water at a rate of 2 L/t is 0.2 percentage points. Because of variations in the moisture content of the grain used in the trial, such a small effect is not easy to observe under industrial conditions and the results obtained are somewhat anomalous. However, the maximum observed increase in the grain moisture content was 2.7% compared to unsprayed control samples, or 0.27 percentage points on grain moisture content of 10%. In all other cases a smaller or no change was observed.

Increases in the moisture content of grain dust as a result of the water applications were generally considerably larger than those of grain, however the data contributes little towards clarifying which of the spray ratios between upper and lower grain surfaces target the grain dust the most effectively. It should be noted that the grain dust on which moisture tests were conducted is dust that became airborne in the bin headspace in spite of the water spray. It is therefore possible that the moisture content of dust remaining in the grain was even higher. If this was the case, the possibility exists that fungal development might occur in dust concentrated in the spout line in the ships hold or in the bin into which sprayed grain is loaded. This needs to be clarified.

There were also indications that the moist dust may increase clogging of the dust aspiration system, a potential problem that could possibly be addressed by shutting off dust aspiration at the spray point, or by installing air dryers at relevant points in the dust aspiration system.

General

Lai and Miller (1982) developed a special application apparatus called a 'Turbulator' to thoroughly mix either water or oil with grain dust. In our trial, the water spray was selectively aimed at the dust by spraying the lower side of the grain stream, as well as the top surfaces. Admixture of water with dust was achieved by applying the spray before the grain was delivered to the elevator boot. The observations of its effects were carried out beyond the elevator. The relative importance of admixture of wetted and unwetted grain (and grain dust) in the elevator boot needs to be clarified. The application method used in our trial succeeded in selectively targeting the grain dust and the increase in the moisture content of the grain dust was substantial (Table 4). The dust moisture content after spraying appeared to be below the levels required for fungal growth in grain. However, the water activity of grain dust with regard to fungal development needs to be investigated to clarify the likelihood of fungal development in wetted grain dust.

Conclusions

The spraying of water on grain at the rate of 2 L/t at a point before the grain enters the elevator substantially reduced the amount of dust becoming airborne at the last point of transfer to a storage bin. Applying the water to both the upper and lower surfaces of the grain stream, with a larger proportion of water directed to the lower surface, appeared to target the grain dust more effectively and delivered a better result than applying all the water to the upper grain surface only. There seems to be scope for further refinement of this concept.

The increase in the grain moisture content as a result of the water application was negligible whereas that of the grain dust was much larger.

To verify our conclusions, a third trial is required to assess the effectiveness of a water spray treatment in suppressing grain dust while grain is being loaded on board a ship.

Acknowledgments

Allan Jones of Jogo Pty Ltd installed the spraying equipment and assisted in executing the trial. The elevator staff in the control room did their best to ensure continuous grain streams. Simon Troman, CSIRO Stored Grain Research Laboratory, assembled the data-logging system, and Jane Green at the CSIRO Stored Grain Research Laboratory, and Jason Shanley and Simon Moore in the elevator laboratory carried out the moisture tests on grain and grain dust.

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