Control of Grain Dust with a Water Spray[1]

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Abstract

Spraying corn with water at the truck loading point reduced dust emission by 60–75% and permitted the meeting of air quality standards. Application of water under the conditions employed did not appreciably increase the moisture content of the corn, which showed no spoilage after storage for one year.

Grain dust explosions have received much attention lately because of a series of eight elevator accidents in December 1977 and January 1978 in which 62 lives were lost, 35 people were injured, and 60 million dollars in damages were incurred (1). A satisfactory solution for eliminating or reducing the dustiness of grain would save lives and property, reduce the danger to workers' health and the hazard of an explosion, and maintain productivity.

Water is an obvious agent for controlling dust emission. It is an effective dust suppressant in the coal industry. Kobrick (2) reported that the concentration of respirable coal dust was reduced 20–60% by the use of water sprays. The usefulness of the airborne capture theory for improving dust suppression in a mining system was investigated (3) by conducting field tests to compare the extent of dust suppression obtained with different water-spray systems during continuous mining. Seibel (4) evaluated water and foam sprays for controlling dust at transfer points in coal cleaning systems and found that, although foam was significantly more effective than water in controlling airborne respirable dust (<125 μm) at a transfer point and along a belt, a strategically arranged water-spray system provided a satisfactory, economical, and convenient dust control method. Courtney et al (5) found that about 60% of the respirable dust produced at the face in continuous coal mining is formed during the sampling operation; the rest is formed during shearing and loading. During the sampling operation, top or bottom sprays were equally effective for dust suppression, reducing dust concentration about 13%. However, in shearing and loading, bottom sprays reduced the dust concentration by 61% and were about 50% more effective than top sprays. The combination of top and bottom sprays was more effective than the separate systems, but water consumption increased 60%.

Zalosh (6) suggested that water-spray treatment of a grain stream at strategic locations in a grain elevator (conveyor transfer points, elevator legs, and rail and truck dump pits) could reduce the danger of grain dust explosions. He derived the following equation, based on principles of heat balance between the rate of heat release by combustion and the rate of heat absorption by water droplet formation:

$$\frac{M_o \Delta H_c}{t_b} = \frac{M_w \Delta H_v}{t_v}$$

where M_o = amount of dust, M_w = amount of water, ΔH_c = heat of combustion of grain dust, ΔH_v = heat of evaporation of water, t_b = time needed for dust particles to burn completely, and t_v = time needed for evaporation of a water droplet. From this equation, Zalosh (6) estimated that 0.24 lb of water was required per pound of dust to preclude an explosion or fire.

A technique for applying various oil-water emulsions to grain was studied by Moen and Dalquist in 1948 (7). Their full-scale tests involved spraying the emulsions on airborne grain as it was discharged from a conveyor belt, adding it to grain moving through a screw conveyor, and spraying it on grain in a revolving drum. Lai et al (8) experimentally applied soybean oil and mineral oil alone and in combination with a grain protectant, malathion, to reduce dust formation during handling and to provide residual protection against insect infestation.

Because water used to control dust emission could result in increased moisture content of grain, water has not been seriously considered as an agent for controlling dust emission of grain. We believe, however, that application of a controlled amount of water at the right time and place and in the right way may alleviate the problem of grain dust emission and thus minimize the possibility of explosions during the transfer of grain without reducing grain quality. The concept is being investigated commercially by The Andersons, Maumee, OH. In this investigation, we examined the feasibility of using a water spray to control emission of dust during spout-to-truck transfer of corn. Because of its fragility, corn produces more dust than other grains and thus creates a greater hazard.

Materials and Methods

We used 120-bu samples from a uniform bulk lot of a hybrid yellow dent corn that had been harvested in 1975 and dried with natural air from an initial moisture content of 23% (wb) to a final moisture content of about 15% (wb). For each test, a sample lot was placed in a clean bin, elevated by a bucket elevator at a rate of 1,000 bu/hr, and discharged into a spout (Fig. 1). At the top of the system, an automatic sampler took samples from the grain stream every 15 sec. At the bottom of the system, the grain stream was treated by a water spray (Fig. 2) and discharged. The bottom of the spout was 6 ft from the floor of an enclosed truck. The truck bed was enclosed with polyethylene sheeting. The air in the truck bed was evacuated by a dust-collecting system (Dustkop model 20 TW 30, AGET Manufacturing Co., Adrian, MI), and the dust entrained in the air was collected (Fig. 2). The airflow rate was

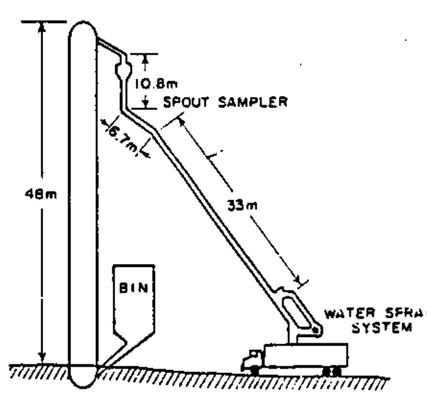

Fig. 1. Spout system of the U.S. Grain Marketing Research Laboratory, Manhattan, KS.

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approximately 1,500 ft³/min. Three samples taken with sampling probes from the grain in the truck after treatment and three samples taken from the grain stream before treatment were each analyzed for test weight, moisture content (wb) (9), and percentages of fines and foreign material. The sampling method used 5-ft grain samples to include representative portions of the grain pile in the truck bed.

We ran replicate experiments with water sprays that added 0% (control), about 0.5%, and about 1.0% of the weight of each sample lot of corn. The water-spray system (Fig. 2) was adapted from an experimental airflow grain retarder developed by Stephens and Foster (10); however, the flow retarder is not required for installation of a water-spray system. A fan driven by a 2.2-kW electric motor was attached to a section of 8 × 8-in. spouting. At the fan outlet, three nozzles sprayed water into the air, which was forced into the spout in the direction opposite to that of the grain flow. A deflector on the bottom side of the duct, located 2 m above the fan outlet, lifted the grain into the airflow to increase the drag on the grain and exposure of the grain to moist air. An intake duct, located 3 m above the fan outlet, permitted air to escape from the spout and return to the fan inlet. A dump-and-flow control unit provided water at pressures and flow rates required by the nozzles. A flowmeter and a valve determined the water flow rates. One pressure gauge measured the pressure of the system and another indicated clogged nozzles.

Table I. Effects of Water-Spray Treatments on Samples from Two Lots of Corn

Application Rate (%)[a]	Dust Collected (g/lot)	Test Weight (lb/bu)		Moisture Content[b] (%)		Fines and Foreign Material (%)	
		Before	After	Before	After	Before	After
Lot 1							
0.0	927	58.4	59.0	14.7	14.9	2.95	4.37
0.48	527	58.6	58.2	14.9	15.4	2.12	3.98
0.86	241	56.3	58.3	14.9	15.4	1.81	2.88
Lot 2							
0.0	785	58.2	58.3	14.8	15.0	2.50	4.22
0.52	375	56.9	58.4	15.1	15.6	2.47	3.89
0.87	261	57.4	58.0	15.6	16.0	2.38	3.80

[a]Percentages, by weight, of each sample lot before and immediately after treatment.
[b]Wet basis.

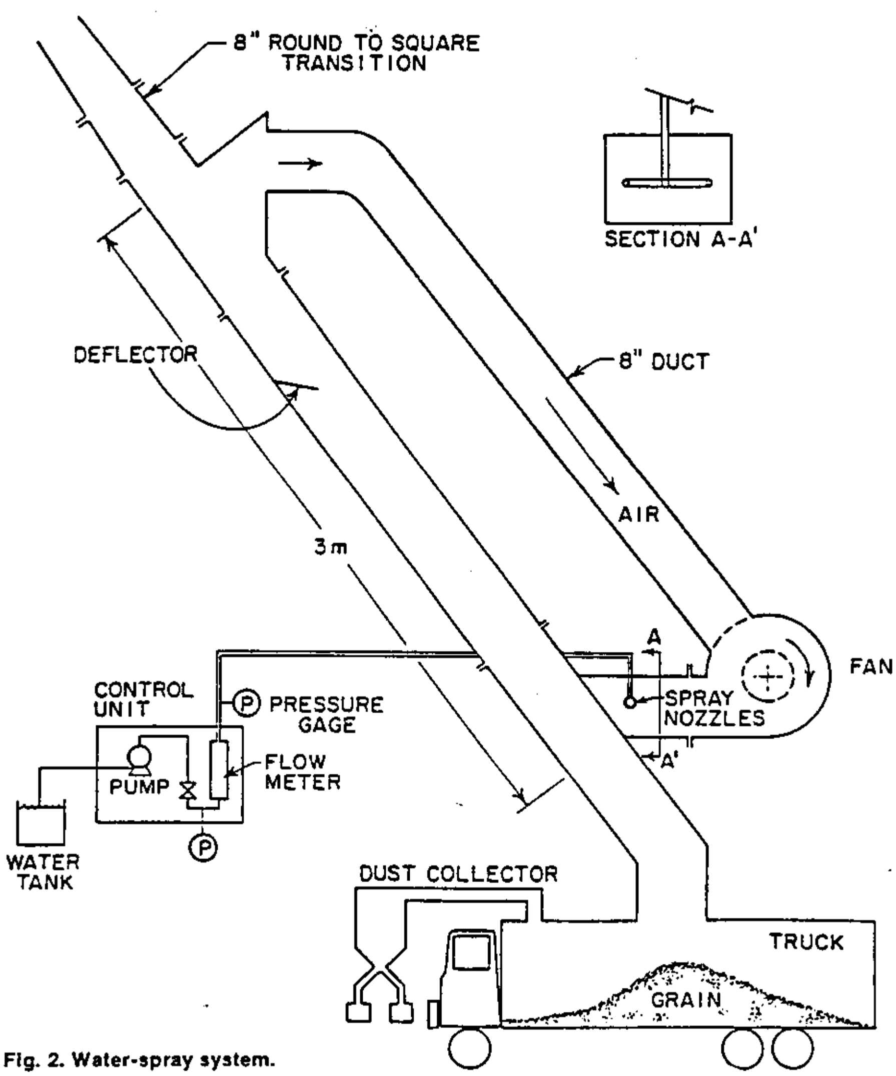

Fig. 2. Water-spray system.

Results and Discussion

Reduction of Dust Emission

Application of water significantly reduced the amount of dust collected in the system (Table I). During tests without a water spray, the air inside the receiving truck was dusty and visibility was almost zero. During tests with added water, the air was clear inside the receiving truck, and grain kernels could be observed as they hit the grain pile. Dustiness was reduced by more than two thirds with water treatment. If the dust generated is about 0.1% of the grain, then the water application rate according to Zalosh (6) should be 0.024% of the grain weight or .00024 lb per pound of grain handled. We applied 20–40 times that much water for safety reasons and to cope with higher rates of dust production. This high level of water also permitted us to test the effect of a greater percent of added water on the spoilage of corn during storage.

Test Weight

Test weight increased slightly (Table I) regardless of the application rate, except for grain treated with 0.48% added water in experiment 1. In tests without application of water, test weight also increased slightly because the increased breakage increased the bulk density. However, the increases were not statistically significant.

Moisture Content of Treated Grain

Increasing amounts of water (Table I) increased the moisture content of the

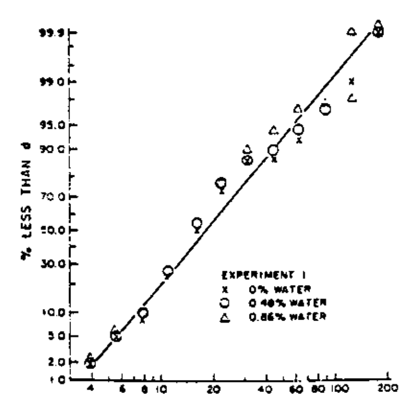

Fig. 3. Particle size distribution of corn dust. d = Stokes-equivalent diameter.

grain a maximum of 0.5% even when 0.87% moisture was added by the spray. Approximately 50% of the water evaporated into the environment, where it could reduce electrostatic charges. The 0.2% increase in moisture when no water was added may be due to sampling error and to the inherent heterogeneous nature of the grain.

Fines and Foreign Matter

A consistent increase in percent of fines and foreign material occurred after each test (Table I). However, the increase probably was due to breakage of the grain (10). Water spray did not significantly reduce corn breakage.

Particle Size Distribution of the Dust

The particle size distribution of collected dust was approximately log normal (Fig. 3). Size distributions of fine dust particles were almost identical for all tests, including the use of no water.

Storage of Corn After Water-Spray Treatment

The corn treated with water spray was stored for one year. Temperature and mold count were monitored periodically. The highest temperature measured during storage was 54° F; mold count was insignificant in all cases. Moisture increase in treated grain was not measurable after the corn was stored for one month.

Concluding Remarks

Although this series of tests indicates that the water spray technique controls dust emission, the technique's major value may be as a means for meeting air quality standards.

This technique could also reduce dust explosion hazards inside a grain elevator if applied inside the facility, eg, to dusty grain on a conveyor belt or in a bucket elevator.

The water spray described in this study slightly increased the moisture content of the grain, but the quality of the corn did not change during storage.

Chiotti and Yoshizaki, in experiments on the adsorption of moisture by grain dust and the control of dust hazards, addressed the fundamental mechanism of moisture adsorption by grain dust and the rate at which the process takes place.[3] Their observations on agglomeration and decreased particle dispersibility are consistent with the finding of this study. Chiotti and Yoshizaki concluded that properly conditioned air introduced into an enclosed grain-conveying system may increase the moisture content of the smaller dust particles and decrease their dispersibility and explosibility without significantly increasing the moisture content of the grain kernels.

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