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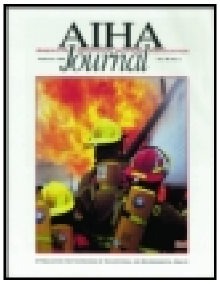

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Reducing Workers' Dust Exposure during Bag Stacking in Enclosed Vehicles

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Reducing Workers' Dust Exposure during Bag Stacking in Enclosed Vehicles

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The Bureau of Mines has evaluated cost effective systems to ventilate enclosed vehicles being loaded directly with bagged product material at mineral processing plants. This evaluation included both forms of transportation: railcars and trailer trucks. The goal of this research was to lower the dust exposure of workers stacking bags in these enclosed vehicles; these workers usually have the highest dust exposures in the entire processing plant. The problem occurs because there is no mechanical ventilation inside these vehicles. As the vehicle is being loaded, dust concentrations increase to substantial levels because released dust has no means of exiting the vehicle or of being diluted with fresh air. In cases where the dust is hazardous, as with silica sand, this may present a serious health hazard. This research project was a two-step effort. The first step was a qualitative laboratory evaluation performed in a railcar to compare different types of ventilation systems (blowing, exhaust, and push-pull systems) using a methane (CH_4) tracer gas technique. An exhaust system located over the snake conveyor was the most effective system at reducing gas levels in and around the bag stacker's work area. The second step then involved a field evaluation at a silica sand processing plant to determine the system's effectiveness in the actual work environment. Three different versions were evaluated in an attempt to optimize the exhaust ventilation system's effectiveness. The most effective version involved exhausting 54.5 m^3/min (2000 ft^3/min) through a fiberglass tube located 1.1 m past the end of the slinger at a 2.0-m height so as not to interfere with the bag stacker's job function. A small exhaust tube drawing approximately 8.8 m^3/min (300 ft^3/min) at the snake conveyor/slinger transfer point captured the dust generated at this location. Dust reductions in and around the bag stacker ranged between 65% and 95% when loading both 22.7-kg (50-lb) and 45.4-kg (100-lb) bags of ground silica sand into railcars and trailer trucks with this system.

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Introduction

This report describes the work performed by the Bureau of Mines to determine a cost effective system for ventilating enclosed vehicles as they exist today. Full-scale laboratory testing was performed to determine effective methods to ventilate these enclosed vehicles. The most effective method then was tested at a mineral processing plant to optimize the technique in a working environment and to determine its effectiveness at lowering dust concentrations inside these vehicles during loading of product material.

Many mineral products are packaged in 22.7-kg or 45.4-kg paper bags. These bags are shipped to the customer on pallets, in either railcars or trailer trucks. Bags are loaded either using a fork lift to load full pallets or directly by workers using a snake conveyor inside the vehicle. Loading bags directly into enclosed vehicles is advantageous from a production cost standpoint because it eliminates the fork lift and operator. In many cases, it is of concern from a health standpoint because of the dust exposure to the stackers which necessitates use of respiratory protection.

This work addresses the latter case. With direct loading, the bags travel down a flexible snake conveyor before passing onto a device called a slinger, which can be raised and lowered to a convenient height for the workers unloading the bags. The stackers take the bags from the slinger and hand stack them onto the pallets.

Except for minor effects caused by outside wind currents, there is no ventilation inside these vehicles. Any dust that is generated during the conveying and loading process remains within the vehicle, where dust concentrations build to substantial levels. This can be a serious health problem and necessitates the use of respiratory protection. The dust generated during loading can come from a number of different sources, the two main sources being product on the outside of the bag and product leakage from the bag valve. The bag-filling process occurs as product flows through a fill nozzle into each bag through an opening called the bag valve. Product on the outside of the bag occurs from product blowback during bag filling, from product leakage from both the fill nozzle and bag valve during the ejection process, and from product on the conveyor. Leakage from the bag valve occurs from movement on the conveyor as the bag travels to the loading area. This leakage can be substantial at conveyor transfer points and during the pallet-loading process.

Full-Scale Laboratory Tests

Full-scale laboratory testing was performed to compare the effectiveness of three different ventilation systems at reducing the bag stacker's dust exposure. Blowing systems, exhausting systems, and a combination of both (push-pull systems) were tried to determine potential effectiveness at drawing the dust away from the bag stacker and removing it from the vehicle. The purpose of this laboratory study was to perform a qualitative analysis to compare one system versus another and not a quantitative evaluation to determine anticipated dust reductions. Since the time needed to set and maintain the ventilating system was a critical factor, it was decided to evaluate only systems in which the majority of the setup would be performed between vehicles and, thus

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require only minimal maintenance time during loading. A system that requires high maintenance during the actual production process would not be acceptable since this would have a significant negative effect on production.

An actual railcar was used to perform the laboratory testing. The car was 15.2 m long, 2.9 m wide, and 3.4 m high (Figure 1). Wood framing covered with brattice cloth simulated a full pallet of bags. On the front edge of each pallet, a small controlled quantity of tracer gas was released to simulate dust. The tracer gas was released and mixed by a small fan located in front of the simulated pallets. Four sampling locations were positioned in and around the simulated bag stacker's work position. To compare the various techniques, gas concentrations at the sampling points were analyzed with two CSI/Meloy HC 500-2C hydrocarbon analyzers (Columbia Scientific Industries, Austin, Tex.) which were calibrated each day before testing began. The methane (CH_4) tracer gas was allowed to build to a predetermined concentration of 1000 ppm CH_4. When this concentration was reached, the ventilation system was turned on. The effectiveness of each technique was based on the gas dissipation rate and the baseline concentration, which was the average concentration that the system stabilized at using the various ventilation systems. Again, this analysis was not a quantitative analysis in predicting anticipated percent dust reductions in an actual work situation but was a comparison of the effectiveness of one system versus another.

A number of fan directions and size variations were tested with the different techniques. For the blowing system, the direction changed from the left back, center, and right side of the car. The outlet of the blowing system was located either in the middle or high in the car on the door side. The exhaust system varied, laying on the bottom of the car or being located halfway up the car. In both cases, the system was located on the door side of the car so as not to interfere with the snake conveyor. The blowing and exhaust ventilating system (push-pull) incorporated the blowing system located high in the car and the exhaust system located on the floor, both on the door side of the car.

Two different fan sizes were evaluated. The first fan had a flow rate of approximately 59.5 m^3/min (2100 ft^3/min), which represents one air change per minute per half of the railcar. The other flow rate was approximately 19.8 m^3/min (700 ft^3/min), which is roughly one air change every 3 min per half of the car.

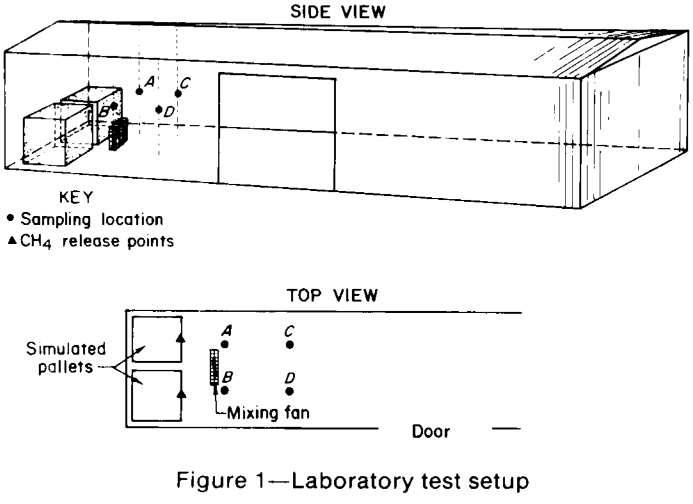

Figure 1—Laboratory test setup

Full-Scale Laboratory Results

These laboratory test results were only used to compare the different systems. Originally, the areas of interest were to be the dissipation of gas once the exhaust system was turned on and the baseline concentration. There was no substantial difference in the dissipation of gas or the decay rate from one system to another, so the baseline gas levels were used as the primary evaluation in comparing the systems. The effectiveness of the different ventilation systems are shown in Table I listed in order of decreasing effectiveness. These values are the average methane tracer gas concentrations from the four different sampling locations. The baseline concentration at each sample location was determined from the strip-chart recorder during testing. Three runs were performed for each ventilation system, and there was such an insignificant change between runs that it was unnecessary to perform a statistical analysis of the variance.

The exhaust system located at the center of the car was identified from the methane tracer gas analysis as the most effective technique and, thus, selected for further study. The methane release point was moved to the top of the pallets to represent dust coming from all over the pallet. To determine the effectiveness of pulling the dust generated up and away from the bag stacker, the exhaust ventilation port was moved from being even with the pallets to 45.7 cm and 91.4 cm past the front edge of the pallets. The capture efficiency increased with distance from the slinger. Since the pallet base dimension is approximately 122 cm square, 91.4 cm was believed to be the greatest distance possible while maintaining the necessary clearance from the back wall on the first pallet.

Field Testing

The effectiveness of the ventilation system selected was evaluated in the actual working environment at a mineral processing plant. An exhaust ventilation system was fabricated and installed over the snake conveyor and slinger. At this plant, both railcars and trailer trucks were loaded from this one snake conveyor.

To optimize this technique in the actual working environment, both types of vehicles (railcars and trailer trucks) were monitored for dust concentrations at various locations, with and without the ventilation system. The RAM-1 real time aerosol dust monitors (GCA Corp., Bedford, Mass.) were used to evaluate respirable dust levels at various locations during loading of the enclosed vehicles. These instruments use a light-scattering device to measure the dust concentration of a sample drawn in from the environment through a 10-mm cyclone. All RAM-1 dust monitors were calibrated simultaneously in a dust box using silica dust before each field evaluation and then checked before each day of testing to

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TABLE I
Average Methane Concentration from Four Sampling Locations for Each Ventilation Method Tested during Laboratory Evaluation

Ranking	System Type	Fan Position	Aver. Conc. at Sample Locations (ppm)
1	exhaust	center, 1.8 m high, even with pallet	95.0
2	exhaust	center, 2.1 m high, even with pallet	110.0
3	exhaust	center, 2.1 m high, 20.3 cm back from pallet	127.5
4	exhaust	floor, right, 30.5 cm from pallet	295.0
5	blowing	roof, center	310.0
6	push-pull	blower, high, left exhaust, floor, left, 59.5 m^3/min	315.0
7	exhaust	blower, high, left exhaust, floor, left, 19.8 m^3/min	341.3
8	blowing	roof, left	345.0
9	blowing	middle, left	372.5
10	exhaust	floor, left, 30.5 cm from pallet	386.7
11	blowing	high, right	427.5
12	blowing	high, left	437.5
13	blowing	middle, center	450.0
14	exhaust	floor, left, 2.4 m from door	510.0
15	blowing	high, center	532.5
16	exhaust	center, 1.8 m, 2.4 m from door	612.5
17	exhaust	floor, left, 1.2 m from door	665.0
18	exhaust	floor, right, 2.4 m from door	685.0
19	blowing	high, left, 19.8 m^3/min blower	707.5
20	exhaust	floor, right, 1.2 m from door	1000.0

determine that the instrument maintained its proper calibration reference. Small adjustments were made when necessary to maintain the calibration setting.

Dust was monitored at four different locations inside the enclosed vehicles (Figure 2):

Location 1—on the lapel of the bag stacker (to give a direct reading of personal dust exposure) while stacking the bags of product onto pallets;

Location 2—at the right side end of the slinger (the bag valve side, which gave a direct reading of dust levels where the bag stacker catches the bags of product);

Location 3—at the transfer point between the snake conveyor and the slinger (for dust levels at this transfer location); and

Location 4—over the snake conveyor, approximately 2.4 m back from the snake conveyor/slinger transfer point (which gave a measurement of the dust buildup inside the main portion of the enclosed vehicle).

The signal from the RAM-1 dust monitor was fed directly into a strip-chart recorder as a function of time, which allowed noting the start and finish time. Any down time associated with loading the vehicle also was noted, and that time was excluded from the dust calculation measurements. Dust concentrations for each vehicle were calculated, using a

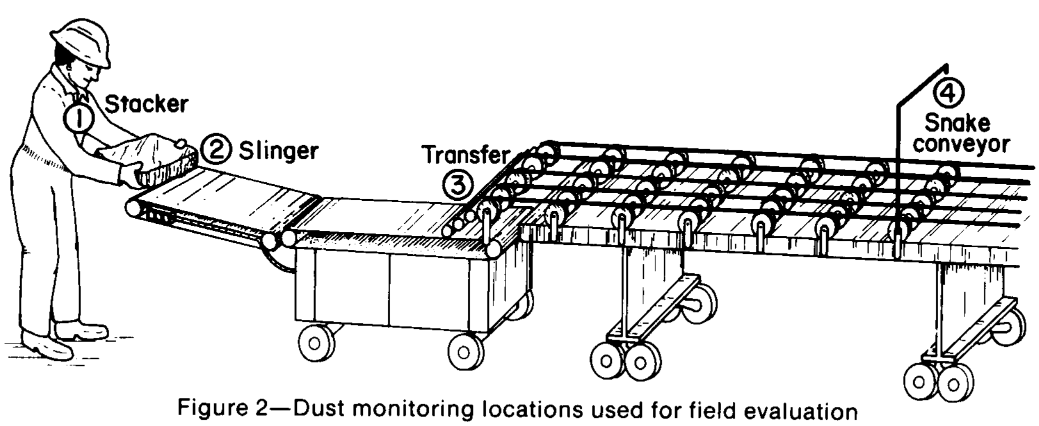

Figure 2—Dust monitoring locations used for field evaluation

planimeter to calculate the area under the curve, then divided by the sampling time. This gives a dust concentration value in milligrams per cubic meter (mg/m^3).

The following factors were taken into account in comparing the mechanical ventilation system to the conventional loading process (with no mechanical ventilation): vehicle type (railcar or trailer truck); bag size (22.7 kg or 45.4 kg); product mesh size (290 or 390); and production rate. All factors would have to be identical for a comparative analysis of the dust control ventilation system.

Three different variations of the exhaust ventilation system on the snake conveyor were evaluated for 1 week each. For all cases, a 59.5 m^3/min fan located outside of the vehicle was used. Flexible tubing, attached to the fan, extended all the way to the snake conveyor/slinger transfer point. From this point, the systems differed as follows.

Test 1: The flexible tubing was connected to a 0.31-m diameter rigid fiberglass tube that extended 1.1 m past the end of the slinger and was 2.0 m above the floor. This allowed the bag stackers to perform their jobs without interference.

Test 2: The flexible tubing was connected to a special transition, composed of two 20.3-cm diameter outlets and one 15.2-cm diameter outlet. The two 20.3-cm lines ran under the slinger on either side of the slinger discharge. The 15.2-cm line was extended to the snake conveyor/slinger transfer point to capture the dust generated at this point (Figure 3).

Figure 3—Ventilation system used for Test 2

Figure 4—Ventilation system used for Test 3

Test 3: The flexible tubing again was connected to the 30.5-cm diameter rigid fiberglass tubing which extended up and out past the bag slinger. The 15.2-cm diameter tubing extended to the snake conveyor/slinger transfer point (Figure 4).

Every enclosed vehicle loaded during the test period was monitored, although there was no control with respect to the vehicle type, mesh size, or bag type, which were based on customers' orders. The first vehicle was monitored as it was ordinarily loaded (no ventilation system). When an identical vehicle was ready to be loaded with the same mesh size and bag type, the exhaust ventilation system was installed.

Table II gives the average respirable dust concentrations with the system off and on for loading an entire vehicle at the various sample locations and gives the percent dust reduction with the system on versus the system off. These values represent a total accumulation of data from all vehicles tested with identical characteristics. This was believed to be most appropriate considering the variation in vehicle loading characteristics and the use of an instantaneous monitoring device, such as the RAM-1 dust monitor. It also was considered more appropriate to evaluate an entire vehicle with the system on or off because of the variance in dust levels at different stages during loading. Without the mechanical ventilation system (system off), there is a buildup of dust as the vehicle is loaded. This would not be fully realized if the ventilation system were turned on and off within the same vehicle. It must be noted that the values were measured only during actual work periods, and thus, they will be higher than what would be normal for a worker's 8-hr exposure level, which includes break periods and times when the system is not operating. There are two values identified in Table II that indicate an increase in the dust exposure at that location when using the ventilation system.

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TABLE II
Dust Reductions of Field Testing Exhaust Ventilation System

Vehicle and Product Size	Monitoring Location	Dust Concentration (mg/m³) Off	On	Reduction in Dust Concentration (%)
		TEST 1		
Railcars:				
290 mesh,	stacker	2.47	0.78	68.4
45.4-kg bags	slinger	1.38	0.50	63.8
	conveyer	2.40	0.28	88.3
Trailers:				
290 mesh,	stacker	2.04	0.75	63.2
45.4-kg bags	slinger	2.08	0.60	71.2
390 mesh,	stacker	1.51	0.77	49.0
45.4-kg bags	slinger	1.69	0.61	63.9
	conveyor	1.52	0.24	84.2
390 mesh,	stacker	1.53	1.50	1.9
22.7-kg bags	slinger	1.48	3.68	148.6[A]
		TEST 2		
Railcars:				
390 mesh,	stacker	3.54	1.46	58.8
45.4-kg bags	slinger	1.50	1.07	28.7
	transfer	1.61	0.82	49.1
	conveyor	0.94	1.03	9.6[A]
Trailers:				
290 mesh,	stacker	3.49	1.61	53.9
45.4-kg bags	slinger	2.64	1.10	58.3
	transfer	1.82	0.71	61.0
	conveyor	1.64	1.07	34.8
390 mesh,	stacker	1.66	1.33	19.9
45.4-kg bags	slinger	1.48	1.07	27.7
	transfer	1.17	0.52	55.6
	conveyor	0.94	0.61	35.1
		TEST 3		
Trailers:				
390 mesh,	stacker	1.76	0.34	80.7
45.4-kg bags	slinger	1.38	0.45	67.4
	transfer	2.07	0.43	79.2
	conveyor	2.80	0.42	85.0
390 mesh,	stacker	4.02	1.38	65.7
22.7-kg bags	slinger	4.04	1.42	64.9
	transfer	6.58	0.76	88.5
	conveyor	4.28	0.24	94.4

[A]Increase in dust concentration

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Discussion

The intent of the full-scale laboratory testing was to establish conditions that could be set up easily and yet be representative of actual field conditions and to select the most effective system for field testing. The factor which was not simulated during laboratory testing and which proved significant during the field evaluation was the dust emitted from the bag valve at the snake conveyor/slinger transfer point. Any dust that was emitted at this transfer point was drawn over the stacker to the exhaust ventilation inlet that was located out in front of the stacker in Test Setup 1. This can be seen from the boxcar and 395-mesh, 45.4-kg bag trailer truck results. There was a 20% to 30% difference in the concentrations at the conveyor location and at the stacker or slinger location because of the dust emitted at the transfer location. The conveyor location, which was behind this dust source, was not affected by it. The results when loading the 22.7-kg bags in Test 1 were greatly reduced from those of the 45.4-kg bags because of the additional dust generated from the bag valve at the snake conveyor/slinger transfer point and, thus, the reason for the increase in dust levels at the slinger locations. The dust being generated at the transfer point flowed directly over the slinger monitor as it was being drawn into the exhaust system.

Because of the dust at the snake conveyor/slinger transfer point, the authors decided to extend a small exhaust port to this location in Test 2. The two 20.3-kg diameter main exhaust lines were routed under the slinger because this would have been a more advantageous location for a permanent location for the system. Both visual observations and actual dust measurements showed the small, 15.2-cm exhaust port to be effective in capturing the dust generated at the transfer location, with an average reduction of 55%. The main exhaust was not as effective as the first system because the inlet underneath the slinger was not powerful enough to pull the dust from the pallet-stacking location along the floor and away from the bag stacker position.

The final design incorporated the exhaust system extended out over the pallets to capture the dust generated when the bags were loaded onto the pallets. Since reducing the worker's (stacker's) dust exposure was the primary goal, the 80.7% reduction in Test 3 was the highest recorded reduction for all three tests. It would have been advantageous to have other vehicles and product sizes in Test 3 to compare with the first two tests, but this was out of the authors' control since it was solely dependent on customer orders for the 1-week test period. Visual observation showed that this system was very effective at capturing the dust rising above the pallets during the stacking process and was the most effective of the three systems tested. The small exhaust port also was used because it effectively captured the dust generated at the snake conveyor/slinger transfer point, which was shown to be a substantial contributor of the dust in Test 1. The dust reductions achieved with this final version ranged between 65% to 95% at all sampling locations. The reductions are substantial considering that a 59.5 m^3/min fan was used, which represents approximately one air change per minute per half of railcar and approximately half an air change per minute when loading a trailer truck. It is obvious that the use of a larger fan would increase the efficiency of the system somewhat. The added efficiency, however, would have to be weighed against the increase in capital and operating costs.

The authors anticipate that a mineral processing plant which installed a similar system as a permanent dust control technique would run the exhaust into a baghouse dust collector. The only constraint on the system would be the tubing size (which also affects fan performance) to be located under or over the snake conveyor.

The bureau-implemented exhaust ventilation system requires minimal capital and operating cost. It is recommended that this system be used in conjunction with a baghouse ventilation system, which represents the only significant cost related to the system. A minimal cost is associated with the hardware necessary for implementing the system, including such things as flexible and fiberglass tubing, brackets to attach the system to the snake conveyor and slinger, and other additional minor hardware supplies. If a baghouse is not available, a fan with a filtering system would have to be incorporated and should be designed to recommended industrial ventilation practices as established by the American Conference of Governmental Industrial Hygienists (ACGIH). About 8 hr were required to set up the system, ready for use.

All exhaust ventilation systems had to be set up before each vehicle was loaded; this required between 5–10 min. Then, as the vehicle was loaded and the snake conveyor continually backed out of the vehicle, brackets and tubing were removed from on top of the snake conveyor because of a clearance problem with the mill building. For an operator who was interested in using this technique, a more permanent installation could be developed. It did not appear in the bureau's interest to pursue a more permanent installation or a deployment system since every plant would require its own design.

Conclusion

The exhaust ventilation system developed by the Bureau of Mines effectively lowers respirable dust concentrations for workers who load bags of product material directly into enclosed vehicles. The final design incorporates exhausting 54.5 m^3/min through a 30.5-cm port located 1.1 m out in front of the slinger at a 2.0-m height. A small, 15.2-cm exhaust tube is used at the snake conveyor/slinger transfer point to capture the dust generated at this location. When this system was used during loading, respirable dust reductions ranged from 65% to 95% in both railcars and trailer trucks, and thus, represented a significant reduction in dust exposures to bag stackers working in these vehicles. The system involves minimal equipment, installation, and operating costs and can be modified by mineral processing plants for permanent installations at their operations.

25 November 1987; Revised 13 August 1988

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