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Jerry C. Tien
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Lowering Respirable Dust Exposures at Mineral Processing Facilities

Andrew B. Cecala, Robert J. Timko, and Edward D. Thimons
Pittsburgh Research Laboratory
N I O S H
Cochrans Mill Road
Pittsburgh, PA 15236

ABSTRACT

This article discusses three research projects performed by the National Institute for Occupational Safety and Health, (formerly the Bureau of Mines), that reduce the respirable dust exposure of plant workers at mineral processing facilities. All three of these projects are very different but they all have the same goal of reducing worker exposure to respirable dust at mineral processing facilities. The first project deals with a total mill ventilation system that reduces dust levels throughout an entire building and lowers the dust exposure of everyone working in the structure. The second project describes a bag and belt cleaner device that reduces the amount of dust on the outside of bags of product and primarily reduces the dust exposure of the bag stackers, as well as anyone handling the bags until their end use. The third project discusses how to reduce a worker's dust exposure from secondary dust sources through improved work practices. This area of research can potentially impact all workers at these facilities. All three of these research projects have been shown to significantly reduce the dust exposure of workers at mineral processing facilities.

KEYWORDS

Respirable Dust, Silica, Mineral Processing Facilities, and Dust Control.

INTRODUCTION

The health hazards of respirable dust in the mining industry have been well documented over the years, both in underground and surface operations. Since many of the products and material processed at these mineral processing facilities contain some portion of silica, there is even more concern, especially with the recent revision in the classification of crystalline silica released by the International Agency for Research on Cancer (IARC). In IARC's Monograph 68 release in June 1997, its states that there is sufficient evidence in humans for the carcinogenicity of inhaled crystalline silica in the forms of quartz and cristobalite from occupational sources. The Mine Safety and Health Administration's (MSHA) dust compliance records continue to show that there is high worker exposure to silica in these types of operations.

This article discusses three projects that reduced the respirable dust exposure of plant workers at mineral processing facilities. The first project involved designing and testing a total mill ventilation system for large structures. This total mill ventilation system uses clean outside air brought in at the base of the mill to sweep and clear contaminated areas, and then discharges this air out of the top of the structure, where it poses a minimal contamination hazard to employees working outside. Average respirable dust levels were reduced by 40 and 64 percent at two field sites using this technique. The second project involved a bag and belt cleaner device that uses a combination of brushes and air jets to clean the dust that collects on the outside of 50- to 100-lb. bags of product and the conveyor belt used to transport them. The system is totally enclosed and under negative pressure to contain all dust cleaned from the bags and conveyor belt. There was a 78 to 93% reduction in the amount of product removed from the bags after passing through this system. The third project reduced worker exposure from secondary dust sources at processing operations through improved work practices. A number of work practices were identified that have been shown to have a significant influence on a worker's respirable dust exposure. These three research projects provide the mineral processing facilities a number of different options to lower worker dust exposures.

TOTAL MILL VENTILATION SYSTEM

The National Institute for Occupational Safety and Health (NIOSH) designed and evaluated total mill ventilation systems (TMVS) at two mineral processing operations (Cecala, *et al.*, 1993). The goal was to reduce respirable dust concentrations to which workers in these operations would be exposed. Dust sampling was performed using both gravimetric samplers and real-time aerosol dust monitors (RAM-1 devices) (Williams and Timko, 1984). The evaluations were conducted by monitoring inside the mill building with and without the TMVS in operation. Mill inlet and exhaust air quality were not monitored.

The first evaluation was performed at a clay processing facility in New York state. The TMVS provided 25,500 cfm of ventilating air to the mill building, representing approximately ten air changes per hour. This ventilation was provided by three 8,500-cfm exhaustors evenly spaced across the roof of the mill building. Three wall louvers were installed to provide an inlet for make-up air near the base of the mill. The louver locations were chosen to provide clean make-up air with a good distribution profile throughout the entire mill. The main functions performed in this structure were crushing and screening of clay product material.

Two weeks of testing were performed at this mill. The first week was in December, when outside ambient air temperatures ranged from 10 to 40° F, with wind chill temperatures as low as 30 to 40° F below zero. The second week of testing was in April, when outside ambient air temperatures ranged between 50 and 80° F. Five locations were monitored for dust concentrations in the mill building during both weeks to provide a good dust profile, (Figure 1). The analysis was performed by monitoring dust levels for 1-hour periods with and without the TMVS in operation.

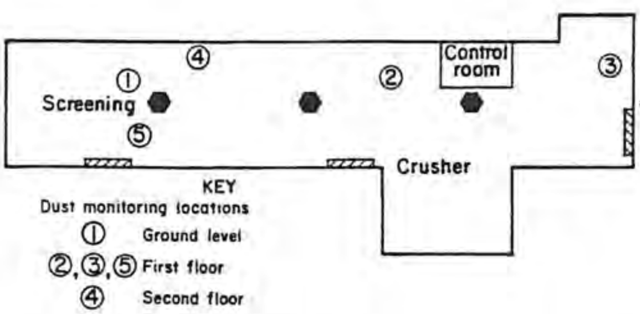

Figure1. Five dust monitoring location at Mill 1.

Both weeks of testing at this mill verified the effectiveness of the TMVS in lowering respirable dust concentrations throughout the entire mill. In December, respirable dust concentrations measured with gravimetric samplers ranged from 0.22 to 2.39 mg/m^3 with the TMVS off, compared to 0.13 to 1.55 mg/m^3 with the TMVS on. In April, respirable dust concentrations ranged from 0.29 to 4.84 mg/m^3 with the system off, compared to 0.21 to 2.37mg/m^3 with the system on.

The percent reduction in airborne respirable dust concentrations as measured by gravimetric and RAM-1 samplers at the five monitoring locations for both weeks of testing at Mill 1 are listed in Table 1. Each value was determined by comparing the average concentration with the TMVS off and on for the entire day of monitoring. The TMVS averaged approximately a 40% reduction in respirable dust concentrations throughout the entire mill for this evaluation. Figure 2 shows a 3-hour period recorded by the RAM-1 located at sample location 5 for day 2 of testing in December. The graph shows approximately 1-hour periods with the TMVS off, on, and off again.

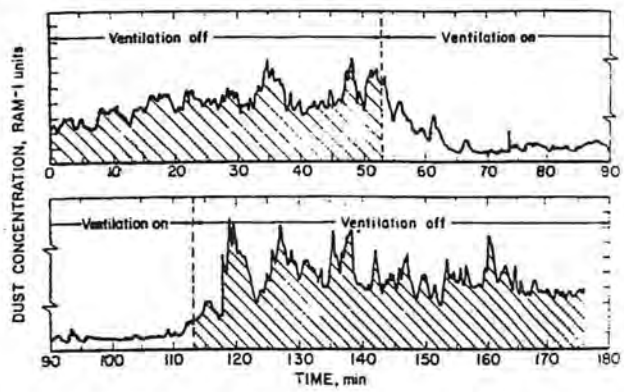

Figure 2. Respriable dust levels at location 5 with and without TMVS.

The second evaluation was performed at a silica sand operation in central Texas for two 14-hour days of testing during June, when outside ambient air temperatures ranged from 70°F to 95°F. The TMVS was composed of four 25,000 cfm belt-driven, propeller-type wall exhaustors providing 100,000 cfm of ventilation, corresponding to about 34 air changes per hour. One fan was located on the top outside wall on each side of the building. Since there were a number of large doors at the base of the mill, there was no need to install additional inlets for incoming make-up air. These doors remained open at all times during testing. Dust concentrations were monitored at six locations concentrations inside the mill building (Figure 3). RAM-1 devices were used at all locations, while gravimetric samplers were used only at the south side of the building at sample locations 2, 4, and 6.

Table 2 shows the results with the RAM-1 devices for both days of testing at five monitoring locations. The

RAM-1 at location 5 malfunctioned and thus, no valid information was obtained for this location. Table 3 lists the results for the gravimetric samplers at monitoring locations 2, 4, and 6. The reduction in respirable dust concentrations with the TMVS system ranged from 47 to 74% as recorded by the RAM-1 instruments. For the gravimetric samplers, this reduction ranged from 60 to 86%. When only two exhaust fans were used (east and west side of building), the respirable dust reduction recorded by the RAM-1 ranged from 6 to 55%, as compared with 25 to 78% for the gravimetric samplers. Using the RAM-1 results, the average respirable mill dust concentration without the TMVS was 2.66 mg/m^3. The average concentrations without the TMVS was 2.66 mg/m^3. The average concentrations with two and four fans were 1.7 and 0.95 mg/m^3, respectively. This corresponds to average reductions for all five dust monitoring locations of 36 and 6 percent, respectively. The effectiveness of the TMVS, seen in Figure 4, indicates the percent reduction in respirable dust levels for both days of testing with both two and four fans.

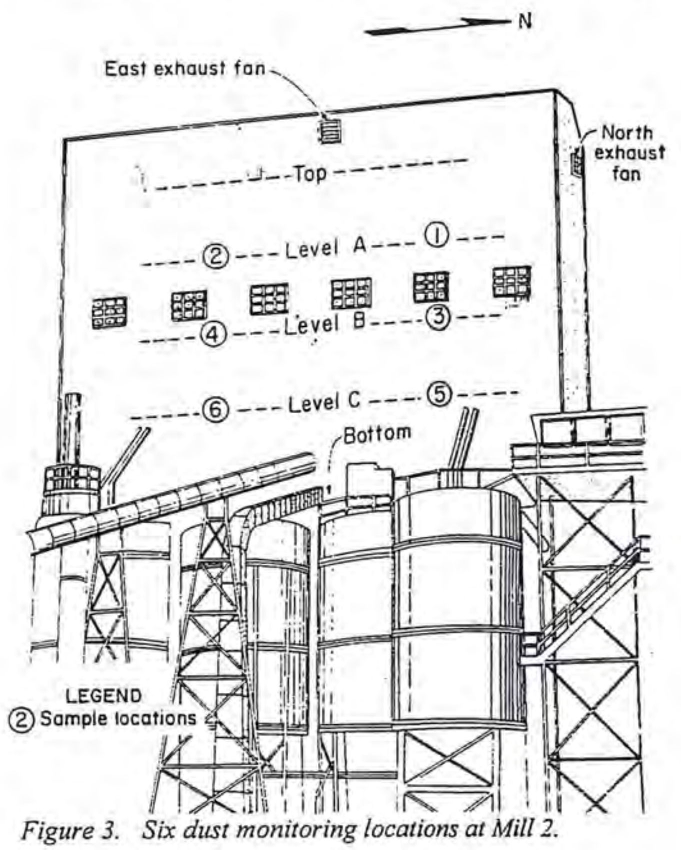

Figure 3. Six dust monitoring locations at Mill 2.

For a TMVS to be effective, there are three design criteria that must be achieved. First, the system should be capable of supplying clean make-up air to the base of the mill. It is normally not possible to supply completely dust-free make-up air, but the intent is to provide a much higher quality of air (less dust) than exists inside the mill building. Contaminated make-up air will cause the ventilation system to increase dust concentrations and worker exposure. This will be discussed in the last section of this report dealing with secondary dust sources. Second, the system needs to provide an effective flow pattern to ventilate the entire mill while providing a sweeping action in the major dust generation areas. This is achieved by the proper positioning of both fans and make-up air intakes. Having a roof exhaustor system would usually be preferable, but this is not always possible due to the physical characteristics of the structure. The location of air intakes is twofold in purpose: (1) to provide clean outside air and (2) to provide an effective flow pattern to purge the entire structure. Third, the shell of the building should be structurally competent, with no voids or openings that allow air to flow into the structure. An exhaust ventilation system draws make-up air into the structure from the point(s) of least resistance. If the points of least resistance are open or broken windows, holes or

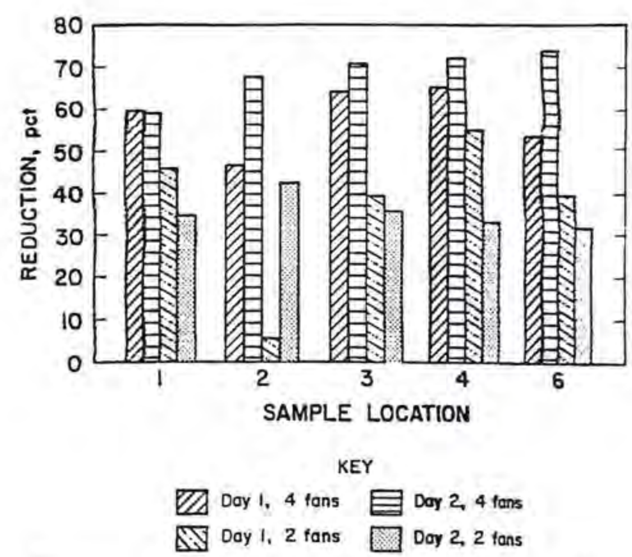

Figure 4. Percent reduction of respirable dust at each monitoring location for 2-days of testing for both two and four fans using RAM-1 devices.

cracks in the wall or roof, or any opening in the vicinity of the exhaust fan(s), the designed ventilation flow pattern will be short circuited, causing the TMVS to be ineffective.

Another consideration when designing a total mill ventilation system is to take into account prevailing wind direction. Wind direction would have a minor effect when using roof exhaustors as in Mill 1, but it should be considered when using wall-type exhaustors, as in Mill 2. With wall exhaustors, fans should not work against the prevailing wind. Where possible, the fan should exhaust with the direction of the prevailing wind which also minimizes the possibility of recirculation or reentrainment of dust back

Results from a dust monitor located immediately downstream from the B&BCD system along the conveyor line were also positive. This was the best location to determine a reduction in respirable dust with the B&BCD, since it evaluates conditions immediately after the unit. There was a 25 to 55% reduction in respirable dust concentrations at this location with the B&BCD in use.

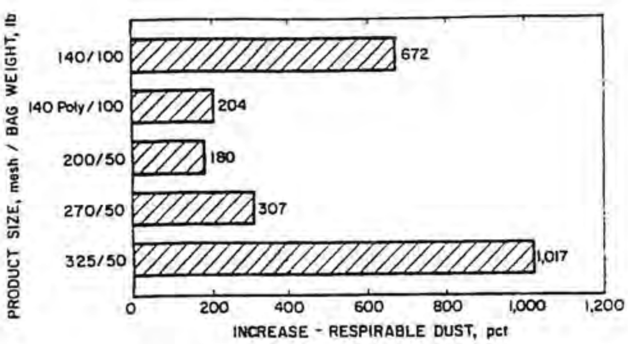

Figure 5. Increase in dust concentrations inside B&BCD while operating, (percent).

The effectiveness of the bag vacuuming procedure was also positive. Bags were pulled directly from the loading station transfer point and vacuumed before going through the device. For comparison, other bags were taken directly from pallets after going through the B&BCD. Table 4 shows the results from the different tests performed using this evaluation technique. The reduction in the amount of product removed varied from 82 to 93% for the different tests and mesh sizes.

REDUCING WORKER EXPOSURE FROM SECONDARY DUST SOURCES

To maintain a healthy work environment and to keep personnel in compliance with respirable dust regulations, plant managers need to consider all work practices that can contribute to an employee's personal dust exposure (Cecala and Thimons, 1986; Cecala and Thimons, 1992). Controlling less obvious dust sources can have a major impact on reducing workers' exposure.

Much of the work discussed in this section deals with bag machine operators. Bag machine operators typically have the highest dust exposure of all plant personnel. The bag machine operator is the person responsible for loading 50 or 100-lb bags of product on a fill spout. Although this section will concentrate on this one job function, many of the secondary dust sources discussed are applicable to other job functions throughout the plant.

Most bagging operations at mineral processing plants use an exhaust ventilation system to draw the dust generated from the bagging process down into the back of the filling unit or into the hopper used to recycle product material. It is important that the air being drawn into the exhaust ventilation system, commonly called make-up air, be clean air. It was observed at one operation that the make-up air was being drawn directly from the bulk-loading area outside the mill. The dust generated from this bulk-loading process traveled through an open door into the mill, substantially contaminating the bag operator (Figure 6). During periods when bulk loading was not performed, the bag machine operator's dust exposure was 0.17 mg/m^3. As trucks were loaded at the bulk loading area, the bag machine operator's exposure increased to 0.42 mg/m^3 due to the contaminated air being drawn in from outside the building. If outside air is used as make-up air, it must be from a location where the air is not contaminated.

A worker's dust exposure can be impacted by the way his or her job is done. Normally, the dust generated by a worker performing a job function is classified as primary dust. For this report, we consider the variation in dust levels from one worker to another as the secondary aspect of the worker's dust exposure. During an evaluation of a dust control system at one processing plant, substantial variations existed in the dust exposure of workers due to differences in the individual work practices. During this evaluation, factors responsible for these differences were identified.

One factor was the amount of time that the bag machine operator allowed the bag to remain on the fill spout before removing it. If the bag remained on the fill spout for a few seconds after it was filled, there was less dust generated from the rooster tail of product that spewed from the bag valve and fill nozzle as the bag was removed. If the operator maintained a rotation that allowed each bag to stay on the nozzle for a few seconds before removal, an identical production rate could be maintained with substantially less dust generation.

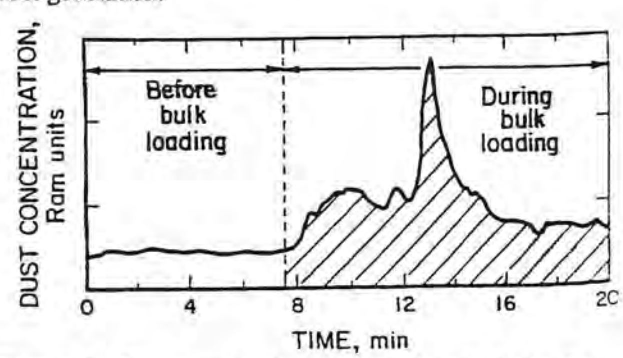

Figure 6. Bag operator's exposure from bulk loading outside mill building.

A second factor was the extent to which the bag valve was sealed by the bag operator. One operator paid no attention to where he grasped the bag as he lifted it from the fill spout and turned to place it on the conveyor. A second operator grasped the bag at the fill spout and crimped it closed as he placed the bag on the conveyor (Figure 7). This substantially lowered the amount of product that spewed from the bag as it was placed on the conveyor. It also reduced the amount of product that leaked from the bag as it traveled for the first few feet on the conveyor.

A third factor impacting the operator's dust exposure is the manner in which the operator removes the bag from the bag spout and places it on the conveyor. More dust is generated when this is done in a forceful, rough manner, rather than in a more continuous, gentle fashion. Figure 8 shows the impact of these factors on the dust exposure of two bag machine operators when four different dust control systems were being tested. Regardless of the effectiveness of the dust control system, worker #1, who failed to employ good work practices while performing this job function, consistently had higher dust exposures. Worker #2 was much more conscientious while performing these duties and his overall dust exposure was about 70% lower than that of his co-worker.

Finally, plant managers should also be aware of the effect of soiled work clothes on a worker's exposure. Figure 9 shows the effect on a bag machine operator who became soiled with product from a fill nozzle that failed to shut off after the bag ejected from the fill machine. The operator's respirable dust exposure before the occurrence was 0.1 mg/m^3;this increased to 1.0 mg/m^3 after being soiled with product, an increase of over ten times his original dust exposure.

Figure 7. Operator crimping fill spout closed.

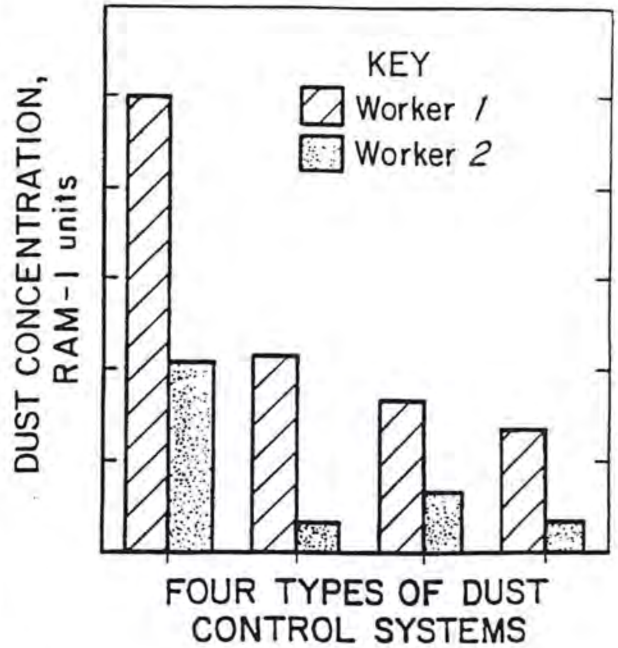

Figure 8. Comparison of operator exposure due to differences in work practices for different types of dust control systems.

Contaminated work clothes can be a major problem for some operations during the winter months when workers wear heavy work coats. Many workers may wash their coats only periodically throughout the winter months, and these coats have the potential to be significant sources of personal dust exposure. Workers should come to work with clean clothes, or the company should provide clean outer coveralls. The type of clothing material should be another consideration. A material with a high percentage of cotton or wool provides more product adhesion than a synthetic material. Companies may want to consider providing their workers with work clothes or throw away coveralls made from a synthetic material.

The respirable dust exposure of workers is impacted by many different factors in minerals processing operations. Frequently, events not directly related to the workers' job function may be more significant sources of contamination than the actual job function. In cases where a worker's dust standard may be low because of high silica content, secondary dust sources have been found to overexpose workers. To effectively keep bag operators' exposures at acceptable dust levels, these secondary dust sources must be controlled.

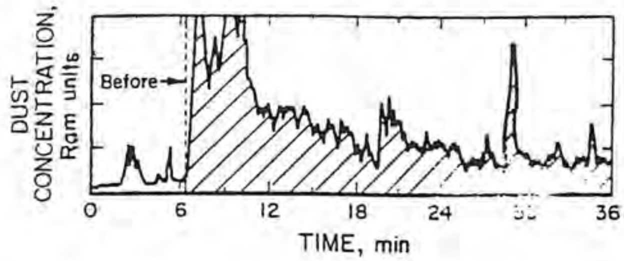

Figure 9. Operator's exposure after clothes became soiled with product.

CONCLUSION

For mineral processing operations to keep workers at acceptable dust levels, management must be aware of the various dust contamination sources and methods to reduce these sources. The TMVS has been shown to reduce respirable dust levels in buildings from 40 to 64% and thus have an impact on lowering the dust exposure of plant personnel working in buildings. The B&BCD has reduced the amount of product on the outside of bags by 78 to 93 percent during the field evaluations performed on this system. There was also a 25 to 55% reduction in the amount of respirable dust immediately downstream from the device. The B&BCD also had a measurable impact on lowering workers' dust exposures in and around the bagging and stacking process. The last area looked at secondary dust sources. The substantial effects of the various secondary dust sources should be recognized, identified, and controlled in an effort to lower worker dust exposures.

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Table 1. Percent dust reduction for gravimetric and RAM-1 instruments at five monitoring locations for both weeks of testing at Mill 1.

Day	1		2		3		4		5	
	Grav	RAM-1	Grav	RAM-1	Grav	RAM-1	Grav	RAM-1	Grav	RAM-1
DECEMBER 1989										
1.....	64.9	54.8	33.3	18.5	40.7	55.0	55.0	53.4	33.5	(1)
2.....	49.0	18.4	54.2	43.8	40.9	35.0	67.4	55.3	(1)	72.5
APRIL 1990										
3.....	37.4	20.1	66.7	53.5	14.6	22.7	48.7	38.2	53.4	12.1
4.....	63.3	44.3	27.7	46.3	0	33.3	27.6	37.2	44.8	29.5
5.....	48.3	16.8	63.5	56.9	27.3	26.2	39.5	35.9	19.2	9.9

(1)Equipment malfunctioned

Table 2. Dust concentration and percent reduction for RAM-1 instruments at five monitoring locations for Mill 2.

Location	Fan off	2 fans		4 fans		4 fans, windows open	
	Conc, mg/m³	Conc, mg/m³	Reduction, pct	Conc, mg/m³	Reduction, pct	Conc, mg/m³	Reduction, pct
DAY 1							
1....	2.17	1.17	46.08	0.88	59.45	(1)	(1)
2....	2.53	2.39	5.53	1.35	46.64	(1)	(1)
3....	2.36	1.43	39.41	0.85	63.98	(1)	(1)
4....	2.04	0.92	54.90	0.71	65.20	(1)	(1)
6....	1.92	1.16	39.58	0.89	53.65	(1)	(1)
DAY 2							
1....	2.59	1.69	34.75	1.06	59.07	1.02	60.62
2....	3.67	2.10	42.78	1.18	67.85	1.18	67.85
3....	3.31	2.13	35.65	0.97	70.70	1.35	59.22
4....	3.68	2.46	33.15	1.02	72.28	1.68	54.35
6....	2.32	1.58	31.90	0.61	73.71	1.48	36.21

(1)No testing performed.

Table 3. Percent reduction of respirable dust levels with gravimetric samplers at three monitoring locations at Mill 2.

Number of fans	Level A, location 2	Level B, location 4	Level C, location 6
DAY 1			
2.....	24.8	56.4	45.6
4.....	70.5	72.6	59.5
DAY 2			
2.....	54.9	52.4	77.5
4.....	76.9	80.5	86.4

Table 4. Vacuum testing of 50-lb bags to determine reduction in product on outside of bags.

Test number	Product size, mesh	Bag weight gain, g		Reduction, pct
		System Off	System On	
1	200	43.7	7.6	82.6
2	270	72.8	5.3	92.7
3	325	63.2	8.9	85.9
4	200	62.6	10.7	82.9
5	325	58.3	5.9	89.9