RI 9596

REPORT OF INVESTIGATIONS/1995

Reducing Respirable Dust Levels During Bag Conveying and Stacking Using Bag and Belt Cleaner Device

UNITED STATES DEPARTMENT OF THE INTERIOR

UNITED STATES BUREAU OF MINES

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UNITED STATES DEPARTMENT OF THE INTERIOR
Bruce Babbitt, Secretary

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Rhea Lydia Graham, Director

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

Metric Units

A	Ampere	m^3/s	cubic meter per second
g	gram	min	minute
kg	kilogram	mg/m^3	milligram per cubic meter
kPa	kilopascal	mg/min	milligram per minute
L/min	liter per minute	mm	millimeter
m	meter	μm	micrometer
m^3/min	cubic meter per minute	$\mu g/m^3$	microgram per cubic meter

U.S. Customary Units

cfm	cubic foot per minute	psi	pound per square inch
ft	foot	scfm	standard cubic foot per minute
lb	pound	V	volt
pct	percent		

REDUCING RESPIRABLE DUST LEVELS DURING BAG CONVEYING AND STACKING USING BAG AND BELT CLEANER DEVICE

By Andrew B. Cecala,[1] Robert J. Timko,[2] and Alexander D. Prokop[3]

ABSTRACT

The U.S. Bureau of Mines has designed and tested a system called the Bag and Belt Cleaner Device (B&BCD) to reduce dust levels in and around the bag conveying and stacking process. The device physically cleans either 22.7 kg (50 lb) or 45.4 kg (100 lb) paper bags by using a combination of brushes and air jets. It is completely self-contained and is kept under negative pressure by a baghouse to ensure that dust and product removed from the bags during cleaning does not flow into the work environment and contaminate workers. The bags travel through the device on a chain conveyor, which permits any product or dust cleaned from the bags to fall into a hopper at the bottom of the device and be recycled back into the process via a screw conveyor. Once exiting the B&BCD, the outside of the bags and the conveyor are essentially product and dust free.

The B&BCD was evaluated at two mineral processing plants to determine reductions with the device in use. The results of both field evaluations showed that the amount of product removed from the outside of the bags varied from 77 to 93 pct.

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INTRODUCTION

The purpose of this study was to determine a cost-effective way to lower respirable dust levels in and around the bag-stacking function at mineral processing operations. In mineral processing facilities, the bag loading and stacking processes are the highest dust exposure job categories in the metal/nonmetal mining industry. Figure 1 shows the respirable quartz exposure level of different job classifications at mineral processing facilities; the highest worker exposures are for bag operators and bag stackers.[4]

The U.S. Bureau of Mines (USBM) has worked on several different research projects to reduce worker exposure during bag stacking. One study dealt with lowering dust concentrations when loading bags on wooden pallets within enclosed railcars or trailer trucks. A flexible snake conveyor expedited the stacking of bags inside these vehicles. Individuals working in the vehicles, referred to as "stackers," were exposed to extremely high respirable dust concentrations during this palletizing process. At times, respirable dust concentrations were 40 to 50 times higher than the worker's threshold limit value (TLV) for the workday. The dust generated inside these enclosed vehicles during the bag-stacking process was not exiting the vehicle or being diluted with fresh air. The USBM examined various methods to effectively ventilate these vehicles and thus lower respirable dust concentrations. The goal was to remove the dust generated during the bag-stacking process and to keep it from contaminating the workers while being exhausted from the vehicle. The most effective design was a system built onto the flexible snake conveyor that was retreated from the vehicle as it was being loaded. The inlet to the exhaust system extended beyond the loading area and pulled dust toward the front of the vehicle and away from the bag stackers. A small exhaust port was also located at the last transfer point to capture the dust liberated at this location. Respirable dust concentrations were reduced between 65 and 95 pct in and around the bag-stacking location using this system (*1*).[5]

The USBM also developed an effective method to lower dust levels at conventional pallet loading operations; those sites where the pallet loading process is always performed at the exact same location. When a pallet is fully loaded, a fork lift carries it away. The cycle is then repeated by positioning a new pallet in the same location as the previous one. The USBM performed an in-depth laboratory analysis investigating various ventilation methods to minimize the bag stacker's dust exposure. The final design used a push-pull ventilation technique to capture dust generated during bag stacking. A low-volume, high-velocity blower system operating at approximately 4.3 m^3/min (150 cfm) generated a stream of air over the top layer of bags on the pallet. As this air stream traveled across the top of the stacked bags, it entrained dust generated during the bag-stacking process. The exhaust ventilation system pulled approximately 70.8 m^3/min (2,500 cfm) of air and dust through the exhaust hood. This exhaust air was filtered through a baghouse or another device before being discharged outside the mill. There was a 70-pct reduction in the bag stacker's dust exposure during laboratory testing and a 76-pct reduction at the first field evaluation. This system has proven itself to be effective and reliable from a dust control, ergonomic, and production standpoint (*2*).

The previous research looked at specific types of pallet loading applications and investigated effective techniques to control the dust generated at these locations. The intent of the current research is to clean both the bags and the belt before they reach the bag-stacking location. This reduces the worker's respirable dust exposure regardless of the bag-stacking method used.

When this work was initiated, an in-depth literature search was performed to determine existing research and technology in this area. There was a significant amount of work performed on conveyor cleaning techniques (*3-5*). This previous research was beneficial in evaluating different methods for cleaning the bags of product.

This research was aimed at designing a system that would have wide application and could be used regardless of the stacking method or location. The B&BCD was designed to be placed in-line between the bag loading and the bag-stacking process. The system was able to handle paper bags between 22.7 kg (50 lb) and 45.4 kg (100 lb), but with minor modifications, it could probably handle most bag sizes. Product removed or cleaned from the bags and belt is collected in a hopper at the bottom of the device and recycled back into the process periodically via a screw conveyor. By removing the product and dust from the exterior of the bags and the conveyor belt, dust liberation is greatly reduced while the bags are transported to the bag-stacking location. The ultimate goal of this research was to improve the health of workers by reducing respirable dust concentrations during the bag-stacking process. Dust exposure is reduced for the bag stacker, other workers in and around the area, as well as the end user of the bagged material.

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[4]Watts, W. F., Jr., and D. R. Parker. Quartz Exposure Trends in Metal and Nonmetal Mining. Internal Report. U. S. Bureau of Mines. Twin Cities Research Center.

[5]Italic numbers in parentheses refer to items in the list of references preceding the figures.

BACKGROUND

In an effort to clean the bags of product material as they move through the device, the B&BCD uses a combination of both stationary and rotating brushes, along with air nozzles. The B&BCD is 3.1 m (10 ft) long and is installed as part of the belt line. Figure 2 shows a schematic of the B&BCD. As bags enter the device, they travel though flexible plastic stripping doors into an air lock chamber. Inside this air lock is a stationary brush on a swing arm that starts the cleaning process on the front and top of each bag. The bag then travels through a second plastic stripping door, exits the air lock chamber and enters the main section of the device.

Once in the main cleaning chamber, the bag travels under a rotating circular brush that further cleans the top of the bags. This brush rotates opposite to the travel direction of the bags, creating additional friction and improving the cleaning action. The sides of the bags are cleaned by a stationary brush positioned on each side of the chamber. An air nozzle was located at the end of each of these brushes. The bags should always travel through the device with the valve on the same side. The valve side of the bag is normally much more contaminated with product than the nonvalve side. This contamination occurs as product spews from the fill nozzle during the fill cycle. Because of this contamination, the bag valve side needs more air to clean the bag than the nonvalve side. On the nonvalve side of the bag, a flat fan airjet delivered approximately 0.08 m^3/min (3.0 scfm) of air. On the valve side of the bag, a plastic airjet nozzle delivered approximately 0.57 mg/min (20 scfm) of air. This nozzle effectively removes product from the outer portion of the bag valve area. A dust cloud from the bag valve occurs each time a bag travels past the nozzle. On the nonvalve side of the bag, the high volume airjet nozzle was not cost-effective due to the additional expense of providing pneumatic air.

An air filter cleans all compressed air. Nozzle air pressure is adjusted with a pressure regulator. The optimal pressure to operate these nozzles is approximately 276 kPa (40 psi).

The last cleaning process involves the bag traveling over a rotating circular brush located beneath the bag. In this case, the brush rotation is in the same direction as the bag movement. Although the movement is in the same direction as the bags, there is acceptable cleaning action because the weight of each bag forces it down on the bristles of the rotating brush. The bag then exits the device by going through another air lock chamber, again having two sets of flexible plastic stripping doors.

A chain conveyor is used for the entire length of the device to allow product removed from the bags to fall into the hopper. Product cleaned from the bags is recycled back into the process. Initially, a high pressure air stream released from a slotted device, known as an air knife, was located at the far side of each of the rotating brushes to provide additional cleaning and to keep the brushes clean. These air knives provided very little, additional cleaning over the rotating brushes and tended to place the device under positive pressure. Because of this, air knives are not recommended as a part of the B&BCD.

The B&BCD is a self-contained system with three hookup requirements. The first is 440 V, three-phase electrical power. The device is protected by a 30-A breaker and requires approximately 14 A of current during normal operation. The second requirement is compressed air. Compressed air powers two air jets and two pneumatic cylinders. The two air nozzles need approximately 0.65 m^3/min of compressed air at 276 kPa. A minimum quantity of air is necessary to periodically change the spacing of the stationary side brushes for 22.7 or 45.4 kg bags. The last requirement is to provide an exhaust air volume of approximately 34 m^3/min to keep the system at a negative pressure relative to the surrounding atmosphere. This prevents dust generated within the B&BCD from flowing out of the unit and contaminating the work environment.

The final recommended design of the B&BCD cost between \$9,000 and \$10,000 to fabricate. Approximately one-third of this cost was attributed to the chain conveyor portion. The other two-thirds would be the additional cost for the various techniques to clean the bags and belt and to contain the dust and material removed within the device. The 34 m^3/min of exhaust air volume to a baghouse is not included in this cost. It is also estimated that fabrication time was approximately 120 employee-hours.

TESTING EQUIPMENT AND PROCEDURES

The B&BCD was evaluated at two silica sand plants. The primary goal of each evaluation was to compare respirable dust concentrations after installation to previous ambient dust levels. At the first evaluation site, the pallet loading process was performed by two bag stackers. At the second evaluation site, this process was performed automatically by a palletizing machine.

The respirable dust monitoring equipment and analysis were similar for both plants. Real-time aerosol dust monitors (RAM-1)[6] were the primary evaluation tool. Owing to the ability to perform preinstallation and postinstallation testing, gravimetric dust samplers were also used at the first evaluation site. Both instruments used 10-mm Dorr-Oliver cyclones to classify the respirable dust fraction, particles having an aerodynamic diameter of 10 μm or less (*6-7*).

In both evaluations, a RAM-1 device was located at each predetermined dust-sampling position. This device measures respirable dust concentrations by light scattering within a sensing chamber. The RAM-1 has been shown to closely simulate gravimetric measurements when calibrated for a specific dust type (*8*). This instrument was ideal for evaluating the effectiveness of the B&BCD.

Gravimetric dust samples were used at the first evaluation. Various studies have shown that gravimetric sampling can simulate dust deposition in workers' lungs (*9*). Gravimetric dust filters were weighed before and after use at the USBM's Pittsburgh Research Center. All gravimetric sampling pumps were calibrated to 1.7 l/min according to procedures specified in "Chapter D - USDOL, Mine Safety and Health Administration (MSHA) Handbook Series, Metal/Nonmetal Health Inspection Procedures, Handbook No. PH90-1V-4, November 1990.

Although both gravimetric and RAM-1 dust monitoring devices measure respirable dust concentrations, the data obtained by each method was very different. Gravimetric samplers provided a single dust concentration value while the unit was operated. They are used by MSHA for compliance measurements to determine a worker's respirable dust exposure over the entire work day. In this work effort, gravimetric devices had a more limited role than the RAM-1 device because they provided only a single value of the time-weighted average concentration and gave no indication of peak values or fluctuations in dust levels during the monitoring period.

The RAM-1 provides a continuous real-time output of respirable dust concentration. With the RAM-1 device, it is easy to determine how changing parameters impact dust levels, making it an excellent tool for performing comparative evaluations. Because of the large volume of dust data obtained, a datalogger unit was used to store the data from each RAM-1 monitor. The datalogger was then dumped to a lap top computer after each day of testing. This information was then processed using various software programs that specialized in data analysis.

One last analysis technique performed at both evaluation sites involved cleaning a specific quantity of bags with and without the B&BCD in operation using a vacuum cleaning device. This was done to measure the amount of product material on the outside of the bags. To do this, ten 45.4 kg bags and twenty 22.7 kg bags were randomly removed from the conveyor line and vacuumed in each test. These bags were set on a piece of plastic and manually vacuumed using a high-efficiency portable vacuum cleaner to remove all product on the outside of each bag. By preweighing and postweighing the vacuum bags to the nearest tenth of a gram on an analytical balance, the amount of product removed from these bags was determined. Using the above measurement techniques and comparing identical product and bag sizes at each site, the ability of the B&BCD to remove external product and dust was determined.

[6]Reference to specific products does not imply endorsement by the U.S. Bureau of Mines.

EVALUATION SITE 1

Testing

The first evaluation of the B&BCD was at a silica sand operation. Testing was performed at the ground silica mill on material formerly called "silica flour," with product sizes from 120 to 325 mesh. A bag operator manually loaded product into 22.7 or 45.4 kg paper bags at a four-station, fluidized air fill machine. As the bags were ejected from the fill station, they traveled a short distance on a chain conveyor and were then dumped onto a second conveyor and traveled out the conveyor belt to the loading platform. Two methods were used to palletize the bags, but in both, bag stackers manually performed the palletizing process. The first method was to load the bags onto pallets at the edge of a loading dock. Once a pallet was completed, it was taken by forklift to either a trailer truck or the warehouse, and a new pallet started. The second method was to load the bags directly onto flatbed trailer trucks. This involved lengthening the conveyor belt and having the bag stackers load the bags directly on the trailer.

During the dust analysis, all loading was performed using a modified version of the previous method. A platform was constructed to extend the loading dock and to permit the installation of the B&BCD. This platform was used to load all pallets during this 2-week test period. In addition, the entire outside loading dock area was enclosed using wood framing covered with nylon reinforced plastic material. This enclosure was fabricated to more precisely measure dust levels in the conveying and pallet loading area by minimizing the effects of background dust sources. Phase 1 of the evaluation was performed for 5 days to determine respirable dust concentrations without the B&BCD. The B&BCD was then installed and the same dust analysis was performed for an additional 5 days of testing (phase 2). Respirable dust was liberated by the movement and handling of bags during the palletizing process. The amount of dust liberated is dependant on the mesh and bag size, these factors were therefore evaluated separately. Figure 3 shows the test layout including the four dust-monitoring locations and the location of the B&BCD during phase 2 of testing.

The performance of the B&BCD at this first test site was impacted by the insufficient exhaust air volume provided to the unit. The device was designed to operate with an exhaust volume of approximately 34 m^3/min. When the unit was originally started, the exhaust volume was 13.4 m^3/min. To increase this value, a vane axial fan was installed and increased the exhaust volume to 20.5 m^3/min. Even at this quantity, the B&BCD was operating at only 60 pct of the designed exhaust volume. The unit was under insufficient negative pressure, resulting in dust leaking from the device into the work area.

Results

The results of testing at this first evaluation site indicate a reduction in dust levels with the B&BCD. Dust levels were compared at the four sample locations during phase 1 (baseline conditions), and phase 2 with the B&BCD. With the gravimetric dust samplers, respirable dust concentrations ranged from 1.10 to 3.72 mg/m^3 in phase 1, compared to 0.13 to 2.19 mg/m^3 with the B&BCD in phase 2. The respirable dust concentration for both phases can be seen in appendix, table A-1. Figure 4 shows the average respirable dust concentrations at all four sample locations. Average dust reductions of 35.0, 19.1, 30.0, and 21.4 pct were obtained with the B&BCD for sample locations 1 through 4, respectively. Gravimetric dust concentrations grouped all product mesh sizes and bag sizes together for each sample location. It would have been preferable to look at each separately, as was done with the RAM-1 technique, but this would have been difficult considering the manpower and the amount of equipment that would have been required. Dust concentrations measured by gravimetric devices were higher than those obtained for compliance sampling for two primary reasons. The first was that the dust- monitoring devices were only operated during bag stacking compared to compliance sampling where they are operated for the entire shift. The second was the enclosing of the work area to minimize the effects of background dust sources. This caused dust levels to increase inside the enclosure because dust liberated during the palletizing process was contained in the area.

The next analysis examined RAM-1 dust monitor results. RAM-1 dust concentrations from each sample location were analyzed, but unlike the gravimetric samples, product mesh sizes and bag sizes were compared separately. Respirable dust concentrations measured with RAM-1 dust monitors for the various mesh sizes and bag sizes in phases 1 and 2 can be seen in appendix, table A-2. Average respirable dust concentrations ranged from 0.99 to 2.02 mg/m^3 in phase 1; compared with 0.63 to 1.89 mg/m^3 with the B&BCD during phase 2 of testing. Figure 5 shows the reduction in respirable dust concentrations with the B&BCD versus normal dust concentrations prior to installation for 45.4 kg bags.

Both gravimetric and RAM-1 dust monitor results were likely affected by the insufficient volume of exhaust air provided to the B&BCD during testing. As dust was cleaned from the bags inside the device, some of this dust would escape and flow out into the test chamber.

Another indication of the effectiveness of the B&BCD was provided by the results of product vacuumed from the bags. The average weight gain per run for phase 1 ranged from 46 to 171 g. This compares to a weight gain of between 9 and 17 g per run during phase 2 with the B&BCD (appendix, table A-3). The comparison can be seen in figure 6 for each mesh and bag size. The reductions in the amount of product on the outside of the bags with the B&BCD were 77.6, 81.2, and 89.9 pct for 200 mesh per 45.4 kg bags, 325 mesh per 45.4 kg bags, and 200 mesh per 22.7 kg bags, respectively. These results should not have been significantly influenced by the lack of exhaust air volume to the B&BCD and provide an indication of the actual reduction in the amount of product on the outside of the bags.

Following this first evaluation, several modifications were made to improve the effectiveness and safety of the B&BCD. These included:

- double entry and exit areas using plastic stripping
- better sealing around various components
- shaft guards on both rotating brushes
- emergency shut off controls on both sides of the device
- a compressed air line dryer
- a device to clean the front of each bag when entering the unit
- a bag spacing adjustment to prevent bags from becoming lodged in the device.

EVALUATION SITE 2

Testing

The second field evaluation on the B&BCD was at another silica sand plant that bagged product that ranged from 140 to 325 mesh. A bag operator loaded ground silica into 22.7 or 45.4 kg paper bags at a four-station fill machine. As the bags were ejected from the fill machine, they traveled on a chain conveyor, rotated 90°, then traveled a short distance on a conveyor belt before entering a 4-m-long inclined bag flattener that removed excess air pressure from within the bags. After exiting the flattener, the bags traveled through the B&BCD. A dust monitor was located inside the B&BCD. The bags then traveled down a short section of conveyor belt before going over a bag weighing and printing device. The second dust monitor was placed immediately before this bag weighing and printing location. If a bag of product was not within an acceptable weight tolerance, it was mechanically removed. Bags that were acceptable were printed with the necessary information, then traveled a short distance on another conveyor belt before reaching the automated palletizer.

The first function of the palletizer unit was to properly align each layer of bags. The third dust monitor was positioned above this bag alignment process. Once aligned, a mechanical arm would slide the entire layer of bags approximately 4 m where it was ready to be loaded onto the pallet. The layer was loaded by holding the bags in place while a dual opening sliding trap door opened and allowed the bags to stack onto the pallet. The fourth dust monitor was positioned above this bag-loading process. The trap door would then close and the pallet would slightly raise to squeeze the upper layer of bags against the sliding door. This compacted the bags by removing additional air from within the bags. After an entire pallet was stacked, it was lowered and transported to a position where it was picked up by a fork lift. A new pallet would then automatically be positioned to repeat the process.

It was not possible to perform preinstallation and postinstallation testing of the B&BCD at this operation because numerous modifications were being made to the bag loading and palletizing process at the same time as the installation of the B&BCD. Because of this, dust concentrations were recorded with and without the B&BCD operating during similar periods for each specific mesh and bag size. The test layout showing the various dust monitoring locations is seen in figure 7.

Results

Testing at this field evaluation site also provided results indicating the effectiveness of the B&BCD at reducing respirable dust concentrations. The actual respirable dust concentrations measured with RAM-1 dust monitors for the various mesh and bag sizes with and without the B&BCD can be seen in appendix, table A-4. These results need to be separated in two different areas. Sample location 1, (inside the B&BCD) should be looked at independently of the other locations. Sample locations 2-4 were similar to those locations at the first field evaluation site and lower dust concentrations should occur with the use of the B&BCD.

Figure 8 shows the increase in dust concentrations inside the B&BCD (location 1). Since the device removed dust and product from the exterior of the bags, dust levels were higher when the device was operating. Respirable dust increased between 180 and 1,000 pct inside the B&BCD during its use.

Figure 9 shows the dust reduction with the B&BCD for sample locations 2 to 4. Note the slight increase with 140 mesh per 100 lb bags at sample location 4, as well as the marginal reduction for the other tests at this location. This was due to the dust generated as the layers of bags were compressed by the palletizer. During this squeezing process, a dust cloud was often observed escaping from the bag valve area. This overwhelmed any dust reductions due to cleaner bag surfaces, figure 10.

There was also a significant increase in respirable dust levels at sample location 3 for the 325 mesh per 50 lb bags. This increase can be attributed to several broken bags during testing. When a bag breaks, it is rejected at the bag-weighing station. Once rejected, it travels down a conveyor to be disposed. The conveyor that carries these bags from the palletizer unit traveled directly beneath sampling location 3. Dust liberated from broken bags had a measurable effect on this sample location because 325 mesh silica sand is the smallest sized material and has the highest fraction of respirable size material.

Again, the results obtained by vacuuming the exterior of the bag provided a good indication of the effectiveness of the B&BCD. The average weight gain per run of bags before going through the B&BCD was between 43.7 and 72.8 g. This compares to a weight gain of between 5.3 to 10.7 g per run after going through the B&BCD. The actual comparison can be seen in figure 11 for each product mesh size and bag size. Reductions in the amount of product on the exterior surfaces of the bags with the B&BCD ranged from 82.6 to 92.7 pct for the five tests.

DISCUSSION

The goal of this research project was to design and test a device to clean the exterior of bags of product material and the conveyor belt between the bag-loading station and the palletizing location. Throughout this research project, modifications were continually made to improve the operational effectiveness and safety of the B&BCD. The final design configuration as listed in this report has shown itself to be very effective from an operational standpoint over this time.

One area of this research project that was not as successful as hoped, was the ability to effectively evaluate the performance of the B&BCD at cleaning the exterior of bags of product material and the belt during the two field evaluations. Conditions at both field evaluation sites had some aspects that caused a degree of negative bias in the analysis. At the first evaluation site, the insufficient exhaust volume impacted on the evaluation of the unit. Several attempts were made to increase the air volume, but even with this, the exhaust volume was still only 60 pct of the designed exhaust volume. At this level, the B&BCD was not operating under sufficient negative pressure to prevent dust from leaking out of the device and into the test enclosure. This negatively affected testing. Two backup RAM-1 dust monitors located close to the B&BCD for spot checks measured respirable dust concentrations up to 64 pct higher with the device operating (phase 2) compared to normal conditions in phase 1. Test results showed that respirable dust reductions ranged from 19.1 to 35.0 pct with gravimetric samplers and from no reduction to 49.7 pct with the RAM-1 dust monitors. Knowing that dust was being emitted from the B&BCD because of the inadequate exhaust volume, this indicated a significant reduction in the amount of dust liberated during the bag-stacking process. The 77.6 to 89.9 pct reductions in the amount of dust and product on the outside of the bags of product showed the effectiveness of the B&BCD.

Determining the effectiveness of the B&BCD was more difficult at the second evaluation site because of the various parameters that were changing and impacting dust levels in the area. The B&BCD was installed simultaneously with a new four-station bag loading station, a bag flattener, a bag weighing and printing station, and a new automated palletizing system. Because of these other components, it was difficult to determine improvements in dust levels because of the B&BCD. One significant bias at this second evaluation site was bag breakage. This problem was created by a combination of two factors being the new bag filling machine along with faulty bags. In fact, due to the significant number of bags that were breaking at the bag filling station, it was approximately 1 year after the installation of the B&BCD before testing could be performed. Even during testing, there were several broken bags through the 5 days of testing that had a measurable impact on contaminating the test area. The USBM's past research on bag breakage showed that significant dust contamination can occur with each broken bag and just a few broken bags in a work day can cause a worker to be overexposed. As with the first evaluation site, the bag vacuuming technique provided a good analysis of the effectiveness of the B&BCD at removing dust and product from the bags and belt. Reductions at the second evaluation site ranged from 82.6 to 92.7 pct. Considering the various factors that affect respirable dust levels in these operations, it was not possible to determine the influence from other components at this second field evaluation site.

CONCLUSIONS

The USBM-designed B&BCD is effective at reducing product contamination of the bags of product material and the conveyor belt at mineral processing operations. The B&BCD uses a combination of air nozzles and mechanical brushes to clean the exterior of the bags and the belt. The system is designed to be under negative pressure so that all the dust and product removed is contained with the system. Product either falls into a hopper at the bottom of the unit and is recycled back into the process using a screw conveyor or is exhausted and filtered from the air using a baghouse dust collector unit. The system is adjustable allowing it to handle two different bag sizes (normally 22.7 and 45.4 kg paper bags) by simply changing a switch that operates two hydraulic pistons to change the bag width.

Because of these various parameters that affected testing of the B&BCD at both field evaluation sites, recorded dust reductions in and around the device were not at levels that would have been anticipated if these negative influences were not present. The bag vacuuming technique was not believed to be negatively impacted by these parameters and provided dust reductions that were significantly higher than the other techniques. We believe that the other evaluation techniques would have recorded similar reductions without the biases as indicated.

Dust levels inside the device during operation were measured up to 1,000 pct higher than with the system not operating. Dust cleaned from the bags with the device operating means there is less potential for dust generation and contamination of mill workers. Significant dust reductions were recorded at both field evaluations. Using the bag vacuuming evaluation technique, dust and product on the bags were reduced between 77.6 and 92.7 pct at both evaluation sites. The unit has been proving itself over time to be a very reliable and effective technique to clean bags of product and the belt at mineral processing plants, thereby improving worker health.

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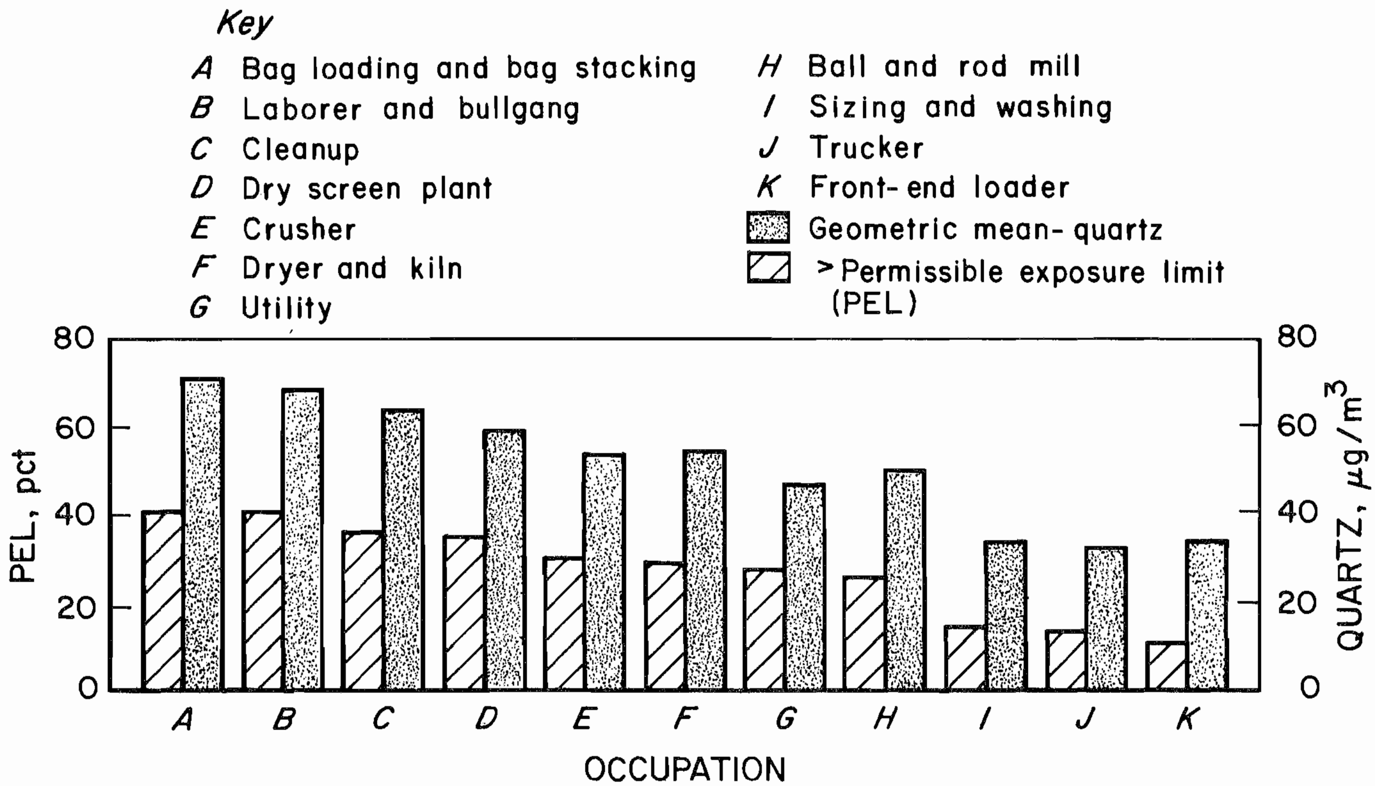
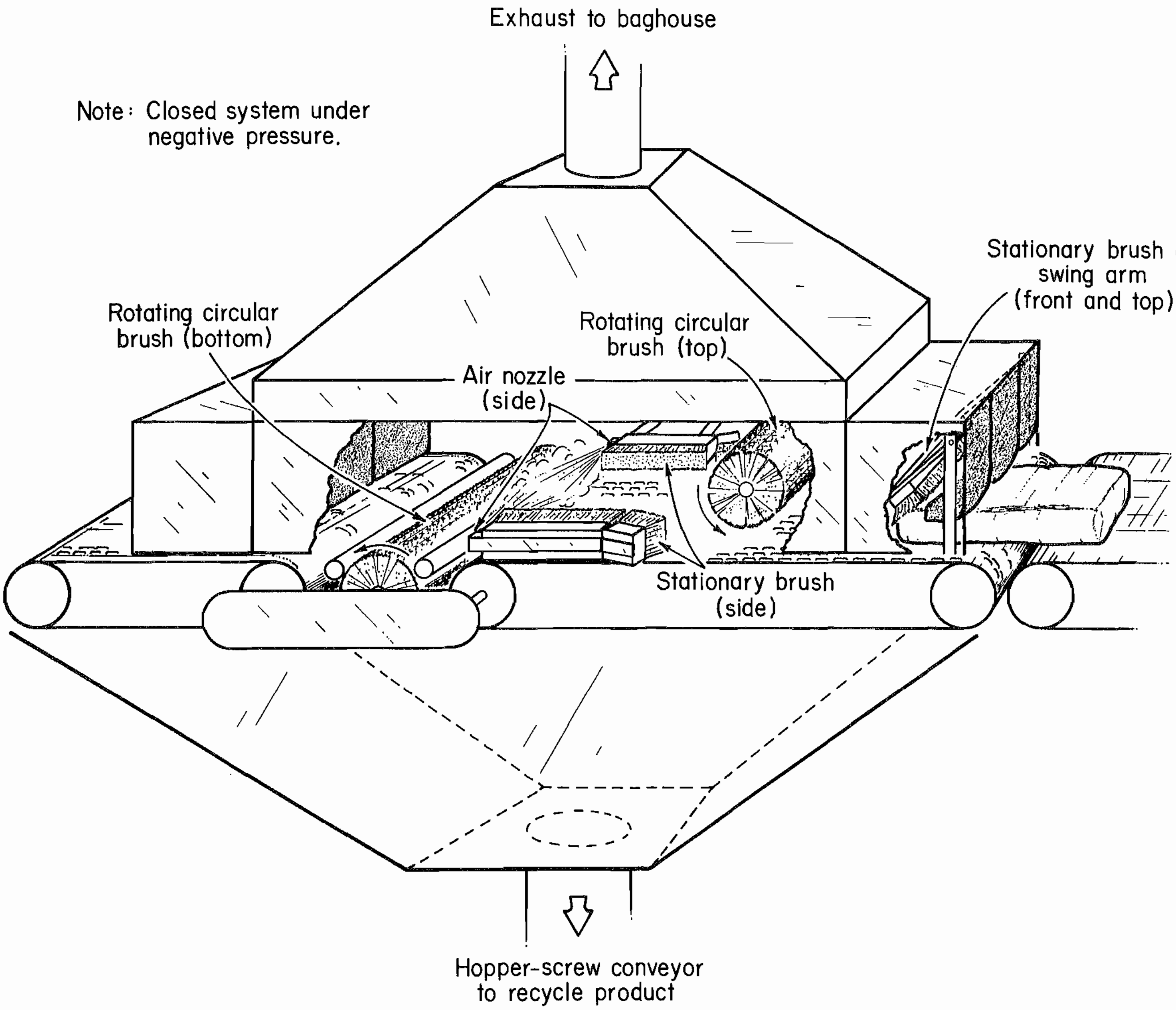
Figure 1



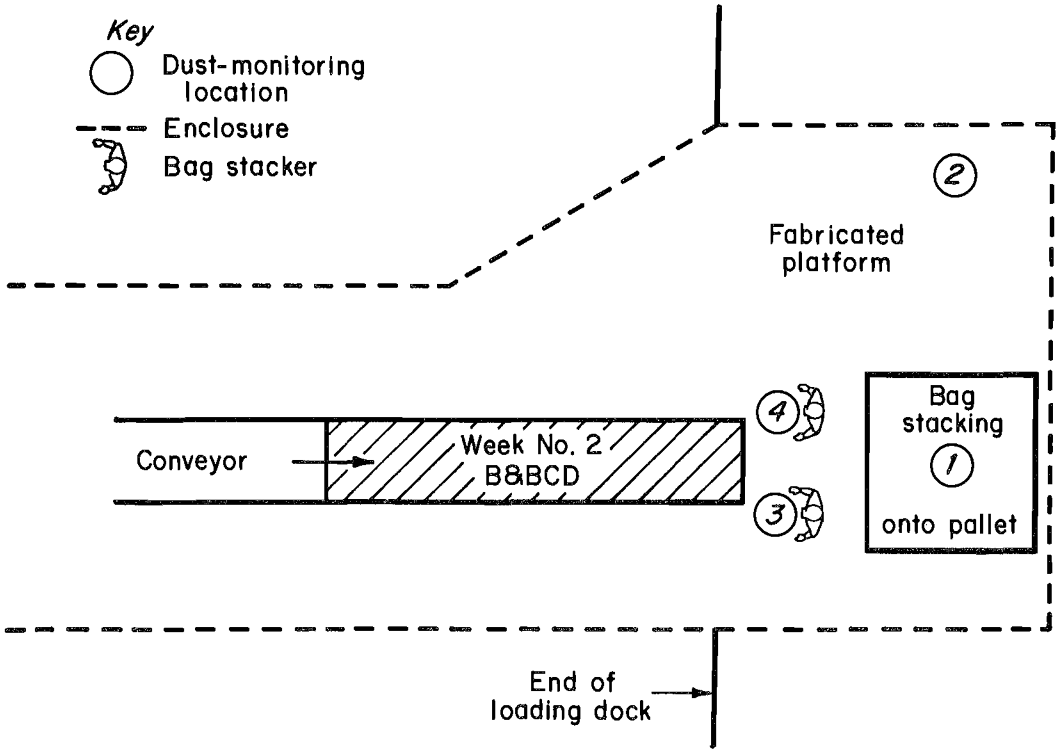
Respirable quartz exposure by occupation in mineral processing facilities for 1988-92.

Figure 2



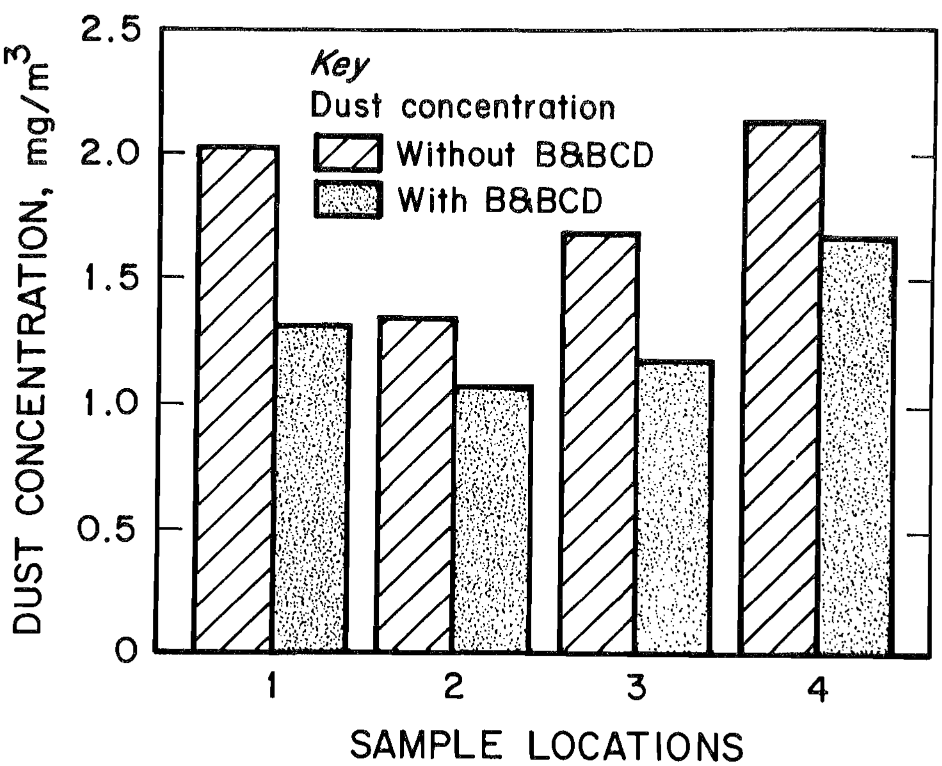
Schematic of B&BCD.

Figure 3



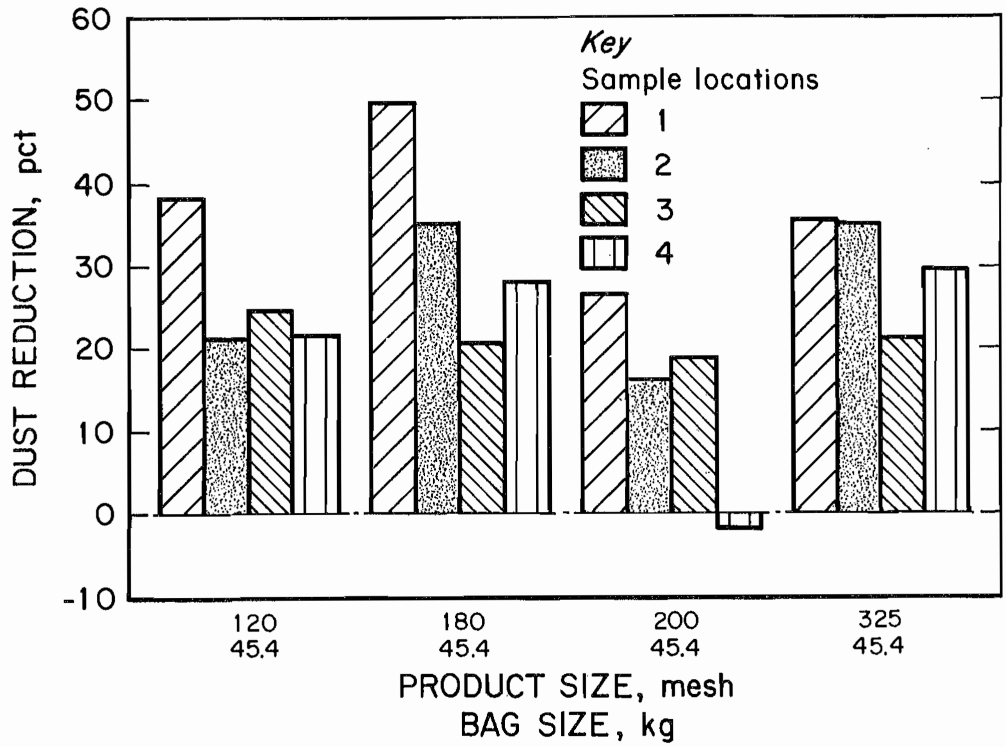
Test layout of evaluation site 1.

Figure 4



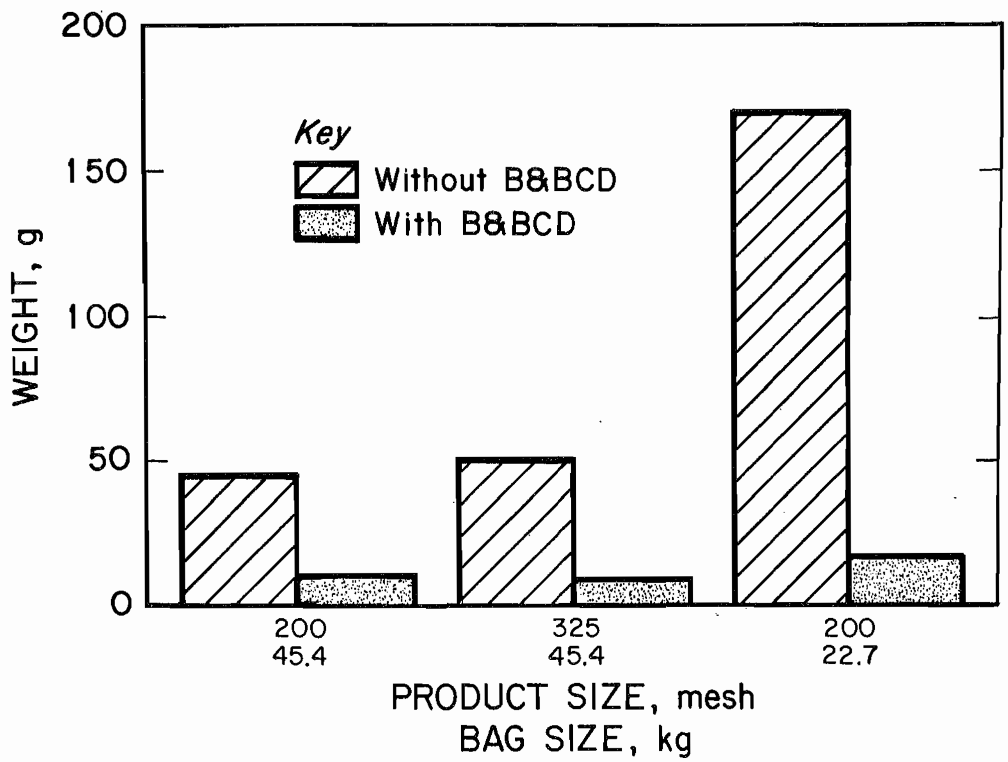
Gravimetric dust concentrations with and without B&BCD at evaluation site 1.

Figure 5



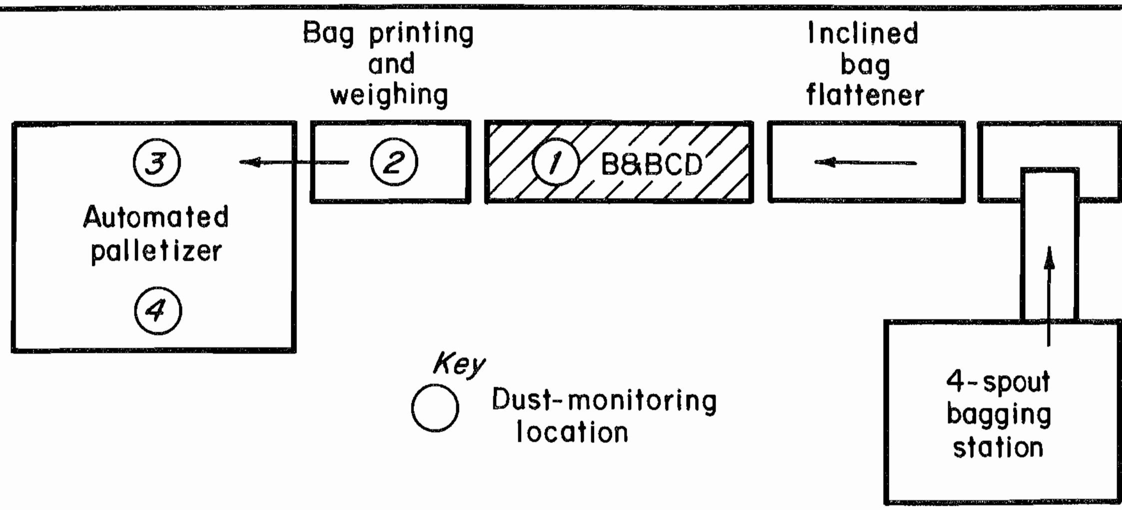
Reduction in RAM-1 dust concentrations with B&BCD at evaluation site 1.

Figure 6



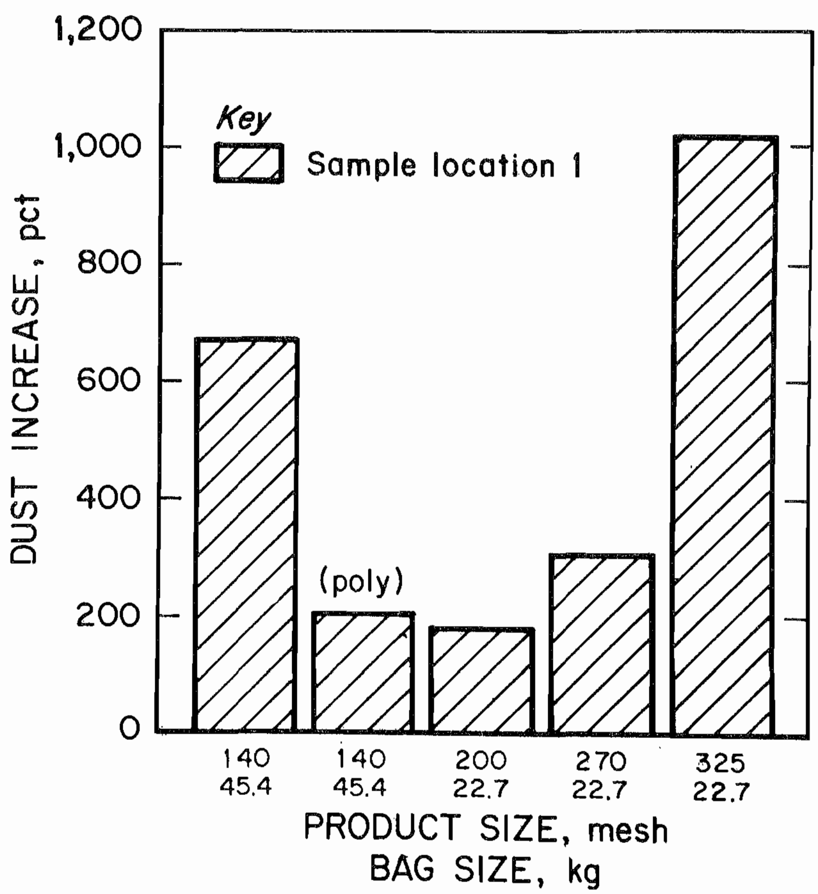
Product removed from exterior of bags with and without the B&BCD at evaluation site 1.

Figure 7



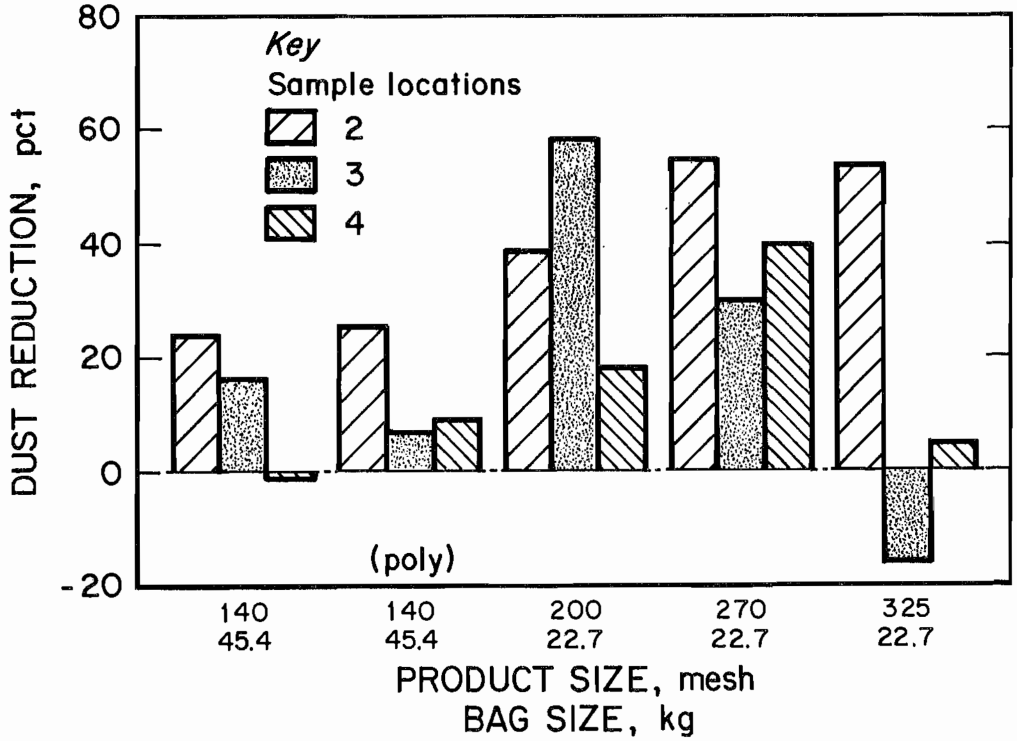
Test layout of evaluation site 2. Numbers in circle are dust-monitoring locations.

Figure 8



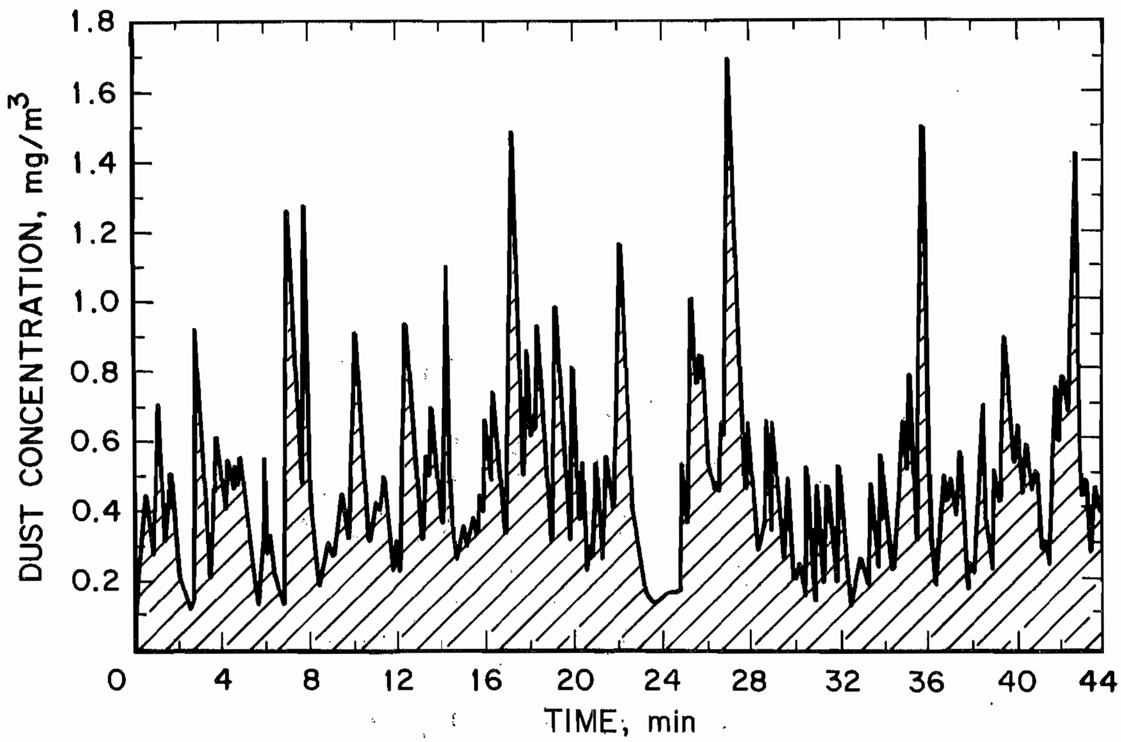
Increase in dust concentrations inside B&BCD at evaluation site 2.

Figure 9



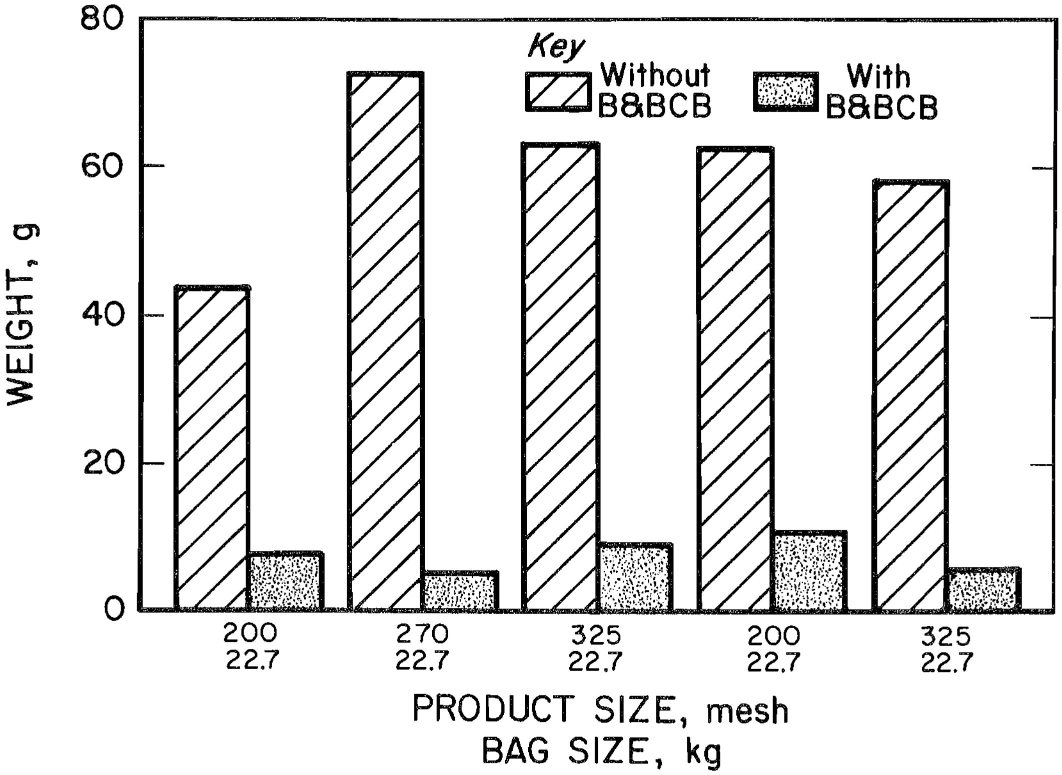
Reduction in RAM-1 dust concentrations with B&BCD device at evaluation site 2.

Figure 10



Dust liberated from squeezing process of palletizer unit at evaluation site 2.

Figure 11



Product removed from exterior of bags with and without B&BCD at evaluation site 2.

APPENDIX.—TEST RESULTS

Table A-1.—Gravimetric results at field evaluation site 1: Normal system

Day	Gravimetric	Dust weight gain, mg	Run time, min	Concentration, mg/m^3
		LOCATION 1		
1	3	1.402	392	2.10
	4	1.377	393	2.06
	5	1.296	393	1.94
2	13	1.350	394	2.02
	14	1.388	395	2.07
	15	1.436	394	2.14
3	23	1.554	246	3.72
	24	0.890	246	2.13
	25	1.554	246	2.05
4	33	0.841	326	1.52
	34	0.828	326	1.49
	35	0.625	326	1.13
Av				2.03
		LOCATION 2		
1	9	0.816	391	1.23
	10	0.922	391	1.39
2	19	0.829	393	1.24
	20	1.170	393	1.75
3	29	0.658	248	1.56
	30	0.591	248	1.40
4	39	0.626	326	1.13
	40	0.608	326	1.10
Av				1.35
		LOCATION 3		
1	1	1.119	407	1.62
2	11	1.481	395	2.21
3	21	0.559	246	1.43
4	31	0.851	326	1.54
Av				1.70
		LOCATION 4		
1	2	1.378	380	2.10
2	12	1.271	395	1.89
3	22	1.227	246	2.93
4	32	0.937	327	1.69
Av				2.15

Table A-2.—Gravimetric results at field evaluation site 1: B&BCD

Day	Gravimetric	Dust weight gain, mg	Run time, min	Concentration, mg/m^3
		LOCATION 1		
6	43	0.671	319	1.24
	44	0.496	319	0.92
	45	0.562	319	1.04
7	53	0.597	362	0.97
	54	0.620	361	1.01
	55	0.653	361	1.06
8	63	0.505	426	0.70
	64	0.887	426	1.23
	65	0.825	426	1.14
9	73	0.913	361	1.49
	74	1.162	361	1.89
	75	1.108	361	1.81
10	85	0.604	187	1.90
	86	0.638	187	2.01
	87	0.452	188	1.41
Av				1.32
		LOCATION 2		
6	49	0.668	318	1.24
	50	0.740	318	1.37
7	59	0.076	360	0.13
	60	0.623	361	1.02
8	69	0.774	423	1.08
	70	0.796	423	1.11
9	79	0.867	359	1.42
	80	0.845	360	1.38
10	89	0.392	186	0.94
	90	0.298	186	1.09
Av				1.08
		LOCATION 3		
7	51	0.552	361	0.90
8	61	0.837	424	1.16
9	71	0.869	379	1.35
10	81	0.426	188	1.33
Av				1.19
		LOCATION 4		
6	42	0.955	402	1.40
7	52	1.012	362	1.64
8	62	0.989	425	1.37
9	72	1.411	379	2.19
10	82	0.597	188	1.87
Av				1.69

Table A-3.—Results of RAM-1 dust monitor at site 1 sample locations, using normal system (without B&BCD)

(All bags were 45.4 kg)

Run	Day	Sample Location 1	2	3	4
120 MESH					
1	2	0.99	1.11	0.90	1.07
2	2	1.00	0.90	1.23	1.30
3	2	1.42	1.39	1.18	1.23
4	5	0.95	0.87	0.90	1.21
5	5	0.73	0.67	0.71	1.00
Av		1.02	0.99	0.98	1.16
180 MESH					
1	1	1.40	0.69	1.35	0.98
2	2	1.49	1.59	1.18	1.51
3	5	1.75	2.05	1.41	1.97
Av		1.55	1.44	1.31	1.49
200 MESH					
1	2	2.76	2.53	2.13	2.28
2	3	1.63	2.02	1.85	1.99
3	3	1.30	1.65	2.48	1.27
4	4	1.53	1.65	1.38	1.88
Av		1.81	1.96	1.96	1.86
325 MESH					
1	3	1.63	1.83	2.75	1.46
2	4	1.32	1.49	1.28	2.36
Av		1.48	1.66	2.02	1.91

Table A-4.—Plant 1: Vacuum testing of bags to determine reduction in product on outside of bags

Run	Bag size, kg	Product size, mesh	Bag weight, g Before	Bag weight, g After	Dust weight, g
NORMAL SYSTEM: WITHOUT B&BCD					
1	45.4	200	36.5	72.9	36.4
2	45.4	200	36.7	93.4	56.7
3	45.4	200	36.8	81.5	44.4
4	45.4	200	36.9	81.5	44.6
Av					45.5
1	45.4	325	36.9	83.8	46.9
2	45.4	325	37.3	91.5	54.2
Av					50.6
1	22.7	200	37.0	305.9	268.9
2	22.7	200	36.9	109.8	72.9
Av					170.9
WITH B&BCD					
1	45.4	200	37.4	48.1	10.7
2	45.4	200	37.3	49.5	12.2
3	45.4	200	37.7	54.2	16.5
4	45.4	200	37.7	49.1	11.4
5	45.4	200	36.7	42.2	5.5
6	45.4	200	37.4	42.4	5.0
Av					10.2
1	45.4	325	37.7	48.0	10.3
2	45.4	325	37.6	45.6	8.0
Av					9.2
1	22.7	200	37.6	52.7	15.1
2	22.7	200	37.8	57.3	19.5
Av					17.3
1	22.7	325	37.4	52.4	15.0
2	22.7	325	37.7	48.5	10.8
3	22.7	325	38.2	62.4	24.2
4	22.7	325	37.8	55.5	17.7
Av					16.9

Table A-5.- Site 2: Results of RAM-1 dust monitor at sample locations

Sample location	1	2	3	4
140 MESH, 45.4-kg BAGS				
Run 1:				
Without B&BCD, g	0.25	0.69	NA	0.44
With B&BCD, g	5.65	0.17	NA	0.73
Reduction, pct	(2160.0)	75.4		(65.9)
Run 2:				
Without B&BCD, g	5.07	0.66	0.37	0.52
With B&BCD, g	9.60	0.50	0.64	0.54
Reduction, pct	(89.3)	24.2	(73.0)	(3.8)
Run 3:				
Without B&BCD, g	2.08	0.56	0.56	0.53
With B&BCD, g	14.27	0.50	0.38	0.45
Reduction, pct	(586.1)	10.7	32.1	15.1
Run 4:				
Without B&BCD, g	11.61	0.69	0.68	0.69
With B&BCD, g	17.45	0.73	0.40	0.63
Reduction, pct	(50.3)	(5.8)	41.2	8.7
Run 5:				
Without B&BCD, g	7.77	0.91	0.34	0.60
With B&BCD, g	44.63	0.86	0.12	0.35
Reduction, pct	(474.4)	5.5	64.7	41.7
140 MESH, 45.4-kg BAGS[1]				
Run 1:				
Without B&BCD, g	6.63	0.67	0.71	0.67
With B&BCD, g	14.27	0.50	0.66	0.61
Reduction, pct	(204.2)	25.4	7.0	9.0
200 MESH, 22.7-kg BAGS				
Run 1:				
Without B&BCD, g	0.25	0.88	0.29	0.45
With B&BCD, g	0.70	0.54	0.12	0.37
Reduction, pct	(180.0)	38.6	58.6	17.8
325 MESH, 22.7-kg BAGS				
Run 1:				
Without B&BCD, g	7.28	1.03	0.43	0.62
With B&BCD, g	64.10	0.51	0.54	0.68
Reduction, pct	(780.5)	50.1	(25.6)	(9.7)
Run 2:				
Without B&BCD, g	7.47	0.89	0.14	0.31
With B&BCD, g	42.86	0.38	0.15	0.25
Reduction, pct	(1017.4)	53.9	(16.4)	4.9

NA Not available; dust monitor malfunctioned.
[1]Full poly liners.

NOTE.—Numbers in parentheses are negative.

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