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Dust Controls for the Bagging of Dry Chemicals: A Case Study

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Researchers from the National Institute for Occupational Safety and Health have studied the control of dust exposures associated with packaging operations (filling of bags with a dry material and subsequent handling operations) to identify dust sources and to determine the effectiveness of some of the dust controls presently in use. This case study describes the evaluation of controls at one plant. The plant used force-flow packer units (packers) to fill bags with a dry powder on either a manual or automatic packaging system. Combinations of ventilation, booths, enclosures, hoppers, work practices, and other controls were used at this packaging operation. For this high volume packaging operation of a crystalline silica material, an automatic system with well-designed capture hoods and high exhaust ventilation rates provided dust control resulting in average personal respirable dust exposures below 0.2 mg/m^3. **Cooper, T.C.: Dust Controls for the Bagging of Dry Chemicals: A Case Study. Appl. Ind. Hyg. 4:161–165; 1989.**

Introduction

There are an estimated 20,000 dry material packaging operations in the United States for filling bags, ranging from single packer units to complex work stations of several packer units. Many pulverized materials create hazardous dust levels during packaging. Many of these packer units (packers) have been retrofitted with dust controls to maintain dust concentrations within acceptable levels during operation. However, recent studies conducted by researchers at the National Institute for Occupational Safety and Health (NIOSH) and others note that many of these dust controls are ineffective.[1–9] This article summarizes an evaluation of available dust controls for filling 56-L (2-ft^3) capacity bags with 23 to 45 kg (50–100 lbs) of a dry product. Some of the controls were incorporated into the packers by the manufacturer; however, most of the dust controls could be retrofitted to existing packaging operations.

The operation studied included both manual and automatic systems for filling bags. Fluidizing-type packers were used to fill bags with powdered materials. Ancillary operations, such as conveying and palletizing, were included in the study.

Study Methods

Walk-through surveys were conducted of packaging operations at 14 plants to identify good dust control systems and to determine potential dust sources. To evaluate the effectiveness of the dust control measures, three of these facilities were selected for in-depth studies. This article covers one of these in-depth studies. Table I summarizes the packaging operations at this plant. Control measures at the plant were evaluated for their ability to maintain the average dust concentrations in the packaging area at or below the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for crystalline silica. Personal and area samples for respirable dust were collected with 37-mm PVC filters for laboratory analysis (NIOSH method P&CAM 259 for crystalline silica).[10] The filter samples were used to determine the dust exposures of the packaging workers, to locate and quantify possible sources of dust emissions, and to determine background dust levels in the packaging areas. Ventilation measurements were used to define air flow patterns and velocities in the vicinity of the exhaust hoods.

Dust Sources

The packer, the bag filling, and the bag handling were observed to be the major sources of dust exposure during packaging operations.

The Packer Machine

The packer spout was a major source of dust. Dust blows from packer spouts with defective or worn shutoff valves. Also, after bag filling and removal, material was observed falling from the packer spout, even when the shutoff valve was completely shut.

Occasional equipment malfunctions on automatic bag fillers, such as a bag incorrectly positioned on the spout, can result in the product being blown into the air or dumped onto the floor. Other dust sources include loose or worn packer fittings which allow dust to leak into the workplace.

Bag Filling

Figure 1 shows the two types of bags studied: self-sealing, pasted-valve bags and tuck-in-sleeve, pasted-valve bags. During bag filling, visible leakage occurs from the valve and the seams of some bags. More visible dust escapes from bags filled on fluidizing packers, as used in this facility, than from bags filled on the other types of packers observed at other plants.

Fluidizing packers use air to fluidize the product so that it will

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TABLE I. Plant Information

Packaging Station	1	2	3
A. Background Information			
1. Packaging Rate	High[A]	High	High
2. Material Packaged	Powder	Powder	Powder
3. Packaging Operation	Manual	Auto[B]	Manual
4. Type of Bag	tispv[C]	sspv[D]	tispv
B. Dust Controls			
1. Exhaust Ventilation at Packer Spout	yes	yes	yes
2. Exhaust Ventilation from Booths at			
a. Packers	yes	yes	yes
b. Ancillary Operations, Total Enclosure	yes	yes	yes
3. Ventilated Capture Hoppers Beneath—			
a. Packers	no	no	yes
b. Ancillary Operations	no	yes	yes
4. Bagging Room Isolation	Partial	Partial	Partial
5. Effective Work Practices	yes	yes	yes
6. Respirator Protection Required	yes	yes	yes

[A]High—over 100 bags per hour per packer station.
[B]Auto—Automatic.
[C]tispv—tuck-in-sleeve, pasted valve, multiply paper bag.
[D]sspv—self sealing, pasted valve, multiply paper bag.

quickly flow into the bag. As the bag fills, vent holes in the walls of the bag help to release the fluidizing air. In multiply bags, these vent holes are staggered so that a seal is formed when the bag is full. Vent holes can, however, allow the product to escape, which contaminates the bag surface and elevates dust exposures in subsequent bag handling operations. Dust can also escape from pinhole-size openings along the seams in the top of some bags.

Some leakage at the packer spout/bag valve interface, in addition to the bag vents, is necessary to relieve the excess pressure from the bag as it fills, especially on fluidizing type packers, and must be controlled. Excessive leakage may be caused by improper sizing of the bag valve relative to the machine spout, by a reduction in spout size from abrasive wear, or by overfilling bags.

Bag Handling Operations

Dust escapes from the valve and seams of filled bags during subsequent handling operations. These operations include removing the filled bag from the manual packer; closing the valve on a tuck-in-sleeve bag; dropping the filled bag onto a conveyor; flipping or dropping the bag along the conveyor line; bag flattening operations; palletizing operations; and disposal of emptied, damaged, or partially filled bags. Also, bags occasionally burst or tear during normal packaging operations, spilling their contents.

Bag Removal

Fluidizing packers aerate the product so it will readily flow into the bag. A settling period is required to allow the fluidizing air to escape into a receiving hood. If the bag is lifted from the spout before this air dissipates, any squeezing action on the bag forces the fluidized dust out of the bag valve (especially with tuck-in-sleeve valve bags) and through the seams of the bag. This frequently results in generation of airborne dust.

Valve Closing

Improper methods for manually closing tuck-in-sleeve valves are another dust source. A commonly observed work practice is the removal of loose product inside the bag valve by flicking the valve before tucking it in. The proper method is to leave the product in the spout when tucking in the sleeve so that the product remains inside the bag.

Bag Transfers

After filling, dust continues to leak from the valve and seams of many bags during subsequent handling operations. The method of bag placement on a conveyor or pallet can significantly affect the amount of this leakage. Tossing or dropping the bags results in greater leakage than gently positioning them on the conveyor or pallet.

Burst and Torn Bags

Bags may break during filling or transfer. Most companies reported an average bag failure rate of 1 to 3 percent. Burst and torn bags result in a large and sudden dust source that must be considered when designing a dust control system. For bags that burst or tear during filling, both the spilled product and the product remaining in the bag were dust sources. The product was usually recycled, leaving an "empty bag" containing up to two pounds of product. The operator typically flattened a stack of emptied bags by hand, forcing out dust-laden air. Additional dust was dislodged from the bags during transport to the disposal area.

Dust Controls

Dust controls may be classified into the following categories: local exhaust at the packer spout, booths and enclosures, spilled product hoppers, isolation, automation, use of stretch and shrink wrap, work practices, and personal protective equipment. Table I summarizes the application of these controls at the plant studied. A description of the controls follows.

Local Exhaust at the Packer Spout

Local exhaust may be used to capture the product escaping at the bag-valve/packer-spout interface during the bag filling and removal phase. For valve-type bags, the spout hood shown in Figure 2 was used. It consisted of an annulus surrounding the packer spout. The exhaust volume around the spout ranged from 6 to 10 m³/min (200 – 340 cfm).

Booths and Enclosures

Ventilated booths can be used to control dust leaking from the valve and seams of the bag during the bag filling cycle, to contain

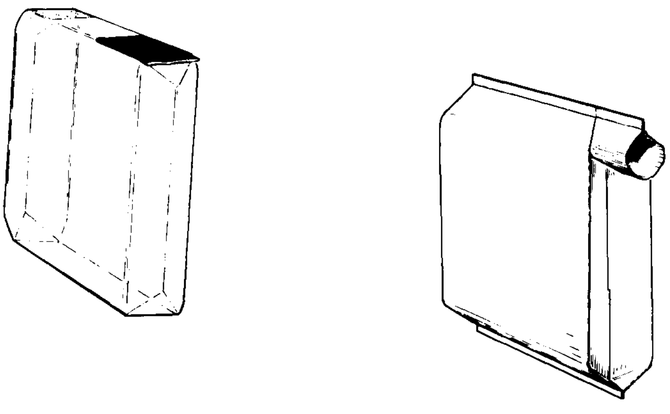

FIGURE 1. Two conventional types of bags. *Left:* pasted-valve, self-sealing (sspv) bag. *Right:* pasted-valve, tuck-in-sleeve (tispv) bag.

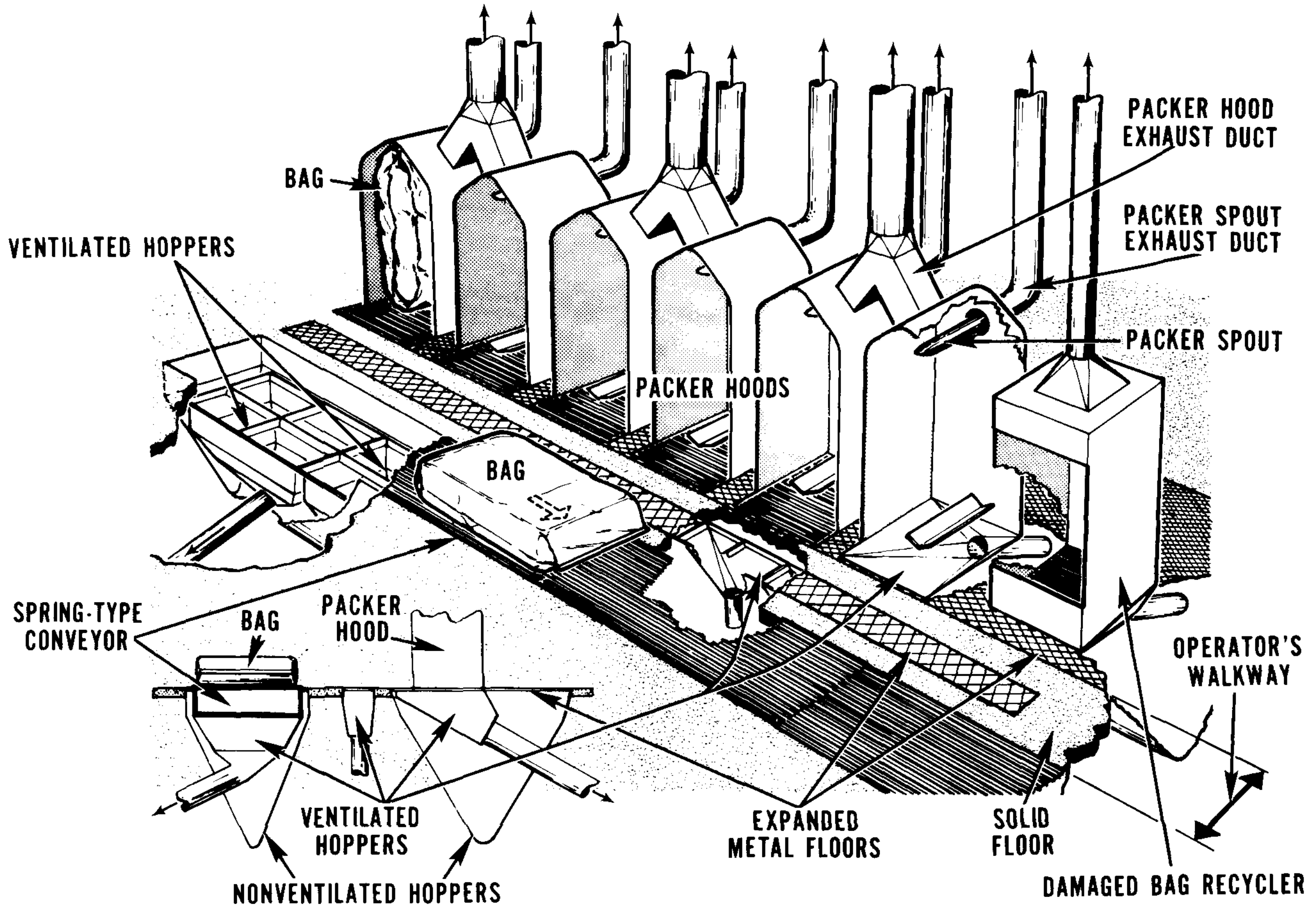

FIGURE 2. Multiple dust control measures at a packaging station.

product spillage from the bag valve and the packer spout during bag removal, and to control dust generated during closing of bag valves. The booths used are shown in Figure 2. Air was exhausted at the packer spout and from the top of the hood through a 15-cm × 15-cm (6-in. × 6-in.) port, located near the packer spout, for a total design capacity of 40 m^3/min (1500 cfm). The floor of the booth consisted of expanded metal overlying a collection hopper, which may or may not have exhaust ventilation. During the study, the measured booth face velocity at the packer station with ventilated hoppers (Station 3) averaged 200 m^3/min (640 fpm). The measured face velocity at the packer station with nonventilated hoppers (Station 1) averaged 150 m^3/min.

Spilled Product Hoppers

Major product spillage comes from packer spouts, bag valves, and burst or torn bags. Ventilated and/or nonventilated hoppers were located beneath this major dust source. They were designed to remove and recover this spillage continually rather than allowing it to accumulate on the floor and reenter the environment as airborne dust. Hoppers were also located beneath bagged product recyclers, bag cleaners, filled bag compactors (flatteners), and along some conveyor sections. Figure 2 shows a system of ventilated hoppers in the bag filling area. These hoppers were located under the packer booth floors, packer units, operator's work area, and the conveyor where the filled bags dropped after being filled.

Isolation of Packaging Operations

Packaging operations can be isolated from other plant operations to confine the potential dust sources within a limited area. This will also limit the number of workers exposed to high dust concentrations.

Automated Packaging Operations

An effective method for reducing operator exposure to airborne dust is to remove the worker from the dust source by automating part or all of the packaging operation. Since automation does not eliminate the dust sources, the use of such measures as ventilation at the packer spout, capture hoods and hoppers, good work practices, and effective maintenance programs are still necessary to protect workers in the vicinity of the operation.

Work Practices

Good work practices augment a good dust control system and should significantly reduce background dust concentrations. Good work practices include prompt and complete cleanup of spills, proper methods for recycling bagged product, disposal of emptied bags, leaving an empty bag on the packer spout while the unit is idle (such as during breaks), and regular scheduled maintenance.

Good work practices and timely cleanup of spills in the work areas are important to prevent plant contamination from airborne dust and tracking. Vacuum or wet sweeping techniques are the preferred cleanup method. Dry sweeping is not recommended, but, if used, dust retardant compounds should be spread over the area prior to sweeping. General cleanup should routinely include overhead rafters, equipment tops, floors, and any areas where dust can accumulate. (Proper design of a new plant may also provide for hosing down of work areas, if the equipment can be made electrically safe and the surfaces are properly coated.)

Personal Protective Equipment

Respirators (NIOSH approved) and other protective equipment should be used, primarily for protection against unexpected events such as burst or torn bags and product line breaks, as well as while maintaining and repairing production equipment. For toxic materials, the use of gloves, coveralls, and head coverings should be considered. Coveralls should be left at the plant site at the end of the shift, thereby preventing dust exposures to the worker's family from contaminated clothing. Coveralls should be disposable or provisions should be made for industrial laundering.

Results

Air samples for respirable dust were collected at each of three packaging stations. The average concentration at Station 1 was 0.19 mg/m^3 for personal samples and 0.05 mg/m^3 for area samples; for Station 2, the average concentration was 0.04 mg/m^3 for personal samples and 0.02 mg/m^3 for area samples; and for Station 3, the average concentration was 0.17 mg/m^3 for personal samples and 0.05 mg/m^3 for area samples. Table II summarizes the results of the dust measurements at the various operations within each packer station. Average personal exposures at Stations 1 and 3 in this plant exceeded both the NIOSH recommended exposure level (REL) and the American Conference of Governmental Industrial Hygienists threshold limit value (TLV) for crystalline silica.

TABLE II. Sample Results

Evaluation Criteria Hazard	mg/m^3 Respirable Dust Cristobalite (crystalline silica)		
Packaging Station	1	2	3
Exposure Standards:			
OSHA PEL	0.30	0.25	0.25
NIOSH REL	0.05	0.05	0.05
ACGIH TLV	0.05	0.05	0.05
Personal Samples:			
Arithmetic mean	0.19	0.04	0.17
Standard deviation	0.18	0.04	0.13
No. of samples	5	2	6
Area Samples:			
Packers			
Arithmetic mean	0.07	0.03	0.05
Standard deviation	0.05	0.04	0.04
No. of samples	17	12	16
Conveyors			
Arithmetic mean	0.07	0.02	0.07
Standard deviation	0.04	0.02	0.05
No. of samples	8	12	5
Palletizing			
Arithmetic mean	0.03	0.01	0.06
Standard deviation	0.02	0.02	0.04
No. of samples	12	6	15
Background			
Arithmetic mean	0.04	0.02	0.03
Standard deviation	0.04	0.02	0.02
No. of samples	12	6	12
Average of Areas			
Arithmetic mean	0.05	0.02	0.05
Standard deviation	0.04	0.03	0.04
No. of samples	49	36	48

On a respirable mass basis, the dust controls observed during the study were capable of maintaining exposures to respirable dust ranging from 0.04 to 0.19 mg/m^3.

In order to gain additional insight into the effectiveness of the dust controls studied, the cumulative percentages of workers with exposures equal to or less than stated exposure levels were plotted on a log-probability scale. This plot is presented in Figure 3. For three fluidizing packer stations packaging a crystalline silica powder in valved bags, the PEL ranged from 0.25 mg/m^3 at Stations 2 and 3, to 0.30 mg/m^3 at Station 1. The plot of the area sampling data appeared to be lognormally distributed. There were too few data points for Station 2 to determine if the personal exposures were lognormally distributed.

At Station 1, a manual packaging station, the personal exposure levels were three to six times greater than the area levels, indicating that most of the personal exposures may have been from the large number of bags manually handled. The arithmetic mean (Table II) for the personal exposures was 0.19 mg/m^3 (63% of the PEL) and was 0.07 mg/m^3 (23% of the PEL) in the area near the packers. All bags were handled at least once, and 5 percent of these were judged to be handled a second time as recycled, damaged bags. There were two operators at this station; each spent half the shift at bag filling and closing and half the shift at palletizing.

At Station 2, an automatic packaging station, the arithmetic mean of the area samples was 0.02 mg/m^3 (8% of the PEL). There were too few samples (only two) to determine a representative personal exposure plot. However, the personal exposures would be expected to be lower than those at Stations 1 and 3 at this facility because fewer bags were manually handled, because operators spent less time in the bag filling and palletizing areas, and because there appeared to be more effective dust controls at the station. The operator manually handled less than 5 percent of the bags compared to 100 percent of the bags at Stations 1 and 3. Since Station 2 was automated, the operator spent less than 20 percent of the shift near such dust sources as bag filling. Also, comparing area dust levels between stations (Table II), it appears that Station 2 has a more effective dust control system than Stations 1 and 3 because area concentrations are lower.

Station 3 has a manual packaging station similar to Station 1. The arithmetic mean for the personal exposures was 0.17 mg/m^3 (68% of the PEL) and was 0.05 mg/m^3 (20% of the PEL) in the area of the packers. These results were similar to Station 1. The main differences between these two stations were that Station 3 had exhaust ventilated hoppers beneath the floor in the bag filling area and that the average capture face velocity at the packer hoods was 30 percent (150 fpm) greater. However, there was little difference between the lognormal plots of Stations 1 and 3; the arithmetic means (Table II) were also similar. The plot for Station 2 area dust concentration indicates slightly lower concentrations than at Stations 1 and 3. The automated station at this facility provided greater protection against dust exposures than the manual stations.

Conclusions/Recommendations

An effective dust control measure eliminates dust generation or contains it before the worker is exposed. Each packaging operation is unique, and the best combination of dust control measures must be determined for that operation. The automated station, Station 2, was effective in protecting the worker against

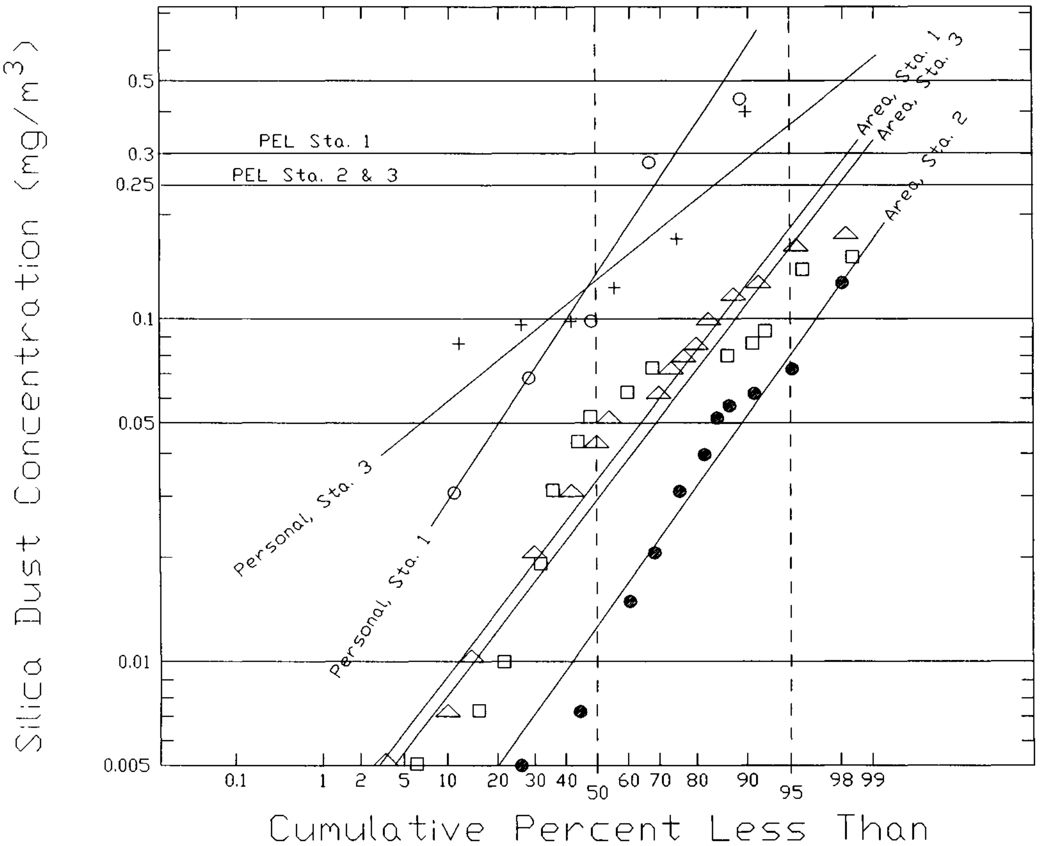

FIGURE 3. Plotted on lognormal probability scale, personal and area exposures.

dust exposures. The control measures contained most of the dust generated during normal packaging operations, controlling 95 percent of the area respirable dust concentrations to below 0.08 mg/m^3. Since the packaging operation was automated, the worker spent less than 20 percent of the shift in the packaging area near the main dust sources. Also, the operator manually handled less than 5 percent of the filled bags, only a few of which had been damaged resulting in leakage from the bag. All three of these factors combined reduced the worker's exposure to airborne dust.

Although the engineering controls were effective in maintaining average dust levels well below the then OSHA PELs, about 20 percent of the exposures approached or exceeded the present PELs. One cause for this higher worker exposure was manual bag handling. Each bag was a potential dust source, leaking dust from its valve and seams. Also, many bags may have had a layer of dust on their surface. Thus, the more bags an operator manually handled, the greater his potential dust exposure. A second cause for higher personal exposures was leaks from ancillary operations within the packaging room. A third cause of elevated worker exposure was poor work practices or improper work station design. Any one or a combination of such adverse conditions can negate the most effective dust control system. In designing an effective dust control system, all potential dust sources must be controlled.

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