

IN-DEPTH SURVEY REPORT
CONTROL TECHNOLOGY FOR FALLING SOLIDS

AT

Cincinnati Paint and Varnish
Cincinnati, Ohio

REPORT WRITTEN BY
William A Heitbrink

REPORT DATE
April 1988

REPORT NO
ECTB 154-12b

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
Division of Physical Sciences and Engineering
Engineering Control Technology Branch
4676 Columbia Parkway
Cincinnati, Ohio 45226

PLANT SURVEYED.	Cincinnati Paint and Varnish 1776 Mentor Avenue Cincinnati, Ohio 40232
SIC CODE.	3479 Paints and Coatings
SURVEY DATE	July 16, 28, and September 10, 1987
SURVEY CONDUCTED BY	William A Heitbrink Karen Spivey
EMPLOYER REPRESENTATIVES CONTACTED	Quinton Ball, Plant Manager
EMPLOYEE REPRESENTATIVES CONTACTED.	None at this plant
ANALYTICAL WORK PERFORMED BY	Data Chem, Salt Lake City, Utah

I. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational safety and health research. Located in the Department of Health and Human Services (formerly DHEW), it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

NIOSH has joined with the U.S. Environmental Protection Agency (EPA), Office of Toxic Substances, in an interagency agreement to study dust generation in the handling of powdered materials. Laboratory bench tests have been devised (by others) to provide a relatively quick and convenient means of estimating a material's relative dustiness.¹ In using these tests, one assumes that the dust generation in the tester simulates the dust generation in an actual powder handling operation.

The goal of the NIOSH/EPA joint effort is to develop a model that will serve as a predictor of potential workplace exposures associated with the handling of solid materials. This model will be used in the review of new chemicals submitted as premanufacturing notices (PMNs) under the Toxic Substances Control Act² and in preliminary analyses of existing chemicals for which personal monitoring data are unavailable. As part of this project, we are evaluating the correlation between worker dust exposure and dustiness test results. If a correlation exists, these tests could be used by manufacturers to develop treatments to reduce the dust exposures caused by powder handling.

In order to correctly evaluate the correlation between worker dust exposure and dustiness test results, the operation producing the worker's dust exposure must be isolated from other sources of dust exposure. A bag emptying operation at Cincinnati Paint and Varnish appeared to meet this criteria. As part of the process for manufacturing custom coatings at Cincinnati Paint and Varnish, bags of different powdered material are emptied into mixing tanks. This is the only source of worker dust exposure in this area of the plant. There is only one worker who performs this task and, as a result, there can be only one source of dust exposure during a given time period at this plant.

II PLANT AND PROCESS DESCRIPTION

PLANT DESCRIPTION

The Cincinnati Paint and Varnish plant was built in the early 1900's. Fewer than ten production employees are used to produce an assortment of paints and varnishes. This company was formally known as the Foy-Johnston paint company. In 1987, the Foy-Johnston product line was sold and the company was renamed Cincinnati Paint and Varnish. The company occupies two buildings on

opposite sides of Mentor Street. The offices are on one side of the street and the production facility is on the other side.

Process Description

This study was conducted on the fourth floor of the production facility. On this floor, paints and varnishes are mixed in a number of tanks. As part of the process for making paints and varnishes, 50-pound bags of powder are emptied into a 600-gallon mixing tank, which is 5 feet in diameter. After the tank has been filled with a carrier solvent, bags of three powdered materials are emptied into the mixer: titanium dioxide, talc, and crystalline silica. As shown in Figure 1, the mixing tank is partially open. The worker sets a pallet of bags next to the mixing tank. To empty these bags, the following procedure is used:

1. The bags are slit with a knife.
2. The worker picks up the bag and pours the contents of the bag into the mixer.
3. The emptied bags are set on the floor next to the mixing tank.

The manner in which powders fall through the air appears to be different for each material. The powders are added in the following order: crystalline silica, titanium dioxide, and talc. After the titanium dioxide is added to the tank, additional liquids are added to the tank. Table 1 summarizes observations about the fall distance and level of agitation for each powder.

Dust Release Sources

Practically every step in the bag opening process causes some dust exposure. Specific sources of dust release are:

1. The exterior surfaces of the bags appear dusty and bag handling may cause dust exposures.
2. Opening and emptying the bags into the mixing tank causes dust emissions, some of which appear to flow into the worker's breathing zone.
3. Handling the emptied bags can cause dust exposure. The bags appear to contain pockets of contaminated air which can be spilled into the workers' breathing zone.

Dust Control Measures

The slot hood shown in Figure 2 was used to capture the dust generated by pouring the powders into the mixing tank. The slot hood is 48 inches long and 1.5 inches high. The velocity in the slot was 6,000 feet per minute and the computed volumetric flow rate was 3,000 cubic feet per minute. Along the lip of the tank where the bags were emptied, the air velocity toward the slot hood ranged from 50 to 100 fpm.

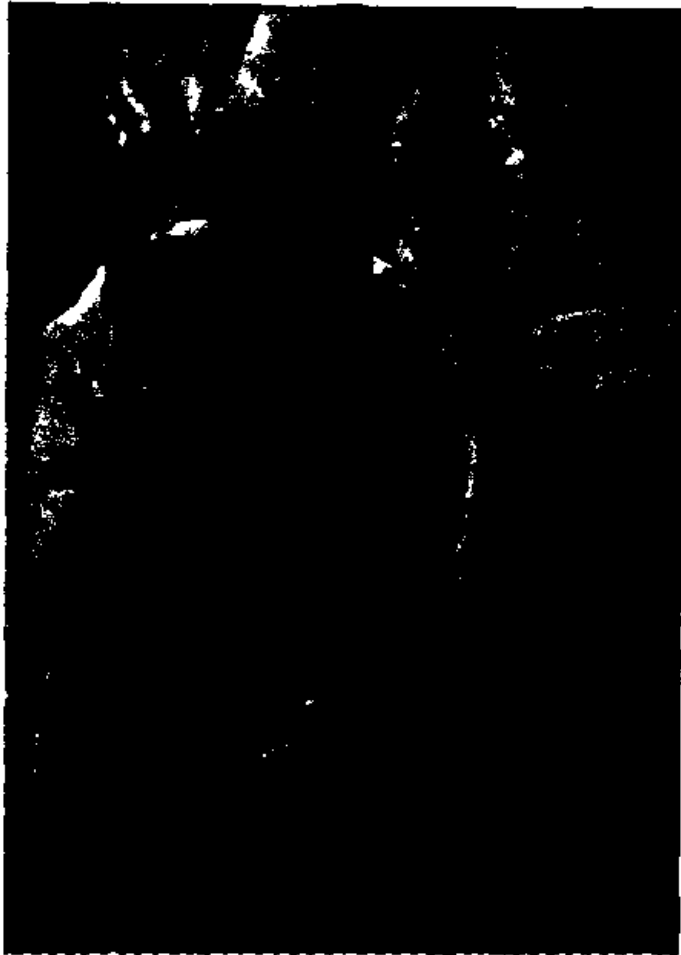


Figure 1 Picture of Tank.

Table 1
Summary of Conditions During Bag Emptying

Powder	Bags Emptied	Fall Distance (cm)	Agitation
Crystalline Silica	34	85	The vortex around the impeller extends about 1 to 1.5 meters below the level of the liquid.
Titanium Dioxide	34	75	Same as for crystalline silica
Talc	17	25	The liquid appears to be more viscous and moves more slowly. The vortex around the impeller appears to be only 0.5 meters deep.

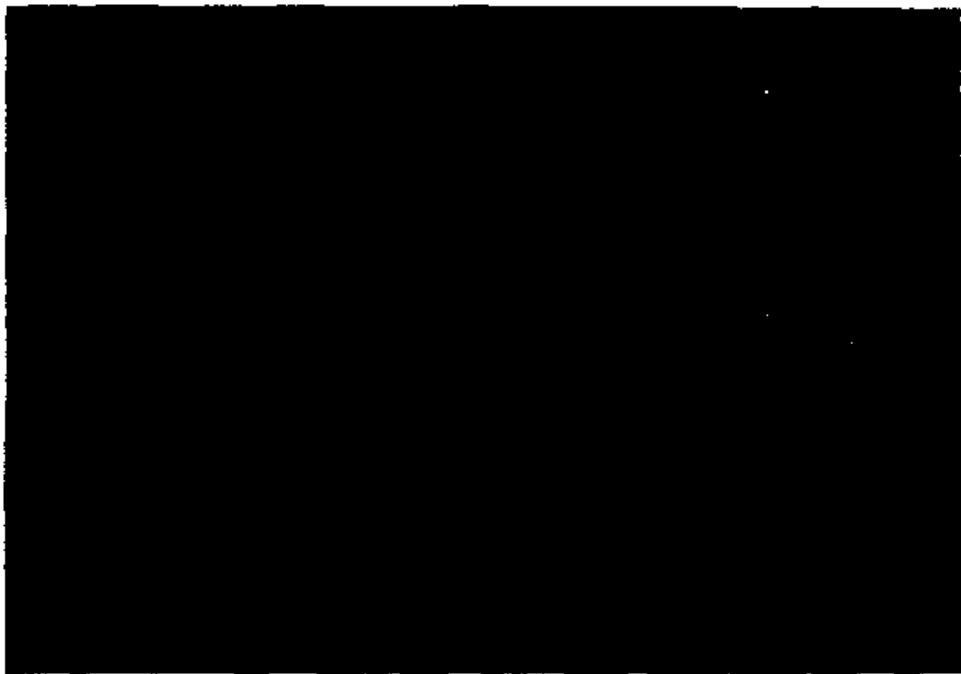


Figure 2 Picture of Slot Hood.

Evaluation Criteria for Air Contaminants

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week, for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects, even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are (1) NIOSH recommended exposure limits (RELs),³ (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs),⁴ and (3) the U.S. Department of Labor (OSHA) permissible exposure limits (PELs).⁵ Often, the NIOSH RELs and ACGIH TLVs are lower than the corresponding OSHA PELs. Both NIOSH RELs and ACGIH TLVs usually are based on more recent information than are the OSHA PELs. The OSHA PELs also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used, the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet only those levels specified by an OSHA PELs.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values, which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

In Table 2, the most stringent evaluation criteria, in terms of mg/m^3 , is for respirable crystalline silica which causes a disease known as silicosis. The NIOSH recommended exposure limit is intended to prevent this disease when exposures occur over a full working life. Silicosis is a form of diffuse interstitial pulmonary fibrosis resulting from the deposition of respirable crystalline silica in the lung. Conditions of exposure may affect both the occurrence and severity of silicosis. Although it usually occurs after 15 or more years of exposure, some forms with latent periods of only a few years are well recognized and are associated with intense exposures to respirable dust.

Table 2
Summary of Occupational Exposure Limits

Substance	NIOSH REL ³	ACGIH TLV ⁴	OSHA PEL ⁵
Crystalline Silica			
Total			30/(% SiO ₂ + 2)mg/m ³
Respirable	0.050 mg/m ³	0.10 mg/m ³	10/(% SiO ₂ + 2)mg/m ³
Talc		2 mg/m ³	20 mmpcf ^a
Titanium Dioxide		10 mg/m ³	15 mg/m ³

^a Millions of particles per cubic foot

high in free silica⁶ Early, simple silicosis usually produces no symptoms. However, both acute and complicated silicosis are associated with shortness of breath, intolerance for exercise, and a marked reduction in measured pulmonary function. Diagnosis is most often based on a history of occupational exposure to free silica and the characteristic appearance of a chest radiograph. Respiratory failure and premature death may occur in advanced forms of the disease. Individuals with silicosis are also at increased risk of contracting tuberculosis. No specific treatment is available, and the disease may progress even after a worker is no longer exposed to silica.

The exposure limits for titanium dioxide and talc are less stringent. In their documentation of the Threshold Limit Values, ACGIH noted that "there has been no evidence of range to health from the inhalation of TiO_2 that does not exceed 10 mg/m^3 of air"⁷ For talc which does not contain fibers, the ACGIH TLV is 2 mg/m^3 . At concentrations higher than this level, excess respiratory disease is reported in the literature summarized by ACGIH.⁷

III METHODOLOGY

As discussed in the introduction, this study is being conducted to evaluate the correlation between worker dust exposure measurements and dustiness test results. The dustiness testers and the industrial processes which produce airborne dust may differ. As a result, the size distribution of the aerosol produced by the dustiness testers may be different than the size distributions produced by operations such as bag opening, emptying, and disposal. This might affect the correlation between worker dust exposure and dustiness test results. As a result, this study was conducted to answer the following questions:

1. Are the workers' dust exposures and dustiness test results correlated?
2. Is the size distribution of the dust produced by the dustiness testers comparable to the size distribution of the dust produced in the workplace?

To answer the first question, the worker's exposure to the total airborne dust was measured and dustiness tests were conducted on bulk samples of the material. Two dustiness test methods were used: the Heubach rotating drum dustiness tester and the MRI tester. In order to evaluate the correlation between dustiness test results and worker dust exposure, the units of concentration must be the same for all of the materials. As a result, total dust concentrations were measured instead of the concentration of each chemical species.

Air Sampling Methodology

The procedures described in Method 0500 of the NIOSH Manual of Analytical Methods were used to measure the total dust concentrations.⁸ Two Dupont P4000 pumps in parallel were used to draw a total of 70 liters per minute of air through preweighed MSA-FWSB filters. For each material, dust sampling was done only while the worker opened and emptied bags of powder into the mixing

tank. This resulted in sampling periods of 10 to 15 minutes for each material. No dust samples were taken when the worker picked up all of the emptied bags for the three different powders and placed them in the trash hopper.

To determine whether the worker was overexposed to crystalline silica, sampling was done for respirable crystalline silica. MSA Model G pumps were used to pull air through first a cyclone and then a preweighed 37 mm MSA FWSB filter. The details of this procedure are described elsewhere.⁹

Dustiness Testing Methodology

Two tests for dustiness were evaluated in this study. The Heubach test was developed by the Heubach Company of Germany to aid in process control work for the production of the company's pigments. The MRI (Midwest Research Institute) Test was developed by MRI in response to a research project sponsored by EPA to develop an inexpensive and quick test for dustiness.

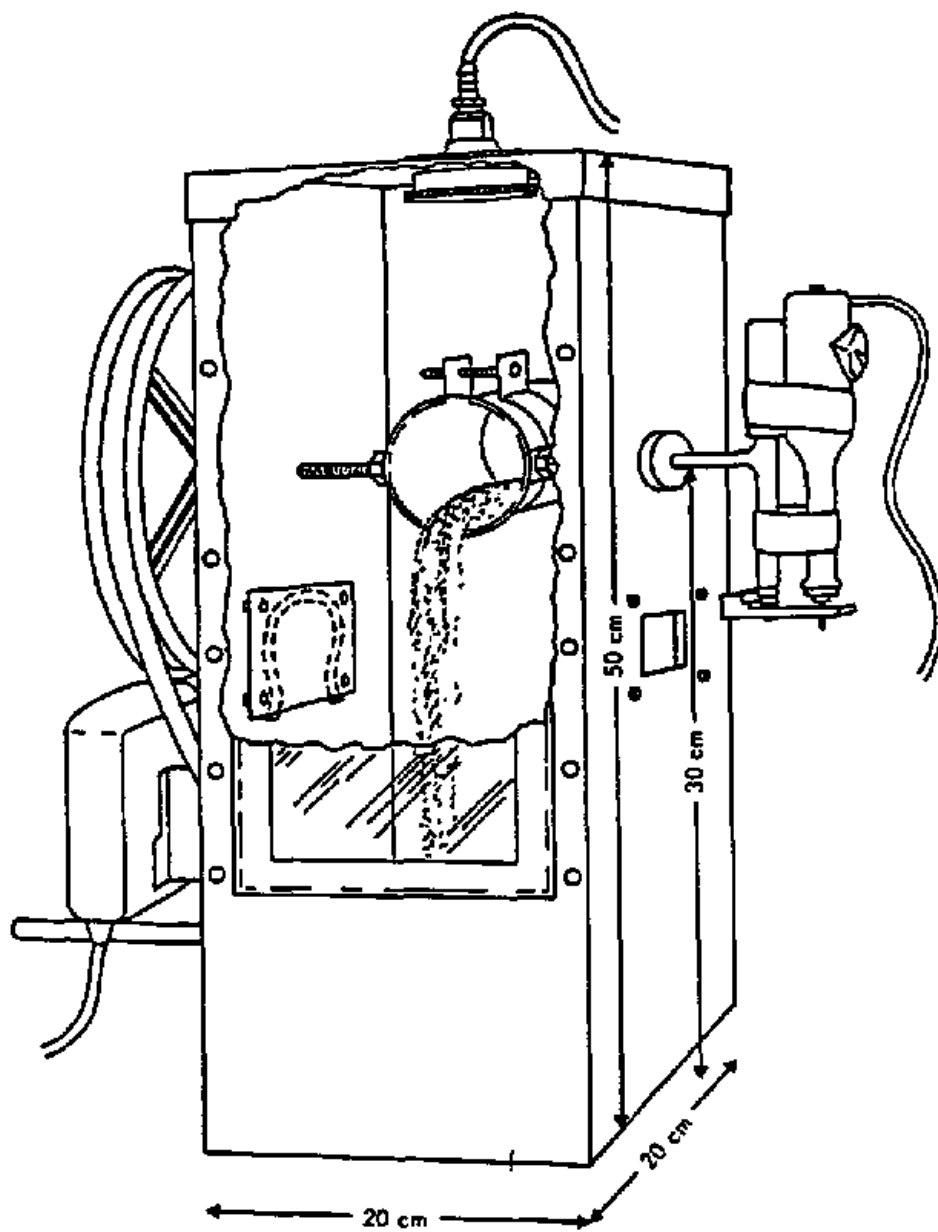
The MRI Dustiness Test

The MRI chamber shown in Figure 3 has a volume of 20 liters. The dustiness of the material is determined by pouring powder from the beaker shown in Figure 3. The resulting dust is collected on a filter which is at the top of the chamber.

At the beginning of each test series, the tare weight of the 250 mL stainless steel cup is recorded. The volume of the cup is measured by weighing it full of water (of known temperature) and calculating the volume. Glass fiber filters are used in the filter assembly to collect the suspended dust. The glass fiber filters are weighed on an analytical balance then placed in a 47 mm filter holder.

Prior to each test, the test cup is cleaned and dried. The chamber is cleaned with a vacuum hose and damp laboratory tissues. The chamber is placed on a styrofoam sheet covered with a new sheet of aluminum foil. The sample cup is filled by pouring loosely the material into the stainless steel cup. It is slightly overfilled, then scraped even with a metal straight edge, and the cup of material is weighed. The cup of material is then inserted into the chamber holder with its pour spout forward in the direction of rotation. The 47 mm glass fiber filter is placed into the stainless steel filter holder and it is screwed into the chamber lid. Finally, the chamber lid is replaced and sealed with tape and the vacuum line is attached. After the stopwatch has been zeroed, the test is begun by turning on, in rapid succession, the power to the vacuum pump and the cup rotor. The stopwatch is started simultaneously with the cup rotor. After 10 minutes, the vacuum pump is turned off and the test is completed.

Immediately after the test, the filter holder is unscrewed from the chamber lid and the exposed filter is set, exposed side up, in a petri dish. Then, the chamber is removed from the aluminum foil surface and the dumped material is discarded. The filters in the petri dish are transported to a weighing room which is temperature and humidity controlled. Before weighing, the



Dustiness Test Chamber

Figure 3 MRI Dustiness Tester.

filters were set in the room for at least 16 hours. The filter is weighed on an analytical balance. The filter weight gain was corrected for the weight changes of blank filters. The blank filters received the same handling as the filters used in the test, with the exception that the dustiness test was conducted without powder. The filter weights were adjusted for the weight changes of these blanks.

The measure of "dustiness" is the mass of suspended particulate collected during a 10-minute period beginning just before the dust pours from the cup. This sampling period corresponds to the time required for about 4.5 air changes in the test chamber. The Dustiness Index is a ratio of the milligrams of dust collected on the filter to the mass of powder, in kilograms, which is placed in the stainless steel beaker.

The Heubach Dustiness Test

The test conditions for the Heubach dustiness tester (Figure 4) which were used at a previous study were used here.¹⁰ In the previous test, conditions were set so that no more than 180 milligrams of powder would be collected on a filter. An amount greater than this is apt to slough off during handling. The approach suggested by Heubach is to select the dustiest material for calibration, then set the airflow rate and the test time so as to collect the desired amount of dust. For practical purposes, it was suggested that a sample of about 20 grams and a flow rate of 4 liters/minute would be typical for a nuisance material in a transfer operation.

The test requires the weighing of the test sample on a trip balance and the weighing of the collection filter before and after the test. The latter weighing is done on a precision laboratory balance accurate to four significant figures.

The weighed dust sample (20 grams) is placed in the rotor or particle generator, which is then mounted on the motor shaft. The filter is weighed and placed in the filter holder. The apparatus is then completely assembled for the test. Since the test conditions have been previously set, the test is initiated by pressing the START button. The test will then run until 20 liters of air have been metered. Sample buildup on the sample filter may slow the flow rate toward the end of the test, in which case the flow rate would need to be monitored and adjusted. It is our experience that this effect is not significant. When the test is completed, the filter is removed from the sample train and weighed to obtain the dust collected. The results are reported in terms of % Dust Lost of the 20 gram sample placed into the particle generator. After a test, the filter is transferred from a filter holder to a petri dish. The filter weighing procedure was the same as described for the MRI test. Then, the apparatus is cleaned with detergent and warm water.

Optical Microscopy

In order to compare the particle size distribution observed in the field to those observed in the dustiness testers, an optical microscope and an image analysis system were used to size the airborne dust samples collected in the

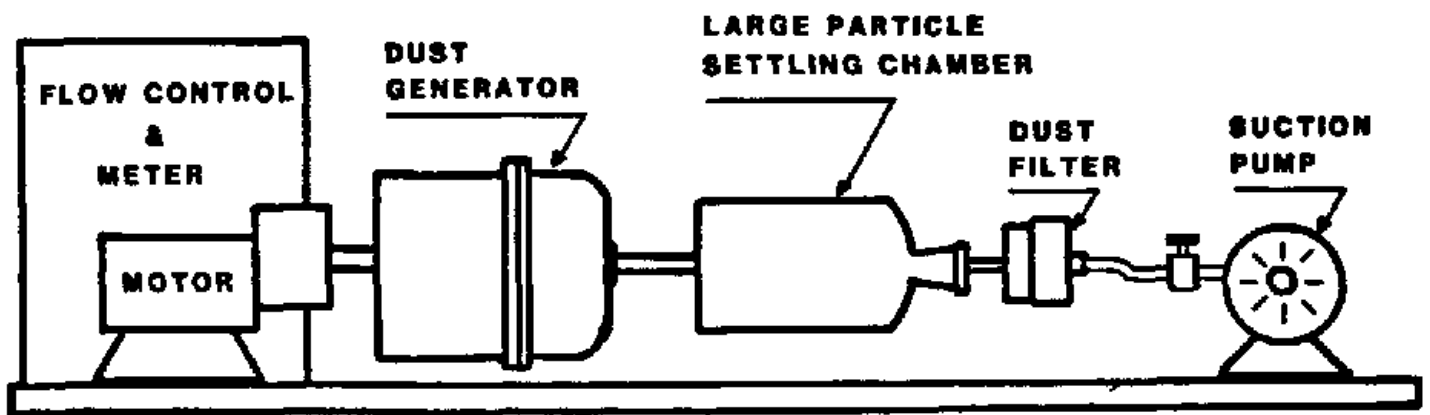


Figure 4. Heubach Dustiness Tester.

workplace and from the dustiness testers. These samples were collected on mixed cellulose ester membrane filters (Millipore Type AA). To collect the air sample for the worker, a 37 mm filter was mounted open-face on the worker and air was drawn through the filter at a flow rate of 7.0 liters per minute for a period of 10 minutes by a DuPont P4000 pump. The pressure loss through the filter was less than 10 inches of water. To obtain a filter sample for optical microscopy from the Heubach dustiness tester, a 3/4-inch copper "tee" was placed in the outlet of the settling chamber. An open-face 25 mm filter was placed on the straight end of the "tee" and a second filter holder and filter was placed on the short part of the "tee." Tubing was used to connect the outlet of both filters to a three-way valve which could cause the air to flow through either branch. The outlet of the three-way valve was connected to the filter holder for the Heubach dustiness tester. The pump for the Heubach tester was used to draw air through the dustiness tester. The three-way valve was used to divert the airflow through the straight part of the "tee" and through the open face 25 mm filter for a period of 30 seconds. The particles collected on this filter were then sized using optical microscopy. The other filter was discarded.

In order to obtain an air sample for sizing the aerosol collected in the MRI dustiness tester, a 37 mm diameter Millipore AA filter was used to sample the aerosol produced inside of the dustiness tester. This filter was placed in an open face 37 mm filter holder. The 37 mm filter holder was mounted perpendicular to the 47 mm filter holder at the top of the dustiness tester, facing the center of the dustiness tester. The outlet of the 37 mm filter holder was connected by tubing to a personal sampler pump which was operated at 0.5 liters per minute.

After the air samples were collected, a wedge was cut out of the filters and the wedge was placed on a clean slide. The slide and wedge were placed under a heated metal block which was heated to 75°C. About 0.5 mL of acetone was injected by a syringe through a septum onto this heated block. The acetone evaporates and renders the filter transparent.

After the filters have been cleared, the particles collected on the filter were sized using optical microscopy and an image analysis system. The image analysis system was Magiscan (produced by Joyce-Lobel Vickers). The images produced by the microscope are sized by the image analysis system. The optical image produced by the microscope is fed by a video camera into a personal computer. The microscopy was carried out at a magnification of 400.

IV RESULTS

The air sampling and dustiness test results are summarized in Table 3. The data for individual days are listed in Appendix 1.

Table 4 lists the sampling results for crystalline silica. Because the total dust concentrations for crystalline silica averaged 3.0 mg/m³, it is possible that the occupational exposure to crystalline silica during the bag emptying might exceed the occupational evaluation criteria for respirable crystalline silica. As a result, the plant was revisited and a sample for respirable crystalline silica was collected on September 10, 1987. During the

Table 3

Summary of Worker Dust Exposure Data and Dustiness Test Results

Material	Average Total Dust Exposure (mg/m ³)	Average MRI Test Result (mg/kg)	Average Heubach Test Result % Lost
Crystalline Silica	3.0	8.3	0.0083
Titanium Dioxide	1.1	20	0.018
Talc	1.65	150	0.36

Table 4
Crystalline Silica Exposure Measurements

Date	Type of Sample	Time (minutes)	Concentration (mg/m ³)
July 16, 1987	Total	10	3.4
July 28, 1987	Total	15	0.87
September 10, 1987	Respirable	10	<0.15 mg/m ³

period that the worker used to empty bags of crystalline silica into the mixing tank, his exposure to respirable crystalline silica was below 0.15 mg/m³. If there were no other sources of exposure to crystalline silica, the workers' 8-hour time-weighted average exposure to respirable crystalline silica would be less than 0.004 mg/m³. This value is less than the evaluation criteria listed in Table 2. This operation is performed less than once per shift.

Figures 5 and 6 presents the results of microscopic sizing of the aerosol collected on the filters for crystalline silica and titanium dioxide. The samples for talc could not be sized because the image was too blurred for accurate sizing because the refractive index of talc (1.5) was too close to the refractive index of the cleared filter medium.¹¹

V DISCUSSION

Regression analysis was used to evaluate whether there was a relationship between dust exposures and dustiness test results. The data were fit to a straight line

$$Y = mX + b$$

where,

- m, b = regression coefficients
- Y = average dust exposure
- X = dustiness test results

Regression analysis was done twice once using the MRI dustiness test results as the values for X and once using the Heubach dustiness test results as the value for X.¹² In both cases, the slope was not significantly different than zero and the value of R² was less than 0.1, which means that the model explained less than 10% of the variability in the concentration data.¹¹ There was no correlation between dustiness test results and worker dust exposure.

The differences in the free-fall of the powders mentioned in Table 1 appear to affect the amount of dust generation. The crystalline silica fell almost one meter before it was mixed into the liquid. In contrast, the talc only had to fall about 25 cm before it contacted the liquid in the tank. In a prior study, dust generation was experimentally found to be proportional to the square of the drop height.¹⁴ When the regression analysis was repeated after normalizing the data by dividing the worker's dust exposure measurements by the ratio of the drop height to the drop height of silica, the value of R² increases to 0.98 from 0.1 for both the Heubach and the MRI dustiness tester. Table 5 lists dust exposure data before and after the adjustment for drop height. The adjusted exposure for talc increased dramatically over the observed dust exposure. This suggests that if the talc had fallen the same distance as the silica, the dust exposures would have increased dramatically.

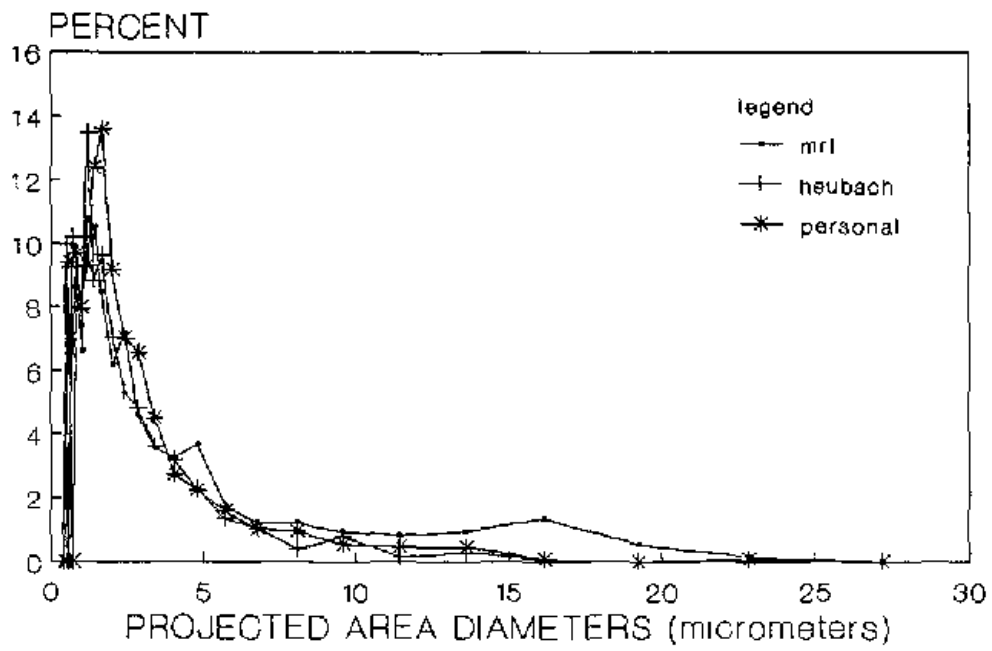


Figure 5. Percentage by Number of Crystalline Silica Particles as a Function of Projected Area Diameter.

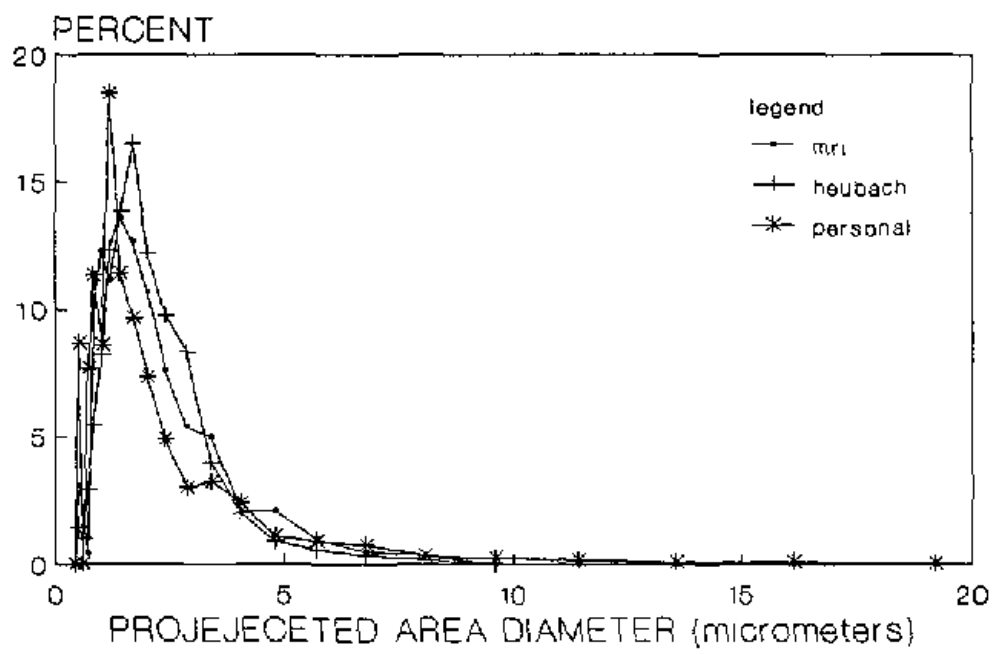


Figure 6. Percentage by Number of Titanium Dioxide Particles as a Function of Projected Area Diameter

Table 5

Adjustment of Exposure Data for Drop Height

MATERIAL	EXPOSURE (mg/m ³)	HEIGHT (h) (cm)	ADJUSTED EXPOSURE $\frac{\text{Exposure}}{(h/h_{\text{silica}})^2}$	MRI	HEUBACH
Silica	3.0	85	3.0	8.3	0.0083
Talc	1.1	75	1.4	20	0.018
Titanium Dioxide	1.7	25	19.6	150	0.36

The size distribution plots in Figures 5 and 6 suggests that the aerosols produced in the dustiness tests are similar to the aerosol produced in the plant

A two sample Kolmogorov-Smirnov two-tailed test (KS) was used to determine whether there are statistically significant differences among the size distributions obtained from the dustiness testers and the personal samples ¹³ This test was applied separately for crystalline silica and for titanium dioxide This KS test determines whether two observed distributions could have come from the same distributions. The test is conducted by determining the largest difference between the two cumulative distributions The critical value of difference for a 95% level of confidence is computed from the following formula

$$1.36((n_1+n_2)/(n_1n_2))^{0.5}$$

where n_1 and n_2 are the sample sizes of the respective distributions For each material, this test was applied three times For the crystalline silica data, the differences in the size distributions were not significant at the 95% level of confidence For the titanium dioxide, the size distribution which came from the Heubach dustiness tester, MRI dustiness tester and the personal dust sample were all different from each other at the 95% level of confidence Much of the discrepancy appears to be due to the particles which are smaller than 1 micrometer in diameter

VI. CONCLUSIONS

This study suggests that material handling procedures are as important in predicting worker dust exposure as material dustiness The lack of correlation between dustiness test results and the raw workers dust exposure data was apparently caused by the differences in drop height during material addition. In general, the results of sizing the aerosol by using optical microscopy indicate that the Heubach, MRI, and personal samples collected roughly the same aerosol, there appear to be no gross differences in the size distributions

VII. REFERENCES

- 1 The B O H S. Technology Committee 1985 British Occupational Hygiene Society Technical Guide No. 4 Dustiness Estimation Methods for Dry Materials Part 1, Their Uses and Standardization and Part 2, Towards a Standard Method British Occupational Hygiene Society, London
- 2 Midwest Research Institute 1986 Exposure to Particulate When Handling Small Volumes EPA Prime Contract No 68-02-4252 U S Environmental Protection Agency, Office of Pesticides and Toxic Substances Washington, D C
- 3 NIOSH 1986 NIOSH Recommendations for Occupational Safety and Health Standards Morbidity and Mortality Weekly Report 35.1s 1s-33s

4. American Conference of Governmental Industrial Hygienists 1985
Threshold Limit Values for Chemical Substances and Physical Agents in the
Work Environment with Intended Changes of 1985-1986 Cincinnati, Ohio
- 5 Title 29 Code of Federal Regulations Part 1910 1000 July 1, 1980
- 6 Ziskind M, Jones RN, Weill H 1976 Silicosis, state of the art Am
Rev Respir Dis vi13 643
- 7 American Conference of Governmental Industrial Hygienists 1980
Documentation of the Threshold Limit Values, Fourth Edition Cincinnati
Ohio
- 8 National Institute for Occupational Safety and Health 1985 Nuisance
Dust, Total Method 0500 In NIOSH Manual of Analytical Methods, 3 ed
NIOSH Publication 84-100 Cincinnati, Ohio
9. National Institute for Occupational Safety and Health 1985
Crystalline Silica, Total Method 7500 In NIOSH Manual of Analytical
Methods, 3 ed NIOSH Publication 84-100 Cincinnati, Ohio
- 10 Heitbrink, W , and W Todd 1987 Final Report Control Technology
for falling solids Report No ECTB 154-10 National Institute for
Occupational Safety and Health Engineering Control Technology Branch,
Cincinnati Ohio 45226
- 11 McCrone W Polarized Light Microscopy Ann Arbor Science. PO Box 1425
Ann Arbor Michigan
- 12 SAS Institute Inc 1986 SAS/STAT Guide for Personal Computers, Version
6 Edition Box 8000, Cary North Carolina
- 13 Siegel, S 1956 Nonparametric Statistics For the Behavioral
Sciences The Maple Press, York, Pa.
- 14 Sutter, S , J Johnston, and J Mishima 1982 Investigation of
accident-generated aerosols releases for free fall spills American
Industrial Hygiene Association Journal V43 540-543

Appendix 1

Listing of Worker Exposure Data and Dustiness Test Results

Dust Exposures

Material	Bags Opened	Sampling Time (min)	Dust Exposure (mg/m ³)	Date
Crystalline Silica	34	11	4.5	July 16
Titanium Dioxide	34	12	0.51	July 16
Talc	17	18	1.5	July 16
Crystalline Silica	34	15	1.5	July 28
Titanium Dioxide	34	12	1.7	July 28
Talc	17	15	1.8	July 28

MRI Dustiness Test Results (mg/kg)

Material	July 16	July 28
Titanium Dioxide	20 2	20 6, 18 7
Crystalline Silica	7 8	10 2, 7 5
talc	105*	187*

* 80 milligrams was collected on filter and material was observed to fall off of filter

Heubach Dustiness Test Results
(weight % lost)

Material	July 16	July 28
Titanium Dioxide	0 016	0 019, 0.025
Crystalline Silica	0 007	0 009, 0 091
Talc	0 29	0 41, 0 44