STUDY REPORT:

EVALUATION OF DUSTINESS TEST METHODS

AND

RECOMMENDATIONS FOR IMPROVED DUST CONTROL

AT

Heubach Inc.
Newark, New Jersey

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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:	Heubach Inc. 256 Vanderpool Street Newark, New Jersey 07114
SIC CODE:	2816 Inorganic Pigments 2865 Organic Dyes and Pigments
SURVEY DATES:	November 10-12, 1987 December 7-9, 1987 January 19-20 and 25-27, 1988
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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. Dustiness tests, which are laboratory bench tests, have been devised (by others) to provide a relatively quick and convenient means of estimating a material's relative dustiness.[1] Dustiness tests consist of a means of generating airborne dust coupled to a means of quantifying the amount of airborne dust generated. In using these tests, one assumes that the dust generation in the tester simulates the dust generation in an actual powder handling operation. This study was conducted to evaluate this assumption.

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 Act[2] and in preliminary analyses of existing chemicals for which personal monitoring data is unavailable. As a first step in this project, NIOSH researchers are evaluating the correlation between worker dust exposure and the results of two dustiness testers. The two devices are the Heubach Model 85 Dust Measurement Appliance and the Midwest Research Institute (MRI) Dustiness Test. If a good correlation exists, these tests could be used by manufacturers to develop treatments to reduce the dust exposures caused by powder handling.

A second purpose of this study was to make engineering control recommendations that can help the plant reduce dust levels. These recommendations were made for the bag filling and bag emptying areas and are included as Part B of this report.

Heubach Incorporated produces an assortment of inorganic lead chromate and organic pigments at their Newark, New Jersey plant. These compounds and pigments differ in bulk density, particle size, and moisture content. Some of these products have been treated to yield what the company refers to as "Low Dust" products. Because these materials have substantial differences in dustiness and were produced on the same machinery with the same workers, this site was selected as a test site for this study.

II. PLANT AND PROCESS DESCRIPTION

Plant Description

The Heubach facility consists of several buildings located on a 15-acre site in an industrial area of Newark, New Jersey. At least three companies have operated chemical plants at this site: Krebbs prior to 1919; DuPont until 1984; and Heubach since January 1984. Today, there are approximately 300 total employees producing an assortment of inorganic lead chromate compounds and organic pigments. The plant operates 24 hours a day, 7 days a week.

Process Description

In Building 12 (the Formulating Building), a continuous process is used to manufacture lead chromate pigments. In the wet processing area, a solution of lead nitrate is heated with steam and a sodium chromate solution in large tanks. The resulting precipitate is dewatered, washed, dried, and conveyed by bucket conveyor up three floors, and emptied into storage bins. In the two dry processing areas, the precipitate is dried, milled, sized, and stored in bins. The product is then weighed and packaged in containers including paper bags, fiber barrels, tote bins, and semibulk bags. Bag filling is performed on the first floor of the processing areas. The wet process area (up to and including washing) and the dry processing area is separated from each other.

In Building 123 (Dry Finishing Building), an intermittent batch-type process blends and repackages lead chromate pigments. Semibulk or sling-type bags, fiber drums, and 50-pound bags of off-specification pigment are emptied (following a recipe card) into dump stations on the third floor of the building. The pigments pass through either pulverizers or dry blenders on the second floor to obtain an on-specification product. The blended product is repackaged in paper bags or fiber drums at packaging stations located on the first floor.

This study was conducted in the packaging (bag filling) area of Building 12 and in the bag emptying area of Building 123 (third floor). During the study, a variety of lead chromate pigments were being handled in these two areas. The correlation was evaluated between the lab dustiness test results and the worker's dust exposure at the force-flow bag filling station and at the east and west bag dumping stations.

Bag filling--

A 15-year-old St. Regis force-flow packer and a 20-year-old St. Regis auger packer are used to package pigment in multi-ply paper bags in 50-pound quantities, as shown in Figure 1. Most of the bag packaging is done on the force-flow packer, depicted in Figures 2 and 3. (Only the force-flow packer station was part of this study.)

At the bag filling station, the operator fills hand-tucked valve-type bags on one force-flow packer. The following is the packaging sequence:

1. The operator places an empty bag on the packer spout and starts the bag filling.

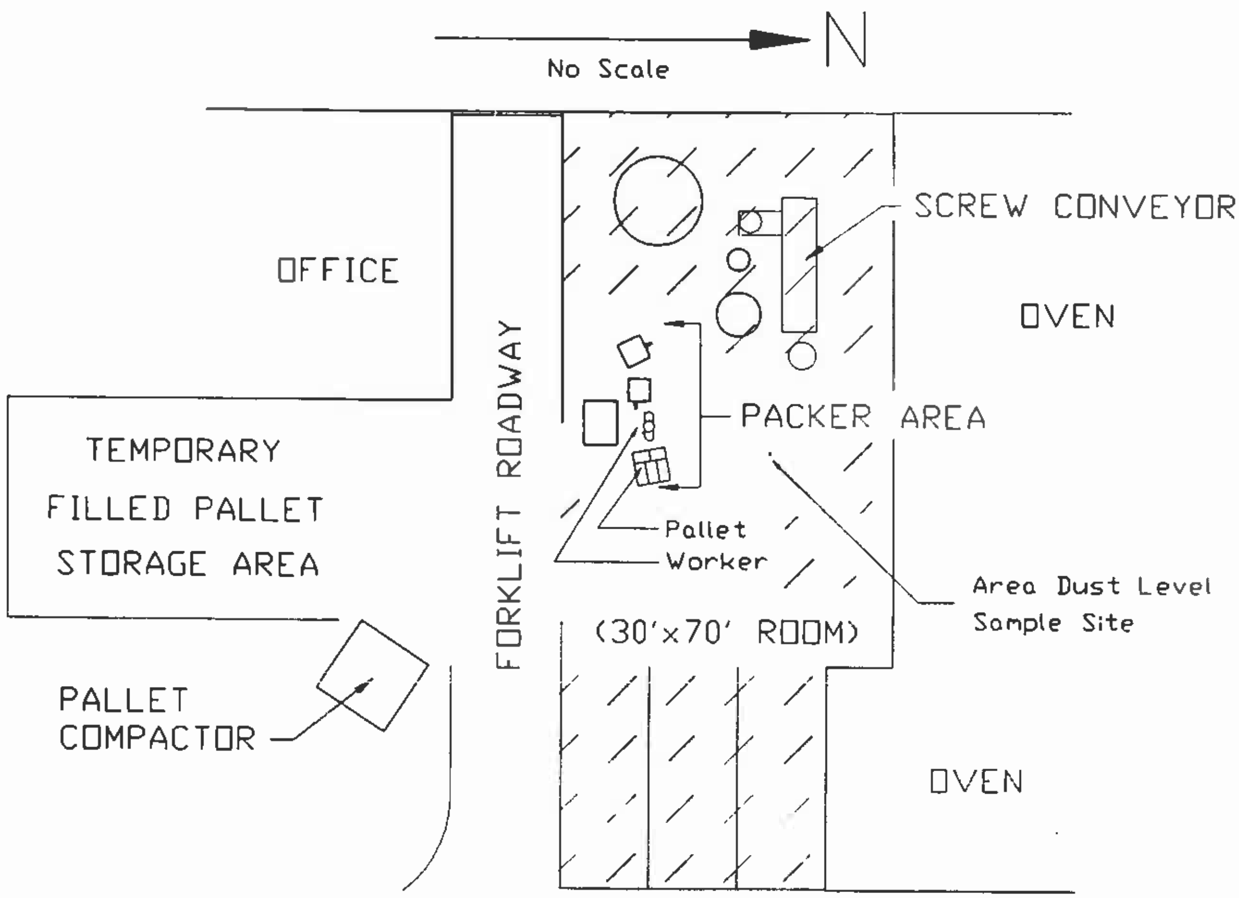


Figure 1. Layout of bag filling area, Building 12.

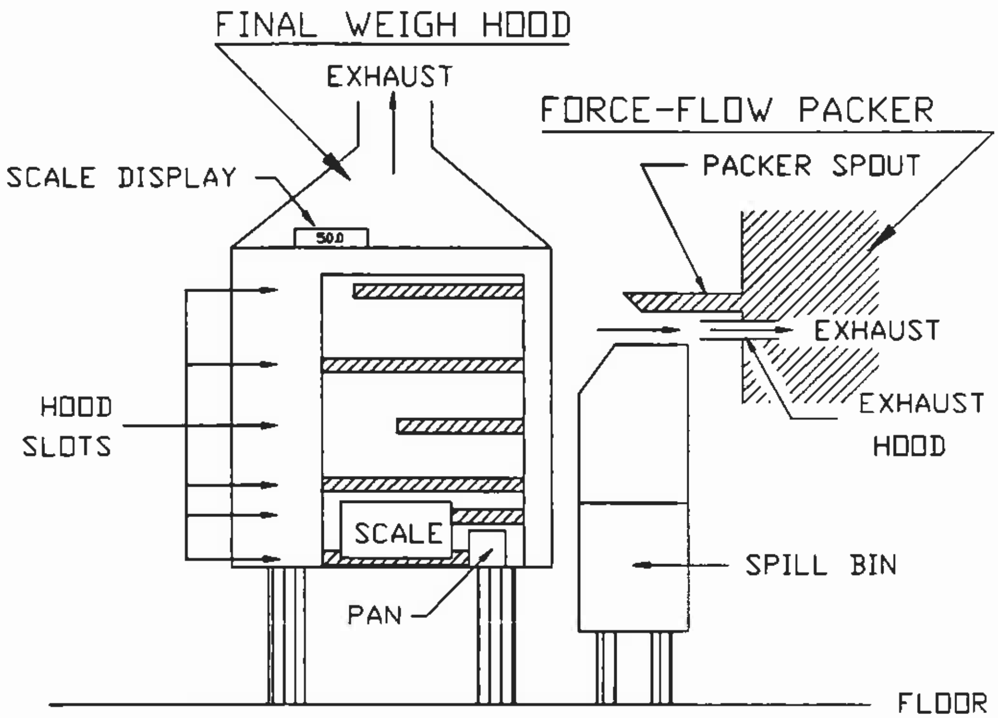


Figure 2. Bag filling station, Building 12 - looking south.

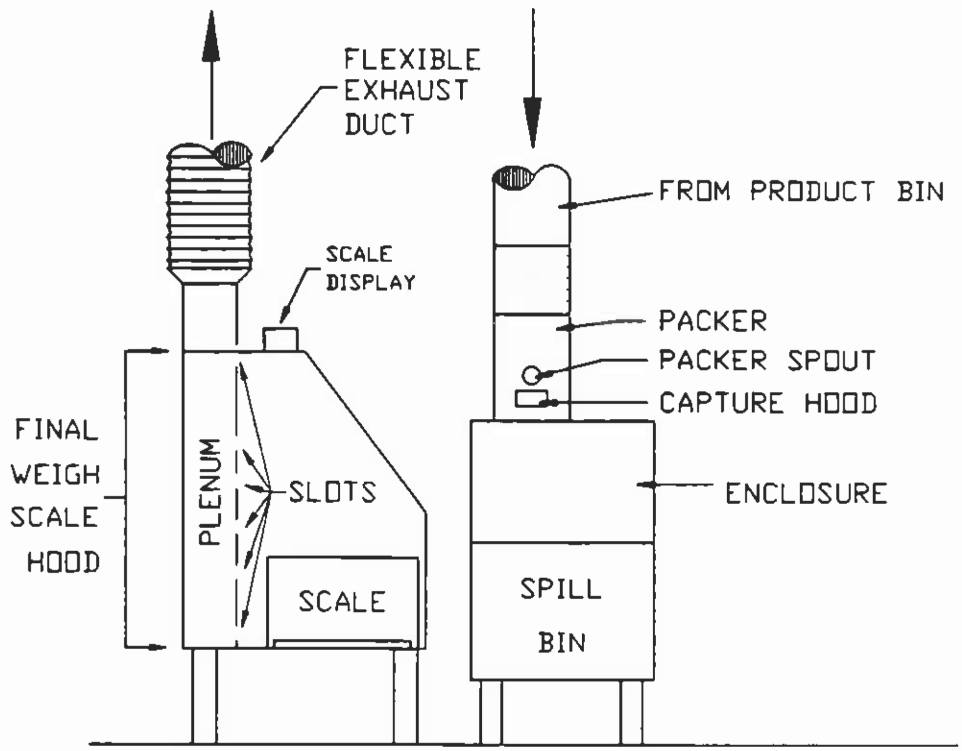


Figure 3. Bag filling station - looking west.

2. Once the bag is filled with approximately 50 pounds, the packer automatically shuts off, the operator manually lifts the bag from the packer spout, and sets it on a scale in a nearby exhaust hood.

3. The operator places another empty bag on the packer spout and starts it filling.

4. Inside the final weigh scale hood, the operator adjusts the filled bag's final weight to 50 pounds by using a narrow scoop to reach through the filled bag's valve to add or remove pigment.

5. The operator manually tucks in the filled bag's valve, lifts the bag from the scale, and drops it onto a pallet sitting nearby on the floor.

6. After the pallet is filled (40 bags, 5 bags to a layer), the operator uses a hand-operated lift to transport it to a nearby compactor. The compacted pallet of bags is temporarily stored in an area near the compactor, where a third operator on a motorized forklift transports it either to storage, shipping, or another process.

7. The packer operator drops another empty pallet on the floor, places a slip sheet on the pallet, and continues packaging.

Normally, two individuals work in the bag filling area, the main packer operator and his relief. A third worker occasionally labels empty bags in the area.

Bag emptying--

Semibulk or sling-type bags, fiber drums, and 50-pound paper bags are emptied at one of five dump stations on the third floor of building 123, as shown in Figure 4. Two of these stations (the East Dump Station and the West Dump Station) are similar in design and are mainly used for emptying 50-pound bags and some fiber drums. These two stations have been in use since 1975. The three other dump stations are mainly used for semibulk bags and barrels. All five stations are used intermittently. (Only the East and West Dump Stations were part of this study.)

The two dump stations for 50-pound bags consisted of a booth-like enclosure over a hopper as depicted in Figures 5, 6, and 7. Air is exhausted from the top and at floor level from the rear of the booth. The booth has a side extension in which a fiber drum could be placed and the empty bags disposed.

The following is the sequence of steps during bag emptying at the bag dump station:

1. The operator uses a forklift to bring a pallet load (40 bags, 50 pounds per bag) to the area and positions it in front of the dumping station. The pallet is left on the forklift and, as the pallet is emptied, the operator raises it to keep the top layer of bags near waist height.

2. The operator cuts a bag open, manually lifts the bag, and sets it on the 3-foot-high shelf of the dump station. Some operators place the

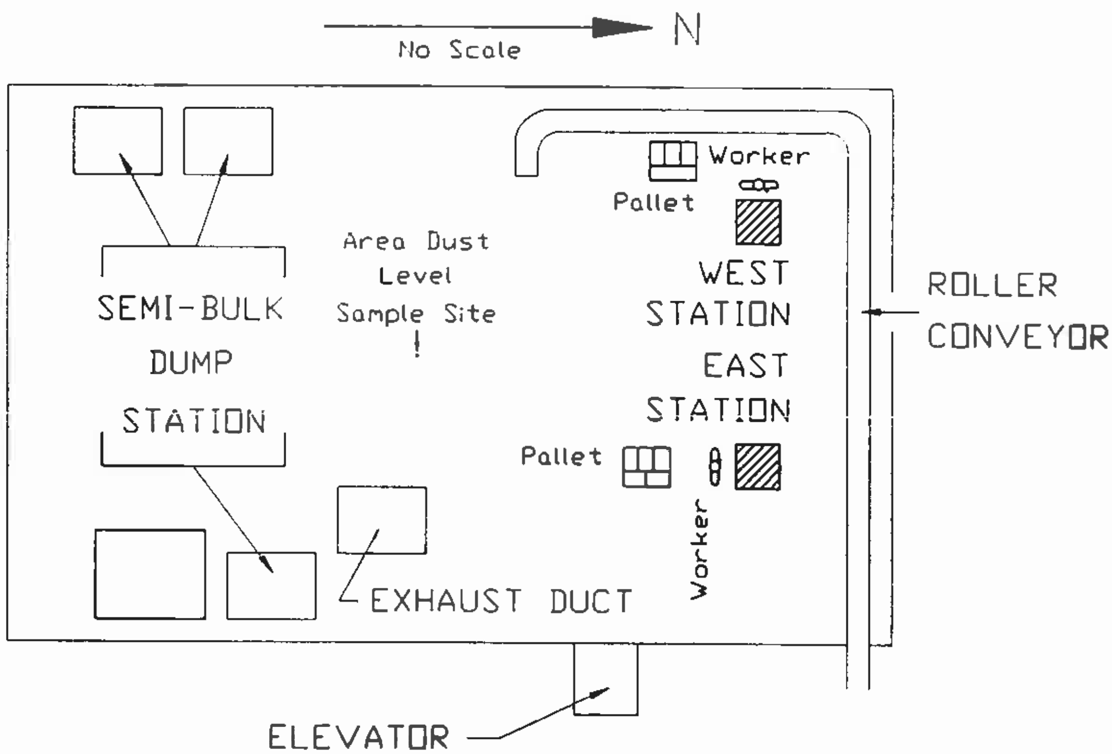


Figure 4. Bag dumping area, Building 123.

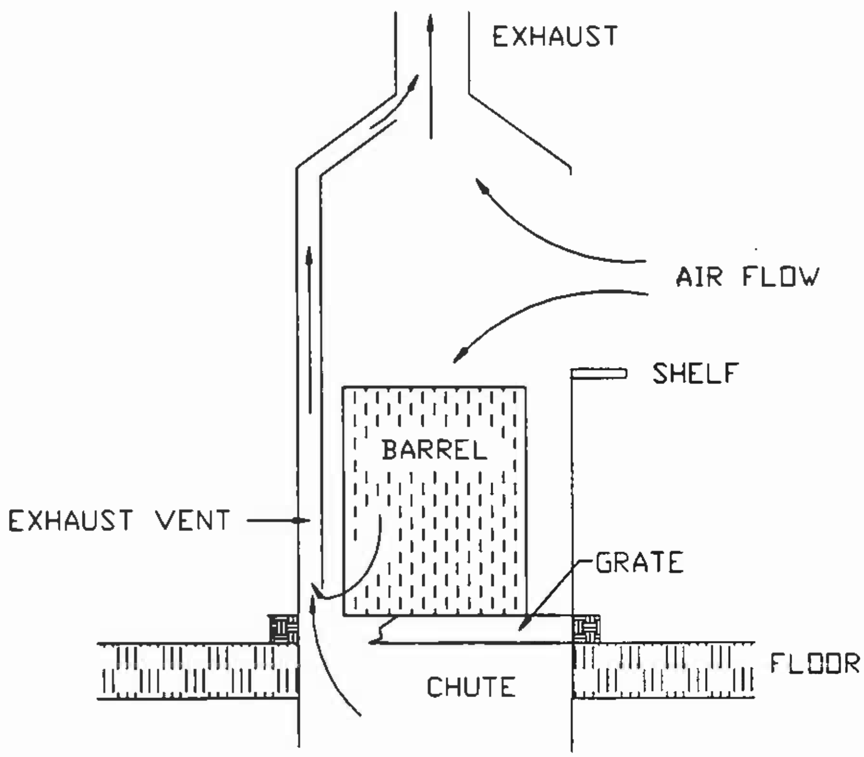


Figure 5. Bag dump station - side view.

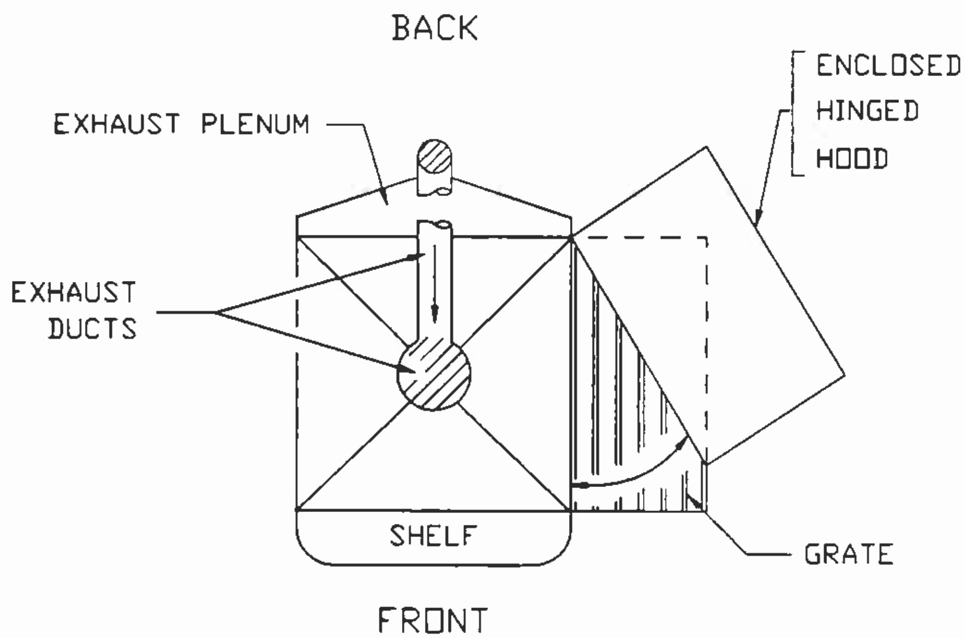


Figure 6. Bag dump station - top view.

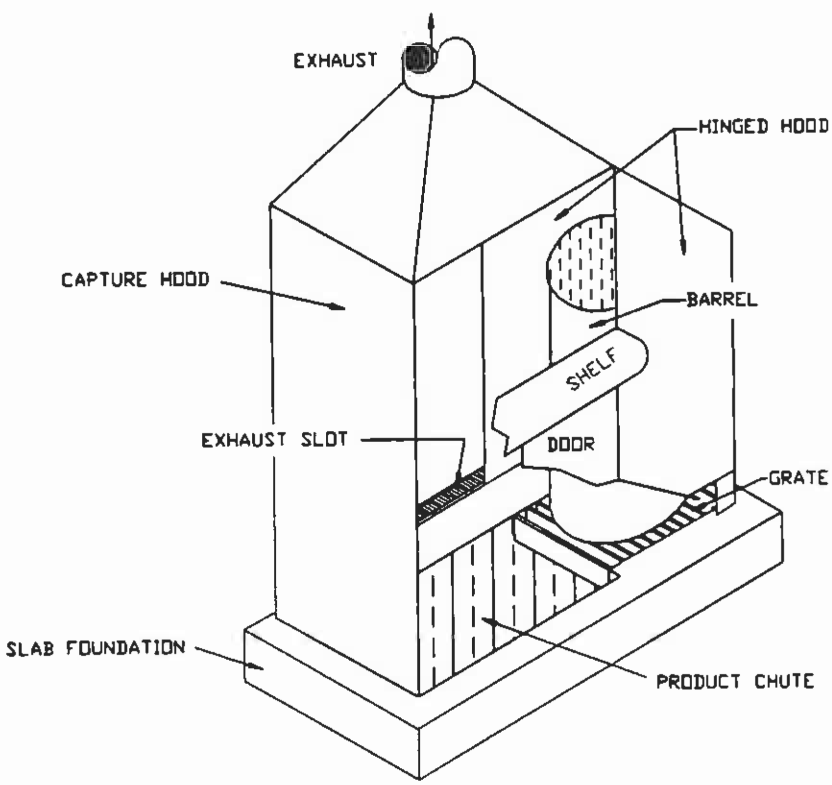


Figure 7. Bag dump station - isometric view.

unopened bag on the shelf before cutting it open. Others cut open five bags, the top layer of bags on the pallet, and then, one bag at a time, set them on the dump shelf.

3. The bag is emptied into the hopper.

4. The operator places the emptied bag into a fiber drum, each drum holding approximately 20 empty bags. Some operators fold the bag while they are still on the shelf and then drop them into the drum. As the drum fills, the operator manually pushes the bags into the drum.

5. When the fiber drum is full, the operator replaces it with an empty drum and places the full drum on the roller conveyor.

There are two workers in this area emptying pigment containers. Normally, only one operator empties bags at the bag dump station.

Health Hazards and Environmental Criteria

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 (REL's), (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLV's), and (3) the U.S. Department of Labor (OSHA) permissible exposure limits (PEL's). Often, the NIOSH REL's and ACGIH TLV's are lower than the corresponding OSHA PEL's. Both NIOSH REL's and ACGIH TLV's usually are based on more recent information than are the OSHA PEL's. The OSHA PEL's also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH REL's, 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 PEL's.

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.

Lead--

Inhalation of lead dust and fume is the major route of lead exposure in industry. A secondary source of exposure may be from ingestion of lead dust deposited on food, cigarettes, or other objects. Once absorbed, lead is excreted from the body very slowly. Absorbed, lead can damage the kidneys, peripheral and central nervous systems, and the blood-forming organs. Chronic lead exposure is associated with infertility and with fetal damage in pregnant women.[3]

For the lead chromate pigment industry, the OSHA permissible exposure limit (PEL) for lead is 0.2 mg/m^3 engineering control, 0.05 mg/m^3 to be achieved through respiratory protection and work practices, for an 8-hour Time Weighed Average (TWA). NIOSH's recommended exposure limit (REL) is <0.1 mg/m^3 (as Pb) for a 10-hour time-weighted average (TWA). The American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) is 0.15 mg/m^3 (as Pb).[4]

Chromium (VI)--

Short-term dust or mist exposure to chromates may cause severe irritation of the nose, throat, bronchial tubes, and lungs. If swallowed, they may cause stomach and kidney problems, and often cause vomiting. Skin exposure may cause ulceration of the skin. Long-term exposure to chromate dusts or mists may cause an ulceration and perforation of the nasal septum, respiratory irritation with symptoms resembling asthma, liver damage, skin rash, and allergic skin rash. An increased amount of lung cancer has been found in employees in the chromate-producing industry. Workers exposed to chromates in concentrations of 0.11 to 0.15 mg/m^3 have developed ulcers of the nasal septum and irritations of the conjunctiva, pharynx and larynx, as well as asthmatic bronchitis. A markedly increased incidence of bronchogenic carcinoma occurs in workers exposed to chromate dust. Chromates of lead are suspect carcinogens.[5]

The current OSHA Permissible Exposure Limit (PEL) for chromates is a ceiling concentration of 0.1 mg/m^3. NIOSH's recommended exposure limit (REL) for carcinogenic chromium (VI) is 0.001 mg/m^3. The American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for chromates of lead is 0.05 mg/m^3 (as Cr).[4]

Control Measures

Occupational exposures can be controlled by the application of a number of well-known principles, work practices, and personal protection. Ongoing monitoring and maintenance of controls to ensure proper use and operating conditions, and the education and commitment of both workers and management to occupational health are also important ingredients of a complete, effective, and durable control system. These principles of control apply to all situations, but their optimum application varies from case to case. The application of these principles are discussed below.

A number of practices are employed by the company to reduce worker dust exposures. These control measures include product modification, process equipment design, local exhaust ventilation, personal protective equipment, and administrative controls.

Engineering Controls--

Some of the lead pigments have been modified by using a proprietary additive in an effort to reduce their dustiness. These products are marketed as "low dust" pigments.

At the bag filling operation in Building 12, process equipment has been designed to reduce dust exposures. The force-flow packer has a catch bin located beneath the packer spout. This bin catches product that falls from the packer spout and the bag's valve during normal bag filling operations. Local exhaust ventilation is provided at the packer spout and the hood enclosing the final weigh scales. At the packer spout, dust escaping from between the spout and the bag valve is captured by a 2-inch by 4.5-inch wide exhaust hood having an average face velocity of 2,000 fpm. During final bag weighing, a hood encloses the scale. Dust-laden air is removed through several 2-inch wide slots along the back of the hood. Slot velocity ranges from 350 to 500 fpm, resulting in an average face velocity for the enclosure of 230 fpm. The exhaust hoods are shown in Figures 2 and 3.

Local exhaust ventilation is provided at the bag dumping operations in Building 123. The hood enclosing the bag dump exhausts air from the top and at floor level at the back of the hood. The average face velocity of this hood is 270 fpm. An extension is located on the side of the hood into which a fiber barrel is placed for the disposal of the emptied bags. After the operator empties each bag, he drops the bag into the barrel. This extension is part of the hood and is under negative pressure due to ventilation of the hood. (Most operators observed did not place barrels in this extension, preferring to set the barrel on the floor outside of the hood. Use of the extension requires awkward postures and may increase exposure, since the operator must place his head within the confines of the hood to compress the bags.)

Protective Equipment--

Because the dust control measures did not maintain dust levels below the lead standard, respirators were used to control worker exposure to airborne lead dust. Three types of respirators were used: half face-mask respirators, full face-piece respirators, and powered air-purifying, helmet-style respirators. The employees are fit tested every 6 months with a half face-mask respirator. If they cannot be fitted, they are provided with a powered air-purifying respirator. Employees working at extra dusty activities, such as brushing out blenders, are provided with a full face-piece respirator. At the end of each shift, the used respirators are turned in, cleaned, repaired, and the filters replaced.

Other personal protective equipment includes hearing protection, rubber gloves, hard hats, plastic aprons, regular and disposable coveralls, underwear, socks and shoes. Foam ear plugs provided hearing protection in posted areas such as the bag filling area in Building 12. Packer operators also put on a clean pair of rubber gloves, disposable Tyvek coveralls, and an apron at the start of each shift. If any of these became torn or excessively soiled during the shift, they were replaced with a clean pair. Workers in other areas of the plant wear cloth coveralls which are laundered daily.

Hygiene--
When the employees enter the plant, they remove all their street clothes and change into clothing provided by the company. At the end of the shift, they remove all their work clothes, shower, and then put on their street clothes. The employees are provided a shower, change room, and lunchroom. They are allowed 20 minutes paid time to shower and change at the end of the shift, and 5 minutes to wash before lunch. All regular clothing is laundered daily and all disposable clothing placed in appropriate receptacles for disposal.

Training programs--
Yearly, each employee watches a 90-minute video on safety. Also, there are weekly meetings on general safety and health related topics. Posters remind the employee of the health hazards of lead and lead chromates.

The remainder of this report is divided into two parts: Part A deals with the evaluation of the dustiness test procedures (the correlation of worker exposure with dustiness test results); Part B discusses potential means of reducing lead exposures in this facility through improved process design, ventilation, and work practices.

PART A

EVALUATION OF DUSTINESS TEST METHODS

III. METHODOLOGY

To determine if the results of the dustiness tests are correlated with the workers' dust exposures, the exposure measurements were concurrently performed with dustiness tests on bulk samples of the material.

Air Sampling Methodology

The procedures described in Methods 7082 and 7300 of the NIOSH Manual of Analytical Methods were used to measure lead and total dust concentrations at the locations listed in Table 1.[9] DuPont P4000 pumps were used to draw 3.5 liters per minute of air through 0.8 μm cellulose ester membrane filters. A sampling time of 30 to 150 minutes was used for each worker. For each material packaged or emptied, separate sets of samples were taken for each worker. Typically, sampling was done on day and evening shifts at each of the two operations, bag filling and bag emptying. In addition to measuring the workers' dust exposure, area dust concentrations were measured at stationary locations in the rooms shown in Figures 1 and 4 and listed in Table 1. These samples were taken to measure the area dust concentration at a height of 4 to 6 feet above the floor.

Dustiness Testing Methodology

In this study, two dustiness tests were selected after an evaluation of many such tests developed by various companies and researchers: the Heubach Model 85 rotating drum dustiness tester and the Midwest Research Institute (MRI) tester. 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 test was developed by Midwestern Research Institute in response to a research project sponsored by EPA to develop an inexpensive and quick test for dustiness.

The Heubach Dustiness Test--

The Heubach Dustiness Test consists of a rotating drum that produces a repeated dust fall through a regulated air stream. The sample pump is run at 15 liters a minute for 5 minutes to obtain a total sample volume of 75 liters. The weight gain of the filter is used to determine the percentage of the 100 grams of powder placed in the drum or a dustiness index value for the sample.

The Heubach dustiness tester is shown in Figure 8. The test conditions for the Heubach tester are set for each type of dust tested so as to obtain a collected dust sample on the filter of not more than 180 mg. 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 the lead chromate pigments, the company found that a sample of about 100 grams and a flow rate of 15 liters/minute produced an adequate loading of dust on the filter.

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 was done on a Mettler AE163 analytical balance which is accurate to 10 micrograms.

Table 1. Air Sampling Locations

Location	Description
I. Bag Filling Area -	
1. Worker	The worker who is operating the bag filling and pallet compacting equipment.
2. Area	On a post about ten feet from the bag filling machine and about six feet above the floor. See Figure 1 for the sample locations.
II. Bag Emptying Area -	
1. Worker	The worker at the bag dumping station.
2. Area	Center of the room about 30 feet from the operator and six feet above the floor. See Figure 4 for the sample locations.

HEUBACH DUSTINESS TEST

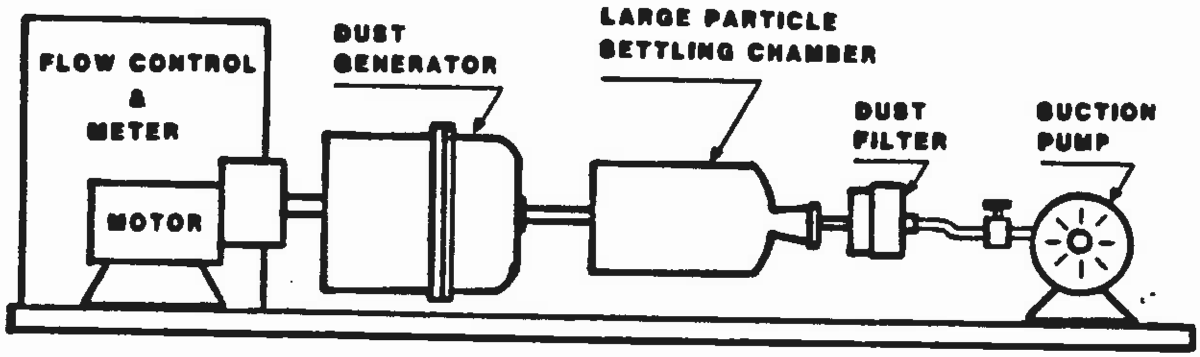


Figure 8. Heubach Dust Measurement Appliance.

The weighed dust sample (100 grams) is placed in the dust 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 75 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. (This effect was not significant in this study.) 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 100 gram sample placed into the particle generator.

The apparatus is cleaned with detergent and warm water. Drying of the metal parts is speeded with the use of a small amount of acetone, especially the particle generator and the settling bottle, which have areas not easily accessed by a towel. Cleanup takes about 15 minutes, at which time another test may be set up.

In order to evaluate the contamination in the dustiness test procedures, blank Heubach dustiness tests were conducted without powder. The weight gain or loss of the filter is a measure of the combined effect of the filter weight stability, laboratory air contamination, and the cleanliness of the dustiness testers.

The MRI Dustiness Test--
The MRI test simulates the pouring and dumping of fine solids by having the material dumped under specified conditions within an enclosed chamber fitted with a sampling filter and constant flow pump system. The cup rotates at a constant speed while dumping the dust and a vibrator helps to completely dislodge the dust. The sample pump is run at 10 liters a minute for 10 minutes to obtain a total sample volume of 100 liters. (In these tests, a critical orifice controlling the flow at 10.8 L/min was used.) The preweighed filter is weighed to determine the percentage of the weighed powder placed in the cup or a dustiness index value for the sample.

The MRI chamber, shown in Figure 9, has a volume of 20 liters. The MRI dustiness index is defined as the milligrams of dust collected per kilogram of material tested.

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 tissue. The chamber is placed on a Styrofoam sheet and 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. The cup of material is weighed and the powder density calculated. The cup of material is

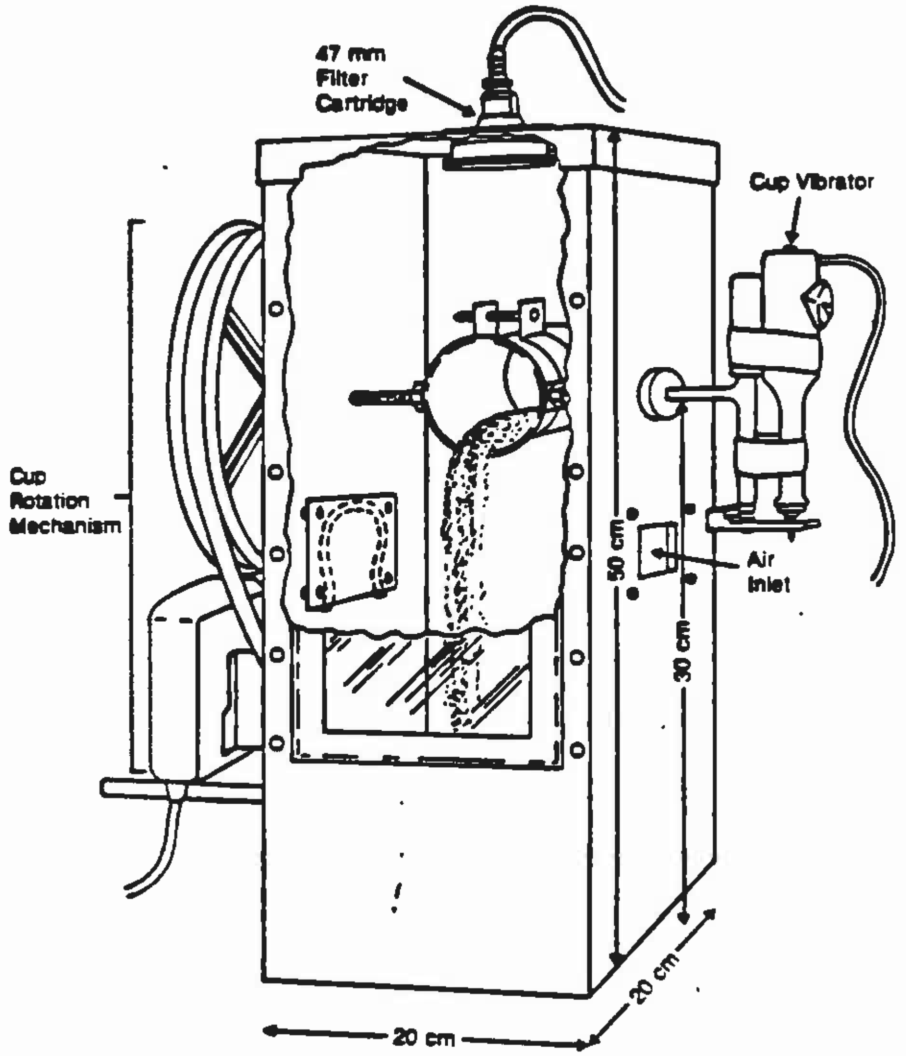


Figure 9. MRI Dustiness Tester.

then inserted into the chamber holder with its pour spout forward in the direction of rotation. The 47 mm glass fiber filter is weighed using a Mettler AE163 analytical balance. The filter is then 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, the cup vibrator, and the cup rotor. The stopwatch is started simultaneously with the cup rotor. During the test, the following times are recorded:

1. Power to rotor, vibrator, and pump.
2. Pour begins.
3. Pour ends.
4. Power off to vacuum pump.

At the end of the test, the tape is removed from the chamber lid and the lid is removed and inverted before the power to the vacuum pump is turned off.

Immediately after the test, the filter holder is unscrewed from the chamber lid and the exposed filter is weighed immediately or it is transferred to a petri dish and transported with its exposed side up to await analysis. Finally, the chamber is removed from the aluminum foil surface and the dumped material is disposed of. The filter is weighed on an analytical balance.

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. The Dustiness Index is a ratio of the dust collected to the total sample:

$$\text{Dustiness Index} = \frac{\text{Dust collected on filter (mg)}}{[\text{Weight of sample (Kg)}]}$$

In order to evaluate the laboratory contamination in the dustiness test procedures, blank MRI dustiness tests were conducted without powder. The weight gain or loss of the filter is a measure of the combined effect of the filter weight stability, laboratory air contamination, and the cleanliness of the dustiness testers.

These tests from both the Heubach and the MRI are empirical in that they do not measure a fundamental property or response of the material being tested. The response of the test must be correlated with a related response to establish a base line or index point. The related response in this study is the personal exposure samples of workers operating bagging equipment. The dustiness of the material results in airborne dusts due to residual material in spouts, air displaced from the bag during filling, bags dropped onto pallets, empty bags placed into barrels, leaks in lines and ducts, and other dust sources during bag filling and bag dumping operations. It is axiomatic that the more dusty the material, the more potential there is for dust exposure. The problem here, however, is to demonstrate that this actually occurs in a real work situation. One problem to confound this is that the process variation of factors related to dustiness of a material may vary significantly or that the exposure to dust may be controlled by environmental factors other than the dustiness. These additional factors may be significant enough to mask minor differences in the measured dustiness of two materials.

IV. RESULTS

Dustiness Test Results

In order to evaluate the correlation between dustiness test results and worker dust exposure, air samples for lead were collected at the bag opening and bag dumping stations. While these air samples were collected, bulk samples of the material being handled were collected. Heubach and MRI dustiness test results were conducted on these bulk samples. Results of these tests are reported in Table 2.

Table 3 summarizes the dustiness test results. Analysis of variance using the SAS General Linear Model procedures showed that both the product being produced and the specific bulk sample significantly affected dustiness test results at a level of confidence greater than 99.9%. This indicates that the dustiness of the material is varying significantly from sample to sample. In Tables 2 and 3, the column labeled grouping presents the results of multiple comparison tests used to examine the differences in dustiness among the different products. These tests are conducted at an overall level of confidence of 95%. Products which have completely different grouping codes differ significantly.

Air Sample Results

Individual filter sample results for airborne lead (as Pb) dust are presented in Appendix I and are summarized in Table 4. The average personal lead concentrations for the bag filling operators handling both treated and untreated pigments were 710 $\mu g/m^3$ with 93% of the 28 samples exceeding the 200 $\mu g/m^3$ OSHA PEL for engineering control (100% of the samples exceeding the 50 $\mu g/m^3$ OSHA PEL for respiratory protection). For the bag emptying operators emptying both treated and untreated pigments, the average was 509 $\mu g/m^3$ with 82% of the 17 samples exceeding 200 $\mu g/m^3$ (100% of the samples exceeding the 50 $\mu g/m^3$). Area samples collected in the bag filling area averaged 474 $\mu g/m^3$ with 89% of the 44 samples exceeding the 200 $\mu g/m^3$ (100% of the 44 samples exceeding the 50 $\mu g/m^3$). Area samples collected in the bag emptying area averaged 62 $\mu g/m^3$ with 12% of the 16 samples exceeding the 200 $\mu g/m^3$ (31% of the 16 samples exceeding the 50 $\mu g/m^3$). Ninety-seven percent (102 out of 105) of the samples collected were above the limit of detection of 2 μg lead and 96% (101 out of 105) were above the limit of quantitation of 6.7 μg lead. There was no lead detected on any of the blanks.

In the bag emptying area, average personal lead exposures were 7 times (for untreated pigments) to 15 times (for treated or "low dust" pigments) greater than the average area levels. This indicates that the exposures were a direct result of their work activities. In the bag filling area, the differences for both types of pigments, untreated and treated, were 1.5 times greater than the area levels. This indicates that the exposures were caused, at least to some degree, by work activities and contamination sources other than bag filling.

Table 2. Dustiness Test Results

DATE	MATERIAL CODE**	HEUBACH % DUST COLLECTED	MRI INDEX (mg/Kg)
11-NOV-87	A	0.027	18.397
11-NOV-87	A	0.051	
09-DEC-87	A	0.017	14.689
09-DEC-87	A	0.015	5.203
09-DEC-87	A	0.020	14.959
11-NOV-87	B	0.020	16.291
11-NOV-87	B	0.021	16.413
12-NOV-87	B	0.012	3.213
12-NOV-87	B	0.011	9.524
19-JAN-88	C	0.033	8.282
19-JAN-88	C	0.041	16.749
20-JAN-88	C	0.033	22.188
20-JAN-88	C	0.030	7.492
07-DEC-87	D	0.046	10.929
07-DEC-87	D	0.051	14.269
08-DEC-87	D	0.077	15.389
09-DEC-87	D	0.067	17.565
09-DEC-87	D	0.058	17.021
19-JAN-88	D	0.078	71.245
20-JAN-88	D	0.149	38.291
20-JAN-88	D		39.123
12-NOV-87	D'	0.023	4.278
12-NOV-87	D'	0.032	4.948
12-NOV-87	D'	0.034	
09-DEC-87	D'	0.036	1.593
09-DEC-87	D'	0.022	
07-DEC-87	A'	0.007	6.079
07-DEC-87	A'	0.011	1.886
07-DEC-87	A'	0.010	
07-DEC-87	A'	0.010	2.936
08-DEC-87	A'	0.006	4.962
08-DEC-87	A'	0.007	2.367
08-DEC-87	A'	0.008	2.713

** Product (X) is standard products. Product (X') is lower dust products.

Table 2. (continued) Dustiness Test Results

DATE	MATERIAL CODE**	HEUBACH % DUST COLLECTED	MRI INDEX (mg/Kg)
10-NOV-87	B'	0.017	3.412
10-NOV-87	B'	0.018	4.981
11-NOV-87	B'	0.013	6.502
11-NOV-87	B'	0.014	7.576
25-JAN-88	B'	0.016	4.084
25-JAN-88	B'	0.016	3.477
26-JAN-88	B'	0.014	7.633
26-JAN-88	B'	0.015	1.763
26-JAN-88	E	0.035	33.133
26-JAN-88	E	0.037	25.306
27-JAN-88	E	0.030	39.438
27-JAN-88	E	0.044	26.994
08-DEC-87	F	0.070	22.237
08-DEC-87	F	0.078	22.924
19-JAN-88	E'	0.016	1.574
19-JAN-88	E'		3.496
20-JAN-88	E'	0.013	3.681
25-JAN-88	C'	0.022	11.007
25-JAN-88	C'	0.029	13.133
25-JAN-88	C'	0.025	8.696
25-JAN-88	C'	0.027	8.318
26-JAN-88	C'	0.024	5.022
26-JAN-88	C'	0.023	6.820
10-NOV-87	F'	0.002	1.434
10-NOV-87	F'	0.002	1.291
11-NOV-87	F'	0.008	4.499
11-NOV-87	F'	0.010	4.750
25-JAN-88	F'	0.006	2.328
25-JAN-88	F'	0.007	2.121
25-JAN-88	F'	0.003	1.748

** Product (X) is standard products. Product (X') is lower dust products.

Table 3. Summary of Dustiness Test Results

Summary of Heubach Dustiness Test Results				
Product**	Geometric		Number of Samples	Grouping
	Mean (mg/m^3)	Standard Deviation		
D	0.075	0.035	7	a
F	0.074	0.005	2	a
E	0.037	0.006	4	b
C	0.034	0.005	4	b
A	0.026	0.015	5	b,c
B	0.016	0.005	4	c,d
D'	0.029	0.006	5	b,c
C'	0.025	0.003	6	b,c
B'	0.015	0.002	8	c,d
E'	0.015	0.002	2	c,d
A'	0.008	0.002	7	d
F'	0.005	0.003	7	d

Summary of MRI Dustiness Test Results				
Product**	Geometric		Number of Samples (N)	Grouping
	Mean (mg/m^3)	Standard Deviation		
E	31.22	6.43	4	a
D	27.97	20.60	8	a
F	22.58	0.49	2	a
C	13.68	7.05	4	b
B	11.36	6.31	4	b,c
A	13.31	5.66	4	b,c,d
C'	8.83	2.90	6	b,c,d
B'	4.93	2.14	8	b,c,d
A'	3.49	1.65	6	c,d
D'	3.61	1.78	3	c
E'	2.92	1.17	3	c
F'	2.60	1.43	7	c

** Product (X) is standard products. Product (X') is lower dust products.

Table 4. Summary Results of Air Sampling				
	Untreated (X) Material		Treated (X') Material	
	Personal	Area	Personal	Area
Bag Emptying Area -				
Number of Samples	7	8	10	8
Arithmetic Mean (ug/m3)	600	102	444	23
Standard Deviation	447	93	209	15
Maximum (ug/m3)	1476	301	876	42
Minimum (ug/m3)	120	25	129	5
Bag Filling Area -				
Number of Samples	14	22	14	22
Arithmetic Mean (ug/m3)	661	422	760	527
Standard Deviation	365	185	520	353
Maximum (ug/m3)	1272	786	2014	1495
Minimum (ug/m3)	267	198	148	81

Analysis

Tables 5 and 6 summarize the workers exposure to lead chromate by job and by product code. The lead exposures were divided by the fraction of lead in each product to estimate the lead chromate exposure. At both job sites, analysis of variance showed that product did not have a significant affect upon lead chromate exposure. This data indicates that the "low dust" treatment apparently did not have much of an effect upon worker exposure to lead chromate. In Figures 10, 11, 12, and 13, lead chromate exposure is plotted as a function of dustiness test results for individual values of dustiness.

The correlation between dustiness test results and worker lead chromate exposure was not significant at the 90% level of confidence. For both the Heubach and MRI dustiness scores, the coefficient of linear correlation between lead chromate exposure and dustiness test result was less than 0.15. Dustiness explained less than 2% of the variability in the dust exposure measurements.

V. DISCUSSION

The data indicates that there is no relationship between dust exposure and dustiness test results at this plant. This result could be due to either the presence of confounding factors or deficiencies in the dustiness test procedures.

In field studies, plant conditions, plant operations, and workers vary throughout the study. Perhaps one of these variables is much more important than the materials' dustiness. In the bag filling area, there are numerous potential confounding factors. The workers' dust exposure appeared to result mostly from process leakage. Also, the treated powders were more difficult to handle than the untreated powders. As a result, the operation of the equipment was altered to compensate for the apparent increase in cohesiveness of the powders handled. This may have caused the dust emission rate from the handling equipment to change.

In both the bag dumping and bag filling areas, different workers were used throughout the study. There is always the possibility that variations in work practices and worker stature are more important than variations in material dustiness. In past studies, ECTB researchers have found that different workers can have significantly different exposures at the same job. In analyzing data from such studies, the worker is usually the largest source of variation in the data.[7]

In the bag dumping area, personal exposures were nearly an order of magnitude greater than the area levels. This indicates that most of the personal dust exposure occurs during the bag emptying operation.

Both the Heubach and MRI Dustiness Testers indicate that the treated products are less dusty than the comparable untreated products. Possibly, the dustiness tests do not consider all of the material properties and handling characteristics which affect dust exposure.

Table 5 Summary of Worker Lead Exposures during Bag Dumping			
Product**	Mean	Standard Deviation	N
A	1476		1
F	955		1
D	354	225	5
B'	597	395	2
D'	327	280	2
E'	476		1
F'	464	175	4

** Product (X) is standard products. Product (X') is lower dust products.

Table 6 Summary of Worker Lead Exposures during Bag Filling			
Product**	Mean	Standard Deviation	N
E	284	16	3
A	1121	217	3
C	854	293	4
B	404	115	4
C'	992	294	3
B'	837	785	4
A'	652	525	6

** Product (X) is standard products. Product (X') is lower dust products.

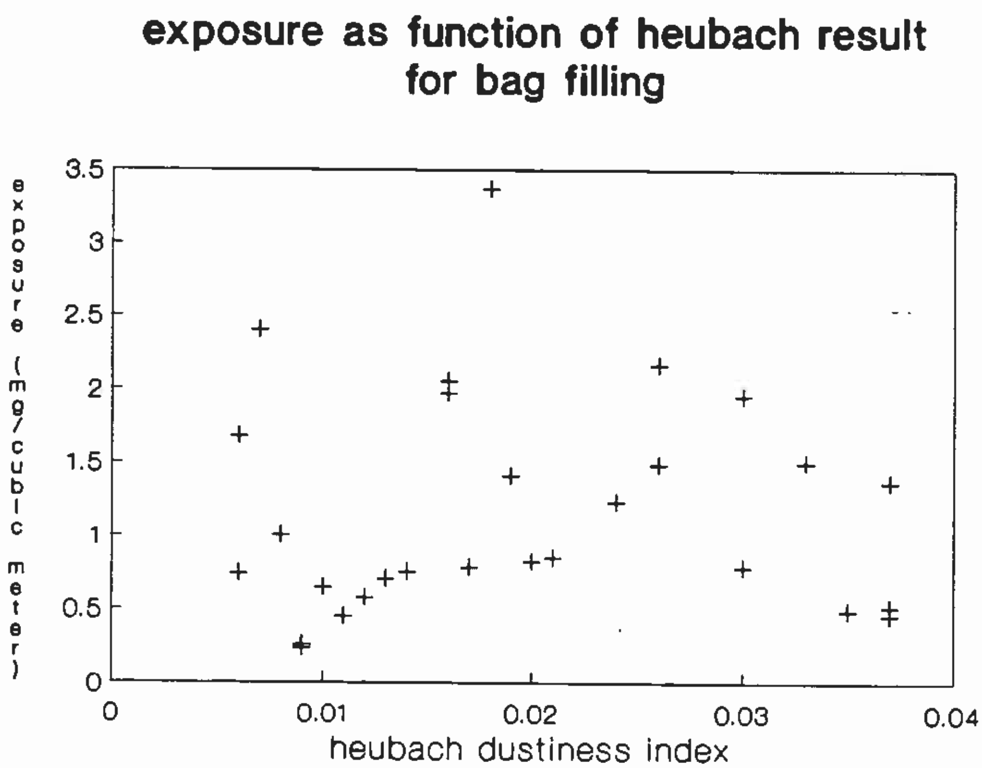


Figure 10. Exposure as a function of Heubach test result (bag filling).

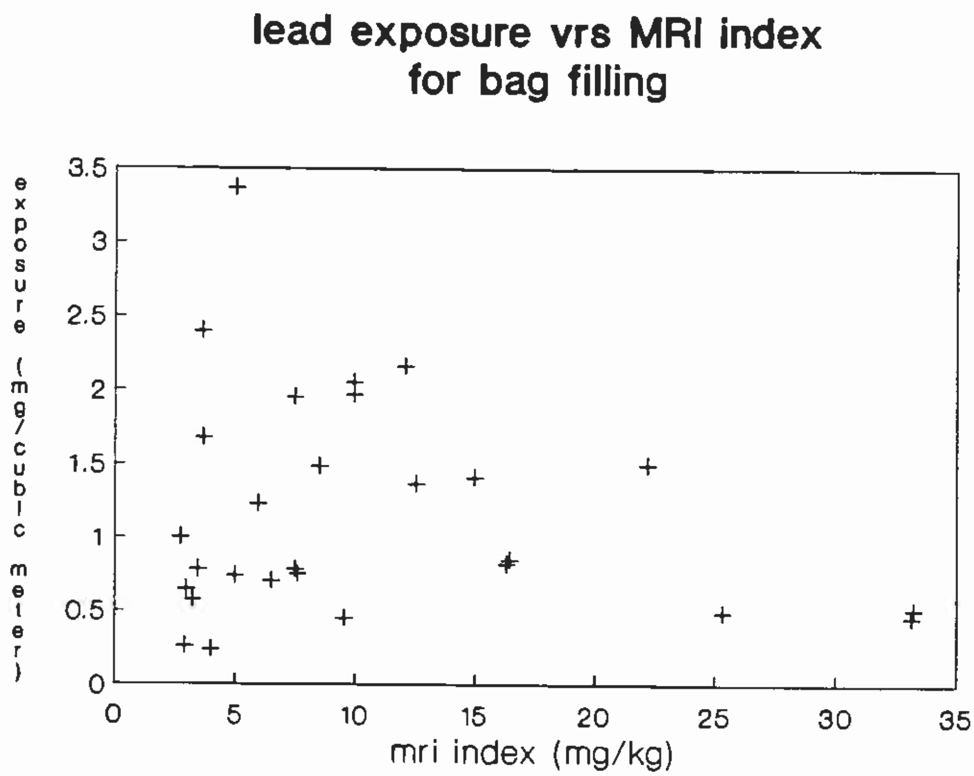


Figure 11. Exposure as a function of MRI index (bag filling).

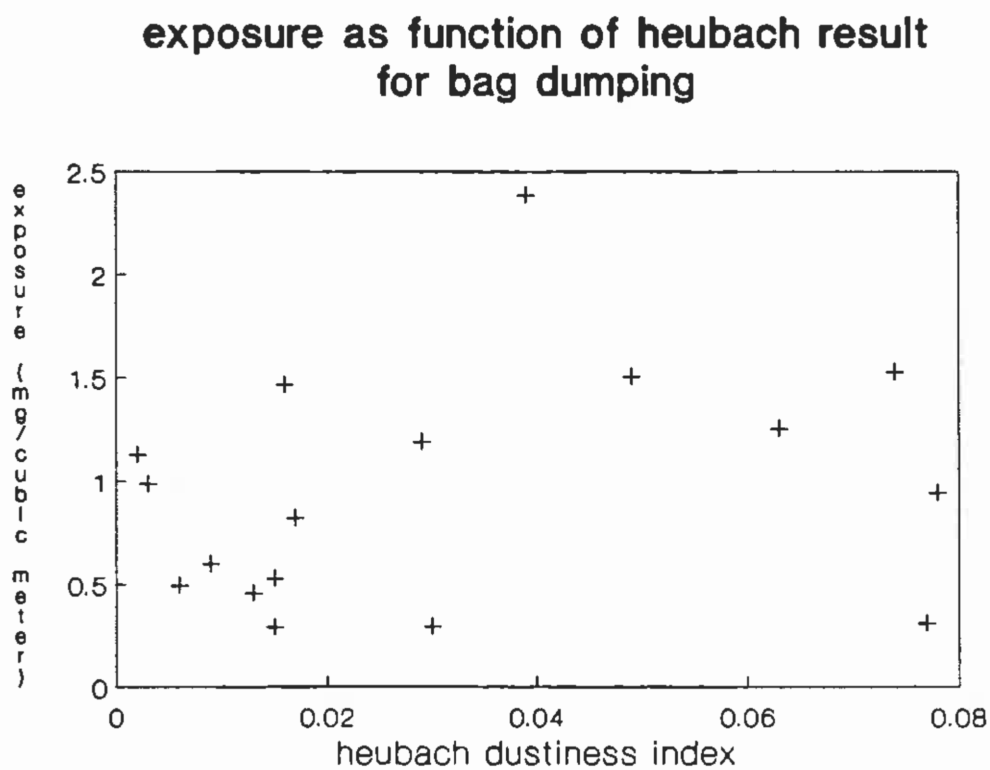


Figure 12. Exposure as a function of Heubach test result (bag dumping).

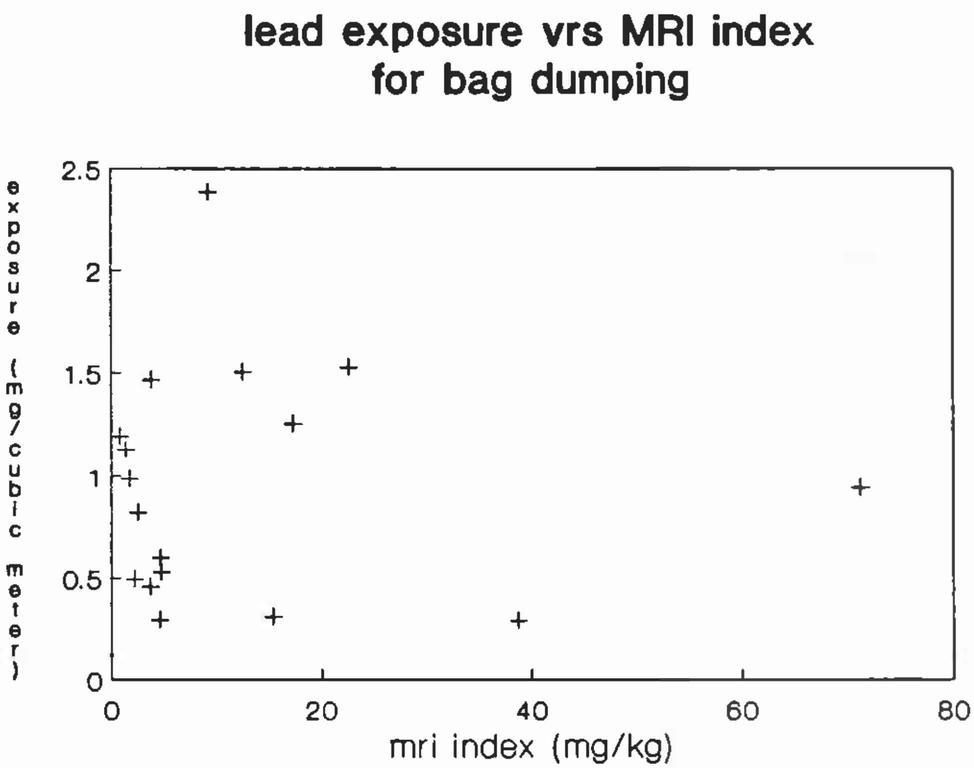


Figure 13. Exposure as a function of MRI index (bag dumping).

In treating the powder to reduce the dust emissions, the cohesiveness of the powder may have increased. The present dustiness tests may not consider the effect of changes in flowability upon dust exposure. Decreasing material flow rate has been shown to increase dust emissions on a per unit mass basis.[8]

VI. CONCLUSIONS AND RECOMMENDATIONS

The Heubach Dustiness Test did not directly simulate the pouring and dumping of fine solids that takes place in the actual manufacturing process, but did allow the solids to repeatedly fall through an air stream and the resultant dust sampled. The MRI Dustiness Test more directly simulated the pouring and dumping of the solids in the actual manufacturing process, by dumping the solids one time within an enclosed chamber and sampling the resultant dust. However, the quality (repeatability) of the Heubach Dustiness Test results seems to be better than for the MRI Dustiness Test results.

The study did show that treating the powder did not greatly change the lead chromate exposures. Treating the powder to suppress dust emissions at this plant is not an effective dust control measure. Other control measures are needed to reduce occupational exposure to lead chromate.

At this plant, there was no correlation between dust exposure and dustiness test results. It is not clear whether this is due to deficiencies in the dustiness tests or due to the presence of confounding factors at this plant. However, this study does indicate that the users of dustiness tests need to evaluate the relevance of the dustiness test results at each site of interest. At some sites, there will be a correlation between dustiness and dust exposures. At other sites, there may not be a relationship, because other factors are more important than material dustiness.

PART B

RECOMMENDATIONS FOR IMPROVED DUST CONTROL

VII. METHODOLOGY

Real-Time Measurements

Aerosol measurements were made using either a Real-Time Aerosol Monitor (RAM) or a Hand-Held Aerosol Monitor (HAM) to identify and prioritize potential sources of exposure to pigment dusts. These instruments sample the workroom air and instantaneously measure the concentration of airborne dusts and mists by measuring the amount of light scattered by these materials. Although the measurements of these instruments are in mg/m^3, these numbers should be considered as estimates of relative concentration, as the amount of light scattered depends on the optical characteristics of the specific aerosol in addition to its concentration. Although neither the HAM nor RAM are specific for lead or lead chromate, they are useful real-time indicators for control of lead dust.

The portable RAM was used in Building 12 in the packaging area and adjacent areas. This unit can be operated with a cyclone preseparator to measure respirable aerosol (dusts and mists well below about 10 micrometers in diameter) or can be operated with a plain inlet to nominally measure all sizes of dust and mists. In this evaluation, the unit was operated with the cyclone preseparator.

The HAM and a video camera were used in Building 123 at the east bag emptying station to record a session of emptying bags of pigment. The HAM, a data logger, and a portable computer were used to measure and record the dust levels during the emptying of sixty-five 50-pound bags of lead chromate pigment. The HAM, operating on the same principle as the RAM, provides instantaneous measurements of total dust levels in mg/m^3. It sends an electrical signal to the data logger, which records it as millivolts. Before the bag emptying operation started, the HAM was calibrated and zeroed, and the data logger was programmed and synchronized with the clock on the video camera. A battery-operated pump was used to draw air through the HAM, which was worn in the operator's breathing zone. A spread sheet program was used to plot the real-time information. By comparing the peaks from this plot with the video, work practices producing elevated dust levels can be identified.

VIII. RESULTS

Observed Dust Sources in Bag Filling

Specific sources of airborne dust observed in the bag filling area during packaging are:

1. During bag filling, while the packer is under pressure, dust-laden air sprays from between the bag's valve and the packer spout. Additional leakage was observed coming from the top seams of some bags. (The company reports an average of one bag a week ruptures during filling.)

2. When removing the filled bag from the packer, pigment falls from the packer spout.

3. When an empty bag is placed on the packer spout, pigment is scraped off the exterior of the spout, falling into the fill bin.

4. As the bag is lifted from the packer spout and set on the scales, the bag's fluidized contents are squeezed and in the process, dust-laden air is forced out the bag's open valve. Also, pigment often falls from the bag's valve onto the floor during this bag transfer from packer to scales.

5. As the bag's final weight is being adjusted, pigment falls from the scoop to the floor or onto the scale.

6. Pigment that has fallen onto the scale is usually brushed off into the overflow pan setting in the hood. Some of this dust-laden air escapes from the hood. Also, some of the pigment falls to the bottom of the hood or onto the floor.

7. Pigment remaining in the bag's tuck-in valve becomes airborne when the bag's valve is closed. This and the above mentioned dust sources contaminate the bag's surface resulting in needless exposure in subsequent bag handling operations, such as bag dumping and bag handling at consumer plants.

8. When the bag is dropped onto the pallet, dust escapes from the bag's valve, surface, and seams.

9. As the pallet load is being compacted, dust escapes from the bag's valves, surfaces, and seams.

10. The pigment chute leading to the packer unit leaks.

11. There are leaks from most of the ancillary equipment on this floor and on the floors above this packaging area.

12. When the packer catch bin is full, the operator shovels excess pigment into a fiber barrel generating airborne dust in the process.

13. When an empty pallet is dropped on the floor, airborne dust is generated from the pigment that has accumulated on the floor and nearby equipment.

14. Nearby forklift traffic generates airborne dust that drifts into the bag filling area.

Observed Dust Release Sources in Bag Dumping

Specific sources of dust observed during bag emptying are:

1. Dust escapes from the opened bag and the bag's outer surfaces when they are cut open and when they are lifted from the pallet to the hood's dump shelf. (The dirtier the bag's surface, the greater the problem.)

2. Dust is generated from the flowing product as the bags are emptied.

3. When folding the emptied bag, dust-laden air is forced from the bag.

4. When manually compacting the emptied bags into the drum, dust is expelled from the drum.

5. Torn bags on the pallet spill pigment onto other bags and onto the floor, becoming a dust source then and during subsequent operations.

Ergonomic Observations

Both bag filling and bag emptying are labor intensive operations. At bag filling, the worker lifts each 50-pound bag twice within a fairly confined space; from the packer spout to the weigh hood and from the weigh hood to drop the bag on the pallet. Each time, he turns 90°, often turning at the waist while holding the full bag. At times, as he stacks the pallet, he stoops over to lift or slide the bag into position. With the pallet on the floor and still nearly empty, he bends over to the greatest extent in order to reach the bag. All of these movement cause strain on the worker's back.

At the bag emptying operation, bending, stretching, and reaching also take place, but to a lesser degree. The operator uses the forklift to keep the top layer of bags near his waist height, about 3 feet above the floor. This eliminates the need to stoop over and lift the 50-pound bag to the 3-foot high dump shelf. The worker still has to bend over to reach across the pallet to slide a bag into position before cutting it open. He also turns about 180° when lifting the bag from the pallet to the hood shelf. However, lifting is minimal, since the bag is already near the height of the shelf. The most awkward part of the operation is when the barrel for bag disposal is inside the hood extension, as originally designed. The worker has to reach and stretch, especially when trying to push the bags into the barrel. Although this does not necessarily put a strain on his back, his head is inside the hood in the path of the dust being expelled from the barrel to where it is being exhausted from the hood. Some workers took extra care in handling the empty bags; placing the bag on the hood shelf with the open end of the bag pointing into the hood, flatten the bag with his hand, fold the bag over several times, and dropping the folded bag into the barrel. This resulted in less need to manually push the bags into the barrel and generate dust in the process. Also, dust expelled from the bag during folding is captured by the hood. Another good work practice used by some workers was to place the full bag on the dump shelf before cutting it open. This should reduce the dust generated, both when cutting the bag open (while it is still on the pallet) and lifting the opened bag to the dump shelf.

Real-Time Sampling Results

The RAM was used to estimate the concentration of lead containing dusts or mists in the wet processing area, dry processing area 1, and dry processing area 2 in Building 12. Concentrations were measured above possible sources, as well as typical work areas. These real-time measurements are presented in Table 7. (The wet process area is physically separated from the two dry

Table 7. Real-Time RAM Aerosol Measurements.

Location	Concentration (mg/m3)
Wet processing area	
above lead nitrate tank	2 - 5
operator's desk	1.3
centrifuge #66	1.1
centrifuge #67	1.2
centrifuge #68	1.3
initial mix tank	1.1
tank T57	0.9
tank T59	0.6
boric acid tank	1.0
door to dry processing area	1.3
alum and soda ash hoppers	0.3
Dry processing area 1	
top of bucket elevator	5.0
Filter #1	4 - 5
Fan platform	5.0
bin #1 (north)	5 - 6
bin #1 (south)	5 - 6
above open hatch on feed hopper	4 - 5
between oven and mill	0.7
air exiting mill vent	0.8
screw #3 (feeding separator)	2 - 3
bag packer (not running)	0.75
bag packer (running)	1.5
oven (dry end - extreme NW corner)	1.5
oven door louvre	0.5 - 0.6
oven wet end	0.7 - 0.8
Dry processing area 2	
aisle by tray dryer	0.2
underneath dryer	0.3
packer (not running)	0.3 - 0.4
filter press (not running)	0.9
mill	3.0
above dryer by fan intake	10.0

Note: these are single, instantaneous measurements used to identify areas or operations causing potential exposure; they may not reflect actual exposures measured by long term sampling techniques.

processing areas. Dry processing area 2 was not running when the real-time dust level measurements were made in the wet process area and dry process area 1.)

Comparing the RAM measurements near the bag packer with the filter sampling data collected in this same area in Building 12, a reading of 1.3 to 1.5 mg/m^3 is very roughly equivalent to a lead concentration of 200 $\mu g/m^3$, the OSHA PEL for engineering control. The presence of other aerosols (i.e., condensing steam) may cause erroneously high readings. Thus, estimates of lead exposure data from the real-time data are tenuous at best.

Wet Processing Area--
In this area, dust (mist) levels are such that lead exposures could exceed the PEL. The highest dust (mist) levels were located above the lead nitrate tank. The majority of the tanks were connected to an exhaust system. (A defective aspirator did not allow smoke tube measurements to be performed, to determine if the exhaust was sufficient to contain the mist from the contained liquids; thus, it is impossible to determine from our data, if the measured levels were caused by mist escaping from the tanks or dust contamination from the dry processing areas.)

Dry Processing Area 1--
The highest dust levels were located on the upper levels of the building with the lead exposures possibly being many times the PEL. Dust levels were particularly high near the dual bin receiving dry pigment from the oven. An exhaust duct was connected to the bin, but flow was insufficient to prevent dust from escaping from the access hatches.

Dust concentrations were lower on the main level (where the pigment is bagged) by a factor of 3 to 5 times. Of particular note are the dust concentrations by the packing machine. The concentration when the packer is running is only twice that when it is idle, indicating that much of the dust originates elsewhere, most probably from the relatively dirty upper levels. (Upper floors are open metal grates, allowing spilled pigment to fall through to lower levels and contaminated air to be exchanged.) The dust levels at the packer are such that the PEL can easily be exceeded. Much of the operators' exposure occurs when they tend equipment located on the upper levels. There is no fresh makeup air introduced into Building 12. Air entered the dry processing area through an open window located near the packing machine. Air entering through this window has the opportunity to pick up dust leaking from screw conveyors before it reaches the operator.

Dry Processing Area 2--
(This area was separate from the packing operations studied and was not part of dustiness test evaluations.) Of particular note are the dust concentrations by the air attrition mill. The mill and dryer are isolated from other areas on the main floor by plastic curtains. Dust concentrations within the curtained-off area were the highest measured on the main level. The highest dust levels were located on the upper level near the fan intake for the pigment dryer. In both areas, dust levels are such that lead exposures could be many times the PEL. The source of the high dust levels could not be ascertained. Part of the exhaust air from the dust collector is recirculated to the dryer,

together with makeup air by means of a recirculating fan; the balance of the dust collector exhaust is removed from the building via an exhaust fan. Failure of the exhaust fan could have resulted in an outflow condition occurring at the makeup air inlet. A more likely scenario places the dust source at the mill: the plastic curtains and the hot dryer combining to form an effective chimney, carrying dust from the mill up to the second level (where the fan inlet is located). As was noted earlier, no fresh makeup air is introduced into Building 12. Air entered this dry processing area from an open door at the end of a main aisle.

Work Task Analysis, Bag Emptying, Building 123

The HAM and video camera were used to determine dust levels during the bag emptying operations on the third floor. Dust sources and their relative concentrations experienced by the operator were measured for the various activities over a 23.5-minute period during normal bag emptying operations. A summary of the work activities performed in emptying bags is presented in Table 8. An excerpt of the work exposure cycle is plotted in Figure 14. Any HAM measurement above 0.01 mv/sec indicates an activity where lead exposures are potentially above 50 $\mu g/m^3$. The data shows that the main dust exposure occurred during bag disposal, bag opening, and lifting opened bags. A summary of these measurements are presented in Tables 9 and 10.

Real-time measurements detected brief exposure elevations during various phases of bag dumping. The greatest potential exposure to the worker is during Activity 8, pushing the emptied bags into the barrel. This activity accounts for 68% of the total dust source and requires 15% of the worker's time.

Activities 4 and 5, cutting open the bag and lifting it to the hood shelf is another major dust source. This activity accounts for about 23% of the total dust exposure and requires 15% of the worker's time.

IX. RECOMMENDATIONS

Building 12

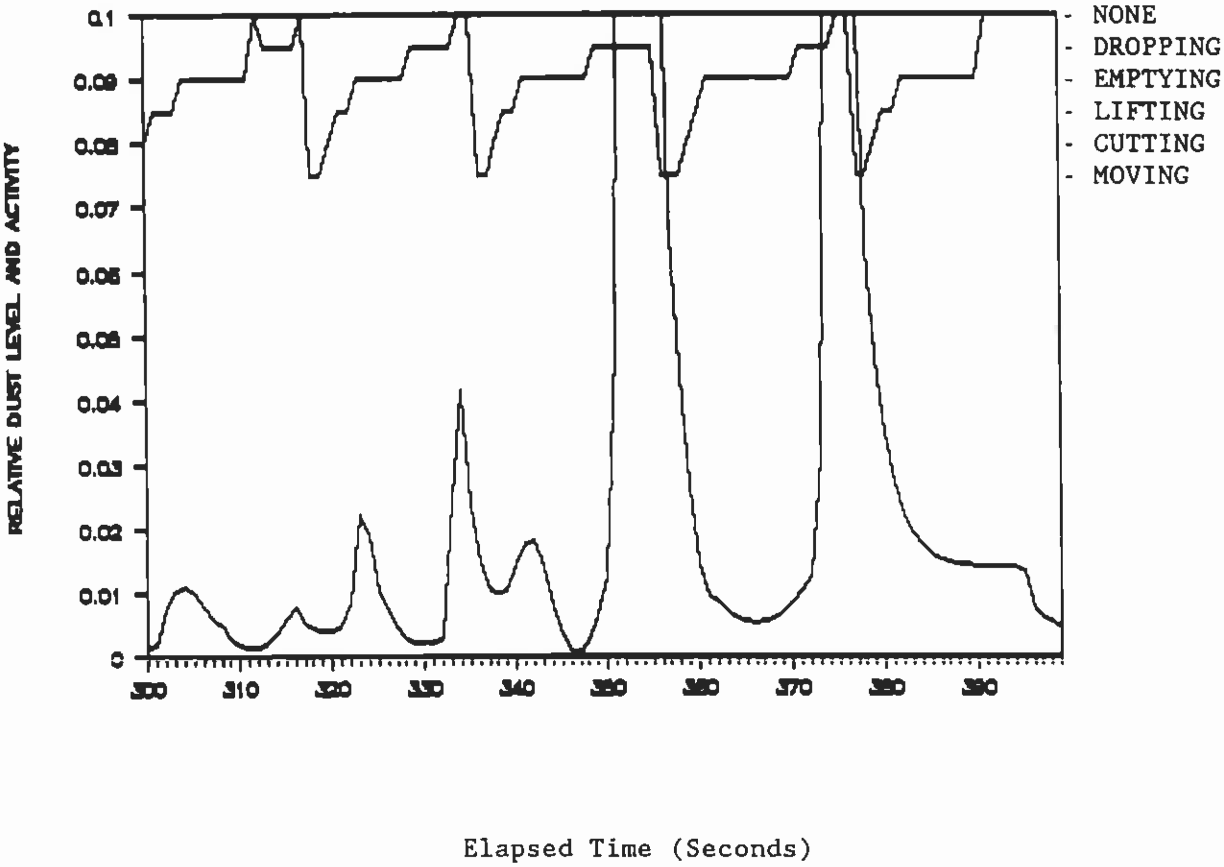
The bag packing operation was identified by the plant as a high exposure operation. The sampling performed in this study confirmed that the bag packer's exposure may be many times the OSHA PEL for engineering control for lead. Much of this exposure appears to be from sources other than bag filling. Real-time measurements indicate that dust leaks in the processing operations are an important contribution. To reduce these sources, a control strategy must include two elements: reducing residual exposures resulting from area contamination from the ancillary operations on all three floors of Dry Processing Area 1, and reducing dust generation from the packing operation.

When handling treated "low dust" pigments, blockages in the conveying system seem to be more frequent, requiring the operator to hammer on the ductwork to keep the pigment flowing. Numerous leaks were observed in the ductwork during hammering and from open transfer points where cover plates had been left off. Additional dust sources were observed during various phases of bag filling, further increasing the operator's potential lead exposure.

Table 8. Work activities in emptying bags.

Activity 1.	Uses a fork lift to bring a pallet of forty 50 pound bags to the dump station, leaving the pallet load on the fork lift. Included in this activity is the going after another pallet load or the adjusting of NIOSH's sampling gear. (Average time 141 seconds or 10% of test time and assumed to be the area dust level.)
Activity 2.	Cut and remove the plastic wrap from the pallet, place the wrap in a fiber drum for disposal, and during emptying, raise the forklift to bring the top of the pallet load to waist height. (Average time 166 seconds or 12% of the test time, contributing 6% of the dust source.)
Activity 3.	Slide the bag from the middle of back row on the pallet into position next to the worker. (Average time 158 seconds or 11% of the test time, contributing 3% of the dust source.)
Activity 4.	Cut open the bag. (Average time 82 seconds or 6% of the test time, contributing 13% of the total dust.)
Activity 5.	Lift the bag and set it on the dump shelf. (Average time 128 seconds or 9% of the test time, contributing 10% of the total dust.)
Activity 6.	Empty the bag. (Average time 509 seconds or 36% of the test time, contributing 0% of the total dust.)
Activity 7.	Drop emptied bag into barrel, usually about 20 bags per barrel, two barrels per pallet load. (Average time 10 seconds or less than 1% of the test time, contributing 0% of the total dust.)
Activity 8.	Manually push bag into barrel. (Average time 215 seconds or 15% of the test time, contributing 68% of the total dust.)

OPERATOR AT BAG DUMP STATION
Real-time Data



ACTIVITY KEY:

On Tables 8 and 9	On Figure 14	Activity
3	0.075	Moving bag on pallet
4	0.080	Cutting bag open
5	0.085	Lifting bag to hood shelf
6	0.090	Emptying bag
7 & 8	0.095	Dropping or pushing bag into barrel
1 & 2	0.1	None, worker away from hood

Figure 14. Work-exposure cycle in bag emptying.

Table 9. Real-time measurement of dust exposure in bag dumping.

Activity - for 1 2/3 Pallet Loads or 65 Bags	Relative Concentration (mv)	Standard Deviation	Activity Time (seconds)
1. None (Background)	0.007	0.010	141
2. Miscellaneous	0.009	0.022	166
3. Moving Bag on Pallet	0.008	0.007	158
4. Cutting Bag Open	0.011	0.018	82
5. Lift Bag to Hood	0.010	0.014	128
6. Empty Bag	0.007	0.020	509
7. Drop Bag into Barrel	0.003	0.001	10
8. Push Bag into Barrel	0.028	0.070	215
Overall Average	0.011	0.033	-
Total Time	-	-	1409

"None" - activities away from the dump station such as going after a second full pallet and adjusting sampling gear (the HAM and data logger).

"Miscellaneous" - activities include cutting stretch wrap off pallet and placing the wrap in a barrel, raising forklift to bring top of pallet load to waist height, and replacing full barrel with an empty barrel.

NOTE: During testing, no other bag dumping took place at the other four stations.

Table 10. Real-time analysis of dust exposure in bag dumping.

Activity - for 1 2/3 Pallet Loads or 65 Bags	% of Total Exposure	% of Total Exposure (Less Area Level)	% of Time
1. None (Area Level)	6	0	10
2. Miscellaneous	10	6	12
3. Moving Bag on Pallet	8	3	11
4. Cutting Bag Open	6	13	6
5. Lift Bag to Hood	8	10	9
6. Empty Bag	22	0	36
7. Drop Bag into Barrel	> 1	0	> 1
8. Push Bag into Barrel	39	68	15
Total	100	100	100

From the RAM real-time data, it appears most of the exposure occurs from operations taking place above the bag filling area. The open-mesh floors above the packer allow dust from these overhead operations to fall to the ground floor where bag filling takes place, resulting in area levels 2 to 4 times greater than the OSHA PEL for engineering control.

Dry Processing Area 1--

There are several dust sources in the dry processing area. Recommendations for each of these sources follow:

1. A 3-story tall bucket elevator transfers pigment from the drying oven into the bin. The elevator casing is open at the top. The opening is covered with filter media. The air in the bucket elevator is hotter than the ambient plant air which results in a "stack" effect, drawing air into the elevator casing at floor level and escaping at the top. The filter media will not remove the micron-sized pigment from this air stream. The opening on top of the elevator should be closed and local exhaust ventilation should be applied to the elevator casing.

2. A positive pressure exists in the dual bin feeding the mill. This pressure is due to displacement of the air in the bin by the product. (This amounts to 3 to 4 cfm at the maximum screw conveyor speed.) Convection currents are caused by the hot product and air entrainment induced as the pigment falls into the bin. Exhaust ventilation should be applied to the bin at the rate of approximately 500 cfm per square foot of access door area. (An in-draft velocity of 500 fpm is recommended for contaminants of high toxicity for operations where contaminants are released into zones of rapid air motion, such as barrel filling.)[9] Increased ventilation may require the use of a vacuum break to permit easy opening of the access doors. Exhaust duct connections to this bin and other process equipment should be tapered to provide minimum pressure loss. Tapering provides an additional advantage in that the air velocity at the point of connection to the process equipment is minimized, resulting in the loss of less product to the ventilation system.

3. Dust also appeared to be escaping from the feed hopper located above the packing machine. The same recommendations in item 2 applies to the feed hopper.

4. The air attrition mill discharges through a length of ductwork (about 50 feet) to one of two air filters for product reclamation. These air filters are connected (on the outlet side) to centrifugal fans for discharge to the outdoors. A positive pressure in the duct connecting the mill with the feeder could result in release of a large volume of pigment to the workroom. Serious consideration should be given to rework this connecting ductwork with heavy gauge material and leak resistant (possibly continuous welded) connections. In addition, a pressure monitor should be mounted in this line to warn of a positive pressure condition (i.e., fan failure or filter plugging) and be connected to an automatic shut down of the mill before a significant release can occur.

5. Dust levels near some screw conveyors were higher than those measured in adjacent areas. Lids on these screw conveyors were missing hold-downs which should be replaced. After replacement, the company should repeat these measurements to determine if repair is sufficient or if ventilation of the screw conveyors is required.

6. Exhaust fans on the air filters are located within the building. Ideally, these should be located outside to minimize in-plant noise and to disperse any clean side leakage. The existing fans need not be moved, but the flexible duct connections between the fans and the ductwork are in need of replacement.

7. The oversize product from the air attrition mill feeds back into the mill in a direction opposed to the in-feed. Pigment dust leaks from this line onto the floor. A better method of recycle would be to connect the oversize feed line to a blow bottle, which would pneumatically transport the oversize to one of the two air filter units for recycle.

8. Improve the conveying system of the product to eliminate bridging in the system. This would eliminate the need for the operator to hammer on the ductwork, creating new leaks in the process.

9. There is no fresh makeup air introduced into Building 12. Air enters the building through open doors and windows, potentially causing cross contamination of all process areas. Ideally, all air exhausted from the building should be replaced by tempered air from an uncontaminated location. By providing a slight excess of makeup air in relatively clean areas, and a slight deficit of makeup air in dirty areas, cross contamination can be reduced. In addition, this air can be directed directly to operator work areas, providing the cleanest possible work environment.

Bag Filling Operation--
There are several dust sources during bag filling. Recommendations for each of these sources follow:

1. The packer operation could be isolated from the other dry processing operations and the isolated packer supplied with fresh air in excess of what is exhausted. Ideally, this fresh air could be supplied in the form of a low velocity air shower (<100 fpm to prevent interference with the exhaust hoods), located directly above the worker.

2. At the packer, use a booth-like hood with an exhaust ventilated hopper that forms the floor of the hood. The hood arrangement should provide additional control over dust production during bag filling. Ventilation should be provided around the packer spout and from the hopper to recover and recycle spilled product. This hopper would replace the nonventilated spill bin presently located beneath the bag filling spout.

3. During the bag's final weight adjustment, pigment falls from the bag during product addition/removal and closing of the bag's valve. The entire bag is surrounded by a booth-like enclosure that has an in-draft face velocity of approximately 230 fpm which appears to be adequate to contain the airborne dust. However, for the product that spills on the scale and floor, use a vacuum instead of a brush to remove the spill.

4. Product falls to the floor and becomes airborne dust due to fugitive air currents from normal traffic and packaging operations. To reduce this dust source, use an open grid-type floor located a few inches above a flowing pool of water to remove the spillage. This floor should extend under the packer, final weight adjustment hood, pallet, and the normal work area of the operator during bag filling and stacking operations.

5. The amount of dust escaping from the tuck-in valve during closing is a function of the amount of pigment remaining in the valve. Carefully fold and close the valve without first flicking the valve to remove the dust.

Dry Processing Area 2--
Since this area was separate from the packing operations and there was insufficient time to become thoroughly acquainted with this operation, specific recommendations for this area cannot be given. The plant is strongly encouraged to perform their own audit of this area.

Wet Processing Area--
A survey of the wet processing area should be performed using smoke tubes to determine if the exhaust used on the tanks is sufficient to contain mist from the solutions. If this survey indicates insufficient exhaust, the open area of the tank could be reduced in order to increase the air velocity into the tank. If, for reasons of tank access, this is not possible, the exhaust volume should be increased to provide the same air velocity as would be accomplished by reducing the area.

Building 123, Bag Emptying Operation

The bag emptying operation was identified by the plant as a high exposure operation. The sampling performed in this study indicates potential personal exposures at 10 times the 50 $\mu g/m^3$ OSHA PEL for respiratory protection. Average area levels were near the 50 $\mu g/m^3$. Real-time measurements indicate that most of the exposure occurs when the empty bags are pushed into the barrel. Another dust source occurred when the bags are cut open and lifted to the dump shelf. To reduce these sources, a control strategy must include a better method for bag opening and disposal.

Recommendations for the bag emptying area follow:

1. Use of the existing bag disposal arrangement, the barrel inside the hood extension, appeared to be counterproductive, as it required the worker to place his head well within the confines of the exhaust hood to compact the empty bags. Also, the cutting open of the bag and

lifting the opened bag to the dump shelf exposed the worker to airborne dust and pigment that could spill on his clothes and on the floor. There are mechanized bag opening machines available which cut open the bag, empty the bag, and dispose of the bag all within the same enclosure. This would remove the worker from the two main dust sources in bag emptying operations. A possible alternative is to modify the present bag dump station by installing an air-operated ram, which could be used to compact the empty bags within the confines of the existing hood and have the worker place the bag on the dump shelf before cutting it open.

2. One worker exhibited extreme care in handling the empty bags: using the dump shelf as a work rest, pointing the open end of the empty bag into the hood, flattening the bag to expel contaminated air and residual product into the hood, folding the bag (while still at the face of the hood), and placing it in the fiber drum (located outside of the hood). This worker's average lead exposure during bag emptying was 10% to 20% lower than for the other workers not employing this careful work practice. This underscores the need for careful training in safe work practices.

3. Since fresh makeup air is available, installation of a fresh clean air shower for each of the bag opening stations would require very little expense. Air velocity from the air shower should be kept low (approximately 100 fpm) to prevent interference with the hood capture.

4. To avoid unnecessary lifting, the workers used the forklift truck when it was available to elevate the pallet to a comfortable work height. Purchase of a second lift would allow both workers continuous access, not only lessening the chance of back strain, but also improving productivity.

5. Dry ice is occasionally used to cool pigments during milling and is added at the dump stations. The dry ice is brought to the third floor via a freight elevator. To avoid potential asphyxiation in the event of an elevator failure, no worker should be permitted to ride the elevator when dry ice is being carried.

Pigment Blending and Bagging Areas, Building 123

This building is supplied with an adequate quantity of makeup air on the third floor and appears to be well distributed throughout the rest of the structure. Since the study was limited to the third floor (the bag dumping area), and due to a lack of time, no measurements were made on the second and first floors where pigments were blended and rebagged. Hence, specific recommendations for these areas cannot be given. The plant is strongly encouraged to perform their own audits in these areas.

General Comment - All Areas

Compliance with a 50 $\mu g/m^3$ environmental limit for lead will require considerable commitment on the part of the plant owner. This commitment will not only require investment in the physical plant to rework and redesign much of the existing processes and process buildings, but will almost certainly require additions to the existing engineering staff of the plant. This last item is especially critical. Technical staff need to be available who can develop an understanding of the processes, show an awareness of plant hygiene, and maintain the expertise and authority to make corrections on a continuing basis.

Evidence of this need abounds throughout the plant. Ventilation data is collected for compliance purposes, yet local exhaust ventilation systems are in visible need of repair. Lead exposure data are collected for compliance purposes, yet no one is available to analyze this data to answer questions such as: Which products result in the highest/lowest exposures? What type of packer produces the highest/lowest exposures? Which packer ventilation configuration produces the best results?

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Appendix I

Worker Exposure Data

BAG FILLING/BAG DUMPING

SHIFT	GA/BZ	GRP #	PRODUCT CODE**	JOB TITLE	DATE	FLOW (l/m)	RUN TIME	VOLUME (l)	LEAD (ug)	CONC. (ug/m3)	% LEAD FROM MSD
2	B	1	B'	BAG FILLING	10-Nov-87	4	01:51	391	180	461	59.8
2	G	1	B'	BAG FILLING	10-Nov-87	4	01:43	361	130	361	59.8
2	B	2	B'	BAG FILLING	10-Nov-87	4	00:55	194	390	2014	59.8
2	G	2	B'	BAG FILLING	10-Nov-87	4	01:03	220	130	590	59.8
2	G	3	NONE	BAG DUMP	10-Nov-87	4	01:56	406	2	5	59.8
2	B	4	F'	BAG DUMP	10-Nov-87	4	01:01	215	140	652	57.8
2	G	4	F'	BAG DUMP	10-Nov-87	4	01:53	395	2	5	57.8
1	B	5	B'	BAG FILLING	11-Nov-87	3	01:35	331	140	423	59.8
1	G	5	B'	BAG FILLING	11-Nov-87	3	01:35	331	79	239	59.8
1	G	5	B'	BAG FILLING	11-Nov-87	4	01:35	334	64	191	59.8
1	B	6	B'	BAG FILLING	11-Nov-87	3	01:00	209	94	450	59.8
1	G	6	B'	BAG FILLING	11-Nov-87	3	01:00	209	85	407	59.8
1	G	6	B'	BAG FILLING	11-Nov-87	4	01:00	211	83	393	59.8
1	B	7	A	BAG DUMP	11-Nov-87	3	00:37	129	190	1476	61.9
1	G	7	A	BAG DUMP	11-Nov-87	4	00:37	130	27	207	61.9
1	G	7	A	BAG DUMP	11-Nov-87	4	00:37	130	39	301	61.9
2	B	8	B	BAG FILLING	11-Nov-87	4	01:27	305	150	493	59.8
2	G	8	B	BAG FILLING	11-Nov-87	4	01:26	301	80	266	59.8
2	B	9	B	BAG FILLING	11-Nov-87	4	00:54	189	96	508	59.8
2	G	9	B	BAG FILLING	11-Nov-87	4	00:52	182	41	225	59.8
2	B	10	F'	BAG DUMP	11-Nov-87	3	01:26	262	91	347	57.8
2	G	10	F'	BAG DUMP	11-Nov-87	4	01:28	308	10	32	57.8
1	B	11	B	BAG FILLING	12-Nov-87	4	01:30	317	110	347	59.8
1	G	11	B	BAG FILLING	12-Nov-87	3	01:30	313	62	198	59.8
1	G	11	B	BAG FILLING	12-Nov-87	4	01:30	315	65	206	59.8
1	B	12	B	BAG FILLING	12-Nov-87	4	01:00	211	57	270	59.8
1	G	12	B	BAG FILLING	12-Nov-87	3	01:00	209	49	235	59.8
1	G	12	B	BAG FILLING	12-Nov-87	4	01:00	210	47	224	59.8
1	B	13	D'	BAG DUMP	12-Nov-87	4	01:04	224	29	129	44.1
1	G	13	D'	BAG DUMP	12-Nov-87	3	01:05	227	2	9	44.1
1	B	14	A'	BAG FILLING	07-Dec-87	3	01:00	209	31	148	61.9
1	G	14	A'	BAG FILLING	07-Dec-87	4	01:00	210	17	81	61.9
2	B	15	A'	BAG FILLING	07-Dec-87	3	01:03	219	35	160	61.9
2	G	15	A'	BAG FILLING	07-Dec-87	4	01:03	221	33	150	61.9
2	B	16	A'	BAG FILLING	07-Dec-87	3	01:00	209	84	402	61.9
2	G	16	A'	BAG FILLING	07-Dec-87	4	01:00	210	37	176	61.9
2	B	17	D	BAG DUMP	07-Dec-87	4	01:37	339	210	619	41.1
2	G	17	D	BAG DUMP	07-Dec-87	3	01:37	339	26	77	41.1
1	B	18	A'	BAG FILLING	08-Dec-87	3	00:36	125	130	1038	61.9
1	G	18	A'	BAG FILLING	08-Dec-87	4	00:36	126	81	643	61.9

Worker Exposure Data

BAG FILLING/BAG DUMPING

SHIFT	GA/BZ	GRP #	PRODUCT CODE**	JOB TITLE	DATE	FLOW (l/m)	RUN TIME	VOLUME (l)	LEAD (ug)	CONC. (ug/m3)	% LEAD FROM MSD
1	G	18	A'	BAG FILLING	08-Dec-87	4	00:36	126	78	619	61.9
1	B	19	A'	BAG FILLING	08-Dec-87	3	01:00	209	310	1485	61.9
1	G	19	A'	BAG FILLING	08-Dec-87	4	01:00	210	210	1000	61.9
1	G	19	A'	BAG FILLING	08-Dec-87	4	01:00	210	200	952	61.9
1	B	20	F	BAG DUMP	08-Dec-87	3	01:30	314	300	955	62.6
1	G	20	F	BAG DUMP	08-Dec-87	4	01:30	315	10	32	62.6
2	B	21	A'	BAG FILLING	08-Dec-87	3	01:15	261	120	460	61.9
2	G	21	A'	BAG FILLING	08-Dec-87	4	01:15	263	78	297	61.9
2	G	21	A'	BAG FILLING	08-Dec-87	4	01:15	263	82	312	61.9
2	B	22	A'	BAG FILLING	08-Dec-87	3	01:00	209	130	623	61.9
2	G	22	A'	BAG FILLING	08-Dec-87	4	01:00	210	76	362	61.9
2	G	22	A'	BAG FILLING	08-Dec-87	4	01:00	210	60	286	61.9
2	B	23	D	BAG DUMP	08-Dec-87	3	01:30	314	40	127	41.1
2	G	23	D	BAG DUMP	08-Dec-87	4	01:00	210	10	48	41.1
1	B	24	A	BAG FILLING	09-Dec-87	3	00:33	115	140	1219	61.9
1	G	24	A	BAG FILLING	09-Dec-87	4	00:33	116	62	537	61.9
1	G	24	A	BAG FILLING	09-Dec-87	4	00:33	116	44	381	61.9
2	B	25	A	BAG FILLING	09-Dec-87	3	01:01	212	270	1272	61.9
2	G	25	A	BAG FILLING	09-Dec-87	4	01:01	214	88	412	61.9
2	G	25	A	BAG FILLING	09-Dec-87	4	01:01	214	88	412	61.9
2	B	26	A	BAG FILLING	09-Dec-87	3	00:56	195	170	872	61.9
2	G	26	A	BAG FILLING	09-Dec-87	4	01:00	210	71	338	61.9
2	G	26	A	BAG FILLING	09-Dec-87	4	01:00	210	93	443	61.9
1	B	27	D	BAG DUMP	09-Dec-87	4	00:31	109	56	516	41.1
1	G	27	D	BAG DUMP	09-Dec-87	3	00:31	108	7	65	41.1
2	B	28	D'	BAG DUMP	09-Dec-87	4	01:27	305	160	525	44.1
2	G	28	D'	BAG DUMP	09-Dec-87	3	01:27	304	6	20	44.1
1	B	29	C	BAG FILLING	19-Jan-88	4	01:12	252	210	833	61.0
1	G	29	C	BAG FILLING	19-Jan-88	4	01:20	280	220	786	61.0
2	B	30	D	BAG DUMP	19-Jan-88	4	02:05	438	170	389	41.1
2	G	30	D	BAG DUMP	19-Jan-88	4	02:09	452	26	58	41.1
2	B	31	E'	BAG DUMP	19-Jan-88	4	01:42	357	170	476	57.9
1	B	32	C	BAG FILLING	20-Jan-88	4	02:30	525	480	914	61.0
1	G	32	C	BAG FILLING	20-Jan-88	4	02:22	497	280	563	61.0
1	B	33	C	BAG FILLING	20-Jan-88	4	00:31	109	52	479	61.0
1	G	33	C	BAG FILLING	20-Jan-88	4	00:44	154	110	714	61.0
1	B	34	C	BAG FILLING	20-Jan-88	4	01:24	294	350	1190	61.0
1	G	34	C	BAG FILLING	20-Jan-88	4	01:22	287	140	488	61.0
2	B	35	D	BAG DUMP	20-Jan-88	4	01:57	410	49	120	41.1
2	G	35	D	BAG DUMP	20-Jan-88	4	01:40	350	9	25	41.1

Worker Exposure Data

BAG FILLING/BAG DUMPING

SHIFT	GA/BZ	GRP #	PRODUCT CODE**	JOB TITLE	DATE	FLOW (l/m)	RUN TIME	VOLUME (l)	LEAD (ug)	CONC. (ug/m3)	% LEAD FROM MSD
2	B	36	E'	BAG DUMP	20-Jan-88	4	01:59	417	110	264	57.9
1	B	37	C'	BAG FILLING	25-Jan-88	4	01:05	228	300	1319	61.0
1	G	37	C'	BAG FILLING	25-Jan-88	4	01:05	228		0	61.0
1	G	37	C'	BAG FILLING	25-Jan-88	4	01:05	228	340	1495	61.0
1	B	38	B'	BAG DUMP	25-Jan-88	4	01:15	263	230	876	59.8
1	G	38	B'	BAG DUMP	25-Jan-88	4	01:15	263	11	42	59.8
1	B	39	F'	BAG DUMP	25-Jan-88	4	00:15	53	15	286	57.8
2	B	40	C'	BAG FILLING	25-Jan-88	4	01:41	353	320	905	61.0
2	G	40	C'	BAG FILLING	25-Jan-88	4	01:41	353	160	453	61.0
2	G	40	C'	BAG FILLING	25-Jan-88	4	01:24	294	340	1156	61.0
2	B	41	F'	BAG DUMP	25-Jan-88	4	01:15	263	150	571	57.8
2	G	41	F'	BAG DUMP	25-Jan-88	3	01:15	261	11	42	57.8
1	B	42	C'	BAG FILLING	26-Jan-88	4	00:35	122	92	751	61.0
1	G	42	C'	BAG FILLING	26-Jan-88	4	00:35	123	89	722	61.0
1	G	42	C'	BAG FILLING	26-Jan-88	3	00:35	122	86	706	61.0
1	B	43	B'	BAG DUMP	26-Jan-88	4	01:13	256	81	317	59.8
1	G	43	B'	BAG DUMP	26-Jan-88	4	01:13	256	7	27	59.8
2	B	44	E	BAG FILLING	26-Jan-88	4	01:00	210	60	286	57.9
2	G	44	E	BAG FILLING	26-Jan-88	4	01:00	211	110	521	57.9
2	G	44	E	BAG FILLING	26-Jan-88	3	01:00	209	63	302	57.9
2	B	45	E	BAG FILLING	26-Jan-88	4	00:31	109	29	267	57.9
2	G	45	E	BAG FILLING	26-Jan-88	3	00:31	108	38	352	57.9
2	G	45	E	BAG FILLING	26-Jan-88	4	00:31	109	25	230	57.9
1	B	46	E	BAG FILLING	27-Jan-88	4	01:05	227	68	299	57.9
1	G	46	E	BAG FILLING	27-Jan-88	4	01:05	229	170	743	57.9
1	G	46	E	BAG FILLING	27-Jan-88	3	01:05	226	160	707	57.9

** Product (X) is standard products. Product (X') is lower dust products.