IN-DEPTH SURVEY REPORT

CONTROL TECHNOLOGY FOR MANUAL DYE WEIGH-OUT OPERATIONS

at

The Glidden Company
Huron, Ohio

REPORT WRITTEN BY
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National Institute for Occupational Safety and Health
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SIC CODE	2850
SURVEY DATE	January 26-29, 1993
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SUMMARY

This survey was conducted to evaluate a ventilated booth used for manual powder weigh-out operations In these operations, powder is quantitatively transferred from drums to small bags The data gathered from this study will be applied to the design of controls for a similar weigh-out operation in the dye industry As shown in past studies, dust exposure increases as the level of powder in the drum decreases and the worker is required to reach deeper and deeper into the drum to reach the powder This places the worker's breathing zone close to or inside the drum, resulting in increased exposure When the worker's head is inside the drum, booth ventilation cannot prevent dust from entering the worker's breathing zone In order to achieve significant reductions in dust exposure, the worker's breathing zone must stay clear of the top of the drum Then, the weigh-out operation can be further controlled with the implementation or modification of a ventilated booth

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is the primary federal organization engaged in occupational safety and health research Located in the Department of Health and Human Services, 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 conducted 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 hazards prevention and control

Since 1976, ECTB has conducted several assessments of health hazard control technology based on industry, common industrial process, or specific control techniques The objective of each of these studies has been to document and evaluate effective techniques for the control of potential health hazards in the industry or process of interest, and to create a more general awareness of the need for, or availability of, effective hazard control measures

A study of manual dye weigh-out operations is being undertaken by the Engineering Control Technology Branch to provide control technology information for the prevention of occupational disease in this industry ECTB has been working on this project with the U S Operating Committee of the Ecological and Toxicological Association of the Dyestuffs Manufacturing Industry (ETAD) ETAD is an international organization comprised of representatives from various dye manufacturing companies Two of the goals of ETAD are "to coordinate and unify the efforts of manufacturers of synthetic organic colorants to minimize possible impacts of these products on health and the environment" and "to achieve these ends in the most economic fashion without reducing the level of protection of health and the environment "[1] ETAD recognizes the potential risks associated with the use of dyes and it is their belief that the best method to reduce these risks is to concentrate on reducing dye exposures To achieve this goal, ETAD organized a steering committee which included members from ETAD, NIOSH, the U S Environmental Protection Agency (EPA), and the American Textile Manufacturer's Institute (ATMI) This steering committee identified dye-weighing operations as requiring research to develop improved techniques to reduce worker exposure to dye dust NIOSH researchers were specifically asked to assist in projects to improve existing work practices and identify/develop local exhaust ventilation controls for the manual dye weigh-out process

The objective of the manual dye weigh-out study is to provide dye and textile shops with information about practical, effective engineering control methods that control worker exposure to air contaminants (dust) To develop this information, ventilation control methods need to be identified and evaluated in the workplace Since very few controls have actually been observed in the dye industry, controls used during similar operations in other industries can be studied

At this plant, the effectiveness of ventilated booths to control dust exposures during manual powder weigh-out operations was evaluated The data collected at this plant will be applied to the study of manual dye weigh-out operations in the dye and textile industries

PLANT DESCRIPTION AND PROCESS DESCRIPTION

The plant ran three shifts, with three weigh-out operators to a shift Each weigh-out operator was responsible for weighing and adding powders as needed to a specific process line The powder was added to the process line by dumping the powder out of previously filled plastic bags, and into a hopper which fed a mixer on the floor below The powder was then mixed with other materials to form powdered coatings The weighing task was performed intermittently as dictated by process needs The powdered coatings are sold primarily for use on metal appliances, particularly major home appliances

A preliminary survey was performed by ECTB in 1985 at this plant [2] The main objective of that survey was to review dust control techniques for manual transfer of chemical powders at this plant The researchers observed a weigh-out booth equipped with local exhaust ventilation used during the manual powder weigh-out operation They recommended that an in-depth evaluation be conducted of the controls associated with this weigh-out booth

At the time of the current in-depth survey, the number of ventilated weigh-out booths used at this site had increased from one to three, and were now located in the Powder Coating Building One of the booths was set up to weigh heavier amounts of material, with the scale located on the floor of the booth The other two booths each used a scale located on a small table The process began by placing a bucket on the scale pan Plastic bags were then labeled to indicate the name and amount of powder to be weighed into each bag A bag was then placed in the bucket, and the powder drum was moved inside the booth, near the scale The worker scooped powder from the drum into the plastic bag Once the proper weight was obtained, the bag was lifted out of the bucket, tied shut, and placed outside the booth The weigh-out process was repeated for each of the labeled plastic bags When a different powder was needed, the entire process began again Filled plastic bags were stacked in boxes or on pallets

DESCRIPTION OF VENTILATED BOOTHS

The three ventilated weigh-out booths were lined up against a wall of the Powder Coatings Plant (see schematic of the weigh-out area in Figure 1)

A 14-inch diameter exhaust duct led from the back of each booth to the main ventilation system The booth used to weigh heavier materials, designated Booth 3, had three sides and a roof The front of the booth was completely open Booth 3 was not evaluated during this study, primarily since the weigh-out task involved shoveling (with a garden shovel) rather than scooping material out of containers Shoveling would not be indicative of typical dye weigh-out operations However, a personal sample was obtained when one worker used this booth The other two booths, designated Booths 1 and 2, were of the

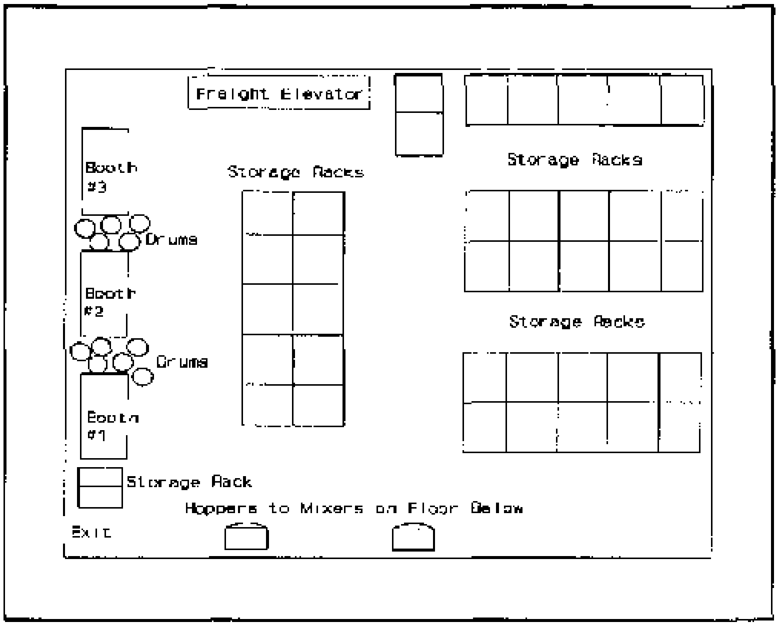

Figure 1. Plant Layout in Weigh-out Area

same design The booths were completely enclosed except for a doorway and four small slots in the front wall, as shown in Figure 2 These small slots allowed makeup air to flow into the booth The four slots on the back wall exhausted the air from the booth

The weigh-out scale was located against the right wall in Booth 2, and the left wall in Booth 1 The dimensions of the scale are diagrammed in Figure 3 The powder drum was also placed inside the booth, usually at an angle to the scale, although this was dependent on worker practice Figure 3 also depicts some of the drum sizes observed at this plant The typical drum was 22 inches in diameter and 3 feet in height Most of the drums were placed on round dollies for ease in moving

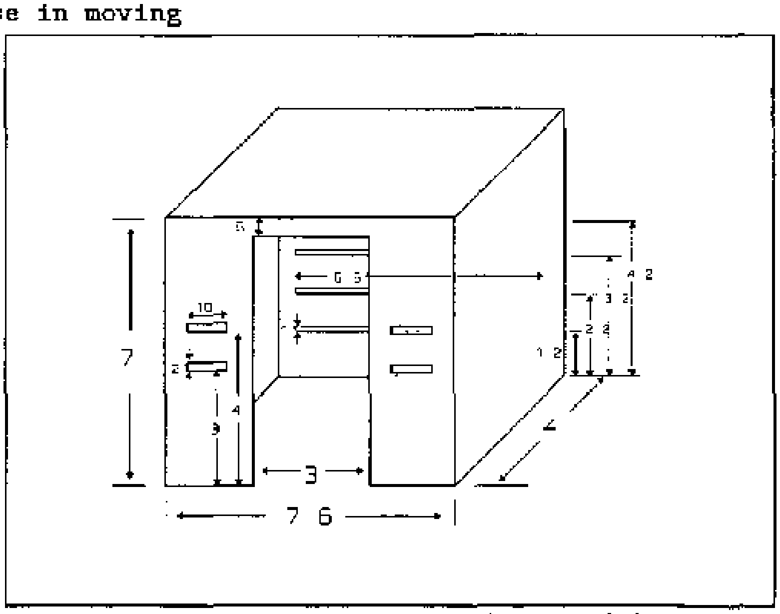

Figure 2. Dimensions for Booths 1 and 2

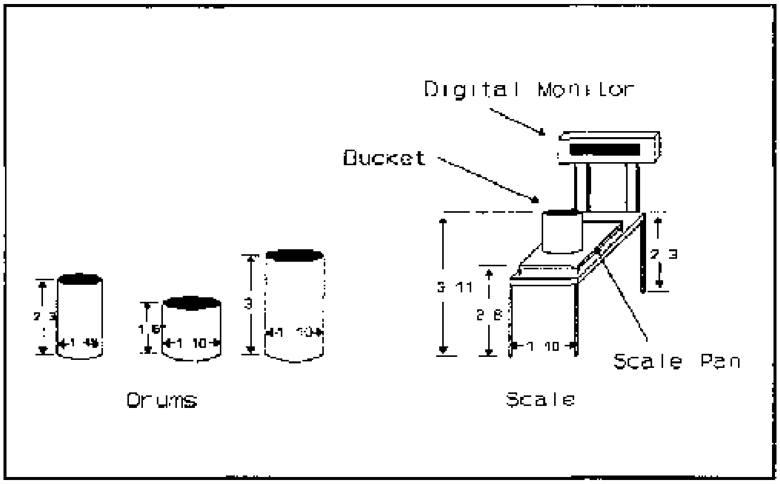

Figure 3. Dimensions of Scale and Drums Used in Booths 1 and 2

POTENTIAL HAZARDS OF MANUAL POWDER WEIGH-OUT OPERATIONS

Workers who manually weigh out powders are exposed to airborne dust Previous studies[3,4,5] have documented potential exposure levels and hazards of workers during weigh-out operations in various industries One study at a rubber plant evaluated the dust exposure of workers who weighed and transferred powdered materials from bags and bins to smaller containers During the sampling period, the majority of personal respirable dust concentration measurements were below 2 mg/m^3 During weigh-out activities, however, dust concentrations increased, peaking at 40 mg/m^3, suggesting an average respirable dust exposure of 15-20 mg/m^3 [3] A similar study of manual weigh-out of powders in a plastic plant found that most breathing zone samples exceeded 10 mg/m^3 [4] A third study, performed in an actual textile drug room, found that TLVs (and subsequently, the PELs) were not exceeded for total or respirable dust during the weigh-out operations [5] However, the author of this study stressed that there may still be potential inhalation hazards from these dyes since their constituents may have established PELs which cannot be ignored

EXPOSURE EVALUATION CRITERIA

As a guide when evaluating hazards posed by workplace exposures such as those from manual weigh-out operations, NIOSH field staff employ environmental evaluation criteria These criteria assess several chemical and physical agents and 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 even if their exposures are maintained below these levels A small percentage may experience adverse health effects due to 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 evaluation criteria 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 in the United States that can be used for the workplace are (1) NIOSH Recommended Exposure Limits (RELs), (2) the American Conference of Governmental Industrial Hygienists's (ACGIH) Threshold Limit Values (TLVs), and (3) the U S Department of Labor (OSHA) Permissible Exposure Limits (PELs) The OSHA PELs are required to consider 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 ACGIH Threshold Limit Values (TLVs) refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects ACGIH states that the TLVs are guidelines The ACGIH is a private, professional society It should be noted that industry is legally required to meet only those levels specified by 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 (STEL) or ceiling values that are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures

The overall objective of this study is to control worker exposure to dust generated by manual powder weigh-out activities Therefore, the exposure evaluation criteria is based primarily on controlling total and respirable dust The PELs established by OSHA require industry to control the 8-hour time-weighted average (TWA) of total dust to 15 mg/m^3 and respirable dust to 5 mg/m^3 [6] The PELs for respirable and total dust were not changed by the 1989 amendment of OSHA's existing Air Contaminants Standard, 29 CFR 1910 1000, which has since been vacated Therefore, the PELs listed above continue to be enforceable by OSHA The TLVs suggested by ACGIH are set at a 10 mg/m^3 TWA for total dust and 5 mg/m^3 TWA for respirable dust [6] There are no RELs recommended by NIOSH for total or respirable dust [6] It is the goal of the overall study to control both the total and respirable dust exposure to as far below the PEL and TLV as possible for the textile dye weigh-out process With this in mind, the engineering controls at this site were evaluated to determine the extent to which particulate exposures were controlled Specific exposure limits for components of the powdered materials used at this site could be found in the Material Safety Data Sheets (MSDSs)

EVALUATION PROCEDURES

The objective of this study was to evaluate the ventilated booths' ability to control worker exposure to airborne contaminants during the weigh-out process To evaluate the booths, air sampling and video exposure monitoring techniques were performed, and ventilation measurements were made

AIR CONTAMINANT EXPOSURE MONITORING

Six short-term personal samples and three long-term area samples for total dust were collected during the 3-day survey All the samples were measured for total particulate (dust) using NIOSH Method 0500 [6] In this method, a known volume of air is drawn through a preweighed PVC filter The weight gain of the filter is then used to compute the milligrams of particulate per cubic meter of air The personal samples were collected using a carbon vane pump operating at a flow rate of 13 L/min Tubing connected the outlet of a filter (attached to the worker's lapel) to a critical flow orifice and the carbon vane pump The pressure downstream of the critical orifice was less than 0 5 atmospheres The area samples were collected to obtain the background level of air contaminants near the weigh-out booths The samples were positioned on the roof of the weigh-out booths All the area samples were collected using a sampling pump (SKC Inc , Eighty Four, Pennsylvania) operating at a flow rate of 5 L/min

VIDEO EXPOSURE MONITORING

Video exposure monitoring was used to study in greater detail how specific tasks affected the worker's exposure to air contaminants [4,7] An aerosol photometer, the Hand-held Aerosol Monitor (HAM) (PPM Inc , Knoxville, Tennessee), was positioned on the worker's chest using a belt and harness A battery-operated pump is used to draw air through the HAM's sensing chamber In the HAM, light from a light-emitting diode is scattered by the aerosol, and forward-scattered light is detected by the HAM The amount of scattered light is proportional to the analog output of the HAM However, the calibration of the HAM varies with aerosol properties such as refractive index and particle size Therefore, the analog output of the HAM is expressed as relative concentrations which has units of volts A personal sampling pump (MSA Model G, Mine Safety Appliance Co , Pittsburgh, Pennsylvania) was used to draw the air in the worker's breathing zone through the HAM's sensing chamber The pump operated at a flow rate of 2 L/min

The analog output of the HAM was recorded by a data logger (Rustrak Ranger, Gulton, Inc , East Greenwich, Rhode Island) attached to the worker's belt When the data collection was completed, the data logger was downloaded to a personal computer (Compaq Portable III, Compaq Computer Corp , Houston, Texas) for storage and analysis The worker's activities were simultaneously recorded on video (Video Camera Recorder Hi8 Handycam, CCD-V701, Sony Corp) for use in a detailed task analysis of the weigh-out operation Data were collected for approximately one hour

VENTILATION MEASUREMENTS

Face velocities were measured using a hot wire anemometer (Model 1040 Digital Air Velocity Meter, Kurz, Carmel Valley, California) Measurements were obtained across the four small slots in the front wall, along the slots in the back wall, at various points across the booth's doorway, and inside the booth Velocities were also measured with a pitot tube in the ductwork of Booths 1 and 2, using a ten-point pitot traverse method [8] A total of twenty readings in each duct was measured, ten across each of two perpendicular diameters From these measurements, the total volume of air exhausted from the booths was calculated

Smoke tubes and a smoking wire apparatus were used to understand the airflow patterns in the booth The smoking wire apparatus consisted of a 3-foot long wire stretched between two stationary poles The wire was coated with paraffin and hooked up to a battery source When the battery source was switched on, the wire emitted a sheet of continuous smoke which visualized airflow patterns in the booth

RESULTS

AIR SAMPLING

Table 1 summarizes the concentration data measured for the weigh-out operation The results of individual air samples are presented in Appendix A The mass of each filter was calculated by subtracting the mean weight change of the blank filters from the analyzed total weight of the sample filter Concentration data were then computed by dividing the mass of each filter by the sample volume One personal exposure exceeded 15 mg/m^3 However, as the PEL is for an 8-hour day and the weighing task is only a fraction of the worker's day, the OSHA PEL for total dust was not exceeded

TABLE 1

Total Dust Concentration Data Summary

Sample Location	N	Geometric Mean (mg/m^3)	Geometric Standard Deviation
Personal Breathing Zone	6	3 3	3 0
Area	3	0 1	1 2

VIDEO EXPOSURE MONITORING

Video exposure monitoring was performed during a weigh-out task which involved three different powders (see Appendix A) The data analysis presented in this paper focuses on the time period during which the third material was weighed During this time, the worker weighed out 10 bags at 12 2 pounds each, from a tall skinny drum The drum was 38 inches tall with a diameter of 14 inches Initially, the powder level in the drum was about 24 inches deep At the end of the task, the powder level had dropped to about 2 inches deep The weigh-out operator during the monitoring was a male, approximately 6'3" in height This worker was in the 95th percentile for stature as compared to a standard population of males [9]

Figure 4 shows the relative exposure of the worker while weighing out the ten bags of this material These data were measured by the HAM and is expressed in volts The majority of the exposure peaks on the graph occurred when the worker was scooping powder out of the drum By the sixth bag weighed, the worker's need to scoop from the lower half of the drum was already causing his face to be positioned right at the drum opening In this situation, the ventilation will not be able to protect the worker from the airborne dust

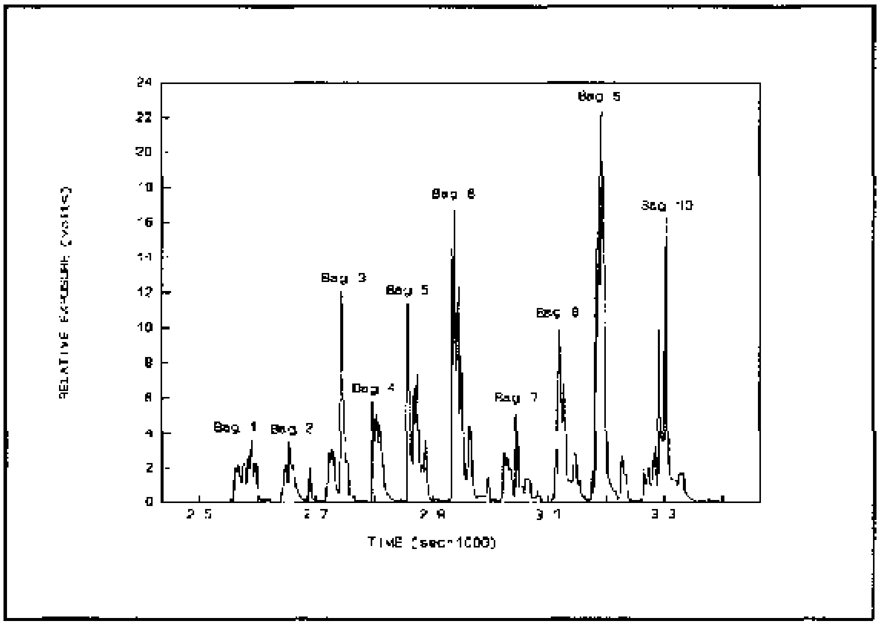

Figure 4 Relative Worker Exposure during Manual Weigh-Out Operation

Figure 5 plots each bag weighed versus the relative dose measured for each bag-weighing period As explained in Appendix B, the relative dose was calculated as the average analog output of the HAM multiplied by the total time for each bag weighing A regression analysis performed on the data (Appendix B) resulted in the calculation of the linear regression curve displayed in Figure 5 The regression curve fits the measured data and shows that worker exposure is affected by bag count

VENTILATION MEASUREMENTS

Twenty ventilation measurements were taken in the ductwork of Booth 1 and Booth 2 Both ducts were 14 inches in diameter The average duct velocity in Booth 1 was measured as approximately 3500 fpm, with a total exhaust volume of 3780 cfm The average duct velocity in Booth 2 was measured as approximately 3400 fpm, with a total exhaust volume of 3670 cfm The hood static pressure was found to be 1 1 inches of water for Booth 1, and 1 3 inches of water for

Booth 2   Table 2 summarizes the face velocities measured for Booths 1 and 2 These velocities are consistent with the control recommendations suggested by ACGIH for intermittent container filling operations [8]

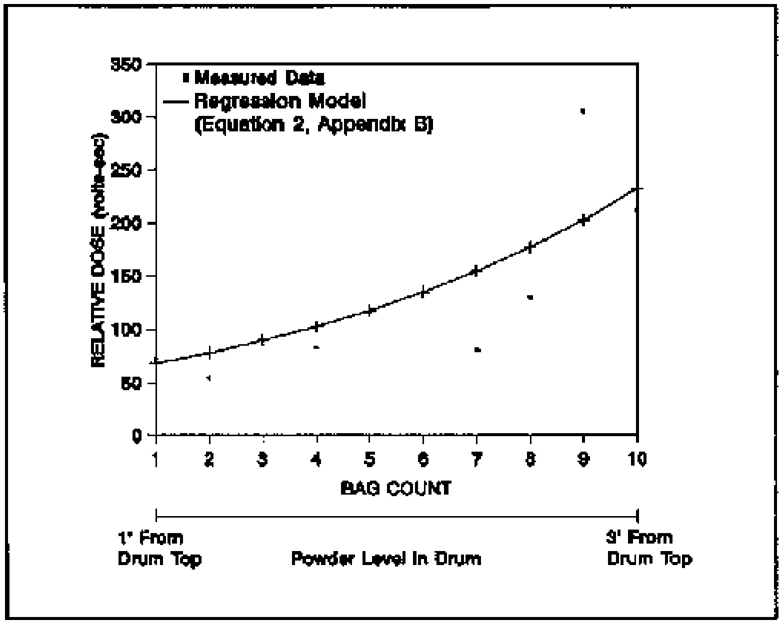

Figure 5. Effect of Depth of Scooping (from a 3'2" High Drum) upon Relative Dose

TABLE 2

Booth Face Velocities (fpm)

Description	Booth 1	Booth 2
Top left hand slot	210	220
Bottom left hand slot	300	210
Top right hand slot	180	160
Bottom right hand slot	200	160
Average at door	194	156
Average at four slots in the back wall	2300	2300
Around bucket placed on the scale	250	150
One foot above the bucket	130	140

By using the smoking wire apparatus and smoke tubes, the airflow patterns inside Booth 2 were observed   The smoking wire apparatus was positioned inside the booth so that the wire was near two of the front wall slots and the booth doorway   The air currents were then able to immediately be traced as they came into the booth The drum was placed in the booth, to the left of the scale, and against the back wall (see Figure 6) The worker stood facing the back wall when scooping from the drum, and then turned slightly to the right when weighing the powder Eddy currents were noted in front of the worker when facing the back of the booth When the worker turned to face the scale, eddy currents raised some of the smoke to a height of about 5 feet, near the worker's breathing zone However, the majority of the smoke flowed around the worker and into the back slots Upon studying the airflow patterns in Booth 1 (same configuration as Figure 6, except with the scale positioned against the left wall), it also appeared that eddy currents brought some of the smoke into the worker's breathing zone

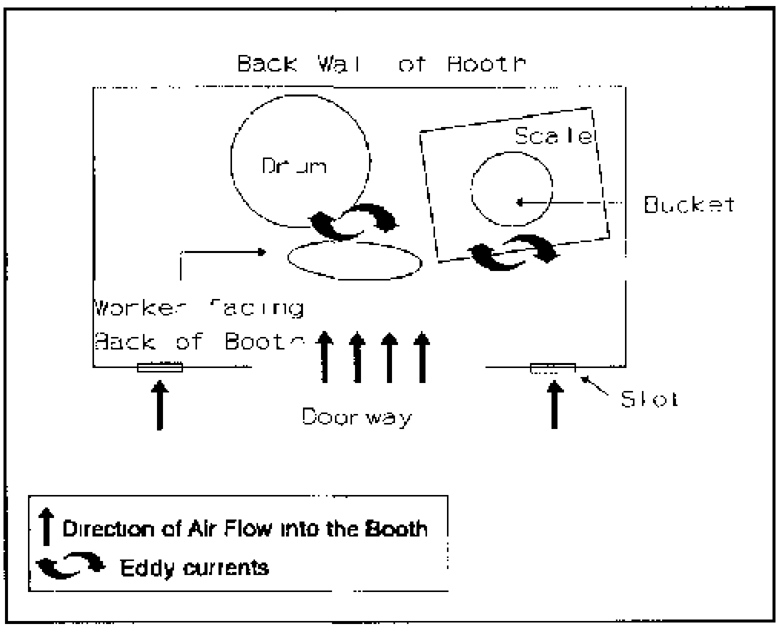

Figure 6. Booth 2 Configuration

To see how a different configuration affected the eddy currents, the equipment in Booth 1 was rearranged as shown in Figure 7 The scale and drum were placed side by side against the left wall so that makeup air was able to flow through the front wall slots, capture air contaminants at the scale and drum, and be exhausted through the back slots Although this setup generated some eddy currents (primarily around the bucket on the scale), the smoking apparatus showed that much of the smoke in the worker's breathing zone was captured and exhausted without entering the worker's breathing zone By facing the side of the booth, the worker avoids having an eddy move dust-laden air directly into his breathing zone No air sampling measurements were obtained with the booth in this setup, as we did not wish to subject the worker to any task modifications

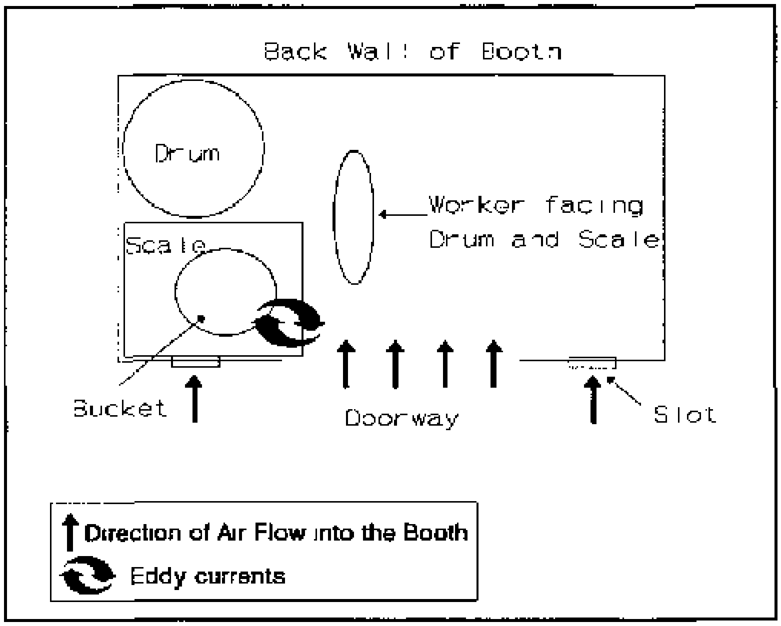

Figure 7. Booth 1 Configuration (for Study Purposes Only)

DISCUSSION

The present configurations of Booths 1 and 2 may contribute to the worker exposure as eddy currents were observed to bring contaminants back into the worker's breathing zone The direction the worker faces enables eddies to transport contaminated air directly into the worker's breathing zone The booth configuration shown in Figure 7 appeared to avoid this eddy transport When the worker faced the side of the booth as shown in Figure 7, there did not appear to be eddies which would transport dust from the weigh-out operation into the worker's breathing zone

The personal and area concentrations summarized in Table 1 and listed in Appendix A, were below permissible levels, except for one sampling period where a concentration of 29 7 mg/m^3 was measured on Worker 1 in Booth 2 During this period, the worker was scooping material from the bottom of a drum The video exposure monitoring performed during this sampling period confirmed an earlier study[4] that worker exposure increases with bag count This is due to the decreasing level of powder in the drum from which the worker is scooping As the powder level decreases, the worker must reach farther and farther into the drum in order to reach the powder As a result, the worker places his or her breathing zone into an area of higher exposure within the confines of the drum In this position, the booth ventilation cannot control the worker exposure to dust

In addition, a previous study of weigh-out operations found that when scooping from the bottom of a drum, a worker with long body dimensions had significantly lower dust concentrations than workers with shorter body dimensions [10] This indicates that the body measurements of individual workers can play a significant role in their exposure to dust during the weigh-out operation Therefore, the exposure data collected on the tall weigh-out operator during this survey could be a low estimate for the exposure a shorter dimensioned worker may face during the same scooping task

Since the scooping task produces such a high exposure, it must be controlled before any significant reductions in overall exposure to the worker during the weigh-out operation can occur One option which could result in lower worker exposures would be the use of shorter drums The height should be such that it would allow all workers to reach the bottom of the drum more easily, diminishing the need for the worker to place his or her breathing zone within the confine of the drum when scooping

CONCLUSIONS

Before recommending a setup for the dye weigh-out operation, more testing needs to be performed to see how the positioning of the worker and the equipment affects exposure Although the booth configuration shown in Figure 7 appeared to reduce the amount of eddy currents around the worker, no air sampling measurements were taken to prove that an exposure reduction would occur from using this setup This is something the plant may eventually want to evaluate Testing should also be performed to determine how the front wall should be configured for the best provision of fresh air into the booth In this study, the four slots in the front wall were positioned to help eliminate dead air pockets inside the booth It may be possible to design the booth so that more fresh air is available, perhaps by having a uniform air distribution across the entire front wall, in the ceiling, or by eliminating the front wall altogether

This study was performed primarily to obtain ideas for the control of air contaminants in the weigh-out operations of the dye industry The real-time data shows that, unless the depth of scooping is restricted, there can be no improvement in the worker's dust exposure Modifying the booth without restricting the depth from which the worker scoops will result in only minor exposure reductions Once the scooping task is controlled, the booth configuration can be modified to reduce exposure to the worker even further

The information collected during this study impacts the overall study of manual dye weigh-out operations in two ways First, the data verify the importance of controlling the worker's dust exposure during the scooping task Second, the data collected on the effectiveness of the ventilated booths at this site will be critical in developing a successful design for a ventilated booth for the manual dye weigh-out process

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APPENDIX A
Particulate Concentration Data During Weigh-out Operation

Date	Type	Task Description	Amount Weighed	Booth	Worker	Time (min)	Mass (mg)	Concentration (mg/m³)
Jan 26	P*	50-lb bags of a material were dumped into plastic bags (in a container on the floor scale) # bags weighed N/A	unknown	3	1	14	0 45	2 47
Jan 26	A	N/A	N/A	-	-	133	0 21	0 12
Jan 26	P	Weighed 2, 12 5-lb bags from a paper bag Weighed 4, 13 6-lb bags of second powder from a drum	79 4 lbs	2	1	19	0 50	2 02
Jan 27	P**	Weighed 13, 4 5-lb bags from a 2'10" high drum Final powder level in drum 2' from top Weighed 10, 2 9-lb bags of second powder Initial powder level 1'10" from top Final powder level 2'5" from top Weighed 10, 12 2-lb bags of third powder from a 3'2" high drum Initial powder level 1' from top Final powder level 3' from top	209 5 lbs	2	1	46	17 75	29 68
Jan 27	A	N/A	N/A	-	-	427	0 30	0 14
Jan 28	P	Weighed 10, 3 7-lb bags from drum Weighed 10, 5 6-lb bags of second powder from drum Weighed 10, 5 6-lb bags of third powder from drum	149 0 lbs	1	2	53	1 44	2 09
Jan 28	A	N/A	N/A	-	-	300	0 14	0 09

APPENDIX A
Particulate Concentration Data During Weigh-out Operation

Date	Type	Task Description	Amount Weighed	Booth	Worker	Time (min)	Mass (mg)	Concentration (mg/m³)
Jan 28	P	Info on first powder weighed was not recorded Weighed 6, 3 2-lb bags and 2, 1 6-lb bags of second powder from drum Weighed 5, 3-lb bags and 2, 1 5-lb bags of third powder from drum	> 28 4 lbs	2	3	23	0 39	1 30
Jan 28	P	Added 0 3 lbs to 10 bags weighed previously (the 5 6-lb bags of the second material listed 3 rows above in this table) Weighed 10, 8 8-lb bags of second powder from drum	91 0 lbs	1	2	25	1 10	3 38
Mean Weight Change of Field Blanks							0 05	
Standard Deviation of Weight Change for Field Blanks							0 03	

* P Personal Sample
A Area Sample

** Video exposure monitoring conducted during this sampling period

APPENDIX B

LINEAR REGRESSION ANALYSIS

The SAS General Linear Models Procedure was used to perform a statistical analysis on the sampling data from this study The analysis was performed on the logarithm of the relative dust dose (LDOSE) to determine how it was affected by the number of bags weighed out (BAG) The relative dust dose was taken as the average analog output of the Hand-held Aerosol Monitor multiplied by the total time for each bag weighing Table A1 presents the results of the analysis

Table A1. Selected Output from SAS

SAS 8 08 Friday, February 19, 1993

General Linear Models Procedure

Dependent Variable LDOSE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1 54388009	1 54388009	8 68	0 0185
Error	8	1 42234233	0 17779279		
Corrected Total	9	2 96622242			

R-Square	C V	Root MSE	LDOSE Mean
0 520487	8 719848	0 421655	4 83557524

Parameter	Estimate	T for H0 Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	4 083186135	14 18	0 0001	0 28824508
BAG	0 136798019	2 95	0 0185	0 04642267

The column labeled "Pr > F" lists the probability that chance could have caused the observed differences in LDOSE If the probability listed is less than 0 05, it is unlikely that the observed differences in the relative concentrations were caused by chance Therefore, when the probability is less than 0 05, one can conclude that the variable in question does have an effect on the relative concentration As shown in Table A1, the variable BAG was found to have a statistically significant effect on the relative dust concentrations (LDOSE) as it has a probability of 0 0185

The model used in the regression analysis was as follows

$$\log(Dose)=\beta_0+\beta_1(BAG) \qquad (1)$$

Where

β_0 = the y intercept

β_1 = the slope of the line

The model can be rewritten as

$$Dose=e^{(4\ 083+0\ 136BAG)} \qquad (2)$$

In summary, the regression analysis shows that the relative dust concentration was affected by the number of bags weighed