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IN-DEPTH SURVEY REPORT:

CONTROL TECHNOLOGY FOR MANUAL TRANSFER OF CHEMICAL POWDERS

AT

The B.F. Goodrich Company
Marietta, Ohio

REPORT WRITTEN BY:
Michael G. Gressel
William A. Heitbrink
James D. McGlothlin
Thomas J. Fischbach

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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:	B.F. Goodrich Industrial Plastics Division Marietta, Ohio
SIC CODE:	3079 Miscellaneous Plastics Products
SURVEY DATE:	December 9-12, 1985
SURVEY CONDUCTED BY:	William A. Heitbrink Michael G. Gressel James D. McGlothlin
EMPLOYER REPRESENTATIVES CONTACTED:	Mr. David W. Smith Safety Manager Walter A. Wegmiller Senior Shift Superintendent Sam Kiggans Senior Shift Foreman
EMPLOYEE REPRESENTATIVES CONTACTED:	Gary Secoy Vice-president ICW Local 343 Elmer Gourly Union Steward ICW Local 343
ANALYTICAL WORK PERFORMED BY:	Utah Biomedical Test Laboratories

Abstract

Past studies have shown that ventilation provides incomplete dust control during weigh-out and transfer of powders. A field study was conducted in a plastics manufacturing plant to evaluate sources of worker dust exposure at a ventilated booth which was used for the weigh-out and transfer of powdered materials from a large drum to small bags. Real-time air sampling, short-term air sampling, and an ergonomic evaluation was performed to determine activities associated with dust exposure. The sources of dust exposure evaluated were: depth of scooping, clothing, worker anthropometry, work practices, biomechanics, and specific items in the worker's job cycle. An evaluation of air flow patterns at this booth revealed the presence of eddies in front of the worker and in the drum which forced dusty air into the worker's breathing zone. Real-time air sampling and work cycle evaluation showed that dust concentrations were highest when the worker was scooping material out of the drum, and these levels increased dramatically when the worker placed his breathing zone inside the drum to scoop the powder. Short-term dust sampling showed that worker and level of material in the drum significantly affected dust concentrations. Soiled clothing had no affect upon worker dust exposure. Anthropometry and work practices significantly affected the worker's dust exposure. Biomechanical analysis showed that manual lifting and transporting 50 pound bags of powdered material may increase the risk of back injury and should be controlled by administrative and/or engineering measures.

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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.

Since 1976, ECTB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of these completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

Purpose of this Study

This study was conducted to evaluate sources of worker dust exposure during the weigh-out and transfer of powdered materials from bags or bins to smaller containers. The ventilation used to control dust generated by this operation appeared to contain dust within the exhaust hood. However, previous studies of these operations always involve some elevation of the worker's dust exposure.[1] The purpose of this study is to determine why ventilation systems for weighing and transfer of powders provide incomplete dust control.

Objectives of this Survey

This survey was undertaken to evaluate dust control at weigh-out and transfer operations. The survey's primary objective was to determine whether the workers' dust exposure was elevated because of dust contaminated clothing and depth at which the worker must scoop from the drum or bin. In order to address this primary objective an ergonomic evaluation was coordinated with air sampling. In addition, real-time air sampling was conducted to identify specific worker activities which generate dust.

PLANT AND PROCESS DESCRIPTION

This plant is part of B.F. Goodrich's Industrial Plastics Division. It was built in 1947, and employs 395 workers. The plant makes a variety of PVC type products such as vinyl backed wall coverings and magnet impregnated plastic stripping. The raw materials for these products are weighed out and then charged into Banbury mixers. After mixing, the plastics are milled, then extruded or calendared into their final form.

This survey was conducted at a ventilated booth which was used to control dust generated by the weigh-out and transfer of powdered raw materials. These powders are assembled into batch lots which are charged into Banbury mixers elsewhere in the plant. During this survey, the powder handled was an acrylic copolymer manufactured by the Rhom and Haas company under the trade name Acryloid K-125 modifier.

At this booth, the worker pre-weighed small batches of the acrylic powder for use elsewhere in the plant. First, the worker emptied fifty-pound bags of powder into a drum until full. He used a scoop to transfer the powder from the drum to a tared bag. Next, he set the bag on a scale and adjusted the weight of powder in the bag. The filled bag was set in a bin behind the scale. The section dealing with ergonomics provides a more detailed description of the worker and his job cycle.

Work Station Description

All work was performed at a ventilation booth shown in Figure 1. In the middle of the "L" shaped work table, there was a hinged platform which was raised to allow a drum of raw material to be placed inside the booth. The scale was set on the work table to the left of the drum. The scale's read-out was on the left wall of the booth at about eye level. The exhaust plenum was the back wall of the booth.

Dust Exposure Limits and Possible Exposure Sources

Bag emptying, manual weigh-out and transfer of powders involves occupational exposure to an airborne dust. For the acrylic material used in this study, there are no specific occupational health standards. Therefore, the nuisance dust exposure limits are assumed to apply. A summary of dust exposure limits for such dusts in Table 1.

The bag emptying and weigh-out and transfer of powders involve a number of potential dust exposure sources which are listed in Table 2. This survey was conducted to evaluate whether worker clothing and depth of scooping affect worker dust exposure. Because the workers' anthropometry varies, the affect of depth of scooping upon dust exposure may vary with the worker.

Emptying the fifty pound bags of powder into the drum generates a dust exposure for the worker. The dust exposure sources associated with bag

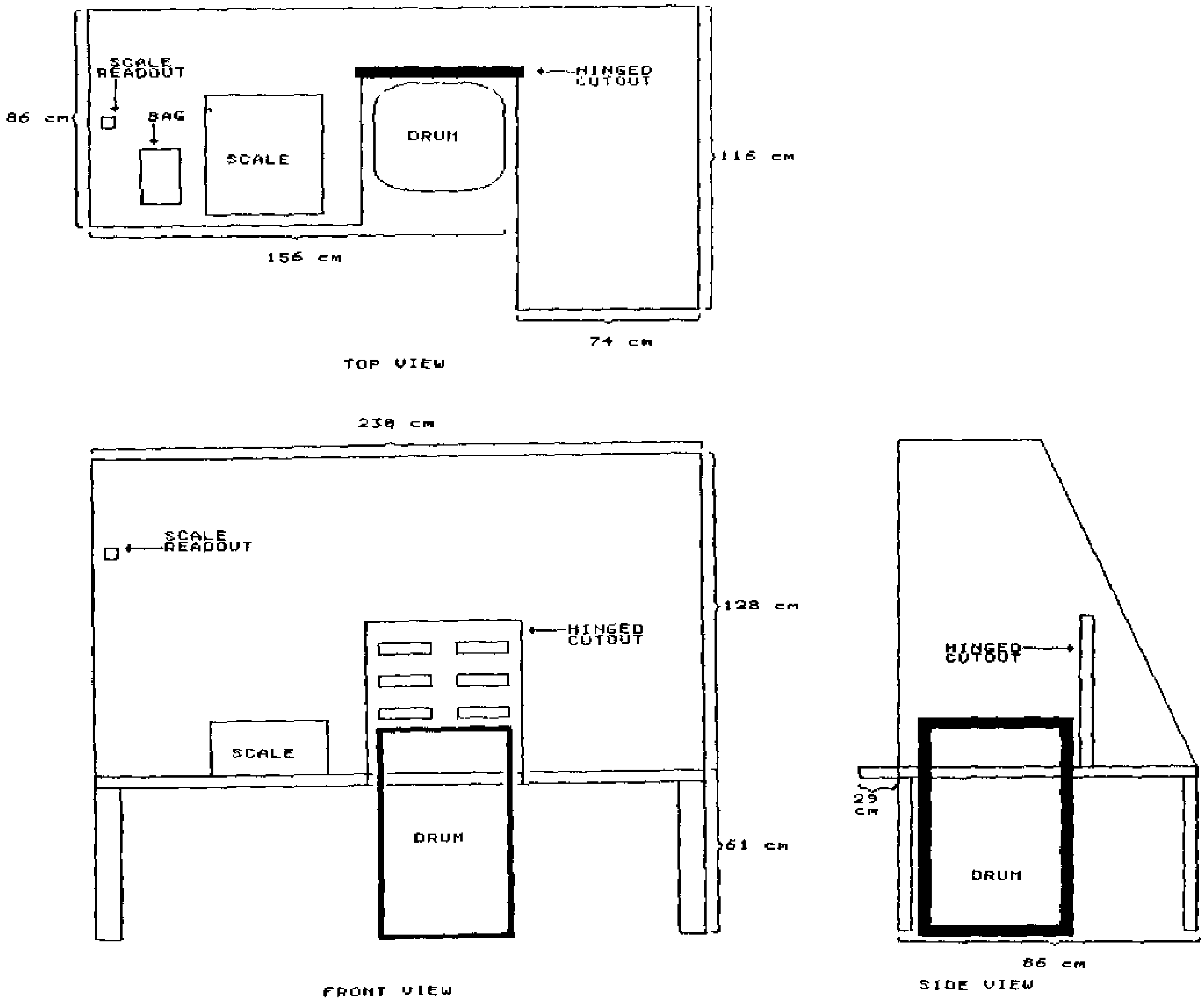


Figure 1 Hood Layout (inside dimensions)

opening include: surface contamination of the bag, opening and emptying the bag, and discarding the empty bag. These exposure sources and methods of controlling these sources of dust exposure have previously been studied and are discussed elsewhere.[1,4] Table 2 lists the apparent sources of dust exposure.

Table 1. Summary of Exposure Limits

Substance	OSHA PEL[2] mg/m3	ACGIH TLV[3] mg/m3
Nuisance Dust-Total	15	10
Respirable Dust	5	5

Table 2. Possible Dust Exposure Sources

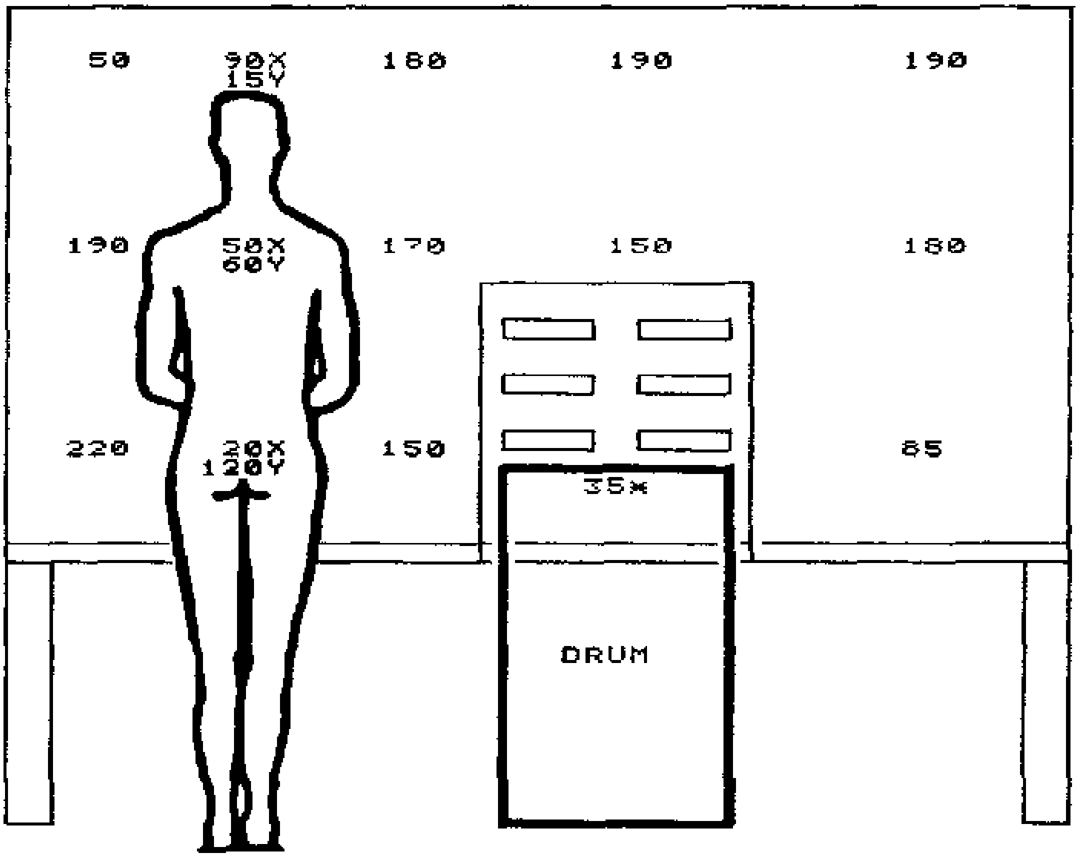
Exposure Source	Comment
Worker clothing	Manual compounding and associated activities generally result in clothing which appear to be dusty and this clothing could become a dust exposure source.
Spillage	Powdered materials are observed to be spilled during manual weigh-out operations. As a result, work surfaces are covered with dust and become sources of dust emissions. This spillage occurs because bags leak dust, scoops are too large in relation to the weigh-out bags, human error, and the handling of emptied powdered material bags.
Dusty bags	Powdered materials are frequently shipped to the plants in bags. Workers transfer materials from these bags to other containers. These bags are frequently dusty and the simple act of lifting them from a pallet to a work surface has been reported to elevate worker dust exposure.[1,4]

Table 2. Possible Dust Exposure Sources (continued).

Exposure Source	Comment
Scooping	When the powdered material is stored in drums, the worker must reach into these drums to transfer the powder to a bag which rests on the scale. When the worker is transferring material from a nearly empty drum, his breathing zone is between the local exhaust ventilation and the dust emission sources.
Empty bag disposal	Frequently, workers are scooping solids from paper bags such as three ply kraft bags. When these bags are emptied, they must be discarded. Handling the dust emissions during bag disposal has been treated in a previous study.[1,4]
Weigh-out and transfer	Transferring material from one container to another. This operation inevitably creates a dust which is not totally controlled by local exhaust ventilation.
Work practices	During the study of manual weigh-out and transfer operations, differences in work practices between workers may cause large variations in personal dust exposure.

Ventilation Description

The ventilated booth is used in an attempt to capture the airborne dust generated by bag emptying and the weigh-out and transfer of powders. Air flow patterns in this hood were documented by using smoke tubes to determine the direction of the air flow and using a velometer to measure the magnitude of the air flow. All measurements were made with a member of the survey team standing at the hood face, in a manner similar to the worker's normal working position. Figure 2 shows the results of the hood velocity measurements. While air velocities varied from 35 to 220 feet per minute, the direction of flow varied substantially as well. Eddies existed in several places within the hood, the most important being the one found in front of the worker as shown in Figure 3. Air was found to flow straight up the worker's body and into his breathing zone. This air current would force any dust generated close to the worker's waist to flow directly into his breathing zone. Another eddy was discovered inside the drum. The air entered the back area of the drum, moved down to the surface of the powder, and exited from the front of the drum carrying with it some of the powder. As shown in Figure 4, this stream of dusty air flowed over the hinged platform. When the worker was scooping from the bottom of the drum, his breathing zone was in this flow of dusty air.



* Velocity reading taken outside of drum.

All reading are air flow into the hood unless otherwise noted.

"X" direction is into the hood; "Y" direction is vertical.

Figure 2. Air Velocities into Weigh-out Hood

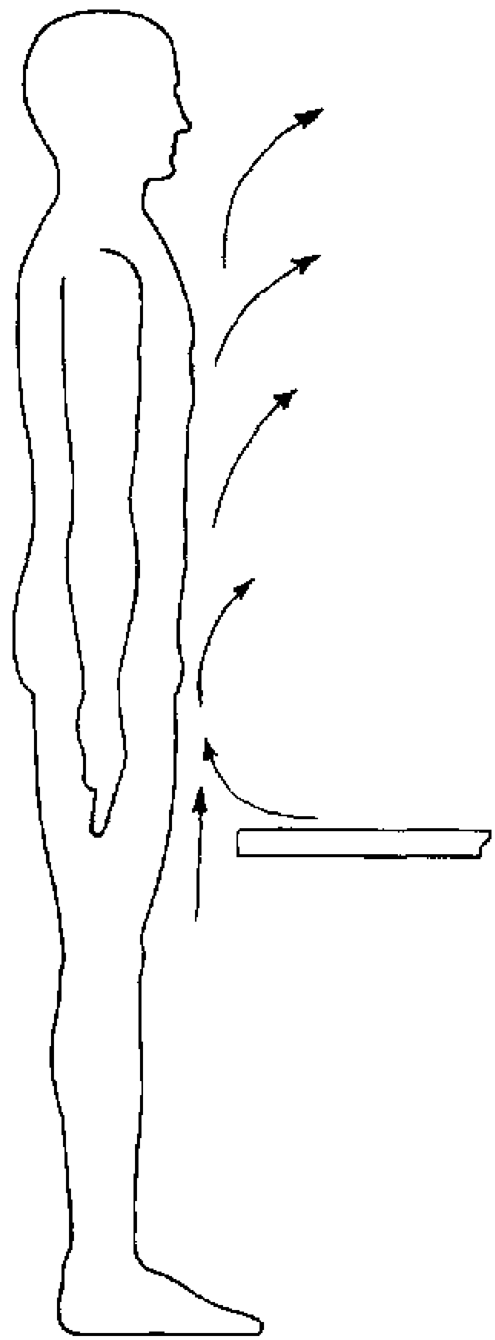


Figure 3. Eddies in Front of Worker.

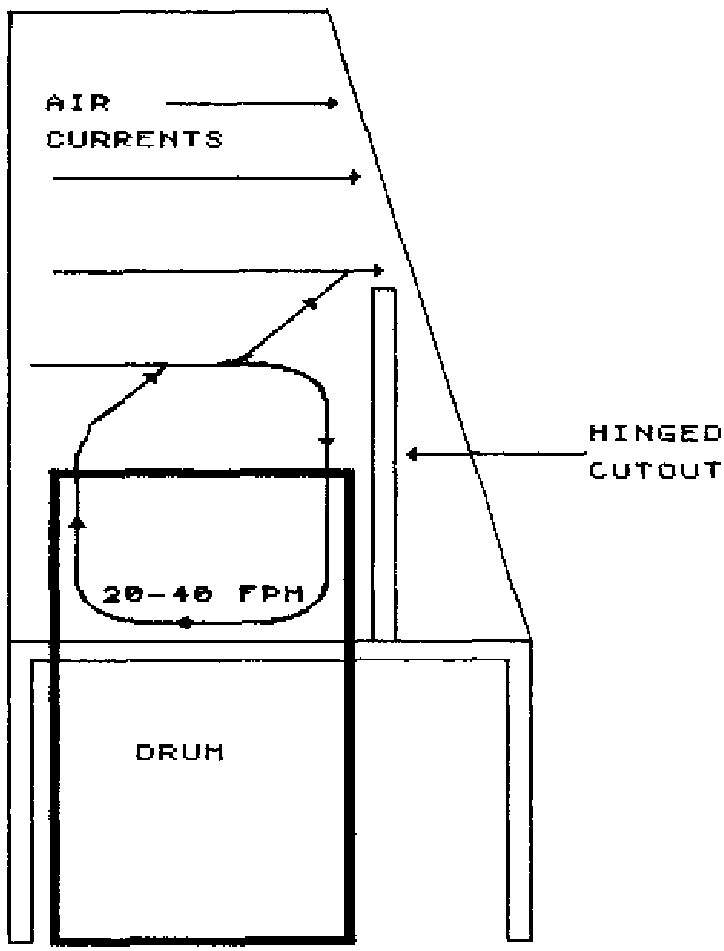


Figure 4. Eddies Due to Hinged Cutout.

Ergonomic Evaluation

Descriptive information and anthropometric measurements were taken on three workers. This data was taken to evaluate the relationship between dust exposure, worker size, and work practices.

Worker Description

Figure 5 diagrams the anthropometric measurements for these workers. The descriptive and anthropometric results are summarized in Table 3. The descriptive data show that while these workers had some experienced in jobs involving materials weigh-out and transfer, it was not their regular job. The third worker was more than 25 years older than the other two workers, had the highest seniority of the three workers (31 years), and was experienced with a variety of jobs including materials weigh-out and transfer. Anthropometric measurements taken from these 3 workers show the female worker (worker #1) to be in the 30-40th percentile for stature, 5 percentile for height of hips, and 5 percentile for forward reach compared to a standard population.[5]. Worker #2 is a tall male who measured in the 90-95 percentile for all anthropometric measurements taken.[5] The third worker was also male and measured in the 40th percentile for most anthropometric categories.

Job Description

Many powdered raw materials are received at the plant in paper bags. The acrylic copolymer powder used during this study, came in plastic lined bags weighing 50 pounds each. The bags of powder were manually lifted from a pallet, carried, and dumped into a fiber drum measuring 33 inches high and 21.5 inches in diameter. The powder was transferred from the drum to 5-pound paper bags via a hand scoop. These small bags containing powder were then weighed on a scale. Usually, two scoops of material were required to achieve the desired weight. Once filled, the bags were manually closed by folding them from the top down. After closing, the bag was placed in a large cardboard bin approximately six feet behind the worker. This fundamental work cycle was repeated until either the drum was empty or the needed number of bags had been weighed out. Occasionally (after approximately 10 bags were weighed out) the worker cleaned the scale of any spilled material by brushing it off with his hand. The worker then retared the scale using a new, clean bag.

The material being weighed in this experiment required 2.64 pounds for each batch. The work standard for this weight was 100 batches in 40 minutes. The workers received incentive pay when they exceeded this standard.

1. Body Length.

2. Shoulder Height.

3. Hip Height.

4. Shoulder Breadth.

5. Foreward Reach.

6. Elbow Height.

7. Underarm Height.

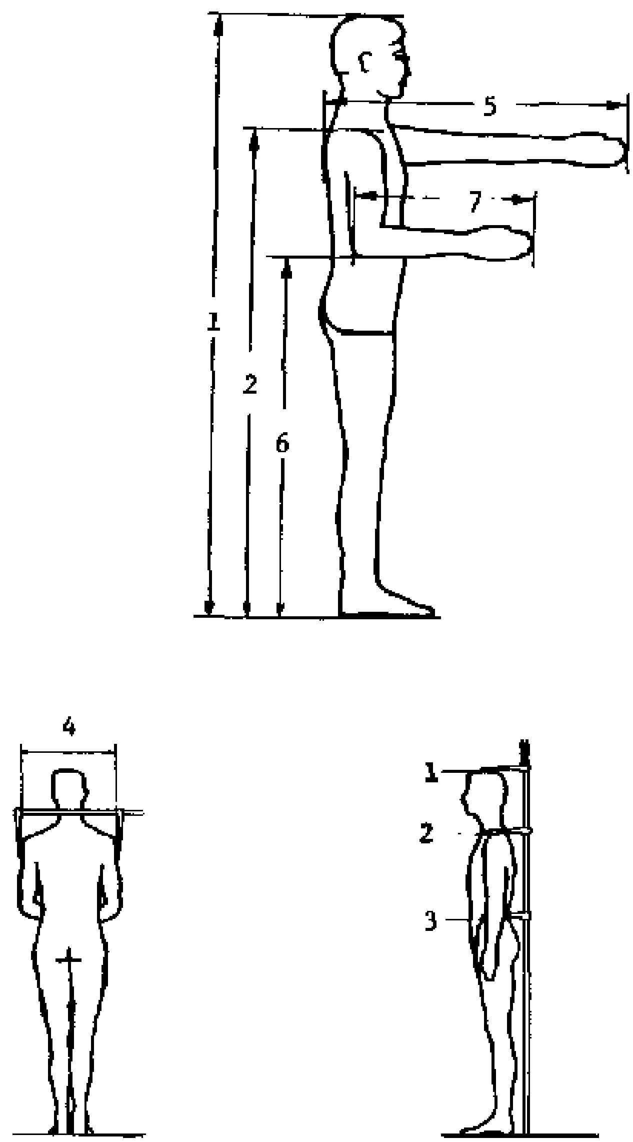


Figure 5. Anthropometric Measurements.

Table 3. Descriptive & Anthropometric Measurements.

Measurement (cm)	Worker 1	Worker 2	Worker 3	Population Percent[5] 50/50 Male Female 5th	50th	95th
Job Title	Utility Worker	Utility Relief	Henshaw Operator			
Gender	Female	Male	Male			
Handedness	Right	Right	Right			
Work Hand	Both	Right	Right			
Age, Years	28	30	55			
Length of Employment	8.5 yr.	9 yr.	31yr.			
Weight, Pounds	113	161	200 (approx.)			
Body Length	164.6	183.7	170.1	154.4	168.0	183.0
Shoulder Height	134.5	153.4	141.1	124.8	137.4	151.7
Hip Height	96.8	111.2	99.4	94.9	103.9	113.5
Shoulder Breadth	40.6	45.9	49.4	36.3	42.3	47.8
Foreword Reach	72.4	86.5	82.9	69.1	77.9	88.8
Elbow Height	100.4	112.2	106.1	96.4	106.7	116.3
Underarm Length	38.3	46.2	43.0	31.9	36.7	41.1

The Work Cycle

A portable video tape ensemble consisting of a recorder, light-sensitive VHS tape, and camera, documented the work cycle. The work cycle was then broken down to fundamental elements as described by Gilbreth[6] and Armstrong.[7] The video tapes were played back in a laboratory in slow-motion and stop-action to provide detailed information on work practices, posture, and equipment. This procedure helped to determine if certain elements in the cycle could lead to increased dust exposure for the worker.

The work elements during the weigh-out and transfer process were also examined over time to determine the effect that powder depth in the drum had on cycle times and work practices. This was accomplished by examining the video tape and taking two time measurements for removal of powder from the drum to fill bags in batch weighing process. The first time measurement was for total cycle time of the workers at three drum levels: full, 1/2 full, and near empty. The second time measurement was for time spent scooping powder from the drum. This cycle time began when the worker first grasped the scoop and ended when the worker positioned the scoop over the bag for precise weighing. Table 4 shows the results of the cycle times for different drum powder levels. Table 5 shows the results for scoop cycle times for these same levels. The basic functional elements for the right and left side of the body during the workers' work cycle are shown in Table 6. Table 7 shows the "critical" elements in the fundamental work cycle that may expose the workers to higher levels of dust relative to other elements in the work cycle.

Table 4. Fundamental Cycle Times for Drum Powder Levels (seconds).

Worker	FULL			1/2 FULL			EMPTY		
	mean	s.d.**	n*	mean	s.d.	n	mean	s.d.	n
1	18.99	1.21	2	-	-	-	22.72	2.26	6
2	-	-	-	29.59	3.29	6	37.88	1.57	5
3	22.55	2.69	6	22.48	1.16	6	26.55	2.37	6

* n - number of samples
** s.d. - standard deviation

Table 5. Scooping Cycle Time for Drum Powder Levels

Worker	FULL			1/2 FULL			EMPTY		
	mean	s.d.	c.v.	mean	s.d.	c.v.	mean	s.d.	c.v.
1	6.43	0.14	2	-	-	-	7.53	0.81	6
2	-	-	-	10.51	2.32	6	10.43	1.28	5
3	6.05	0.50	6	7.17	0.48	6	9.19	0.76	6

Table 6. Fundamental Work Cycle Elements.

Left Side	Right Side
1. Reach for Bag	1. Idle
2. Grasp Bag	2. Idle
3. Open Bag	3. Idle
4. Move Bag over Drum	4. Reach for Scoop
5. Position Bag over Drum	5. Load Powder on Scoop
6. Hold Bag	6. Move Scoop to Bag
7. Hold Bag	7. Dump Powder from Scoop to Bag
8. Move Bag to Scale	8. Hold Scoop
9. Position Bag on Scale	9. Move Scoop
10. Release Bag, Inspect Scale	10. Hold Scoop
11. Hold Bag	11. Position Scoop over Bag
12. Hold Bag	12. Add or Remove Powder from Bag with Scoop or Hand
13. Release Bag	13. Move Scoop to Drum
14. Idle, Inspect Scale	14. Release Scoop in Drum or on Table
15. Grab Bag	15. Grab Bag
16. Fold Bag	16. Fold Bag
17. Release Bag	17. Grab Bag
18. Idle	18. Move Bag into Shipping Bin
19. Idle	19. Position Bag in Shipping Bin
20. Move to Booth	20. Move to Booth

Table 7. Critical Elements in the Work Cycle Which May Increase Dust Exposure.

Side/Element (L=left,R=right)	Comment
L 3	The worker opens the paper bag by "flicking" his wrist to force air into the bag to open it. This technique is an efficient time saver but may generate residual airborne dust from the surrounding work station.
R 5,6,7	Scooping powder, moving the powder to the bag, and dumping the powder into the bag may cause significant airborne dust exposure. Dust exposure may be caused by a combination of mechanical transfer of dust from the 55-gallon drum to the bag and the proximity of the worker's breathing zone being near the transfer process. As the drum is emptied the worker has to reach deeper into the drum to get the powder. During this reaching process he partially puts his head into the drum to retrieve the material. Because the drum is an unventilated confined space, it is hypothesized that dust exposure may increase as the drum is emptied by the worker.
L,R 16	Folding the bag pleats and closing the filled paper bag causes residual air and dust to rapidly escape from the bag. This process forms a small but visible dust "cloud" which migrates toward the worker's breathing zone.

Job Description and Work Cycle of Experienced Worker

In the course of performing this survey, a highly experienced worker was observed at another manual weigh-out station. His actions were recorded on video tape to compare his work practices and cycle times to those of the three workers studied. No anthropometric measurements were made on this worker. Table 8 shows the experienced worker's cycle time, and standard deviation, for a similar weigh-out and transfer job. Table 9 shows the elements which comprised this workers basic work cycle. While a smaller weight of material was required, (1.2 pounds versus 2.6 pounds) the batch weighing and material transfer process was similar. The cycle time for this worker was approximately 66 percent less compared to the the average cycle time for the 3 workers above. This difference was primarily the result of efficient work practices and motion economy which eliminated several nonproductive steps. These step saving practices were the result of a worker configured work station where all materials required to perform the weigh-out and transfer process were within

Table 8. Basic Cycle Time for Experienced Worker (seconds).

Work Cycle Time	Standard Deviation	Sample Size
5.35	0.82	5

Table 9. Fundamental Work Cycle Elements Experienced Worker.

Left Side	Right Side
1. Move hand to bag	1. Hold scoop
2. Reach for bag	2. Hold scoop
3. Grasp bag	3. Move scoop to drum
4. Flick open bag	4. Position scoop in drum
5. Idle	5. Use scoop
6. Move bag to scale	6. Move scoop to scale
7. Position bag on scale	7. Position scoop over bag
8. Hold bag	8. Pour scoop contents into bag
9. Idle (inspect scale)	9. Hold scoop
10. Grasp bag	10. Hold scoop
11. Move bag to receiving drum	11. Hold scoop
12. Inspect drum (see where to drop bag)	12. Hold scoop
13. Position bag	13. Hold scoop
14. Release bag	14. Hold scoop

easy reach. Specific step saving practices included simultaneous use of both hands (the left hand to grab a bag while the right hand reached and scooped powder material), precision weighing of powder into the bag by careful scoop pouring while inspecting the weigh scale, and not folding the bags before putting them into the receiving drum (since the bags were bottom heavy there was no need to fold the bags to secure the powder contents). Because of other job demands, no personal dust measurements could be taken on this worker.

Musculoskeletal Hazards

There appeared to be two types of musculoskeletal hazards involved with this job. The first hazard was the method used by most of the workers to open the small bags for receiving raw material. These workers opened the bags by holding them by a flap and giving them a flick of their wrist. This type of motion may cause wrist and/or elbow tendonitis. The other musculoskeletal hazard was manual lifting and transfer of 50 pound bags of powder from the wooden pallets and carrying them to the fiber drums. Risk factors for manual lifting include weight lifted, size of the load, and frequency of lift. Personal risk factors include gender, age, anthropometry, lift technique, and strength. Because the bulk density of this material was 1.1 g/cc, the bags were large and awkward to handle. Lifting of heavy weights at a distance from the body may cause back injury.

To determine the degree of biomechanical stress during the lift and transfer process, the moment-arms of the body segments were calculated using "frozen" posture angles from the plant videotapes and a software program developed by the University of Michigan, Center for Ergonomics.[8] The anthropometric, posture, and load handling information were coded into a microcomputer which calculated estimates of the resultant forces and torques created by the load at the hand(s) for the elbows, shoulders, L5/S1 spinal disk, hips, knees, and ankles. In the sample analysis performed here, worker #3 (male) was evaluated for manually lifting a 50 pound bag of powder and transporting it to the drum. Figure 6 shows the worker postured to "pull" the bag closer to his body before lifting. Here, the elbow was the limiting joint for performing this type of movement. This worker appeared very strong and had no difficulty in pulling the load closer to the body before lifting. For the majority of the population, however, there is a significant limitation in the elbow joint for pulling a 50 pound load closer to the body (3% of females capable). This can be a limiting factor when recommending manual material movement techniques. This pull task does not result in any compressive loading of the back. Figure 7 shows the worker postured to lift this load from the pallet. Nearly 90% of average (50 percentile) male and female workers are capable of lifting this 50 pound bag in this posture.[5] Compressive forces for the back, as computed from the posture recorded on video tape, are 4342 Newtons (976 pounds) for average size males and 3613 Newtons (812 pounds) for average size females. The NIOSH Work Practices Guide for Manual Lifting[9] indicates that these back compressive forces may result in an overexertion back injury if not controlled administratively or through engineering controls. [The Work Practices Guide recommends administrative controls when back compressive forces exceed the action limit of 3425 Newtons (770 pounds), and engineering controls when back compressive forces exceed the maximum permissible limit of 6361 Newtons (1430 pounds)]. Work practices and lifting techniques play a large role in limiting the risk for back injuries. To demonstrate this point, calculations were performed for this worker lifting a 50 pound bag at the initial contact point (Figure 6). A high percentage of both male and female employees are capable of lifting such a load, however, the back compressive forces increases to 5456 Newtons (1227 pounds) for the average male and to 4626 Newtons (1040 pounds) for the average female. This is an increase of more than 1000 Newtons for such a subtle difference in lift angle. The workers involved in heavy materials handling should be aware of the subtle but effective techniques for lifting to prevent back injuries.

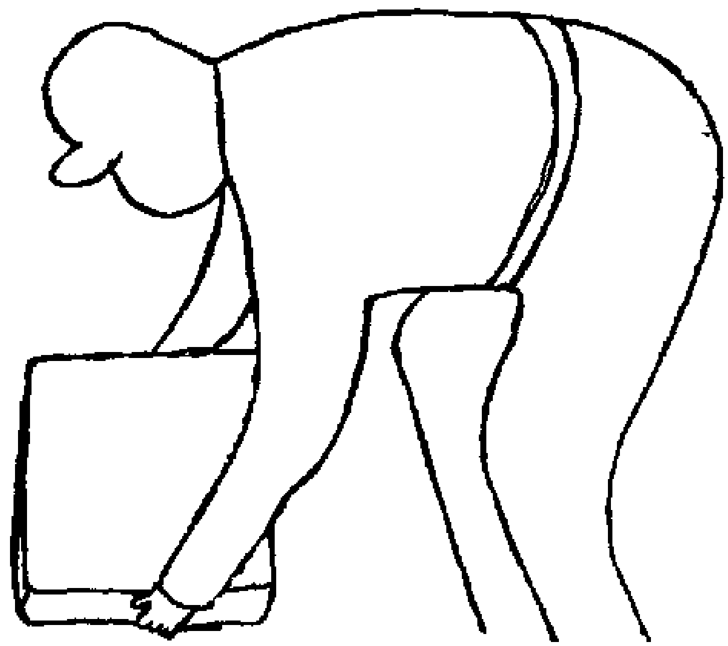


Figure 6. Worker in "Pulling" Position.

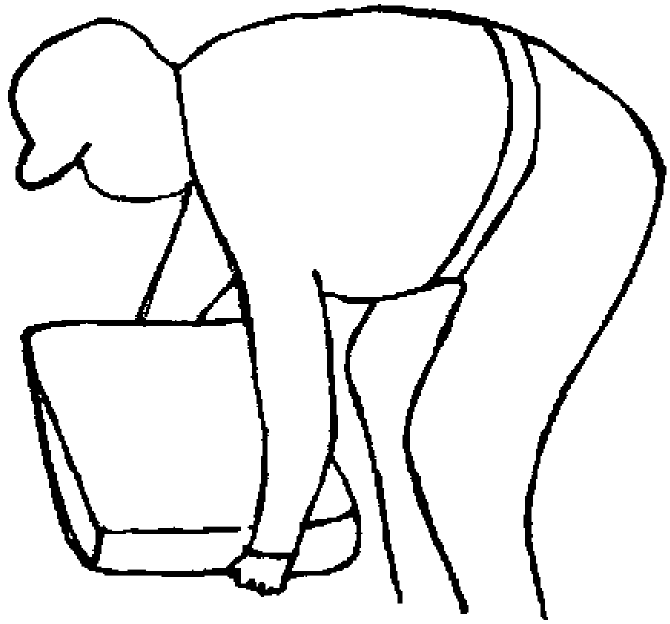


Figure 7. Worker in Lifting Position.

METHODOLOGY

Experimental Design

This survey was conducted to evaluate the effects of both dusty clothing and depth of scooping from the drum on the worker's dust exposure. Two hypotheses, therefore, were evaluated and are stated as follows:

1. Dusty clothing affects the worker's dust exposure.

2. The depth from which the worker scoops powder affects his dust exposure.

A 2x2 factorial experiment with 6 replications was conducted to evaluate the effects of clothing and depth of scooping upon dust concentration. A total of 24 gravimetric runs were conducted over a three day period using a different worker each day. Four runs were conducted in the morning and four in the afternoon. Of these groups of four, one run would look at scooping from the bottom of the drum with clean clothing, one at scooping from the bottom with dirty clothing, one at scooping from the top with dirty clothing, and one at scooping from the top with clean clothing. The dirty clothing used was the worker's own coveralls in which he performed some operations which were considered dusty, such as emptying a bag of powder into the drum. The clean clothing consisted of disposable coveralls which were used once and then discarded. A drum was considered full if it was two thirds or more full and considered empty if one third or less remained in the bottom.

In addition to the gravimetric air sampling, the effect of depth of scooping on dust concentration was further evaluated using real-time instrumentation. A single worker (worker 3) was used to perform this portion of the experiment. It was conducted with dirty clothing and began with a full drum. The worker weighed out material until the drum was nearly empty. During this period, the real-time instruments monitored the respirable dust concentration.

Sampling Procedures

The equipment used in this study is listed in Table 9. For the gravimetric method, air was drawn through a filter and critical flow orifice by a carbon vane pump. The filters were MSA type FWSB 37-millimeter with 5.0 micron pore size which is mounted mounted in a filter cassette. The critical orifices were calibrated at 14-16 liters of air per minute. The filters were connected to the orifices with Tygon tubing and a lure which fastened to the filter cassette. While in the field, flow rates of several of the filters were checked. Because of some variation in the flow rates, all of the filters used were checked in the laboratory for flow rate and pressure drop across the filter. The apparatus used to measure the flow rate and pressure drop is shown in Figure 8. All orifices were calibrated at atmospheric pressure. However, in the field, the pressure at the orifice differed from atmospheric by the pressure drop across the filter. Because the flow rate through a critical orifice is proportional to the upstream absolute pressure[10], the

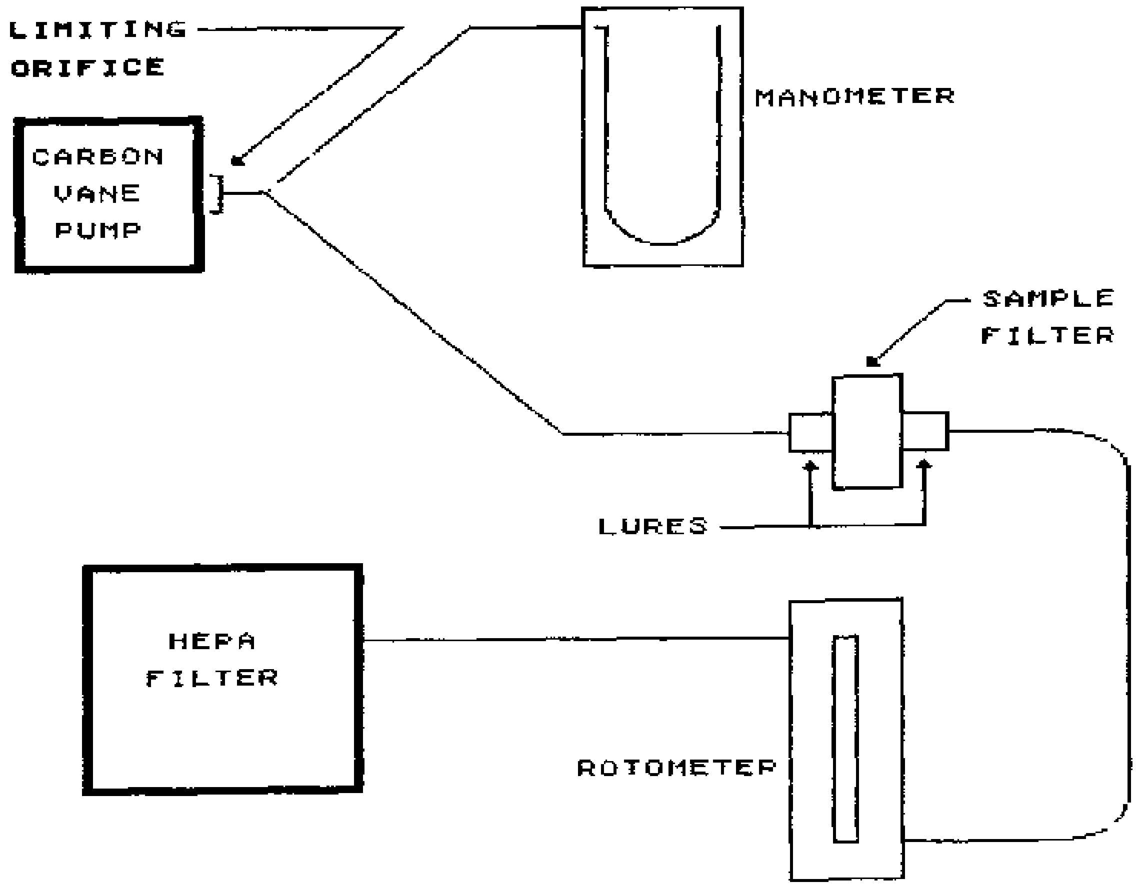


Figure 8. Filter Flow Calibration Assembly.

Table 9. Equipment List

Item	Use
GCA Real-Time Aerosol Monitors-2 (RAM)	Respirable dust monitoring at fixed locations.
PPM Hand-Held Aerosol Monitor (HAM)	Respirable dust monitoring on worker.
Carbon Vane Pumps 15 lpm at 20 inches of Hg vacuum	Sampling of total dust.
MSA Model G Pumps 1.7 lpm	Active sampling for the HAMs.
Video Cameras and Recorder with:	Recording of events during real-time sampling.
Time input including minutes and seconds	
Automatic focus and zoom lense	
TSI Air Velocity Meter	Measuring hood face velocity.
Apple II Plus computer equipped with:	Record analog output of RAMs, HAMs, and event marking switches.
dual disk drives	
AI 13 Card (Interactive Structures)	Analog to digital conversion.
The Clock Card (Mountain Computer)	Internal clock for computer.
Anthropometric Equipment Kit	To take anthropometric measurements of subject workers.

flow rates were corrected for the effect of this pressure loss by using the following equation:

$$Q1 = Q2\ (P1 - P2)\ /\ P1$$

where, Q1 is actual flow, Q2 is calibrated flow, P1 is atmospheric pressure, and P2 is the filter pressure loss.

Table 10. Air Sampling Locations
Gravimetric Method

Location Number	Location Description	Comment
1	Stand 28 ft. from hood face	Background sample.
2	I-beam 5 ft. from hood face	Over bin sample.
3	Hood face	1 ft. below worker's head on left wall of hood.
4	Worker's hat	On top of hat.
5	Left worker's lapel	Used on all runs.
6	Right worker's lapel	Not used on first 4 runs.

Just prior to the beginning of a run, all the necessary filters were fastened into place. A run generally last 10 to 20 minutes and usually involved the filling of 24 to 36 bags at 2.64 pounds per bag. The total bags filled along with the total run time, the orifice and calibration flow rate, and the filter number were recorded. Halfway through the run, the drum being used would have to be replaced by another which was full (or one third full). This transfer was never done by the subject worker, but rather by the survey team. At the end of a run the pumps were turned off and the filters recapped. At this point a new set of filter would replace the used ones, and a new run would begin. Gravimetric air sampling locations are given in Table 10 and diagrammed in Figure 9.

For the real-time analysis, two types of instruments were used: HAMs (hand-held aerosol monitor) and RAMs (real-time aerosol monitor). Two RAMs were used, one for background dust and one for dust within the hood, while one HAM was used for monitoring the worker's breathing zone dust concentration. Real-Time sampling locations are given in Table 11.

The RAM's and the HAM's use forward-scattered light to precisely monitor respirable dust concentrations. The instrument's manufacturer claims that the monitors' precision is better than 0.1% full-scale. Calibration curves generally have correlation coefficients better than 99%.[11] However, the instruments calibration does depend upon the aerosol. Rubow and Marple[11] noted that for two coal dust test aerosols, there was a 20% difference in the slope of the calibration curve. This study bases conclusions upon measuring concentration difference to determine what increases concentration. As long as weighing out the powder does not change its optical properties, the slope of the calibration curve will not change and the study's ability to detect concentration differences will be unaffected.

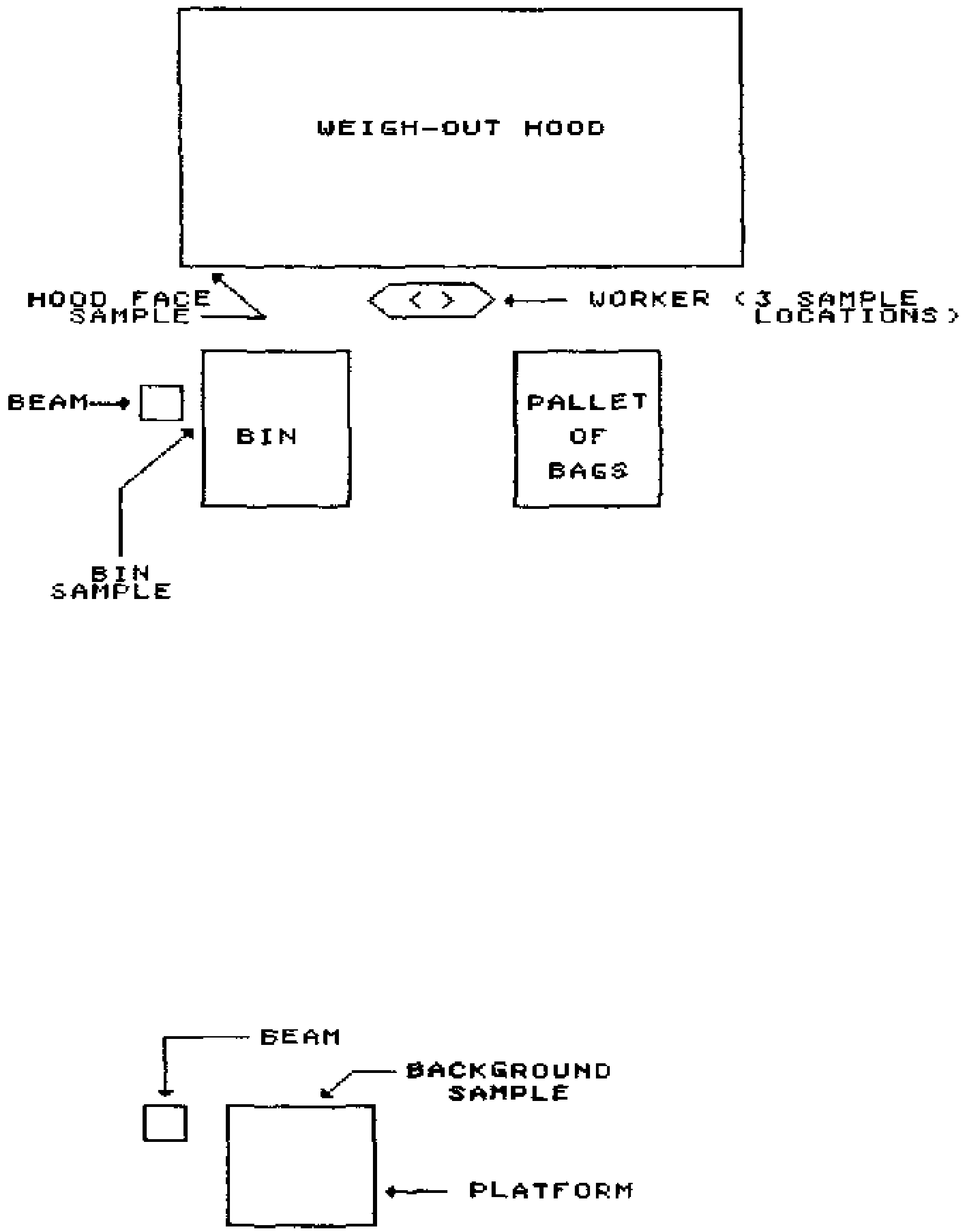


Figure 9. Filter Sample Locations.

The RAMs' and the HAM's analog output were connected to an Apple II Plus computer through an AI 13 analog to digital converter. The computer was programmed to convert these digital signals to voltage values. The computer was further programmed to take readings every two seconds and to store these values in several data files. Each data file contained 100 readings, and it took the computer 30 to 60 seconds to write the readings to the disk. During this time, the computer would not take any readings, so the worker was instructed to stop work until the computer was finished writing the disk. The internal clock of the computer was synchronized with the clock on the video camera. This enabled the video to be viewed along side the computer output and to see what the dust exposure is for any given movement by the worker. This experiment lasted about 22 minutes with 56 bags of powder weighed out. Before the experiment was conducted, the worker emptied three bags of powder into the drum. The experiment was terminated when there was very little powder left in the drum.

Table 11. Sampling Locations
Real-Time Sampling

Location Number	Location Description	Comment
1	10 feet from hood face	RAM, background sample.
2	Beside the scale	RAM, interior of hood.
3	Worker's left lapel	HAM, worker breathing zone.

Results

The air sampling data were statistically analyzed to determine which factors affect dust generation. The short term dust samples were analyzed to determine whether worker, clothing, depth of scooping, and sampling location affected dust concentrations. Measurements taken with the HAM and the two Ram's were analyzed to study the association between the analog output of the Ham and the individual components of the job.

Analysis of Real Time Data

The analog output of the real time instrumentation mounted at the locations described in Table 11 were statistically analyzed to resolve two issues:

1. How much powder can the worker remove from a full drum before his dust exposure, as measured by the HAM, increases?

2. Which components of the worker's job contribute to his dust exposure?

The details of this statistical analysis are summarized in Appendix 1. The analysis involved fitting the analog data to a model which included autoregressive terms and structural terms.

A key assumption in data analysis is the independence of measurements.[12] The autoregressive terms are needed because the successive readings of the instrument response are not independent. This lack of independence is caused by the dynamics of the situation. When a dust generating event occurs, dust concentrations do not increase immediately; transportation time is needed for the air to move the dust cloud from the point of generation to the inlet of the instrument. For example, dust generated by scooping the powder out of the drum will travel 1 to 2 feet in air which is moving at a speed of 0.5 to 1 feet per second. Once, the air arrives at the inlet to the instrument, it is sampled. The instrument was used with a time content of 1 second which implies that the instrument will require 2-3 seconds to complete 90 % of its respond to a step change in concentrations.[13] As a result, instrument response could lag dust generating events by 2-5 seconds. This suggests that autoregressive terms are needed in the analysis.

The model's structural terms included parameters describing the number of bags which have been weighed-out and the specific task that the worker was doing. These tasks were:

1. Scooping. During this task, the worker removed material from the drum and poured it into the bag.

2. Weighing. Adjusting the final weight of the material in the bag.

3. Turning. Placing the bags into the bin.

The data is listed in Appendix V; a plot of the predicted values using the

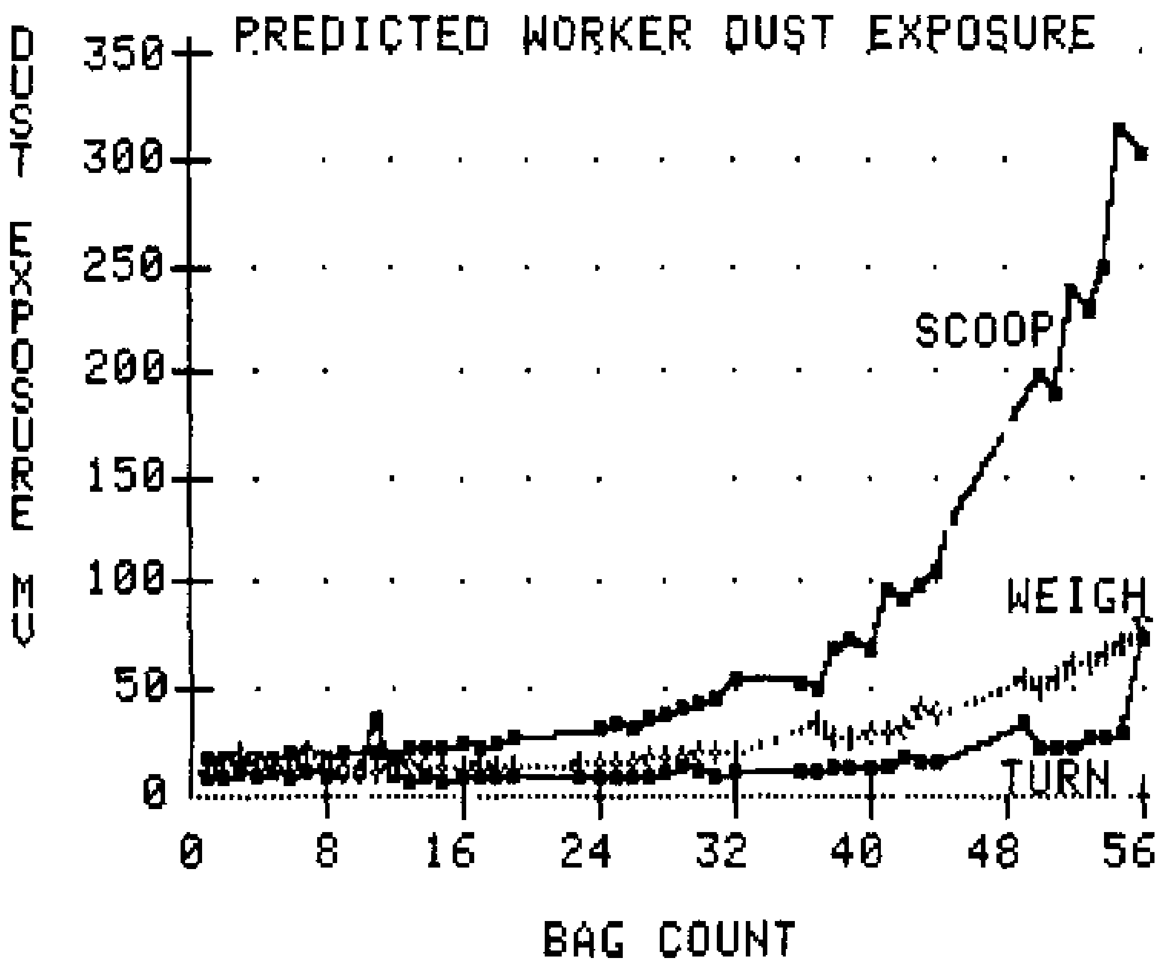


Figure 10. Predicted response of HAM in millivolts plotted as a function of bag count for scooping, weighing and turning. The readings plotted are the last reading taken while scooping, weighing and turning for each bag.

model is shown in Figure 10. This figure shows that the worker's dust exposure (the analog output of the HAM) increased while the worker is scooping. During weighing and turning, the worker's dust exposure either remains constant or fails to increase as fast. Figure 11a, the selected real-time data, and Figure 11b, the selected predicted data, show this through the direction of the slope of the curves during scooping weighing and turning. A positive slope indicates an increase in worker dust exposure, while a negative slope indicates a decrease.

This suggests the most of the workers dust exposure is caused by the scooping of the power from the drum. Dust exposures caused by weighing and turning are either controlled by the ventilation system or are much smaller than the dust exposures caused by scooping. The HAM response during the weighing activity appears to be associated with higher dust exposure than the turning activity. The scooping activity causes an order of magnitude increase in the worker dust exposure and several seconds are required for the instrument's response to reach steady state. Possibly, the difference in exposure between weighing and turning is an artifact caused by the high dust exposures during scooping. However, it is just as possible that weighing contributes to the worker's dust exposure and the difference between the turning and weighing is real.

Analysis of the Filter Data

Statistical analysis of the dust concentration data was conducted to address the study's hypothesis:

> Dusty clothing and the level of material in the drum affect the worker's dust exposure.

To address the hypothesis, a factorial experiment was conducted which involved the following variables:

Clothing. The worker wore either dirty work clothing or clean Tyvek clothing.

Drum. The worker scooped material from either the bottom third of a drum or from the top third of the drum.

Location. The sampling locations in Table 10.

Worker. The three workers who worked at the booth.

The concentration data was analyzed as if it were a full factorial experiment involving the four variables listed above. Before analysis, the natural logarithms of the concentrations were taken. The SAS General Linear Models Procedure was used to perform the analysis of variance, while multiple comparison tests were used to examine differences between treatment means.[14]

The pressure loss through the filter may have induced some bias in the analysis of the data. As a result, the statistical analysis was done with both censored and uncensored data. Data was censored by deleting data records

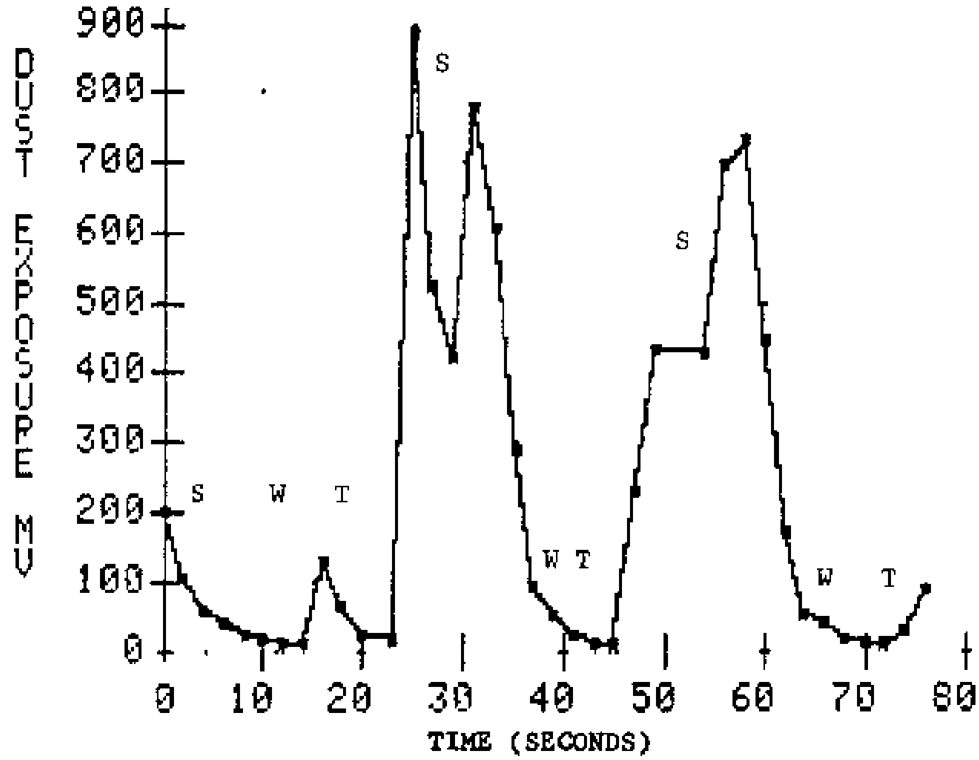


Figure 11a. Actual Real-time Data for Bags 51 Thru 53.
S-Scooping, W-Weighing, T-Turning.

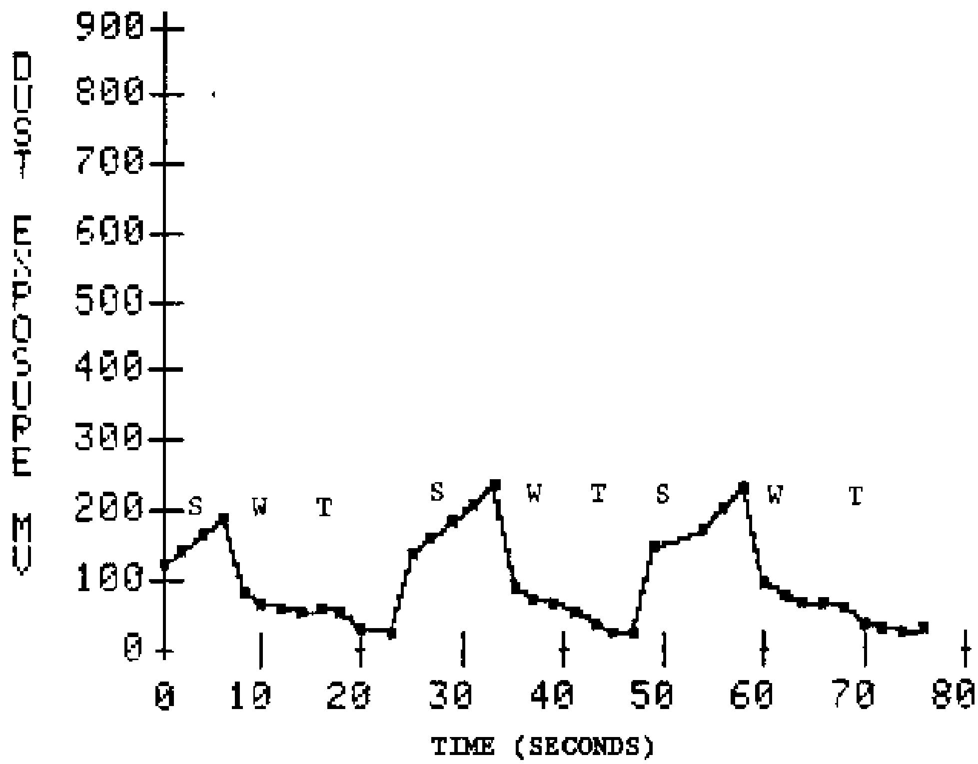


Figure 11b. Predicted Real-time Data for Bags 51 Thru 53.
S-Scooping, W-Weighing, T-Turning.

which had pressure losses greater than 48 inches of water and filter weight gains of less than 2 milligrams. Filters with weight gains in excess of 2 milligrams could have increased pressure losses due to loading. For example, three filters had weight gains of over 50 milligrams and pressure losses in excess of 50 inches of water.

Generally, censoring the data did not have a major impact upon the conclusions drawn from the statistical analysis. In some cases, the probabilities associated with interaction terms in the analysis of variance shifted. The data was quite variable. Adjusting the flow rates for the measured pressure loss involved as much as a 20% adjustment in the volume. At worst, the error in the sample volume and computed concentration is 20%. This error is small compared to the errors estimated in the analysis of variance. The geometric standard deviation computed from the mean square error of the analysis of variance was 3. For such data, the two standard deviation limits were one-ninth to nine times the geometric mean.

For both the censored and uncensored data, an analysis of variance showed that location, worker, and depth of scooping from the drum significantly affected concentration. The terms involving the workers' clothing do not appear to affect concentration. As a result, clothing was excluded from subsequent analyses. The results of the analysis conducted for the censored and uncensored data are listed in Table 12.

Table 12. Analysis of Variance Conducted to Evaluate Whether Clothes Affected Concentration

Source of variation	degrees of freedom	Probability of seeing such large differences due to chance	
		Uncensored data	Censored data
location	5	0.0001	0.0001
worker	2	0.0016	0.087
drum	1	0.0007	0.0026
clothes	10	0.92	0.54
drum-clothes interaction	1	0.35	0.35
location-clothes interaction	5	0.66	0.82
degrees of freedom for error		123	98

For both the censored and uncensored data, the total dust concentration data was analyzed as if it were a full factorial experiment involving sampling location, worker, and depth of scooping from the drum. The results of the analysis of variance is shown in Table 13. With the exception of the location-worker interaction, separate analysis of the censored and uncensored data leads to the same conclusions. Both analyses show that the height of material in the drum had a very significant affect upon concentrations. In addition, the drum-location interaction and the drum-worker interaction are significant. This implies that the effect of level of material in the drum varies with the sampling location and the worker. As a result, the separate statistical analyses were conducted for the different levels of material in the drum.

Table 13. Analysis of Variance For Complete Data Set.

Source of Variation	Degrees of Freedom	Probability of seeing such large differences due to chance	
		Uncensored data	Censored data
location	5	0.0001	0.0001
worker	2	0.0001	0.0001
drum	1	0.0001	0.0001
location-worker interaction	10	0.0077	0.18
drum-worker interaction	2	0.008	0.0017
location-drum interaction	5	0.0017	0.016
location-drum-worker interaction	10	0.2	0.5
degrees of freedom for error		103	78

When the drum was full, an analysis of variance summarized in Table 14 showed that both sampling location and worker affected dust concentrations. Multiple range tests were conducted to examine differences in concentration due sampling location and worker. As shown in Table 15, the samples collected on the worker's were significantly higher than the area sampling results. Table 16 summarizes the affect of worker upon the geometric mean dust concentrations based upon all sampling locations. Worker 3, who is more experienced, had lower dust exposures than the other two workers.

Table 14. Summary of Analysis of Variance Concentrations When Drum is Full.

Source of variation	degrees of freedom	Probability of seeing such large differences due to chance	
		Uncensored data	Censored data
location	5	0.0001	0.0001
worker	2	0.004	0.018
location-worker interaction	10	0.07	0.5
degrees of freedom for the error term		51	41

Table 15. Comparison of Total Dust Concentrations by Location When Drum is Full.

Location	Uncensored data GM (mg/m^3)	N	Grouping*	Censored Data GM (mg/m^3)	N	Grouping*
Right lapel of worker	16	10	A	16	10	A
Left lapel of Worker	5	12	B	7.6	10	A,B
Worker's hat	2	12	B	4.6	9	B
Bin	0.47	12	C	0.43	10	C
Background	0.41	12	C	0.43	11	C
Face of hood	0.3	11	C	0.33	9	C

*-The grouping is based upon the Waller-Duncan multiple comparison test. This test is conducted at approximately an overall level of confidence of 95%. Means which have the same letter do not differ significantly.
GM - Geometric Mean
N - Number of samples

Table 16. Comparison of Geometric Mean Dust Concentrations by Worker When Drum is Full.

Worker	Uncensored data GM (mg/m^3)	n	Grouping*	Censored Data GM (mg/m^3)	N	Grouping*
2	2.3	24	A	2.8	22	A
1	1.9	21	A	2.1	20	A
3	0.73	24	B	0.9	17	B

*-Grouping is Based upon the Waller-Duncan multiple comparison test. Geometric Means with different letters differ significantly.

When the drum was less than one third-full, an analysis of variance summarized in Table 17, showed that sampling location and worker had a significant affect upon dust concentration. As shown in Table 18, samples collected on the worker were much larger than samples collected at fixed locations. Table 19 shows the effect of the worker upon the geometric mean dust concentrations. Worker 2, who had longer body dimensions than the other two workers, had significantly lower dust concentrations than the other two workers .

Table 13 indicates that there is a significant drum-sampling location interaction and worker-sampling location interaction. This indicates that there are significant differences in the geometric mean concentrations between Table 15 and Table 18. Apparently, the workers' dust exposure, as measured by the three personal samples are increased by scooping powder from the bottom third of the drum. The worker-drum interaction in Table 13 indicates the effect of height of material in the drum varied with the worker. Comparing Tables 16 and 19, the dust concentrations measured by worker 2 were apparently unaffected by the level of material in the drum. In contrast, scooping material from the bottom of the drum appears to increase the dust concentrations experienced by workers 1 and 3.

In the preceding analysis, the effect of worker is treated as an experimental block. The workers were tested only one day a piece. As a result, any worker differences may be confounded with conditions in the plant which may have changed from day to day. Because the preceding analysis showed worker to be a significant factor, statistical analysis, presented in Appendix I, was performed on the personal sampling data. An analysis of variance showed that worker, level of material in the drum, and the interaction between these two variables were statistically significant at a level of confidence greater than 95%. Table 20 shows how level of material in the drum affected each worker's dust exposure. The significance of the difference was estimated using linear contrasts.

Table 17. Summary of Analysis of Variance Concentrations When Drum is Empty.

Source of variation	degrees of freedom	Probability of seeing such large differences due to chance	
		Uncensored data	Censored data
location	5	0.0001	0.0001
worker	2	0.0018	0.0013
location-worker interaction	10	0.03	0.12
degrees of freedom for the error term		52	37

Table 18. Comparison of Total Dust Concentrations by Location When Drum is Empty.

Location	Uncensored Data GM (mg/m^3)	n	Grouping*	Censored Data GM (mg/m^3)	N	Grouping*
Right lapel of worker	54	10	A	57	10	A
Left lapel of Worker	26	12	B	31	11	A
Worker's hat	7.9	12	C	12	7	B
Bin	0.48	12	D	0.74	7	C
Face of hood	0.42	12	D	0.46	9	C
Background	0.33	12	D	0.43	11	C

*-The grouping is based upon the Waller-Duncan multiple comparison test. Means which have the same letter do not differ significantly.

Table 19. Comparison of Geometric Mean Dust Concentrations by Worker When Drum is Empty.

Worker	Uncensored data GM (mg/m^3)	N	Grouping*	Censored Data GM (mg/m^3)	N	Grouping*
1	3.9	22	A	5.6	17	A
3	2.7	24	AB	4.9	17	A
2	2.1	24	B	2.3	21	B

*-Grouping is Based upon the Waller-Duncan multiple comparison test, Geometric Means with different letters differ significantly.

Table 20. Effect of Level of Material in Drum upon Geometric Mean of Personal Dust Exposure.

Worker	Drum Condition		Significance of Difference
	Empty	Full	
1	49	8.0	0.2
2	14	14	0
3	16	1.4	0.006

Discussion and Conclusions

The two hypotheses, dusty clothing effects worker dust exposure and the depth of scooping from the drum effects worker dust exposure, were evaluated. After analysis of the data collected, the workers' dust exposure when wearing clean clothing was not significantly different from the exposure when wearing dirty clothing. Dusty clothing had no appreciable affect on the worker's dust exposure. The polyethylene-lined plastic bags and limited contact with heavy materials handling during experiment may have limited this type of exposure.

Depth of scooping from the drum, however, significantly affected the workers dust exposure. Depending upon the worker, scooping from the bottom of the drum increased the dust exposure. There appeared to be a possible relationship between the workers size and his dust exposure when scooping from the bottom of the drum. For the tallest worker, there was no significant difference between scooping from the bottom or the top of the drum. The shortest worker, though, had the greatest increase in dust exposure when scooping from the bottom versus the top. Because of the short worker's small arm length, she had to get her face closer to the drum in order to scoop from the bottom.

Work practices may also play a part in worker dust exposure during manual weigh-out of powders. While the tallest worker had no significant difference between the full and empty drums, he had a consistently higher dust exposure than the third worker when scooping from the top of the drum. This would suggest a relationship between work practices and worker dust exposure.

The filter data showed that worker's dust exposure was elevated when scooping from the top of the drum. The worker stands in front of the drum to scoop powder from the drum and to pour powder into the bag. This operation generates dust close to the waist of the worker. The air flow patterns, as shown in Figure 3, suggests that this dusty air is forced into the breathing zone of the worker. The filter data and the real-time data showed, further, that the increase in worker dust exposure was caused by the weigh-out operation, and that it was very close to the worker. The real-time data showed little or no increase in dust levels away from the drum as it was emptied. The filter data showed that there was a concentration gradient across the workers' body, and that it increased as the distance from the sampler to the drum decreased (right lapel to drum, hat to drum). This suggests much of this exposure is caused by scooping material out of drum.

All statistical inferences of the real-time data apply to the specific worker used for the study, as there were no other workers studied. If anything, the fitted model understates the relationship of bag count and scooping the material to an increase in worker dust exposure. Thus, to the extent that bag count is a valid indicator of level of material in the drum, these results show that worker dust exposure increases as the level of material in the drum drops. Furthermore, about half-way into the drum the dust exposure during scooping appears to increase significantly, as measured by the HAM. This increase in worker dust exposure occurs predominantly while the worker is scooping material and it generally decreases (or fails to increase as fast) while the worker weighs the bag or turns to place it in the bin.

While most of the breathing zone samples did exceed the PEL for nuisance dust (15 milligrams per cubic meter), it should be kept in mind that the operation studied may not have represented the day-to-day operations of this job. It should also be noted that the workers evaluated in the study reported limited experience in performing this job. While the results showed abnormally high dust levels, all three workers wore respirable dust respirators during the experiment to protect them from these high levels. Background samples did show that dust concentration levels within the plant to be substantially below the nuisance dust PEL, indicating that the dust was controlled within the vicinity of the weigh-out booth. However, there is definitely potential for dust exposures during this job. The results of this study strongly suggest that the booth ventilation contains the dust emissions generated by this job; but does not adequately control personal dust exposures without the addition of personal protective equipment. The air flow patterns at this booth suggest that the ventilation may even contribute to the worker's dust exposure.

RECOMMENDATIONS

Based upon this study, several recommendation can be made to improve the material weigh-out process, and decrease dust exposure.

1. As much as possible, avoid scooping from the bottom of the drum. There are several ways of accomplishing this. The use of half-height drums, false bottoms in the drums, or keeping the drum full of the raw material are just three options.

2. Remove or reposition the hinged platform from in front of the air intake. This should help to provide more even air flow across the dust source. This should keep the dusty air further from the workers' breathing zone.

3. Encourage supplier to use plastic lined bags for raw materials. Plastic-lined bags do not sustain as much leakage as other types of bags.

4. Consider using methods to reduce stress on the back. A mechanical lift could possibly be used to raise the raw material bags at the booth. This should help reduce the back injury rate related to lifting heavy objects.

5. Further research should be performed by NIOSH to find more information about the effects of depth of scooping on worker dust exposure. Furthermore, research on the design of a work station that maintains both acceptable work conditions as well as high efficiency by including both ergonomic and ventilation design principles should be conducted. This research should concentrate on eliminating eddies which force contaminated air into the worker's breathing zone. Furthermore, this research must also consider the lay out of the work station to provide a smooth flowing weigh-out process

In addition, some modifications to the work practices listed in Table 7 can be made. These recommendations are listed in Table 20.

Table 20. Work Practice Recommendations Based upon Elements Shown in Table 7.

Side/Element from Table 5.	Comment
L 3	The bag should be opened with two hands -- one hand to hold the bag and the other to open it. This process takes more time but will reduce potential dust exposure as well as tendinitis problems to the wrist and elbow.
R 5,6,7	Scooping powder, moving the powder to the bag, and dumping the powder into the bag may cause significant airborne dust exposure. Use practices which minimize the height through which powders free-fall through air. Consider the following examples: Before tipping a scoop over to unload it, lay the scoop on top of the powder, raise the handle and gently pull the scoop away from the powder.
L,R 16	Folding the pleates and closing the filled paper bag causes residual air and dust to rapidly escape from the bag. The process small dust "cloud" could be reduced or eliminated by aiming the opening of the bag away from the worker, and closing the bag more carefully.

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APPENDIX I

Summary of Statistical Analysis

Real-Time Statistical Analysis Results

Objectives of the Analysis

The analysis was directed towards answering the following questions:

1. Did the dust exposure of the worker, as measured by the worker ARM readings on the worker's arm, change as the level of material in the barrel decreased, or not, and, if so, was the change an increase or a decrease?

2. The work cycle was conceptualized as repeated cycles of scooping material from the barrel and pouring it into a bag, weighing the bag, and finally, turning to place the filled bag into a container. These cycles were conceptualized as having the three phases of scooping, weighing, and turning. A second question was whether the phase of the cycle had any effect on dust exposure of the worker, and , if so, which increased and which decreased dust exposure, and were these effects constant throughout the entire operation or did such effects change as the level of material in the barrel decreased?

3. Measures of ambient dust levels were also taken with measurements at the hood and at some distance from the hood in the room where the work occurred. Did these change during the work operation? If so, how did these measures change? And, if so, did such changes account for the changes in worker dust exposure, if any?

Important Modifying Conditions

Readings on each measurement device were recorded every 2 seconds in the internal memory of a computer, except that after each 100 readings the recorder paused to transfer the recorded measurements from internal memory to external storage on a diskette. The computer also recorded the time of each measurement. Thus, there are gaps in the data after each 100 measurements. During data collection the worker was asked to wait when the observers became aware that the transfer was occurring. However, there was usually some delay before the onset of the transfer was detected by the observers and the worker usually continued working for short times while there was no dust measurement.

It is believed that there is a lag of at least 2 seconds between a change in the level of dust reaching any of the three dust measuring devices until that change is registered on the reading of that device.

Preparation of the Data for Analysis

Three indicator variables were defined as followed:

SCOOP: = 1 if the worker was involved with scooping material from the barrel to put into the bag , and
= 0 otherwise;

WEIGH: = 1 if the worker was weighing the bag, and
= 0 otherwise;

TURN: = 1 if the worker was turning to place the filled bag in the container, and
= 0 otherwise.

These indicator variables were scored by viewing a videotape of the work operation which included time recordings at intervals of two seconds. Thus, there was a coincident score for each of these variables for each of the three simultaneous recordings of dust measurements. This videotape was reviewed a second time to score the three indicator variables during the times that the worker continued his work while the computer was transferring data to the diskette. There were no associated dust measurements with these additional scores.

The scores on the three indicator variables were used to create four additional variables used in the analysis:

BAGCNT : Each time the worker initiated the scooping phase of a new cycle, this variable was incremented by 1. This is equivalent to incrementing this variable by 1 each time SCOOP changed from 0 to 1. However, this incrementation was lagged by 2 seconds to accommodate the lag in the dust measures described above. Thus, BAGCNT was incremented by 1 two seconds after SCOOP changed from 0 to 1. The initial value of BAGCNT was 0. This variable is an approximate surrogate measure of the level of material in the barrel as the latter should decrease approximately as a function of the number of bags of material removed from the barrel.

SCP : This was 0 except that after the SCOOP variable changed from 0 to 1, with a lag of two seconds, SCP was incremented by 1 every two seconds until two seconds after the SCOOP variable changed from 1 to 0. SCP is an approximate measure of the time spent scooping material from the barrel in a particular cycle, with a lag of two seconds.

WGH : This variable is an approximate measure of the time spent weighing the bag in a particular cycle. WGH was 0 except that after the WEIGH variable changed from 0 to 1, with a lag of two seconds, WGH was incremented by 1 every two seconds until two seconds after the WEIGH variable changed from 1 to 0.

TRN : This variable is an approximate measure of the time spent turning and placing the bag in the container in a particular cycle. TRN was 0 except that after the TURN variable changed from 0 to 1, with a lag of two seconds, TRN was incremented by 1 every two seconds until two seconds after the TURN variable changed from 1 to 0.

The three dependent or response variables for the analysis are WORKER, the dust measurements recorded on the arm of the worker; HOOD, the dust measurements recorded in the hood multiplied by 5 to achieve a scale comparable to that for the worker dust exposure measurements; and AMBNT the dust measurements recorded away from the hood multiplied by 5 to achieve a scale comparable to that for the worker dust exposure measurements. The analysis used the natural logarithms of these measures as a preliminary analysis indicated that the variances of these measurements increased with their overall level.

Analysis to Fulfill Objectives

The objectives of the analysis may be restated in terms of the variables introduced above as follows:

Objective 1:

BAGCNT is a surrogate measure of the level of the barrel. If the level of dust as recorded on the arm of the worker, is not related to the level of the barrel then WORKER (after transforming to the logarithm of the original measures) should not change as the level of the material in the barrel decreases. If WORKER is positively related to BAGCNT, then it may be concluded that worker exposure increases as the level of the barrel decreases. Thus, the first objective was to determine if WORKER is positively related to BAGCNT or not.

Objective 2:

If worker dust exposure is not related to what the worker is doing during each cycle of filling a bag, then WORKER should not be related to SCP, WGH, or TRN. On the other hand, if scooping material increases dust exposure then the longer the worker spends scooping material, the higher the dust levels should increase, and, consequently, WORKER should be positively related to SCP independently of BAGCNT. Corresponding statements can be made relating the effects of weighing and turning to WGH and TRN, respectively. Thus, the second objective had three sub-objectives:

a) to determine if SCP is positively related to BAGCNT or not;

b) to determine if WGH is related to BAGCNT or not, and, if it is, to determine the direction of the relationship; and

c) to determine if TRN is related to BAGCNT or not, and, if it is, to determine the direction of the relationship.

Objective 3:

If the ambient dust levels are not affected by the worker's work, then neither HOOD nor AMBNT should be related to the analytical variables. If such is not the case, then the difference between WORKER and some function of the ambient dust measures would be analyzed for a relationship to the analytical variables. If the relationship vanishes, then it could be concluded that any relationship of worker dust exposures to the work is a function of changes in ambient dust levels rather than to the work. If there is a relationship, then it reflects an effect of the work on the worker's dust exposure level.

Because changes in dust measures are not immediately registered on the measurement devices but are delayed and because there a tendency for dust levels to subside somewhat slowly once dust levels have been increased, a positive autocorrelation between successive measures of dust was anticipated and substantiated by a preliminary analysis. This violates a key assumption of the statistical models for most statistical analyses: that errors are independently distributed. The presence of these autocorrelations was accommodated by use of an autoregressive time series analysis, which includes parameters to account for the autocorrelations, so that inferences about the parameters of interest can be made. The statistical model includes two major components: the autoregressive effects to account for the unwanted statistical dependency, and the "structural" part which includes the effects of the variables of interest for fulfilling the objectives of the study. The first component was there to facilitate the analysis involving the second component. Thus, most of the remaining discussion concentrates on the second or structural component and ignore the first or time series component.

The strategy for the analysis was to fit a parsimonious regression model involving the relation of WORKER (the logarithm of the variable is understood) to the variables BAGCNT, SCP, TRN, and WGH. Preliminary results for Objectives 1 and 2 were obtained by tests of hypotheses concerning the coefficients of the variables BAGCNT, SCP, TRN, and WGH after fitting models linear in those variables. But then more complex models, if needed, were to be fit to determine if the preliminary results accurately indicate the direction and form of the relationship and to provide a good practical description of how dust levels were related to the variables in the study. The objective was not necessarily to closely model the response but to model the response sufficiently to provide a fair representation of the manner in which the response was related to the variables used so that the objectives of the analysis could be fulfilled.

Terms were added in the following order only if the two sided t-test that the coefficient of a variable is 0 was rejected at the .05 level. In the case in which three variables were added, the criterion was that the two sided t-test of the hypothesis that the coefficient of a variable is 0 is rejected at the (.05/3) level for at least one of the three variables.

BAGCNT
SCP, WGH, TRN
$BAGCNT^2$
BAGCNTxSCP, BAGCNTxWGH, BAGCNTxTRN
SCP^2, WGH^2, TRN^2

The SAS procedure AUTOREG was used for the analysis. Up to 25 autoregressive terms could have been included and backward elimination was used to fit an autoregression model.

Results

The criterion for adding sets of terms was fulfilled in each case. The preliminary results for Objectives 1 and 2 are as follows:

Objective 1	The hypothesis that the coefficient of BAGCNT is 0 in a linear model including only a constant and BAGCNT must be rejected as the t-test is significant at the .0001 level. The point estimate of the coefficient is positive which indicates that dust exposure increases as the number of bags filled increases, or as the level of material remaining in the barrel decreases.

Objective 2

The hypothesis that WORKER is not affected by any one or more of the three variables, SCP, WGH, or TRN must be rejected because of the additions to the regression sum of squares associated with adding these variables to the model with BAGCNT alone. The t-test of the hypothesis that the coefficient of SCP is zero is significant at the .0001 level (which exceeds the criterion). The point estimate of the coefficient of SCP is positive which indicates that dust exposure increases the longer the worker is scooping material from the barrel. The t-test of the hypothesis that the coefficient of WGH is zero is not significant at the .05 level (at the .40 level). The point estimate of the coefficient of WGH is positive. These results do not support a relationship of time the worker is weighing material to the dust level. Finally, the t-test of the hypothesis that the coefficient of TRN is zero is significant at the .0001 level (which exceeds the criterion). The point estimate of the coefficient of TRN is negative which indicates that dust exposure decreases the longer the worker is turning to place the filled bag in the container.

The fitted model for the worker dust exposure measurements was a second order model in the explanatory or analytical variables, e.g. it included all terms in

$$(1+BAGCNT+SCP+WGH+TRN)^2$$

(since all the crossproduct terms among SCP, WGH, and TRN are zero).

While there was evidence of lack of fit, examination of the residuals indicated that the fitted model conservatively represented the trends to be described. Inspection of residuals plotted by time did not indicated marked time relationship to lack of fit.

The fitted model for the worker dust exposure measurements is the sum of the following four components:

$$-4.56 + .00256 \times BAGCNT + .00083 \times BAGCNT^2$$

$$.146 \times SCP \quad + .0003 \times BAGCNT \times SCP \quad - .0032 \times SCP^2$$

$$-.044 \times WGH \quad - .0054 \times BAGCNT \times WGH \quad + .038 \times WGH^2$$

$$-.434 \times TRN \quad - .0089 \times BAGCNT \times TRN \quad + .119 \times TRN^2$$

BAGCNT ranged from 0 to 56 while SCP ranged from 0 to 5, WGH from 0 to 6, and TRN from 0 to 6.

Examination of the coefficients of the fitted model and the plots of the values predicted by this model support the preliminary results and indicate:

1. Worker dust exposure level increases dramatically as a function of BAGCNT.

2. For SCP, for any constant value of BAGCNT, the linear slope - which is positive - predominates and the slope increases as BAGCNT increases.

3. For WGH, at any given level of BAGCNT, worker exposure decreases but the slope increases with WGH, but the slope decreases as BAGCNT increases.

4. For TRN, at any given level of BAGCNT, worker exposure decreases as TRN increases but this is moderated by an increase of the slope as TRN increases, but the slope decreases as BAGCNT increases.

These relationships are illustrated in Figure 11b. In Figure 11b, the predicted value of worker exposure while SCP is positive is indicated by the points plotted with "S", while WGH is positive predicted values are indicated by the points plotted with "W", and while TRN is positive predicted values are indicated by the points plotted with "T".

Confidence Intervals for Parameter Estimates

The estimates of the coefficients of the terms in the model are restated below with estimates of their standard errors and 95% confidence intervals. The intervals should be interpreted cautiously because they are not simultaneously valid at the 95% confidence level, these are averages from a model with statistically significant (but not practically significant) lack of fit, and the estimators of the coefficients are correlated. These statistics are based on the full fitted model, which accounts for the fact that in some cases, e.g., for the coefficient of BAGCNT, the addition of the term in the order described above resulted in an estimate of the coefficient that was statistically significant, i.e., different from 0, but the estimate of the same coefficient in the full fitted model is not statistically significantly different from 0.

Table I : Estimates of Coefficients, Standard Error Estimates, and 95% Non-simultaneous Confidence Intervals

TERM	ESTIMATE OF COEFFICIENT	STANDARD ERROR ESTIMATE	95 % CONFIDENCE INTERVAL LOWER LIMIT	UPPER LIMIT
BAGCNT	.0026	.0112	-.019	.025
SCP	.1455	.1253	-.100	.391
WGH	-.0444	.1092	-.258	.170
TRN	-.4335	.1144	-.658	-.209 ***
$BAGCNT^2$	.000838	.000185	.00048	.0012 ***
SCPxBAGCNT	.000295	.00168	-.003	.0036
WGHxBAGCNT	-.00543	.001787	-.009	-.002 *
TRNxBAGCNT	-.00889	.001723	-.012	-.0055 ***
SCPxSCP	-.0032	.0277	-.057	.052
WGHxWGH	.038	.02237	-.006	.082
TRNxTRN	.1186	.02337	.075	.162 ***

Meaning of Symbols

* Significance at the .05 (two tail) level;
** Significance at the .01 (two tail) level;
*** Significance at the .001 (two tail) level;

If the terms with non-significant estimates of coefficients are deleted and the resulting model is fitted to the data, the resulting fitted model becomes (all estimates of coefficients of terms would be nominally significant):

$$-4.377 + .00095\ BAGCNT^2$$

$$-.0084\ BAGCNT \times WGH + .036\ WGH^2$$

$$-.586\ TRN - .010\ BAGCNT \times TRN + .153\ TRN^2$$

This model implies that:

Worker dust level increases quadratically with BAGCNT;

The increase with BAGCNT is not increased nor decreased during the "scooping" phase of the cycle;

At any level of BAGCNT, worker dust levels decrease during the "weighing" phase of the cycle with the magnitude of the decrease increasing with BAGCNT, but this decrease becomes progressively smaller the longer the worker spends weighing; and at any level of BAGCNT, worker dust levels decrease more (relative to the decrease during weighing) during the "turning" phase of the work cycle, with this decrease becoming greater as BAGCNT increases but it is moderated the longer the worker spends in the "turning" cycle.

A hidden implication is that the increase in worker dust exposure levels occurs during the "scooping" phase of the work cycle, as the dust level tends to decrease in both of the other phases of the cycle.

The practical conclusions, i.e., the implications for the correlates of dust generation during the entire task and for each work cycle, are the same for either the "full" fitted model or the "reduced" model. The additional "sum of squares" accounted for by regression in the "full" model relative to the "reduced" model is statistically significant. This implies that one or more or some function of the coefficients deleted from the "full" model would be significant if added to the "reduced" model. Since it is doubtful that finding the term or terms that would account for this would alter the basic practical implications of the results concerning dust generation, no further investigations were undertaken. All plots used the predicted values from the "full" fitted model.

Results of the Analyses of Ambient Dust Measures

Both measures of ambient dust levels were also related to the worker variables. The fitted model for HOOD was as complex as that for WORKER while only a linear term in BAGCNT was needed for AMBNT. The difference of WORKER - HOOD was then analyzed and the relationships found for WORKER alone were approximated.

When residuals were examined, the predicted values tended to be too small when SCP was positive and were too large when SCP was negative.

Conclusions

All statistical inferences apply to the specific worker used for the study as there are no degrees of freedom for between worker differences. If anything, the fitted model understates the relation of BAGCNT, and scooping the material, on increases in the level of worker dust exposure. Thus, to the extent that BAGCNT is a valid indicator of level of material in the barrel, these results support the proposition that worker dust exposure increases as the level of material drops in the barrel, and that the increases in worker dust exposure occur predominantly while the worker is scooping material while worker dust exposure decreases (or fails to increase as fast) while the worker weighs the bag or turns and places the bag in the container.

If anything, ambient dust levels are increased by the work and the changes related to the work can not be explained by independent coincidental changes in ambient levels, although with non-experimental data there must be some doubt about this as well as any other conclusions from these results.

The conclusions of the analysis would not be materially different if the results of the analysis of the dust level measurements had been used rather than the results from the analysis of the logarithms of those measurements.

Figure 10 plots worker dust exposure against the count of bags either filled or being filled and it may be observed that much of the increase occurs after the about half of the 56 bags have been filled.

Filter Data Statistical Analysis Results

Design

This was a planned study to determine the adequacy of dust control technology.

Three workers were studied on three separate days, once in the morning and again in the afternoon. For each study period the worker was observed with two sets of clothing and scooping material from a drum filled to two levels, one-half full or completely full. Six different dust measurements were recorded simultaneously for each combination of clothing and drum level: three personal measures of dust exposure which were at the right shoulder, the left shoulder, and on the hat; and two background locations. The background locations were at the face of the bin, at the bin, and in the room.

Right shoulder readings were added after the first day and are not present for one worker.

The objectives are to determine if drum level affects dust exposure of the worker as measured by the measurements on or at his body and if type of clothing worn increases, decreases, or has no effect on the dust exposure of the worker. The two background measurements provide information about non-experimental sources of contamination which might affect the results of the study.

Analysis Strategy

The background measurements and the body measurements were studied separately. If the background measurements are related to the factors of interest in the study, these measures would be used to adjust the body measurements for the effects of background contamination.

Different measures for the same worker may be related to characteristics of the worker which cannot be randomized or controlled. If the basic experimental unit is the time segment in which the worker does a particular task, it is clear that these are unique to each worker-morning-or-afternoon session (hereafter, worker session). Different units in the same session may be related or subject to common sources of distortion. Within each session the order in which the worker performed the activities of the experiment was randomized so that the units were randomized within sessions.

The three body measurements and the three background measurements were taken simultaneously. Since each measurement instrument operates independently there is no reason to expect that their respective measurement errors would be correlated. Thus, it seems reasonable to assume that any differences reflect measurement differences.

If each worker session is considered as a block, then the study may be viewed as a randomized block design at each type of measurement, i.e. the randomized units are the four time segments in which a worker performed the scooping of material. The statistical inferences pertain to the three specific workers on the two respective occasions that each were studied. Generalizations beyond this must be based on non-statistical considerations, e.g., expert knowledge, etc.

There are two major sources of variance: between units and within units. The between units variance may be analyzed into between workers, between treatments, between sessions within workers and the interactions of these. Within unit variance may be analyzed into between measurement location, and (between) interactions between measurement location and the identifiable between unit factors, such as workers, sessions, treatments, and the interactions among these.

Regarding the between unit portion, it has been often argued (e.g. Scheffe, Davis) that, since units were not randomly assigned across blocks, that the treatment effects are confounded with treatment x unit interactions and that treatment x block interactions are also confounded with treatment x unit interactions. Since there is no true replicate, there is no source which is attributable solely to error and treatment x unit interactions which might be a comparison factor. Thus, to obtain a comparison factor it is necessary to assume that either some or all of the treatment x block interactions are zero, so that the corresponding nominal treatment x block interactions term may be used as the comparison, or that the treatment by unit interaction is zero. Unlike most "textbook" randomized block designs, there are three independent (by assumption) measures on each unit so that the unit by location of measure interaction should be free of treatment by unit interaction.

In this case the total treatment by block interaction sum of squares may be partitioned into two major sources: (1) Clothing type and drum level by worker ; and (2) Clothing type and drum level by session within worker. (Each of these may be further partitioned into three sources as well.) The sum of the variance attributable to interactions of sessions within worker and the treatments seems a logical candidate for the comparison term for testing hypotheses concerning between unit factors of interest, i.e., clothes, drum levels, workers, etc. The interaction term involving location of measure, sessions within worker, and the treatments appears to be a logical candidate for the comparison term for the "within" units portion of the analysis. However, it is possible that the unit differences, especially those common to the same worker, are so small that there is little difference between the comparison term for the between units and the comparison term for the within units portions of the analysis. In that case, these could be combined to increase the power of the analysis.

Preliminary analysis suggested that the analysis use the logarithms of the measurements.

Background Readings Results

The analysis departed from the above in that it proceeded immediately as though the design were a factorial in worker, drum level, clothing, and location of measurement with session as a replicate, save for the "main" effect of session within worker. This seems reasonable in that background sources of dust should not be caused by the worker and the entire notion of the "units" as associated with the workers does not seem applicable.

The F-ratio for total regression, i.e., all sources put together, was 1.80 with 47 and 23 degrees of freedom, which achieves the 0.065 significance level, which is consistent with the null hypothesis, but barely so, that background sources of dust were not related to the factors of interest. None of the main effects would be significant if analyzed separately but the variation among workers is nearly so (p less than .056), while the session within worker (P less than .02) effects would be significant. These results might reflect differences in background levels on different occasions which are confounded with worker and worker session effects, the blocks for the study. The clothes by drum (P less than 0.005), and the drum by location of measurement (P less than .001), interactions would be significant if analyzed separately. The results of the analysis of variance are shown in Table I.

Body Measurement Results

The SAS procedure PROC GLM was used for the analysis. All sums of squares reported are "Type III" sums of squares, in the terminology of SAS PROC GLM. Thus, these cannot be meaningfully added, nor are they statistically independent. The main advantage is that each reflects an adjustment for the effects of all other factors in the model and closely approximate the "extra sum of squares" for the factor as if it were the last one added to the model. In this case, the actual design is only slightly unbalanced so that the differences between the "Type I" sum of squares and the ones shown were never enough to substantially change the conclusions. The results are shown in Table II.

The mean square for the treatments by session within worker is 3.53 with 12 degrees of freedom(df), while the location by treatments by session within worker mean square is 1.424 with 20 df. The ratio of 2.48 is statistically significant at the 0.05 level. Thus, it appears not wise to combine these for a single comparison term.

Among the various component sources for the treatments by session within worker interaction, the mean squares range from 2.07 for the sessions within worker to 4.88 for the sessions within worker by drum level; each has 3 df. These do not appear enough noteworthy to attempt to narrow the choice of comparison further.

Two factors or sources seem clearly large regardless of how they might be analyzed: between workers and between measurement locations. Neither of these is of particular interest.

On the other hand, the results seem equally clear that there is little difference between the levels of dust for the two types of clothing no matter how analyzed. The same is true, i.e., the effects appear small at most, for the clothes by drum level interaction and every other interaction term involving clothes.

As shown in Table II, the mean square for drum level is more than ten times the size of the session within worker by treatments interaction. The ratio is statistically significant at the 0.066 level using a F-test with 1 and 12 degrees of freedom. The F-test for drum level by worker interaction barely misses significance at the 0.05 level although the mean square appears elevated and the actual probability level is .052.

No other source was statistically significant.

Contrasts

Analyses of contrasts between drum levels and between drum levels by worker are shown in Table III on the transformed logarithm scale.

For drum level, the estimated difference is 1.49, which is 4.44 on the original scale. The 95% confidence intervals shown apply for the transformed scale, only. However, the end points have been transformed back to the original scale, but these do not yield a 95% confidence interval on the original scale.

Two sets of estimates are provided for the drum and worker contrasts: drum level within worker, or the differences between full and empty for each individual worker; and drum by worker, which refers to the interaction contrasts of drum by worker, i.e., the contrasts among the first set, e.g., the first contrast of the first set to the average of the other two (multiplied by 2), etc.

For the drum within worker contrasts, a set of three intervals is given in Table III. This set of intervals is a 95% confidence interval set. For worker 1 the estimated drum effect is slightly greater than the average while the amount of fill of the drum almost has no effect for worker 2, and the estimated effect is much higher than the average for worker 3. Nevertheless, the drum by worker interaction was not statistically significant as indicated by the fact that none of the F-ratios for the three drum by worker contrasts is significant at the .05 level.

Reanalysis

As noted above the available evidence provides no support for any effect of the clothing changes for these workers. What if the analysis had excluded clothing as a factor? Any answer from these data is somewhat speculative since an analysis is after the fact. However, the data was analyzed by adding the sums of squares involving clothing to the error sums of squares, in an appropriate manner for both the between units and the within units analysis. The results, of course, are "after the fact" and are intended to generate suggestions for future work. This is not equivalent to ignoring clothing in the analysis but these results approximate those that would have occurred had clothing been ignored because of the design is nearly balanced. The results are shown in Tables IV and V.

The main difference is that the worker by drum interaction achieves statistical significance.

Table I. Analysis of Background Dust Concentration.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	47	126.28168803	2.68684443	1.80	0.0653	0.785829	73.2246
ERROR	23	34.41701399	1.49639191		ROOT MSE		LCONC MEAN
CORRECTED TOTAL	70	160.69870202			1.22327099		-1.67057281

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
DRUM	1	0.61386716	0.41	0.5282	1	0.15934285	0.11	0.7471
WORKER	2	7.61839241	2.55	0.1003	2	9.77481511	3.27	0.0564
WORKER*DRUM	2	1.73092007	0.58	0.5688	2	2.03592273	0.68	0.5164
CLOTHES	1	4.41809233	2.95	0.0992	1	5.57600905	3.73	0.0660
CLOTHES*DRUM	1	12.86519223	8.60	0.0075	1	14.23793840	9.51	0.0052
WORKER*CLOTHES	2	1.18542772	0.40	0.6774	2	1.34607254	0.45	0.6433
WORKER*CLOTHES*DRUM	2	2.69248841	0.90	0.4205	2	2.34060849	0.78	0.4692
LOC	2	7.56429378	2.53	0.1018	2	6.76949778	2.26	0.1268
DRUM*LOC	2	0.88775558	0.30	0.7461	2	0.28401906	0.09	0.9098
WORKER*LOC	4	39.60622445	6.62	0.0011	4	40.60657169	6.78	0.0009
WORKER*DRUM*LOC	4	1.64800698	0.28	0.8909	4	1.68595692	0.28	0.8868
CLOTHES*LOC	2	1.33828354	0.45	0.6449	2	0.57297431	0.19	0.8271
CLOTHES*DRUM*LOC	2	4.54057580	1.52	0.2405	2	4.24539912	1.42	0.2625
WORKER*CLOTHES*LOC	4	2.64843390	0.44	0.7766	4	2.92513084	0.49	0.7440
WORK*CLOT*DRUM*LOC	4	6.01584429	1.01	0.4252	4	5.36955315	0.90	0.4817
Session(Worker)	3	16.20118609	3.61	0.0286	3	18.18250595	4.05	0.0189
Session*Drum(Worker)	3	5.22330902	1.16	0.3451	3	6.00998022	1.34	0.2863
Session*Clothes(Worker)	3	4.92010107	1.10	0.3708	3	5.36897508	1.20	0.3334
Session *Clothes*Drum(Worker)	3	4.56329322	1.02	0.4035	3	4.56329322	1.02	0.4035

Notes

1. These dust concentrations were measured at the face of the hood, at the bin, and in the room.

2. Loc refers to the location of the dust concentration measurement.

Table II. Analysis of Variance of Logarithms of Dust Exposure Measurements on Workers.

Surce	df	Sum of Squares	Mean Square	F-Ratio	P Level (P < value)	
Between 'Units'						
Hrkers	2	38.26	19.13	5.42	0.02	
Drum Level	1	37.99	37.99	10.76	0.01	
Hrker by Drum Level	2	26.73	13.36	3.79	0.052	
Clothing	1	1.09	1.09	0.31	0.59	
Hrker by Clothing	2	6.94	3.47	0.98	0.60	
Drum by Clothes	1	0.06	0.06	0.02	0.89	
Hrker by Drum by Clothes	2	0.01	0.01	0.02	0.99	
'Error'						
Replicate(Worker)	3	6.20	2.07	1.45	0.26	Compared
'' by Drum	3	14.64	4.88	3.43	0.04	to
'' by Clothes	3	11.99	4.00	2.81	0.07	
'' by Drum by Clothes	3	9.53	3.18	2.23	0.12	Within
						'Units'
Sub-total for Error	12	42.36	3.53	2.48	0.03	Error
Total Between 'Units	23					
Within 'Units'						
Location of Measurement	2	53.13	26.57	18.66	0.0001	
Location x Worker	4	6.54	1.64	1.15	0.36	
Location x Drum	2	0.64	0.32	0.22	0.8	
Location x Worker x Drum	4	10.01	2.50	1.76	0.18	
Location x Clthes	2	1.68	0.84	0.59	0.56	
Location x Worker x Clothes	4	8.40	2.10	1.47	0.25	
Location x Drum x Clothes	2	0.22	0.11	0.08	0.93	
Location x Worker x Drum x Clothes	4	0.77	0.19	0.13	0.97	
Error'						
Location x Repl(Wor	5					
'' x Drum	5					
'' x Clothes	5					
'' x Drum x Clothe	5					
Total Error (within)	2	28.48	1.42			
Total Within Units	4					
Grand Total	6					

Table III. Analysis of Contrasts Between Drum Levels and Drum Level by Worker.

Contrast	df	Sum of Squares	Mean Square	F-ratio	P level (P < value)		Estimate	Std Err	T - ratio	95 % Confidence Lower	Upper	Description
Drum within Worker												
Drum within Worker1	3	15 75	5 25	1 42	> 06	(simultaneous)	1.871	0 886	2 11	-0 609	4 35	Worker1: empty-full (simul)
Drum within Worker2	3	0 068	0 0227	0 01		(simultaneous)	-0 11	0 7926	-0 13	-2.329	2 11	Worker2- empty-full (simul)
Drum within Worker3	3	49 06	16 02	4 33	05	(simultaneous)	2 8302	0 767	3 69	0 683	4 98	Worker3: empty-full (simul)
							Original Scale (not a 95 % Confidence Interval)					
							6 49			0.544	77 57	Worker1 empty-full (simul)
							0 096			0.092	8 24	Worker2: empty-full (simul)
							16 95			1.979	145 17	Worker3 empty-full (simul)
Drum by Worker Interaction												
Drum by Worker1	2	0 85	0 42	0 12	> 25	(simultaneous)	0 292	0 595	0 490			Worker1 difference vs average difference
Drum by Worker2	2	22 88	11 44	5 24	10 > 05	(simultaneous)	-1 614	0 634	-2 546			Worker2 difference vs average difference
Drum by Worker3	2	14 38	7 19	2 04	> 10	(simultaneous)	1.323	0 655	2 018			Worker3 difference vs average difference
Drum Level	1	37 992	37 992	10 76	01		1 4904	0.454	3 28	0 562	1 383	Empty vs full
							Original Scale (not a 95% Confidence Interval)					
							4 439			1.75	3 985	Full vs empty

BETWEEN MEAN SQUARE FOR ERROR 3.6300

Table IV. Analysis After Adding All Sum of Squares Involving Clothing to the Error Sum of Squares.

Source	df	Sum of Squares	Mean Square	F-Ratio	P Level (P < value)
Between 'Units'					
Workers	2	38.26	19.13	6.82	0.0064
Drum Level	1	37.99	37.99	13.55	0.002
Worker by Drum Level	2	26.72	13.36	4.77	0.021
Error	18	50.47	2.80	2.27	0.0209*
Total Between 'Units	29			*Compared to within error	
Within 'Units'					
Location of Measurement	2	53.13	26.575	21.49	0.0001
Location × Worker	4	b.54	1.64	1.32	0.28
Location × Drum	2	0.64	0.32	0.26	0.77
Location × Worker × Drum	4	10.01	2.50	2.03	0.11
Total Error (within)	32	39.55	1.24		
Total Within Units	56				
Grand Total	35				

Table V. Analysis of Contrasts Involving Drum Level and Drum Level and Worker After Clothing Sum of Squares is Added to the Error Sum of Squares.

Contrast	df	Sum of Squares	Mean Square	F-ratio	P level (P < value)		Estimate	Std Err	T-ratio	95 % Confidence Lower	95 % Confidence Upper	Description
Drum within Worker												
Drum within Worker1	3	15 75	5 25	1.87	0 17	(simultaneous)	1 87	0 789	2 37	-0 34	4 08	Worker1 empty-full (simultaneou
Drum within Worker2	3	0 068	0 02	0 01	0 999	(simultaneous)	-0 11	0 706	-0 16	-2 09	1 87	Worker2:empty-full (simultaneou
Drum within Worker3	3	49 06	16 02	5 71	0 0065	(simultaneous)	2 83	0 684	4 14	0 92	4 74	Worker3.empty-full (simultaneou
							Original Scale (not a 95 % Confidence Interval)					
							6 49			0 71	59.25	Worker1:empty-full (simultaneou
							0 90			0 12	46 47	Worker2:empty-full (simultaneou
							16 95			2.80	114.93	Worker3:empty-full (simultaneou
Drum by Worker Interaction												
Drum by Worker1	2	0 85	0 42	0 15	0.86	(simultaneous)	0 291	0 53	0 55			Worker1 difference vs average difference
Drum by Worker2	2	22 88	11 44	4 08	0 034	(simultaneous)	-1.614	0 56	-2 86			Worker2 difference vs average difference
Drum by Worker3	2	14 38	7 19	2 56	0 103	(simultaneous)	1 323	0 58	2.26			Worker3 difference vs average difference
Drum Level	1	37 99	37.99	13.55	0 002		1 4904	0 40	3 68	0 66	1.23	Empty vs full
								Original	scale	(not a 95 % Confidence Interval)		
							4 44			1.94	3 43	Empty vs full
Error Mean Square		2 804										

APPENDIX II

Anthropometric Questionnaire

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
DIVISION OF PHYSICAL SCIENCES AND ENGINEERING
ENGINEERING CONTROL TECHNOLOGY BRANCH

ACTIVE SURVEILLANCE QUESTIONNAIRE
DEVELOPED FOR B.F.GOODRICH

Date: Mo ___ ___ Day ___ ___ Year ___ ___

Worker ID: ___ ___ ___ Job Title ____________________

Worker Name: First ____________ Last ____________________

Gender: 1 Male ___ 2 Female ___

Handedness: Right ___ Left ___ Both ___ Work Hand: Rt ___ Lt ___ Bo ___

Date of Birth: Mo ___ ___ Day ___ ___ Year ___ ___ Age ___ ___

Length of Employment with B.F.Goodrich: Mo ___ ___ Years ___ ___

Length of Employment at this Plant: Mo ___ ___ Years ___ ___

When did you start <u>this</u> job? Mo ___ ___ Day ___ ___ Year ___ ___

Is this the only job you do? Yes ___ No ___

If No, what other jobs do you perform: ____________________

____

Approximately what percentage of time is spent during an 8-hour work shift performing <u>this</u> job? Percentage ____.

How much material do you "Bag" during an 8-hour work shift? Pounds ____
No. of Bags ____. (Company Production data: Pounds ____ Bags ____).

Do you have any suggestions about improving your job? ____________

____

____

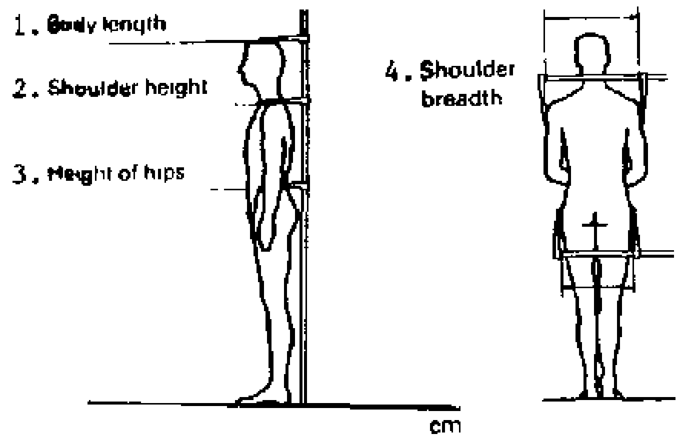
____

____.

ANTHROPOMETRIC DATA
STANDING POSITION

Date: Mo ___ ___ Day ___ ___ Year ___ ___

Worker ID: ___ ___ ___

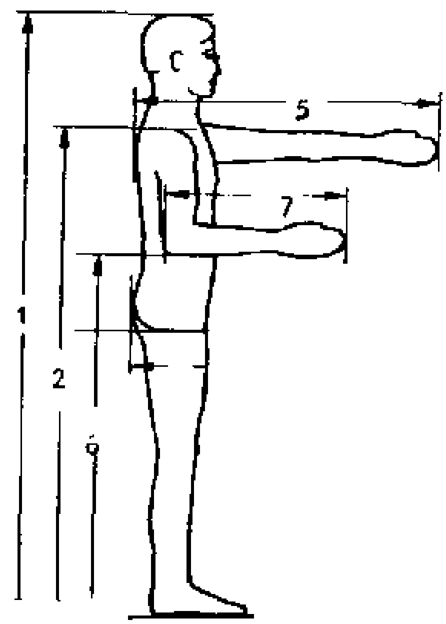


1 Body Length ___ ___ ___ . ___

2 Shoulder Height ___ ___ ___ . ___

3 Height of Hips ___ ___ ___ . ___

4 Shoulder breadth ___ ___ ___ . ___



5 Forward Reach (fingers in grasping position) ___ ___ ___ . ___

6 Elbow Height ___ ___ ___ . ___

7 Underarm length (elbow to fingertip) ___ ___ ___ . ___

Work Area: Container Height ___ ___ ___ . ___

Container Diameter ___ ___ ___ . ___

Distance between container and measuring area ___ ___ ___ . ___

Measuring area table height ___ ___ ___ . ___

Bag height ___ ___ ___ . ___

Material transfer tool: Weight ___ ___ Size: Height ___ ___ ___

length ___ ___ ___ . ___ Handle diameter ___ ___ ___ . ___

Handle length ___ ___ ___ . ___.

APPENDIX III

Biomechanical Strength Analysis

STATIC STRENGTH PROGRAM (V2.0)
ANALYSIS SUMMARY FOR:
MARIETTA OHIO B.F.GOODRICH

INDEPENDENT VARIABLES	MALE	FEMALE
HEIGHT (M)	1.77	1.62
WEIGHT (KG)	75.20	62.10
FORCE EXERTED/HAND (N)	111.20	111.20
DIRECTION OF FORCE * **	0.00	0.00
NUMBER OF HANDS USED IN TASK	2	2

POSTURE ANALYZED:

JOINT	ANGLE **
ELBOW	-50
SHOULDER	-80
HIP	5
KNEE	130
ANKLE	75

* - ANGLE OF FORCE ACTING UPON THE HAND
** - ANGLES ARE ABOVE(+)/BELOW(-) RIGHTWARD HORIZONTAL AXIS

MODEL PREDICTIONS

PROPORTION OF POPULATION WITH
SUFFICIENT STRENGTH CAPABILITY

JOINT	% MALES CAPABLE	% FEMALES CAPABLE
ELBOW	61	3
SHOULDER	87	31
LOW BACK (L5/S1)	99	13
HIP	99	98
KNEE	97	96
ANKLE	99	99

	MALE	FEMALE
COMPRESSIVE FORCE (N) AT L5/S1 DISK	-306	-734

ANALYST:JAMES D. MCGLOTHLIN DATE:02-09-1986 TIME:20:46:15

STATIC STRENGTH PROGRAM (V2.0)
ANALYSIS SUMMARY FOR:
MARIETTA OHIO B.F.GOODRICH

INDEPENDENT VARIABLES	MALE	FEMALE
HEIGHT (M)	1.77	1.62
WEIGHT (KG)	75.20	62.10
FORCE EXERTED/HAND (N)	111.20	111.20
DIRECTION OF FORCE * **	-90.00	-90.00
NUMBER OF HANDS USED IN TASK	2	2

POSTURE ANALYZED:

JOINT	ANGLE **
ELBOW	-80
SHOULDER	-95
HIP	5
KNEE	130
ANKLE	70

* - ANGLE OF FORCE ACTING UPON THE HAND
** - ANGLES ARE ABOVE(+)/BELOW(-) RIGHTWARD HORIZONTAL AXIS

MODEL PREDICTIONS

PROPORTION OF POPULATION WITH SUFFICIENT STRENGTH CAPABILITY

JOINT	% MALES CAPABLE	% FEMALES CAPABLE
ELBOW	99	99
SHOULDER	99	99
LOW BACK (L5/S1)	99	96
HIP	94	87
KNEE	99	99
ANKLE	98	98

	MALE	FEMALE
COMPRESSIVE FORCE (N) AT L5/S1 DISK	4342	3613

ANALYST: JAMES D. MCGLOTHLIN DATE: 02-09-1986 TIME: 20:39:32

STATIC STRENGTH PROGRAM (V2.0)
ANALYSIS SUMMARY FOR:
MARIETTA OHIO B.F.GOODRICH

INDEPENDENT VARIABLES	MALE	FEMALE
HEIGHT (M)	1.77	1.62
WEIGHT (KG)	75.20	62.10
FORCE EXERTED/HAND (N)	111.20	111.20
DIRECTION OF FORCE * **	-90.00	-90.00
NUMBER OF HANDS USED IN TASK	2	2

POSTURE ANALYZED:

JOINT	ANGLE **
ELBOW	-50
SHOULDER	-80
HIP	5
KNEE	130
ANKLE	75

* - ANGLE OF FORCE ACTING UPON THE HAND
** - ANGLES ARE ABOVE(+)/BELOW(-) RIGHTWARD HORIZONTAL AXIS

-----MODEL PREDICTIONS-----

PROPORTION OF POPULATION WITH
SUFFICIENT STRENGTH CAPABILITY

JOINT	% MALES CAPABLE	% FEMALES CAPABLE
ELBOW	99	86
SHOULDER	99	83
LOW BACK (L5/S1)	98	93
HIP	89	72
KNEE	99	98
ANKLE	96	93

	MALE	FEMALE
COMPRESSIVE FORCE (N) AT L5/S1 DISK	5456	4626

ANALYST: JAMES D. MCGLOTHLIN DATE: 02-09-1986 TIME: 20:30:58

APPENDIX IV

Data Acquisition Program

```
560  HIMEM: 38144
590 CT$ = " GOSUB  RETURN  &  REM
      LOAD  COLOR=  GOSUB  ON  PRINT
      REM  STOP  PRINT  WAIT  GOSUB
      RESTORE  RETURN  LOAD  DEF
     "
600 PT$ = "01/26 04:23:50.168"
610  ONERR  GOTO 5490
620 D$ =  CHR$ (4)
625 ZP = 0
630 HEX$ = "0123456789ABCDEF"
650  DIM CO$(16),DSC$(13),PARM$(1
     3),PD$(13),TM$(100)
660  DIM CAL(15),CH(16),GAIN(15),
     GC(15),RT(16),V(16),VOLTS(16
     ),RDG(100,16)
670  PRINT D$;"BLOAD READ CLOCK.O
     BJ,A$300"
690  FOR I = 1 TO 10: READ BYTE: POKE
     834 + I,BYTE: NEXT
700  DATA 104,168,104,166,223
710  DATA 154,72,152,72,96
720  FOR I = 1 TO 13: READ DSC$(I
     ): NEXT
740  DATA  "EQUIPMENT............
     .."
750  DATA  "RUN NUMBER...........
     .."
760  DATA  "ACTIVE CHANNELS......
     .."
770  DATA  "CHANNEL CODES........
     .."
780  DATA  "FILENAME.............
     .."
790  DATA  "OUTPUT FORMAT........
     .."
800  DATA  "GAIN CONTROL.........
     .."
810  DATA  "CALIBRATION CONSTANTS
     .."
820  DATA  "READING INTERVAL.....
     ..."
830  DATA  "# OF READINGS........
     .."
840  DATA  "PRINTER OPTION.......
     .."
850  DATA  "PRINTER SLOT... .....
     .."
860  DATA  "EXECUTE / QUIT.......
     .."
910  FOR I = 1 TO 3: READ OF$(I):
      NEXT
920  DATA "SAS","TELEGRAPH","SAS/
     TELEGRAPH"
```

```
940  FOR I = 1 TO 2: READ PD$(I):
      NEXT
950  DATA  "READINGS","OFF"
970  FOR I = 0 TO 7: READ GC$(I):
      NEXT
980  DATA  " (0) +0.0 TO +5.0 V",
     " (1) +0.0 TO +1.0 V"
990  DATA  " (2) +0.0 TO +0.5 V",
     " (3) +0.0 TO +0.1 V"
1000  DATA  " (4) -5.0 TO +5.0 V"
     , " (5) -1.0 TO +1.0V"
1010  DATA  " (6) -0.5 TO +0.5 V"
     , " (7) -0.1 TO +0.1 V"
1030  FOR I = 1 TO 13: READ PD$(I
     ):PARM$(I) = PD$(I): NEXT
1040  DATA  "RAMS","1"," "," ","T
     EMP","SAS"," "
1050  DATA  "1-- 1","00 MIN 10 SE
     C","100","OFF","0","E/D/ CR
     "
1060 RN = 1:NC = 0:RC$ = "":FL$ =
     "TEMP"
1070 DLY = 10:NR = 100:FD = 2:FS =
     0
1080  FOR I = 0 TO 15:CAL(I) = 0:
      NEXT
1090 LPP = 50:OF = 1:RC = 0:REWR =
     100:VM = 2
1110 SLOT = 5
1130  PRINT : PRINT D$;"NOMON CIO
     "
1140  TEXT : HOME : PRINT  CHR$ (
     140): HOME : SPEED= 255
1150  POKE 34,16
1160  GOSUB 5270
1170  FOR I = 1 TO 39: PRINT "-";
     : NEXT : PRINT
1180  INVERSE : PRINT "
     RETURN FOR NO CHANGE
      ": NORMAL
1190  HOME : PRINT "CLEARING MEMO
     RY...PLEASE WAIT":X =  FRE (
     .9)
1200 LINE = 1
1205  IF ZP       0 THEN  GOTO 140
     0
1206 ZP = ZP + 1
1210 FG = 0:FI = 1
1220  HOME
1300  FOR I = 1 TO 11:PARM$(I) =
     PD$(I): NEXT
1360  FOR I = 0 TO 15:GC(I) = 0: NEXT

1370  FOR I = 0 TO 15:CAL(I) = 0:
      NEXT
```

```
1390 PARM$(8) = "1-- 1"
1400  POKE 34,0: VTAB 1: HTAB 1: GOSUB
     5280: POKE 34,16: HOME
1420  HOME : GOSUB 5300:LINE = 2:
      GOSUB 5310
1430  PRINT "ENTER THE RUN NUMBER
     "
1440  INPUT "(2 DIGITS MAXIMUM 01
     -99) --   ";R$
1450  IF R$ = "" THEN  GOTO 1500
1460 R =  VAL (R$): IF R   1 OR R
        99 THEN  GOTO 1420
1470 RN = R
1480 PARM$(LINE) = R$: GOSUB 5310

1500  HOME : GOSUB 5300:LINE = 3:
      GOSUB 5310
1510  PRINT "CHANNELS TO READ"
1520  INPUT "(0123456789ABCDEF)--
      ";R$
1530  IF R$ = "" THEN  GOTO 1870
1540 R =  LEN (R$)
1550  IF R   16 THEN  GOTO 1500
1560  FOR I = 1 TO R: FOR J = 1 TO
     16
1570  IF  MID$ (HEX$,J,1) =  MID$
     (R$,I,1) THEN J = 16: GOTO 1
     600
1580  NEXT J
1590  PRINT : FOR K = 1 TO 5: CALL
      - 198: NEXT : PRINT "'"; MID$
     (R$,I,1);"' NOT VALID": FOR
     PSE = 1 TO 2000: NEXT :I = R
     :J = 16: GOTO 1500
1600  NEXT I
1610  FOR I = 1 TO R - 1: FOR J =
     I + 1 TO R
1620  IF I = J THEN  GOTO 1650
1630  IF  MID$ (R$,I,1)        MID$
     (R$,J,1) THEN  GOTO 1650
1640  FOR K = 1 TO 5: CALL  - 198
     : NEXT : PRINT : PRINT : PRINT
     "'"; MID$ (R$,I,1);"' DUPLIC
     ATED":I = R:J = R: FOR PSE =
     1 TO 2000: NEXT : GOTO 1500
1650  NEXT J
1660  NEXT I
1670 NC = R:AC$ = R$:RC$ = R$
1680 FC$ = "": FOR I = 1 TO NC:FC
     $ = FC$ + "  " +  MID$ (RC$,I
     ,1): NEXT
1690  FOR I = 1 TO R
1700 CH$ =  MID$ (AC$,I,1)
1710 CH =  VAL (CH$)
```

```
1720  IF  ASC (CH$) > 64 AND  ASC
     (CH$) < 71 THEN CH =  ASC (C
     H$) - 55
1730 CH(I) = CH
1740 CAL(CH) = 1
1750  NEXT
1760  IF NC < 8 THEN  GOTO 1830
1770  HOME
1780  PRINT "WARNING: THERE MAY B
     E SOME SAS PROBLEMS"
1790  PRINT "           WHEN USING
     THIS MANY CHANNELS."
1800  PRINT "           IF SO, USE
     'NONUM' TO PARKLAWN."
1810  PRINT
1820  PRINT "PRESS A KEY ";: GET
     KB$: PRINT
1830 PARM$(LINE) = R$:PARM$(LINE +
     1) = R$: GOSUB 5310
1840 PARM$(7) = "": FOR I = 1 TO
      LEN (AC$):PARM$(7) = PARM$(
     7) +  STR$ (GC(CH(I))): NEXT

1850  GOSUB 5280
1870  HOME : GOSUB 5300:LINE = 4:
      GOSUB 5310
1880  IF NC = 0 THEN  GOTO 2110
1890  PRINT "ENTER THE CHANNEL CO
     DES"
1900  PRINT "(1 CHARACTER PER CHA
     NNEL)"
1910  PRINT "( DO NOT USE ANY BLA
     NKS )"
1920  PRINT "(YOU SHOULD ENTER ";
     NC;" CODES)"
1930  INPUT " --  ";R$
1940  IF R$ = "" THEN  GOTO 2110
1950  IF  LEN (R$) < NC THEN  CALL
      - 198: PRINT : PRINT "TOO F
     EW CODES": GOTO 2040
1960  IF  LEN (R$) > NC THEN  CALL
      - 198: PRINT : PRINT "TOO M
     ANY CODES": GOTO 2040
1970  FOR I = 1 TO NC: FOR J = I +
     1 TO NC
1980  IF I = J THEN  GOTO 2010
1990  IF  MID$ (R$,I,1) <>  MID$
     (R$,J,1) THEN  GOTO 2010
2000 I = NC:J = NC: CALL  - 198: PRINT
     : PRINT "DUPLICATE CODE FOUN
     D": GOTO 2040
2010  NEXT J
2020  NEXT I
2030  GOTO 2060
```

```
2040  FOR I = 1 TO 2000: NEXT
2050  GOTO 1870
2060 RC$ = R$
2070  FOR I = 1 TO NC:CO$(I) =  MID$
     (RC$,I,1): NEXT
2080 FC$ = "": FOR I = 1 TO NC:FC
     $ = FC$ + " " +  MID$ (RC$,I
     ,1): NEXT
2090 PARM$(LINE) = R$: GOSUB 5310

2110  HOME : GOSUB 5300:LINE = 5:
      GOSUB 5310
2120  PRINT "ENTER THE FILENAME"
2130  INPUT "(16 CHARS MAXIMUM) -
     -  ";R$
2140  IF R$ = "" THEN  GOTO 2200
2150 R$ =  LEFT$ (R$,16)
2160  IF  LEFT$ (R$,1)   "A" OR  LEFT$
     (R$,1)   "Z" THEN  GOTO 2110

2170 FL$ = R$
2180 PARM$(LINE) = R$: GOSUB 5310

2200  HOME : GOSUB 5300:LINE = 6:
      GOSUB 5310
2210  PRINT "SELECT THE OUTPUT FO
     RMAT:": PRINT
2220  FOR I = 1 TO 3: PRINT "  ";
     I;")  ";OF$(I): NEXT : PRINT

2230  INPUT "WHICH (1-3) --  ";R$

2240  IF R$ = "" THEN  GOTO 2290
2250 R =  VAL (R$): IF R   1 OR R
       3 THEN  GOTO 2200
2260 OF = R
2270 PARM$(LINE) = OF$(OF): GOSUB
     5310
2290  HOME : GOSUB 5300:LINE = 7:
      GOSUB 5310
2300  PRINT "GAIN CONTROL: ( KEY
       CR ) ";
2310. GET R$: PRINT
2320  IF R$ =  CHR$ (13) THEN  GOTO
     2560
2420  PRINT : FOR I = 0 TO 3: PRINT
     GC$(I);GC$(I + 4): NEXT : PRINT

2430  INPUT "CHANNEL ID , GAIN CO
     NTROL (0-7) --  ";CH$,GC$
2440 CS$ = CH$: GOSUB 6050
2450  IF CS = 0 THEN  PRINT "CHAN
     NEL NOT ACTIVE": GOTO 2490
```

```
2460 GC =  VAL  (GC$): IF GC      =
     0 AND GC     = 7 THEN  GOTO 2
     490
2470  PRINT "INVALID GAIN CONTROL
     "
2480  FOR FSE = 1 TO 2000: NEXT :
      GOTO 2290
2490 GC(CH) = GC
2500 PARM$(7) = "": FOR I = 1 TO
      LEN (AC$):PARM$(7) = PARM$(
     7) +  STR$ (GC(CH(I))): NEXT

2510  IF GC = 0 THEN GAIN(CH) = 4
     .99878
2520  IF GC = 1 THEN GAIN(CH) = 0
     .99976
2530  IF GC = 2 THEN GAIN(CH) = 0
     .49988
2540  IF GC = 3 THEN GAIN(CH) = 0
     .09998
2541  IF GC = 4 THEN GAIN(CH) = 4
     .99878
2542  IF GC = 5 THEN GAIN(CH) = 0
     .99976
2543  IF GC = 6 THEN GAIN(CH) = 0
     .49988
2544  IF GC = 7 THEN GAIN(CH) = 0
     .09998
2550  GOSUB 5310: GOTO 2290
2560 AG = 8: FOR I = 0 TO 15
2570  IF GC(I)    AG THEN AG = GC(
     I)
2580  NEXT
2600  HOME : GOSUB 5300:LINE = 8:
      GOSUB 5310
2610  PRINT "0/8  1/9  2/A  3/B
     4/C  5/D  6/E  7/F"
2620  FOR I = 0 TO 15
2630  IF I / 2 =  INT (I / 2) THEN
      INVERSE
2640  PRINT  LEFT$ ( STR$ (CAL(I)
     ) + "    ",4);
2650, NORMAL
2660  PRINT " ";
2670  NEXT : PRINT
2680  PRINT "CALIBRATION CONSTANT
     S: ( KEY   CR ) ";
2690  GET R$: PRINT
2700  IF R$ =  CHR$ (13) THEN  GOTO
     3220
2720  INPUT "CHANNEL ID , CAL. VA
     LUE --, ";CH$,CC$
2730 AC =  LEN (AC$)
2740  FOR I = 1 TO AC
```

```
2750  IF  MID$ (AC$,I,1) = CH$ THEN
     I = AC: GOTO 2780
2760  NEXT
2770  PRINT : PRINT : PRINT : PRINT
     "NOT AN ACTIVE CHANNEL": CALL
      - 198: GOTO 2800
2780 CC =  VAL (CC$): IF CC     =
      - 1000 OR CC     = 1000 THEN
      PRINT : PRINT : PRINT : PRINT
     "CONSTANT OUT OF RANGE": CALL
      - 198: GOTO 2800
2790  GOTO 2810
2800  FOR FSE = 1 TO 2000: NEXT :
      GOTO 2600
2810  FOR I = 1 TO 16
2820  IF  MID$ (HEX$,I,1) = CH$ THEN
     CAL(I - 1) =  VAL (CC$):I =
     16: GOTO 2840
2830  NEXT
2840 MN = CAL(0):MX = CAL(0)
2850  FOR I = 1 TO 15
2860  IF CAL(I)    MN THEN MN = CA
     L(I)
2870  IF CAL(I)    MX THEN MX = CA
     L(I)
2880  NEXT
2890 PARM$(LINE) =  LEFT$ ( STR$
     (MN),6) + "-- " +  LEFT$ ( STR$
     (MX),6): GOSUB 5310
3200  GOTO 2600
3220  HOME : GOSUB 5300:LINE = 9:
      GOSUB 5310
3230  PRINT "ENTER THE INTERVAL B
     ETWEEN"
3240  INPUT "READINGS (SECONDS) -
     -  ";R$: PRINT
3250  IF R$ = "" THEN  GOTO 3350
3260 R =  VAL (R$): IF R    1 OR R
        900 THEN  GOTO 3220
3270  IF R         INT (R) THEN  GOTO
     3220
3280 DLY = R
3290.MIN =  INT (DLY / 60):SEC =
     DLY - MIN * 60
3300 DLY$ = ""
3310 DLY$ = DLY$ +  RIGHT$ ("0" +
      STR$ (MIN),2) + " MIN "
3320 DLY$ = DLY$ +  RIGHT$ ("0" +
      STR$ (SEC),2) + " SEC"
3330 PARM$(LINE) = DLY$: GOSUB 53
     10
3350  HOME : GOSUB 5300:LINE = 10
     : GOSUB 5310
3360  PRINT "# OF READINGS PER IN
     STRUMENT"
```

```
3370  INPUT "(2000 MAXIMUM) --  "
     ;R$
3380  IF R$ = "" THEN  GOTO 3430
3390 R =  VAL (R$): IF R   1 OR R
      > 2000 THEN  GOTO 3350
3400 NR = R
3410 PARM$(LINE) = R$: GOSUB 5310

3430  HOME : GOSUB 5300:LINE = 11
     : GOSUB 5310
3440  PRINT "PRINTER OPTION": PRINT

3450  FOR I = 1 TO 2: PRINT "   ";
     I;") ";PO$(I): NEXT
3460  PRINT
3470  INPUT "SELECT (1-2) --  ";R
     $
3480  IF R$ = "" THEN  GOTO 3540
3490 R =  VAL (R$): IF R   1 OR R
        2 THEN  GOTO 3430
3500 PO = R
3505  IF PO = 1 THEN PARM$(LINE +
     1) = "1":PS = 1
3510  IF PO = 2 THEN PARM$(LINE +
     1) = "0":PS = 0
3520 PARM$(LINE) = PO$(R): GOSUB
     5310
3540  HOME : GOSUB 5300:LINE = 12
     : GOSUB 5310
3550  INPUT "PRINTER SLOT (0-7) -
     -  ";R$
3560  IF R$ = "" THEN  GOTO 3610
3570 R =  VAL (R$): IF R   0 OR R
        7 THEN  GOTO 3540
3580 PS = R
3590 PARM$(LINE) = R$: GOSUB 5310

3610  HOME : GOSUB 5300:LINE = 13
     : GOSUB 5310
3620  INPUT "E(XECUTE) / Q(UIT) -
     -  ";R$
3630  IF R$ = "" THEN  GOTO 1420
3640. IF R$       "E" AND R$
     "Q" THEN  GOTO 3610
3650  IF R$ = "Q" THEN  POKE 34,0
     : PRINT : PRINT "---PROGRAM
     TERMINATED---": END
3660  IF NC = 0 THEN  GOTO 1500
3670  IF (PO = 2 AND PS      0) OR
     (PO = 1 AND PS = 0) THEN  GOTO
     3540
3690 OP$ = D$ + "OPEN "
3700 CL$ = D$ + "CLOSE "
3710 UK$ = D$ + "UNLOCK "
```

```
3720 RD$ = D$ + "READ "
3730 WR$ = D$ + "WRITE "
3740 DE$ = D$ + "DELETE "
3750  HOME
3760 RDG = 0
3770  INVERSE : VTAB 15: HTAB 1: PRINT
     " PRESS CONTROL-D TO TERMINA
     TE THIS RUN ": NORMAL : HOME

3780  POKE  - 16368,0
3790  IF PO = 2 THEN  GOTO 3830
3800  PRINT : PRINT D$;"PR#";PS
3810  GOSUB 5690
3830  FOR M = 1 TO NR
3840 RDG = RDG + 1
3850  GOSUB 4760
3860  GOSUB 4610
3870  PRINT M;") "; MID$ (CT$,7,8
     );"  ";: FOR K = 1 TO NC: PRINT
      INT (RDG(RDG,CH(K)) * 1000 +
     .5) / 1000;" ";: NEXT : PRINT
     : GOTO 4380
4380  IF M = NR THEN  GOTO 4530
4390  IF (M / LPP) =  INT (M / LP
     P) THEN  PRINT  CHR$ (12): IF
     PO = 1 THEN  GOSUB 5690
4400 PK =  PEEK ( - 16384)
4410  IF PK       160 THEN  GOTO 4
     450
4420  HOME : FLASH : VTAB 20: HTAB
     17: PRINT " PAUSE ": NORMAL
     :X =  FRE (9): VTAB 22: HTAB
     8: PRINT "PRESS ANY KEY TO C
     ONTINUE": POKE  - 16368,0
4430  IF  PEEK ( - 16384)   127 THEN
      GOTO 4430
4440  HOME
4450  POKE  - 16368,0
4460  IF PK = 145 THEN M = NR: GOTO
     4530
4470  IF RDG    = REWR AND PO = 1
      THEN  PRINT : PRINT D$;"PR#
    0"
4480  IF RDG    = REWR AND OF
     2 THEN  GOSUB 4800
4490  IF RDG    = REWR AND OF
     1 THEN  GOSUB 4930
4500  IF RDG    = REWR AND PO = 1
      THEN  PRINT : PRINT D$;"PR#
     ";PS
4510  IF RDG    = REWR THEN RDG =
     0:FI = FI + 1
4520  GOSUB 5340
4530  NEXT M
```

```
4540  POKE  - 16368,0
4550  PRINT : PRINT  CHR$ (12): PRINT
     : PRINT D$;"PR#0"
4560  IF OF      2 THEN  GOSUB 48
     00
4570  IF OF       1 THEN  GOSUB 49
     30
4580  GOSUB 5100
4590  GOTO 1140
4610  FOR I = 0 TO 15
4620 AI13 =  - 16256 + SLOT * 16
4630  POKE AI13,16 * GC(I) + I
4640 VOLTS(I) =  PEEK  (AI13 + 1) *
     256 +  PEEK  (AI13)
4650  NEXT I
4670  FOR I = 0 TO 15
4680  IF GC(I)    4 THEN VOLTS(I) =
     VOLTS(I) * GAIN(I) / 4095 *
     CAL(I): GOTO 4700
4690 VOLTS(1) =  - (2048 - VOLTS(
     I)) * GAIN(I) / 2048 * CAL(I
     )
4700  NEXT I
4710  FOR I = 1 TO NC
4720 RDG(RDG,CH(I)) = VOLTS(CH(I)
     )
4730  NEXT I
4740  RETURN
4760  CALL 768
4770 TM$(RDG) =  MID$ (CT$,7,8)
4780  RETURN
4800 RC = 1: PRINT
4810 FO$ = "SAS." + FL$ + "." +  STR$
     (FI)
4820  PRINT OP$;FO$: PRINT CL$;FO
     $: PRINT DE$;FO$
4821  PRINT OP$;FO$
4830  PRINT WR$;FO$
4840  FOR I = 1 TO RDG
4850  FOR J = 1 TO NC
4860  PRINT  INT (RDG(I,CH(J)) *
     1000 + .5) / 1000;" ";
4870. NEXT
4880  PRINT TM$(I);"  ";RN;PC$
4890  NEXT
4900  PRINT CL$;FO$
4910  RETURN
4930 RC = 2: PRINT
4940 FO$ = "TGPH." + FL$ + "." +
      STR$ (FI)
4950  PRINT OP$;FO$: PRINT CL$;FO
     $: PRINT DE$;FO$
4951  PRINT OP$;FO$
4960  PRINT WR$;FO$
```

```
4970  FOR I = 1 TO NC
4980 L = 3
4990  FOR J = 1 TO RDG
5000 L = L +  LEN ( STR$ ( INT (R
     DG(J,CH(I)) * 1000 + .5) / 1
     000)) + 10
5010  IF L   70 THEN  PRINT "--":
     L = 3: GOTO 5000
5020  PRINT TM$(J);",": STR$ ( INT
     (RDG(J,CH(I)) * 1000 + .5) /
     1000);" ";
5030  NEXT
5040  PRINT "--"
5050  PRINT "END OF CHANNEL ";CH(
     I)
5060  NEXT
5070  PRINT CL$;FO$
5080  RETURN
5100  HOME : PRINT "READ DATA FIL
     E ? (Y/N) -- ";
5110  GET YN$: IF YN$       "Y" AND
     YN$       "N" THEN  GOTO 5110

5120  IF YN$ = "N" THEN  GOTO 525
     0
5130  TEXT : HOME : PRINT : PRINT
     D$;"CATALOG": PRINT : PRINT

5140  PRINT : INPUT "DATA FILE TO
      READ --  ";DF$
5150  IF DF$ = "" THEN  GOTO 5250

5155  PRINT : PRINT D$,"VERIFY ";
     DF$
5160  INPUT "PRINTER SLOT ? ( OR
     =SCREEN) --  ";OS$
5170 OS =  VAL (OS$): IF OS   0 OR
     OS   7 THEN  GOTO 5160
5180  IF OS       0 THEN  PRINT D$
     ;"PR#";OS
5190  PRINT D$;"MON I"
5200  PRINT D$;"OPEN ";DF$
5210  PRINT D$;"READ ";DF$
5220  GET F$: PRINT F$;: GOTO 522
     0
5230  PRINT : IF OS       0 THEN  PRINT
     D$;"PR#0"
5240  PRINT : PRINT D$;"CLOSE ";D
     F$
5245  PRINT : PRINT D$;"NOMON I"
5247  GOTO 5100
5250  RETURN
5270  FOR I = 1 TO 13: PRINT DSC$
     (I): NEXT
```

```
5280  FOR I = 1 TO 13: VTAB I: HTAB
     24: CALL  - 868: PRINT FARM$
     (I): NEXT
5290  RETURN
5300  VTAB LINE: HTAB 24: CALL  -
     868: PRINT FARM$(LINE): HOME
     : RETURN
5310  VTAB LINE: HTAB 24: CALL  -
     868: INVERSE : PRINT FARM$(L
     INE): NORMAL : HOME : RETURN

5340 T(1) =  VAL ( MID$ (FT$,7,2)
     )
5350 T(2) =  VAL ( MID$ (FT$,10,2
     ))
5360 T(3) =  VAL ( MID$ (FT$,13,2
     ))
5370 T(4) =  VAL ( MID$ (FT$,16,3
     ))
5380 T(3) = T(3) + DLY
5390  FOR I = 3 TO 1 STEP  - 1
5400 TTL = T(I)
5410 T(I) = TTL -  INT (TTL / 60)
      * 60
5420  IF I      1 THEN T(I - 1) =
     T(I - 1) +  INT (TTL / 60)
5430  NEXT
5440 ET$ =  MID$ (FT$,1,6) +  RIGHT$
     ("0" +  STR$ (T(1)),2) + ":"
      +  RIGHT$ ("0" +  STR$ (T(2
     )),2) + "." +  RIGHT$ ("0" +
      STR$ (T(3)),2) + "." +  RIGHT$
     ("000" +  STR$ (T(4)),3)
5450  CALL 768
5460  IF FT$    ET$ THEN  GOTO 545
     0
5470  RETURN
5490 ER =  PEEK  (222)
5500  CALL 835
5510  IF FD = 1 OR FD = 2 THEN  PRINT
     : PRINT D$;"PR#0"
5520  IF ER      5 AND ER      6 THEN
      HOME : FOR BELL = 1 TO 5: CALL
      - 198: NEXT : PRINT
5530  IF ER = 4 THEN  GOTO 5590
5540  IF ER = 5 THEN  GOTO 5600
5550  IF ER = 6 THEN  GOTO 5610
5560  IF ER = 8 THEN  GOTO 5620
5570  IF ER = 9 THEN  GOTO 5630
5575  IF ER = 53 OR ER = 69 OR ER
      = 191 OR ER = 254 THEN  GOTO
     1140: REM BAD INPUT
```

```
5590  PRINT "WRITE PROTECT ERROR"
     : PRINT : PRINT "REMOVE THE
     WRITE PROTECT TAB": PRINT "E
     XISTING ON THIS DISKETTE.": GOTO
     5640
5600 RC = 0: GOTO 5230
5610 RC = 0: GOTO 5100
5620  PRINT "I/O ERROR": PRINT : PRINT
     "MAKE SURE DISKETTE WAS INIT
     IALIZED": PRINT "MAKE SURE D
     OOR ON DRIVE IS CLOSED.": GOTO
     5640
5630  PRINT DE$;FD$: PRINT "DISK
     FULL ERROR": PRINT : PRINT "
     INSERT ANOTHER INITIALIZED D
     ISKETTE": PRINT "TO SAVE THE
      CURRENT READINGS."
5640  PRINT : PRINT "PRESS ANY KE
     Y TO RETRY ";: GET KB$
5650  PRINT : HOME
5660  IF RC      2 THEN RC = 0:I =
     RDG:J = NC: GOTO 4800
5670  IF RC = 2 THEN RC = 0:I = N
     C:J = RDG: GOTO 4930
5690  PRINT : PRINT
5700 PG = PG + 1
5710  PRINT "DATA ACQUISITION....
     .";
5720  CALL 768
5730  PRINT CT$;
5740  PRINT  SPC( 9);"PAGE  ";PG
5750  PRINT "RUN NUMBER.... .....
     .";RN; SPC( 5);
5760  PRINT "ACTIVE CHANNELS.....
     .";AC$; SPC( 5);
5770  PRINT "FILENAME............
     .";FL$
5780  PRINT
5790  RETURN
6050 CS = 0:CH =  - 1
6060 AC =  LEN (AC$)
6070  FOR I = 1 TO AC
6080  IF  MID$ (AC$,I,1) = CS$ THEN
     I = AC:CS = 1: GOTO 6110
6090  NEXT
6100  GOTO 6130
6110 CH =  VAL (CS$)
6120  IF  ASC (CS$)   64 AND  ASC
     (CS$)   71 THEN CH =  ASC (C
     S$) - 55
6130  RETURN
```

APPENDIX V

Real-time and Filter Data

Filter Data

A complete listing of the filter data is listed. There were tWo types of clothing worn for the experiment, clean, which was the disposable clothing, and dirty, which was the workers' own coveralls. The two drum levels (signified as DRUM) were full, being two-thirds or more full, and empty, being one-third full or less. There were six sampling locations and are shown in Figure 9. Flow is given in standard cubic feet per hour, pressure drop across the filter (P DROP) in inches of water, weight on the filter (WEIGHT) in milligrams, and concentration in milligrams per cubic meter.

Real-time Data

The real-time data is given as strings. The members of the string are as follows:

1	RAM, inside the hood, volts.
2	RAM, background, volts.
3	HAM, worker lapel, volts.
4,5,6	Event markings.
7	Time, hours:minutes:seconds.
8	Run number.
9,10,11, 12,13,14	Active channel numbers.

FILTER DATA

CLOTHING	DRUM	LOCATION	WORKER	FLOW	P DROP	WEIGHT	CONCENTRATION
Dirty	Full	Back Ground	1	29	32	0.04	0.142
Dirty	Full	Bin	1	30	33	0.04	0.136
Dirty	Full	Face	1	29	35	0.05	0.180
Dirty	Full	Hat	1	29	37	0.15	0.546
Dirty	Full	Left Lapel	1	29	37	0.25	0.903
Dirty	Empty	Back Ground	1	17	50	0.05	0.154
Dirty	Empty	Bin	1	25	50	0.10	0.294
Dirty	Empty	Face	1	29	34.5	0.11	0.325
Dirty	Empty	Hat	1	29	44	15.52	47.069
Dirty	Empty	Left Lapel	1	28	50	105.58	325.592
Clean	Full	Back Ground	1	29	30	0.01	0.049
Clean	Full	Bin	1	27	50	0.04	0.197
Clean	Full	Face	1	29	34	0.04	0.197
Clean	Full	Hat	1	29	37	5.13	25.700
Clean	Full	Left Lapel	1	29	36	0.26	1.290
Clean	Empty	Back Ground	1	29	31.5	0.05	0.244
Clean	Empty	Bin	1	30	35	0.03	0.141
Clean	Empty	Face	1	10	50	0.07	0.359
Clean	Empty	Hat	1	17	50	1.90	9.814
Clean	Empty	Left Lapel	1	28	40	18.47	92.160
Clean	Full	Back Ground	1	29	31.5	0.05	0.258
Clean	Full	Bin	1	30	33	0.04	0.198
Clean	Full	Face	1	29	34	0.04	0.208
Clean	Full	Hat	1	29	36	0.18	0.946
Clean	Full	Left Lapel	1	28	38	3.11	16.317
Clean	Full	Right Lapel	1	28	38	4.36	22.719
Dirty	Empty	Back Ground	1	29	33	0.07	0.339
Dirty	Empty	Bin	1	30	32.5	0.07	0.323
Dirty	Empty	Face	1	30	35.5	0.10	0.488
Dirty	Empty	Hat	1	17	50	0.55	2.810
Dirty	Empty	Left Lapel	1	28	45	35.73	178.766
Dirty	Empty	Right Lapel	1	28	50	75.66	381.226
Dirty	Full	Back Ground	1	29	32	0.23	1.350
Dirty	Full	Bin	1	30	35	1.49	8.413
Dirty	Full	Face	1	29	38	7.71	46.004
Dirty	Full	Hat	1	29	33	5.58	33.077
Dirty	Full	Left Lapel	1	28	40	15.17	91.011
Dirty	Full	Right Lapel	1	29	39.5	15.36	91.395
Clean	Empty	Back Ground	1	29	33	0.10	0.500
Clean	Empty	Bin	1	30	35	0.11	0.528
Clean	Empty	Face	1	29	37	0.08	0.405
Clean	Empty	Hat	1	29	37	1.43	7.283
Clean	Empty	Left Lapel	1	28	42	2.21	11.332
Clean	Empty	Right Lapel	1	28	50	90.11	469.169
Clean	Empty	Back Ground	2	29	31.5	0.01	0.035
Clean	Empty	Bin	2	14	50	0.06	0.211
Clean	Empty	Face	2	29	36	0.08	0.284
Clean	Empty	Hat	2	28	50	1.52	5.643

FILTER DATA

CLOTHING	DRUM	LOCATION	WORKER	FLOW	P DROP	WEIGHT	CONCENTRATION
Clean	Empty	Left Lapel	2	28	49	4.34	15.956
Clean	Empty	Right Lapel	2	29	39.5	14.41	51.252
Dirty	Full	Back Ground	2	12	50	0.03	0.112
Dirty	Full	Bin	2	22	50	0.05	0.179
Dirty	Full	Face	2	29	38	0.06	0.217
Dirty	Full	Hat	2	29	37	0.65	2.365
Dirty	Full	Left Lapel	2	28	38	2.66	9.636
Dirty	Full	Right Lapel	2	28	40	4.27	15.447
Dirty	Empty	Back Ground	2	29	29.5	0.00	0.000
Dirty	Empty	Bin	2	30	33.5	0.02	0.069
Dirty	Empty	Face	2	14	50	0.11	0.413
Dirty	Empty	Hat	2	29	33	0.99	3.577
Dirty	Empty	Left Lapel	2	28	39	3.10	11.304
Dirty	Empty	Right Lapel	2	28	34	2.54	9.075
Clean	Full	Back Ground	2	29	32.5	0.02	0.069
Clean	Full	Bin	2	30	34	0.08	0.263
Clean	Full	Face	2	29	37	0.12	0.417
Clean	Full	Hat	2	29	38	0.75	2.632
Clean	Full	Left Lapel	2	28	37.5	1.65	5.742
Clean	Full	Right Lapel	2	28	45	3.99	14.077
Dirty	Empty	Back Ground	2	29	33	0.04	0.194
Dirty	Empty	Bin	2	30	33	0.07	0.323
Dirty	Empty	Face	2	29	34	0.10	0.486
Dirty	Empty	Hat	2	29	37	2.69	13.259
Dirty	Empty	Left Lapel	2	29	37	1.63	7.979
Dirty	Empty	Right Lapel	2	28	36.5	7.67	37.237
Clean	Empty	Back Ground	2	29	31	0.02	0.095
Clean	Empty	Bin	2	30	32.5	0.03	0.136
Clean	Empty	Face	2	29	33	0.27	1.287
Clean	Empty	Hat	2	29	37.5	1.09	5.294
Clean	Empty	Left Lapel	2	28	40	9.20	44.681
Clean	Empty	Right Lapel	2	29	31	3.38	15.912
Clean	Full	Back Ground	2	29	28	0.00	0.000
Clean	Full	Bin	2	30	32.5	0.03	0.165
Clean	Full	Face	2	29	34	0.12	0.695
Clean	Full	Hat	2	29	38	5.75	33.883
Clean	Full	Left Lapel	2	28	40	16.18	95.204
Clean	Full	Right Lapel	2	28	41	14.74	86.372
Dirty	Full	Back Ground	2	29	28.5	0.25	1.324
Dirty	Full	Bin	2	30	33	0.04	0.205
Dirty	Full	Face	2	30	31	0.05	0.267
Dirty	Full	Hat	2	29	37	1.85	10.095
Dirty	Full	Left Lapel	2	29	37	4.26	23.087
Dirty	Full	Right Lapel	2	29	32	3.50	18.586
Clean	Empty	Back Ground	3	29	34	0.10	0.412
Clean	Empty	Bin	3	24	50	0.21	0.863
Clean	Empty	Face	3	23	50	-0.01	-0.043
Clean	Empty	Hat	3	28	50	1.45	6.291

FILTER DATA

CLOTHING	DRUM	LOCATION	WORKER	FLOW	P DROP	WEIGHT	CONCENTRATION
Clean	Empty	Left Lapel	3	27	50	0.97	4.180
Clean	Empty	Right Lapel	3	28	38	18.54	76.757
Dirty	Empty	Back Ground	3	29	31	0.01	0.047
Dirty	Empty	Bin	3	30	32	0.14	0.625
Dirty	Empty	Face	3	21	50	-0.01	-0.049
Dirty	Empty	Hat	3	29	40	1.52	7.317
Dirty	Empty	Left Lapel	3	26	50	2.67	13.123
Dirty	Empty	Right Lapel	3	28	38	19.71	93.076
Clean	Full	Back Ground	3	29	31	0.00	0.000
Clean	Full	Bin	3	30	32	0.04	0.195
Clean	Full	Face	3	25	50	0.00	0.000
Clean	Full	Hat	3	26	50	0.11	0.594
Clean	Full	Left Lapel	3	26	50	0.29	1.555
Clean	Full	Right Lapel	3	29	31	0.54	2.729
Dirty	Full	Back Ground	3	29	31.5	0.34	1.753
Dirty	Full	Bin	3	30	32	0.08	0.394
Dirty	Full	Face	3	24	50	0.01	0.054
Dirty	Full	Hat	3	23	50	0.07	0.382
Dirty	Full	Left Lapel	3	27	50	0.10	0.542
Dirty	Full	Right Lapel	3	28	34	1.45	7.474
Dirty	Full	Back Ground	3	29	30	0.04	0.243
Dirty	Full	Bin	3	30	32.5	0.09	0.525
Dirty	Full	Face	3	29	32	0.03	0.183
Dirty	Full	Hat	3	25	50	-0.01	-0.065
Dirty	Full	Left Lapel	3	29	35	0.17	1.047
Dirty	Full	Right Lapel	3	29	34	1.33	8.115
Clean	Full	Back Ground	3	29	31	0.08	0.519
Clean	Full	Bin	3	30	32	0.02	0.124
Clean	Full	Face	3	29	39	-0.01	-0.066
Clean	Full	Hat	3	29	36	0.09	0.596
Clean	Full	Left Lapel	3	29	34.5	0.28	1.835
Clean	Full	Right Lapel	3	29	35.5	1.43	9.332
Dirty	Empty	Back Ground	3	29	30.5	0.06	0.416
Dirty	Empty	Bin	3	30	34.5	0.21	1.404
Dirty	Empty	Face	3	26	50	0.01	0.073
Dirty	Empty	Hat	3	25	50	0.14	1.031
Dirty	Empty	Left Lapel	3	28	38	0.56	3.963
Dirty	Empty	Right Lapel	3	29	35	8.56	59.678
Clean	Empty	Back Ground	3	29	30	0.07	0.453
Clean	Empty	Bin	3	30	33	0.04	0.249
Clean	Empty	Face	3	29	33.5	0.16	1.046
Clean	Empty	Hat	3	29	43	10.61	71.649
Clean	Empty	Left Lapel	3	28	44	21.80	146.603
Clean	Empty	Right Lapel	3	28	37	3.14	20.574

Real-time Data

.029	.049	3E-03	2E-03	2E-03	2E-03	13:34:16	2	0	1	2	3	4 5
.037	.049	4E-03	2E-03	2E-03	4E-03	13:34:18	2	0	1	2	3	4 5
.034	.048	.012	1.289	2E-03	2E-03	13:34:20	2	0	1	2	3	4 5
.056	.049	.015	1.288	2E-03	2E-03	13:34:22	2	0	1	2	3	4 5
.052	.05	.015	1.288	1E-03	2E-03	13:34:24	2	0	1	2	3	4 5
.044	.051	.015	1.287	2E-03	4E-03	13:34:27	2	0	1	2	3	4 5
.039	.049	.01	1.287	2E-03	2E-03	13:34:29	2	0	1	2	3	4 5
.037	.052	5E-03	4E-03	1.287	1E-03	13:34:31	2	0	1	2	3	4 5
.034	.051	.01	2E-03	4E-03	1.288	13:34:33	2	0	1	2	3	4 5
.031	.052	.01	2E-03	2E-03	1.289	13:34:35	2	0	1	2	3	4 5
.034	.054	.014	2E-03	4E-03	4E-03	13:34:37	2	0	1	2	3	4 5
.043	.051	.013	1.287	2E-03	2E-03	13:34:39	2	0	1	2	3	4 5
.078	.05	9E-03	1.287	2E-03	2E-03	13:34:41	2	0	1	2	3	4 5
.083	.056	.039	2E-03	1.287	2E-03	13:34:43	2	0	1	2	3	4 5
.078	.054	.029	2E-03	1.287	2E-03	13:34:45	2	0	1	2	3	4 5
.059	.054	.017	2E-03	1.287	2E-03	13:34:47	2	0	1	2	3	4 5
.054	.054	01	2E-03	1.287	2E-03	13:34:49	2	0	1	2	3	4 5
.044	05	5E-03	2E-03	1.287	2E-03	13:34:51	2	0	1	2	3	4 5
.038	.052	6E-03	2E-03	4E-03	1.287	13:34:53	2	0	1	2	3	4 5
.037	.056	8E-03	2E-03	4E-03	1.287	13:34:55	2	0	1	2	3	4 5
.034	.06	.015	2E-03	4E-03	1.287	13:34:57	2	0	1	2	3	4 5
.034	.059	.011	2E-03	4E-03	4E-03	13:34:59	2	0	1	2	3	4 5
.032	.059	.01	1.287	2E-03	4E-03	13:35:01	2	0	1	2	3	4 5
.049	.057	.01	1.287	2E-03	2E-03	13:35:03	2	0	1	2	3	4 5
.054	.059	.015	1.285	1E-03	2E-03	13:35:06	2	0	1	2	3	4 5
.049	.056	.019	.059	2E-03	2E-03	13:35:08	2	0	1	2	3	4 5
.046	.054	.017	2E-03	1.287	3E-03	13:35:10	2	0	1	2	3	4 5
.049	.052	.016	2E-03	1.287	2E-03	13:35:12	2	0	1	2	3	4 5
.043	.05	8E-03	4E-03	1.285	1E-03	13:35:14	2	0	1	2	3	4 5
.049	.052	6E-03	2E-03	1.285	1E-03	13:35:16	2	0	1	2	3	4 5
.049	.051	6E-03	2E-03	1.285	2E-03	13:35:18	2	0	1	2	3	4 5
.043	.05	.073	2E-03	.043	2E-03	13:35:20	2	0	1	2	3	4 5
.039	.051	.031	2E-03	2E-03	1.287	13:35:22	2	0	1	2	3	4 5
.034	.052	.014	2E-03	4E-03	1.287	13:35:24	2	0	1	2	3	4 5
.034	.054	.012	2E-03	2E-03	1.287	13:35:26	2	0	1	2	3	4 5
.037	.054	.011	1.284	2E-03	4E-03	13:35:28	2	0	1	2	3	4 5
.043	.052	.01	1.284	1E-03	2E-03	13:35:30	2	0	1	2	3	4 5
.048	.056	.015	5E-03	1.284	2E-03	13:35:32	2	0	1	2	3	4 5
.044	.054	9E-03	2E-03	1.284	2E-03	13:35:34	2	0	1	2	3	4 5
.04	.051	.016	.016	1.284	2E-03	13:35:36	2	0	1	2	3	4 5
039	.051	.016	2E-03	1.284	2E-03	13:35:38	2	0	1	2	3	4 5
.034	.054	.014	2E-03	1.284	2E-03	13:35:40	2	0	1	2	3	4 5
.033	.052	.032	2E-03	.154	2E-03	13:35:42	2	0	1	2	3	4 5
.029	.051	.054	2E-03	4E-03	1.287	13:35:45	2	0	1	2	3	4 5
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.044 .062 2E-03 1.281 2E-03 2E-03 13:48:02 2 0 1 2 3 4 5
.044 .063 7E-03 1.279 1E-03 2E-03 13:48:04 2 0 1 2 3 4 5
.044 .062 .015 1.279 2E-03 2E-03 13:48:06 2 0 1 2 3 4 5
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.042 .062 .029 1.268 1.267 2E-03 13:48:10 2 0 1 2 3 4 5
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.046	.073	.147	4E-03	1.279	2E-03	13:52:39	2	0	1	2	3	4	5
.046	.073	.06	2E-03	1.279	2E-03	13:52:41	2	0	1	2	3	4	5
.045	.073	.018	2E-03	1.279	2E-03	13:52:43	2	0	1	2	3	4	5
.046	.073	.02	2E-03	1.279	2E-03	13:52:45	2	0	1	2	3	4	5
.044	.071	.018	2E-03	2E-03	1.279	13:52:47	2	0	1	2	3	4	5
.048	.077	.019	2E-03	2E-03	1.279	13:52:49	2	0	1	2	3	4	5
.045	.076	.017	2E-03	2E-03	1.279	13:52:51	2	0	1	2	3	4	5
.045	.077	.015	1.278	2E-03	2E-03	13:52:53	2	0	1	2	3	4	5
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.068	.078	.071	1.277	2E-03	2E-03	13:52:57	2	0	1	2	3	4	5
.082	.076	.163	1.277	2E-03	2E-03	13:52:59	2	0	1	2	3	4	5
.073	.073	.107	2E-03	1.277	2E-03	13:53:01	2	0	1	2	3	4	5
.063	.071	.042	1.277	2E-03	4E-03	13:53:03	2	0	1	2	3	4	5
.06	.071	.123	7E-03	1.277	2E-03	13:53:05	2	0	1	2	3	4	5
.056	.074	.145	2E-03	1.277	2E-03	13:53:07	2	0	1	2	3	4	5
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.05	.071	.068	2E-03	1.277	1E-03	13:53:14	2	0	1	2	3	4	5
.048	.074	.025	2E-03	1.277	2E-03	13:53:16	2	0	1	2	3	4	5
.048	.076	.016	2E-03	4E-03	1.279	13:53:18	2	0	1	2	3	4	5
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.048	.077	.011	2E-03	4E-03	1.279	13:53:24	2	0	1	2	3	4	5
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.054	.068	.106	1.277	2E-03	2E-03	13:53:30	2	0	1	2	3	4	5
.056	.071	.054	1.276	2E-03	2E-03	13:53:32	2	0	1	2	3	4	5
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.045	.071	.012	2E-03	1.277	2E-03	13:53:38	2	0	1	2	3	4	5
.044	.068	6E-03	2E-03	1.277	2E-03	13:53:40	2	0	1	2	3	4	5
.043	.07	8E-03	2E-03	1.277	2E-03	13:53:42	2	0	1	2	3	4	5
.043	.07	.127	2E-03	4E-03	1.279	13:53:44	2	0	1	2	3	4	5
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.043	.068	.02	2E-03	2E-03	1.278	13:53:48	2	0	1	2	3	4	5
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.054	.07	.522	1.274	2E-03	2E-03	13:53:55	2	0	1	2	3	4	5
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.049	.071	.011	2E-03	4E-03	1.278	13:54:11	2	0	1	2	3	4	5
.05	.068	.011	1.193	2E-03	5E-03	13:54:13	2	0	1	2	3	4	5

.052	.066	.231	1.274	2E-03	4E-03	13:54:15	2	0	1	2	3	4 5
.052	.066	.43	1.273	2E-03	2E-03	13:54:17	2	0	1	2	3	4 5
.057	.066	.428	1.273	2E-03	2E-03	13:54:22	2	0	1	2	3	4 5
.054	.068	.695	1.273	2E-03	2E-03	13:54:24	2	0	1	2	3	4 5
.049	.068	.732	1.273	2E-03	4E-03	13:54:26	2	0	1	2	3	4 5
.046	.063	.446	1E-03	1.276	2E-03	13:54:28	2	0	1	2	3	4 5
.044	.062	.167	2E-03	1.276	2E-03	13:54:30	2	0	1	2	3	4 5
.044	.062	.053	2E-03	1.276	2E-03	13:54:32	2	0	1	2	3	4 5
.048	.062	.036	2E-03	4E-03	1.277	13:54:34	2	0	1	2	3	4 5
.049	.063	.017	2E-03	4E-03	4E-03	13:54:36	2	0	1	2	3	4 5
.045	.063	.011	1.276	2E-03	2E-03	13:54:38	2	0	1	2	3	4 5
.046	.066	9E-03	1.276	2E-03	2E-03	13:54:40	2	0	1	2	3	4 5
.046	.066	.027	1.274	1E-03	2E-03	13:54:42	2	0	1	2	3	4 5
.049	.068	.086	.27	1.259	2E-03	13:54:44	2	0	1	2	3	4 5
.056	.066	.373	1.273	2E-03	2E-03	13:54:46	2	0	1	2	3	4 5
.063	.065	.24	1.274	1E-03	2E-03	13:54:48	2	0	1	2	3	4 5
.061	.063	.426	1.273	2E-03	2E-03	13:54:50	2	0	1	2	3	4 5
.054	.062	.289	1.273	2E-03	2E-03	13:54:52	2	0	1	2	3	4 5
.046	.063	.125	1.274	2E-03	4E-03	13:54:54	2	0	1	2	3	4 5
.043	.07	.046	2E-03	1.277	2E-03	13:54:56	2	0	1	2	3	4 5
.042	.066	.021	2E-03	1.276	2E-03	13:54:58	2	0	1	2	3	4 5
.046	.063	.016	2E-03	1.276	2E-03	13:55:01	2	0	1	2	3	4 5
.049	.066	.094	2E-03	4E-03	1.277	13:55:03	2	0	1	2	3	4 5
.049	.062	.049	2E-03	2E-03	1.277	13:55:05	2	0	1	2	3	4 5
.06	.061	.024	2E-03	4E-03	4E-03	13:55:07	2	0	1	2	3	4 5
.072	.066	.02	1.277	2E-03	4E-03	13:55:09	2	0	1	2	3	4 5
.111	.066	.242	1.274	2E-03	4E-03	13:55:11	2	0	1	2	3	4 5
.117	.066	.383	1.273	2E-03	2E-03	13:55:13	2	0	1	2	3	4 5
.112	.063	.132	1.274	2E-03	2E-03	13:55:15	2	0	1	2	3	4 5
.093	.062	1	1.273	2E-03	2E-03	13:55:17	2	0	1	2	3	4 5
.077	.063	.856	1.273	2E-03	2E-03	13:55:19	2	0	1	2	3	4 5
.068	.062	.492	1.272	2E-03	2E-03	13:55:21	2	0	1	2	3	4 5
.059	.066	.153	2E-03	1.276	2E-03	13:55 23	2	0	1	2	3	4 5
.051	.065	.044	2E-03	1.274	1E-03	13:55:25	2	0	1	2	3	4 5
.049	.062	.065	2E-03	1.276	2E-03	13:55:27	2	0	1	2	3	4 5
.046	.062	.041	2E-03	4E-03	1.277	13:55:29	2	0	1	2	3	4 5
.046	.062	.019	2E-03	2E-03	1.277	13:55:31	2	0	1	2	3	4 5
.046	.065	.039	2E-03	4E-03	1.277	13:55:33	2	0	1	2	3	4 5
.05	.065	.022	1.274	2E-03	2E-03	13:55:35	2	0	1	2	3	4 5
.056	.063	.013	1.274	2E-03	4E-03	13:55:37	2	0	1	2	3	4 5
.061	.066	.011	1.274	2E-03	2E-03	13:55:39	2	0	1	2	3	4 5
.243.	.063	.371	1.273	2E-03	2E-03	13:55:42	2	0	1	2	3	4 5
.206	.068	.225	2E-03	1.276	2E-03	13:55:44	2	0	1	2	3	4 5
.151	.071	.473	1.272	2E-03	2E-03	13:55:46	2	0	1	2	3	4 5
.115	.071	.545	2E-03	1.274	2E-03	13:55:48	2	0	1	2	3	4 5
.098	.07	.231	1E-03	1.274	2E-03	13:55:50	2	0	1	2	3	4 5
.077	.068	.074	2E-03	5E-03	4E-03	13:55:52	2	0	1	2	3	4 5
.076	.068	.066	2E-03	2E-03	1.277	13:55:54	2	0	1	2	3	4 5
.076	.073	.034	2E-03	2E-03	1.277	13:55:56	2	0	1	2	3	4 5