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IMPROVED DUST CONTROL AT CHUTES, DUMPS, TRANSFER  
POINTS AND CRUSHERS IN NONCOAL MINING OPERATIONS

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Improved Dust Control at Chutes, Dumps, Transfer  
Points and Crushers in Noncoal Mining Operations

9 June 1978

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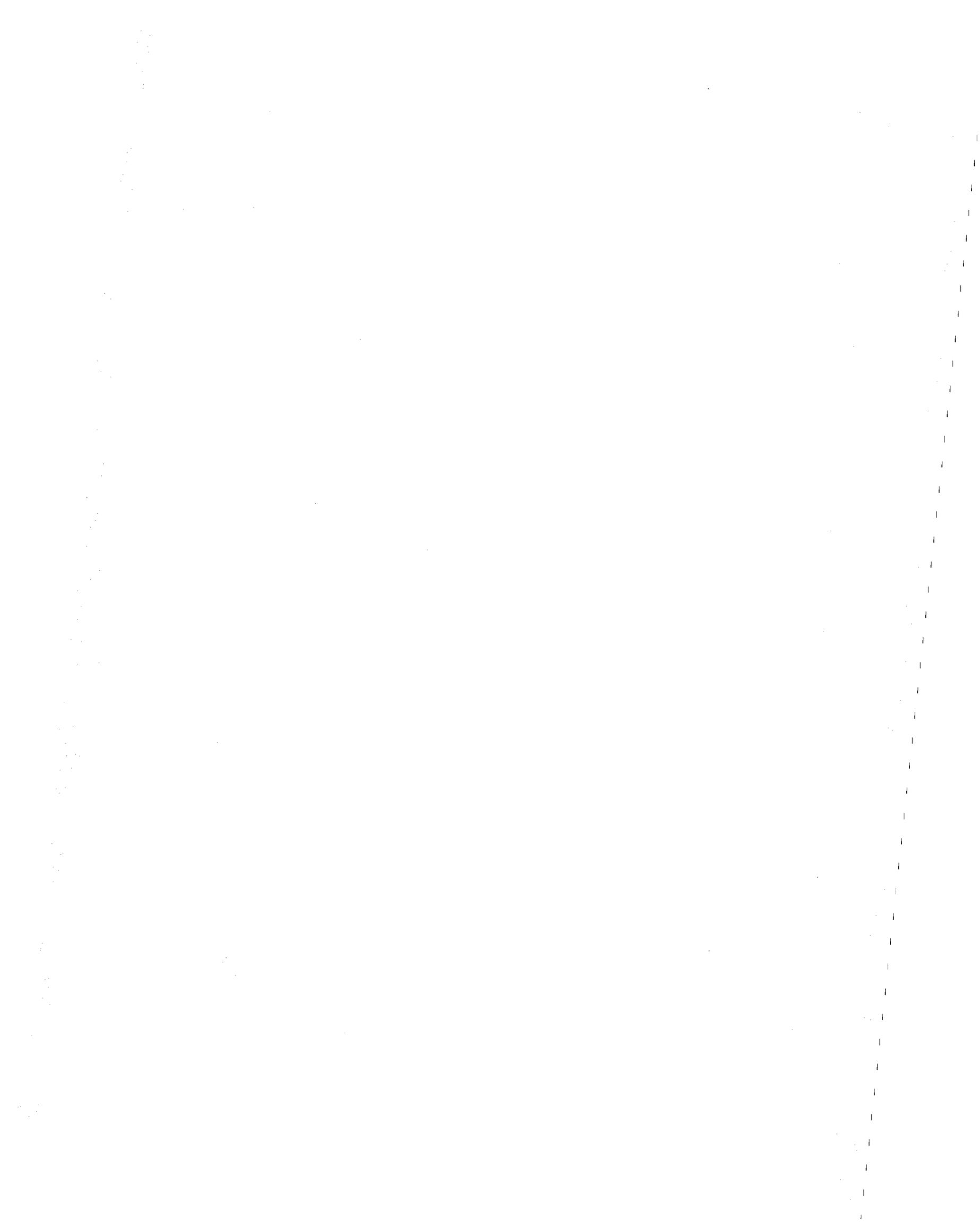
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## FOREWORD

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This report is a summary of work completed as part of this contract during the period 19 June 1973 to 31 December 1976. The draft of the final report was submitted by the authors on 29 July 1977 and the final report on 9 June 1978.



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## ABSTRACT

Improved methods of dust control in the metal and nonmetal mining industries were studied. Preliminary dust surveys were made at selected mines and three mines were chosen for additional studies. Dust control effectiveness was evaluated using full shift gravimetric sampling and GCA Dust Monitor readings. Analyses for free silica content and particle size distribution were conducted.

A belt washing system which was used to control dust at a transfer point was evaluated. The average reduction of respirable dust was 48% and the average reduction of total dust was 78%. The belt washing system not only maintained the work place within compliance but reduced maintenance problems along the beltway by 90%.

Exhaust ventilation at a crusher was evaluated for control effectiveness. Ventilation, along with operation of the crusher control room under slight positive pressure, maintained the work place within compliance.

An exhaust ventilation system was designed for use at an underground rotary dump. Although the system was not installed or evaluated, details on the design are given.

High expansion foam was used at an ore chute in an attempt to control dust at the draw point and loading point. Results indicated that foam did not effectively control dust.



## INTRODUCTION

The objective of this program was to evaluate improved methods of dust control at crushers, chutes, dumps and transfer points in noncoal mining operations. No new methods of dust control, with the possible exception of foam, have been developed over the recent years; foam has been studied as a means of dust control in coal mines on continuous mining machines and beltways. Since no new methods have been developed recently, it was the goal of this program to demonstrate that existing control systems, when properly sized and maintained and with appropriate modifications, can effectively reduce respirable dust concentrations to levels less than the Threshold Limit Values.

The primary effort on the program was to improve existing dust control equipment by procedures such as installing tight fitting enclosures and skirting, reducing or eliminating openings in systems, gasketing access ports, installing or modifying water spray systems and installing belt washers. Foam was studied as part of this program and it was necessary to determine the effects of foam on the flotation processes used in the metal mining industry.

The program consisted of three separate phases:

- Phase I - Review existing dust control methods and systems
- Phase II - Design and/or modify dust control systems
- Phase III - Demonstrate the feasibility of the selected dust control systems.

Phases I and II were completed during the course of the program. Phase III was only partially completed due to production curtailment or changes in mining operations by the participating mining companies.

During Phase I extensive dust surveys were conducted at several different mines and processing plants. Samples were taken at limestone, copper, trona, salt and iron mining operations. The sampling program was conducted using a GCA RDM Respirable Dust Monitor\* and personal gravimetric samplers. The

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\*GCA Corporation, GCA Technology Division, Bedford, MA 01730

GCA monitor was used for spot checks and the personal gravimetric samplers were used to acquire full shift data on total and respirable dust concentrations. Crystalline silica analysis and particle size determinations were made on selected samples.

During Phase II, dust control systems were designed for selected dust sources at a copper mine and a trona mine. Detailed drawings were submitted to each company. However, operational changes at each of the mines prevented the installation of the proposed changes.

Phase III required the demonstration of the feasibility of the proposed dust control systems. Since the recommended systems were not installed, testing could not be conducted. However, the evaluation of high expansion foam to control dust at a grizzly line and a belt washing system at a transfer point was accomplished.

## SUMMARY

A number of mines were subjected to a preliminary dust survey in order to:

1. Determine the existence, location and magnitude of dust sources.
2. Evaluate dust control systems and techniques which are currently being used to control dust.

One of the primary objectives of the program was to determine the feasibility of using existing dust control systems for a broad range of other dust control problems.

A basic premise of the program was that existing dust control techniques would be evaluated by employing both short term and full shift dust concentration measurements.\* It was established early in the program that many of the potential test sites were not suitable since the test area was contaminated not only by the dust source being studied but also by neighboring dust sources. Typical examples of this problem were:

1. Multiple crushers and transfer points housed within the same building.
2. Bypassing of ventilation air through ore passes resulting in either reduced ventilation at a test site downstream of the ore pass or contamination of the test site with air passing through the ore raise.
3. Variable air currents through partially enclosed buildings.

As a result of these problems many of the potential test sites which were evaluated proved to be unacceptable locations for the purposes of the study.

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\*Short term dust concentration measurements were made with the GCA Respirable Dust Monitor and full shift measurements were made with gravimetric samplers.

Time and cost effectiveness were considered during development of the program. It was decided that the dust control systems to be evaluated would be:

1. Working systems which could be upgraded or modified.
2. Minimal cost systems which could be installed by the participating mining companies.

This approach avoided the potentially long delivery times for dust control and collection systems and eliminated the need for large capital investments in these systems. The mining companies were very cooperative during the study, but were in some cases limited in their participation by uncontrollable factors such as strikes and production curtailment.

Preliminary surveys were conducted at 5 limestone, 2 copper, 2 iron, 1 trona and 1 salt mine. As a result of these preliminary surveys, 1 copper, 1 trona and 1 iron mine were selected for further study of dust control techniques.

At the copper mine, high expansion foam was applied at the draw point to an ore chute. Three different types of foam were used, and the results indicated no reduction in dust levels. At the same copper mine, recommendations were made for reducing dust at the primary crusher (install skirting, gasket openings, install scavenger belt), a rotary dump (install local exhaust system) and a transfer point (install belt washing system). Guidelines are presented in this report for sizing and installing these control systems, but due to production curtailments at the mine, the installations were not completed thus no data on the effectiveness could be acquired.

At the trona mine, recommendations were made for improving dust control procedures at a dump and at a crusher. Due to a pending change in mining procedures, the mining company elected not to modify the dust control procedures until the new mining plan was put into operation.

A detailed study of a conveyor belt washing system was conducted at an iron mine. Data were collected with the belt washing system in both the ON and OFF modes and the results indicated a reduction in respirable dust concentration (full shift measurement) of 48% with the belt washing system ON. Total dust concentration was reduced by 78% with the belt washing system in the ON mode. Without the use of a belt washing system at the location which was studied the work place would have been out of compliance.

Samples were taken to determine dust concentration, silica content and particle size. An evaluation of these samples has led to the following conclusions:

1. There is poor agreement between gravimetric values acquired with vinyl versus silver membrane filters.
2. Particle size analyses indicated that the geometric mean size by count was about 1.0 micrometer.
3. The ratio of respirable dust to total dust varied considerably and depended upon the manner in which the dust was generated, the "aging" of the dust and dust control procedures.
4. There is poor agreement between silica analyses by the x-ray diffraction method on silver membrane filters and the infrared method on vinyl membrane filters.

## DUST SAMPLING AND ANALYSIS

The Federal Metal and Nonmetallic Mine Safety Act (Public Law 89-577) and Federal Register specify the air quality that must be maintained in working areas of mines and mills. It is mandatory that "the exposure to airborne contaminants of a person working in a mine shall not exceed, on the basis of a time weighted average (TWA), the threshold limit values (TLVs) adopted by the American Conference of Governmental Industrial Hygienists, as set forth and explained in the most recent edition of the Conference's publication entitled Threshold Limit Values of Airborne Contaminants." The TLVs for minerals containing silica and silicates, as well as nuisance particulates, are presented in Table 1. The nuisance particulates listed in Table 1 are representative of the different types of dust that might be encountered in the noncoal mining industry. This list is not meant to be all-conclusive, thus any dusts not listed in the table and containing less than 1% quartz should be considered as nuisance particulates and the recommended TLV's for nuisance particulates should be applied.

These rules and regulations mandate the allowable dust levels based on the free silica content of the mineral being mined. Thus, in order to effectively evaluate dust control requirements and procedures, measurements of both the dust concentration and the free silica content are required. In addition, a knowledge of particle size will aid in the selection of dust control systems or techniques.

Dust concentration measurements were made using a GCA Respirable Dust Monitor, Model RDM-101 and MSA gravimetric samplers. Measurements were made of both the total and respirable dust concentrations. Samples for silica analyses were collected on vinyl membrane filters (infrared analyses) and silver membrane filters (x-ray diffraction analyses). Particle sizes of selected samples were measured using optical microscopy techniques.

### Dust Concentration Measurements

GCA Respirable Dust Monitor - The GCA Dust Monitor is an instrument which provides short-term measurements of respirable mass or total mass concentrations. The instrument automatically collects a one minute sample and the concentration is electronically determined by automatic measurement of beta radiation attenuation of the collected dust. The instrument is portable and is powered with rechargeable Ni-Cd batteries.

TABLE 1 - THRESHOLD LIMIT VALUES FOR AIRBORNE CONTAMINANTS

Silica

Cristobalite, Crystalline	Use one-half the value calculated from the count or mass formulae for quartz
Quartz	TLV in mppcf: <sup>a</sup>
	$\frac{100^b}{\% \text{ quartz} \times 10}$
	TLV for respirable dust in mg/m <sup>3</sup> :
	$\frac{10 \text{ mg/m}^3^c}{\% \text{ respirable quartz} \times 2}$
	TLV for "total dust", respirable and non-respirable:
	$\frac{30 \text{ mg/m}^3}{\% \text{ quartz} \times 3}$
Silica, fused	Use quartz formulae
Tridymite	Use one-half the value calculated from formulae for quartz
Amorphous, including natural diatomaceous earth	20 mppcf

Silicates (<1% quartz) mppcf

Asbestos, all types	-- <sup>d</sup>
Mica	20
Perlite	30
Portland Cement	30
Soapstone	20
Talc (nonasbestiform)	20
Talc (fibrous) use asbestos limit	--
Tremolite (see talc, fibrous)	--
Graphite (natural)	15

Nuisance Particulates (30 mppcf or 10 mg/m<sup>3</sup> total dust)

Alundum (Al <sub>2</sub> O <sub>3</sub> )	Marble
Calcium carbonate	Rough
Corundum (Al <sub>2</sub> O <sub>3</sub> )	Silicon Carbide
Gypsum	Tin Oxide
Limestone	Titanium Dioxide
Magnesite	

<sup>a</sup>Millions of particles per cubic foot of air, based on impinger samples counted by light-field techniques

<sup>b</sup>The percentage of quartz in the formula is the amount determined from airborne samples, except in those instances in which other methods have been shown to be applicable.

<sup>c</sup>Both concentration and percent quartz for the application of this limit are to be determined from the fraction passing a size-selector with the following characteristics:

Aerodynamic Diameter (μm) (unit density sphere)	% Passing Selector
22	30
2.5	75
3.5	50
5.0	25
10.0	0

<sup>d</sup>Asbestos (all types) 5 fibers/ml 5 μ in length as determined by the membrane filter method at 400-450X magnification (4 mm objective) phase contrast illumination. Concentrations of 5 fibers/ml but not to exceed 10 may be permitted for 15 minute periods each hour up to five times daily.

Respirable dust concentration can be determined using a precollector (Dorr-Oliver cyclone) which removes all particles greater than 10 micrometers aerodynamic diameter. Total dust concentrations were estimated by removing the precollector. The standard sampling time is one minute, but this time can be increased to allow measurement of lower dust concentrations. A digital display ( $\text{mg}/\text{m}^3$ ) indicates the concentration immediately after the sampling period.

In this program, the instrument was particularly useful in locating specific dust sources and for determining the effectiveness of dust control procedures. Since the device provides instantaneous display of the dust concentration, a number of data points with the dust control system in the operating mode and in a nonoperating mode could be acquired in a short period of time. Variable dust concentrations during transient operations and variations in product moisture could be evaluated rapidly, also.

Personal Gravimetric Samples - Personal gravimetric sample pumps were used to collect full shift samples at selected sampling sites. The pumps were operated at 1.7 liters per minute as recommended by MESA. The pumps were calibrated on the surface and when used for underground sampling they were calibrated for the altitude at which sampling was to be conducted. Both total mass concentration and respirable mass concentration samples were taken.

Vinyl membrane filters were used to collect the dust for free silica analysis by the infrared method. The filters were preweighed and postweighed to the nearest 0.01 milligram. Silver membrane filters were used to collect samples for x-ray diffraction analysis of free silica content of the dust. Mass concentration was determined on these filters, also.

#### Free Silica Analysis

X-ray Diffraction Analyses - Samples for analysis of free silica content by x-ray diffraction techniques were collected on silver membrane filters which were preweighed and postweighed to the nearest 0.01 milligram. Samples were collected at a flowrate of 1.7 liters per minute through a size selective cyclone to assure that only the respirable fraction was deposited on the filter. The analyses were conducted at the Denver Technical Support Center.

Infrared Analyses - Samples for analysis of free silica content by the infrared technique were collected on vinyl membrane filters which were preweighed and postweighed to the nearest 0.01 milligrams. Samples were collected at a flowrate of 1.7 liters per minute through a size selective cyclone to assure that only the respirable fraction was deposited on the filter. The analyses were conducted at the Pittsburgh Mining and Safety Research Center.

## Particle Size Analysis

Samples for particle size analyses were collected on vinyl membrane filters. The particle size analysis was conducted at the University of Pittsburgh, Graduate School of Public Health. Sizing was accomplished with a Zeiss photomicroscope with phase contrast illumination at a magnification of 1000X.

## Discussion of Sampling and Analytical Results

A sampling plan was developed for each dust control system or technique which was evaluated. In certain cases, the plan was developed in order that the following factors could be evaluated:

1. Reproducibility of gravimetric sampling based on duplicate sample pumps.
2. Comparison of gravimetric values acquired with vinyl membrane and silver membrane filters.
3. Comparison of the infrared and x-ray diffraction methods for free silica analysis.

Two sample pumps were located side by side near the head pulley of a conveyor belt. Each pump was calibrated for a sampling rate of 1.7 liters per minute. The filter holders were fitted with vinyl membrane filters which were preweighed to the nearest 0.01 mg. The filters were vacuum dried at room temperature for 1 hour prior to pre and postweighing.

The results of 8 sets of samples which were taken to determine full shift dust concentration at the head pulley are as given in Table 2. The results indicate excellent agreement between the values acquired with side by side samplers. The maximum deviation for the 8 sets of samples was  $\pm 0.03$  mg.

Gravimetric samplers were fitted with silver membrane filters for collection of samples for x-ray diffraction analyses. These filters were vacuum dried at room temperature for 1 hour as were the vinyl membrane filters. The samplers with the silver membrane filters were located beside the duplicate samplers (with vinyl membrane filters) at the head pulley. Results are presented in Table 3. The results indicated a poor agreement between the vinyl membrane and silver membrane dust concentration measurements.

TABLE 2 - COMPARISON OF DUPLICATE GRAVIMETRIC SAMPLERS  
USING VINYL MEMBRANE FILTERS

<u>Sample No.</u>	<u>Dust Concentration (mg/m<sup>3</sup>)</u>	<u>Average Dust Concentration (mg/m<sup>3</sup>)</u>	<u>Deviation (mg/m<sup>3</sup>)</u>
1	0.15, 0.17	0.16	±0.01
2	0.37, 0.32	0.35	±0.03
3	0.28, 0.30	0.29	±0.01
4	0.25, 0.25	0.25	±0.00
5	0.28, 0.26	0.27	±0.01
6	0.59, 0.59	0.59	±0.00
7	0.21, 0.19	0.20	±0.01
8	0.54, 0.51	0.52	±0.02

TABLE 3 - COMPARISON OF VINYL MEMBRANE RESPIRABLE MASS  
 CONCENTRATION WITH SILVER MEMBRANE  
 RESPIRABLE MASS CONCENTRATION

<u>Sample No.</u>	<u>Vinyl Membrane Dust Concentration (mg/m<sup>3</sup>)</u>	<u>Silver Membrane Dust Concentration (mg/m<sup>3</sup>)</u>	<u>Deviation* (mg/m<sup>3</sup>)</u>
1	0.16	0.15	+0.01
2	0.35	0.29	+0.06
3	0.29	0.20	+0.09
4	0.25	0.23	+0.02
5	0.27	0.47	-0.20
6	0.59	0.51	+0.08
7	0.20	0.30	-0.10
8	0.52	0.41	+0.11

\*Vinyl membrane minus silver membrane

Additional vinyl membrane and silver membrane samples were taken on a grizzly line at a copper mine. The filters were pretreated as described earlier. The results are summarized in Table 4. Of the 22 sets of samples which were taken, one showed no difference, 11 showed a lower concentration on the silver membrane filter and 10 showed a higher concentration on the silver membrane filter. Those showing a lower concentration ranged from  $-0.04 \text{ mg/m}^3$  to  $-0.96 \text{ mg/m}^3$  with an arithmetic average of  $-0.45 \text{ mg/m}^3$ . Those showing a higher concentration ranged from  $+0.02 \text{ mg/m}^3$  to  $+0.92 \text{ mg/m}^3$  with an arithmetic average of  $+0.36 \text{ mg/m}^3$ .

At this time, no firm conclusions can be drawn, since the differences show no specific trends. It has been suggested that the pore size of the silver membrane filters is less uniform than the vinyl membrane filters. In addition, dust is poorly bonded to silver membrane filters and some may be lost during transit in the mail. The comparative side by side sampling done at the belt head pulley demonstrates the reproducibility using vinyl membrane filters. This indicates that the vinyl membrane filters are likely uniform, but it does not explain why concentrations measured with silver membrane filters are both higher and lower than those measured with vinyl membrane filters.

Both total and respirable dust samples were taken at the belt head pulley with the belt washer both ON and OFF, using vinyl membrane filters. The same type of sample pumps and filter holders were used for both total and respirable samples with the only difference being that the Dorr-Oliver cyclone was removed for the total sample. The results are presented in Table 5.

With the belt washer ON, the total dust to respirable dust ratio averaged 3.4 with a range of 2.1 to 5.1. With the belt washer OFF, the total dust to respirable dust ratio averaged 6.6 with a range of 2.6 to 9.4. The relationship between total dust concentration and respirable dust concentration is dependent upon many factors including the source of the dust and the age of the dust cloud. These results indicate that dust control procedures also have an effect on this relationship.

Samples for free silica analysis were collected on vinyl membrane filters for analysis by the infrared method and on silver membrane filters for analysis by the x-ray diffraction method. Table 6 shows that agreement between the two methods was poor.

TABLE 4 - COMPARISON OF VINYL MEMBRANE AND SILVER MEMBRANE SAMPLES TAKEN ON GRIZZLY LINE

<u>Set No.</u>	<u>Vinyl Membrane Sample (mg/m<sup>3</sup>)</u>	<u>Silver Membrane Sample (mg/m<sup>3</sup>)</u>	<u>ΔC* (mg/m<sup>3</sup>)</u>
1	1.38	0.76	-0.62
2	1.35	1.46	+0.11
3	1.39	0.98	-0.41
4	1.07	0.11	-0.96
5	1.00	1.39	+0.39
6	1.49	2.41	+0.92
7	0.84	0.95	+0.11
8	2.92	2.45	-0.47
9	0.85	0.62	-0.23
10	1.20	1.05	-0.15
11	0.81	0.93	+0.12
12	1.02	1.04	+0.02
13	2.46	3.07	+0.61
14	0.91	0.87	-0.04
15	0.93	0.93	0.00
16	1.74	1.05	-0.69
17	1.90	2.70	+0.80
18	1.73	1.26	-0.47
19	1.06	1.35	+0.29
20	2.45	2.20	-0.25
21	0.75	0.55	-0.20
22	1.89	2.08	+0.19

\*Difference is relative to concentration based on vinyl membrane filter

TABLE 5 - COMPARISON OF RESPIRABLE AND TOTAL DUST SAMPLES  
TAKEN AT A CONVEYOR BELT HEAD PULLEY

<u>Set No.</u>	<u>Belt Washer Mode</u>	<u>Respirable Dust Concentration (mg/m<sup>3</sup>)</u>	<u>Total Dust Concentration (mg/m<sup>3</sup>)</u>	<u>T/R Ratio</u>
1	ON	0.16	0.47	2.9
2	OFF	0.35	2.09	6.0
3	ON	0.29	0.58	2.0
4	OFF	0.25	0.65	2.6
5	ON	0.27	1.21	4.5
6	OFF	0.59	5.55	9.4
7	ON	0.20	0.77	3.9
8	OFF	0.52	3.49	6.7
9	ON	0.20	0.52	2.6
10	OFF	0.75	6.09	8.1
11	ON	0.33	0.68	2.1
12	OFF	0.23	1.73	7.5
13	ON	0.28	1.42	5.1
14	OFF	0.43	3.48	8.1
15	ON	0.21	0.93	4.4
16	OFF	0.79	4.16	5.3

TABLE 6 - COMPARISON OF FREE SILICA ANALYSIS BY  
 INFRARED (VINYL MEMBRANE FILTERS) AND X-RAY  
 DIFFRACTION ANALYSIS (SILVER MEMBRANE FILTERS)

<u>Sample Location</u>	<u>Percent Free Silica (% SiO<sub>2</sub>)</u>	
	<u>Infrared Analysis</u>	<u>X-ray Diffraction Analysis</u>
Grizzly Line	7.9, 3.2	20.7, 25.2, 15.8 17.9, 16.0
Average	5.5	19.1
Pony Set	12.7	5.8, 6.7
Average	12.7	6.3
Rotary Dump	15.5, 21.2	14.6, 9.5, 18.3 9.9
Average	18.4	13.1
Crusher	29.7, 25.0 21.0, 20.4	25.6, 15.8, 10.0
Average	23.9	17.1

## Summary

The GCA Dust Monitor proved to be a useful tool for locating dust generating sources and for evaluating the effectiveness of dust control systems. The gravimetric sampler was effective in determining whether or not an operation was in compliance.

The reproducibility of side by side samplers using vinyl membrane filters for measurement of respirable mass concentration was excellent. The agreement between respirable mass concentration as measured with vinyl membrane filters and silver membrane filters was poor. The agreement between x-ray diffraction and infrared analyses for silica content was poor, also. The procedure for collecting samples for silica analysis by x-ray diffraction has been modified since this program was conducted. Samples are now collected on vinyl membrane filters, and the collected dust is transferred to a silver membrane substrate for x-ray diffraction analysis.\*

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\*Personal communication with Mr. George Weems, Denver Technical Support Center.

## PARTICLE SIZE ANALYSIS

Samples for particle size analysis were collected at a copper mine, since particle size is an important guideline in selecting dust control equipment. Samples were collected using a gravimetric sampling pump. With the cyclone in place on the sampler, only particles smaller than 10 micrometers would be deposited on the filter media. Particle sizing was accomplished with an optical microscope using phase contrast illumination at a magnification of 1000X. Size distribution was calculated on the basis of the number of particles.

Samples were collected at the 2015 ft level in the main drift and on the grizzly line, and at the 2075 ft level in the haulageway and in the pony set. The results are shown in Table 7 and Figure 1. Of the ten samples which were submitted to particle size analysis, only 1 (#90) showed particles larger than 5 micrometers.

The geometric mean size count by number according to locations was as follows:

<u>Location</u>	<u>Geometric Mean Particle Size (<math>\mu\text{m}</math>)</u>	<u>Average (<math>\mu\text{m}</math>)</u>
Haulage Level, 2075 ft	1.02, 1.02	1.02
Pony Set, 2075 ft	1.12, 1.03, 1.04	1.06
Main Drift, 2015 ft	0.82, 0.80	0.81
Grizzly Line, 2015 ft	0.83, 0.82, 0.81	0.82

The average size of particles collected on the 2075 ft level was 1.04 micrometers. The average size of particles collected on the 2015 level was 0.82 micrometers.

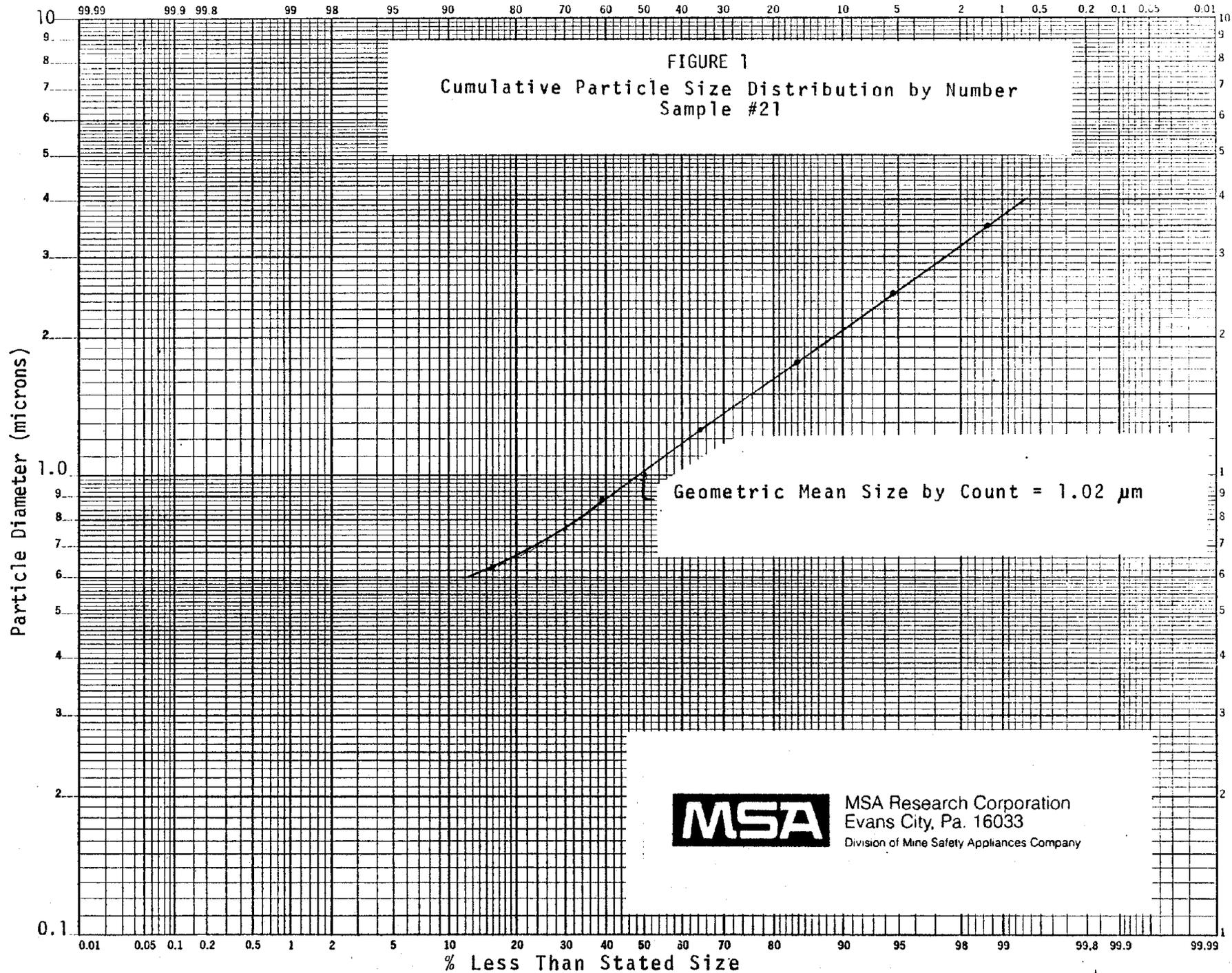
Particle size analyses indicated that the geometric mean size as determined by particle count ranged from 0.81 to 1.06 micrometers. Samples taken in areas where the dust inventory had the opportunity to "age", i.e., where the larger particles had the opportunity to settle out, exhibited the lowest geometric mean size.

TABLE 7 - RESULTS OF PARTICULATE SIZING

Upper Size Microns	Cumulative % Less Than Stated Size by Number									
	Sample #									
	3	16	21	22	28	36	52	90	138	160
0.63	17.03	26.64	15.74	28.82	29.00	21.40	14.16	17.50	27.59	28.57
0.88	36.24	55.74	38.72	57.64	56.71	39.74	34.70	40.83	57.76	54.84
1.25	63.76	78.69	64.26	75.98	81.82	55.02	57.08	58.33	81.03	75.12
1.76	85.59	92.62	83.83	87.77	94.81	79.04	77.63	77.92	93.53	91.71
2.50	93.89	98.36	94.47	94.76	97.84	92.14	90.41	89.58	98.71	97.24
3.50	97.82	100.00	98.72	100.00	100.00	98.25	98.63	97.56	100.00	100.00
5.00	100.00	---	100.00	---	---	100.00	100.00	99.59	---	---
7.00	---	---	---	---	---	---	---	100.00	---	---
Total No. of Particles Sized	229	244	235	229	231	229	219	240	232	217

27

Sample No.	Location	Microscope: Zeiss Photomicroscope with Phase Contrast Illumination
21	Haulage Level 2075'	Objective: 25x, N.A. = 0.60 Optovar: 2.0x Eyepiece: 20x with Porton Graticule Total Magnification = 1000x
90	" " "	
52	Pony Set #6	
3	Pony Set #5	
36	Pony Set #4	
16	Main Drift 2015'	
138	Main Drift 2015'	
160	Grizzly Line	
22	" "	
28	" "	



## CONVEYOR BELT WASHING SYSTEM

Conveyor belts are recognized as major dust sources in both underground and surface operations. Dust will generally adhere to wet belts, however as belts become dry respirable dust can become airborne. Larger sizes particulates dislodge from dry belts and collect at idlers and take-up pulleys. Thus, the release of dust from belts can result in health hazards and maintenance problems.

A belt washing system on the return side of the head pulley can remove the adhering dust and eliminate these problems. A fully operational belt washing system was studied to determine the effectiveness of such a system.

### Description of the Facility

The belt washing system which was evaluated was located at a taconite processing plant. The belt on which the washing system was installed transported the product from the secondary crusher storage bins to the final grinding operations and was housed in a gallery 200 ft long.

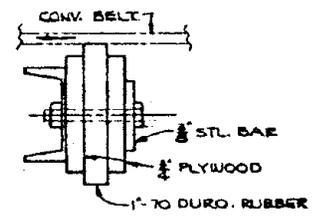
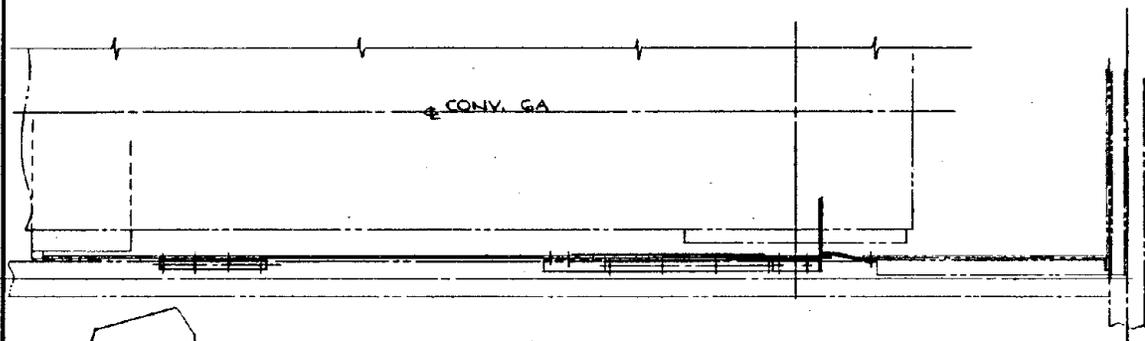
Drawings of typical two spray header and four spray header washing systems are presented in Figures 2 and 3, respectively. Major features of the systems include:

1. A belt scraper at the head pulley
2. Spray headers between the head pulley and the take-up pulley
3. A belt scraper to remove excess water
4. A spray header to wash down the hopper
5. A hopper for collection of the product removed from the belt.

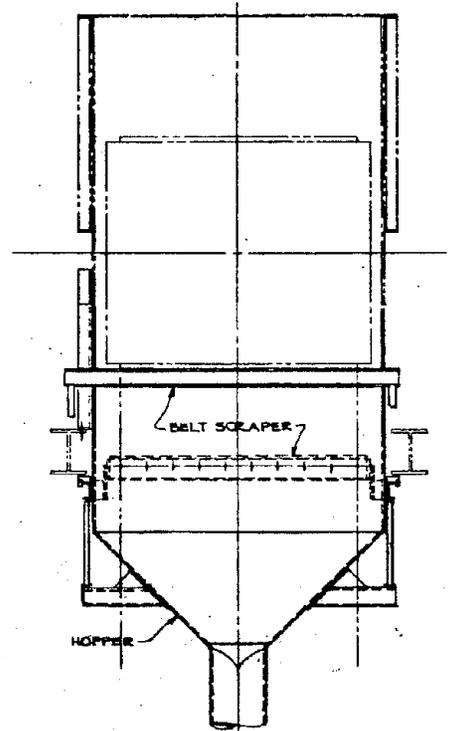
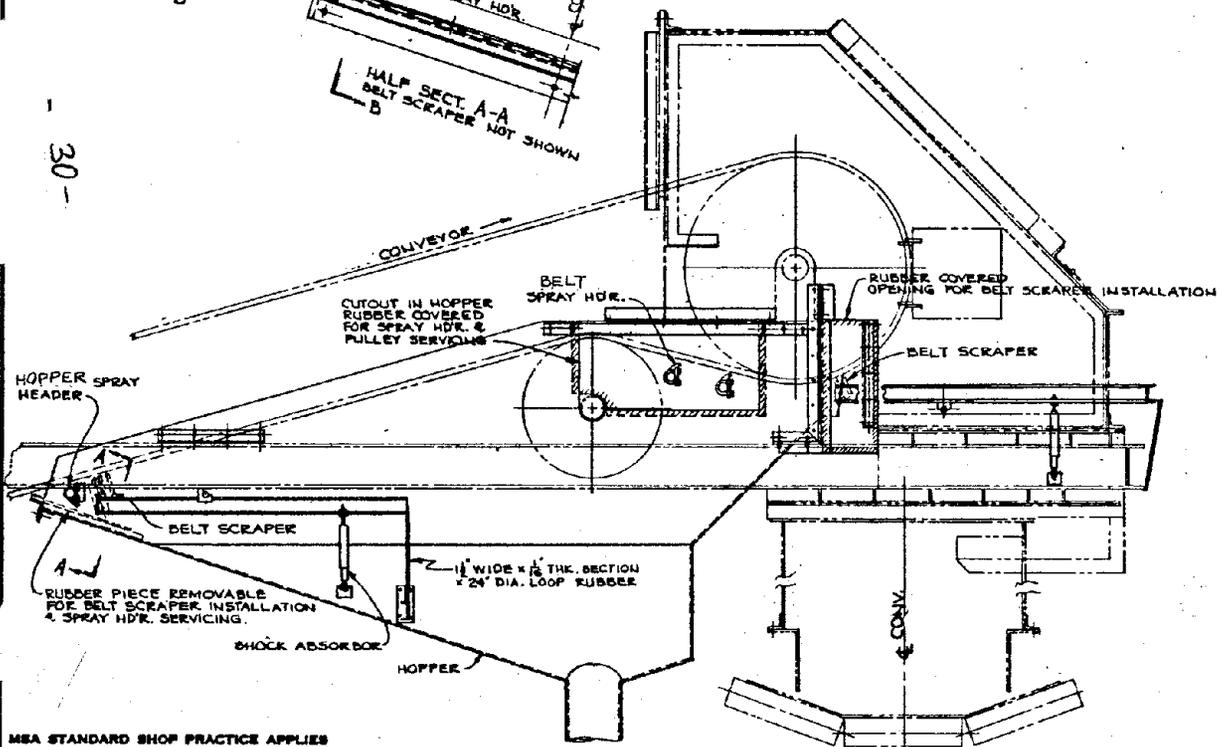
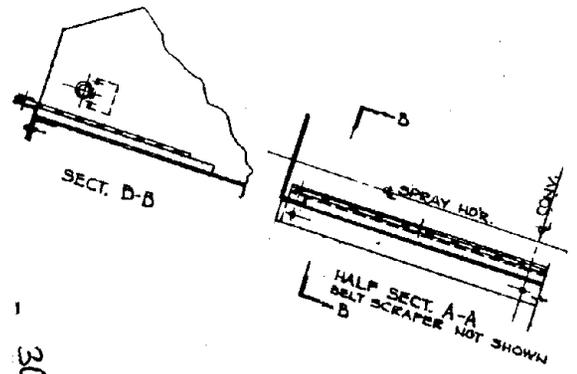
The belt scraper at the head pulley served to remove large particulates adhering to the belt. The product which was removed fell to the receiving conveyor belt. Each spray header was fitted with 12 spray nozzles delivering a flat, solid spray on the belt. At a pressure of 50 psi, the four spray bars delivered water at a total of approximately 150 gpm. The belt scraper was supported on a fulcrum and tension was maintained with a 24 in. diameter rubber loop. A standard automotive type shock absorber prevented the belt scraper from cycling. The hopper spray header rinsed the slurry from the belt into the hopper discharge. This liquid was pumped directly to the wet rod mills.

Contact the sponsoring organization, U.S. Bureau of Mines, for information on the availability of additional drawings for this system.

PARTS LIST			REVISIONS
ITEM	PT. NO.	REQ'D.	



BELT SCRAPER DETAIL



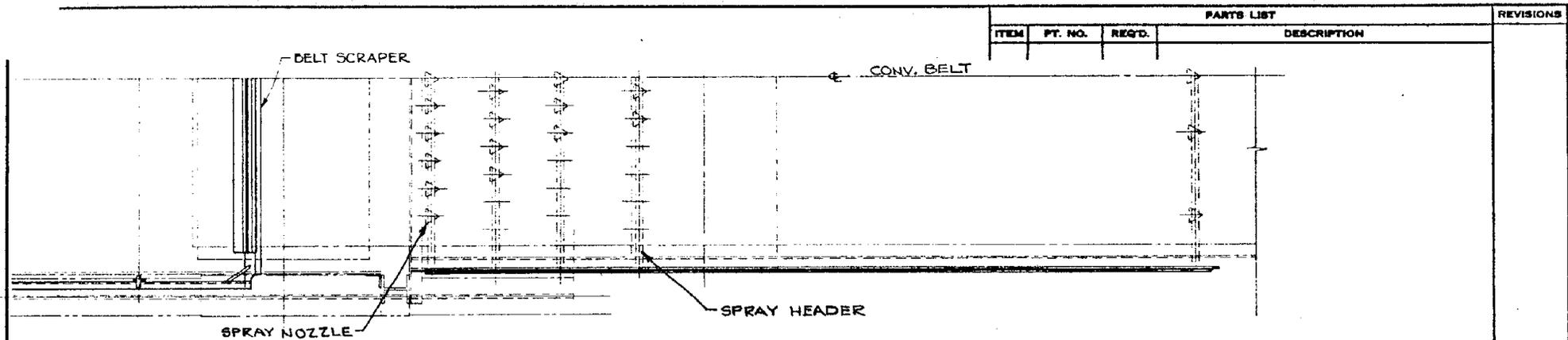
MSA STANDARD SHOP PRACTICE APPLIES

<b>MSA RESEARCH CORPORATION</b> EVANS CITY, PA., U.S.A. ALL MACHINED SURFACES ARE UNLESS OTHERWISE SPECIFIED.	TOLERANCES UNLESS OTHERWISE SPECIFIED	
	FRACTIONAL	+ -
	DECIMAL	+ -
	ANGULAR	+ -
DO NOT SCALE DRAWING		

FIGURE 2 - TYPICAL 2 SPRAY BAR BELT WASHING SYSTEM

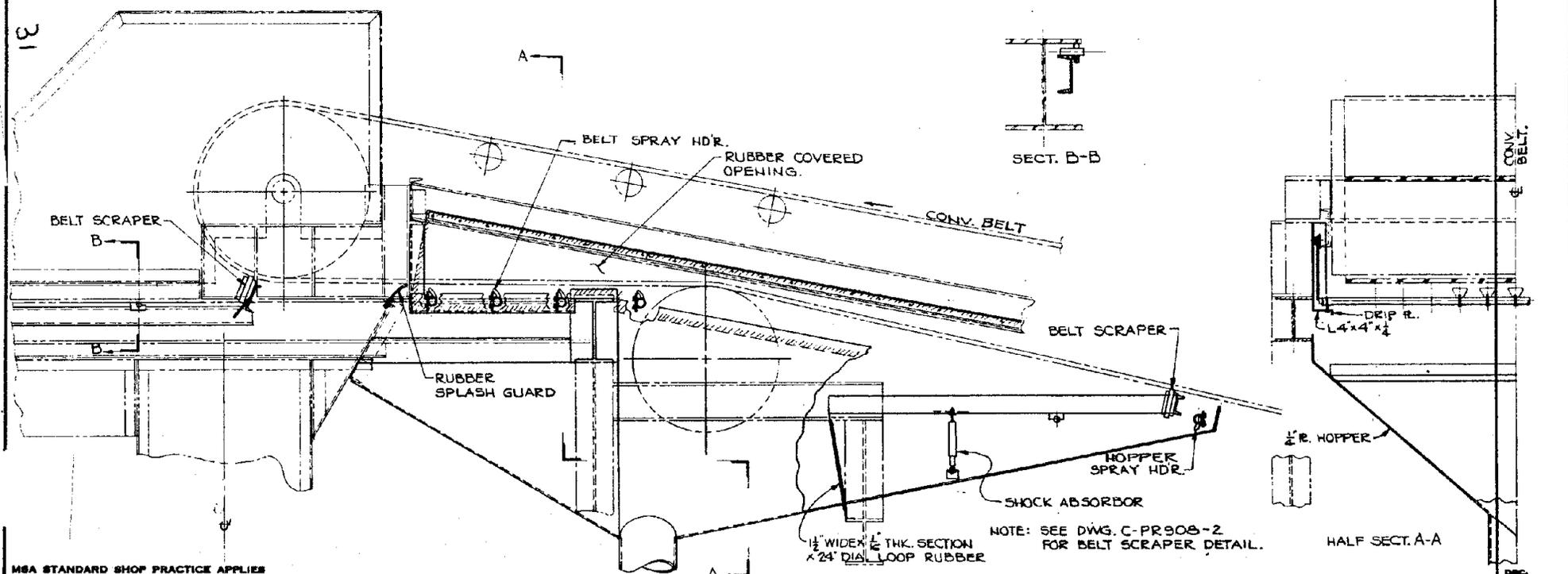
DR.	HLBORN	5-10-74
CHK'D		
APP'D		
JOB NO.	AC 905	
SCALE	3/16" = 1'-0" & 1" = 1'-0"	

PART NUMBER  
**C-PR 908-2**



PARTS LIST			REVISIONS
ITEM	PT. NO.	REQ'D.	

Contact the sponsoring organization, U.S. Bureau of Mines, for information on the availability of additional drawings for this system.



MSA STANDARD SHOP PRACTICE APPLIES

MSA RESEARCH CORPORATION EVANS CITY, PA., U.S.A.	TOLERANCES UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES ARE UNLESS OTHERWISE SPECIFIED.	FRACTIONAL + - DECIMAL + - ANGULAR + -
	DO NOT SCALE DRAWING

FIGURE 3 - TYPICAL 4 SPRAY BAR BELT WASHING SYSTEM

DR.	H.L. BORN	5-17-74	PART NUMBER <b>C-PR908-3</b>
CHK'D			
APP'D			
JOB NO.	AC 908		
SCALE	3/4" = 1'-0"		

The spray bars were 1-1/2 in. diameter Schedule 40 black iron pipe. Nine 5/32 in. diameter holes were drilled along the length of the pipe on 6 in. centers. Each spray bar was fitted with 15 Link Belt nozzles (Fig. 3362, Catalog No. 900). At 50 psig each nozzle delivered 3.2 gpm. The belt scrapers were fabricated from 1 in. thick x 6 in. wide x 4-1/2 ft long durometer rubber supported between two lengths of plywood.

#### Evaluation of Belt Washer System Effectiveness

Full Shift Gravimetric Samples - The effectiveness of the belt washing installation was evaluated initially by comparing gravimetric dust concentration measurements obtained with the belt washer ON and OFF. A total of 8 shifts were obtained with the belt washer ON and 7 shifts were obtained with the belt washer OFF.

Gravimetric samplers were located uniformly on both sides of the belt (Figure 4). The results of this study are shown in Table 8.

With the belt washer operating normally, the mean respirable dust concentration taken over the entire belt length with vinyl filters was  $0.24 \text{ mg/m}^3$  with a standard deviation of  $\pm 0.12 \text{ mg/m}^3$ . Data obtained for the belt washer OFF were  $0.49 \text{ mg/m}^3$  with a standard deviation of  $\pm 0.26 \text{ mg/m}^3$ .

Mean respirable dust concentrations obtained in the area of the head pulley only were  $0.21 \text{ mg/m}^3$  with a  $\pm 0.07 \text{ mg/m}^3$  standard deviation for the belt washer operating normally. With the belt washer OFF the mean respirable dust concentration was  $0.41 \text{ mg/m}^3$  with a  $\pm 0.14 \text{ mg/m}^3$  standard deviation.

Total dust concentrations were also taken with vinyl and silver filters. With vinyl filters, the mean total dust concentration measured at the head pulley area was  $3.55 \text{ mg/m}^3$  and  $0.79 \text{ mg/m}^3$ , respectively, for the belt washer OFF and operating normally. Table 9 presents a summary of the total and respirable dust concentration data and the resultant data concentration reduction effected by the belt washer. Respirable dust concentration, as measured by gravimetric sampling with vinyl membrane filters, was reduced an average of 48% with the belt washing system ON.

Ore samples were obtained in an effort to determine if ore moisture content was influencing dust concentrations. These data are presented in Table 10, where it is seen that data are so scattered that no correlation can be made between moisture content and dust concentration. The moisture content was determined by drying the ore samples to a constant weight. A mean moisture content of 0.22% with a range of 0.15% to 0.33%

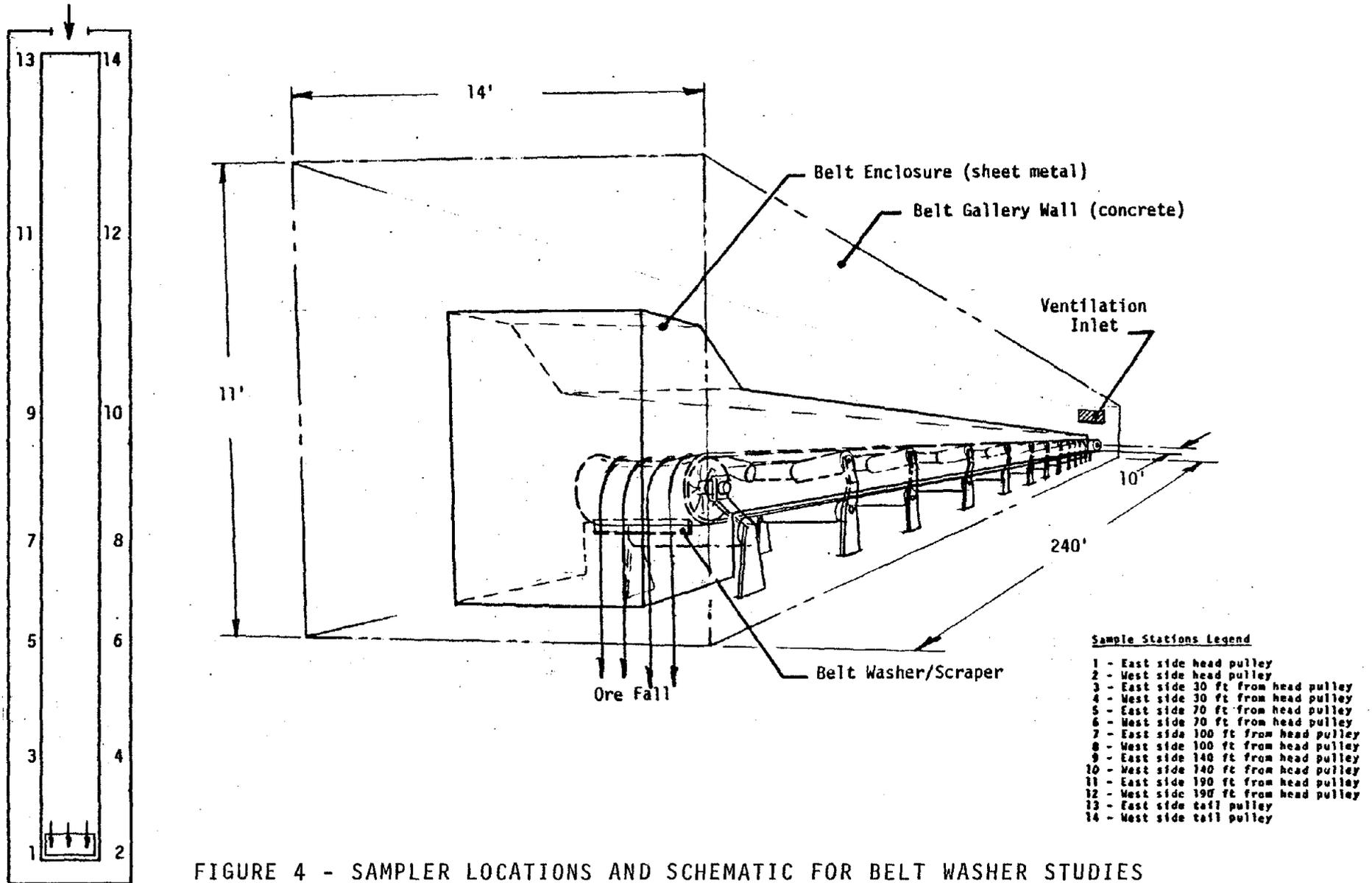


FIGURE 4 - SAMPLER LOCATIONS AND SCHEMATIC FOR BELT WASHER STUDIES

TABLE 8 - DUST CONCENTRATION DATA FROM BELT WASHER EVALUATION  
(Dust Concentration [mg/m<sup>3</sup>])

Date	Washer Status	Sample Stations													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
12/9/74	ON	0.13 0.93T	0.34	S0.31 S3.97T	0.29		0.36	0.29		0.37		0.22	0.86T	0.38	
12/10/74	ON	0.30 1.55T	0.28	S0.22 S1.34T	0.43		0.38			0.35	0.07	0.20	0.34T	0.14	
	OFF	0.36 2.22T	0.59	S0.59 S2.84T	0.92					0.29	0.10		0.72T	0.16	
12/11/74	ON	0.15 S0.23	0.10	0.66T S1.05T	0.20		0.10	0.17		0.15		0.12	0.96T	0.31	
	OFF	0.60 S0.46	0.30	4.09T S3.31T			0.08	0.38		0.16			1.65T	0.27	
12/12/74	ON	0.16 S0.19	0.13	0.63T S0.79T			0.13			0.10		0.67	0.75T	0.98	
	OFF	0.60 S0.97	0.30	5.44T S1.90T	0.72		0.68	0.95		0.70		0.70	1.38T	0.87	
12/13/74	ON	0.23	0.15 0.17 S0.15 0.47T S0.59T		0.20 0.52T	0.10				0.12		0.12			
	OFF	0.36	0.37 0.32 S0.29 2.09T S1.79T		0.75 0.16 6.09T					0.71		0.44			
12/16/74	ON	0.15	0.28 0.30 S0.20 0.58T S0.80T		0.33 0.38 0.68T					0.40		0.40			
	OFF	0.28	0.25 0.25 S0.23 0.65T S0.75T		0.23 0.53 1.73T					1.09		0.76			
12/17/74	ON	0.28 0.26 S0.47 1.21T S1.44T	0.53	0.28 1.42T			0.21	0.26		0.23					
	OFF	0.59 0.59 S0.51 5.55T S2.67T	0.27	0.43 3.48T			0.13	1.00		0.38					
12/18/74	ON	0.21 0.19 S0.30 0.77T S1.37T	0.13	0.21 0.93T			0.13	0.25		0.13					
	OFF	0.54 0.51 S0.41 3.49T S2.41T	0.29	0.79 4.16T			0.44	0.79		0.67					

Sample Stations Legend

- 1 - East side head pulley
- 2 - West side head pulley
- 3 - East side 30 ft from head pulley
- 4 - West side 30 ft from head pulley
- 5 - East side 70 ft from head pulley
- 6 - West side 70 ft from head pulley
- 7 - East side 100 ft from head pulley
- 8 - West side 100 ft from head pulley
- 9 - East side 140 ft from head pulley
- 10 - West side 140 ft from head pulley
- 11 - East side 190 ft from head pulley
- 12 - West side 190 ft from head pulley
- 13 - East side tail pulley
- 14 - West side tail pulley

Sample Legend

- xx.xx = Vinyl respirable
- Sxx.xx = Silver respirable
- xx.xxT = Vinyl total
- Sxx.xxT = Silver total

TABLE 9 - EFFECT OF BELT WASHER ON DUST  
CONCENTRATION NEAR THE HEAD PULLEY

Belt Washer Mode	Total Dust (mg/m <sup>3</sup> )		Respirable Dust (mg/m <sup>3</sup> )	
	<u>OFF</u>	<u>ON</u>	<u>OFF</u>	<u>ON</u>
Vinyl Filter	3.55	0.79	0.41	0.21
Reduction		78%		48%
Silver Filter	2.13	1.06	0.48	0.27
Reduction		50%		44%

TABLE 10- MOISTURE CONTENT-DUST CONCENTRATION  
FROM BELT WASHER EVALUATION

<u>Date</u>	<u>Washer Status</u>	<u>Time (hr)</u>	<u>Moisture Content (%)</u>	<u>GCA (mg/m<sup>3</sup>)</u>		<u>Gravimetric (mg/m<sup>3</sup>)</u>	
				<u>East Side</u>	<u>West Side</u>	<u>East Side</u>	<u>West Side</u>
12/12/74	ON	1345	0.17	0.24			
		1445	0.30				
		1545	0.20	0.37	0.21	0.16	0.13
12/13/74	OFF	0815	0.19	0.43			
		0915	0.21		0.85		
		1015	0.18	0.37			
		1115	0.25		0.31	0.36	0.34
			ON	1200	0.28		
		1315	0.15				
		1415	0.10	0.37	0.35		
		1515	0.15				
		1600	0.27			0.23	0.16
12/14/74	OFF	0800	0.20	0.34	0.29		
		0930	0.31				
		1030	0.29	0.28	<0.2		
		1130	0.15			0.28	0.25
			ON	1315	0.26		
		1400	0.21	0.45			
		1500	0.22		0.42		
		1545	0.21			0.15	0.29
12/17/74	OFF	1000	0.20	1.25			
		1110	0.25	3.10	0.73		
		1150	0.21	1.90	1.20	0.59	0.27
		ON	1400	0.23	0.40		
			1500	0.20		0.55	
		1530	0.11			0.27	0.53
12/18/74	OFF	0800	0.39	0.76			
		0900	0.33		0.44		
		1100	0.26	1.91	0.84	0.52	0.29
		ON	1530	0.25		0.20	0.25

was determined. For these observations the dust concentrations were obtained by gravimetric and GCA sampling on both the east and west sides of the head pulley.

Quartz Content - A number of dust samples obtained with vinyl filters for total and respirable dust levels were analyzed for alpha quartz. Data for samples obtained at the belt head pulley and tail pulley are presented in Table 11.

One sample yielded a significantly higher quartz content than any other. The sample weight, however, was only 0.05 gm with a quartz content of 52%. Also, the tail pulley dust quartz content is lower than at the head pulley. These results are likely to be for dust on the incoming ventilation air rather than for the magnetite ore. Ventilation air which was drawn in from outside entered the belt vault at the tail pulley.

The average quartz content of all samples (total and respirable) taken at the head pulley was 31%. With the belt washing system OFF, the respirable samples showed a quartz content of 40%. With the belt washing system ON, the respirable samples showed a quartz content of 27%. Since the observed difference is based on only three samples with the system ON and four samples with the system OFF, it may not be significant. If the Threshold Limit Values for this operation were based on the quartz content of respirable dust, the values would be 0.24 mg/m<sup>3</sup> with the system OFF and 0.34 mg/m<sup>3</sup> with the system ON:

$$\text{TLV for respirable dust (OFF)} = \frac{10 \text{ mg/m}^3}{\% \text{ respirable quartz} + 2} = \frac{10}{40 + 2} = 0.24 \text{ mg/m}^3$$

$$\text{TLV for respirable dust (ON)} = \frac{10 \text{ mg/m}^3}{\% \text{ respirable quartz} + 2} = \frac{10}{27 + 2} = 0.34 \text{ mg/m}^3$$

Table 9 shows that the average respirable dust concentration was 0.41 mg/m<sup>3</sup> with the system OFF and 0.21 mg/m<sup>3</sup> with the system ON. This demonstrates that the belt washing system is necessary to maintain the work place in compliance.

GCA Dust Surveys - Additional GCA surveys were made with the belt washing system ON and OFF. Although GCA data are short term measurements compared with full shift gravimetric data, the relative GCA values demonstrate the effectiveness of the belt washing system.

The results are presented in Figures 5 through 14. While the dust concentration varies from day to day and from time to time throughout a given day, the results do show a dramatic reduction in dust concentration with the belt washing system in operation.

TABLE 11- ALPHA QUARTZ CONTENT OF IRON ORE  
PELLETIZING PLANT DUST

<u>Respirable Dust Sample Location</u>	<u>Belt Washer Mode</u>	<u>Sample Weight (mg)</u>	<u>% Quartz</u>
E. Head Pulley	OFF	0.32	38
E. Head Pulley	ON	0.05	52
W. Tail Pulley	OFF	0.43	11
W. Tail Pulley	ON	0.31	12
W. Head Pulley	OFF	0.10	42
W. Head Pulley	ON	0.12	26
E. Head Pulley	OFF	0.22	40
E. Head Pulley	ON	0.12	32
E. Head Pulley	OFF	0.16	32
E. Head Pulley	ON	0.11	23
<u>Total Dust</u>			
E. Tail Pulley	OFF	0.74	12
E. Tail Pulley	ON	0.24	15
W. Head Pulley	OFF	0.26	26
W. Head Pulley	ON	0.23	32
E. Head Pulley	OFF	2.06	17
E. Head Pulley	ON	0.52	26
E. Head Pulley	OFF	1.10	21
E. Head Pulley	ON	0.51	27

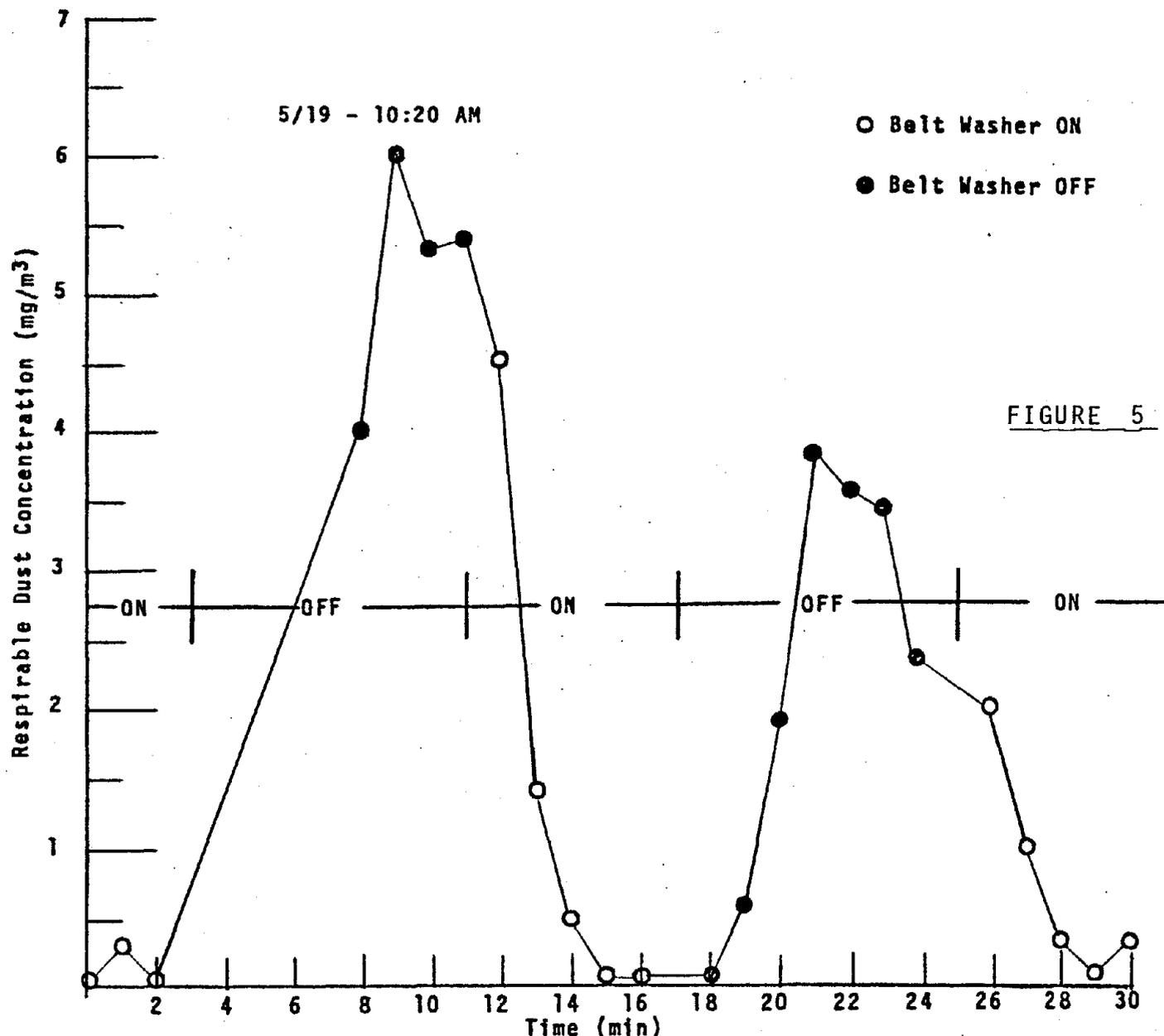


FIGURE 5

EFFECT OF BELT WASHER SYSTEM ON RESPIRABLE DUST CONCENTRATION  
(GCA Model RDM-101)

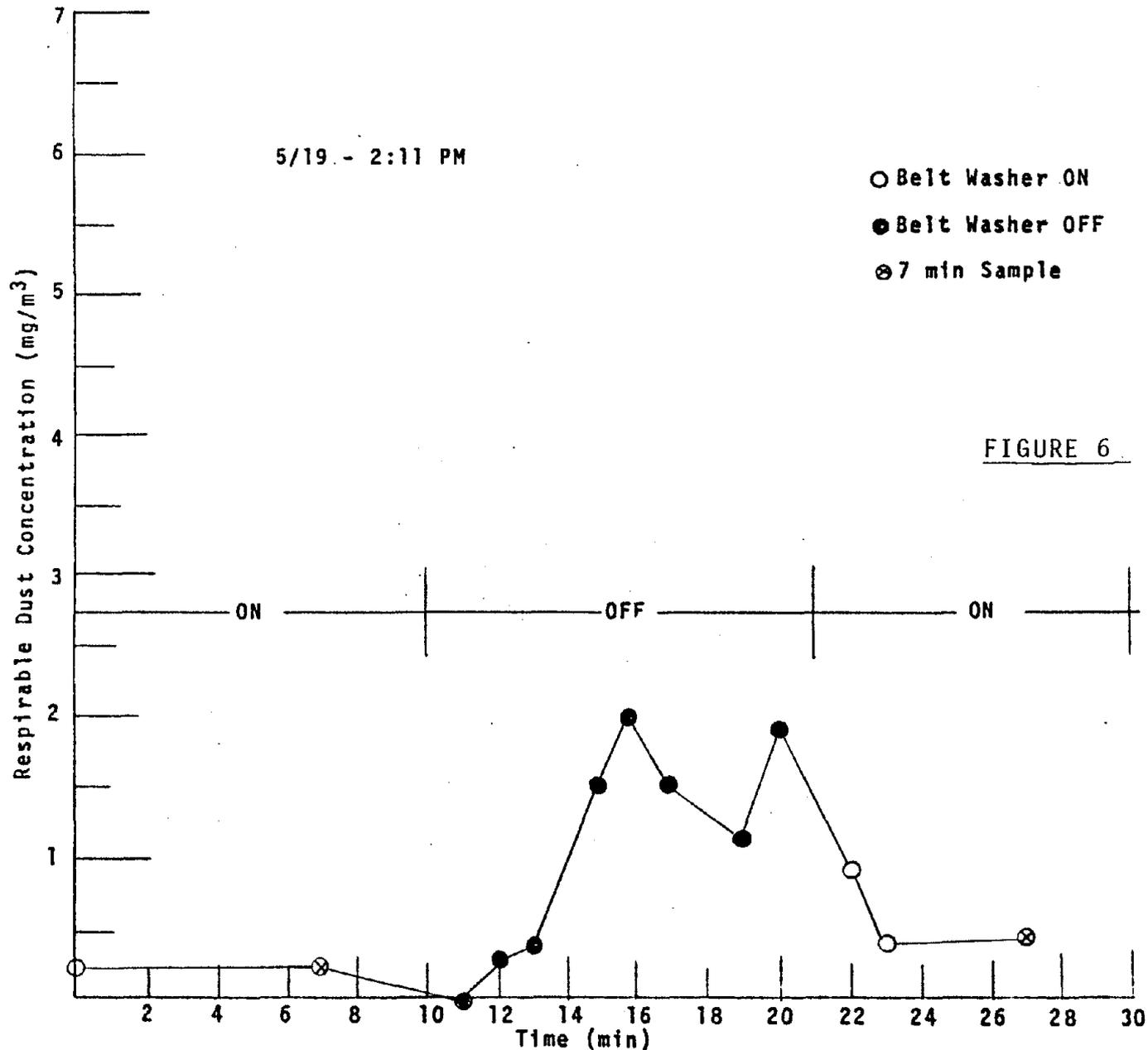


FIGURE 6

EFFECT OF BELT WASHER SYSTEM ON RESPIRABLE DUST CONCENTRATION  
GCA Model RDM-101

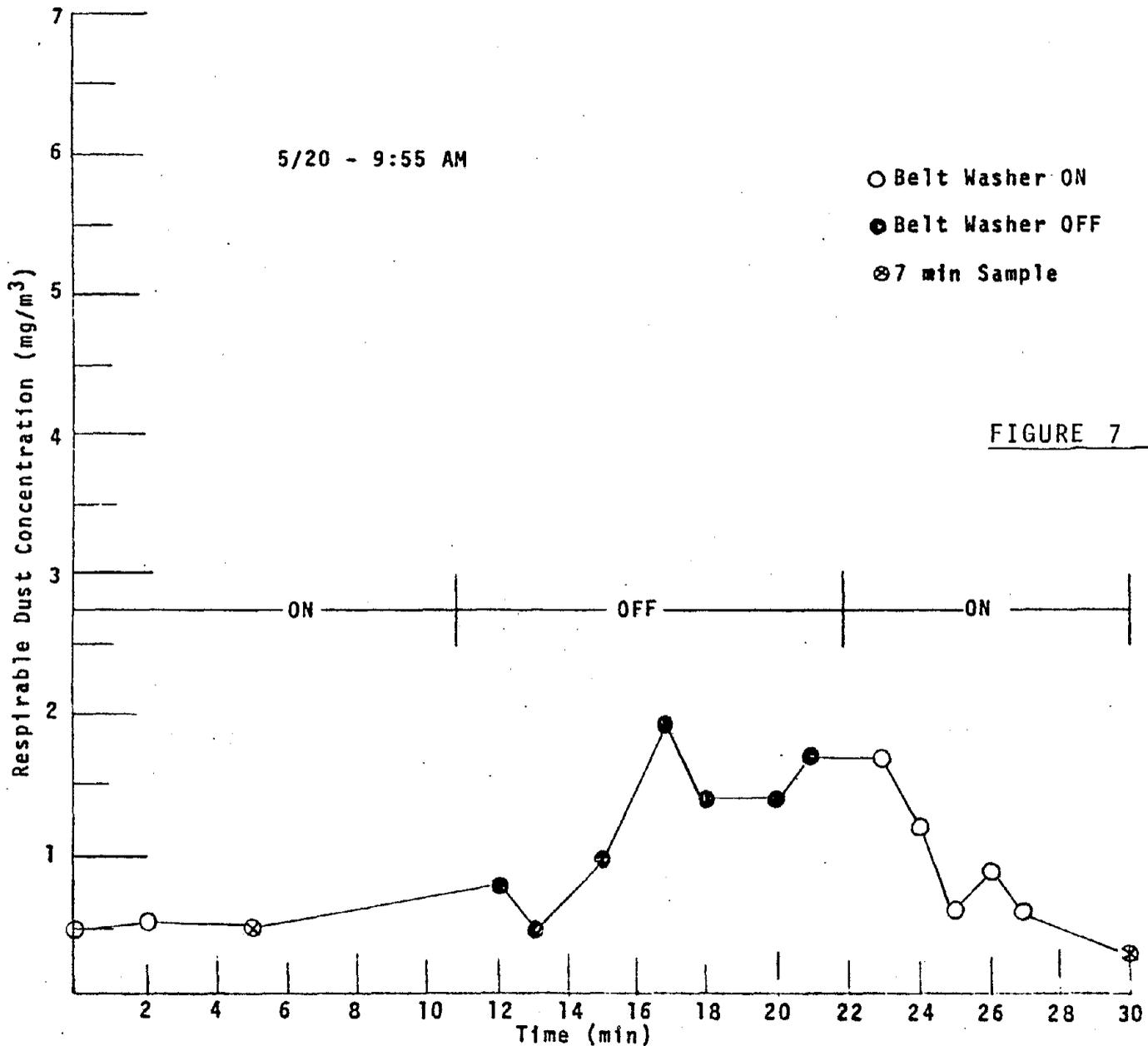
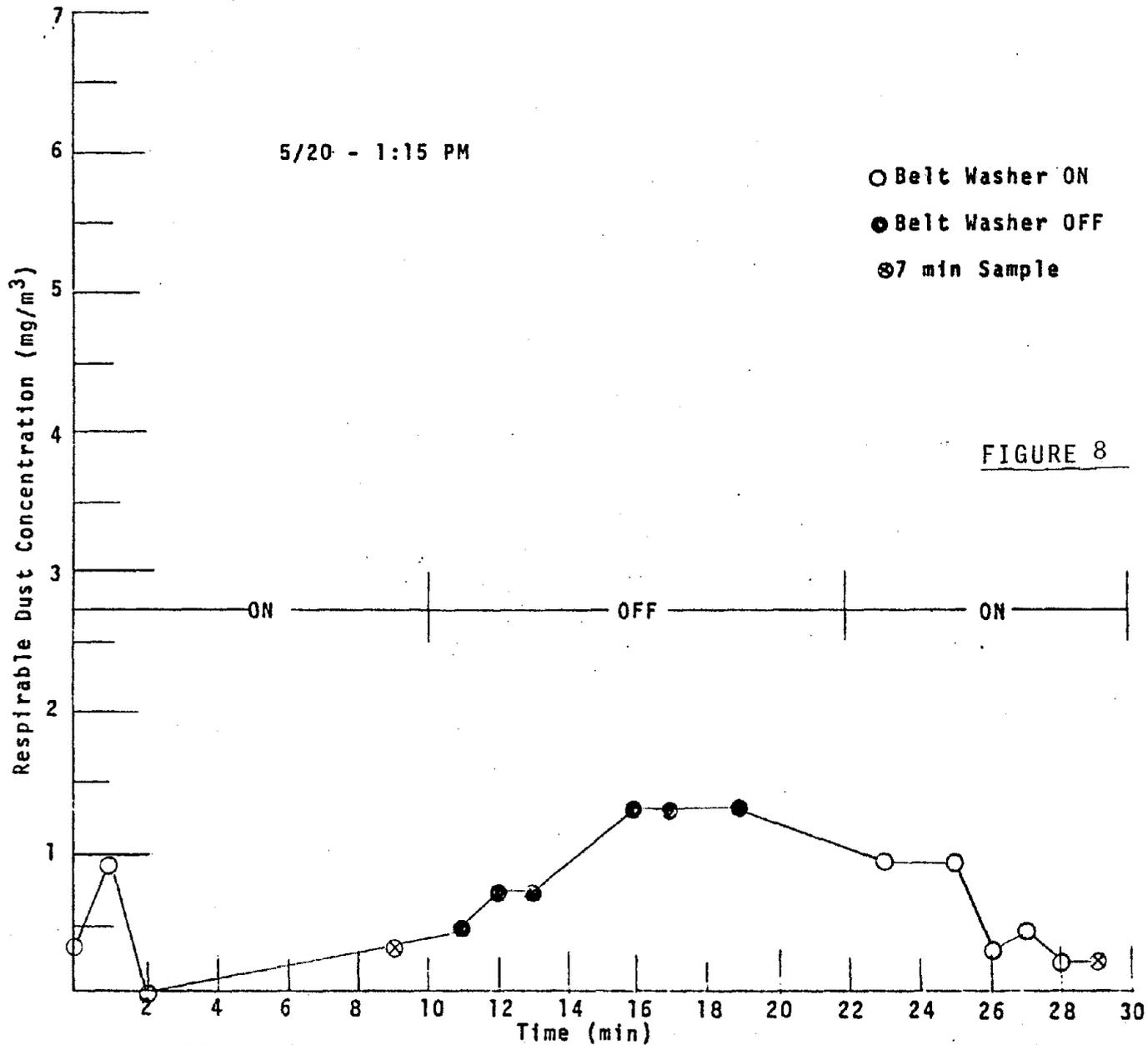


FIGURE 7

EFFECT OF BELT WASHER SYSTEM ON RESPIRABLE DUST CONCENTRATION  
GCA Model RDM-101



EFFECT OF BELT WASHER SYSTEM ON RESPIRABLE DUST CONCENTRATION  
GCA Model RDM-101

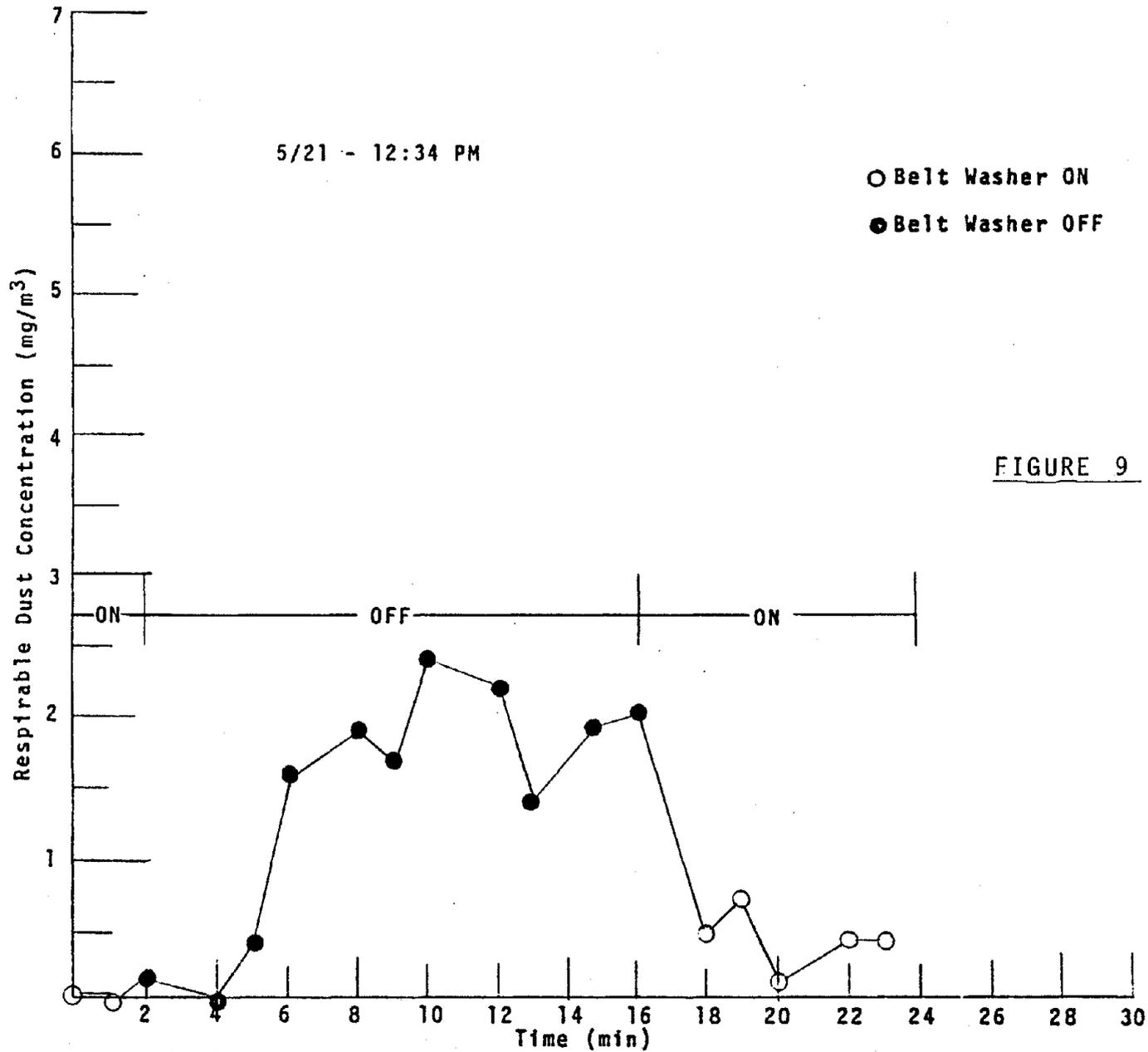


FIGURE 9

EFFECT OF BELT WASHER SYSTEM ON RESPIRABLE DUST CONCENTRATION  
GCA Model RDM-101

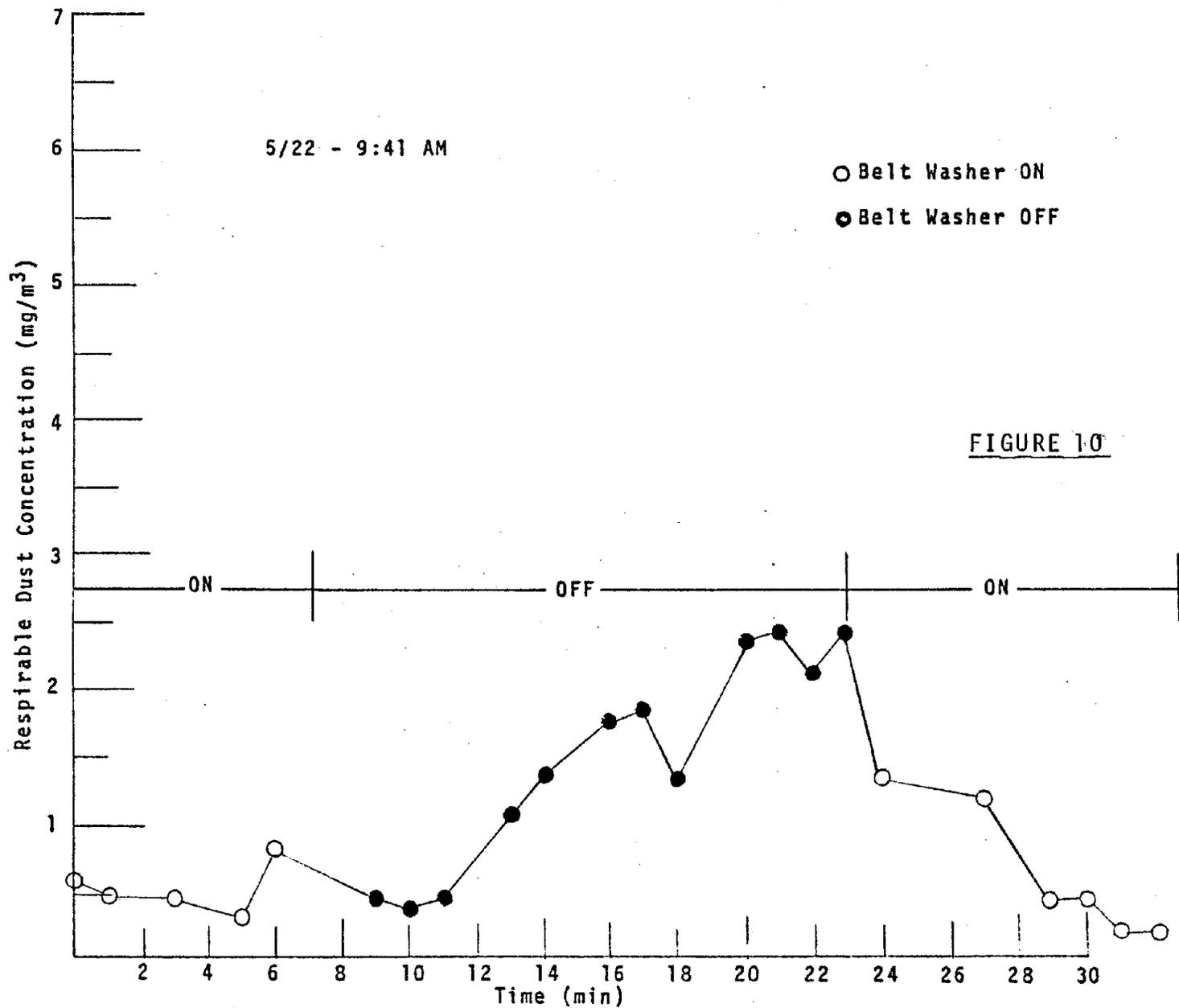
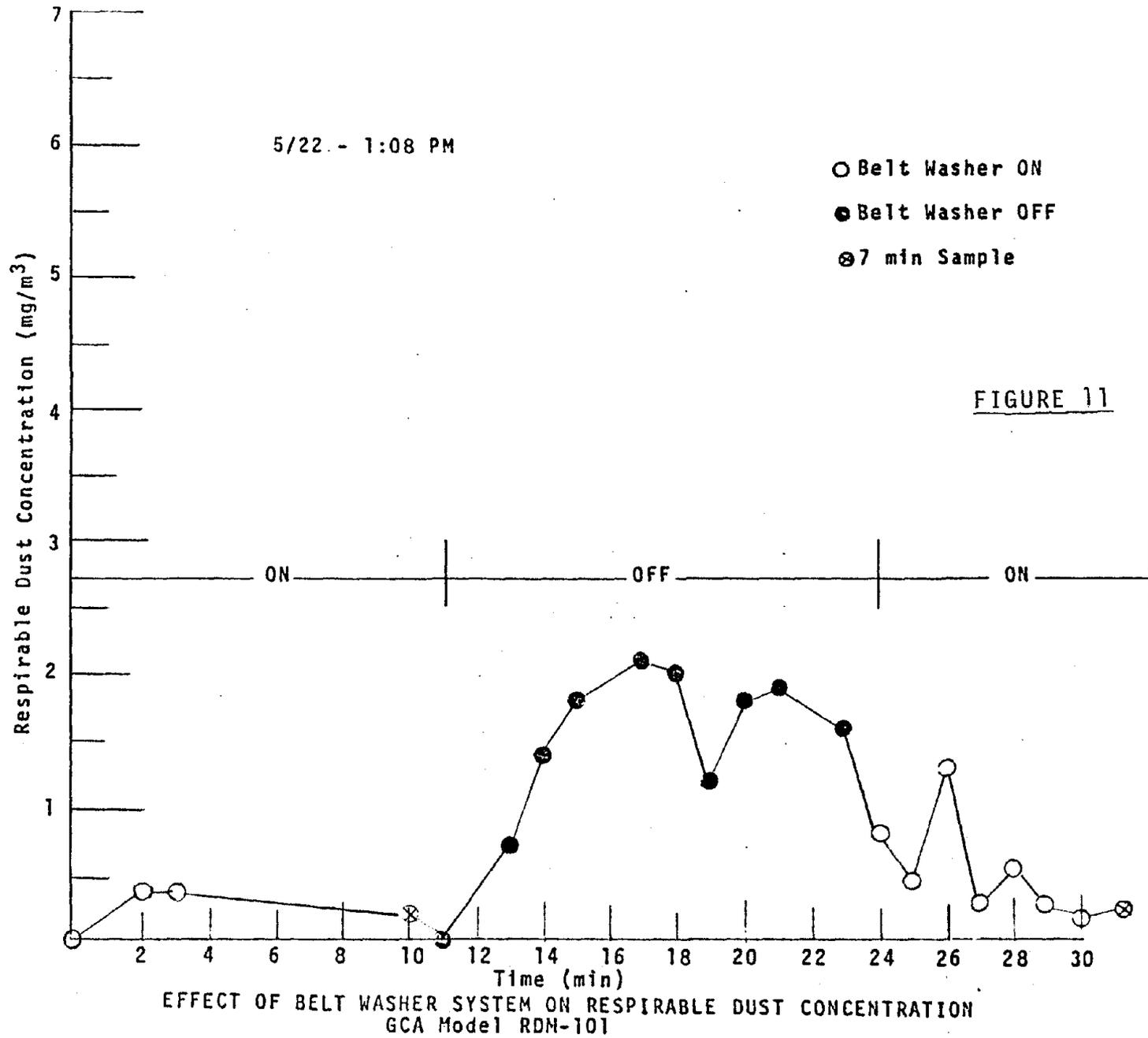


FIGURE 10

EFFECT OF BELT WASHER SYSTEM ON RESPIRABLE DUST CONCENTRATION  
GCA Model RDM-101



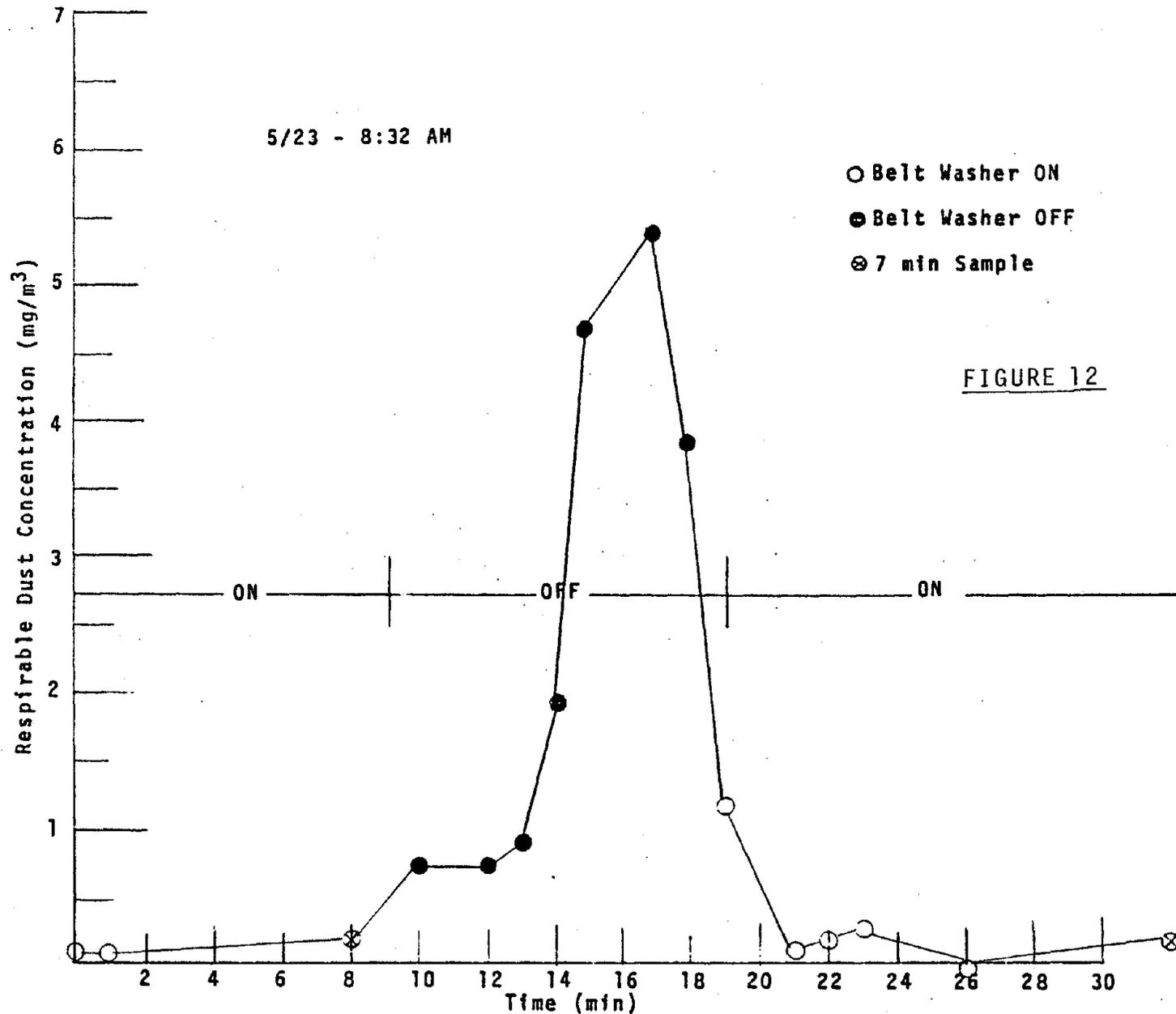


FIGURE 12

EFFECT OF BELT WASHER SYSTEM ON RESPIRABLE DUST CONCENTRATION  
GCA Model RDM-101

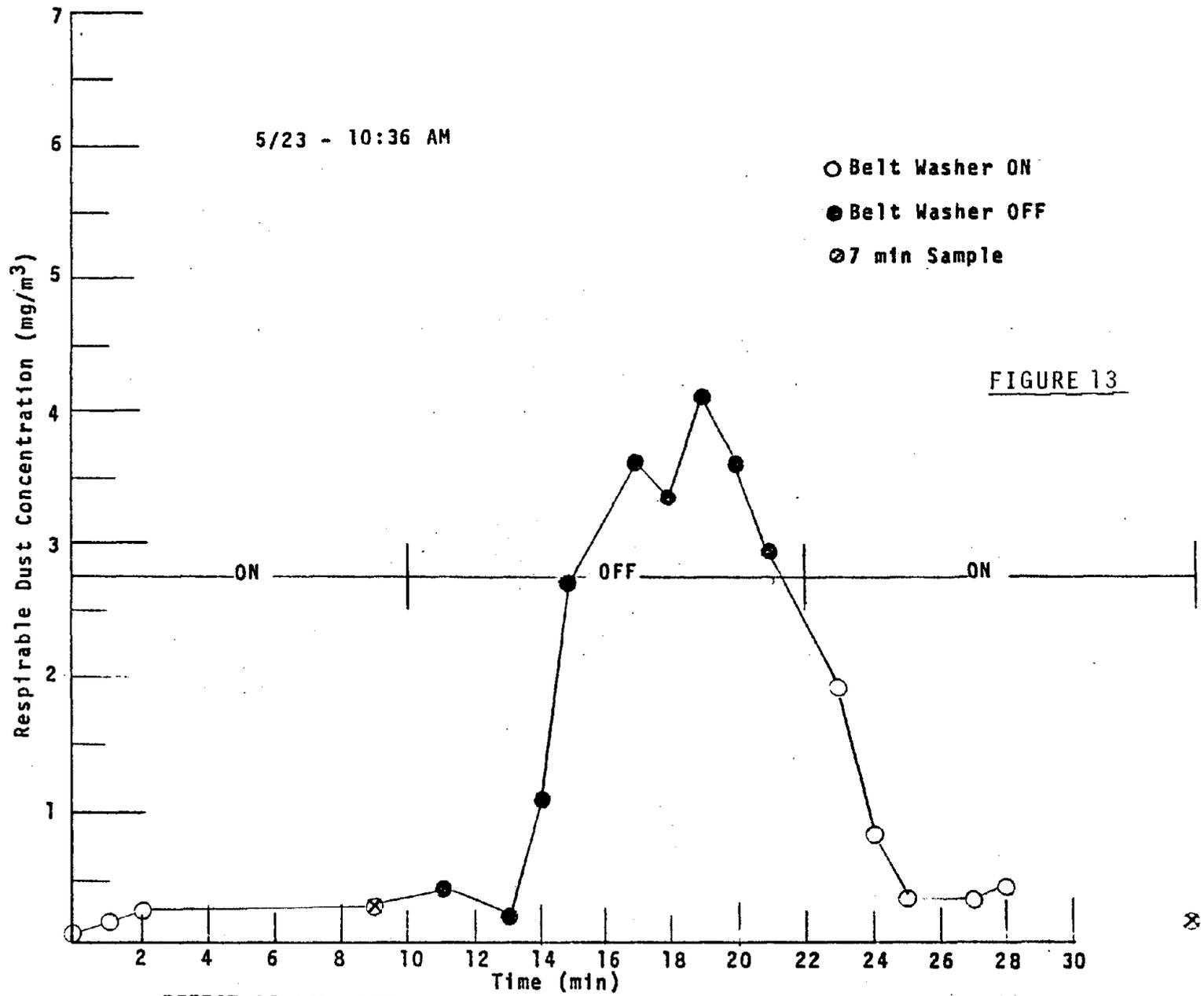


FIGURE 13

EFFECT OF BELT WASHER SYSTEM ON RESPIRABLE DUST CONCENTRATION  
GCA Model RDM-101

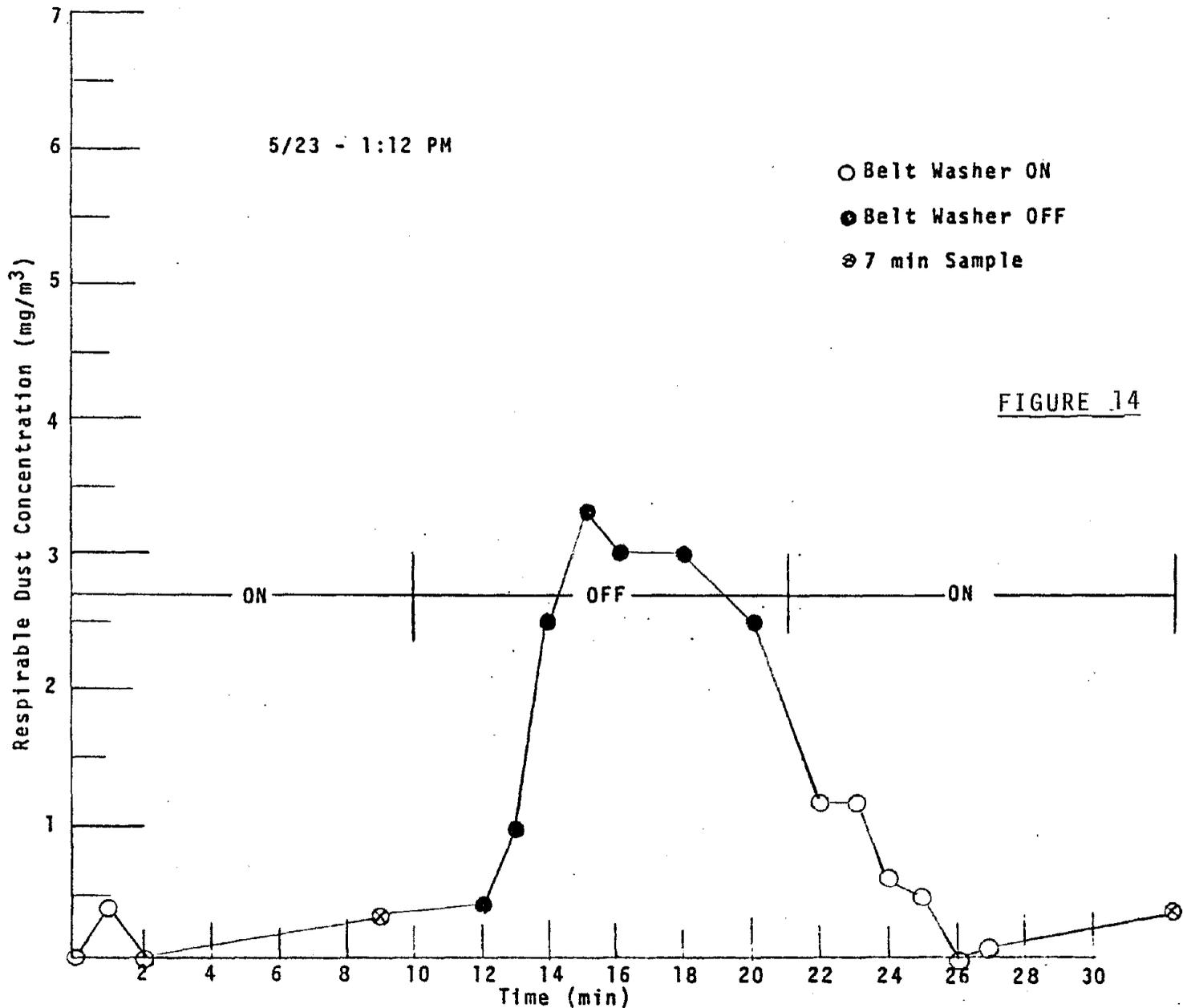


FIGURE 14

EFFECT OF BELT WASHER SYSTEM ON RESPIRABLE DUST CONCENTRATION  
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## CONTROL OF DUST AT DUMPS

Generation of dust at dumps is intermittent due to the nature of the operation. Cars rapidly discharge the product into the dump resulting in an immediate displacement and updraft of dust laden air. Water sprays located at the mouth of a dump can reduce the quantity of dust ordinarily released during the dumping operation and water sprays can be operated intermittently thus minimizing the total water inventory. However, once dust has become airborne sprays have a limited capacity for capture, and it appears that ventilation is a necessary procedure for effective control of dust at dumps.

During this study, dust surveys were conducted at a number of dumps. An underground rotary dump was selected for installation and demonstration of the effectiveness of exhaust ventilation at a dump site. Although the ventilation system was never installed, the preliminary dust surveys which were conducted, the recommendations which were made for upgrading the operation, and the design of an exhaust ventilation system are presented to provide guidelines for dust control at a rotary dump.

### Description of the Underground Rotary Dump Facility

Figures 15 and 16 show the general layout of the rotary dump as well as the loading station and the exhaust air shaft. Trains service the dump at the rate of approximately one train every 10 minutes. The cars are rotated 180° to a fully inverted position and then returned to the upright position in about 5 seconds. Three cars with a capacity of 12 tons each are dumped simultaneously. At a density of 1 ton cu yd, 36 tons of ore would displace approximately 1000 cu ft of air in 5 seconds, for a calculated rate of 12,000 cfm.

Personnel in the dump area included the dump operator and a train crew of two or three men. The existing method of dust control was to ventilate the complete rotary dump area by exhausting air through the area and up the associated air/product shaft. Visual observation of the dumping operation indicated that displaced air and entrained dust surged out of the ore pass behind the ore car, indicating that localized exhaust ventilation would be required to effectively control dust.

### Preliminary Dust Survey

Full shift respirable dust samples were taken at the rotary dump operator's station and at a location in the return air shaft (Figure 15). The results of respirable dust samples taken for seven consecutive working days are presented in Table 12.

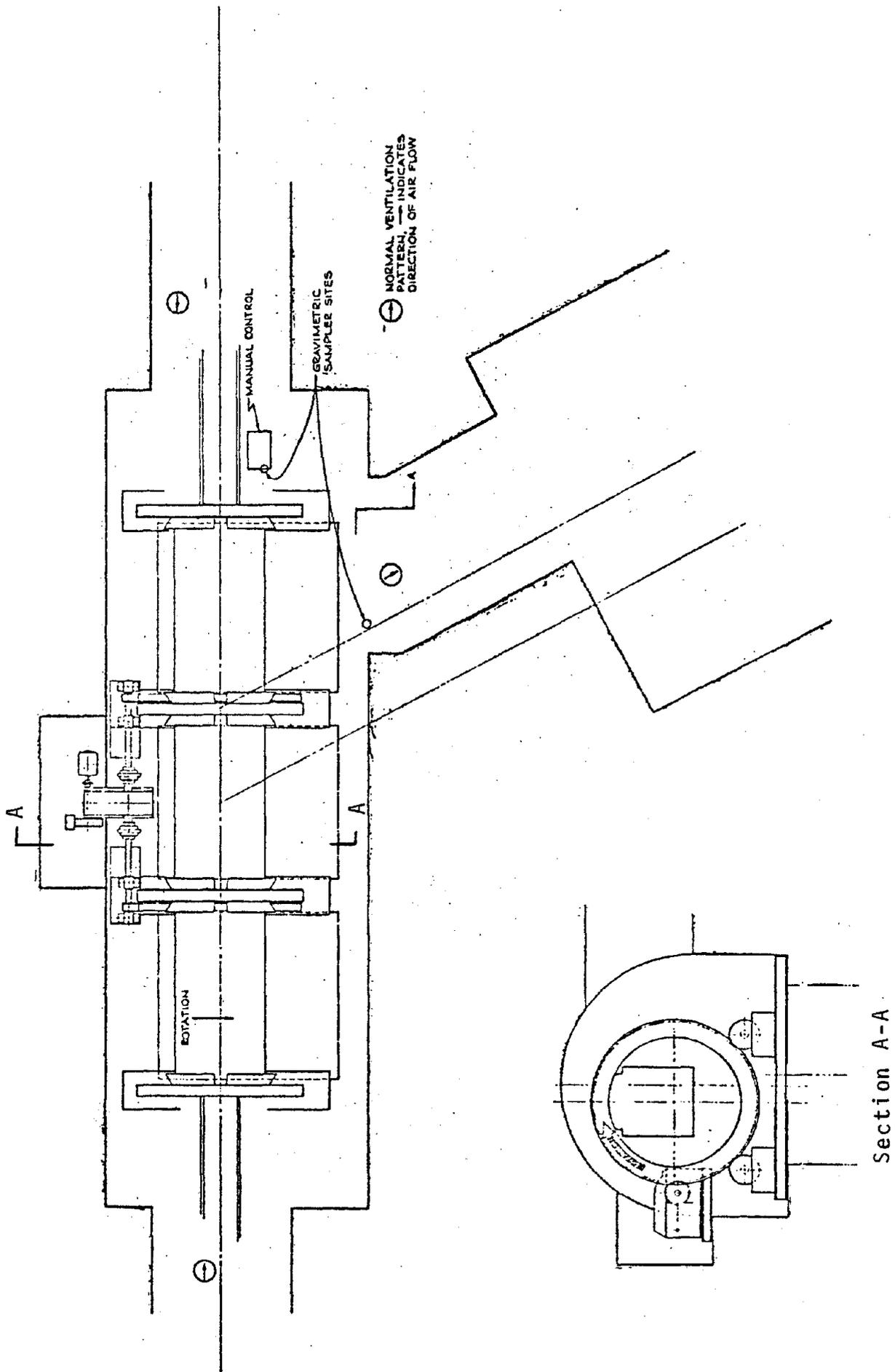


FIGURE 15 - PLAN VIEW OF THE ROTARY DUMP

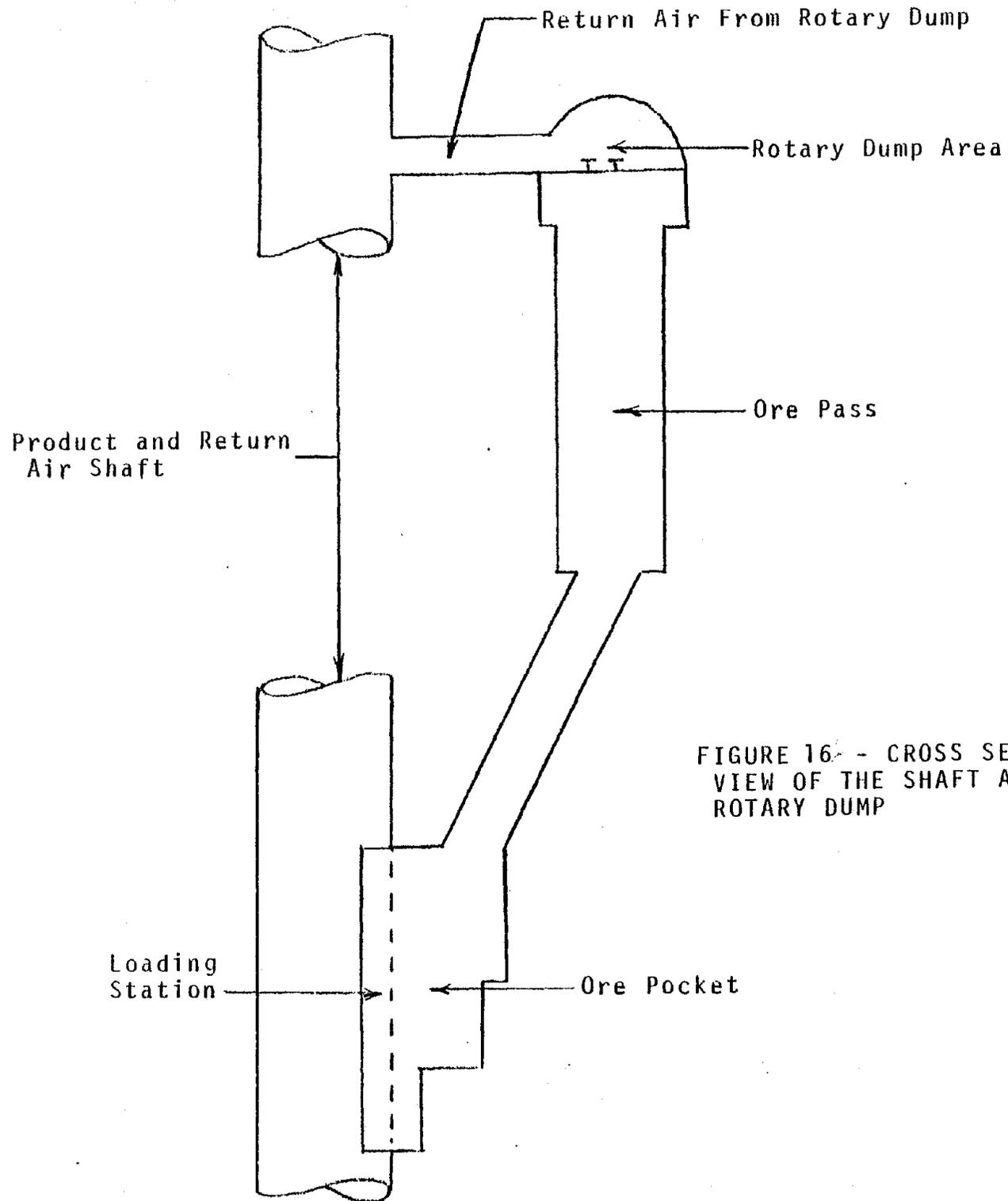


FIGURE 16 - CROSS SECTIONAL VIEW OF THE SHAFT AND ROTARY DUMP

TABLE 12- FULL SHIFT RESPIRABLE DUST CONCENTRATIONS - ROTARY DUMP

Day	1	2	3	4	5	6	7	8
Location	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Mon.	Tues.
<u>Rotary Dump, Operator's Station</u>								
Dust Concentration (mg/m <sup>3</sup> )	1.66	2.43	0.80	1.53	1.28	1.20	1.80	1.98
Shift Production (tons)	4515	6049	3961	5410	5026	5282	6666	6411
Concentration/Production (mg/m <sup>3</sup> /ton x 10 <sup>4</sup> )	3.68	4.01	2.02	2.83	2.55	2.27	2.70	3.08
<u>Between Dump and Air Shaft</u>								
Dust Concentration (mg/m <sup>3</sup> )	2.05	2.60	2.10	1.81	1.38	1.16	0.90	0.90
Shift Production (tons)	4515	6049	3961	5410	5026	5282	666	6411
Concentration/Production (mg/m <sup>3</sup> /ton x 10 <sup>4</sup> )	4.54	4.30	5.30	3.35	2.75	2.35	1.74	1.40

Table 12 also lists the tonnage values for each day and the correlation of dust concentration with tonnage. The respirable dust concentration ranged from 0.80 to 2.43 mg/m<sup>3</sup> at the operator stations, and from 0.90 to 2.60 mg/m<sup>3</sup> in the return air drift between the dump and return air shaft. Correlation between concentration and tonnage ranged from 2.02 mg/m<sup>3</sup>/ton x 10<sup>4</sup> to 4.01 mg/m<sup>3</sup>/ton x 10<sup>4</sup> at the operator's station. Of all operations surveyed (transfer points, draw points, crushers, chutes, etc), this area showed the best correlation of dust concentration with tonnage. Good correlation would be expected in this area because the amount of dust generated is directly dependent upon the amount of ore dumped, and because other dust sources do not exist in the area.

### Design of Dust Control System

The gravimetric sampler results and visual observations of dust displacement during dumping indicated that the existing ventilation scheme did not adequately control dust at the dump site. It was felt that local exhaust ventilation could be used to overcome the dust surge during dumping, and trap and transport the dust before it could escape from the mouth of the dump. In a new dump installation it would be recommended that a drift be driven below the mouth of the dump and that air would be exhausted through the drift. The dust entrained in the exhaust stream could be discharged to the return air stream, or if there were no return airways nearby, the dust could be removed by filtration, wet scrubbing, electrostatic precipitation, etc.

Since this was an existing rotary dump operation and since the objective of the program was to demonstrate the effectiveness of selected principles of dust control, it was recommended that exhaust hoods be installed in the dump area, with the effluent air from the hoods ducted to and exhausted up the return air/product shaft.

It was estimated that air was displaced at a rate of 12,000 cfm during dumping of 3 cars (36 tons) in 5 seconds. The exhaust fan rate and duct sizes were based on this calculated displacement rate. The design of a rotary dump is such that it is impractical to provide a seal around supporting structures, and thus it was recommended that the exhaust system be rated at 25,000 cfm to overcome leakage in the open areas. The cost increase of a 25,000 cfm system compared to a 12,000 cfm system would be minimal. Figure 17 shows the recommended configuration for the exhaust hoods.

The solution which was selected was not envisioned as a totally satisfactory arrangement, but rather was an approach to proving the principle that exhaust ventilation in such applications would adequately control dust. Under ideal conditions, the exhaust pickup point would be located in the ore bin, and

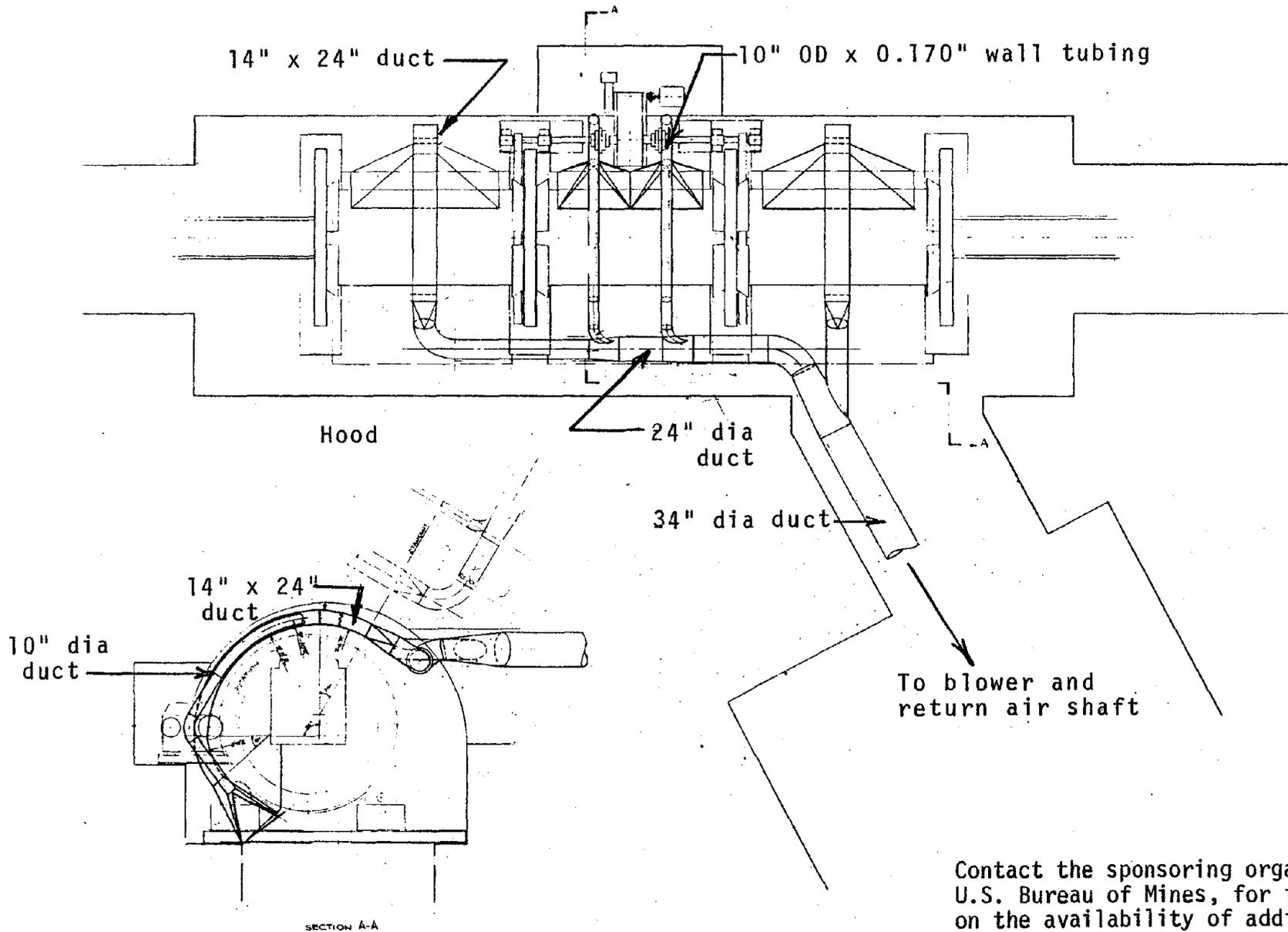


FIGURE 17 - PROPOSED PLAN FOR EXHAUSTING DUST FROM THE ROTARY DUMP

arrangements would be made to exhaust directly to a return airway thus eliminating the hood and overhead duct. Due to a curtailment in production and a resultant cutback in maintenance expenditures, the mine was not able to install the exhaust system. However, the principle is a valid approach to dust control and the design guidelines are presented to provide direction in sizing a system.

## CONTROL OF DUST AT CRUSHERS

Crushers are recognized as significant dust sources in both underground and surface facilities. The nature of the crushing operation results in the generation and possible dispersion of dust during all stages of the operation including ore charging, the crushing operation itself and crushed ore discharge. The crushing operation can therefore contribute to the overall dust inventory in a mine when the crusher is located underground or in a processing plant when the crusher is located on the surface.

During charging operations, dust can be dispersed by the upsurge of dust laden air during fall of the ore into the mouth of the crusher. The crushing action may dislodge small particulates adhering to the ore and generate additional particulates as a result of the crushing action. As ore passes through the crusher and falls to the conveying system, dust laden air can be dispersed at the crusher outlet.

Because of the variety of dust sources in crushing operations, a number of dust control techniques have been employed to minimize dust dispersion. In cases where the crusher is located in a remote area with no possibility of dust contamination of mine or mill work areas, employee protection has been accomplished through the use of pressurized, filtered air in the enclosed operator's booth. Although this procedure may be effective in reducing employee exposure, it is not an engineering solution to dust control. Local exhaust ventilation can effectively control dust dispersion at the crusher inlet. Exhaust ventilation has been used in a variety of configurations including sweeping air across the crusher inlet, exhausting down through the crusher, and completely hooding and enclosing the crusher and maintaining the enclosure under negative pressure. The dust laden ventilation air must be directed to a return airway or passed through an air cleaning system. Water sprays have been used prior to and during charging of ore to the crusher to effectively prevent dispersion of dust adhering to the ore surfaces. During the actual crushing operation, additional dust is generated by the crushing/grinding action and water has been shown to have limited capture capabilities for freshly generated dust.

During this study, dust surveys were conducted at a number of crushers. A surface, side car dump operation using local exhaust ventilation sweeping across the crusher mouth and a positive pressure operator's station was selected for further study to evaluate and demonstrate the effectiveness of these combined dust control procedures. Another crushing operation

where dust control problems existed was chosen to demonstrate the improvement of dust control procedures by upgrading existing dust capture and collection systems. Although this upgrading was not instituted, recommendations which were made are presented to provide guidance to the industry.

#### Evaluation of an Exhaust Ventilation/Pressurized Booth Dust Control System

An iron ore mine is using a combination exhaust ventilation and pressurized operator's booth to control dust and to minimize employee exposure to the respirable dust hazard. The crusher is a 60 inch diameter gyratory type and is fed by side dump railroad cars. The operator is housed in the control booth located approximately 30 feet from the crusher.

Air is directed across the crusher mouth and into the exhaust ventilation system which is located about 10 feet above the crusher at a rate of 75,000 cfm. Dust laden air is transported to a baghouse collector. The operator's control room is maintained under a positive pressure of 3 in. water with a 500 cfm blower. Air is filtered through a high efficiency filter (99.9% efficient for particles larger than 0.3 microns). A double door on the control room minimizes the exchange of air during entry or egress from the room.

Figure 18 is a schematic diagram of the area showing the locations of the dust samplers which were used to determine dust concentration in the crusher area, in the control room and in the adjacent processing plant. Total and respirable dust samples were taken for 5 consecutive days with the quantity of ore which was crushed ranging from 18,765 tons/shift to 27,690 tons/shift (Table 13).

The samplers located outside of the control room (sampler locations 3 and 4) showed respirable dust concentrations ranging from 0.80 mg/m<sup>3</sup> to 5.76 mg/m<sup>3</sup>. The average respirable dust concentration outside of the control room was 4.20 mg/m<sup>3</sup>. The total dust concentration outside the control room range from 30.01 mg/m<sup>3</sup> to 104.49 mg/m<sup>3</sup> with an average concentration of 72.69 mg/m<sup>3</sup>.

The 10 respirable dust samples taken inside the control room ranged from 0.11 mg/m<sup>3</sup> to 0.28 mg/m<sup>3</sup> with an average of 0.18 mg/m<sup>3</sup>. The average total dust concentration inside the control room was 0.27 mg/m<sup>3</sup>. The respirable fraction of the dust accounted for 66% of the total dust concentration.

Samples were also taken in the processing plant which was adjacent to the crusher area and separated from the crusher with a concrete wall. The average respirable dust concentration in the plant was 0.19 mg/m<sup>3</sup> while the total dust concentration was 0.75 mg/m<sup>3</sup>. Visual observation of the dust pattern within the crusher area indicated that the exhaust ventilation system minimized the possibility of dust entering the processing plant area.

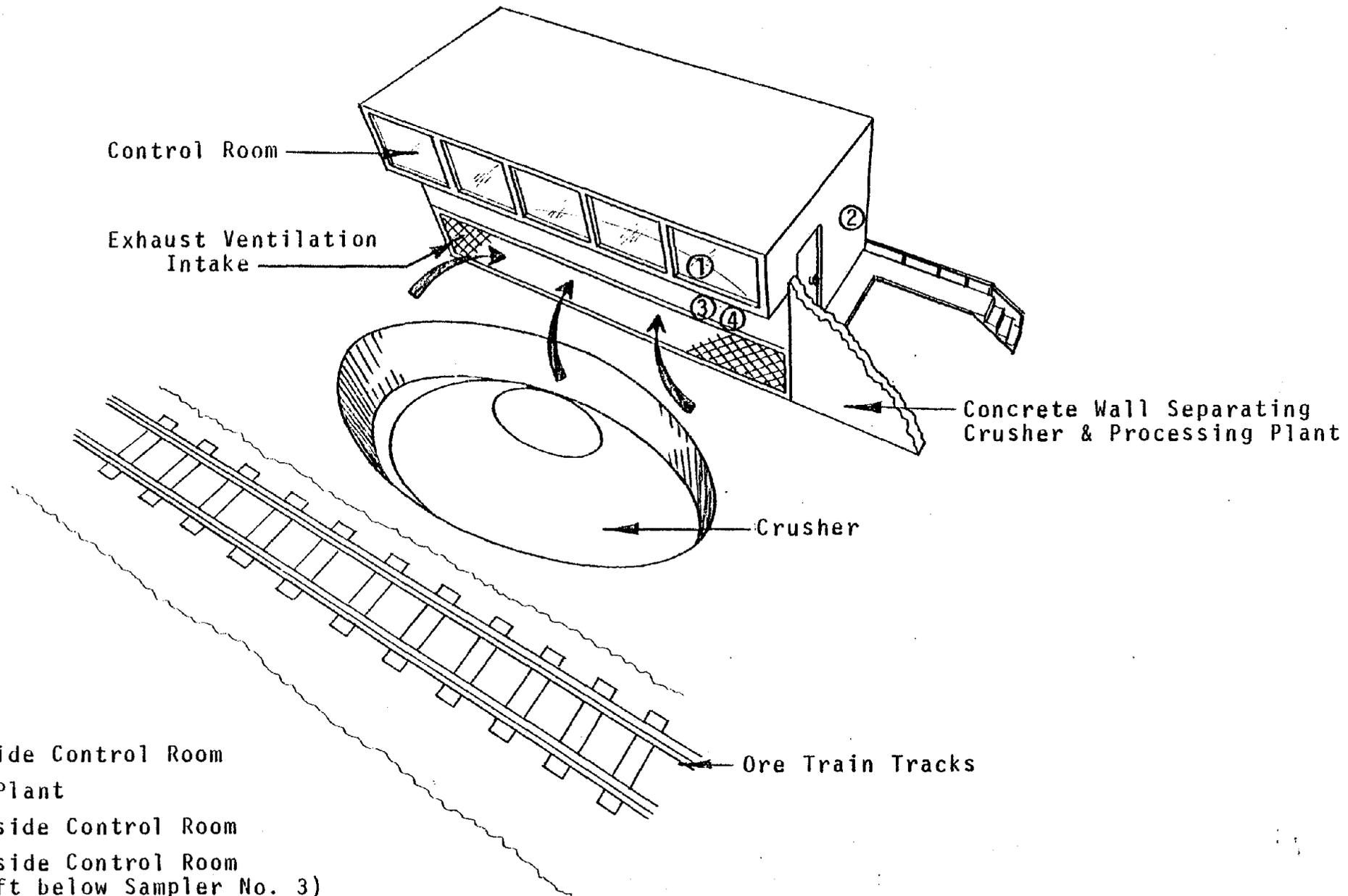


FIGURE 18 - SCHEMATIC DIAGRAM OF DUMP-CRUSHER FACILITY

TABLE 13- GRAVIMETRIC SAMPLE DATA, CRUSHER AND CONTROL ROOM

<u>Test No.</u>	<u>Tons</u>	Dust Concentration (mg/m <sup>3</sup> )			
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>
1	18,765	T 0.26	T 1.80	T 83.36	--
		0.27	0.29	3.66	0.80
		0.18	0.17	4.12	1.13
2	22,490	T 0.21	T 0.68	T 66.97	T 104.49
		0.28	0.15	2.81	5.57
		0.27	0.27	4.38	5.70
3	27,690	T 0.34	T 0.42	T 83.88	T 83.16
		0.15	0.17	4.69	5.76
		0.11	0.20	4.93	5.24
4	27,230	T 0.26	T 0.29	T 84.95	T 68.35
		0.17	0.14	4.71	4.82
		0.12	0.16	4.58	4.57
5	24,650	T 0.29	T 0.58	T 49.02	T 30.01
		0.12	0.17	4.18	4.23
		0.17	0.15	4.08	4.07

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Legend

- Sample Station No. 1 - Inside Control Room
- 2 - In Plant
- 3 - Outside Control Room at Crusher
- 4 - Outside Control Room 5 ft below No. 3
- TXX.XX - Vinyl Filter Total
- XX.XX - Vinyl Filter Respirable

Respirable dust samples which were taken were analyzed for free silica content by the infrared technique. An average silica content of 27% was determined in this manner. The TLV based on this free silica content was calculated as follows:

$$TLV = \frac{10 \text{ mg/m}^3}{\% \text{ quartz} + 2} = \frac{10}{27+2} = 0.34 \text{ mg/m}^3$$

The results of the 10 respirable dust samples taken in the control room showed an average dust concentration of 0.18 mg/m<sup>3</sup> indicating that the exhaust ventilation system and pressurized control room techniques controlled the respirable dust at a level well below the Threshold Limit Value. The adjoining processing plant was also maintained at a dust level below the TLV, but it is doubtful that effective dust control could have been accomplished if localized exhaust ventilation had not been used at the crusher.

#### Recommendations for Dust Control at a Copper Ore Crusher

A dust survey was made at a copper ore crusher and, based on the survey results and visual observation of the operation, recommendations were made regarding implementation of dust control procedures. Infrared analysis of the respirable dust collected on vinyl membrane filters indicated a free silica content of 23%. This results in a TLV of 0.4 mg/m<sup>3</sup>.

The crusher processed ore at a rate of 5000-7000 tons/shift. Although the crusher operator was in an enclosed booth, maintenance workers and general laborers working in the crusher building could be exposed to dust levels exceeding the TLV of 0.4 mg/m<sup>3</sup>.

Figure 19 is a schematic of the crusher system showing the pan feeders and belt conveyors, the dust enclosures and the exhaust ventilation system. Coarse ore is fed to the crusher with a pan feeder. Undersize ore drops through the grizzly located at the mouth of the feeder and falls approximately 40 ft into a hopper. The oversize ore passes through the crusher and onto the same pan feeder that services the undersize ore hopper. The ore is then transferred to conveyor belts where it is transported to the fine ore storage bins.

Dust is controlled with enclosures and exhaust ventilation; no water is used at the crusher. The pan feeder to crusher and the crusher mouth are enclosed and maintained under exhaust. The pan feeder at the exit of the crusher is enclosed and exhausted, as are the two transfer points located within the crusher building.

A number of dust sources exist at this operation including:

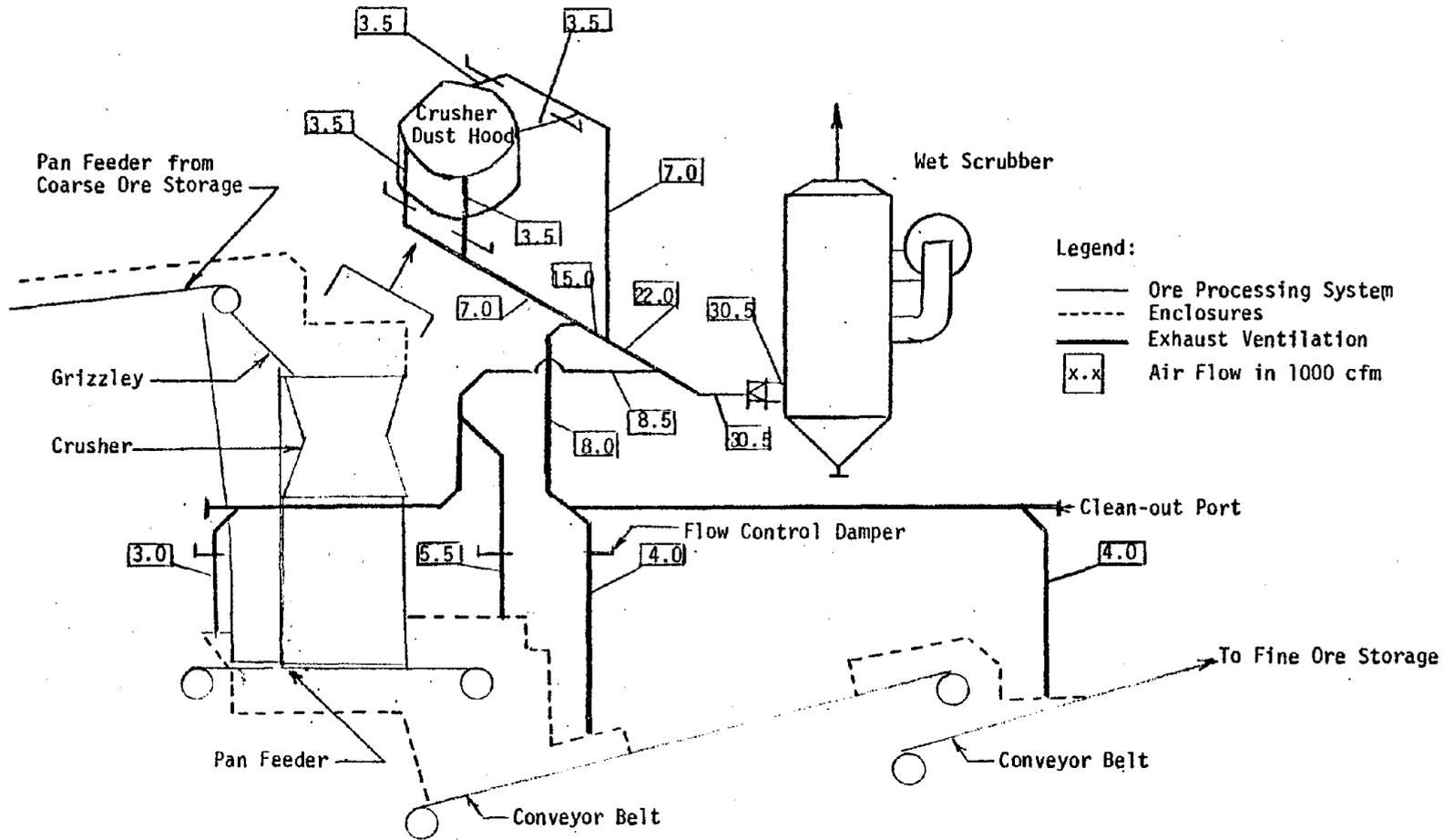


FIGURE 19 - CRUSHER SYSTEM SCHEMATIC

1. Fugitive dust on support structures.
2. Bolts (1-1/4 in.) support protective plates on the inside of the crusher. The bolt holes through the crusher body were burned through, resulting in irregular holes where dust escapes.
3. This same condition exists at the grizzly hopper.
4. Maintenance and inspection plates at the grizzly level are neither tightly fitted nor gasketed.
5. The same condition exists at the inspection doors on the enclosure covering the pan feeder-belt transfer point at the crusher exit and at the crusher discharge.
6. The ore drops 10-12 ft between the pan feeder and belt. This location is partially enclosed and is under exhaust ventilation. However, the tail end of the pan feeder is not enclosed and is an obvious dust source.
7. A gap between the hopper and the pan feeder is a major dust source at the crusher exit.

Full shift respirable dust samples were taken at the crusher floor level and at the right and left sides of the pan feeder. Results of full shift samples taken during seven consecutive working days are given in Table 14.

The results show that the dust concentration at the floor level ranged from 0.11 to 0.78 mg/m<sup>3</sup>. The dust concentration at the right side of the pan feeder ranged from 0.94 to 10.3 mg/m<sup>3</sup>, while that on the left side ranged from 0.69 to 4.07 mg/m<sup>3</sup>. Visual observation of the natural air pattern within the crusher building suggested that the dust concentration would be higher on the right side of the pan feeder. Of the 19 samples taken in the vicinity of the crusher, only 3 were below the TLV of 0.4 mg/m<sup>3</sup>.

Prior to installation of any dust control system, it was recommended that the fugitive dust sources be eliminated. These sources included:

1. Remove dust from crusher support members.

TABLE 14 - FULL SHIFT RESPIRABLE DUST CONCENTRATIONS AT THE CRUSHER

Day	Location	1 Mon.	2 Tues.	3 Wed.	4 Thurs.	5 Fri.	6 Sat.	7 Mon.
		Dust Concentration (mg/m <sup>3</sup> )						
	Crusher (floor level)	0.67	0.68	0.11	0.05	0.18	0.78	0.58
	Crusher (left side of pan feeder)	3.88	2.48	1.85	0.69	3.86	4.07	1.50
	Crusher (right side of feeder)	4.74	5.70	4.00	0.94	10.3	--	--

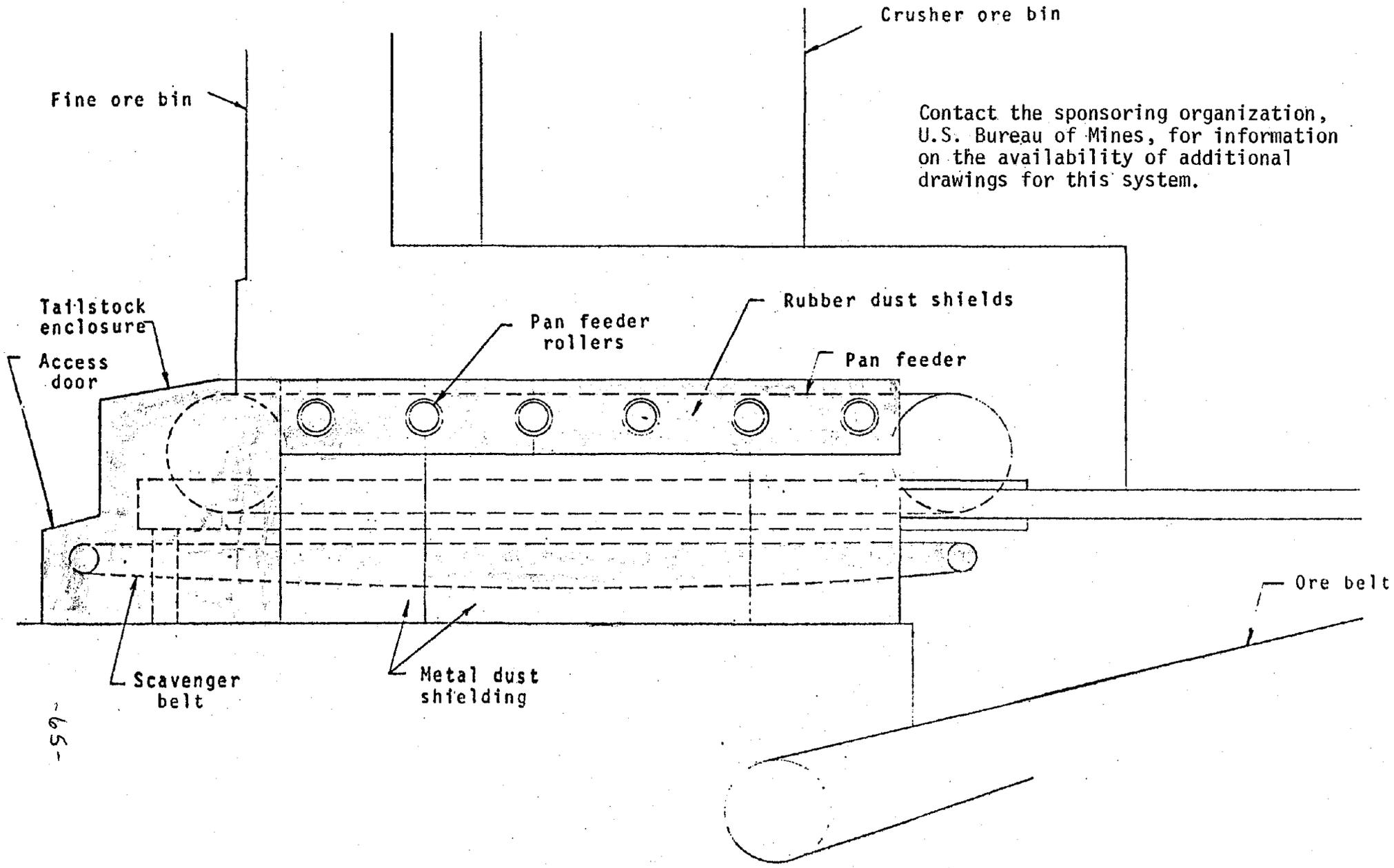
2. Seal bolt holes.
3. Place adequate seals on inspection and maintenance plates.

It was then recommended that the following measures be instituted:

1. Eliminate all openings in the primary crusher enclosure.
2. Extend enclosure on the crusher discharge pan feeder to enclose tail pulley (Figure 20).
3. Install skirting on crusher hopper-pan feeder interface (Figure 20).
4. Install scavenger belt to pick up pan feeder dribblings without the necessity of opening the enclosure (Figure 20).

The recommended improvements at the crusher discharge are shown as the shaded areas in Figure 20.

To demonstrate and evaluate the effectiveness of these control procedures, a sampling plan was formulated and was to be conducted following the installation. However, a curtailment in production prevented the mine from assigning the necessary personnel to install the recommended dust control systems. Although additional sampling was not conducted, it is believed that implementation of these recommendations would have reduced dust in the area to an acceptable level. The recommendations have been presented here to provide guidelines for the mining community for control of dust under similar circumstances.



Fine ore bin

Crusher ore bin

Contact the sponsoring organization,  
U.S. Bureau of Mines, for information  
on the availability of additional  
drawings for this system.

Tailstock enclosure

Access door

Pan feeder rollers

Rubber dust shields

Pan feeder

Ore belt

Scavenger belt

Metal dust shielding

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FIGURE 20 - PROPOSED ENCLOSURE AT THE 3C CRUSHER EXIT

## CONTROL OF DUST AT CHUTES

A mine employing block caving as the method of ore retrieval was chosen to evaluate possible methods of dust control at chutes. The working levels are located at 300 ft intervals, and each working level consisted of a grizzly level and a haulage level located 300 ft below (Figure 21). Ore is trapped from the caving ore body through finger raises to the grizzly level. The ore falls into chutes or finger raises located between the grizzly level and the haulage level. On the haulage level, ore is drawn from the chutes into mine cars.

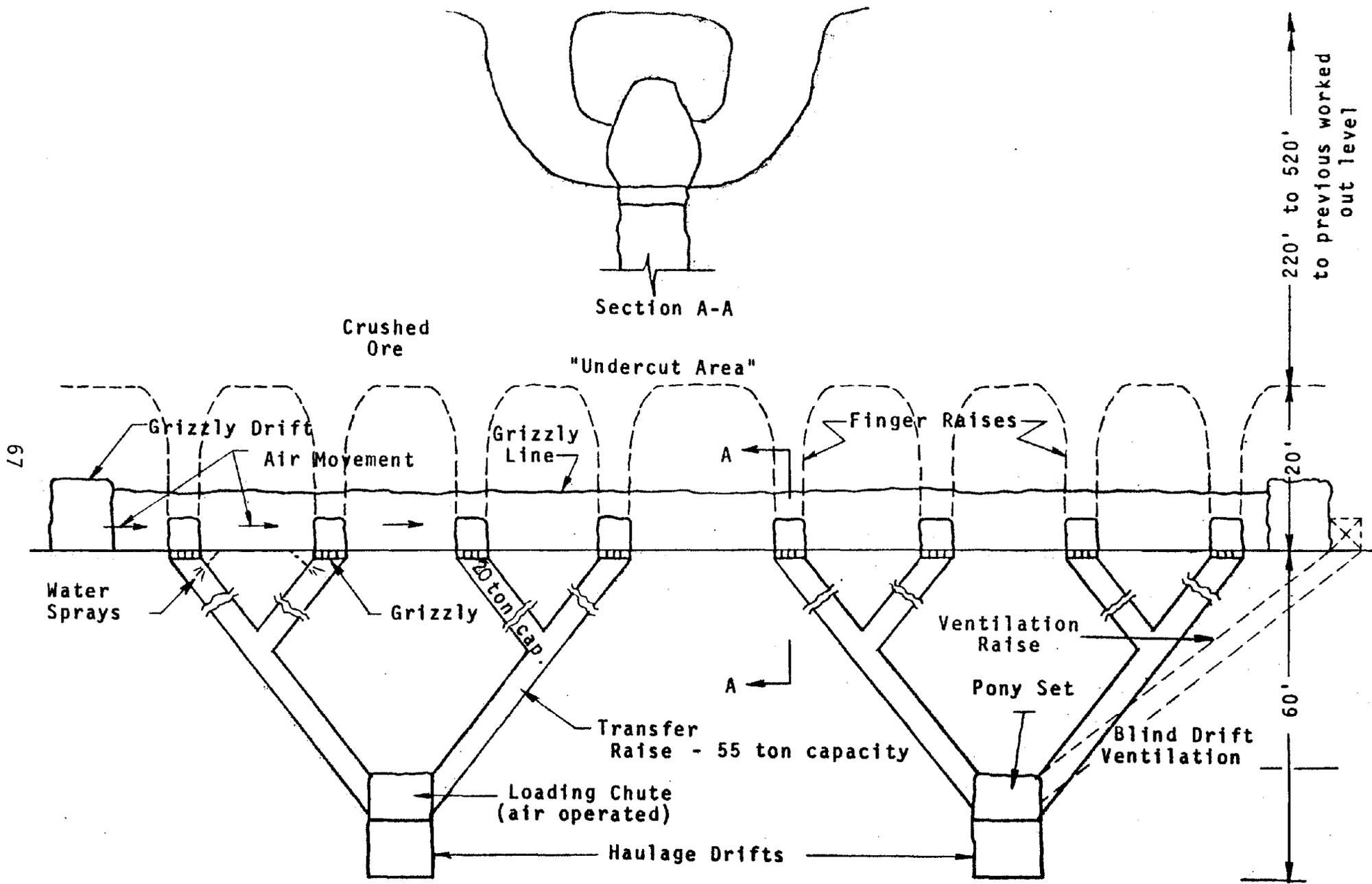
### Current Dust Control Methods

The two methods of dust control which are employed are ventilation and water sprays. A plan view of a grizzly level is shown in Figure 22. Intake air drifts supply fresh air to the grizzly lines. The return air from the grizzly line is collected in the dead-ended ventilation (access) drift and exhausted through ventilation raises to the haulage levels. A ventilation raise services 3 or 4 grizzly lines and contains a 25,000 cfm fan. When the ore raises are empty, the return air can also flow to the haulage level through these open raises. Because of this air flow pattern, the intake air to the haulage level can be contaminated with dust from the grizzly line operations.

In addition to ventilation, water sprays are used at the draw points on the grizzly line and at the chutes on the haulage level. These are turned on manually when the transfer raise is being loaded or discharged into the mine car.

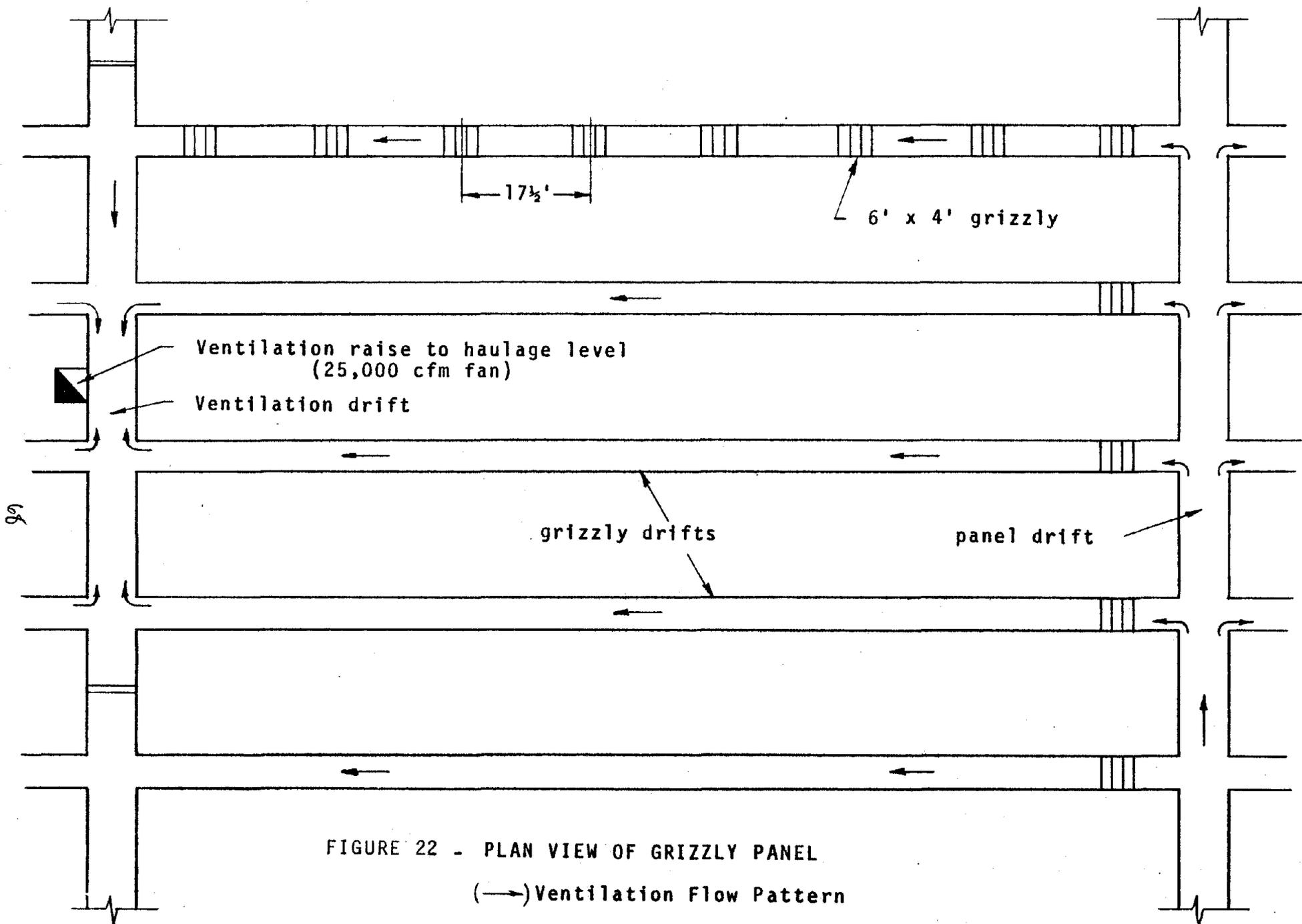
As stated above, intake air to the haulage level is contaminated with dust from the grizzly line. Furthermore, auxiliary blowers (venturi type) used in the grizzly lines can cause reverse air flow in other grizzly lines. For safety, company policy dictates that 2 men shall operate in a grizzly line in view of each other. As a result, one must always be on the downstream side of the other, and thus subject to dust produced during the chute tapping operation. Finally, complete discharge of the ore from the raises result in high dust concentrations at the pony set (chute puller) on the haulage level.

It is difficult to regulate the amount of water which is used with the uneven ore flow through the grizzly. The ore is sometimes dry, fine and free-flowing, whereas at other times requires considerable barring and/or breaking of large lumps to maintain flow. Sometimes the sprays are forgotten and left on. As a result, water sprays are either too heavy, or too



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FIGURE 21 - GENERAL SCHEMATIC OF BLOCK CAVING OPERATION



light. Fine sprays are plugged by corrosion products which are dislodged from the internal pipe walls during blasting. Thus spray nozzles must be designed to give a coarse spray.

### Results of Preliminary Survey

A preliminary survey was conducted using gravimetric samplers to collect full shift respirable dust samples. Samples were taken for 8 consecutive working days on the grizzly line and at the pony set. Results are presented in Table 15.

The grizzly line measurements were taken downstream of the chutetapping operations and the haulage level measurements were taken in the pony set. Production values for each day were acquired and an attempt was made to correlate dust concentrations with the number of tons of ore. Dust concentrations on the grizzly line ranged from 0.86 mg/m<sup>3</sup> to 2.33 mg/m<sup>3</sup>. This appears to be a reasonable spread in light of the ventilation problems and the variations in water usage. The correlation between the dust concentration and the production values was rather poor ranging from 1.67 to 7.33 mg/m<sup>3</sup>/tonx10<sup>3</sup>. Since ventilation, water usage and fugitive dust from other working areas all contribute to the dust concentrations, this is not surprising.

The range of dust concentrations at the pony set was greater (1.08 to 9.79 mg/m<sup>3</sup>) than that at the grizzly line, and the correlation between dust concentration and production values was also very poor. Again, this would be expected based on the previously mentioned variables.

### Recommended Dust Control Procedures

Ventilation is a constant source of problems in and around the grizzly and chute. An attempt is made to maintain an air velocity of 180 ft/min in all working grizzly lines from the grizzly drift toward the access drift. This is difficult to maintain throughout working sections of the mine under the dynamic conditions presented during the load-out operations. Problems begin with maintaining a balance of air throughout the entire grizzly level of the mine to be sure that all sections of the work area have an adequate supply of air to draw on. Ventilation doors with smaller air openings are used at the end of each grizzly drift. A major loss of ventilation air within the drift is empty transfer raises. Small venturi-type air movers, operating off of compressed air, are employed in the grizzly lines to supply additional air in particularly dry and dusty working areas. The auxiliary blowers are helpful, but under certain conditions can overload available exhaust capacity causing a reversal of air in adjacent grizzly lines moving dust laden air into the intake air supply.

TABLE 15 - FULL SHIFT RESPIRABLE DUST CONCENTRATIONS,  
GRIZZLY LINE AND PONY SET

Day	1	2	3	4	5	6	7	8
Location	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Mon.	Tues.
Grizzly Line Dust Concentration (mg/m <sup>3</sup> )	1.04	1.62	2.33	1.52	0.86	--	2.20	1.06
Shift Production (tons)	624	624	396	504	384	--	300	252
Concentration Pro- duction (mg/m <sup>3</sup> / tonx10 <sup>3</sup> )	1.67	2.60	5.88	3.02	2.24	--	7.33	4.22
Pony Set Dust Concentration (mg/m <sup>3</sup> )	1.11	9.79	1.99	7.48	5.41	4.18	1.08	0.87
Shift Production (tons)	372	132	396	108	336	288	84	--
Concentration/Pro- duction (mg/m <sup>3</sup> / tonx10 <sup>3</sup> )	2.98	74.17	5.03	69.26	16.10	14.51	12.86	--

For reasons of safety, company policy dictates that two men shall operate on a grizzly line in view of each other. As a result, no matter what the condition of the ventilation, one worker must be downstream of the other, and thus subjected to dust laden air. This policy has evolved over the past several years and appears to be necessary to reduce grizzly line accidents. Dust control measures, therefore, must take this into account.

Finally, open transfer raises are a direct line for dust laden air from the grizzly line to the pony set and haulage level below, and as previously mentioned serve to by-pass available ventilation air. The design of the chute at the base of the raise is such that a considerable opening exists even when the chute door is closed. If this loss could be eliminated it would help in maintaining adequate air velocities at the grizzly level, although all air and accompanying dust would still contaminate the haulage level below.

Closing the chute opening could be accomplished by two methods:

1. Maintaining a plug of ore at the base of the raise.
2. Designing an airtight chute.

Maintaining a plug at the base of the raise is a simple enough solution on paper, but on a practical basis it is apparently unworkable. Grizzly line crews have quotas that are assigned, and these are met at the expense of all available muck. Attempts by the company to enforce this policy of maintaining a plug has failed in the recent past. Modifying the chute design to an airtight configuration has some problems. The present design employs rails to block approximately half of the transfer raise opening several feet up from the chute to take some of the pressure off of the chute. The opening created by this partial blocking is then used by the chute puller in the pony set to bar down blockages in the transfer raises. This opening, thus, is a source of dust to the chute puller, but is necessary, a fact which must be taken into account in the design of dust control measures.

Although it was difficult to obtain valid dust measurements as evidence for it, observations and comments of veteran grizzly line foremen indicate that the major source of dust in the grizzly and haulage areas is caused by displaced air in filling the transfer raise. In an empty raise, dust emanates primarily from the grizzly of the raise connecting the raise being tapped until the muck makes a seal at the "Y" junction. Thereafter, dust is evolved from the raise being filled.

Water sprays at the end of the transfer raise are said to be beneficial in suppressing dust, but at the same time a source of wet bottom conditions at the haulage level below. The water sprays are operated manually by the chute tapper at the grizzly, but it is difficult to regulate the water with the muck flow through the grizzly. If the ore is fine and dry, the muck flows freely and creates considerable dust. If coarse, the chute tapper may spend considerable time barring down and breaking large rocks, during which time the sprays may be allowed to operate causing wet conditions in the haulage level below.

The water sprays in the pony set are activated by the chute puller during the loading operation. Of necessity, both these sprays, and those at the end of the transfer raise, are coarse, losing considerable effectiveness. Fine sprays were tried, but clogged frequently. It was the opinion of the ventilation engineer that corrosion products loosened during blasting caused the clogged filters.

The reduction of dust concentrations around the chutes encompasses more than the operation of the chutes themselves. It also involves filling the transfer raises, the ventilation patterns of the working section and operation of the grizzly crew overhead. Improvement in these areas, therefore, would not only reduce dust levels on the haulage level but undoubtedly favorably affect the conditions of the grizzly line.

The following dust control procedures were suggested:

1. The use of high expansion foam in place of water sprays at the grizzlies and possibly at the chutes.
2. The use of a dust seal on the chutes at the pony sets.
3. The use of an ore plug at the base of the transfer raise.

Improved dust control measures at the grizzlies must be portable, accommodate the transfer raise filling operation, and use available and permissible sources of energy. The method employed must take into account the variation in muck flow and the chute tapper working full time to maintain muck flow. In addition, a number of grizzly lines within a panel may be worked and the device must be portable in order to move it from one grizzly line to another.

High expansion foam from a water powered foam unit, partially for completely filling the raise prior to the raise filling operation, was proposed to suppress dust at the grizzly level. In addition to reducing dust at the grizzly line, its

effect could continue through the loading and dumping operation in the mine. The portable unit used water, which was already available on the grizzly line and could readily be moved from grizzly to grizzly by one man. Filling the raise with foam prior to filling the raise with ore eliminated the need for regulation by the chute tapper during tapping operations.

It is estimated that the amount of foam concentrate required would be about 0.015 lb/ton of ore. Preliminary tests by the mine's metallurgical laboratory indicates that this foam dosage will reduce total copper recovery from 87.5% to 86.9%. The company did not feel this is a significant reduction and that, if dust suppression with foam is effective, then the flotation process might be altered to account for the surfactant effect on the foam. Another possible approach is to use a different type of foam concentrate but at this time it seemed advisable to use an existing concentrate for demonstration purposes.

A long lived foam (MSA Superfoam) was chosen for the tests since it would be more resistant to collapse during the drawing operation. The generator which was used delivered foam at the rate of 450 gpm with an expansion ratio of 350:1. Prior to drawing, the raises were filled to the floor of the grizzly level, and additional foam was added during drawing to replace that which collapsed.

The results of respirable dust concentration on the grizzly line are given in Table 16. The results indicate that dust concentrations while foaming were higher than when the normal water spray system is used.

Samples were taken at the haulage level also. Samplers were located in the pony sets with one sampler running continuously during the shift and the other only during ore car loading. The results are shown in Table 17. Due to the curtailment in production, the mine was not able to install the dust seal at the pony set and additional testing maintaining an ore plug in the chute could not be accomplished. It is believed that these procedures would improve dust control measures, and that mines having this type of problem should institute such procedures and evaluate their effectiveness.

TABLE 16 - RESPIRABLE DUST CONCENTRATION CONSTANT, GRIZZLY LINE

Test No.	Respirable Dust Concentration (mg/m <sup>3</sup> )						
	Intake (A)	FOAM Return (B)	B-A (C)	Intake (D)	CONTROL* Return (E)	E-D (F)	C/F
1	1.00	1.35	0.35	1.22	1.39	0.17	2.1
2	2.63	1.45	--	0.63	0.84	0.27	--
3	1.51	2.92	0.41	--	1.20	--	--
4	1.27	2.46	1.19	0.63	1.02	0.39	3.1
5	0.66	1.74	1.08	0.83	0.93	0.10	10.8
6	1.20	1.90	0.70	0.77	1.06	0.29	2.4
7	1.16	2.45	1.29	1.27	1.89	0.62	2.1
8	0.16	1.25	1.09	0.11	0.70	0.59	1.8
9	0.31	0.90	0.59	0.40	0.59	0.19	3.1

\*Control data was taken with the normal water sprays in operation

TABLE 17 - RESPIRABLE DUST CONCENTRATIONS,  
 PONY SET (mg/m<sup>3</sup>)

Test No.	FOAM		CONTROL (4)	
	<u>Continuous</u> (2)	<u>Intermittant</u> (3)	<u>Continuous</u> (2)	<u>Intermittant</u> (3)
1	No ore was drawn			
2	2.44	1.67	2.87	3.93
3	5.17	3.13	6.34	5.79
4	2.13	3.25	3.99	3.45
5	4.03	5.87	2.46	5.38
6	3.20	5.17	2.77	2.86
7	5.46	4.71	5.11	31.97
8	2.96	2.99	4.64	4.26
9	5.32	9.50	4.44	2.86
7 day average (1)	3.61	4.51	3.93	4.10

(1) Excluding Run No. 7

(2) Gravimetric samplers operated for the full shift

(3) Gravimetric samplers operated only during ore car loading

(4) Normal water spray system operating

## RECOMMENDED DUST CONTROL PROCEDURES AT A TRONA OPERATION

The use of water may have to be limited in those operations where water soluble minerals are being recovered. Typical examples of this type of mineral are trona and potash. The use of excessive amounts of water can result in caking of the product on transfer belts, plugging of screens and so on. Dust surveys were conducted at a trona operation, and recommended dust procedures were developed.

### Preliminary Dust Survey

Sampling Procedure - Gravimetric samplers and a GCA Model RDM-101 Respirable Dust Monitor were used for the dust surveys. The gravimetric samplers were used as area samplers rather than personal samplers and thus provided dust concentration data that was directly related to the operation under study rather than to personnel working in the area.

The gravimetric samplers were also used to collect respirable dust on vinyl membrane filters for free silica analysis by the infrared technique. Results of these analyses are summarized below:

<u>Location</u>	<u>Free Silica Content (% SiO<sub>2</sub>)</u>
Main Transfer Point	0.6
Haulageway	2.8
Dump	2.2
Crusher	2.3

Using the highest free silica value (2.8%), the TLV for the operation would be:

$$TLV = \frac{10 \text{ mg/m}^3}{\% \text{ SiO}_2 + 2} = \frac{10}{2.8 + 2} = 2.1 \text{ mg/m}^3$$

Main Transfer Point - No dust controls were employed at the Main Transfer Point. Full shift gravimetric samples were taken at the main underground transfer point and at two locations along the beltway. The results were as shown in Table 18. The dust concentration on the west side was higher than that on the east side due to the prevailing ventilation pattern in the area. In nearly all cases, the dust concentration exceeded the TLV established for the operation.

TABLE 18 - DUST CONCENTRATION, MAIN TRANSFER POINT

Test No.	Location (mg/m <sup>3</sup> )			
	Main Transfer West Side	Main Transfer East Side	Belt, 150 ft from TP	Belt, 300 ft from TP
1	10.40	6.01	---	---
2	11.12	7.30	3.71	3.95
3	10.31	8.19	6.45	3.07
4	12.26	9.72	2.75	2.25
5	12.53	7.54	3.23	2.76
6	21.39	8.48	2.94	2.81
7	4.03	3.29	1.77	1.58

Ore Dump Area - The ore bin was located at the base of the ore product shaft at the termination of the main belt. The ore bin opening was approximately 12 ft x 12 ft and had a depth of approximately 40 ft. The bin was almost completely covered. A bin attendant, in charge of skip loading, was located in clean intake air.

Product was dropped from the main belt into the ore bin through an abandoned Pennsylvania roll crusher. The belt dump was partially enclosed; however, no dust collection system was employed. Ventilation in this area comes down the main shaft, through the ore bin and continues toward the mining sections.

Table 19 presents dust concentration data for the ore dump area using the gravimetric sampler located just downstream of the dump. Although the dust concentrations which were observed showed surprisingly low values, the area in general had several inches of dust accumulated on the floor and structures. Much of the accumulated dust is believed to be deposited by the head of the main belt. This condition would be remedied by a clean-up maintenance but the clean-up itself is a source of airborne dust.

TABLE 19 - ORE DUMP CONCENTRATION

Test No.	Concentration (mg/m <sup>3</sup> )
1	0.49
2	1.20
3	1.33
4	0.98
5	1.27
6	0.59
7	1.13

## Recommended Dust Control Procedures

Main Transfer Point - It was recommended that the main transfer point be enclosed, and that the enclosure be provided with exhaust ventilation. Because of the location of the transfer point, the dust laden exhaust ventilation could not be easily ducted to a return airway. Thus, it was recommended that the dust laden air be passed through a wet scrubber.

The following information was used to size the enclosure:

Belt width - 36 in.  
Belt speed - 600 fpm  
Ore bulk density - 90 lb/ft<sup>3</sup>  
Product flowrate - 840 tons/hr  
Height of product fall - 5 1/2 ft

The enclosure was to extend 25 ft from the transfer point along each belt. It was recommended that a 5000 cfm fan be used to exhaust the enclosure.

A wet collector rated at 5000 cfm was recommended for collection of the dust. The system was a passive device which did not require a continuous water supply and had no moving parts. The minimal water consumption of the scrubber was an attractive feature for applications in a trona mine. It was calculated that the sludge would have to be removed on a weekly basis. It was recommended that the sludge be packaged in 55 gallon drums and transported to the surface for disposal.

Ore Dump Area - It was recommended that a belt washing system be installed at the head pulley of the ore dump. The purpose of the belt washing system was not only to reduce dust in the dump area, but equally importantly to reduce dust levels along the entire length of the product beltway. In addition to improving dust control along the beltway, it was estimated that maintenance and clean up requirements along the beltway could be reduced by 90%.

The belt washing system recommended had a water consumption rate of approximately 15 gpm. It was suggested that the water effluent from the scrubber system be discharged directly into the dump. Since an operator was in the neighborhood of the dump, the total water consumption could be minimized by operating the belt washing system only when product was present on the belt.

Primary Crusher - A new dust collection system was being installed at the primary crusher but installation had not been completed during the studies at the trona operation.

Therefore no sampling program was conducted. However, a discussion of the system is warranted since it may provide guidelines for similar installations.

A dry cyclone collector had been used to collect dust from the exhaust ventilation enclosures at the primary crusher. The collection system had not been functioning at the efficiency for which it was designed. Rather than trying to upgrade the existing dry collector, management had decided to install a baghouse collector.

Some problems had been encountered with the baghouse collector including balancing of air flows and plugging of the filter bags. Flows were being balanced by adjusting the air flowrate dampers. It was determined that plugging of the filters was caused by deposition of wet product on the bag filter surfaces. To avoid this problem, heaters were being installed on the dusting system to dry the product and thus eliminate plugging of the filters.

## DISCUSSION

The objective of this program was to demonstrate the effectiveness of various dust control systems and techniques at crushers, chutes, dumps and transfer points. To attain this goal, preliminary dust surveys were conducted at a number of surface and underground operations to determine the specific location and magnitude of dust sources. Possible methods for controlling dust were then recommended, based on the type of dust source and available support facilities.

Because of curtailment in production at some of the mines, some of the recommended dust control procedures could not be instituted. However, the rationale for selecting specific dust control procedures and the design of the systems have been included in this report to provide guidelines to the mining industry.

### General Procedures for Selecting Dust Control Systems

The study indicated that many of the dust control systems which were in operation were not functioning at the optimum design level. The efficiency of some exhaust ventilation systems was found to be reduced due to worn or poorly fitted skirting and shrouding, improperly balanced air flows, open and nongasketed inspection ports and so on. Several water spray systems were found to be ineffective due to plugged spray nozzles. An initial approach to optimizing dust control should involve the upgrading of existing dust control procedures.

Dust sampling should be conducted to determine the magnitude of the dust problem, as well as providing a base for determining the effectiveness of the dust control procedures which will be used. Full shift, gravimetric dust sampling will provide information required on the effectiveness of a dust control system. A direct reading dust monitor such as the GCA Model RDM-101 can be used effectively to locate dust sources, to determine the magnitude of the problem and to evaluate the efficiency of a dust control system.

The silica content of the ore being processed, or of the respirable dust in the work area, must be measured to determine the Threshold Limit Value. Samples of fugitive dust deposited in the work area can be analyzed by wet chemical methods, and samples of respirable dust can be analyzed by infrared or x-ray diffraction techniques.

### Control of Dust at Crushers

Crushers present a complex dust control problem in that all of the operations associated with crushing (charging, crushing,

discharge) can dislodge dust adhering to the ore and/or create new dust. Water sprays at the mouth of the crusher offer some degree of dust control by promoting adherence of dust to the ore surface. However, water is relatively ineffective for capturing airborne dust which may be generated during crushing. In addition, the use of water may be negated by certain minerals which are water soluble such as trona and potash. Water may also adversely affect other processing operations by causing caking on belts, wet haulageways and subsequent crushing and grinding operations.

Exhaust ventilation at the crusher charging and discharging ports provides an effective method of preventing the dispersion of dust to working areas and a means of transporting dust to a collection device. The exhaust ventilation rate at the crusher charge port must be sufficiently high to overcome any air upsurge created by the charging operation. A tight fitting hood will contain the dust within a confined area and can minimize the exhaust air flowrate. Material discharged from the crusher generally falls to a pan belt or conveyor belt; maintaining the fall height to a minimum will reduce the dispersion of dust. The pan belt or conveyor should be hooded and maintained under exhaust ventilation. Tight fitting skirts between the hood and conveyor will reduce the required exhaust ventilation rate.

Although maintaining the crusher operator booth under positive pressure with filtered air is not an engineering solution to dust control, it does provide an effective method for maintaining the work area in compliance with the established Threshold Limit Value. One company maintained a safe work place at a dump/crusher operation by using a pressurized control booth along with sweeping air across the crusher mouth and ducting it to a collector.

#### Control of Dust at Chutes

Chute loading and discharging is generally an intermittent process. While water will enhance dust abatement, this procedure can result in the use of unrealistically large volumes of water, as well as wet work areas at the chute discharge port. Water sprays are recommended but provisions should be made to minimize water consumption.

During this study, chutes were filled with high expansion foam prior to charging ore to the chutes. Higher dust levels, when compared to water sprays, were encountered at the chute charge point, and no change was found at the ore discharge point. Water consumption was significantly lower with foam than with water sprays, resulting in less accumulation of water at the discharge level.

Open chutes may result in perturbation of the ventilation pattern in a mine by providing a bypass for the air.

Maintaining an ore plug at the bottom of the chute can rectify this problem thus eliminating reduced air flow at other work sites or contamination of the work sites with dust laden air.

### Control of Dust at Dumps

Control of dust at dumps poses an extremely challenging problem because of the inherent need to keep the charge port open. In addition, the inherent nature of the dumping process results in the instantaneous development of large volumes of dust laden air. Water sprays are of limited use due to the large area which must be covered.

Exhaust ventilation is the most promising candidate for dust control at dumps. The exhaust port or ports should be relocated beneath the top level of the dump so that dust laden air is drawn away from the open charge point. The exhaust system must be sized to overcome the anticipated air displacement surge created during dumping. The exhausted air can be directed to a return airway or if necessary processed through a dust collection system.

Exhaust ventilation has been used to sweep across the dump, also. However, it was necessary to house the dump operator within a positive pressure, clean air booth to assure that work area was below the Threshold Limit Value.

### Control of Dust at Transfer Points

Dust generated at transfer points is primarily the result of dislodging dust which is adhering to the falling ore. The adherent qualities of dust can be enhanced by the use of water sprays at transfer points. However, this does not completely eliminate dust and if the ore is dry or the use of water restricted, then an exhaust enclosure should be used at the transfer point.

Dust adhering to belts can also be dislodged at transfer points or at any other location along the beltway. Belt washing systems were shown to effectively remove dust from the load bearing surface of belts. Water sprays were directed onto the belt on the return beltway just beyond the head pulley. This procedure effectively reduced dust concentration below the TLV not only at the head pulley but also along the entire length of the beltway. An additional benefit of this system was a 90% reduction in maintenance costs along the entire beltway.

APPENDIX A

PRELIMINARY SURVEYS

## EXPERIMENTAL PROGRAM

The basic objectives of this program were to investigate the feasibility of various dust suppression methods or devices for crushers, chutes, dumps and transfer points (Phase I), to design and install dust suppression systems at selected dust generation sources (Phase II), and to demonstrate through field sampling programs the effectiveness of the selected dust control procedures. The primary goal of the program was to provide to the mining industry information on methods or devices readily adaptable to the control of dust at various dust generation sources.

A number of different mining operations including copper, limestone, trona, salt and iron were surveyed under Phase I. The results of these preliminary surveys resulted in the selection of a copper mine and a trona mine where dust problems existed, and where dust control systems could be installed.

### Phase I - Review of Existing Dust Control Methods and Systems

Sampling Procedures - Detailed sampling procedures were developed during the course of the program. The following samples were taken:

- A. GCA Model RDM-101 respirable dust samples
- B. Personal gravimetric samples
  - 1. Total
  - 2. Respirable
  - 3. Vinyl membrane
    - a. concentration
    - b. free silica-IR
  - 4. Silver membrane
    - a. concentration
    - b. free silica-x-ray diffraction

A preliminary GCA survey was made at each mine, and the information was used to develop a sampling program.

Personal gravimetric samplers were used to determine dust concentrations at the various locations of interest. Since the intent of the program was to determine existing dust concentration and to evaluate the reduction of dust concentrations after implementation of dust control systems, the gravimetric samplers were used as area rather than personal samplers. This approach provided direct information on dust concentrations at a given site, and eliminated the need for cataloging the activities and movements of workers and the problem of equating a worker's time-exposure profile with measured dust concentrations.

The gravimetric samplers were operated at 1.7 liters per minute and were calibrated at the mine site using a bubble meter. Calibration at the mine site eliminated the need for correction factors imposed by the differences in altitude or mine depth. Total and respirable dust samplers were taken by operating the samplers with and without the Dorr-Oliver cyclones. Total dust samples were of particular interest in those cases where the free silica content was low and the TLV was governed by the nuisance dust limits.

Both vinyl membrane and silver membrane filters were used with the gravimetric samplers. Infrared analyses\* for free silica were run on those samples collected on vinyl membrane filters, and x-ray diffraction analyses\*\* were run on those samples collected on silver membrane filters. Differences were observed in the collection efficiency of the two types of filters, and in the free silica content as measured by the two analytical methods.

Particle size analyses\*\*\* were conducted on some of the samples which were collected on the vinyl membrane filters. Optical microscopy with phase contrast illumination was used at a magnification of 1000X. Of ten samples taken at various operations in a copper mine, only one showed particles larger than 5 micrometers (99.59% by number 5 micrometers). The average geometric mean particle size of all samples was 0.90 micrometers with a range of 0.80 to 1.12 micrometers.

Preliminary Surveys - Preliminary surveys were conducted at 5 limestone, 2 copper, 2 iron, 1 trona and 1 salt mine. The purpose of these surveys was to evaluate the effectiveness of dust control procedures currently in use and to select specific sites where improved dust control procedures could be instituted and evaluated.

A preliminary survey was made at a secondary crusher at a limestone plant. Stone was fed to the crusher by belt and samples were taken at:

1. Discharge from the belt feed
2. Crusher mouth
3. Crusher discharge

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\*Conducted by Mine Safety Appliances Co., Pittsburgh, Pa.

\*\*Conducted by U.S. Bureau of Mines, Denver, Colorado

\*\*\*Conducted by University of Pittsburgh, School of Public Health

The free silica content of the stone was less than 1% so the TLV for respirable dust was 5 mg/m<sup>3</sup>. The results were as follows based on the average of full shift respirable samples taken on three consecutive days:

1. Belt discharge - 4.7 mg/m<sup>3</sup>
2. Crusher mouth - 6.8 mg/m<sup>3</sup>
3. Crusher discharge - 33.0 mg/m<sup>3</sup>

The only dust control measures which were used were two small water jets at the belt discharge. Total water flow was less than one gpm.

It was obvious that dust problems existed at the crusher and that dust control procedures were needed. However, a number of other dust sources existed within the plant. These sources would have interfered with interpretation of the effectiveness of any dust control procedures, hence this site was considered unacceptable as a test site.

A limestone mine processing 1000 TPH was surveyed. Free silica content of the rock was 3.8% giving a TLV of 1.7 mg/m<sup>3</sup>. A recent survey by a consulting firm indicated the following dust exposures:

- |                      |                          |
|----------------------|--------------------------|
| Driller operator     | - 6.50 mg/m <sup>3</sup> |
| Crusher operator     | - 0.54 mg/m <sup>3</sup> |
| Shaker room operator | - 8.10 mg/m <sup>3</sup> |
| Shaker room operator | - 7.50 mg/m <sup>3</sup> |
| Millman              | - 0.74 mg/m <sup>3</sup> |

The driller operator and shaker room operators were obviously exposed to dust levels exceeding the TLV.

Multiple crushing, milling and screening operations existed within the plant. A survey was conducted with the GCA to aid in selection of sampling sites.

Specific locations were selected in the general area of the crushers, hammermills, shaker screens and belts and full shift samples were taken at the following locations:

Location  
No.

1. Primary Crusher (CR-1) - at the base, 6 ft above ground as C-1 feed belt exits crusher foundation area

- 2        Primary Crusher - at 2nd level opposite rotary drive units, and about 10 ft above C-1 feed belt.
- 3        Primary Crusher - directly outside operator booth.
- 4        Primary Crusher - 5 ft off of floor underneath crusher, above C-1 tailstock.
- 5        Cone Crusher - base of CR-2, located about 12 ft out from crusher on belt C-7 (about 12 in. above belt).
- 6        Below Hammermills (CRs 3,4 & 5) - 6 ft off of floor between CRs 4 and 5.
- 7        Below Hammermill - 5 ft off of floor underneath crusher, above C-1 tailstock.
- 8        At S-7 Shaker Screens - midway on S-7 about 5 ft off of floor, on hammermill side.
- 9        Transfer Point - underneath split transfer of C-34 to C-31 and 32 (from hammermills back to screens).
- 10       Feed Belt Dump - between dump points off of belts C-31 and 32 to screens S-6 and S-7.

Results of samples taken on two consecutive days were as follows:

<u>Sample Location</u>	<u>1st Day</u>	<u>2nd Day</u>
1	32.2	19.4
2	20.5	20.3
3	4.8	3.6
4	36.6	31.3
5	--	14.9
6	--	136.6
7	92.7	113.5
8	57.0	52.0
9	4.8	--
10	22.6	14.0

All of the areas which were surveyed had dust levels exceeding the TLV.

At one time a baghouse collector was used in the shaker building. This system is no longer used since it "plugged so often." The plant was fitted with a centrally controlled Chem-jet spray system. A cursory survey of the spray points showed that most of the spray nozzles were plugged. A request was made

to replace the plugged nozzles at the secondary crusher; this site was chosen since it was removed from other processes and thus less susceptible to background dust from other sources. GCA samples were taken with the spray both on and off. No difference in dust levels was observed indicating that the spray unit was ineffective.

Severe dust problems existed at all locations in this limestone plant. It would have been impossible to isolate on one dust source, since fugitive dust from other sources nearly would have prevented a realistic evaluation of the effectiveness of the chosen dust control procedure. Therefore, it was decided that it would be impractical to conduct studies at this site.

Three underground limestone mines and associated processing plants were visited and surveyed. Each of these mines was inherently wet, and due to the natural moisture content of the rock no significant dust problems existed at these mines. They were therefore deemed unacceptable as test sites.

A copper operation where 90% of the ore processed was from an open pit mine and the remaining 10% was from an underground mine was visited and surveyed. The underground mine was inherently wet while the surface mine exhibited varying degrees of wetness depending upon climatic conditions. Free silica content of the ore is 15% giving a TLV of  $0.6 \text{ mg/m}^3$ .

An underground dump was surveyed with the GCA monitor. Since the mine was wet, the underground environment was relatively dust free (background =  $<0.2 \text{ mg/m}^3$ ). Surveys using the GCA monitor were made during two separate car dumpings. The first dump of five cars over a 15 second period showed a maximum level of  $3.2 \text{ mg/m}^3$ . The second dump of three cars over a 13 second period showed a maximum level of  $3.0 \text{ mg/m}^3$ . It should be noted that these are transient peak readings and that a time weighted, full shift sample would be much lower. Because this mine is so wet, it did not seem to be a suitable location to conduct this study.

The surface facilities at this mine were surveyed. Approximately 90% of the ore being processed was from an open pit which was dry and the remaining 10% was from the wet underground mine. The primary crusher processes 600 TPH of ore. Five Chem-jet sprays are used at the ore chute discharge to the shaker screens above the primary crusher. Undersize material falls into the fine ore storage bin and oversize material is transferred by belt to the primary crusher. The entry to the crusher is partially enclosed and maintained under negative pressure. The discharge from the primary crusher to the coarse ore bin and the discharge from the bin to the transfer belt is fitted with sprays. The transfer belt is also enclosed and maintained under negative pressure feeding to a baghouse. Fines

from the baghouse are returned to the belt by a screw conveyor; this is a practice which should be avoided since respirable dust can become airborne again. The company is considering slurring the baghouse material and pumping it directly to the rod mills.

Respirable dust samples were taken at:

	Full Shift <u>(mg/m<sup>3</sup>)</u>	GCA
1. Belt feed to primary crusher	<0.1	0.3, 0.8
2. Belt feed from crusher	1.3	10.5, 10.0
3. 25 ft from crusher hopper	10.0	11.1, 11.8
4. Crusher building floor space	<0.1	1.6, 0.5

Based on the full shift samples, the belt feed from the crusher and the crusher hopper area exceed the TLV of 0.6 mg/m<sup>3</sup>.

Other spot checks were made with the GCA monitor:

1. Belt transfer point from storage to secondary crusher feed belt.
  - a. Vibrator level - 6.2 mg/m<sup>3</sup>
  - b. Belt level - 3.0 mg/m<sup>3</sup>
2. Feeder to secondary crusher - 2.3, 1.8 mg/m<sup>3</sup>
3. Secondary crusher - 4.3 mg/m<sup>3</sup>
4. Storage bin - 2.1 mg/m<sup>3</sup>
5. Belt from storage bin - 2.3 mg/m<sup>3</sup>

Sly collectors are being used at the belt transfer points and other belt enclosures. Ducon collectors along with Chem-jet sprays are being used in the secondary crusher feed system. In spite of these dust control devices, dust is not being effectively controlled.

The surface facilities at this mine exhibited obvious areas where dust control procedures could be instituted. However, it was felt that it would be more expedient to conduct the studies at a mine/processing plant site where dust problems existed both in underground and surface activities.