SAFETY IN MINES RESEARCH ADVISORY COMMITTEE

SIMRAC

Draft Final Project Report

Title: **GRAVIMETRIC DUST SAMPLING FOR CONTROL PURPOSES AND OCCUPATIONAL DUST SAMPLING**

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Research Agency: **CSIR : Division of Mining Technology**

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EXECUTIVE SUMMARY

Prior to the introduction of gravimetric dust sampling, konimeters had been used for dust sampling, which was largely for control purposes. Whether or not absolute results were achievable was not an issue since relative results were used to evaluate workplace conditions and the effectiveness of dust control measures, establish trends in workplace dust levels and to assist with the design of ventilation systems. Some attempts were made to establish occupational dust exposures levels but the instruments used and the units of measurement (i.e. particles per mℓ) were not deemed to be suitable.

The availability of gravimetric dust sampling pumps that could operate at a constant flow rate for the duration of a working shift offered a means of conducting full shift samples. With the introduction of gravimetric sampling all *official* dust sampling with konimeters for control purposes ceased.

Although individual employees were sampled for a full shift, the sampling strategy required by law[3] was such that results were compiled in terms of "activities" and not in terms of occupations. As indicated in a previous research project [1] there is a very substantial amount of data which has only been used to determine a mine risk on which a compensation levy is based. This mine risk is based on these individual samples which go through an extensive averaging process. The full shift samples have been shown to be ineffective in establishing workplace risk, workplaces or processes where unsatisfactory dust levels exist and, once the dust report for a sampling cycle has been compiled, it is all but impossible to trace a person with an unsatisfactory exposure level or his movements during the day of sampling. In effect, dust sampling for control purposes disappeared and sampling was conducted for the sole purpose of establishing a "risk".

Conclusive proof that this risk was being based on highly variable dust concentrations and highly variable and uncontrollable quartz concentrations was outlined in a previous research report [1]. Risks based on such variables were shown to be largely meaningless, not equitable and not reflective of measures implemented to control dust emissions. The 1959 Johannesburg Conference on Pneumoconiosis[3] drew attention to the necessity for different sampling strategies for dust control purposes and for occupational dust surveys, which could be used for epidemiological studies.

Since mines are equipped with instrumentation that could provide invaluable data for epidemiological studies on a very large scale, a clear cut sampling strategy was seen to be needed as well as a recommendation on how best to conduct dust sampling for control purposes.

Before any experimental work was conducted in occupational dust sampling or control dust sampling, certain technical issues regarding dust sampling with gravimetric samplers were investigated. These are highlighted below, namely

- pump orientation has no significant or practical bearing in sampling for dust,
- optimum results are obtained using a 25 mm diameter filter of 0,8 μm porosity at a standard flow rate of 1,9 ℓpm,
- shielding of pumps appears to enhance sensitivity,
- location of sampling, with respect to dust source, has a bearing on total to respirable dust ratio, and
- shorter sampling times (15 minutes) provide equally representative results in comparison with longer sampling times (eg 120 minutes) and also provide more detail.

In a previous research project[(1)] it was proposed that standard gravimetric samplers used over a very short period, ie 12 - 15 minutes, could be used to collect dust samples at different places within the workplace to give indications of dust levels at these localities. Initial trials [(1)] indicated good potential with the proposed technique and the present project explored the use of the technique to determine dust levels in workplaces.

The results presented in this report show that:

- workplace risk could be calculated from average working face dust levels on the basis of either a measured average quartz concentration or on a standard quartz concentration[(1)],
- by sampling all the workplaces on a regular basis a "mine risk" can be determined which, as a matter of course, permits inter-mine comparisons,
- the technique allows results to be recorded on environmental engineering survey reports,
- the technique also provides inspectors with a reliable and practical methodology to conduct checks, and that
- independent surveys can be carried out in a meaningful way.

The short duration sampling technique has been shown to be viable and its implementation is strongly recommended.

Simultaneously with the short duration sampling experiments occupational dust surveys were also conducted. Originally, only two occupations were chosen, viz. support (timbering) and stope supervisors. However, the introduction of multiskilling ensured that more occupation categories were sampled than was actually required.

Although relatively small numbers of samples were collected for the various occupations, clearly discernible differences in Time Weighted Average (TWA) dust concentrations can be seen and the occupations can be ranked in terms of dust concentrations or risk, based either on average quartz concentrations or a standard quartz concentration. The ranking was found to be mine specific but, when all the data were pooled for the mines monitored, machine drill operators emerged with the highest levels.

A comparison of mine records for the previous two gravimetric dust sampling cycles was made with CSIR: Mining Technology's results at the request of a special interest group.

The software packages used by some mines made comparison with CSIR: Mining Technology's results impossible. The frequency distribution of the results indicates that the mines show more exposure in the lower exposure ranges than does CSIR: Mining Technology.

Risk could be expressed in terms of average dust exposures for a group or based on actual or a standard quartz concentration of 20 percent. Whichever system is selected, differences in exposures or risk for different groups are discernible. These differences, even though apparently small, can be significant when examined in terms of dose/response where a small increase in dose can result in a very substantial increase in response or effect.

Occupational dust exposures should be used for epidemiological studies and not to establish a mine risk.

Industry now has the instrumentation and the infrastructure in place to be able to participate in meaningful epidemiological studies. At present, estimations of exposures are still based on a study conducted nearly 40 years ago with inappropriate instrumentation and, unless a start is made very shortly with occupational dust surveys, this situation will not change. With arguably the largest mining industry in the world, South Africa is at the brink of being able to establish the largest and best occupational dust exposure data base ever. The sheer weight of evidence will assist occupational medicine practitioners to better estimate working life exposures for matching with physiological responses and which could assist with the initiation of a timeous intervention policy to protect workers' health.

The establishment of an industry data base of occupational exposure levels for dust, based on specific occupational dust sampling, which should be an ongoing process, will take years to establish. In the meantime, a very substantial amount of dust sampling data already exists. These are the results submitted by mines to the Government Mining Engineer (GME) (now the Chief Inspector of Mines) since 1992. Unfortunately, results were requested in terms of "activities" and not "occupations". Mine records could be examined and classified in terms of occupations and in this way a picture of the different exposure levels could be built up more rapidly than by waiting several years for results from the occupational dust sampling proposed above, which could, however, be used to update such a data base. To establish mine health and safety risks it will be necessary to link exposure to medical surveillance and records. Since it is highly unlikely that an adequate number of dust samples could be collected for any given individual on a mine to be of use with medical surveillance it would be advantageous to be able to make use of typical exposure results from a national or industry data base. The establishment of the data base proposed here is strongly recommended, thereby putting to meaningful use results which heretofore have only been used for the determination of compensation levies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES Cont .....

LIST OF FIGURES

LIST OF FIGURES cont ....

LIST OF FIGURES cont ....

LIST OF FIGURES cont ....

LIST OF FIGURES cont ....

LIST OF FIGURES cont ....

1. INTRODUCTION

A previous SIMGAP project, GAP046[1], showed that large variations exist in dust levels and quartz concentrations for a given person on a shift to shift basis. These large variations were also identified at fixed position samplers in working areas at representative places, and poor correlation was found between results obtained at representative places and between those for personal monitors in the same working place during the same shift. In addition, correlation between personal samplers, ie. for dust exposures of different persons during the same shift in the same working places, was also poor. These findings were applicable to both underground and surface workings.

In the Government Mining Engineer's (GME) (now known as the Chief Inspector of Mines) personal gravimetric dust sampling programme [2] full shift samples are collected on selected personnel from which 8 hour Time Weighted Average (TWA) dust concentrations are determined. This is essentially an averaging process and any very high or peak dust concentrations thus go undetected and unreported. This present sampling technique and strategy has thus not been effective in identifying high personal or high workplace dust levels.

When dust sampling with konimeters was abolished, all official monitoring of workplace dust levels ceased. Since dust sampling (personal) is implemented mainly to calculate a "risk" on which a levy is based, *official* reporting on workplace dust levels also ceased. While it is true that some mines unofficially re-instated konimeter sampling as an aid to determining and controlling dust emission, most mines only do what is required by law. No dust levels are being entered on environmental engineering reports, nor are they required.

The results of limited short duration dust sampling tests were reported in SIMGAP Project GAP046 and it was proposed that a short duration gravimetric dust sampling technique be developed that can address shortcomings in the present dust sampling strategy and still make use of dust sampling equipment already acquired by mines.

The present gravimetric dust sampling programme has not yielded results that are meaningful for risk calculations nor for equitable risks. Furthermore, the results are not meaningful for dust control in the workplace, for evaluating control measures, nor for identifying individuals, workplace or operations with unsatisfactory exposure or dust levels. The reports submitted to the GME are also unsatisfactory for epidemiological research or studies, mainly due to the fact that data are generated with respect to various mining *activities* and not for specific *occupations*.

Previous occupational dust surveys, although thorough, were carried out on an industry basis by a very small team, the Pneumoconiosis Research Unit (PRU). Monitoring equipment included konimeters and thermal precipitators, which gave dust concentrations in terms of a particle count (ppmℓ) and modified thermal precipitators (MTP) which gave results in terms of respirable surface area (RSA). For epidemiological studies, internationally, these measuring units are no longer accepted and the konimeter and the MTP cannot monitor continuously. Continuous monitoring is considered to be fundamental to personal exposure determination as are exposures and doses in terms of mass concentrations.

At present, estimation of exposure still relies heavily on the results of the previous occupational dust surveys conducted almost 40 years ago and which were not truly eight- hour personal exposures nor were all working groups represented. In addition, no reliable conversion exists for changing from one set of measuring units to another.

Whereas previous surveys were conducted with, what is now apparent, inappropriate instrumentation, industry is now fully equipped with gravimetric dust samplers, developed to operate at a constant flow rate and measure shift long exposures. The infrastructure is also already in place to routinely conduct occupational dust surveys for all occupations and all population groups.

The project reported on here was thus carried out to develop a method of short term dust sampling to assist with the identification of unsatisfactory dust levels in workplaces, to test the effectiveness of remedial actions and to investigate occupational dust sampling for a limited number of occupations using personal samplers and the infrastructure already in place.

No definitive work has been carried out on the effect of pump orientation on sampling results. A limited study on this aspect was therefore included in this investigation.

It was visualized that dust masses collected over a 12 - 15 minute sampling period could be very low. To improve the dust mass to filter mass ratio, 13 mm diameter filters were used on the preliminary trials which were conducted under the auspices of SIMGAP Project GAP046. However, it was considered necessary to experiment with different filter diameters and porosity and different pump flow rates to determine the best combination for short duration dust sampling.

During the present investigation, a special interest group met with CSIR: Mining Technology on several occasions to discuss results and the objectives and direction of the project. The group comprised members from the Department of Minerals and Energy, the Sub-committee of Group Environmental Engineers, and unions. At one stage the project suffered a two month delay while a separate study was made of possible dust monitors and sampling methods, and comparisons were made with other reported results. The impact of this delay was that the number of surveys had to be reduced. The interest group requested that copies of mine personal gravimetric dust sampling reports be obtained and the results of occupational dust exposures reported by mines be compared with results produced during this investigation.

A. TECHNICAL CONSIDERATIONS

2. ORIENTATION TESTS

During previous investigations (SIMGAP GAP046) it was noted that sampling pumps were not always worn in the upright orientation. The pumps are often at an incline, sometimes horizontal and even completely inverted. The effects on sampling results of various pump orientations were not known and, since the occurrence of non standard orientation is widespread and common throughout the industry, a few orientation tests were included in this investigation. In addition to pump orientation, there are circumstances, also very common in the industry, when the wearer of the pump has his back to the airstream or in some other manner shields the pump. During the second set of tests the effects of shielding as well as orientation were checked.

2.1. Test sites

The first set of tests was conducted downstream of an underground tip and the second set of tests, with shielding, took place in a main underground return airway at a different mine.

2.2 Methodology

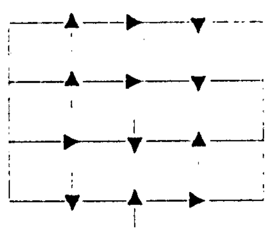
A portable sampling grid made from flat bars was made up from a "meccano set" type of structure. The grid had 300 mm centres. The structure was rigid enough to support the sampling pumps but offered little resistance to air flow. Once the grid had been erected at the sampling site , conventional sampling pumps with standard 10 mm cyclones were suspended at specific points in the grid and in different orientations ie facing upwards (normal), sideways or completely inverted. Two tests were conducted at each test site. At the second test site pumps were tested under normal conditions (not shielded) and also when shielded. The shielding was introduced to reduce the air flow over the pumps and thereby simulate conditions when the wearer has his back to the airflow or in some other way obstructs the flow of air over the pump. The tests allowed comparisons to be made not only on the basis of different orientations but also between shielded and unshielded sampling results. The layout of the sampling grid and pump orientation pattern are shown in Figure 1 where the arrow heads indicate pump orientation direction.

Airflow velocities at the test sites were measured using anemometers.

ENVIRONMETAL CONDITIONS

ORIENTATION - TEST 1 (Day 1)

TIME	VELOCITY m/s	WB/DB deg C
09h35	1.2	30.5/31.5
09h55	1.1	31.0/32.0
10h15	1.4	30.7/32.0
10h35	1.1	31.0/32.7
10h55	1.2	31.0/32.5
11h10	1.4	30.7/32.0
11h25	1.3	30.8/31.8
11h35	1.3	30.7/31.7



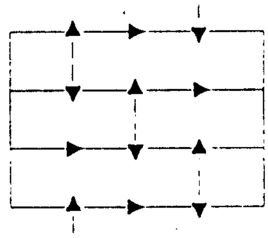
REMARKS :

Loco at tip @ 09h20 to 09h35
Loco at tip @ 09h40 to 09h55
Loco at tip @ 10h35 to 10h45

Frame dimensions
1700 x 1700 mm

ORIENTATION - TEST 2 (Day 1)

TIME	VELOCITY m/s	WB/DB deg C
09h00	1.5	30.0/31.0
09h20	1.8	30.5/31.5
09h40	1.6	30.5/31.5
10h00	1.7	30.7/32.0
10h20	1.7	30.5/31.7
10h40	1.7	30.4/32.0
11h00	1.8	30.5/31.7
11h15	1.6	30.5/31.7



REMARKS :

Loco at tip @ 09h55 to 10h00
Loco at tip @ 10h30 to 10h45
Loco at tip @ 11h00 to 11h25

▲ Up position
► Side position
▼ Down position

Figure 1 SAMPLING GRID AND PUMP ORIENTATION

2.3 Results

Results of the monitoring exercises are set out in Table 1 and Figures 2 to 5 for the first orientation test and in Table 2 and Figures 6 to 9, for the second test.

Table 1 RESULTS OF FIRST ORIENTATION TESTS DOWNSTREAM OF A TIP.

ORIENTATION	TEST 1 mg/m³	TEST 2 mg/m³
UPWARDS	1.517	0.984
	1.402	0.758
	1.525	0.981
	1.741	0.940
AVERAGE	1.546	0.916
SIDEWAYS	1.494	0.817
	1.727	0.932
	1.543	0.966
	1.655	1.140
AVERAGE	1.605	0.964
DOWNWARDS	1.589	0.862
	1.626	0.869
	1.735	1.024
	1.853	1.061
AVERAGE	1.701	0.954

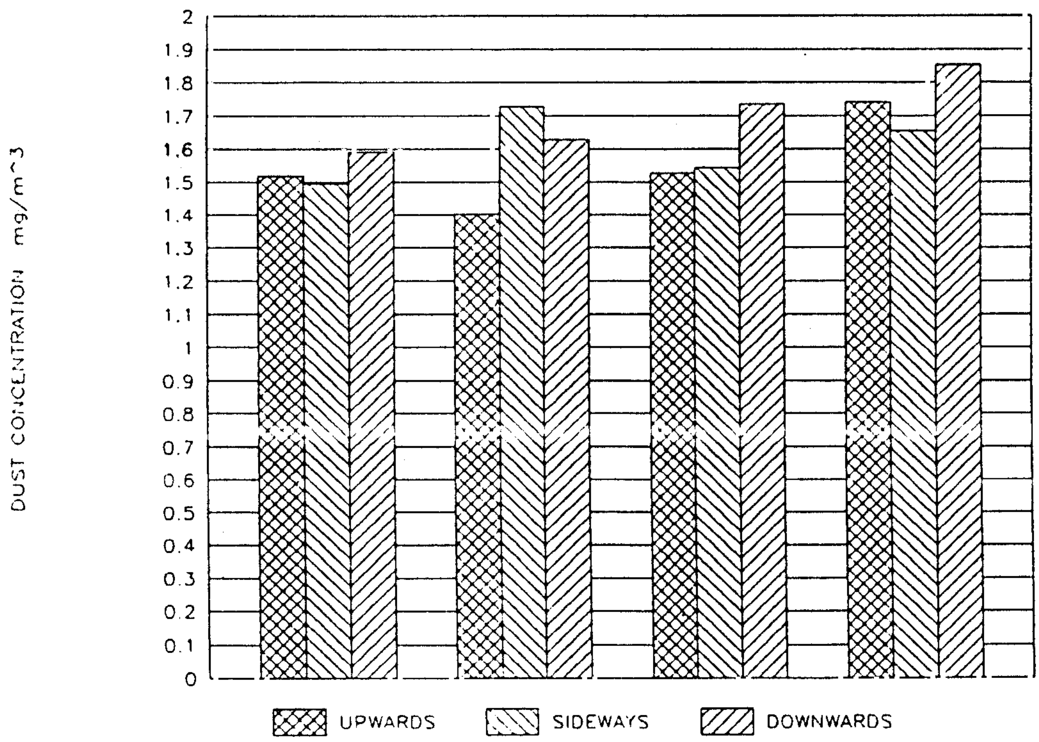


Figure 2 TEST 1 - FIRST SET OF ORIENTATION TESTS

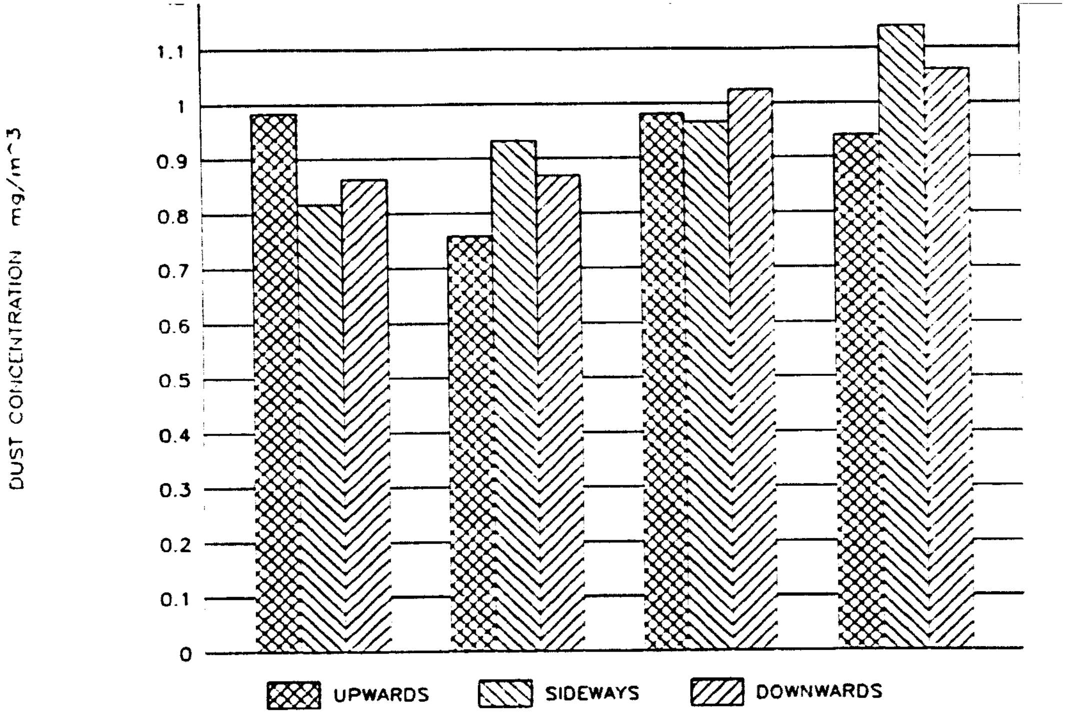


Figure 3 <u>TEST 2 - FIRST SET OF ORIENTATION TESTS</u>

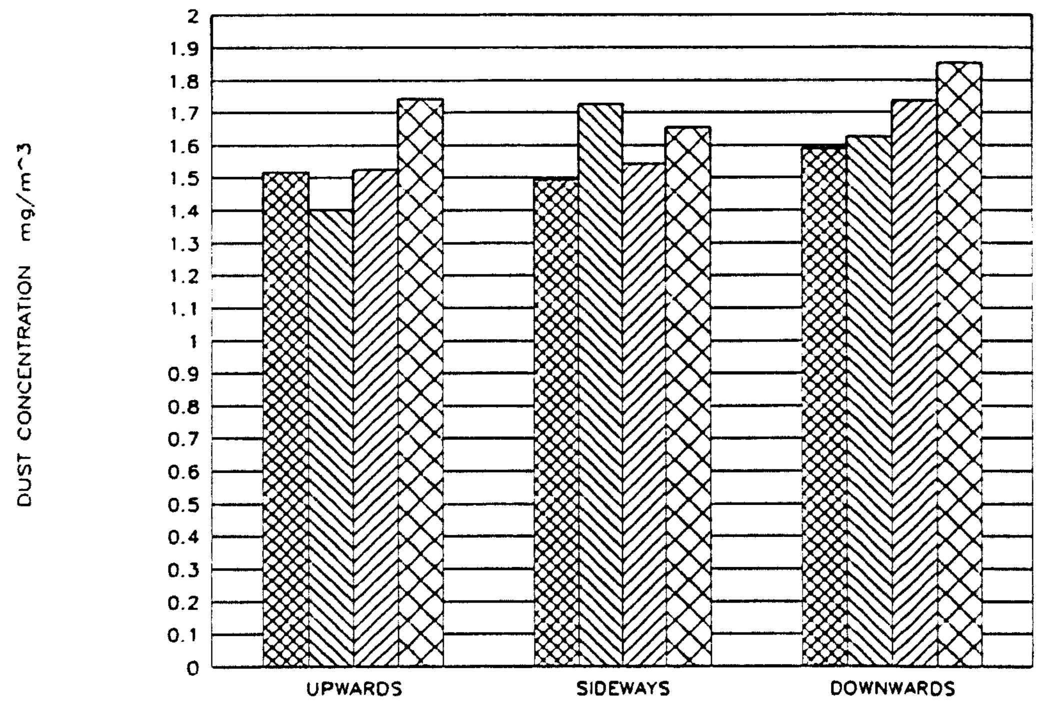


Figure 4 <u>FIRST ORIENTATION SET - FIRST TEST WITH ORIENTATIONS GROUPED</u>

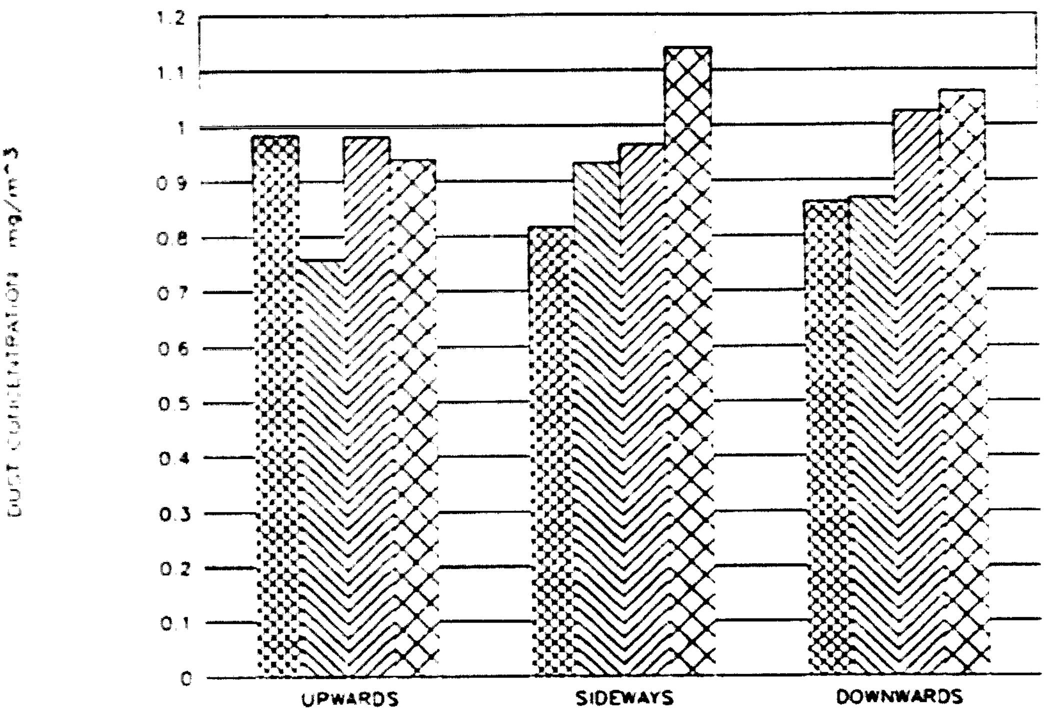


Figure 5 **FIRST ORIENTATION SET - SECOND TEST WITH ORIENTATIONS GROUPED**

Table 2 **RESULTS OF SECOND SET OF ORIENTATION TESTS**

ORIENTATION TESTS - NORMAL AND SHIELDED						
	UNSHIELDED mg/m³			SHIELDED mg/m³		
POSITION	UPWARDS	SIDEWAYS	DOWNWARDS	UPWARDS	SIDEWAYS	DOWNWARDS
FIRST TESTS						
1	4.67	2.07	2.56		1.54	2.16
2	1.77	2.27	1.92	1.53	1.52	1.49
3	2.21	2.03	1.82	1.44	1.42	1.29
4	2.34	2.77	0.56	1.28	2.96	
5	2.65	2.59	2.43	2.16	1.35	
6					1.58	1.48
Average	2.73	2.35	1.86	1.60	1.73	1.61
Std Dev	1.01	0.29	0.71	0.33	0.56	0.33
Minimum	1.77	2.03	0.56	1.28	1.35	1.29
Maximum	4.67	2.77	2.56	2.16	2.96	2.16
SECOND TESTS						
1	4.21	1.70	1.51	1.74	1.59	1.99
2	1.54	1.68	1.62	1.70	1.62	1.72
3	1.61	1.65	1.57	1.86	1.39	2.63
4	1.65	1.96		1.74	1.67	4.93
5		1.73	1.73	1.72	1.78	
6		0.66	1.77	1.46	1.63	1.72
Average	2.25	1.56	1.64	1.70	1.61	2.60
Std Dev	1.13	0.42	0.10	0.12	0.12	1.21
Minimum	1.54	0.66	1.51	1.46	1.39	1.72
Maximum	4.21	1.96	1.77	1.86	1.78	4.93

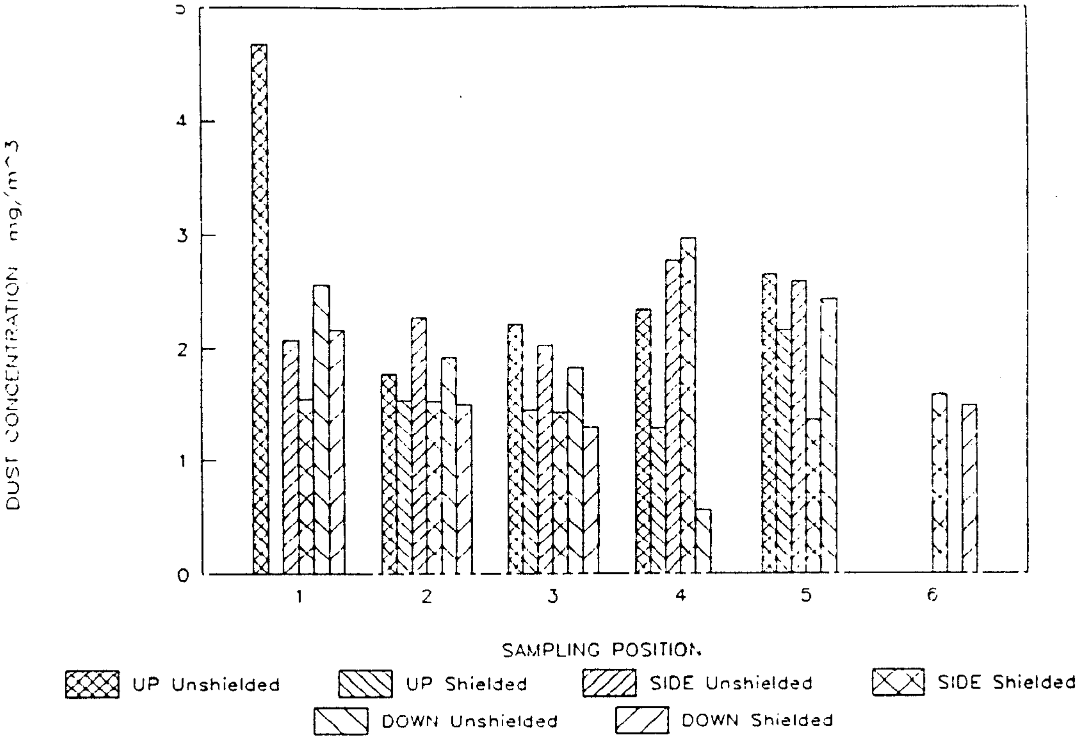


Figure 6 TEST 1 - SECOND SET OF ORIENTATION TESTS

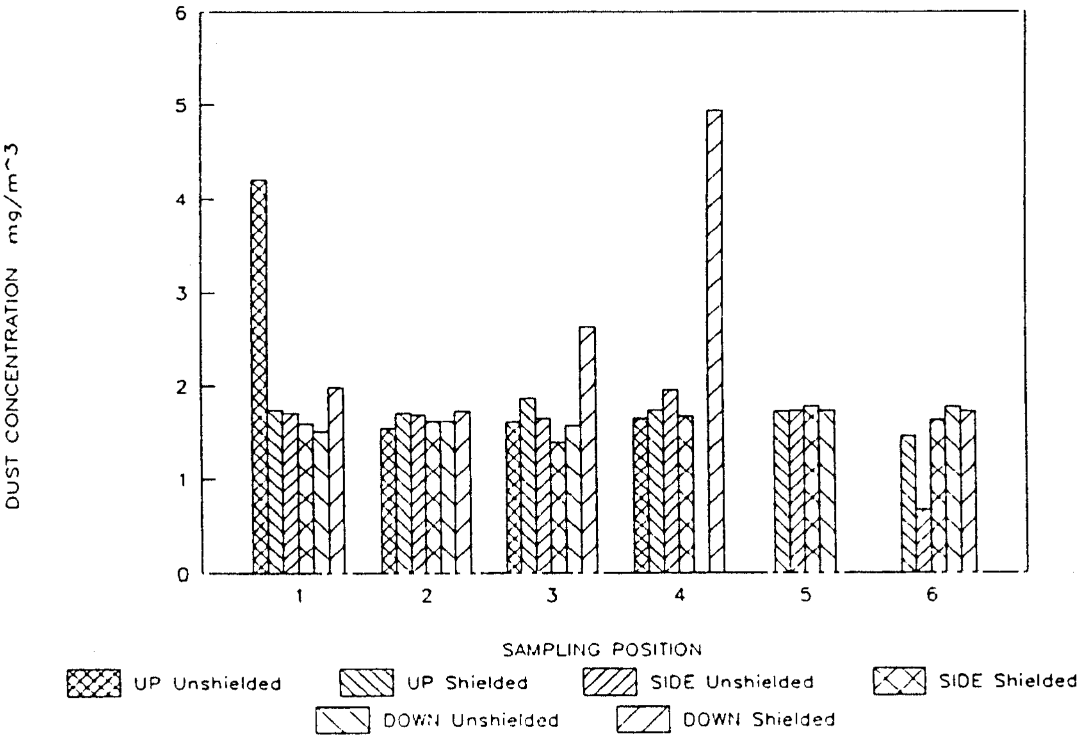


Figure 7 TEST 2 - SECOND SET OF ORIENTATION TESTS

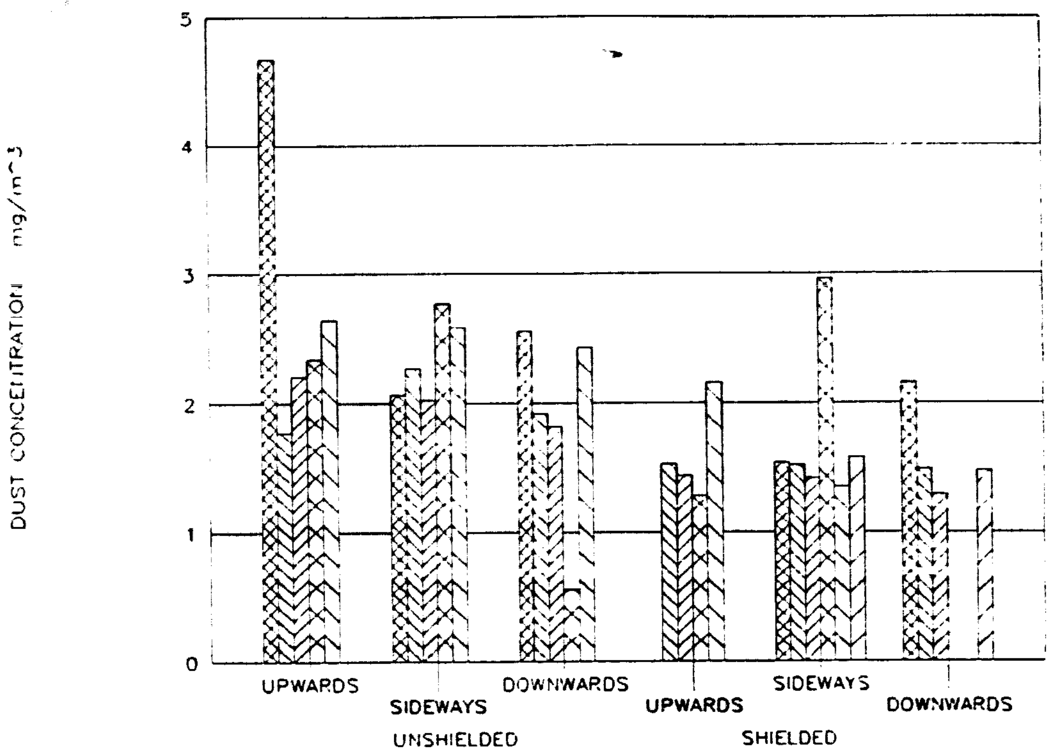


Figure 8 <u>SECOND ORIENTATION SET - FIRST TEST WITH ORIENTATIONS GROUPED</u>

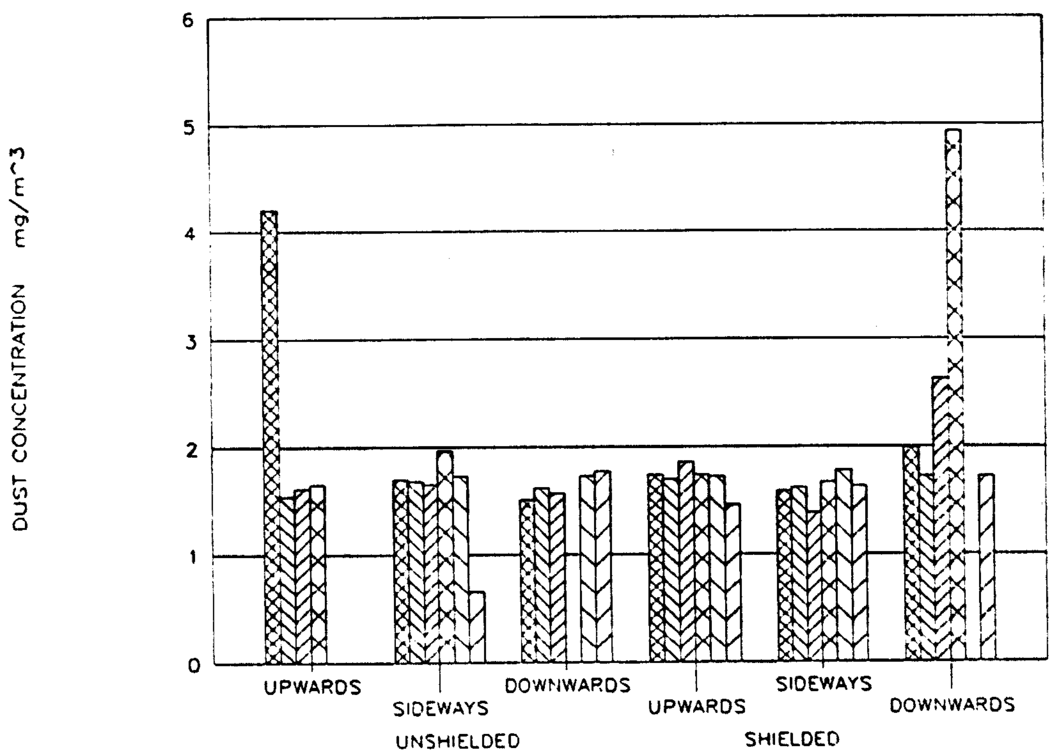


Figure 9 <u>SECOND ORIENTATION SET - SECOND TEST WITH ORIENTATIONS GROUPED</u>

2.4 Discussion

2.4.1 First set of orientation tests

Figures 2 and 3 indicate that there does not appear to be any bias towards a particular orientation.

In Figures 4 and 5 the results of particular orientations were grouped for assistance in visual evaluation. Once again no particular bias is evident.

Under practical, operating conditions dust concentrations at the measuring site would not be expected to be uniform or homogeneous. It was considered that results from an actual site would hold more relevance than those that may be obtained under artificial conditions in a dust duct.

2.4.2 Second set of orientation tests

Unshielded and shielded results for the different orientations are shown side by side for the two tests in this set of observations - Figure 6 & 7. Once again no particular bias towards a particular orientation can be defined. This becomes much clearer when the different orientations are grouped and shielded and unshielded results are separated. This is shown graphically in Figures 8 and 9. Although some individual results were found to be higher than the majority of all the others, and some were found to be lower, (Figures 6 - 9), it was not always the same sampler that gave a high or a low result. The aberations are more likely to be due to the non-homogeneous nature of the dust "cloud" being sampled and the sampling position on the grid than to differences due to eother to pump orientation or shielding.

The unshielded results, for particular orientations, appear to be higher than the shielded results for Test 1, which is what would be expected. This is shown in Figure 8. However, this distinction cannot be seen for the second test's results (Figure 9) where differences are not clearly discernible.

2.5 Conclusions

Although individual dust concentrations for a particular orientation may be noticeably higher than other dust concentrations, there does not appear to be any recognisable differences in results between any of the orientations. No particular bias can be found in results of shielded and unshielded samples. The randomness of the results, in collaboration with non-uniform or non- homogeneous dust concentrations at the test site, and different sampling positions on the grid suggest strongly that orientation of sampling pumps has little or no influence on results. Similarly, from the results of the limited tests conducted, measured concentrations do not appear to be affected one way or the other by shielding.

3. SAMPLING RATES, FILTER SIZES AND POROSITY

This part of the investigation was aimed at assessing/evaluating various sampling rates, filter sizes and porosity to support recommendations on the most acceptable and viable sampling strategy.

On anticipation of a possible sampling period of between 12 - 15 minutes it followed that only small amounts of dust would be collected on the filter. For this reason smaller diameter filters than those usually used, ie 13 mm diameter, were experimented with. These filters were only available with a porosity of 1,2 μm but this was considered to be acceptable as it would prevent premature choking of the filters in very dusty conditions. The maximum practical sampling rate that can be handled through such a filter was found in laboratory tests to be 1,5 ℓpm[1*]. However, a change to this size filter, even if only for short duration samples to determine workplace dust levels, would represent a considerable change to current sampling equipment and, furthermore, the purchase of a balance capable of measuring one μg (ie. 10^{-6}g) would also become necessary to improve accuracy. It was therefore deemed necessary to investigate other sampling rates and filter sizes.

Filter porosity tests were conducted in order to determine whether or not the porosity of the filters would influence dust concentrations, particularly for the short duration samples. A mix of respirable and total dust samples did not give clear indications of porosity suitability, particularly because the cyclones used on the smaller cassettes appeared to be a mismatch. It was therefore decided to conduct porosity tests on total dust samples only.

It became clear that the removal of the stopper from the cassette to give total dust did not yield reliable results and consequently tests were repeated with open face cassettes.

1* Throughout this report the notation of ℓpm is meant to indicate a flow rate of litres per minute. The notation is commonly used in Industry, trade literature and in some overseas literature.

3.1 Test site

Two sets of monitoring exercises were conducted at each of two different sites, both in major returns from sections but not in Return Airways. Each exercise was carried out on a different day. Porosity tests were conducted at a third site, which was at a specific process at a surface location.

3.2 Methodology

Sampling pumps were fitted with:

a) 13 mm diameter filters, 1,2 μm porosity and adjusted for a flow rate of 1,5 ℓpm. It was not feasible to sample at a higher flow rate for this particular filter. Respirable and total dust samples were collected.

b) 25 mm diameter filters, 1,2 μm porosity and adjusted to sample at 1,9 ℓpm (standard). Both respirable and total dust samples were collected.

c) 25 mm diameter filter, 0,8 μm porosity (standard) and adjusted to sample at 1,9 ℓpm. Both respirable and total dust samples were collected.

Four pumps of each configuration were arranged in a sampling grid. The investigation was aimed at assessing the performance of different filter sizes and porosity and different flow rates.

In addition, the suitability of respirable and total dust samples were also evaluated for possible short duration sampling.

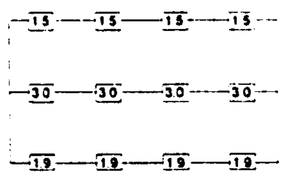
The sampling grid, described in Section 2.2, was erected at the selected sites. Sampling pumps were suspended as shown in Figure 10, which also shows typical environmental conditions for two of the test runs for interest.

ENVIRONMENTAL CONDITIONS

TEST 1 (Day 1)

TIME	VELOCITY m/s	WB/DB deg C
09h36	3.0	29.0/35.0
10h08	3.0	29.5/34.7
10h37	3.0	29.5/34.6
10h49	3.0	29.0/34.8
11h19	3.0	28.9/34.6

FLOWRATES (lpm)



TEST 2 (Day 1)

TIME	VELOCITY m/s	WB/DB deg C
09h20	1.7	30.7/32.1
09h50	1.5	30.5/32.0
10h15	1.4	30.3/32.0
10h26	2.0	29.0/31.0
10h45	2.8	26.2/29.5
11h05	2.8	26.4/29.2

FLOWRATES (lpm)

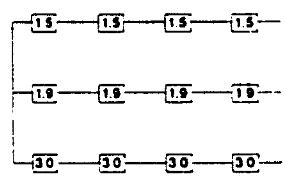


Figure 10 SAMPLING GRID AND PUMP ARRANGEMENTS FOR TWO TEST RUNS

During the first monitoring set, Test 1, site 1, five test runs were made with the sampling rates and respirable/total dust sampling configuration shown in Figure 11. All individual test runs were made over 15 - 20 minutes. A total of 12 samples was collected for each run.

A second monitoring exercise, Test 2, at the same site, featured six test runs. The sampling rates and pump configuration are shown in Figure 12.

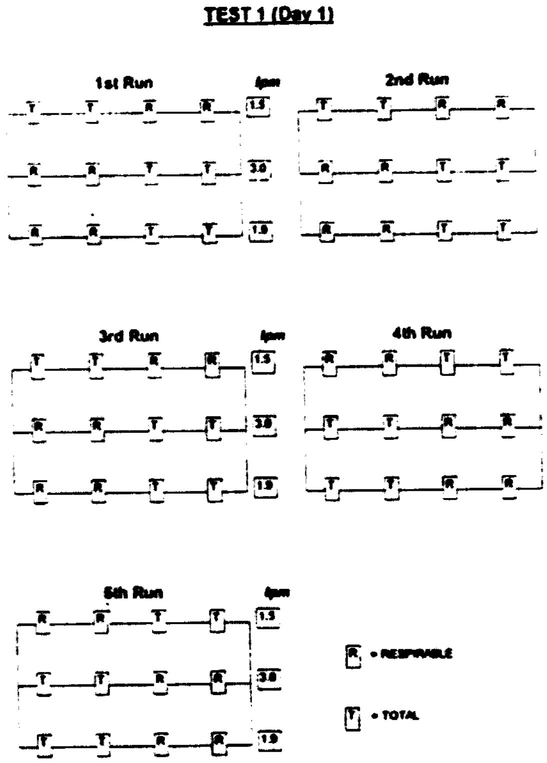


Figure 11 MONITORING EXERCISE 1 - TEST 1. SAMPLING RATES AND PUMP CONFIGURATION

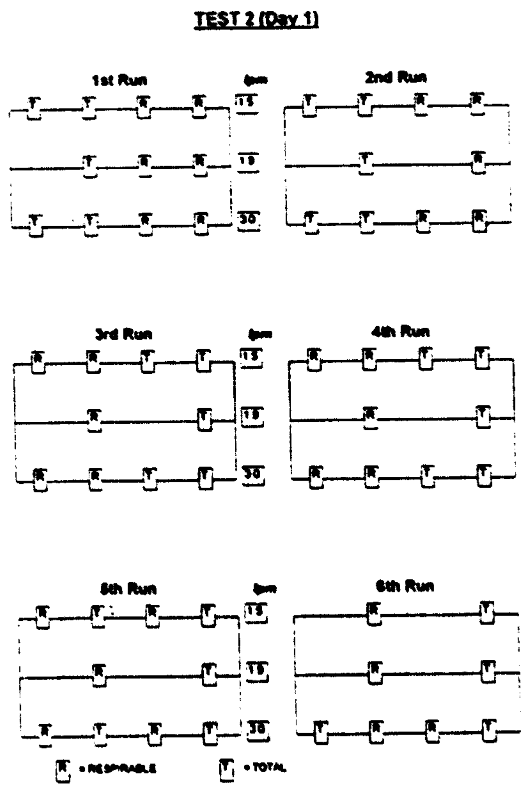


Figure 12 MONITORING EXERCISE 1. TEST 2 . SAMPLING RATES AND PUMP CONFIGURATION

The monitoring exercise was repeated at a different mine but the sampling grid, sampling rate and pump configuration were kept identical. Sampling times were also kept unchanged.

Porosity tests were conducted at a surface locality for two different porosity filters viz 0,8 μm and 1,2 μm and two different sampling rates viz 1,5 ℓpm and 1,9 ℓpm. Tests lasted 15 minutes and 60 minutes. Only total dust samples were collected and this was done by removing the stoppers from the cassettes. These times were chosen firstly because it was anticipated that short duration sampling would be conducted over 15 minute periods and, secondly, to make comparisons of four successive 15 minute samples with a single one hour sample.

A second set of porosity tests was conducted at the surface site, similar to the first test, but included 120 minute samples. For these tests open face filters were used to collect total dust.

3.3 Results

3.3.1 Monitoring Exercise 1

The results of the two exercises are shown in Table 3 and are presented graphically in Figures 13 - 27.

The data for both tests were used to compare the use of:

a) total and respirable dust samples on the same size filters (same flow rates)
b) respirable dust collection on different size filters and different flow rates
c) respirable dust collection on filters at different flow rates
d) total dust samples on different size filters and different flow rates
e) total dust collection on filters at different flow rates
f) total and respirable dust collection on the same size filters but with different flow rates.

Table 3 **RESULTS OF THE FIRST SET OF MONITORING EXERCISES**

PUMP METHOD TESTS																		
Test	Flow Rate	Filter Size	Respirable		Total Dust		Flow Rate	Filter Size	Respirable		Total Dust		Flow Rate	Filter Size	Respirable		Total Dust	
Number	lpm	Diam mm	Dust Conc mg/m^3		Conc mg/m^3		lpm	Diam mm	Dust Conc mg/m^3		Conc mg/m^3		lpm	Diam mm	Dust Conc mg/m^3		Conc mg/m^3	
EXERCISE 1																		
1	1.5	13	0.141			0.015	1.9	25	0.613	0.143	0.306	0.611	3	25		0.745	0.529	0.980
2			0.620	0.526	0.147	0.553			0.693	0.685	1.973	1.618			0.472	0.172	0.833	1.127
3			0.418	0.274	0.104	0.072			3.048	1.747	1.661	1.205			0.802	1.154	0.613	0.360
4			0.233	0.102	0.542	0.239			1.488	1.171	1.039	0.616			1.324	0.929	0.283	1.056
5			0.259	0.140	0.202	0.761			0.138	1.274	1.039	0.685			1.176	0.887	0.779	0.737
Average			0.334	0.261	0.249	0.328			1.196	1.004	1.204	0.947			0.944	0.777	0.607	0.852
Std Dev			0.168	0.166	0.173	0.286			1.022	0.547	0.576	0.402			0.332	0.330	0.196	0.279
Maximum			0.620	0.526	0.542	0.761			3.048	1.747	1.973	1.618			1.324	1.154	0.833	1.127
Mimimum			0.141	0.102	0.104	0.015			0.138	0.143	0.306	0.611			0.472	0.172	0.283	0.360
EXERCISE 2																		
1			1.591	1.529	1.907	1.833			2.603	1.942		2.674			1.314	1.132	3.122	2.769
2			1.508	1.197	1.870	0.869				2.716		2.961			2.125	2.043	3.737	4.022
3			0.468	0.212	1.146	0.611				1.614		2.740			1.513	1.160	1.602	1.893
4			2.326	1.383	2.252	2.599				1.722					1.680	2.100		
5			1.541	2.379	2.138	2.905				1.102		2.476			1.813	3.448	1.643	2.613
6			1.696			2.044				1.894		1.857			1.127	1.512	6.272	2.257
Average			1.522	1.340	1.863	1.810			2.603	1.832		2.542			1.595	1.899	3.275	2.711
Std Dev			0.547	0.694	0.385	0.837			0.000	0.481		0.376			0.327	0.790	1.714	0.722
Maximum			2.326	2.379	2.252	2.905			2.603	2.716		2.961			2.125	3.448	6.272	4.022
Mimimum			0.468	0.212	1.146	0.611			2.603	1.102		1.857			1.127	1.132	1.602	1.893

An examination of the results presented show apparently little distinction between total dust and respirable dust concentrations, as sampled. Also, the effect of using mismatched equipment, eg 13 mm diameter filter but with a 25 mm cyclone (even with a part of the slot blanked off to ensure the same tangential velocity for the lower sampling rate of 1,5 ℓpm) are evident. The sampling train consisting of a 25 mm filter and a 25 mm cyclone operated at a flow rate of 1,9 ℓpm (reference sampling train) consistently gave higher dust concentrations than the 13 mm filters with 25 mm cyclones operated at 1,5 ℓpm. The reference sampling train also consistently gave higher results than the 25 mm filter and 25 mm cyclones operated at 3 ℓpm.

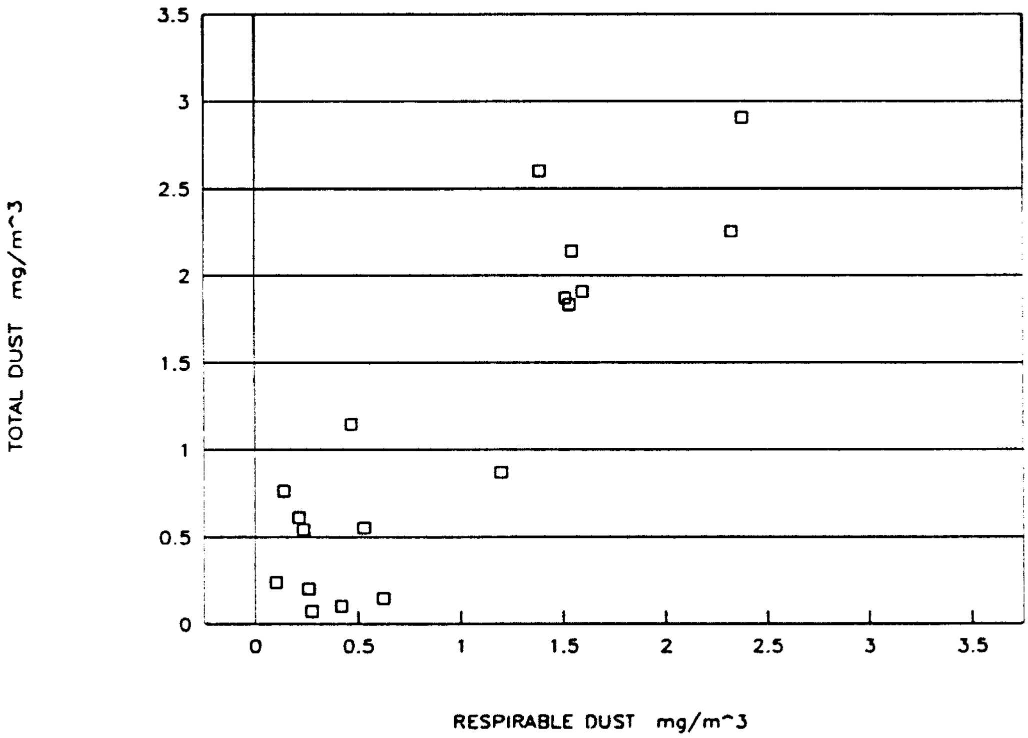


Figure 13 <u>RESPIRABLE DUST AND TOTAL DUST FOR 13 mm FILTERS WITH A SAMPLING RATE OF 1,5 ℓpm</u>

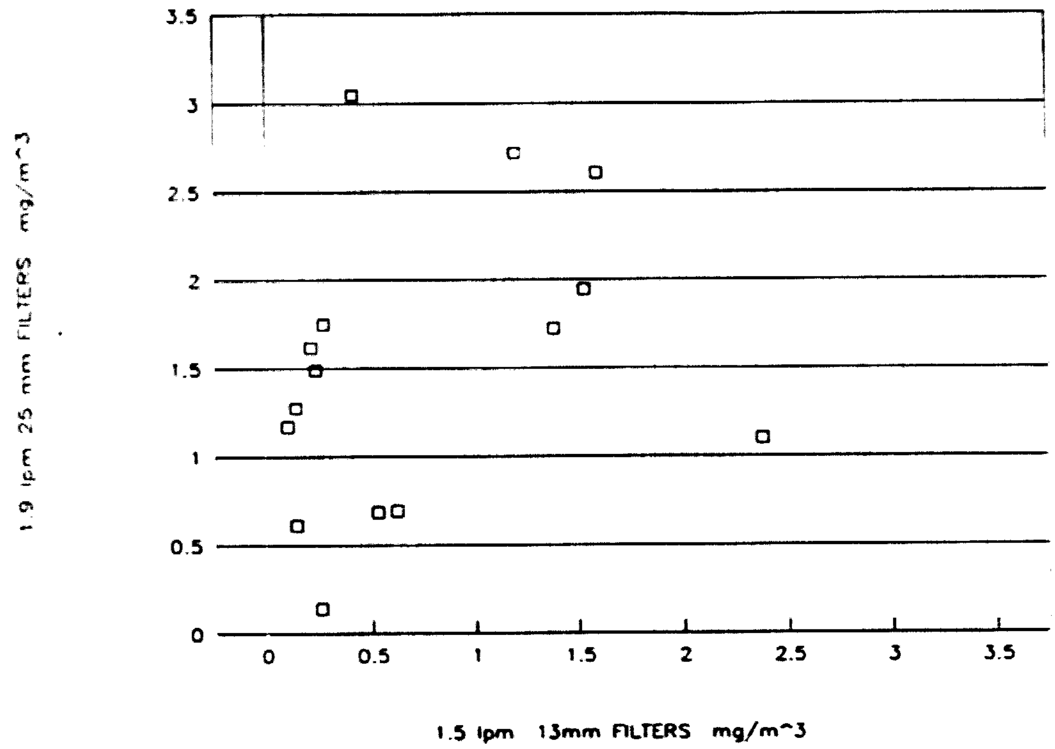


Figure 14 **RESPIRABLE DUST COLLECTED ON 13 mm FILTERS (1.5 ℓpm) AND 25 mm FILTERS (1.9 ℓpm)**

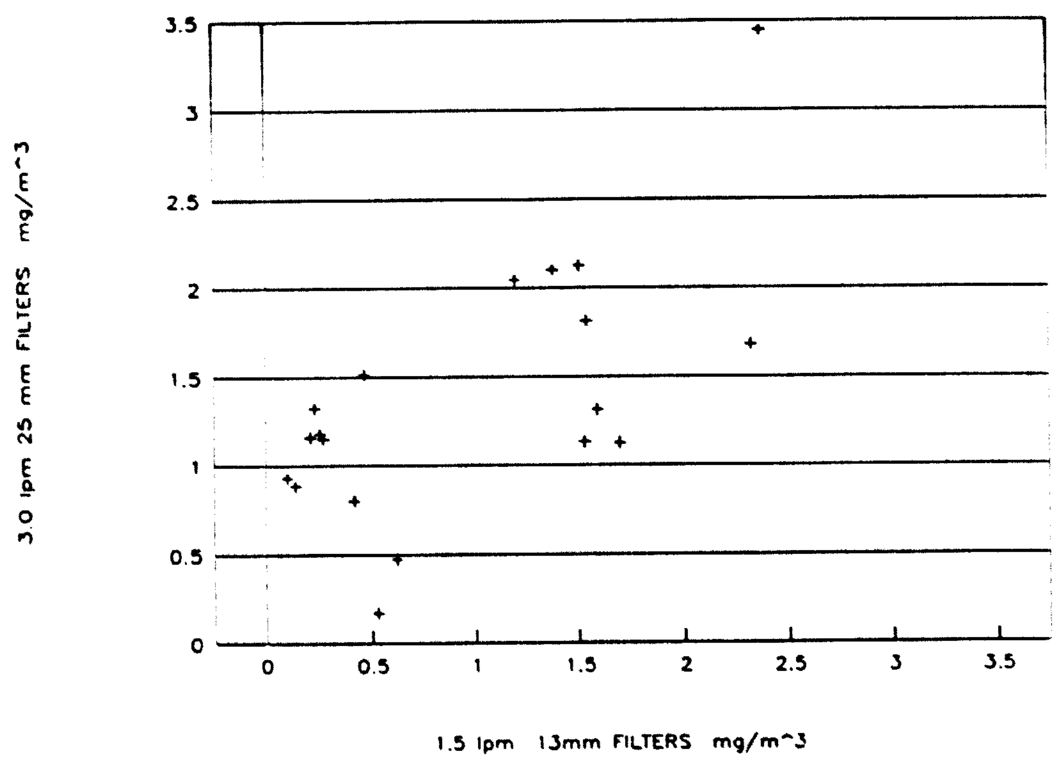


Figure 15 **RESPIRABLE DUST COLLECTED ON 13 mm FILTERS (1.5 ℓpm) AND 25 mm FILTERS (3 ℓpm)**

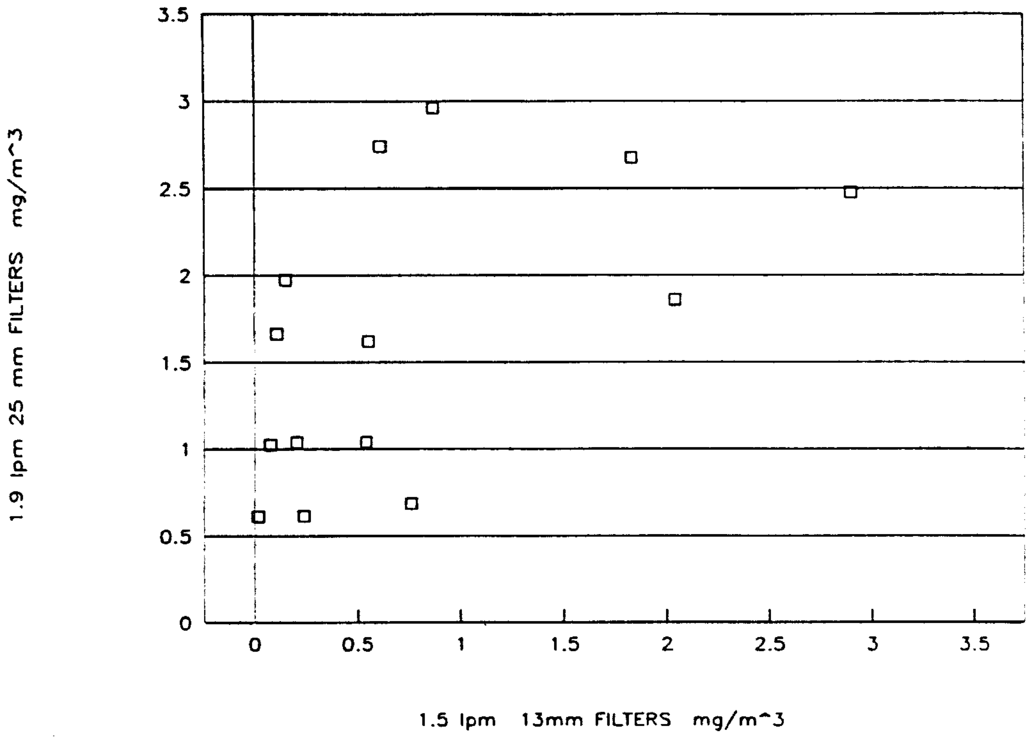


Figure 16 **TOTAL DUST COLLECTED ON 13 mm FILTERS (1.5 ℓpm) AND 25 mm FILTERS (1.9 ℓpm)**

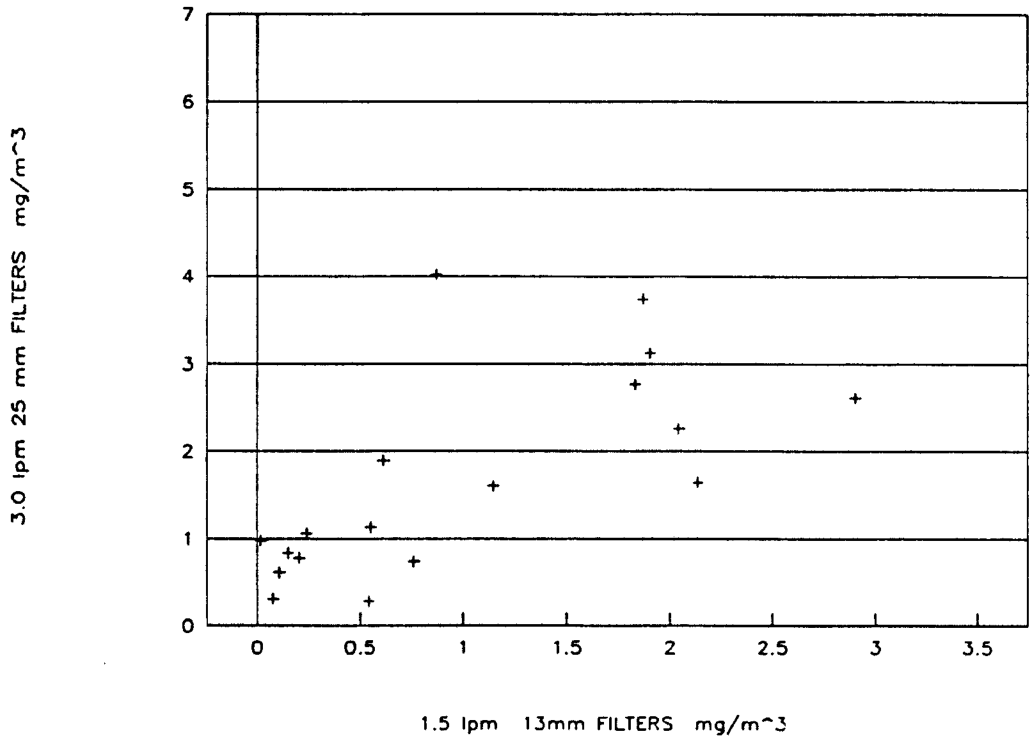


Figure 17 **TOTAL DUST COLLECTED ON 13 mm FILTERS (1.5 ℓpm) AND 25 mm FILTERS (3 ℓpm)**

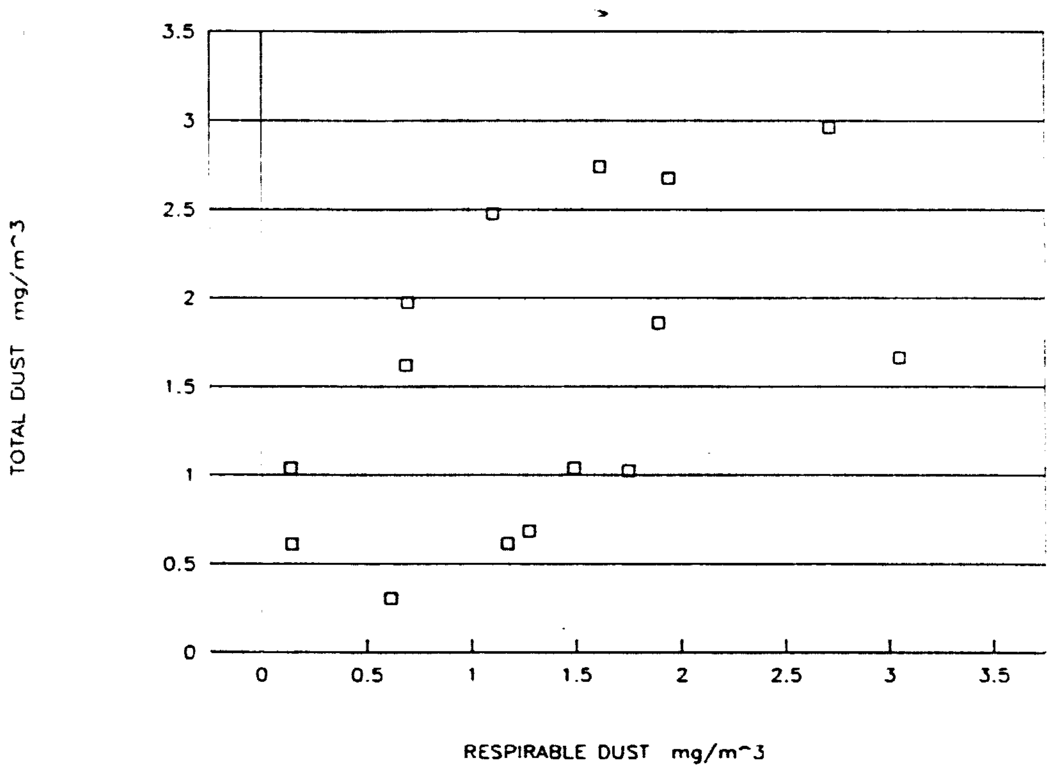


Figure 18 **RESPIRABLE DUST AND TOTAL DUST COLLECTED ON 25 mm FILTERS (1.9 ℓpm)**

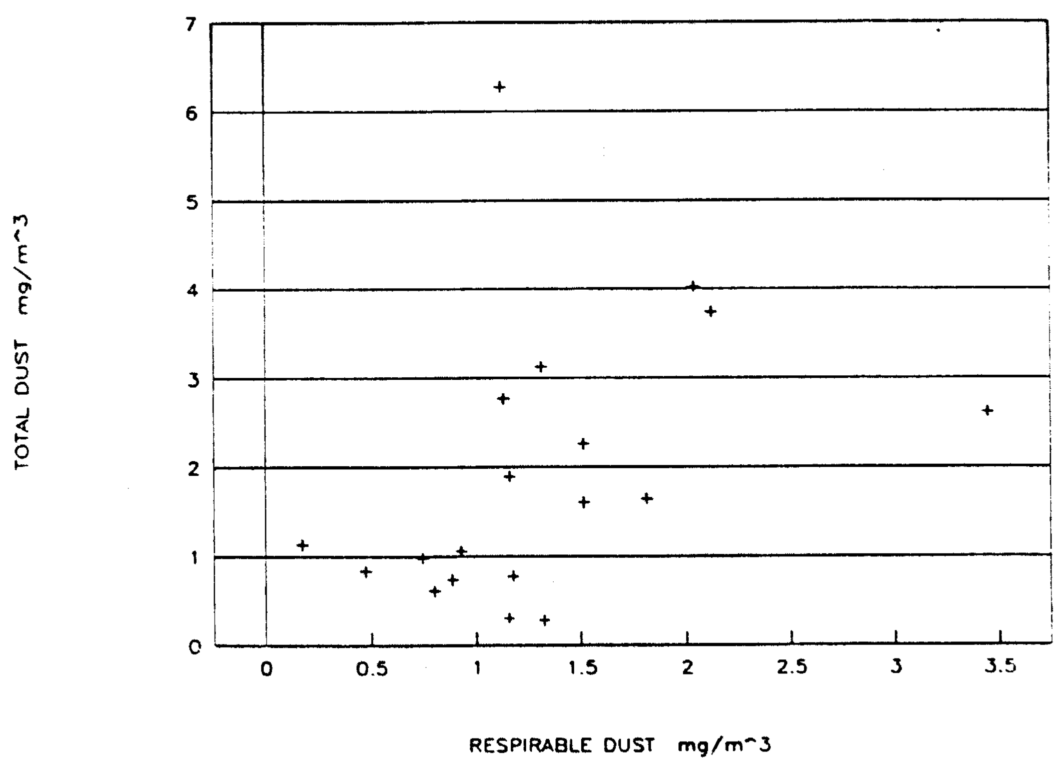


Figure 19 **RESPIRABLE DUST AND TOTAL DUST COLLECTED ON 25 mm FILTERS (3 ℓpm)**

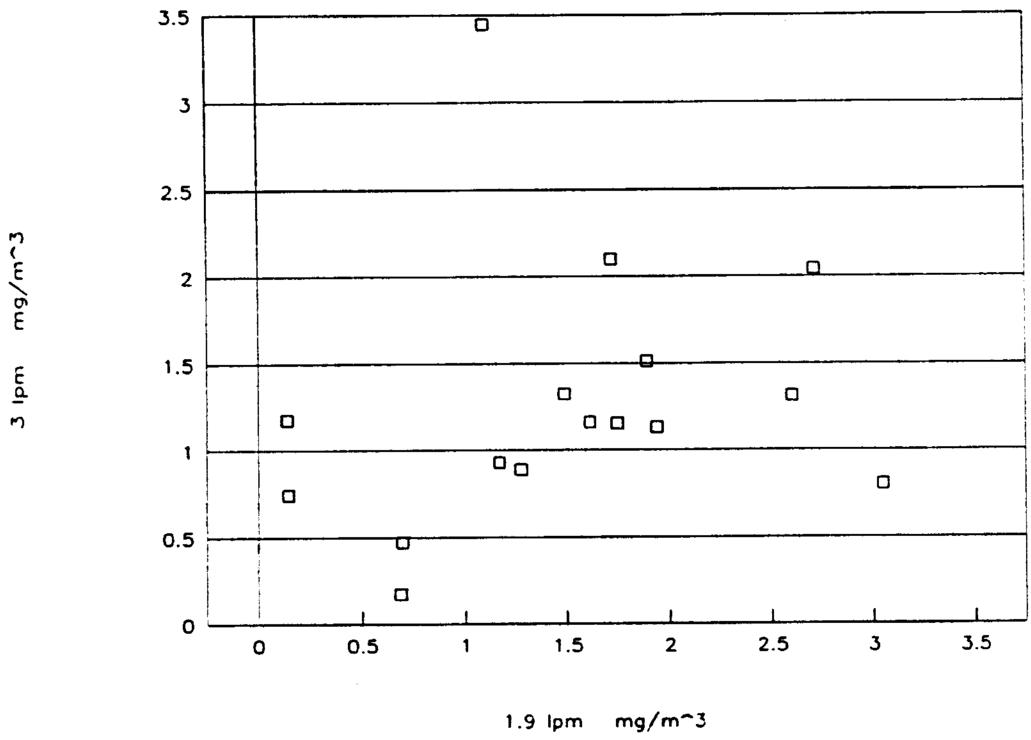


Figure 20 <u>RESPIRABLE DUST COLLECTED ON 25 mm FILTERS AT 1.9 ℓpm AND 3 ℓpm</u>

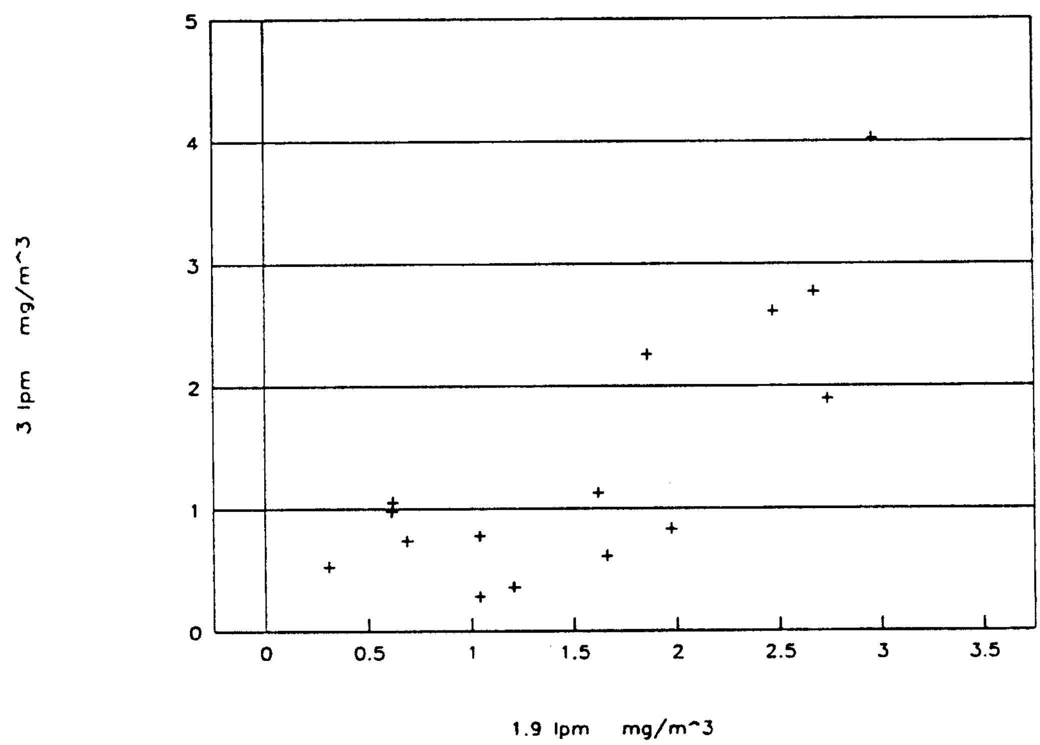


Figure 21 <u>TOTAL DUST COLLECTED ON 25 mm FILTERS AT 1.9 ℓpm AND 3 ℓpm</u>

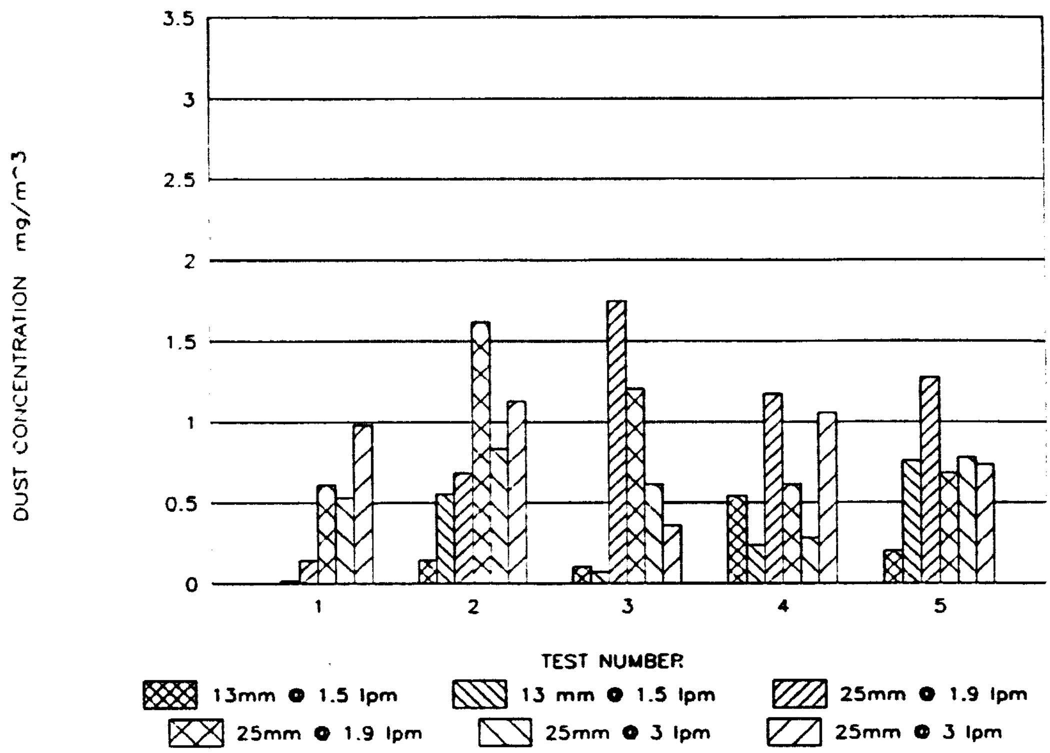


Figure 22 **RESPIRABLE DUST SAMPLES COLLECTED AT THREE SAMPLING RATES (FIRST TEST RUN)**

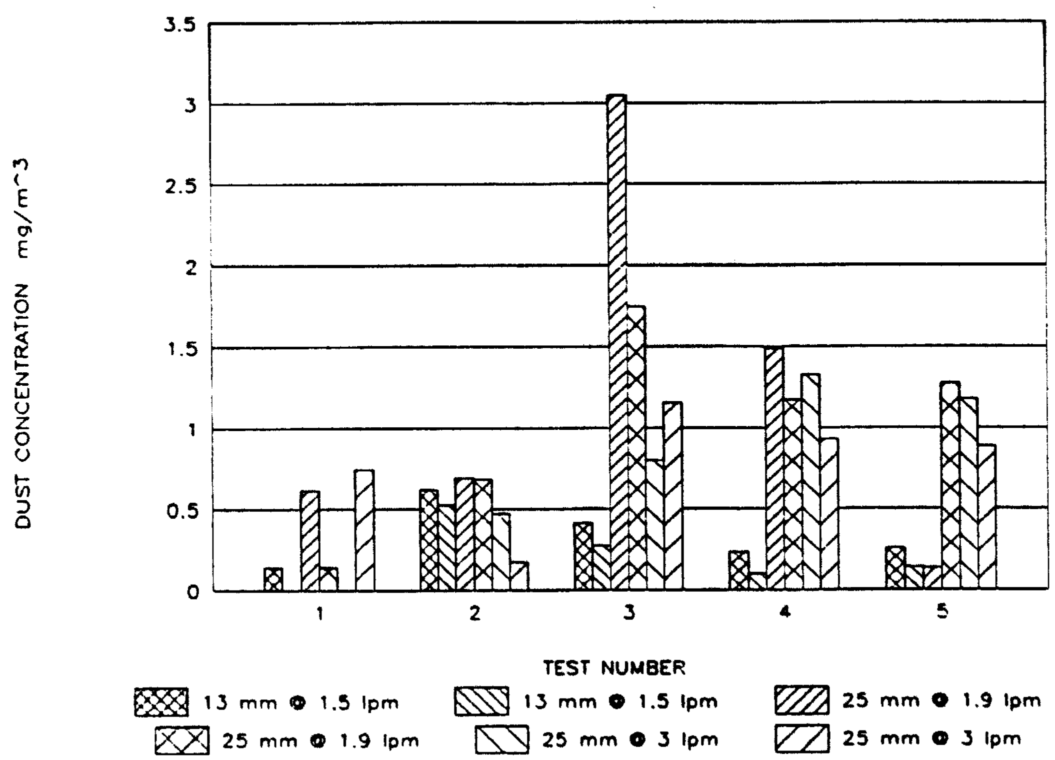


Figure 23 **RESPIRABLE DUST SAMPLES COLLECTED AT THREE SAMPLING RATES (FIRST TEST RUN)**

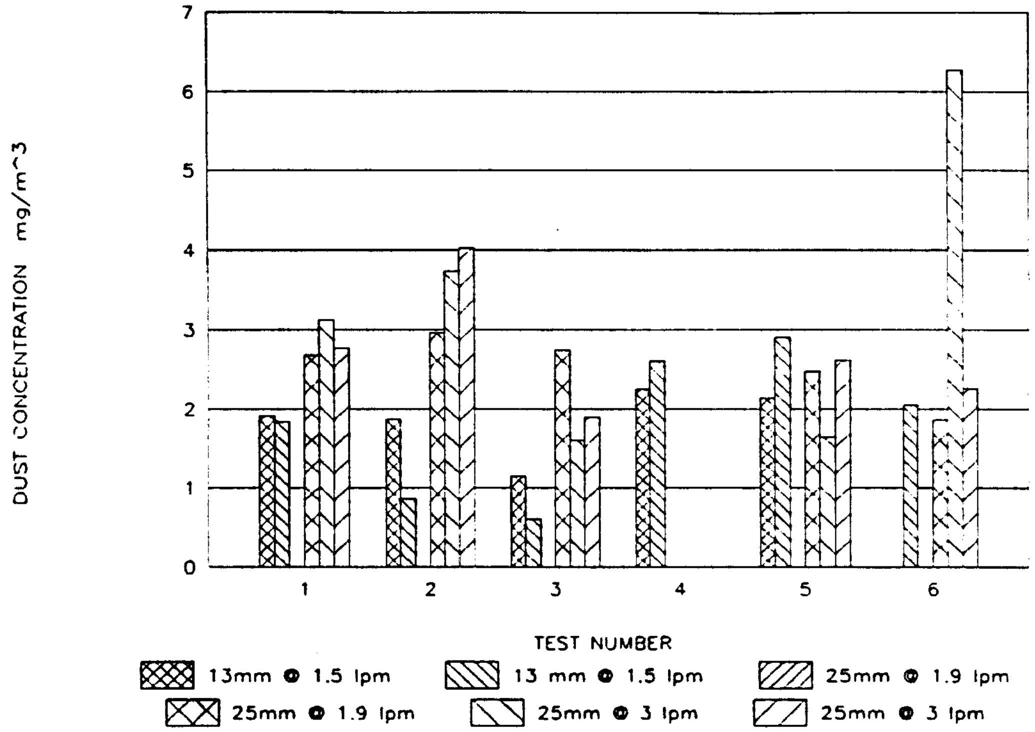


Figure 24 <u>TOTAL DUST SAMPLES COLLECTED AT THREE SAMPLING RATES (SECOND TEST RUN)</u>

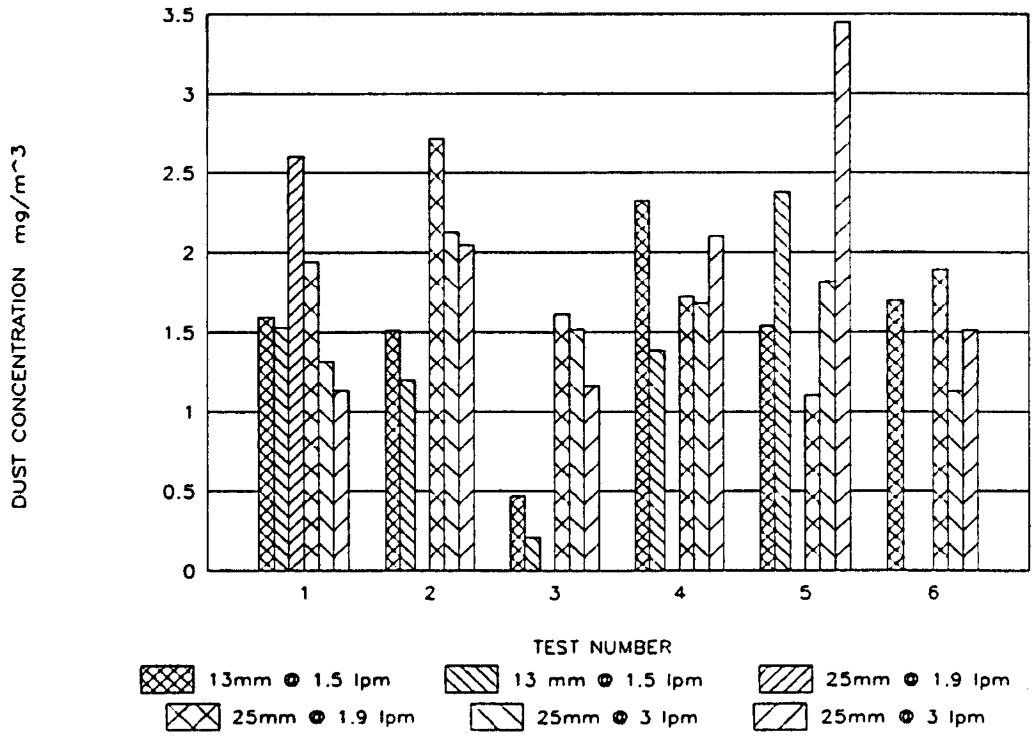


Figure 25 <u>TOTAL DUST SAMPLES COLLECTED AT THREE SAMPLING RATES (SECOND TEST RUN)</u>

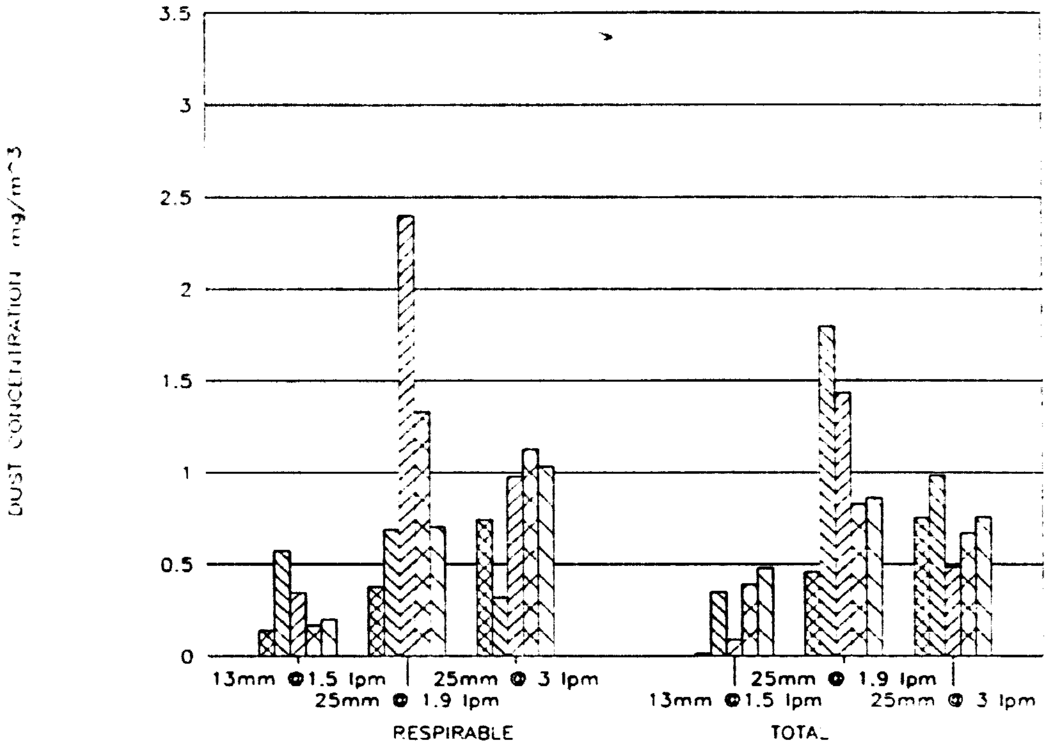


Figure 26 **RESPIRABLE AND TOTAL DUST SAMPLES COLLECTED AT THREE SAMPLING RATES (FIRST TEST RUN)**

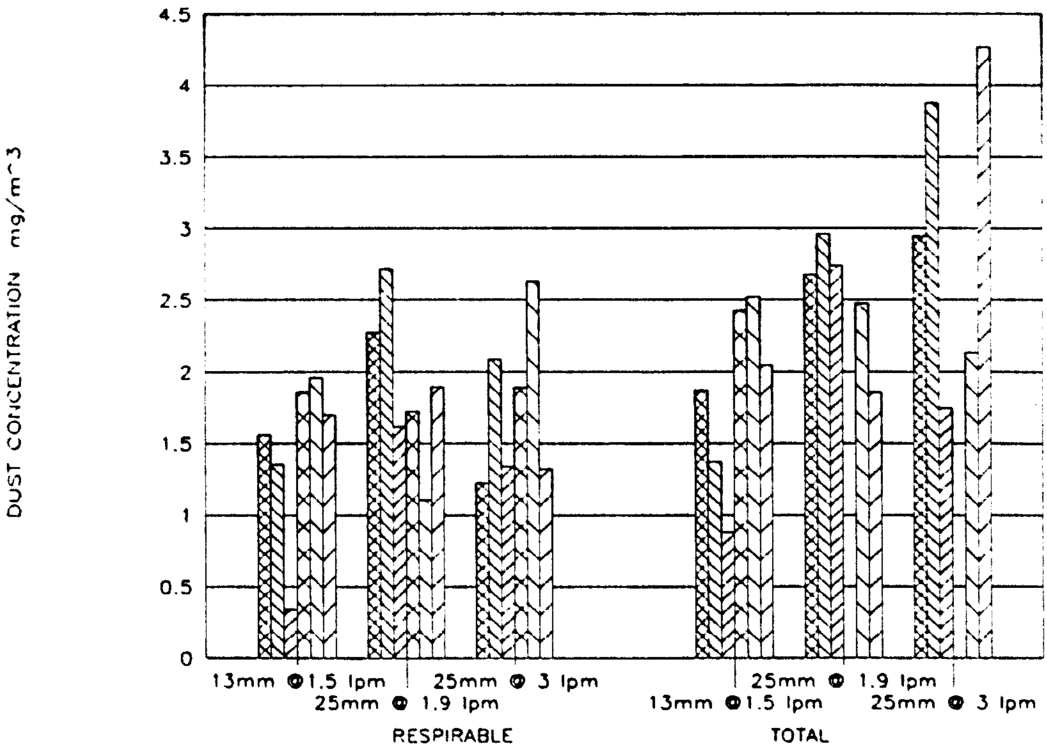


Figure 27 **RESPIRABLE AND TOTAL DUST SAMPLES COLLECTED AT THREE SAMPLING RATES (SECOND TEST RUN)**

3.3.2 Monitoring Exercise 2

In this series of tests respirable and total dust samples were collected at the three different sampling rates and, in addition, pumps were both shielded and unshielded.

The results of this monitoring exercise are set out in Table 4 and presented graphically in Figures 28 - 45.

In this part of the investigation respirable and total dust samples, for comparison, were collected on a common filter size, at different flow rates. Both shielded and normal (unshielded) samples were collected.

The results again indicate little difference between respirable dust samples and total dust samples.

In studying the effects of shielding, contrary to expectations, the shielded samples appear to yield higher results than the unshielded (normal) samples. The absence of "flushing" ventilation could be responsible for this result.

Once again no clear cut differences between total dust and respirable dust samples are evident - probably due to the fact that course particles had settled out before the air reached the sampling test zone.

Table 4 RESULTS OF THE SECOND SET OF MONITORING EXERCISES

		SHIELDED																	
	Test	Flow Rate	Filter Size	Respirable		Total Dust		Flow Rate	Filter Size	Respirable		Total Dust		Flow Rate	Filter Size	Respirable		Total Dust	
	Number	lpm	Diam mm	Dust Conc		Conc		lpm	Diam mm	Dust Conc		Conc		lpm	Diam mm	Dust Conc		Conc	
				mg/m^3		mg/m^3				mg/m^3		mg/m^3				mg/m^3		mg/m^3	
	1	1.5	13	2.102	0.960	2.471	0.813	1.9	25		0.912	1.368	2.281	3	25	1.024	0.310	2.024	1.667
	2			1.613	1.564	1.716	1.658			1.404	0.667	1.404	1.053			2.027	0.800	2.293	1.680
FIRST TEST	3			1.418	1.702	1.476	1.613			1.263	1.368	2.807	2.070			2.213	2.373	2.027	1.573
	4			1.440	1.613	1.524	1.644			1.123	1.018	1.123	1.368			2.293	1.227	1.147	1.867
	Average			1.643	1.460	1.797	1.432			1.263	0.991	1.676	1.693			1.889	1.178	1.873	1.697
	Std Dev			0.275	0.293	0.400	0.358			0.115	0.252	0.662	0.501			0.509	0.763	0.433	0.107
	Maximum			2.102	1.702	2.471	1.658			1.404	1.368	2.807	2.281			2.293	2.373	2.293	1.867
	Minimum			1.418	0.960	1.476	0.813			1.123	0.667	1.123	1.053			1.024	0.310	1.147	1.573
		UNSHIELDED SAMPLERS																	
	1			1.015	0.813	0.826	0.982			0.197	0.211	0.428	0.316			0.659	0.381	0.643	0.548
SECOND TEST	2				1.049	0.858	1.276			1.333	0.596	0.421	0.807			0.843	1.161	1.238	0.810
	3			0.831	1.222	0.729	1.151			5.053	0.421	1.754	0.807			2.214	3.238	2.548	3.405
	4			1.280	1.222	0.929	1.573				0.702	0.491	0.316			0.381	0.405	1.024	1.524
	Average			1.042	1.077	0.836	1.246			2.194	0.483	0.774	0.562			1.024	1.296	1.363	1.572
	Std Dev			0.184	0.168	0.072	0.216			2.074	0.186	0.567	0.246			0.706	1.164	0.716	1.117
	Maximum			1.280	1.222	0.929	1.573			5.053	0.702	1.754	0.807			2.214	3.238	2.548	3.405
	Minimum			0.831	0.813	0.729	0.982			0.197	0.211	0.421	0.316			0.381	0.381	0.643	0.548

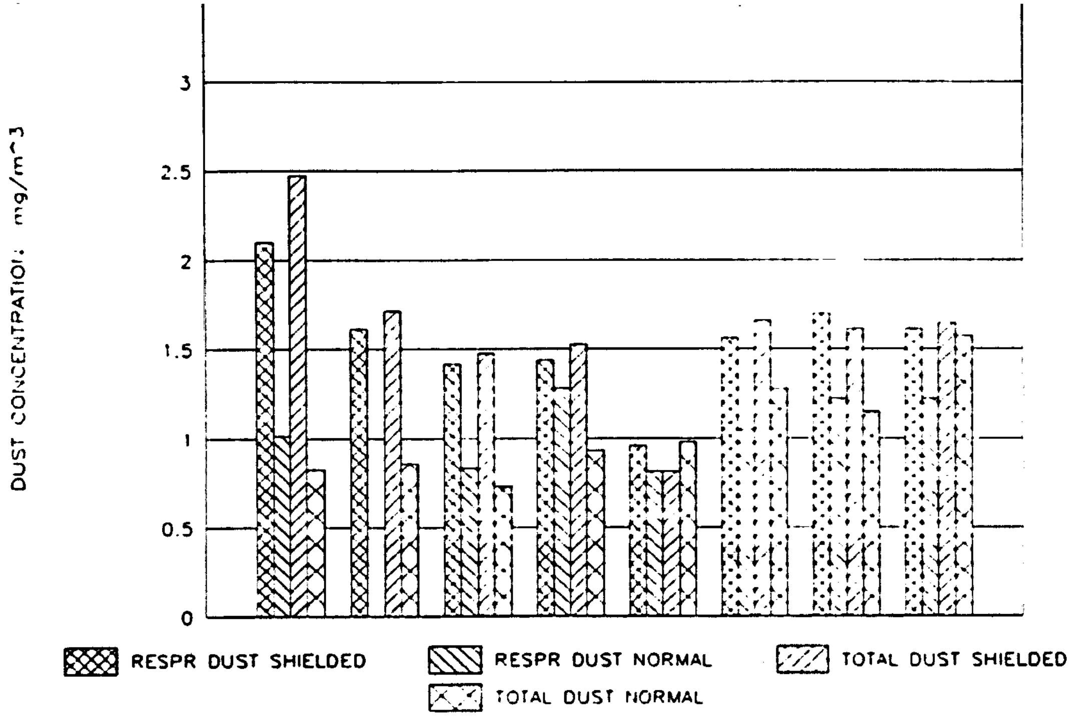


Figure 28 RESPIRABLE AND TOTAL DUST, SHIELDED AND UNSHIELDED, (NORMAL) COLLECTED ON 13 mm FILTERS AT 1.5 ℓpm

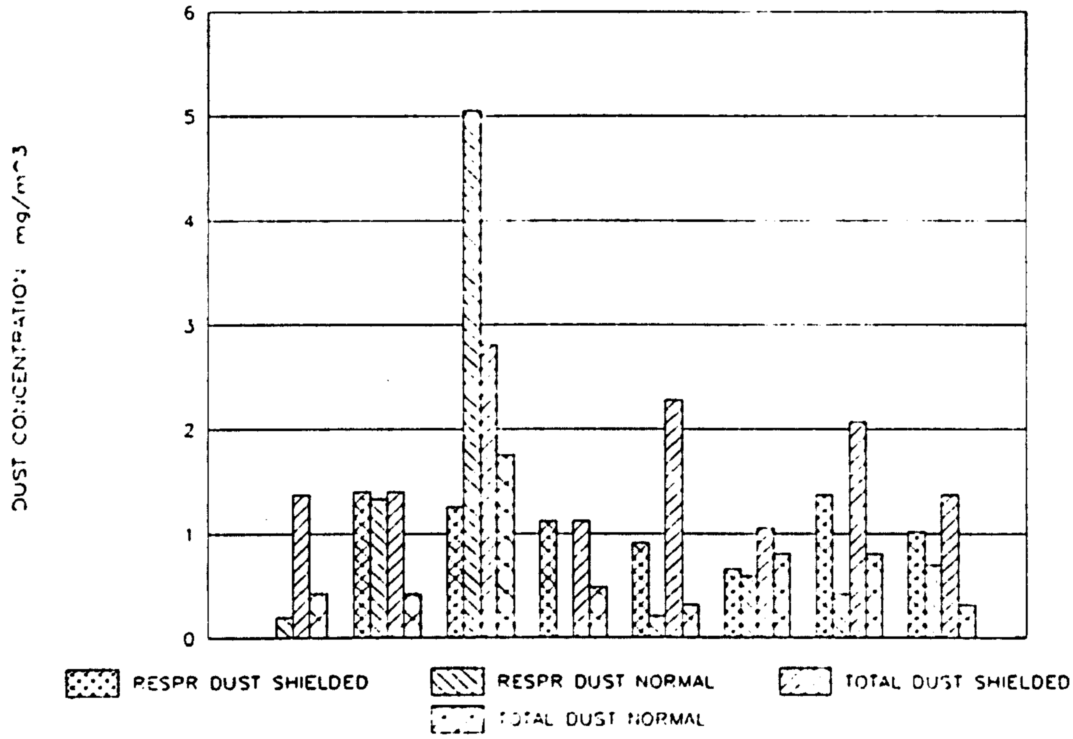


Figure 29 RESPIRABLE AND TOTAL DUST, SHIELDED AND UNSHIELDED (NORMAL), COLLECTED ON 13 mm FILTERS AT 1.9 ℓpm

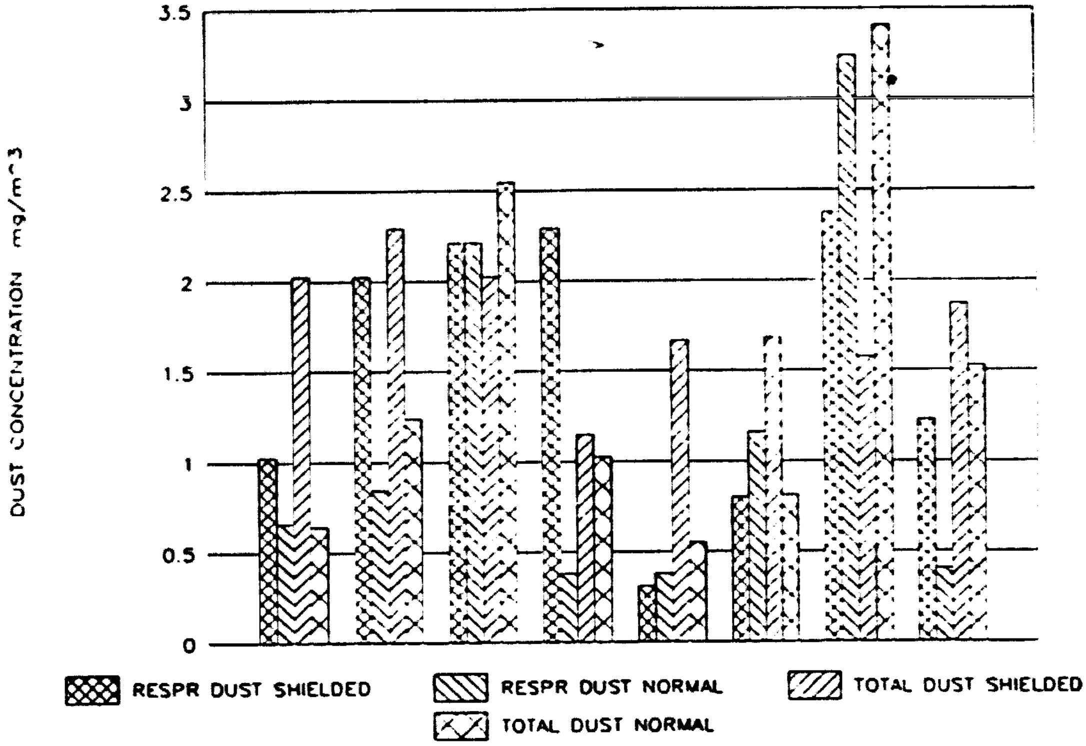


Figure 30 RESPIRABLE AND TOTAL DUST, SHIELDED AND UNSHIELDED (NORMAL), COLLECTED ON 25 mm FILTERS AT 3 ℓpm

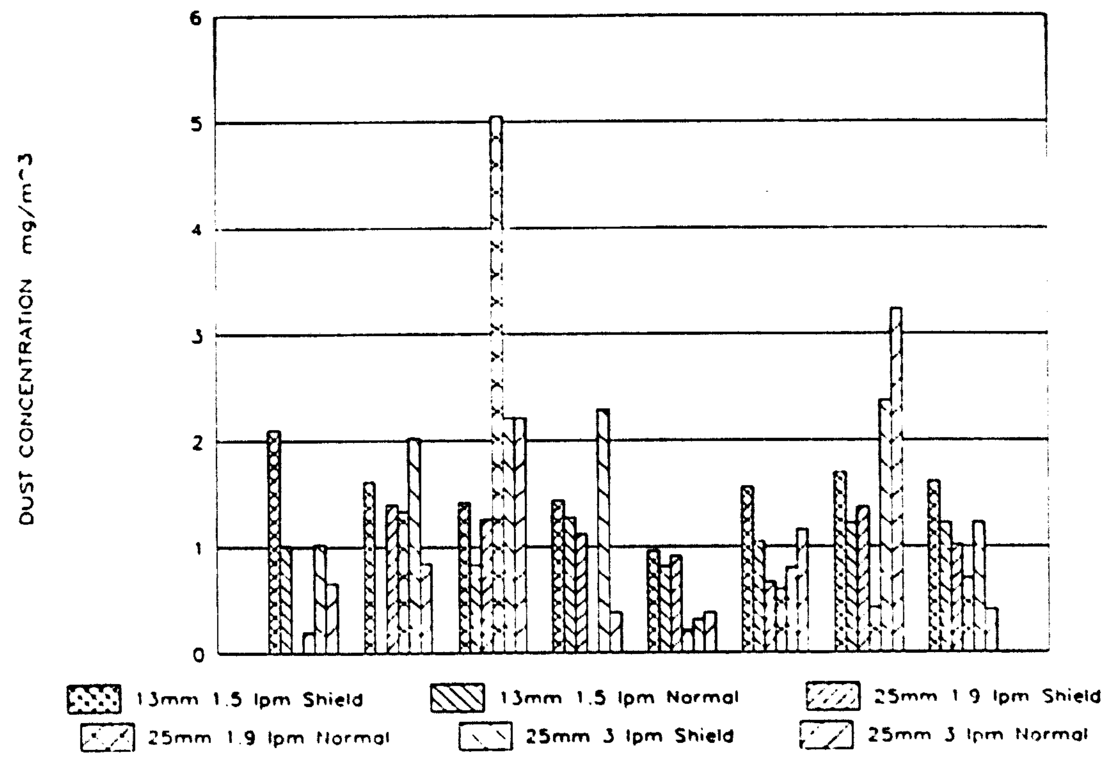


Figure 31 RESPIRABLE DUST, SHIELDED AND UNSHIELDED (NORMAL) COLLECTED AT THREE SAMPLING RATES

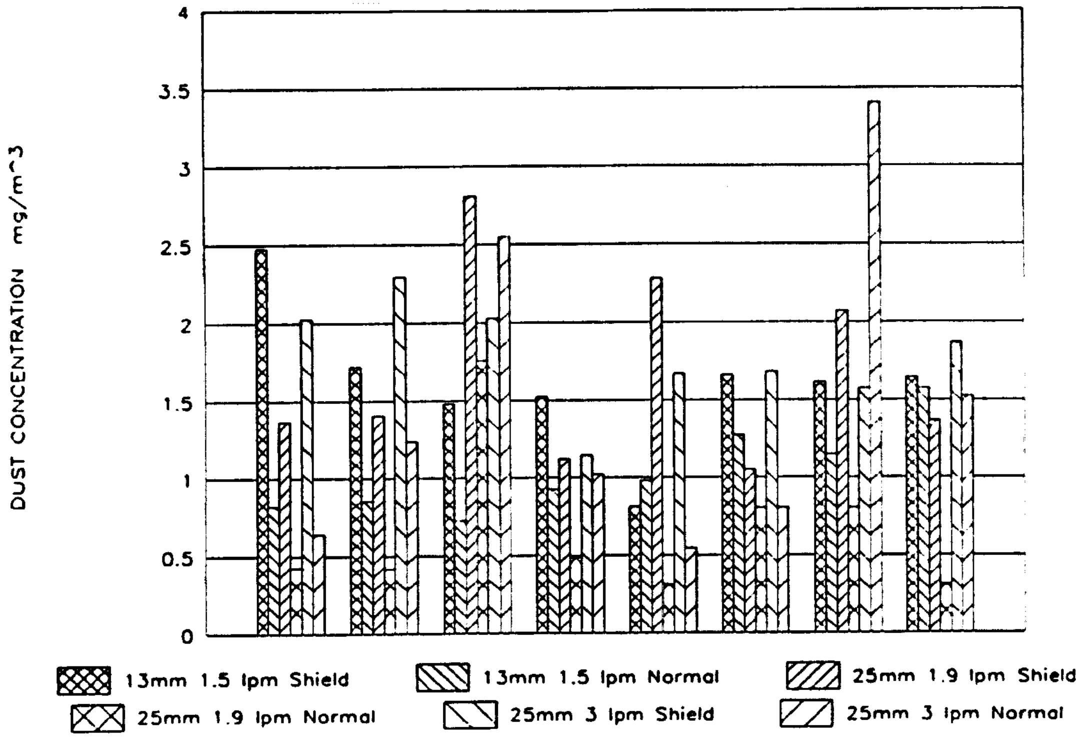


Figure 32 TOTAL DUST, SHIELDED AND UNSHIELDED (NORMAL), COLLECTED AT THREE SAMPLING RATES

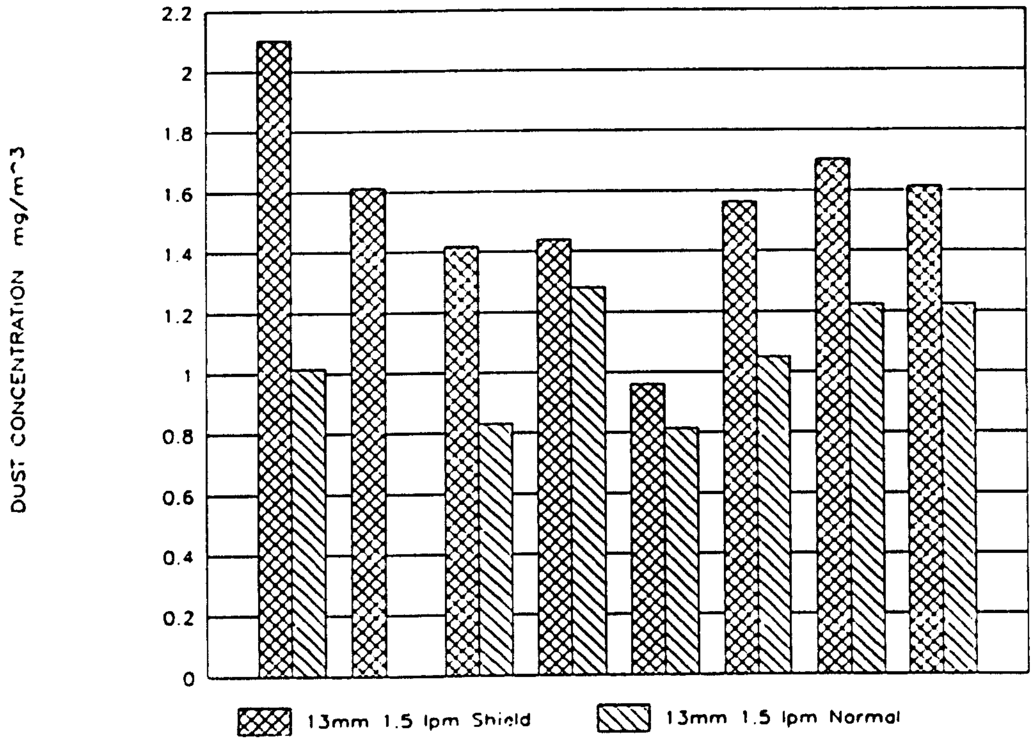


Figure 33 RESPIRABLE DUST, SHIELDED AND UNSHIELDED (NORMAL), COLLECTED AT 1.5 ℓpm ON 13 mm FILTERS

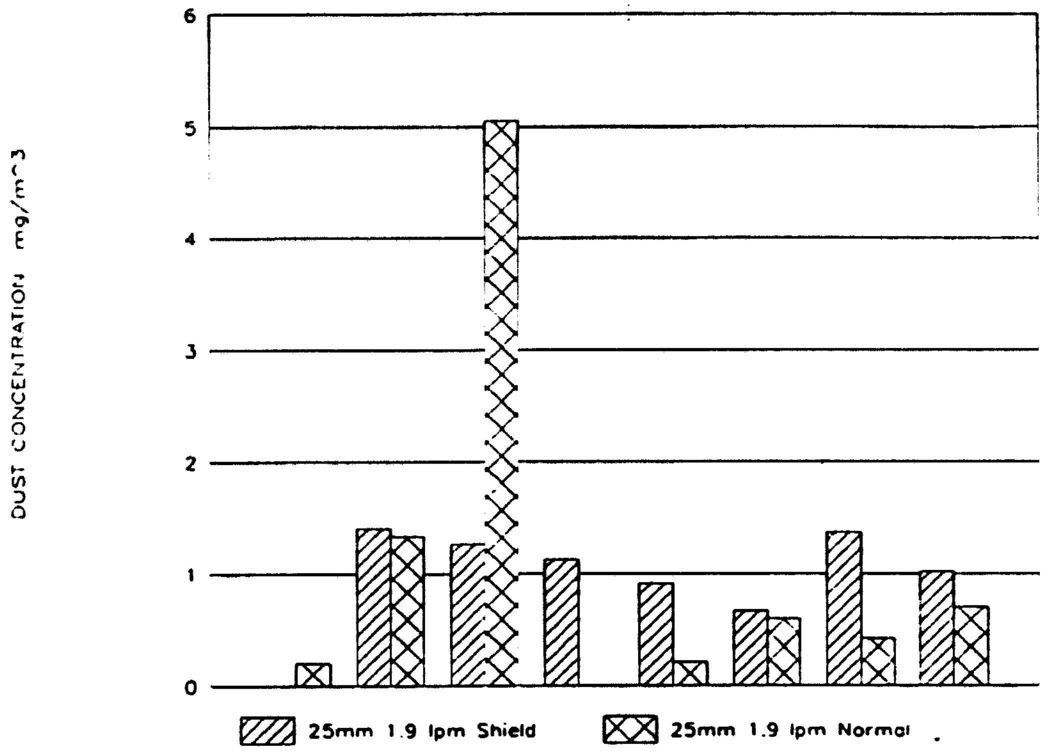


Figure 34 RESPIRABLE DUST, SHIELDED AND UNSHIELDED (NORMAL), COLLECTED AT 1.9 lpm ON 25 mm FILTERS

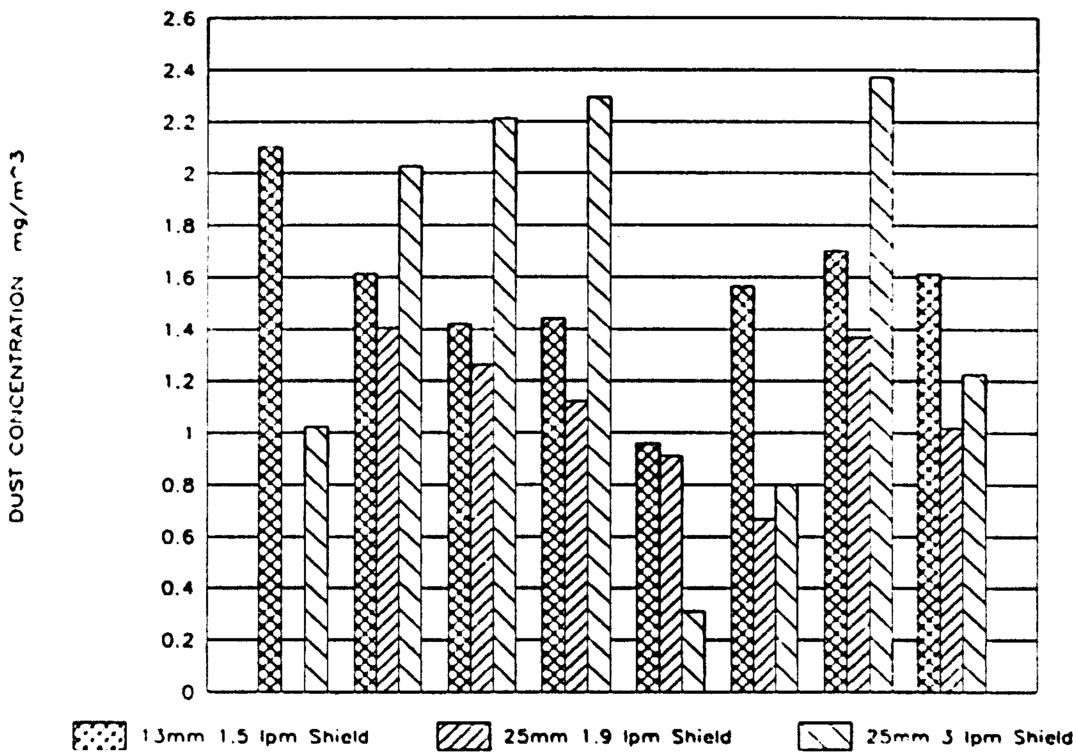


Figure 35 RESPIRABLE DUST, ONLY SHIELDED, COLLECTED AT THREE SAMPLING RATES

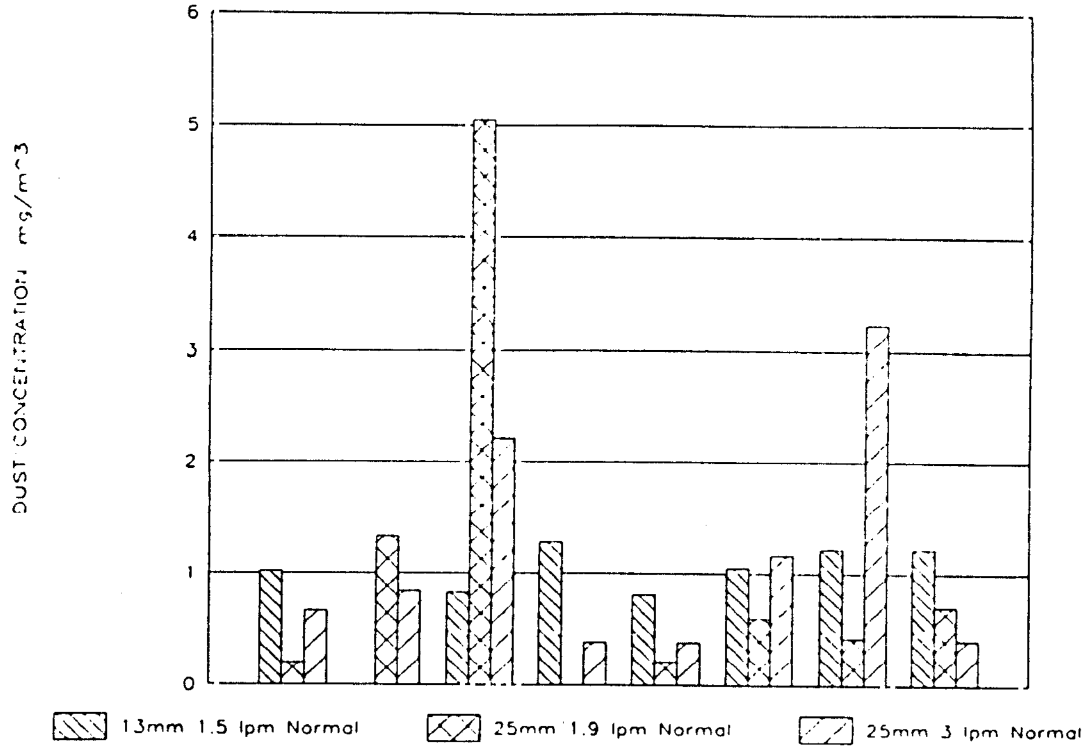


Figure 36 RESPIRABLE DUST, UNSHIELDED (NORMAL), COLLECTED AT THREE SAMPLING RATES

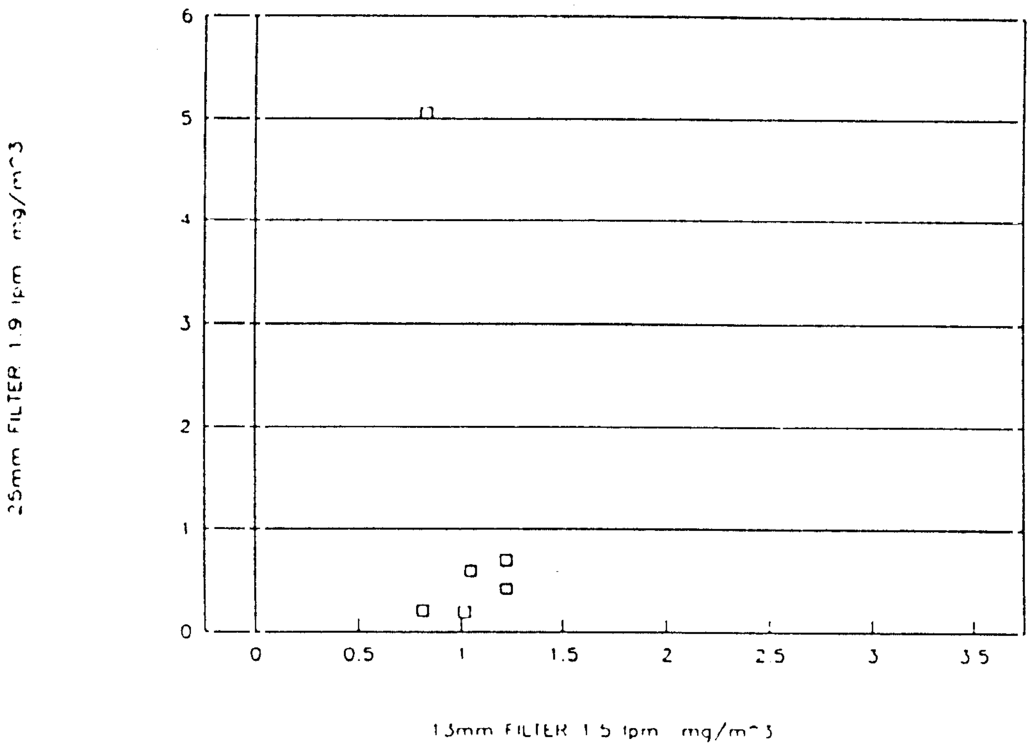


Figure 37 RESPIRABLE DUST, UNSHIELDED (NORMAL), COLLECTED AT 1.5 ℓpm AND 1.9 ℓpm

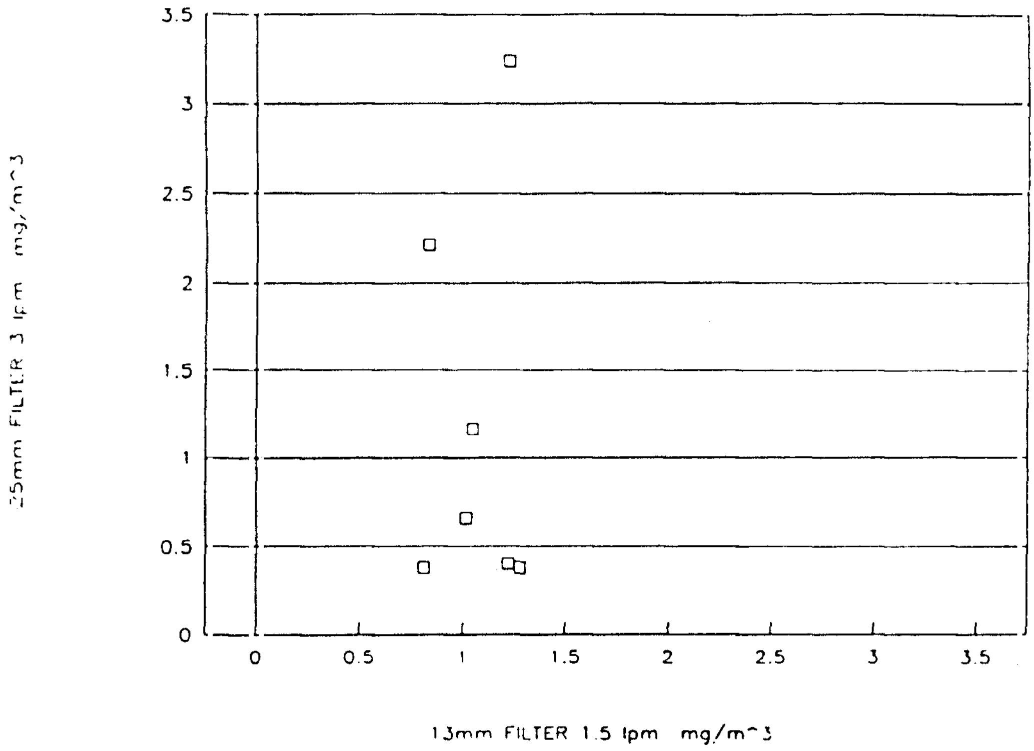


Figure 38 RESPIRABLE DUST, UNSHIELDED (NORMAL), COLLECTED AT 1.5 ℓpm AND 3 ℓpm

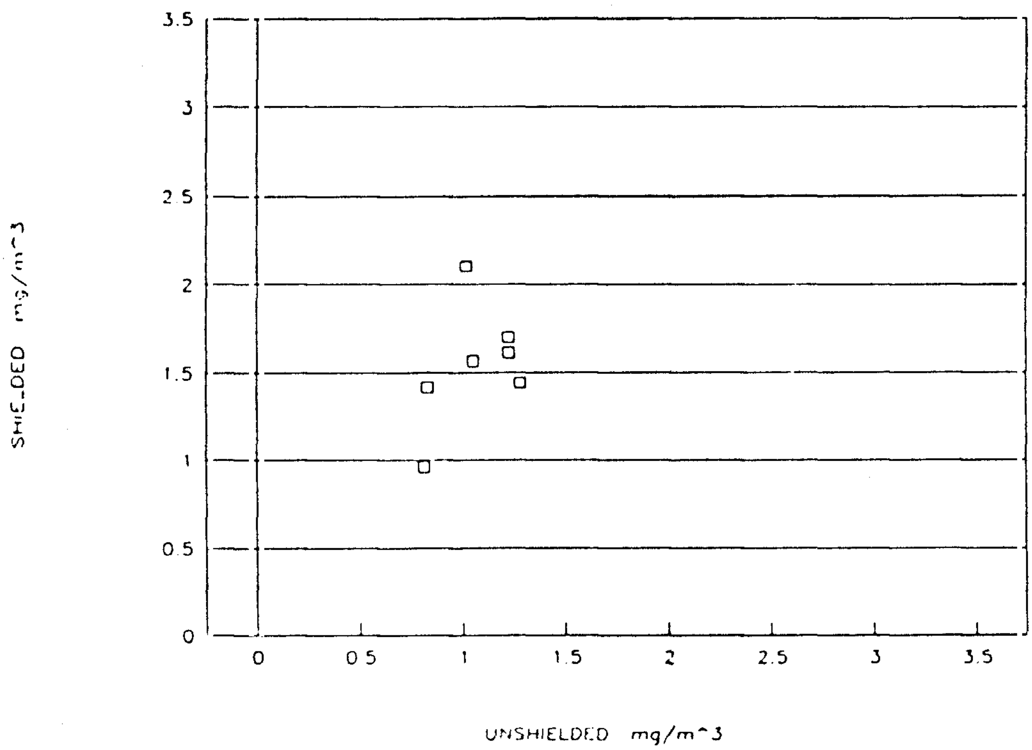


Figure 39 RESPIRABLE DUST, SHIELDED AND UNSHIELDED (NORMAL), COLLECTED AT 1.5 ℓpm

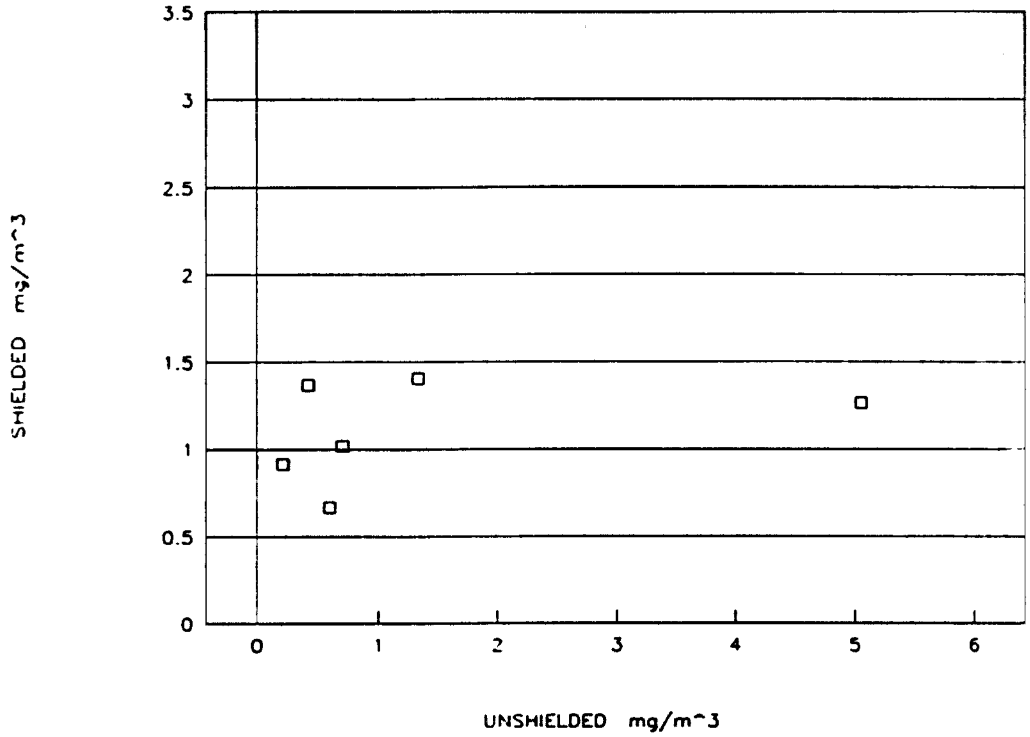


Figure 40 RESPIRABLE DUST, SHIELDED AND UNSHIELDED (NORMAL), COLLECTED AT 1.9 ℓpm

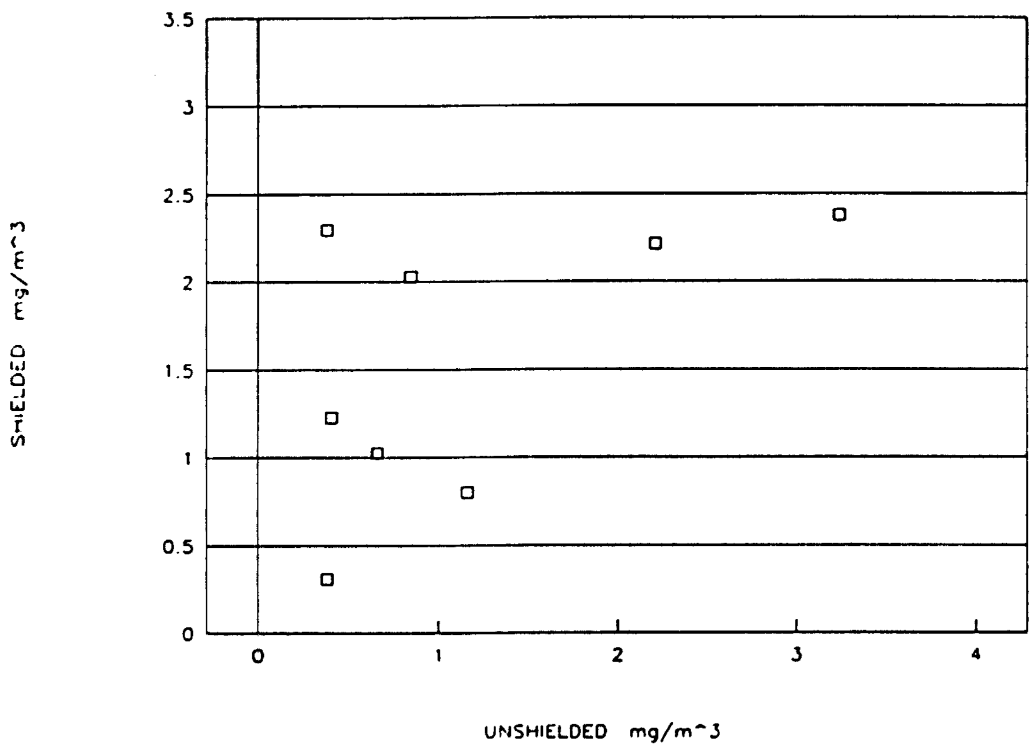


Figure 41 RESPIRABLE DUST, SHIELDED AND UNSHIELDED, COLLECTED AT 3 ℓpm

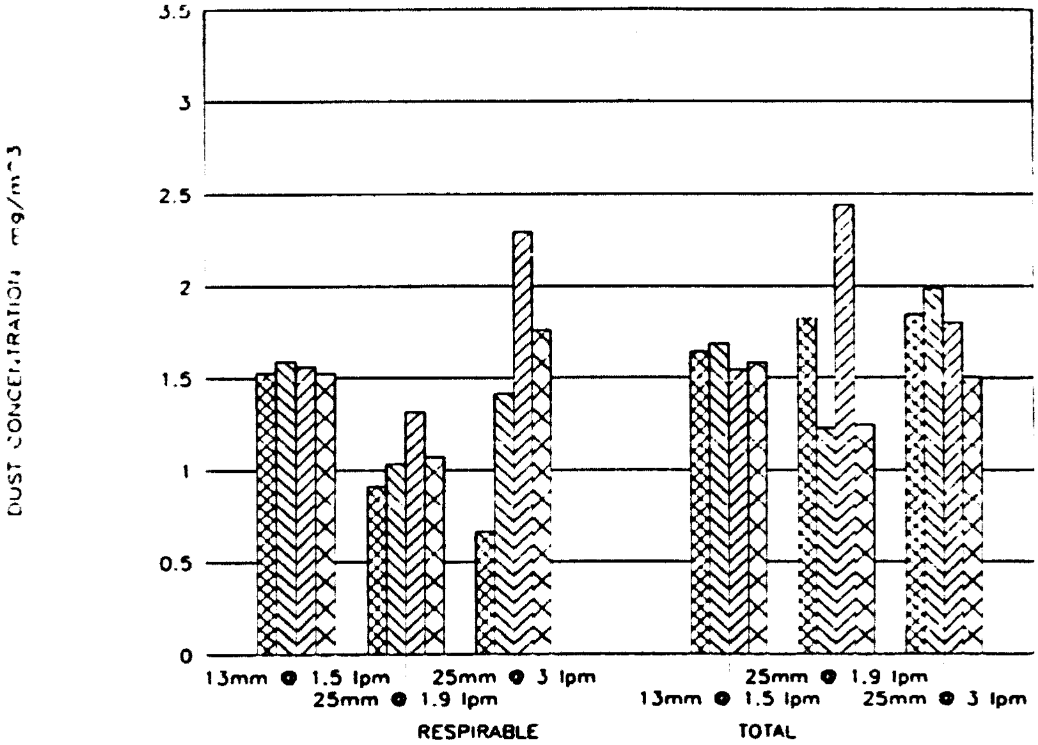


Figure 42 <u>**RESPIRABLE AND TOTAL DUST, SHIELDED, COLLECTED AT THREE SAMPLING RATES**</u>

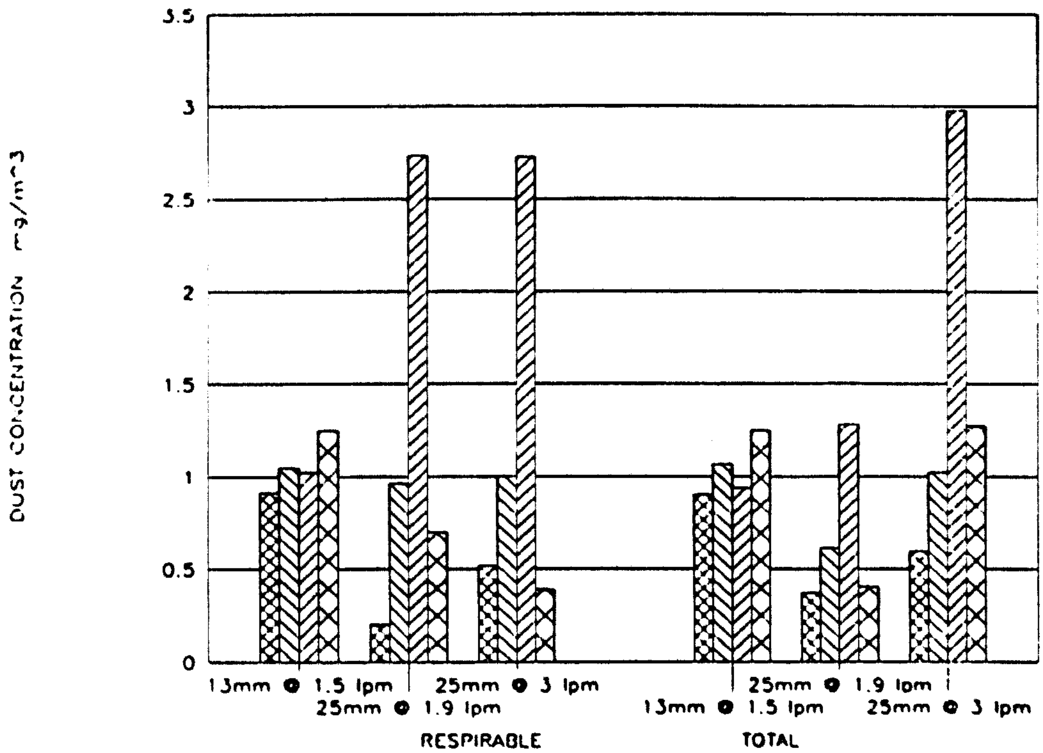


Figure 43 <u>**RESPIRABLE AND TOTAL DUST, SHIELDED, COLLECTED AT THREE SAMPLING RATES**</u>

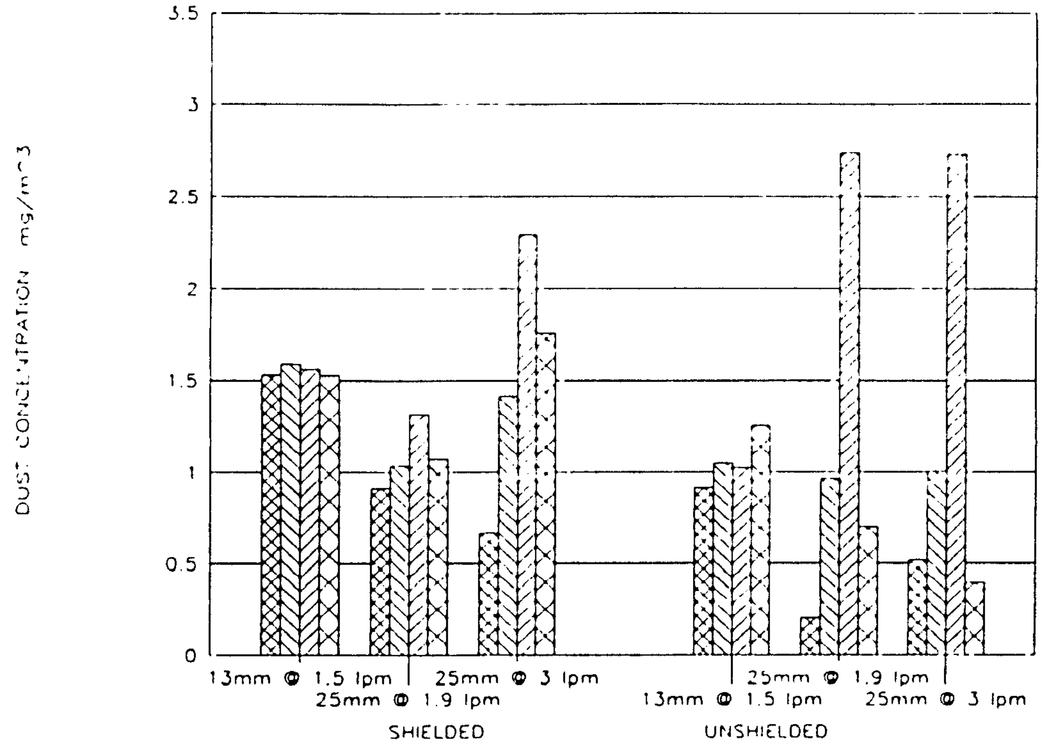


Figure 44 SHIELDED AND UNSHIELDED RESPIRABLE DUST COLLECTED AT THREE SAMPLING RATES

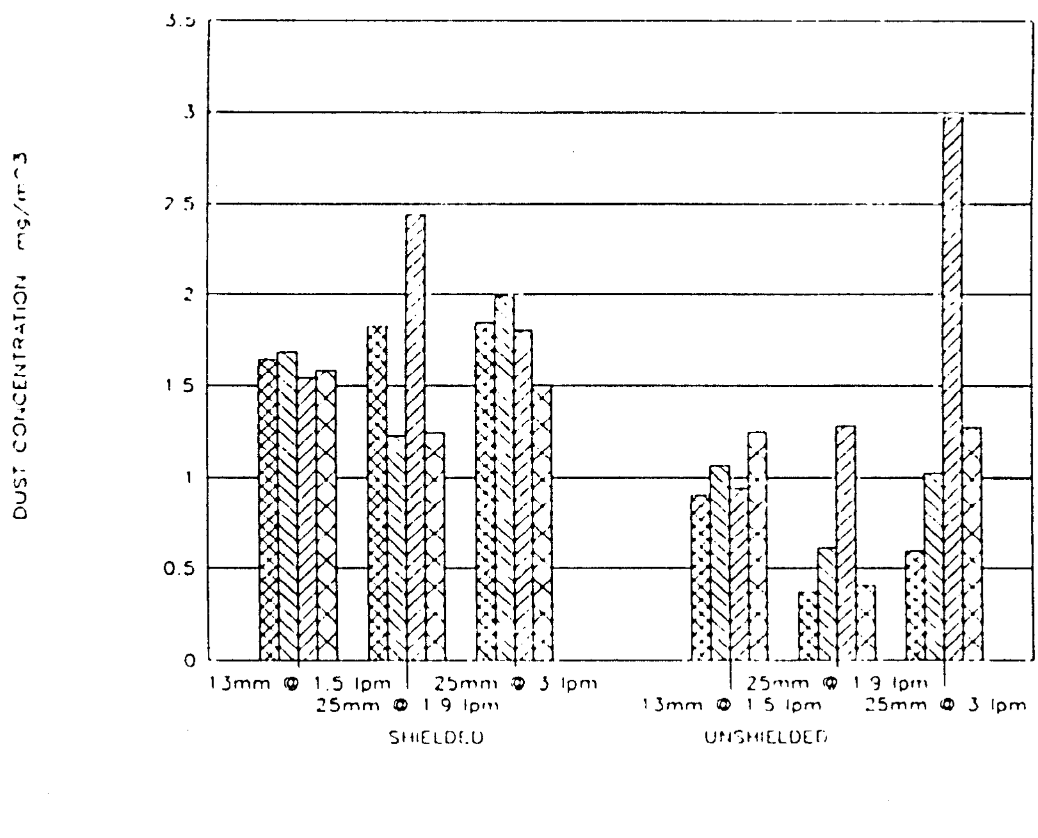


Figure 45 SHIELDED AND UNSHIELDED TOTAL DUST COLLECTED AT THREE SAMPLING RATES

3.3.3 Porosity Tests

The sampling pump arrangement is shown in Figure 46 for the first test series. Total dust samples were collected by removing the plugs from the cassettes.

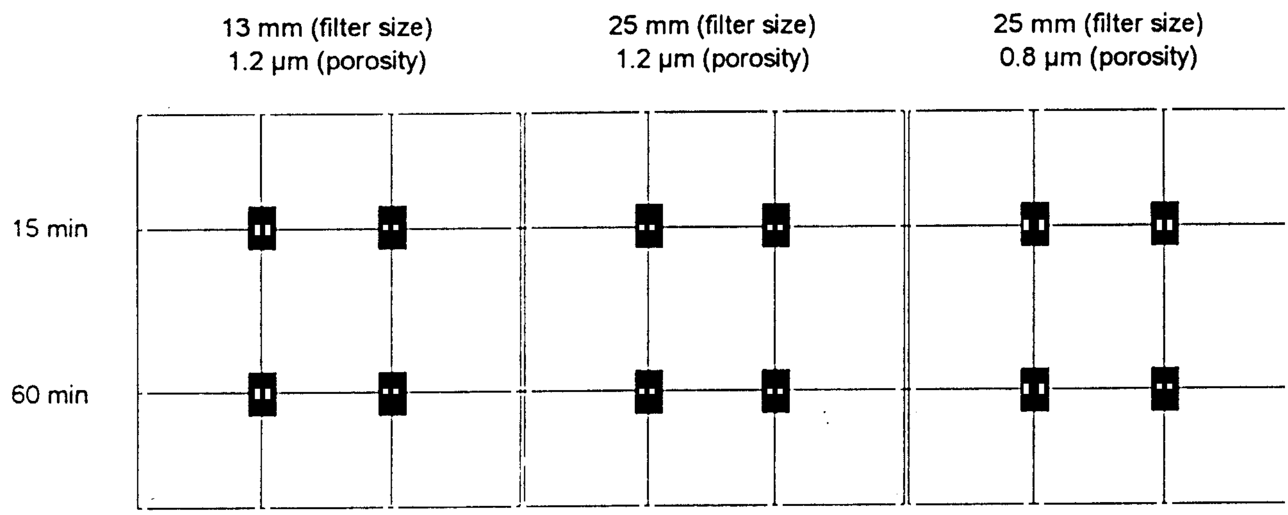


Figure 46 SAMPLING PUMP ARRANGEMENT FOR THE FIRST FILTER POROSITY TESTS

Shown in Table 5 are the results of the first sampling exercise. Tests were not conducted at a sampling rate of 3 ℓpm because it was considered that this flow rate would never be used for full shift monitoring. Also, there did not appear to be any merit in sampling at this high flow rate for short duration monitoring with a mismatched separating cyclone.

TABLE 5 RESULTS OF THE FIRST FILTER POROSITY TESTS

	15 MINUTE TESTS	STANDARD TOTAL DUST COLLECTION		60 MINUTE TESTS	STANDARD TOTAL DUST COLLECTION	
	13mm 1.5 lpm POROSITY 1.2 mg/m^3	25mm 1.9 lpm POROSITY 1.2 mg/m^3	25mm 1.9 lpm POROSITY 0.8 mg/m^3	13mm 1.5 lpm POROSITY 1.2 mg/m^3	25mm 1.9 lpm POROSITY 1.2 mg/m^3	25mm 1.9 lpm POROSITY 0.8 mg/m^3
RUN 1	0.343	1.291	1.758		0.649	0.447
	0.413	0.698	0.943		0.527	0.856
AVERAGE	0.378	0.995	1.351		0.588	0.652
RUN 2	0.494	1.640	1.653	0.12	0.447	0.123
	0.507	1.501	1.992	0.308	0.527	0.565
AVERAGE	0.501	1.571	1.823	0.214	0.487	0.344

Figure 47 graphically depicts the results of this investigation.

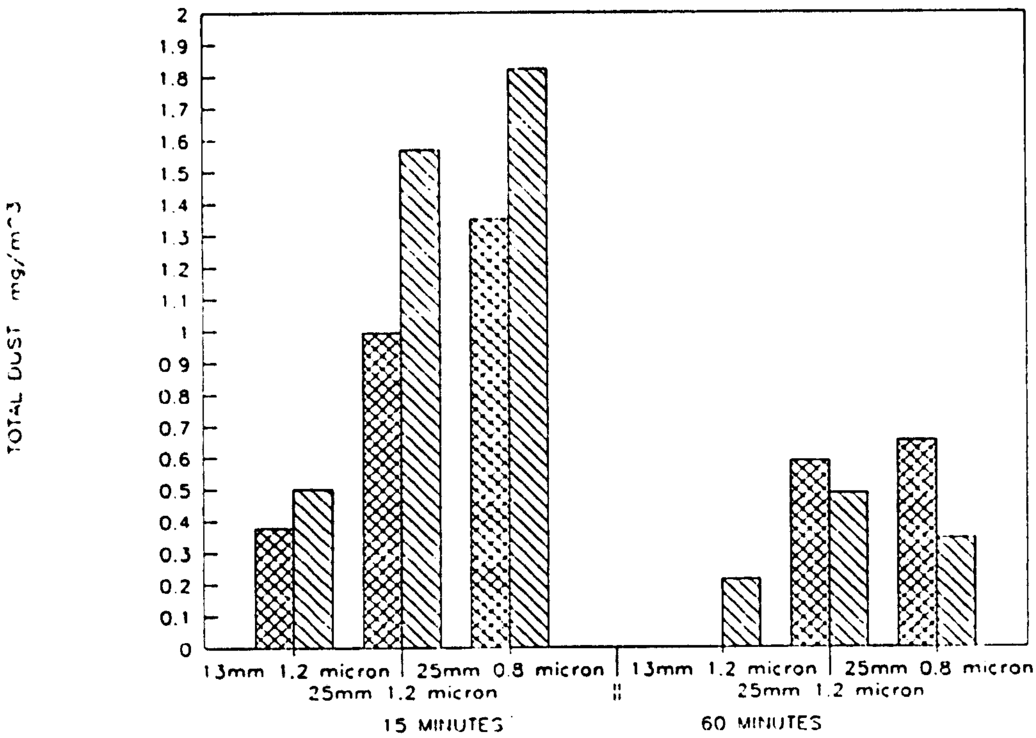


Figure 47 TOTAL DUST SAMPLING RATE AND FILTER POROSITY COMPARISON FOR THE FIRST POROSITY TESTS

Results of the second set of porosity tests are set out in Table 6. In these tests total dust samples were collected as open face samples.

The arrangement of the sampling pumps and grid is shown in Figure 48. Any given pump was always suspended at only one sampling point.

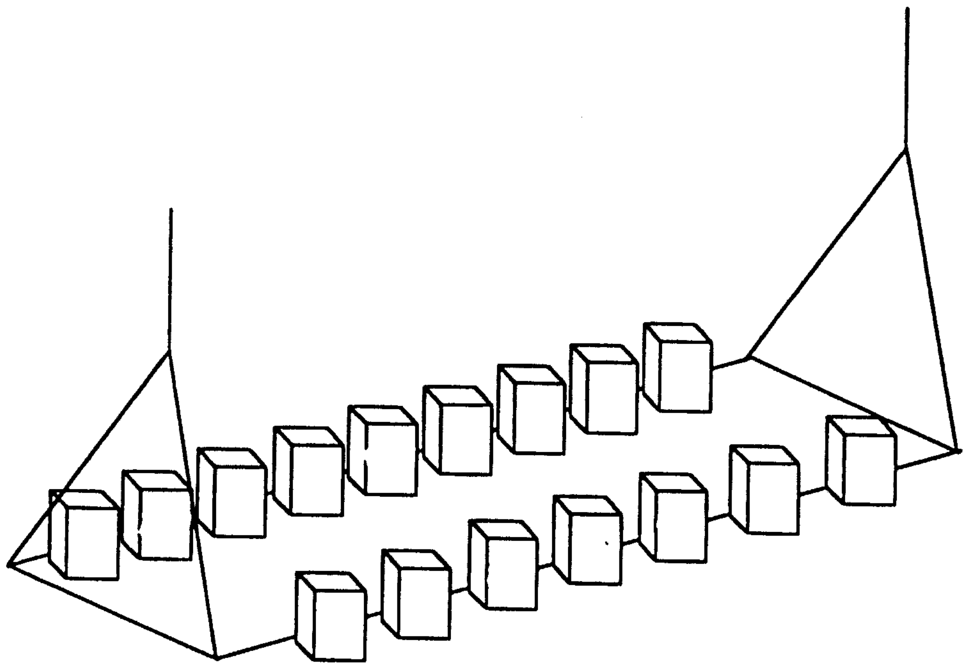


Figure 48 SAMPLING PUMP AND GRID ARRANGEMENT FOR THE SECOND SET OF POROSITY TESTS

The results shown in Table 6 have been analysed and are graphically depicted in Figures 49 to 54.

Under the test conditions, differences in results from the different porosity filters was more likely to have been due to actual differences in a non-homogenous dust stream than to differences in filter performance. This is seen in the occasional higher or lower result in the grid. This is also considered to be the reason for differences in the cumulative dust loads compared.

An important result can be seen in the comparison of 15 minute average dust concentrations with those of one hour samples. The 15 minute samples indicate considerable variation in dust concentrations, but the longer duration (one hour) samples can give no hint of the variations, however significant, because they are one hour averages.

Table 6 RESULTS OF SECOND FILTER POROSITY TESTS

	Test Number	Filter Dia	Pump Number	Porosity Micrometres	Run Time min	Vol Samp m³	Mass Collected mg	Cumul Mass mg		Actual Conc mg/m³
	1	25	D12	0.8	15	0.029	0.299	0.299		10.45
	2	25	D12		15	0.029	0.192	0.491		6.71
15 Minute	3	25	D12		15	0.029	0.429	0.920		15.00
Tests	4	25	D12		15	0.029	0.646	1.566	1.566	22.59
	5	25	D12		15	0.029	0.131	1.697		4.58
	6	25	D12		15	0.029	0.131	1.828		4.58
	7	25	D12		15	0.029	0.254	2.082		8.88
	8	25	D12		15	0.029	0.011	2.093	2.093	0.39
	1	25	D10	0.8	15	0.029	0.146	0.146		5.07
	2	25	D10		15	0.029	0.276	0.422		9.58
15 Minute	3	25	D10		15	0.029	0.522	0.944		18.13
Tests	4	25	D10		15	0.029	0.713	1.657	1.657	24.70
	5	25	D10		15	0.029	0.240	1.897		8.33
	6	25	D10		15	0.029	0.150	2.047		5.21
	7	25	D10		15	0.029	0.337	2.384		11.70
	8	25	D10		15	0.029	0.030	2.414	2.414	1.04
	1	13	D1	1.2	15	0.023	0.114	0.114		5.05
	2	13	D1		15	0.023	0.084	0.198		3.72
15 Minute	3	13	D1		15	0.023	0.240	0.438		10.62
Tests	4	13	D1		15	0.023	0.316	0.754	0.754	13.99
	5	13	D1		15	0.023	0.076	0.831		3.38
	6	13	D1		15	0.023	0.054	0.884		2.37
	7	13	D1		15	0.023	0.162	1.046		7.15
	8	13	D1		15	0.023	0.010	1.055	1.055	0.42
	1	13	D4	1.2	15	0.023	0.089	0.089		3.90
	2	13	D4		15	0.023	0.119	0.208		5.25
15 Minute	3	13	D4		15	0.023	0.194	0.402		8.54
Tests	4	13	D4		15	0.023	0.328	0.730		14.47
	5	13	D4		15	0.023	0.066	0.796		2.92
	6	13	D4		15	0.023	0.043	0.839		1.91
	1	25	10	0.8	60	0.115	1.119	1.119		9.73
60 Minute	2	25	10		60	0.115	0.780	1.899		6.78
Tests	1	25	D13		60	0.114	1.260	3.159		11.10
	2	25	D13		60	0.114	0.776	3.935		6.84
	1	13	D2	1.2	60	0.091	1.518	1.518		16.68
60 Minute	2	13	D2		72	0.109	0.915	2.433		8.41
Tests	1	13	D5		60	0.090	0.930	3.363		10.31
	2	13	D5		60	0.090	0.416	3.779		4.62
	1	25	9	1.2	63	0.118	1.549	1.549		13.14
60 Minute	2	25	9		60	0.112	0.906	2.455		8.07
Tests	1	25	6		60	0.115	1.122	3.577		9.77
	2	25	6		60	0.115	0.599	4.176		5.22
Two Hour	1	25	12	0.8	121	0.231	0.159			0.69
Tests	2	25	D15		120	0.229	1.837			8.02
Two Hour	1	13	D11	1.2	120	0.182	1.509			8.27
Tests	2	13	D3		120	0.181	1.931			10.60
Two Hour	1	25	5	1.2	120	0.230	0.259			1.13
Tests	2	25	8		120	0.228	2.352			10.32

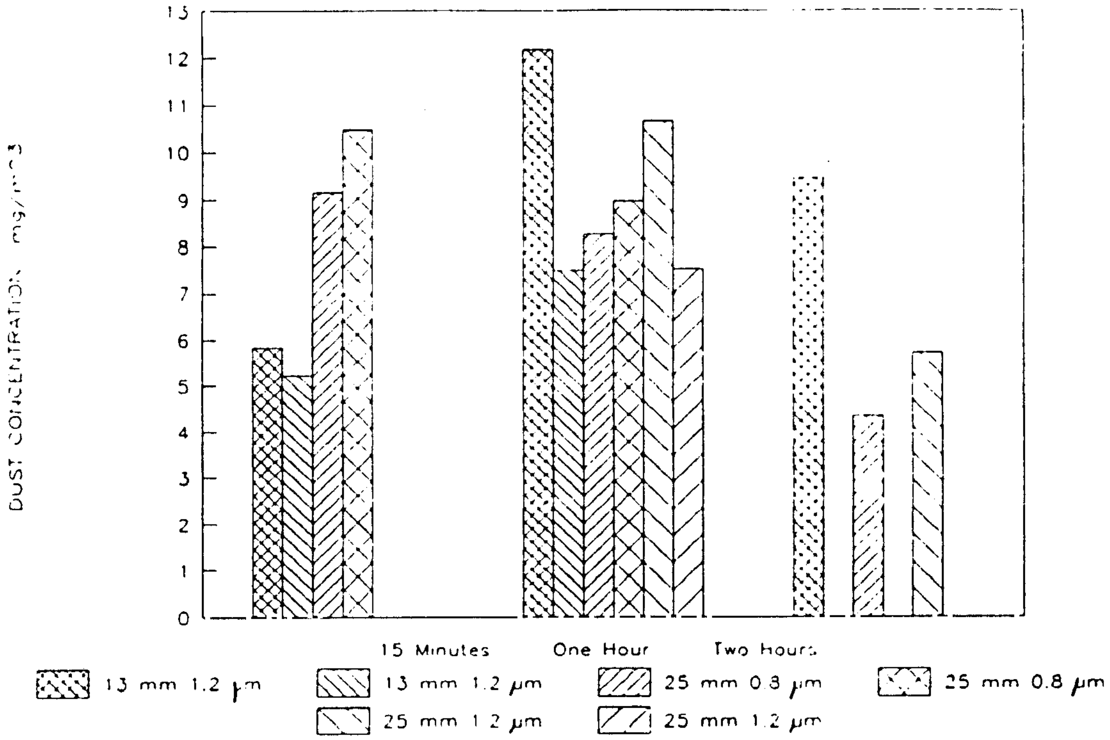


Figure 49 TOTAL DUST SAMPLING RATE AND FILTER POROSITY COMPARISON FOR THE SECOND POROSITY TESTS

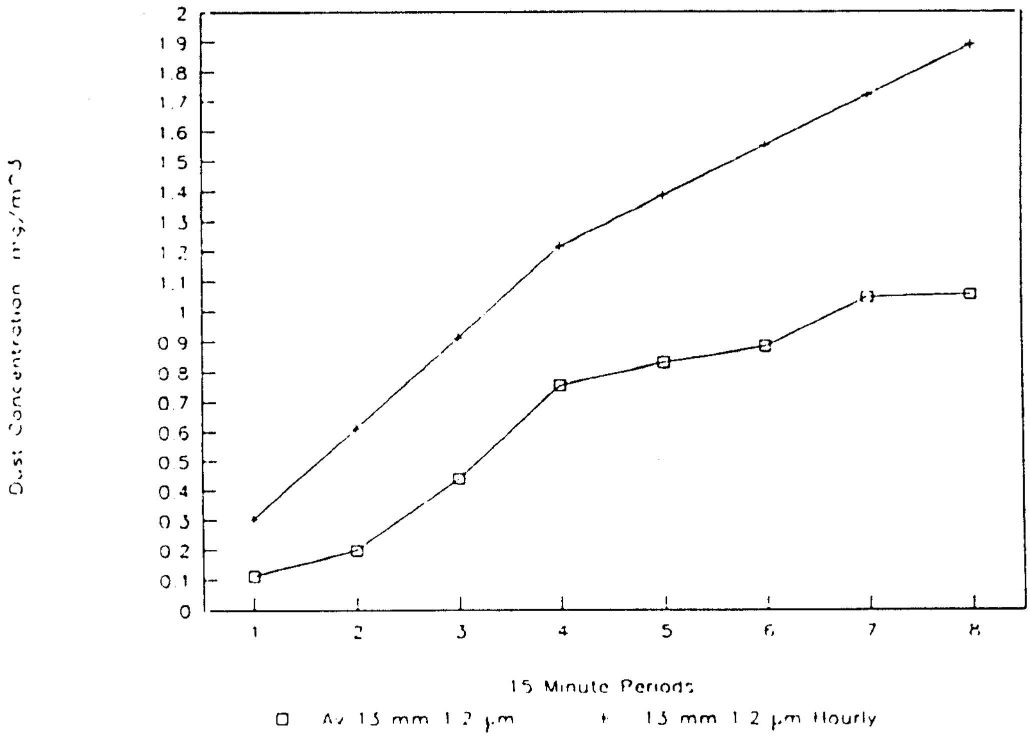


Figure 50 CUMULATIVE DUST LOADS OVER TWO HOUR SAMPLE PERIOD FOR 13 mm FILTERS - TEST 2

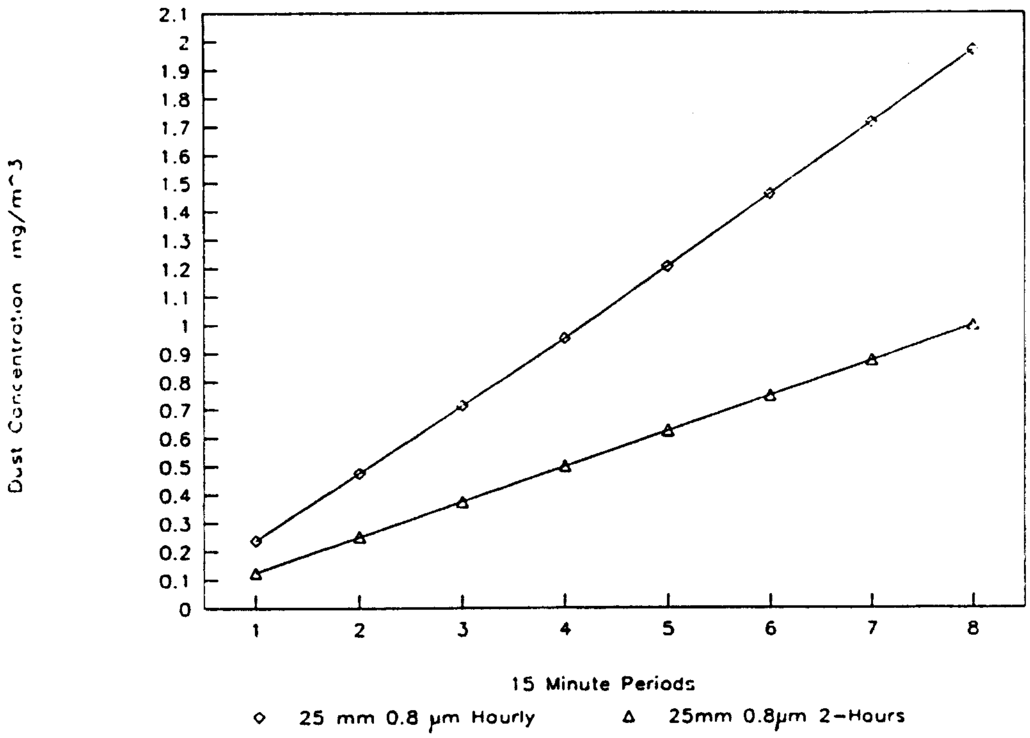


Figure 51 CUMULATIVE DUST LOADS OVER TWO HOUR SAMPLE PERIOD FOR 25 mm 0.8 μm POROSITY FILTERS - TEST 2

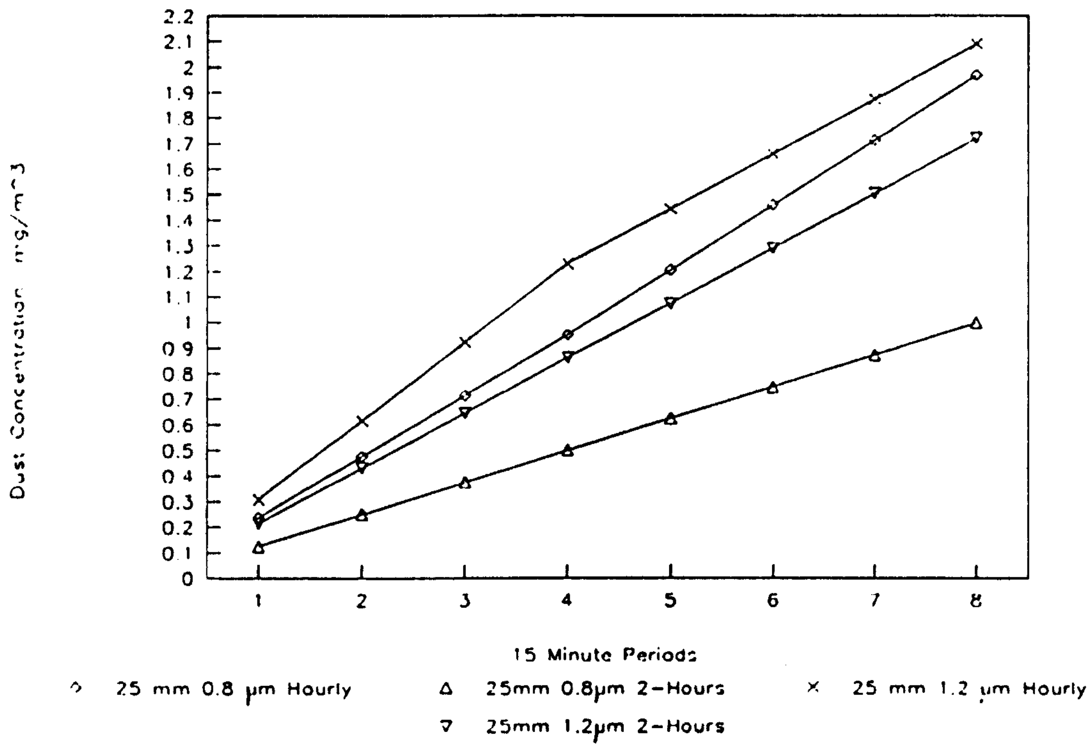


Figure 52 CUMULATIVE DUST LOADS OVER TWO HOUR SAMPLE PERIOD FOR 25 mm FILTERS - TEST 2

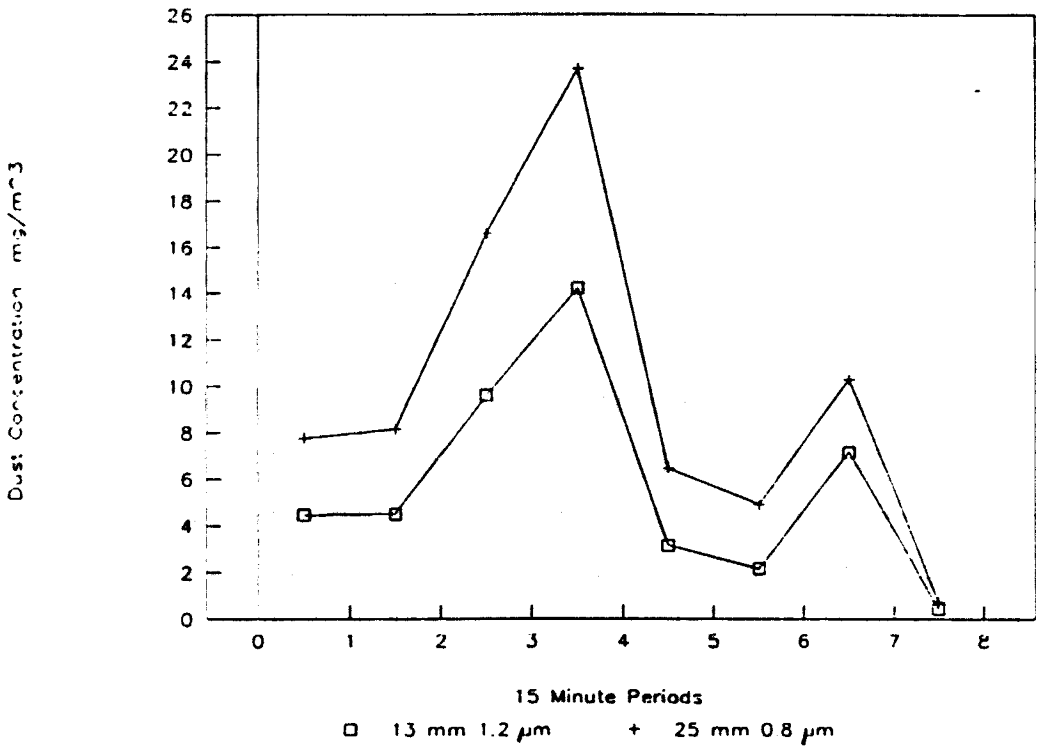


Figure 53 DUST CONCENTRATIONS FOR 15 MINUTE PERIODS FOR 13mm - 1.2 μm, 25 mm - 0.8 μm POROSITY FILTERS - TEST 2

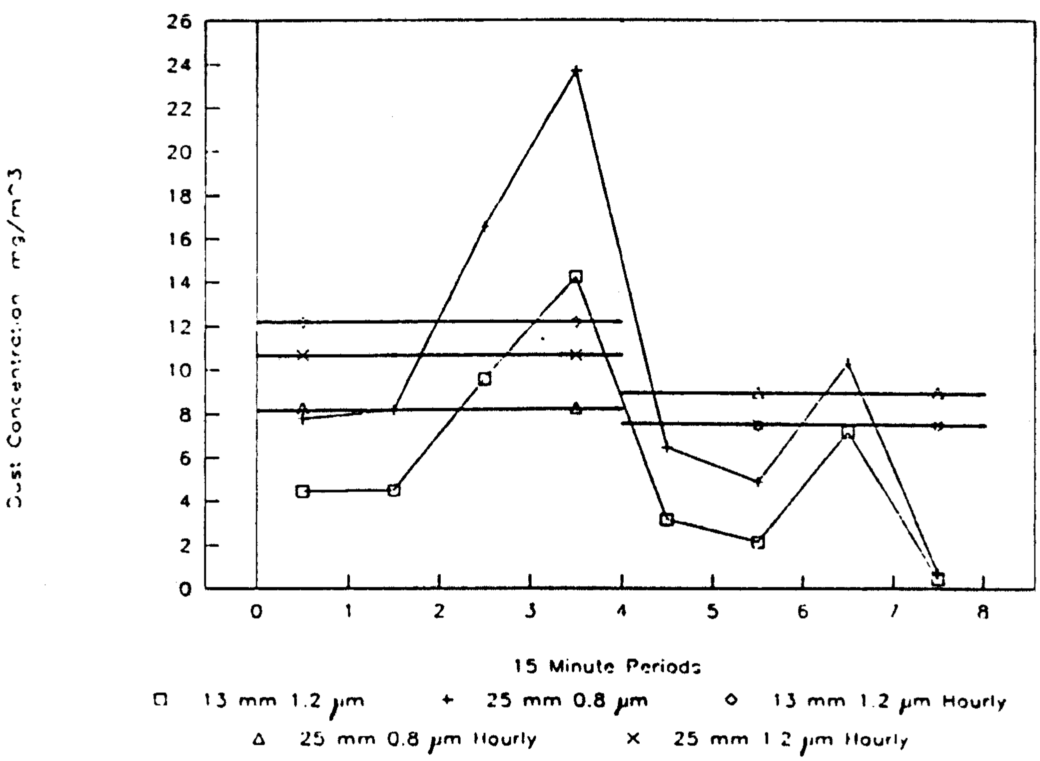


Figure 54 DUST CONCENTRATIONS FOR ALL FILTERS TESTED OVER TWO HOUR SAMPLE PERIOD - TEST 2

3.4 Discussion

3.4.1 Monitoring Exercise 1

It had been considered that total dust samples, because of inherently higher sample masses, could be used in place of respirable dust samples as indicators of workplace dust levels, particularly where dust concentrations are very low. However, on the first set of tests for the first monitoring investigation no significant differences could be found in results obtained for respirable or total dust, irrespective of filter size or sampling rate. This is seen in Figures 13, 18, 19, 30 and 31. These results indicate that there would be no advantage in collecting total dust samples in place of respirable dust samples.

In a comparison of filter sizes and sampling rates, Figure 14 shows that sampling at 1,9 ℓpm with a 25 mm filter returned higher dust concentrations than did the 1,5 ℓpm 13 mm filter arrangement. No clear differences could be found when a similar comparison was made between 1,5 ℓpm - 13 mm filters and 3 ℓpm 25 mm filters (Figure 15).

In a further comparison, shown in Figure 20, dust concentrations collected at 1,9 ℓpm are higher than those collected at 3 ℓpm. All filters used were 25 mm.

Similar comparisons were made for total dust samples and the results are plotted in Figures 16, 17 and 21. Once again dust concentrations of samples collected at 1,9 ℓpm were higher than those collected at 1,5 and 3 ℓpm, and those collected at 3 ℓpm were higher than those collected at 1,5 ℓpm.

Composite results for the first five tests of the first monitoring exercise are shown for respirable and total dust in Figures 22 and 23 respectively. Similarly, composite results are plotted for the second set of six tests in Figures 24 and 25.

By plotting results of all three sampling rates side by side the dust concentrations measured at 1,9 ℓpm can be seen to be higher than for other sampling rates for respirable dust. However, the dust concentrations at 3 ℓpm for total dust were found to be higher than for the other two sampling rates for the second set of six tests.

These findings are better illustrated in Figures 26 and 27. In Figure 26 the results for the respirable dust collected at the three sampling rates have been grouped separately from the results of the total dust samples. The same grouping was done for the second set of six tests in Figure 27.

With regard to the first test site, little difference can be seen between total dust and respirable sample concentrations. This is probably due to the fact that the bulk of the coarse particles had settled out of the airstream before it entered the Return Airway where sampling took place. It is, however, apparent that the dust samples collected at 1,9ℓpm give higher dust concentrations than those collected at a slower or higher rate. This can be explained by the fact that the same type of separating cyclone was used in all sampling configurations. The air velocity through the slot into the cyclone varies with the collecting rate as does the separating efficiency. The design sampling rate is 1,9 ℓpm and the results obtained from these samples are more likely to be representative of conditions than those collected at the other two sampling rates.

The total dust samples were not open face samples but samples collected by removing the plug from the cassette as per the GME's guidelines [(2)]. Once again sampling efficiencies were affected by sampling rates deviating from the standard 1,9 ℓpm. It is thus obvious that sampling components should not be mismatched.

3.4.2 Monitoring Exercise 2

In the second set of six tests of the first monitoring exercise, the results of sampling at 1,9 ℓpm were higher than those for the other two rates, confirming the above findings. As far as the total dust samples are concerned, the results are different from those reported above with the concentrations apparently ascending with ascending sampling rates but differences are only slight. This is clearly seen when averages are compared. These results are probably affected by the presence of more coarse particles than was the case for the first test series. Clearly, equipment components must be performance matched and since results are achievable using a standard sampling train there are no justifiable reasons to deviate from this configuration.

In the second monitoring exercise, in addition to testing different filter sizes and sampling rates, the effect of shielding was also investigated. The shielding represented the situation when the wearer of the pump was facing away from the airstream and therefore obstructing the flow rate over the sampling pump.

The effects of shielding are illustrated in Figure 28 when respirable dust samples are compared with total dust samples for 13 mm filters sampled at 1,5 ℓpm. It can be seen that, contrary to expectations, both the respirable and total dust shielded samples realized higher dust concentrations than the unshielded samples. This is also clearly seen in Figures 33 and 39. The pattern of shielded dust concentrations exceeding unshielded concentrations was repeated for the samples collected at 1,9 ℓpm and 3 ℓpm as seen in Figures 29 and 30 respectively. These last two Figures indicate that the phenomenon persisted for respirable and total dust. In Figure 40 it can be seen that the shielded dust concentrations for samples collected at 1,9 ℓpm are higher than for the unshielded although Figure 34 indicates that the differences are small. A similar comparison is made for samples collected at 3 ℓpm, as depicted in Figure 41, but in this case the bias is much less evident. The unexpected results were most likely due to turbulence caused by the shielding and the prevention of a "flushing" airstream.

The results of all the respirable dust samples are shown in Figure 31 and those of the total dust in Figure 32. There does not appear to be any bias towards any particular sampling rate.

To make this clearer, the respirable shielded and unshielded samples were separated and plotted in Figures 35 and 36 respectively. These figures confirm no bias towards a particular sampling rate but do show that the shielded samples were giving higher dust concentrations than the unshielded samples (see above).

To assist in easier detection of trends, the respirable and total dust samples were grouped for shielded and unshielded samples. These results are shown in Figures 42 and 43. In addition, the shielded and unshielded samples were then grouped for respirable and total dust sampling and shown in Figures 44 and 45.

All the above were additionally grouped according to sampling rates. There is no particular bias towards a sampling rate or towards respirable or total dust except for the shielded total dust samples. Shielded samples also yield higher dust concentrations than unshielded samples.

This bias towards higher concentrations for shielded samples was unexpected and could have been due to the fact that any high dust concentrations were not being "flushed" from behind the shielding. This is unlikely to occur in practice as the wearer of the pump will not spend the entire shift facing away from the airstream. The results therefore have no practical significance in the implementation of gravimetric dust sampling.

3.4.3 Porosity, and Sampling Time, Tests

As can be seen in Figure 47 the 15 minute samples collected at 1,9 ℓpm on 0,8 μm porosity filters gave the highest dust concentrations. As could be expected the 0,8 μm filter built up a greater dust load than the 1,2 μm filter at the same sampling rate. The samples collected at 1,5 ℓpm on 1,2 μm filters showed much lower dust loadings than the other two filters. Although these were all total dust samples, *they were not open face samples* and the sampling rates and sampling orifices could have had an influence on results.

The results of the 60 minute samples were more compatible than the shorter duration samples, but the two samples collected at 1,9 ℓpm still had higher dust loadings than the 1,5 ℓpm sample. The 60 minute samples would be more the equivalent of "traverse" samples than short duration samples. The concept of "traverse" samples will be discussed in the next section.

One important point to note is that the 60 minute sample results showed much lower dust concentrations than the 15 minute samples. A variable dust load could have diluted the dust concentrations thereby lowering the 60 minute average.

A second set of porosity and sampling time tests was carried out with the same diameter filters but total dust samples were collected using a true open face sampling technique.

This was done to minimise the influence of air being drawn through a comparatively small hole in the cassette (plug hole), and then entering the cassette chamber which could act as a plenum and thereby affect deposition.

Under the second test conditions the one hour test results appeared to be higher for the 13 mm filters than the 15 minute averages for these filters (Figure 49). This is completely opposite to the results obtained for the first test. The two hour samples collected on 13 mm filters also indicate lower dust concentrations than the one hour samples. The 15 minute samples collected on 25 mm filters of 0,8 μm porosity were higher than for either the one hour or two hour samples. The two hour samples collected on 25 mm 1,2 μm porosity filters rendered lower dust concentrations than for the same type of filters deployed over one hour intervals. With the exception of one 13 mm filter, the results obtained over the one hour sampling interval are fairly uniform and would be more so if the averaging process was extended once more.

The differences seen in the results over the three sampling intervals, with a variation in dust concentration levels for a given filter porosity, are more due to the effect of a non-homogeneous dust load than to filter porosity. This can be seen more clearly in the following figures. In Figure 50 the cumulative dust loadings for the 15 minute samples are shown with results of the one hour sample averages. The cumulative one hour dust loadings are seen to be almost twice the cumulative dust loadings for the 15 minute samples. Since the samples were collected in the same airstream but not exactly side by side, the differences in dust masses collected could have been due to a non-homogeneous dust concentration.

In Figure 51 a similar picture is seen when one hour and two hour samples for 25 mm filters of 0,8 μm porosity are compared. Once again the sampling pumps were in the same airstream but at different points in the airstream which could have been at different concentrations. When a comparison of all 25 mm filters is made (Figure 52) three of the filters returned results which were close in magnitude and within experimental error and the fourth result, already discussed, could have been due to a lower dust concentration at the sampling point. The average dust concentrations for each 15 minute sampling period were plotted for the 13 mm filters of 1,2 μm porosity and the 25 mm filters of 0,8 μm porosity. The results are shown in Figure 53. Variations in concentrations over each 15 minute period are clearly demonstrated. The dust levels for the 13 mm filters are lower than those for the 25 mm filters but the dust concentrations tracked each other very well. At the same dust concentrations it was not anticipated that filters of different sizes and porosities would give different results. The differences in dust concentrations seen in Figure 53 could therefore be ascribed to actual differences in dust levels at the sampling positions of the different pumps. The results shown in Figure 55 clearly indicate that dust concentrations were not in a steady state or in equilibrium. This is an important observation and the non-steady state of dust levels can be shown to be common in the workings. The impact of fluctuating dust levels on sampling strategies will be discussed in the next section.

In addition to the 15 minute dust concentrations the one hour averages for the 13 mm, 25 mm (0,8 μm) and 25 mm (1,2 μm) filters were plotted and are shown in Figure 54. The one hour concentrations give a false impression of steady state conditions. The second hour concentrations are lower that the first hour's, which mirrors the results of the 15 minute samples and thus shows fluctuations over a longer time base. The longer the time base, the greater will be the effect of averaging and the peaks and valleys in the fluctuations thus go undetected. This is also an important principle which impacts on sampling strategies and will also be discussed in the next section. Owing to non-homogenous dust levels at the sampling stations, the dust concentrations measured on the filters of different porosity were not equal and differences in dust concentrations for the hour tests were considered to be due to these variations rather than to differences in filter behaviour.

3.5 Conclusions

The overall conclusions are that the most reliable results were obtained when sampling at a flow rate of 1,9 ℓpm with a 25 mm diameter filter of 0,8 μm porosity. Other flow rates gave lower dust concentrations, largely due to a mismatch of filter and cyclone characteristics. Differences between total dust and respirable dust results were not clearly distinguishable and this was considered to be because the coarse dust particles had settled out of the airstream before it reached the test zone. A change to total dust sampling is considered to be unjustifiable and one that could complicate rather than benefit gravimetric dust sampling.

Surprisingly, shielded dust concentrations were found to be higher than unshielded concentrations - under conditions where pumps are shielded for long intervals, dust concentrations are likely to be higher than when pumps are not shielded. Turbulence on the downstream side of this shielding and the absence of a "flushing" airstream are the most likely causes for the elevated dust concentrations. However, shielding would not affect personal dust samples to any marked extent because the wearer of the pump is unlikely to shield the pump for an entire shift.

Under the test conditions, as could be expected, filters of 0,8 μm porosity built up a greater dust load than did the 1,2 μm filters at the same sampling rate and over the same sampling time. The samples collected at 1,5 ℓpm on 1,2 μm porosity filters showed much lower dust loadings that the other two filters tested. Comparing filter porosities in a non-homogeneous dust stream is difficult and filter porosity should be selected when the characteristics of the dust to be sampled are known. The size distribution of the dust to be sampled is a very important parameter in filter selection and, unless all samples are collected on filters of the same porosity comparisons of dust concentrations should not be made.

Tests conducted over different time intervals were aimed at establishing if dust deposits are made uniformly on the filters or if the filters "blind" quickly causing dust deposition rates to decrease significantly with time. If filters were found to blind within a short time period then it would have been concluded that incorrect dust loadings were being reported for eight hour shifts. There is insufficient evidence for absolute conclusions to be drawn.

Due to the non-homogeneous nature of the dust stream at the test site, differences in dust loadings on the test filters were most likely to have been due to this than to actual differences in performance of different filters used at different sampling rates.

When one hour or two hour dust concentrations are plotted a false impression of steady state conditions is given. The average concentrations over 15 minute intervals showed significant differences over successive intervals. The longer time base has the effect of averaging the peaks and valleys, which thus go undetected. Not detecting peak concentrations is becoming an important issue and could impact heavily on sampling strategies.

When sampling over short time intervals such as 12 to 15 minutes there may be a concern that under conditions of very low dust concentrations there may be insufficient dust on the filter to be able to weigh it accurately. Under such conditions dust concentrations could simply be reported as too low to assess (TLA) and there should be no concerns for health problems in such areas.

B. STRATEGIC DIRECTION

4. SHORT DURATION SAMPLING

4.1 Introduction

When gravimetric dust sampling was introduced into gold and platinum mines all official sampling with konimeters ceased since mines were unwilling to conduct surveys using two different types of instruments and different sampling strategies and techniques. The "snap" konimeter samples were used to give an indication of the dustiness of working places, or whether remedial measures were needed to reduce or control dust levels and their effectiveness. By taking samples at specific time intervals, decay patterns of a dust cloud, such as in a development end or a stoping section after a blast, could be determined.

The konimeter was unsuitable for studies of dose over a shift long exposure. By contrast gravimetric samplers are designed specifically to determine personal exposures over a full shift but, in the South African mining context, have only been used to calculate a mine risk on which a compensation levy is then based.

A previous study[1] indicated large intra- and inter-shift differences in dust concentrations for a given employee. Peak dust concentrations and their durations and very high dust concentrations during the full shift measurement cannot be identified and therefore remain undetected. Because of the extensive averaging system used to arrive at a mine "risk", even high 8-hour Time Weighted Averages become masked. Even if such high dust concentrations are noted very soon after their measurement, the reasons for the elevated levels and places where high dust concentrations may have been encountered can not readily be identified. If any high dust concentration is detected in the mine's report at the conclusion of a sampling cycle (every six months), the possibility of locating the person and retracing his movements for that particular shift to try to establish reasons for the high dust concentration must be regarded as remote, especially since certain working places could have closed down since the sample was collected. Thus, for this sampling system the results are not usable for control purposes.

It thus became obvious that shift long exposures were of little use for determining the levels of dustiness in workplaces or in identifying workplaces or processes where unsatisfactory amounts of dust are liberated. For internal control purposes many conscientious mines reinstated konimeter dust sampling, albeit unofficially. Other mines simply complied with the minimum requirements of the law, viz to carry out dust sampling for the calculation of mine "risk".

It also became clear that, when large numbers of samples are collected, any efforts to reduce dust levels on a mine are unlikely to be detected in the present sampling strategies. The situation is exacerbated for "risk" determination by the large variation in both dust and quartz concentrations that can be encountered in shift-wise variations of both these parameters.

The personal gravimetric dust sampling strategy could prove very useful for determining personal exposure levels and the results for a given occupation could be pooled for a representative exposure of an occupation group and thereby yield useful information. Such data, in fact, provide the basis for good epidemiological studies and estimates of worker exposure.

As an alternative to using konimeters for control dust sampling, a way was sought whereby gravimetric dust sampling equipment could be used to indicate levels of dustiness in workings. The technique should assist in identifying workplaces where unsatisfactory amounts of dust are liberated and the reasons therefor. The technique should also assist in determining if any remedial control actions have been effective. In addition, the technique should permit communicating the results of measurements on standard environmental engineering reports together with the results of other environmental measurements. In this way attention can be directed to unacceptable conditions and practices with the aim of improving the levels of dustiness in mines and should be of particular benefit to those mines where control dust sampling was completely abandoned.

Although Tyndallometers monitor *aerosol* concentrations, on a continuous basis, they are useful to indicate just how these concentrations can vary within a very short space of time (Figure 55).

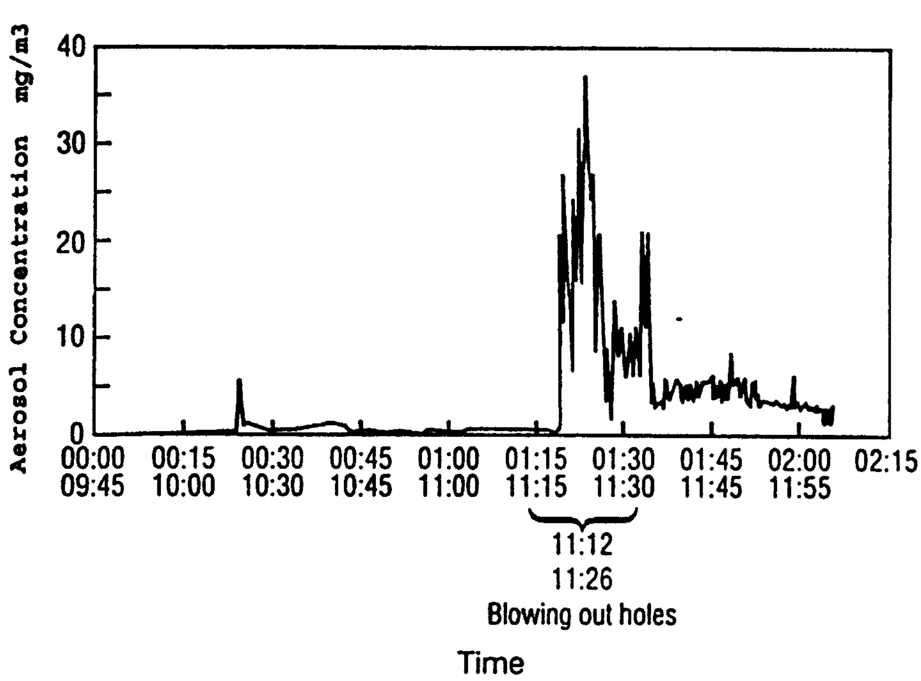


Figure 55 CONTINUOUS TRACE OF AEROSOL CONCENTRATIONS MEASURED BY A TYNDALLOMETER

This trace can explain why successive konimeter dust counts can vary substantially from each other. The differences are probably due to actual variations in dust concentrations and not, as has been widely thought, solely due to instrument error. It can readily be seen that the average concentration can be low even though very high peaks may exist. The longer the sampling period, the greater will be the effect of averaging and the less representative it will be of workplace conditions. Figures 53 and 54 illustrate similar findings with a longer timebase where high peak values are again averaged out of contention in the evaluation of workplace conditions.

On the other hand, the shorter the duration of the sample the closer it approaches being a "snap" sample where substantial differences can be recorded in very short time intervals and high dust concentrations may not be sampled at all. A better indication of workplace dust levels may logically be deemed to lie between the extremes of full shift samples and "snap" samples. With this in mind the concept of short duration workplace dust sampling, utilizing currently deployed sampling equipment, was explored in preliminary tests in a previous project [1]. In these tests the technique employed was to start the sampling pumps when the environmental official reached the first position in a stope, for example, and operated until all other measurements such as air temperatures, air velocity, etc had been completed. This realized a 10 to 12 minute sample. The team then moved on to the next position and repeated the process except that the sampling cassette was exchanged for a "fresh" cassette. In this way separate dust samples were collected in the return from the stope, at several monitoring positions in the stope as well as in the worked out areas and finally in the intake air to the stope. It was clear that differences in dust concentrations at the different measuring stations could be seen and that, where high dust concentrations had been found, the reasons could be reported. Full shift samples collected during the same shift in the working places bore little resemblance to the short duration sample results. It was also observed that if the dust concentration and comments on unsatisfactory conditions were entered on environmental reports, as was done with konimeter dust sampling results, attention could be directed to places and practices where remedial action was necessary. This type of dust sampling could thus assist mines in directing efforts towards dust control and in reinstating dust control sampling. If dust emission or liberation is controlled then personal exposures will also be controlled.

It was considered that short duration sampling could be used as an indication of *workplace* risk. For this reason it became necessary to explore any difficulties that could occur in determining the quartz content of such samples or, generally, in establishing the quartz content of the airborne dust in the workplace. It was previously recommended [1] that an industry average of 20 percent for airborne quartz should be adopted. The implications of moving away from actual quartz concentrations to the industry average also had to be investigated and commented on.

The results of the first trials[1] were very encouraging and based on this, the present research proposal was compiled, presented and then accepted.

4.2 Test Sites

The investigations were conducted at four mines.

4.2.1 Site 1: A deep gold mine in the Gauteng Province producing 215 kT/month with an underground staff complement of 10 500. Mining takes place in three reefs using longwall, mini-longwall and scattered mining methods.

4.2.2 Site 2: A medium depth (1939 m) platinum mine in the North-West Province with an underground labour complement of 2 500 persons. Monthly production is 170 kT from extensive scattered mining operations.

4.2.3 Site 3: A shallow gold mine (1734 m) in the Gauteng area, mining three reefs using mechanized and scattered mining methods. The underground labour force is 10 300 persons and 730 kT/month are mined.

4.2.4 Site 4: This medium depth (2084 m) gold mine is situated in Mpumalanga province and employs 5 900 persons to mine 140 kT/month from a single reef in scattered mining operations.

4.3 Methodology

Standard sampling pumps were used (not the rotating sponge type). However, because it was anticipated that dust loads on the filters could be low after only a 10 to 12 minute sampling time, it was decided to use 13 mm diameter filters instead of the usual 25 mm diameter filters. The use of a smaller filter would give a better dust mass to filter mass ratio than would be possible for light loads with the larger filter. It was also found that the sampling rate had to be decreased to 1,5 ℓpm since the pumps were unable to operate at 1,9 ℓpm with the small filters.

Even though encouraging results had been achieved in the first trials, many aspects of this proposed sampling strategy still remained to be investigated, notably the effects of different filter porosities on results, the effects of using mismatched cyclones and cassettes and the influence of different sampling rates on calculated dust concentrations.

It was also considered that comparisons with konimeter samples and continuous tyndallometer samples would be useful. In addition, workplace or traverse samples were collected for evaluation. These are samples collected by starting a standard sampling arrangement with a 25 mm filter when the working place is entered and stopped when the working place is exited. As well as the abovementioned samples integrated samples were evaluated. Such samples are collected by operating a standard sampling arrangement with a 25 mm diameter filter exactly as a short duration sample, but without changing the filters at each measuring locality. In this way the dust load during each measuring period of 12 to 15 minutes is collected on a single filter.

Over and above all the above samples, full shift samples were collected for comparison.

For the sake of completeness, rotating sponge samples in integrated and traverse mode were also collected.

Towards the end of the tests, short duration samples were also collected in development ends to determine whether or not the technique could be equally well applied in a different monitoring situation. At the last test site, comparisons were also made between total dust samples and respirable dust samples.

As far as possible, pairs of samples were always collected throughout these tests. The following chart indicates what samples were collected.

LISTING OF SAMPLE TYPES COLLECTED AT THE VARIOUS TEST SITES

MINE	FULL SHIFT	SHORT DURATION 13 mm	SHORT DURATION 25 mm	SHORT DURATION SPONGE	INTEGRATED 25 mm	TRAVERSE 25 mm	KONIMETER	TYNDALLOMETER	INTEGRATED SPONGE	TRAVERSE SPONGE	TOTAL DUST 13 mm	TOTAL DUST 25 mm
1	✓	✓			✓	✓	✓	✓				
2	✓	✓	✓	✓	✓	✓		✓				
3	✓	✓	✓					✓	✓	✓		
4	✓	✓	✓					✓	✓	✓	✓	✓

4.4 Results

Extensive short duration surveys were conducted in 41 stopes and 26 development headings, spread over the four test sites. Examples of the individual results of the various dust sampling modes, measuring points and working place layout are shown in Figures 56 to 121. The remaining 69 sketches of the stopes and development ends measured have been appended (Appendix A).

Data from each mine have been compiled into tables for more convenient analyses. The various relationships investigated at the four test sites are then presented graphically.

At Mines 1,3 and 4 it was found not to be possible to determine the amount of quartz present in the short duration samples, irrespective of the size filter used. The detection limit of the X-ray Diffraction method is 20 μg of quartz and this was found to be undetectable in the small masses of dust collected over a 12 - 15 minute duration. Consequently, the traverse and integrated samples were analysed for quartz content, wherever possible, and these results were then used for risk calculation. The calculation of an Air Quality Index and/or risk based on samples which are not eight hour Time Weighted Average samples is not correct for *personal* risk, but, since a *workplace* risk is being investigated, the approach was considered to be justified.

No "risk" calculations were done for Mine 2 since all the airborne samples had a quartz content less than five percent and comparing such results with those based on an industry average of 20 percent quartz would have been meaningless.

4.4.1 Mine 1

Table 7 RESULTS OF SHORT DURATION SAMPLING (MINE 1)

POSITION	STOPE 1			QUARTZ	STOPE 2	QUARTZ	STOPE 3	QUARTZ	STOPE 4	STOPE 5	STOPE 6	STOPE 7	STOPE 8	QUARTZ	STOPE 9	AVERAGES	
		mg/m3	Ave	PERCENT	mg/m3	PERCENT	mg/m3	PERCENT	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	PERCENT	mg/m3	mg/m3	Quartz %
RETURN	2.20		2.20				1.47		1.53	1.40	0.85	1.13	4.78			1.91	
FACE	2.72	2.13	2.43		1.67		1.80		1.53	1.00	1.47	2.47	6.11		2.60		
FACE	3.49	3.21	3.35		2.15		2.00		1.00	1.53	1.33	1.67	1.61		2.87		
FACE	2.15	4.88	3.52		6.53		1.33		0.40		0.67	2.13			2.53		
FACE	2.79	2.47	2.63		30.67		9.52					1.47					
FACE							2.20										
FACE							2.00										
AVE FACE	2.79	3.17	2.98		10.26		3.14		0.98	1.27	1.16	1.94	3.86		2.67	3.14	
OLD AREA	2.19	2.64	2.42		2.12				3.07		0.56		0.78				
OLD AREA					1.60				3.06								
OLD AREA					1.87												
AVE OLD AREA	2.19	2.64	2.42		1.86				3.07		0.56		0.78			1.74	
INTAKE	2.60	3.20	2.90				2.67		2.60	1.33	2.36	1.27			2.33		
INTAKE AVERAGE	2.79	2.87	2.83				2.67		2.60	1.33	2.36	1.27			2.33	2.20	
TRAVERSE	3.97		3.97	0.6	1.48	8.0	1.03	6.9		0.89	0.98	1.09	1.69	13.4	1.26	5.16	7.23
INTEGRATED	0.97	0.64	0.81	10.3	1.42	13.1	1.26	12.7	1.86	1.63	1.45	1.47	3.25	12.1	1.87	7.02	12.05
FULL SHIFT					1.35	5.0			1.26		0.76	0.86	0.42			1.93	

Table 8

RESULTS OF KONIMETER DUST SAMPLES (MINE 1)

POSITION	STOPE 1					STOPE 3					STOPE 4					STOPE 5				
	ppml			Ave		ppml			Ave		ppml			Ave		ppml			Ave	
RETURN	158	90	82	110	101	56	70	62	63	121	150	112	60	107	53	46	30	18	31	67
	106	90	106			124	118	120			46	44	68			70	68	62		
FACE	86	134	122	114	103	140	148	132	140	77	1500	1500	1500	1500	244	70	64	50	61	109
	124	58	128			76	72	84			253	234	246			116	112	100		
FACE	114	196	112	141	183	156	150	138	148	110	1500	1500	378	1126	139	60	44	28	44	103
	252	154	142			126	104	100			152	136	130			128	94	86		
FACE	112	132	126	123	124	130	148	154	144	123	116	108	72	99	40					
	148	104	120			124	110	136			48	42	30							
FACE	88	114	100	101	111	118	132	112	121	137										
	108	124	102			138	130	142												
FACE						88	76	92	85	119										
FACE						120	118	118												
AVE FACE	129	127	119	120	130	122	119	121	128	113	595	587	393	908	141	94	79	66	53	106
OLD AREA	108	1500	76	561	94						180	198	212	197						
	102	82	98																	
OLD AREA											166	154	146	155						
OLD AREA																				
AVE OLD AREA	105	791	87	561	94						173	176	179	176						
INTAKE	106	132	148	129	139	178	162	160	167	77	112	94	52	86		130	32	16	59	
·	124	114	180			90	68	74												
INTAKE																				
AVERAGE	115	123	164	129	139	134	115	117	167	77				86					59	

POSITION	STOPE 6					STOPE 7					STOPE 8				
	ppml			Ave		ppml			Ave		ppml			Ave	
RETURN	114	66	54	78	82	86	90	82	86	93	132	148	140	140	144
	66	88	92			100	104	74			128	146	158		
FACE	86	20	30	45	121	138	114	86	113	111	142	158	122	141	126
	180	72	112			148	92	92			100	134	144		
FACE	302	1500	1500	1101	145	148	112	100	120	129	72	64	78	71	88
	146	158	130			126	134	128			110	92	62		
FACE	90	132	74			174	142	164	160	169					
	106	44	112			160	172	176							
FACE						180	114	104	133	141					
						142	156	124							
FACE															
FACE															
AVE FACE	152	321	326	573	133	152	130	122	131	138	106	112	102	106	107
OLD AREA	86	116	92	98	144						112	108	120	113	132
	152	96	184								134	122	140		
OLD AREA															
OLD AREA															
AVE OLD AREA	119	106	138	98	144						123	115	130	113	132
INTAKE	146	86	100	111	68	148	128	118	131	123	86	90	50	75	70
·	72	66	66			136	114	120			50	82	78		
INTAKE						72	68	84	75	88					
AVERAGE	109	76	83	111	68	68	100	96							
						106	103	105	103	106	68	86	64	75	70

LOCALITY		STOPE 2	
Position	Ref.	Dust Concentration mg/m^3	Konimeter Count p/ml
Return			
Face	1	1,67	
Face	2	2,15	
Face	3	6,53	
Face	4	30,67	
Face			
Face			
Ave. face		10,26	
Old area	5	2,12	
Old area	6	1,60	
Old area	7	1,87	
Ave. old area		1,86	
Intake			
Intake			
Traverse		1,48	
Integrated		1,42	
Full shift		1,35	

SKETCH

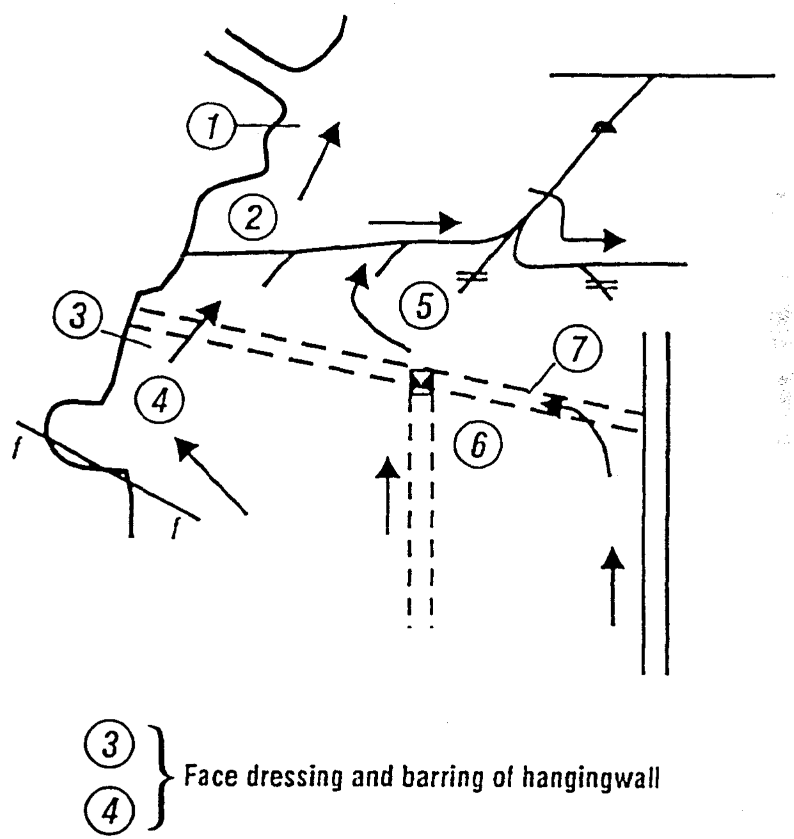


FIGURE 56. SHORT DURATION DUST SAMPLING

MINE 1 - STOPE 2

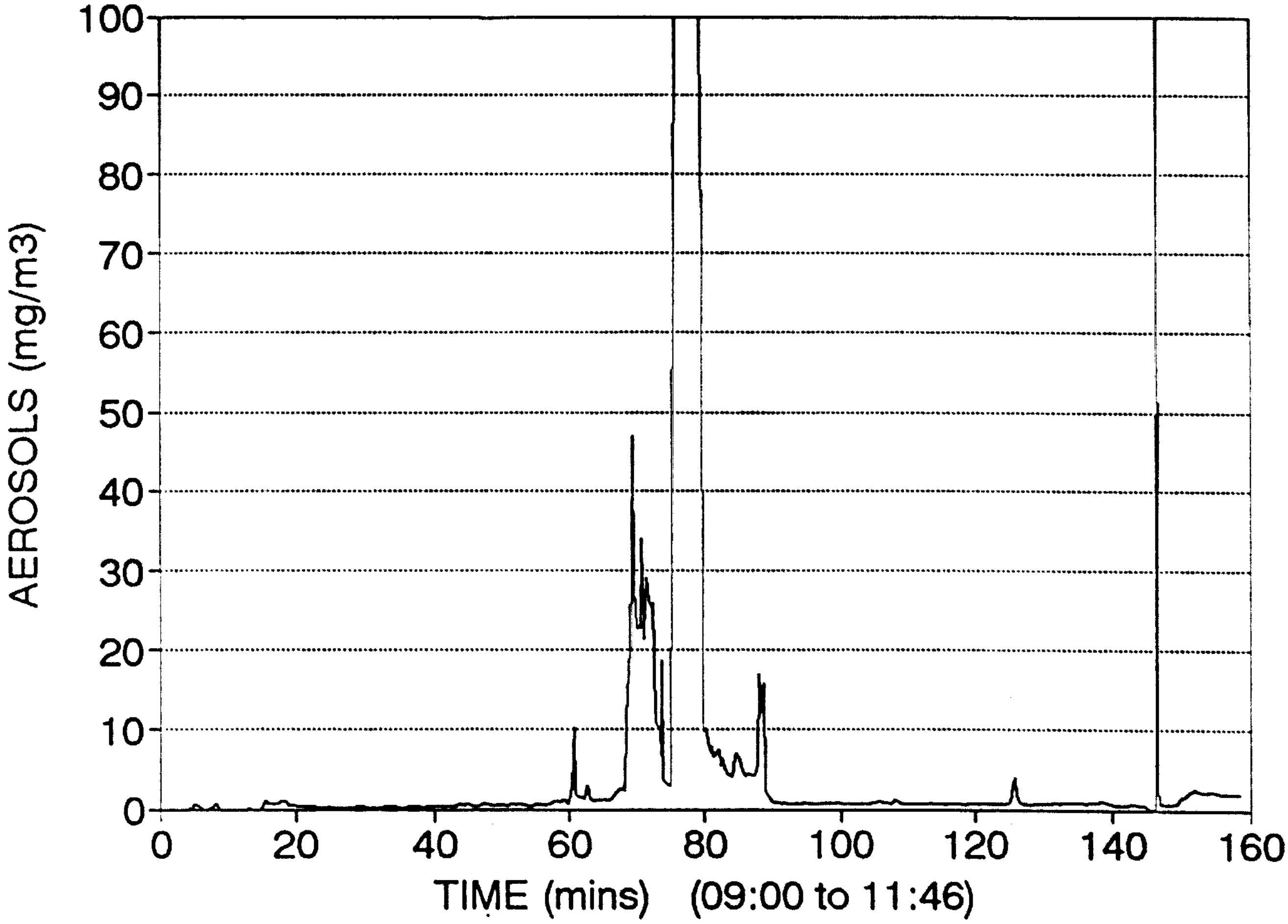
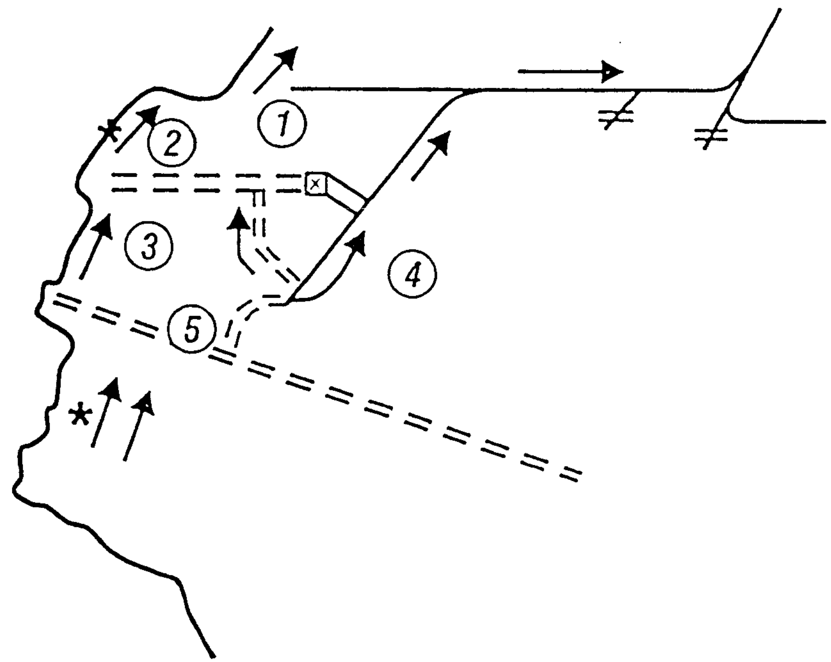


FIGURE 57. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 1 - STOPE 2

LOCALITY		STOPE 8	
Position	Ref.	Dust Concentration mg/m^3	Konimeter Count p/ml
Return	1	4,78	132 - 148 - 140
			128 - 146 - 158
Face	2	6,11	142 - 158 - 122
			100 - 134 - 144
Face	3	1,61	72 - 64 - 78
			110 - 92 - 62
Face			
Face			
Face			
Face			
Ave. face		3,86	106 - 112 - 102
Old area	4	0,78	112 - 104 - 120
Old area			134 - 122 - 140
Old area			
Ave. old area		0,78	124 - 124 - 130
Intake	5	Spoiled	86 - 90 - 50
			50 - 82 - 78
Intake			
Traverse		1,69	
Integrated		3,25	
Full shift		0,42	

SKETCH



* Impact rippers in operation

FIGURE 58. SHORT DURATION DUST SAMPLING

MINE 1 - STOPE 8

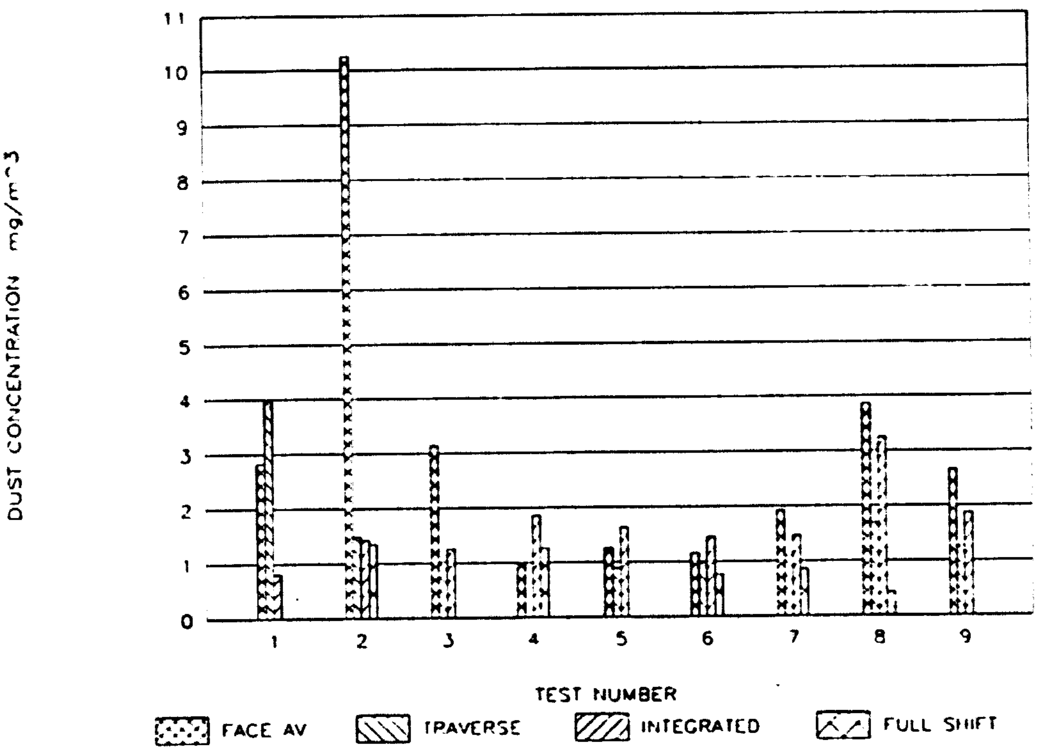


Figure 59 **COMPARISON OF THE DIFFERENT SAMPLING MODES (MINE 1)**

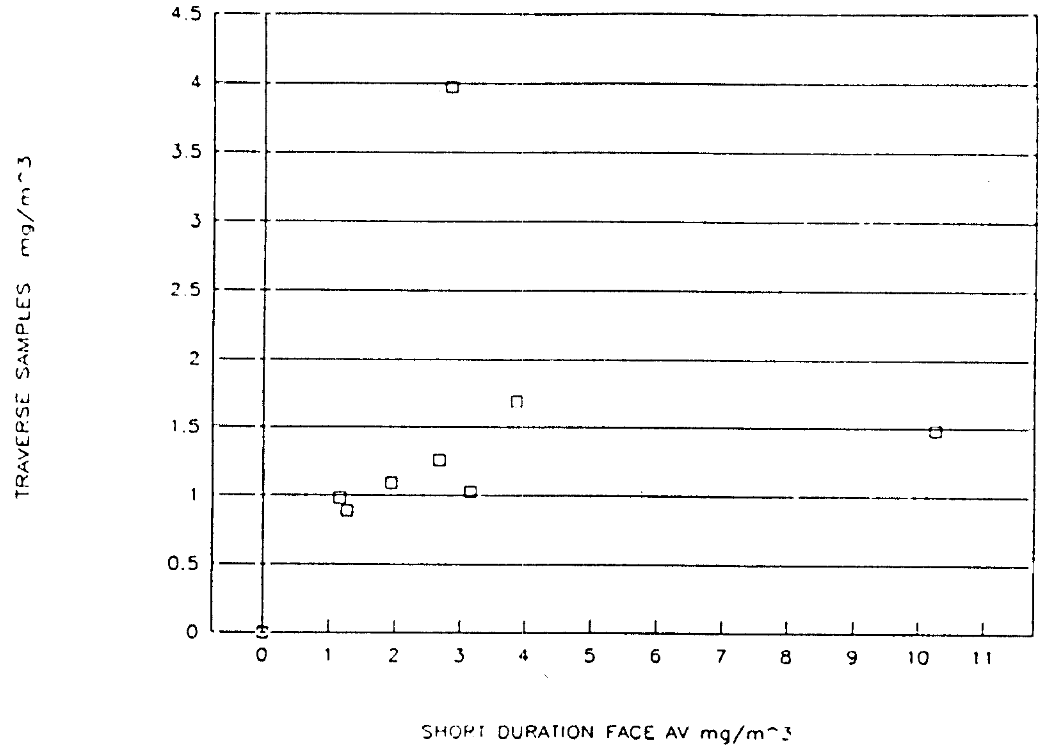


Figure 60 COMPARISON OF SHORT DURATION AND TRAVERSE SAMPLES (MINE 1)

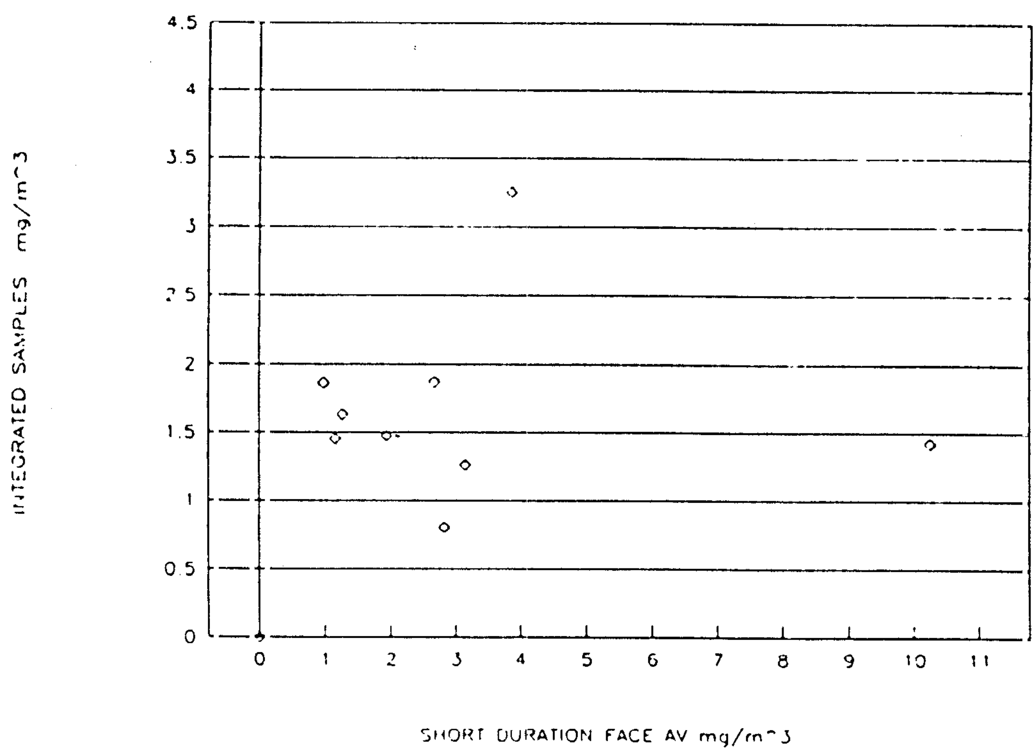


Figure 61 COMPARISON OF SHORT DURATION AND INTEGRATED SAMPLES (MINE 1)

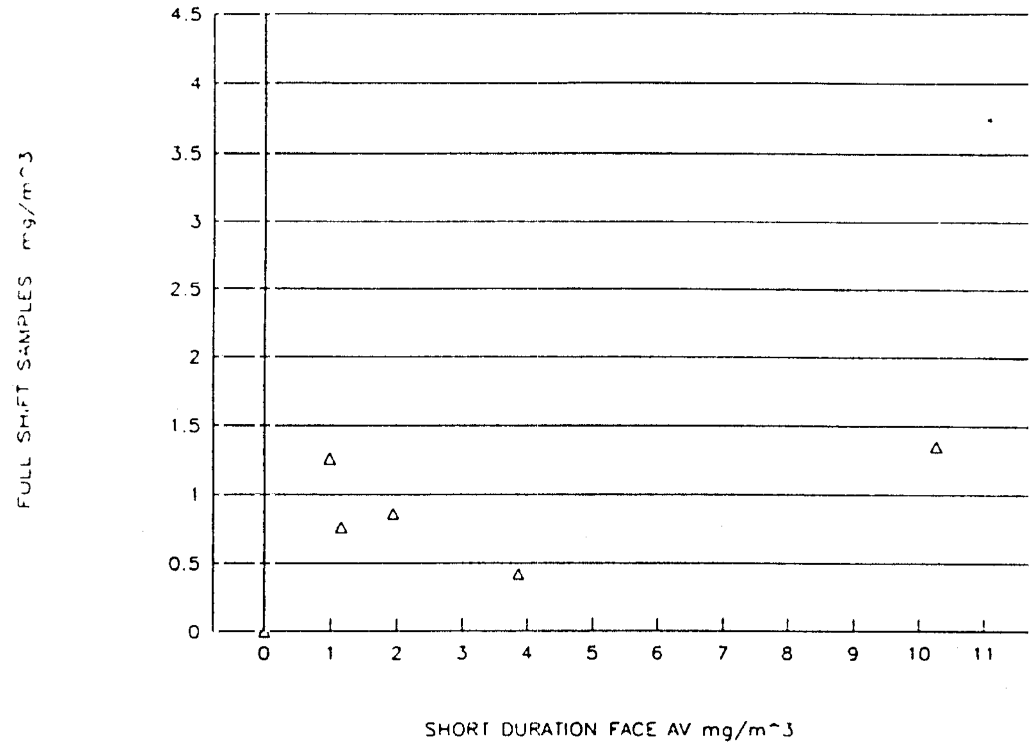


Figure 62 COMPARISON OF SHORT DURATION AND FULL SHIFT SAMPLES (MINE 1)

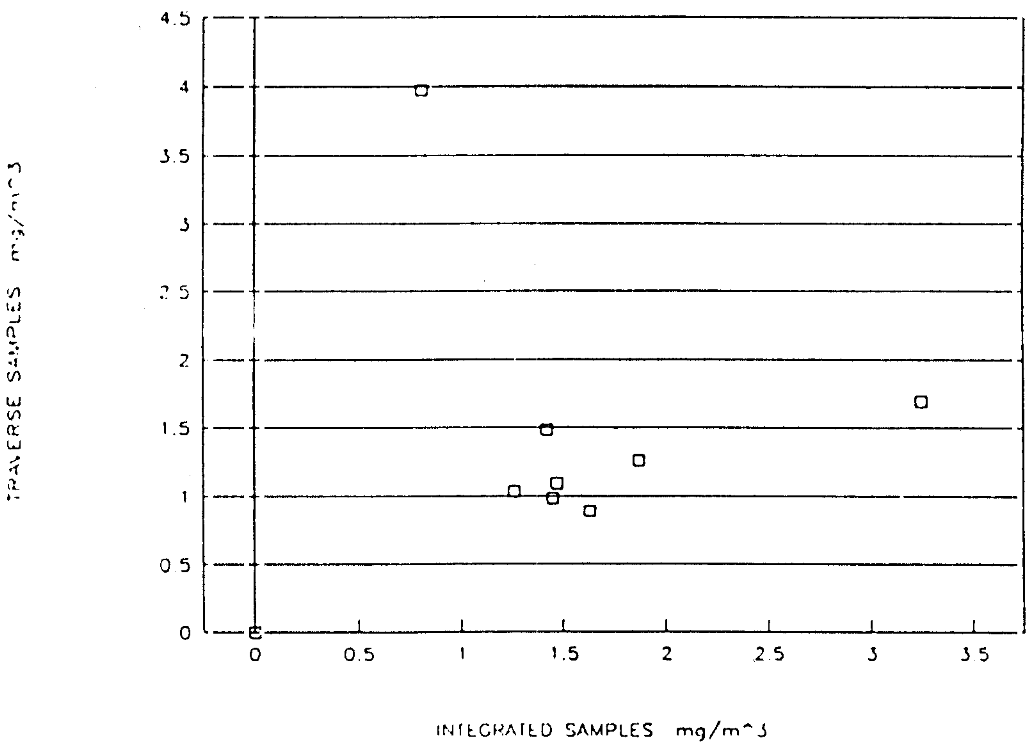


Figure 63 COMPARISON OF INTEGRATED SAMPLES AND TRAVERSE SAMPLES (MINE 1)

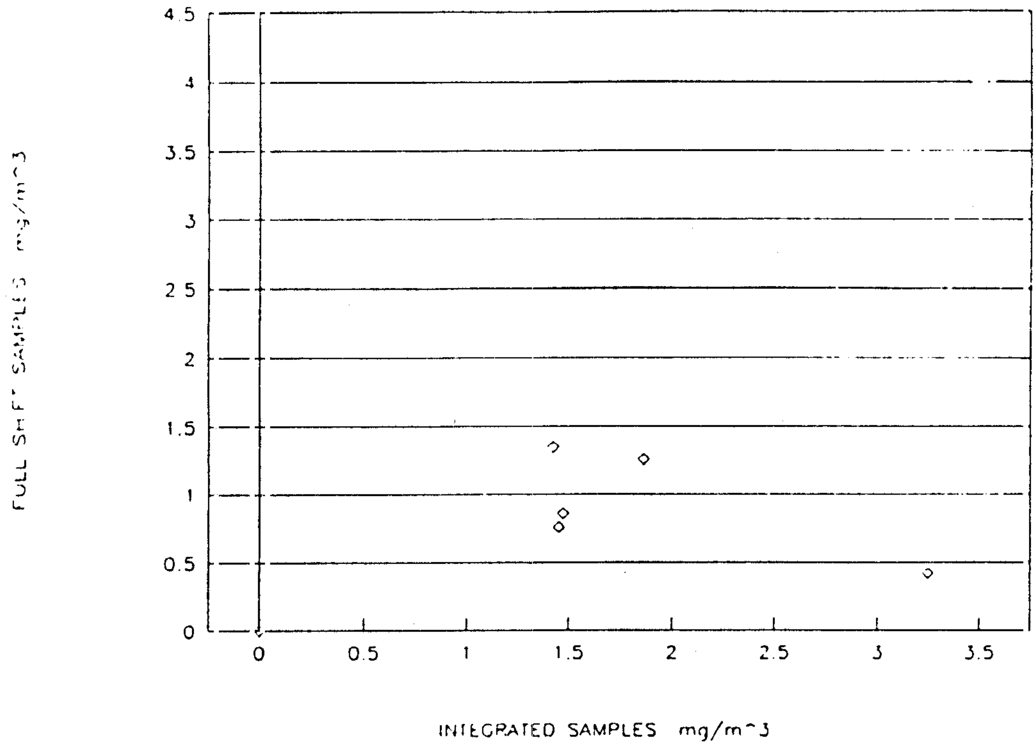


Figure 64 COMPARISON OF INTEGRATED SAMPLES AND FULL SHIFT SAMPLES (MINE 1)

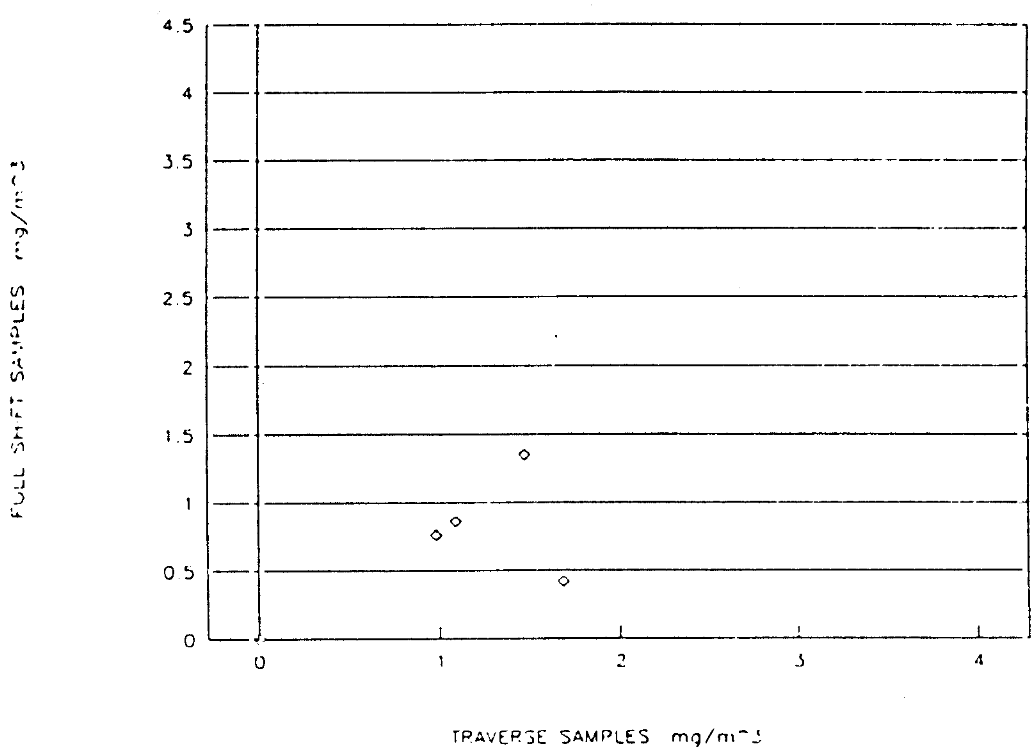


Figure 65 COMPARISON OF TRAVERSE SAMPLES AND FULL SHIFT SAMPLES (MINE 1)

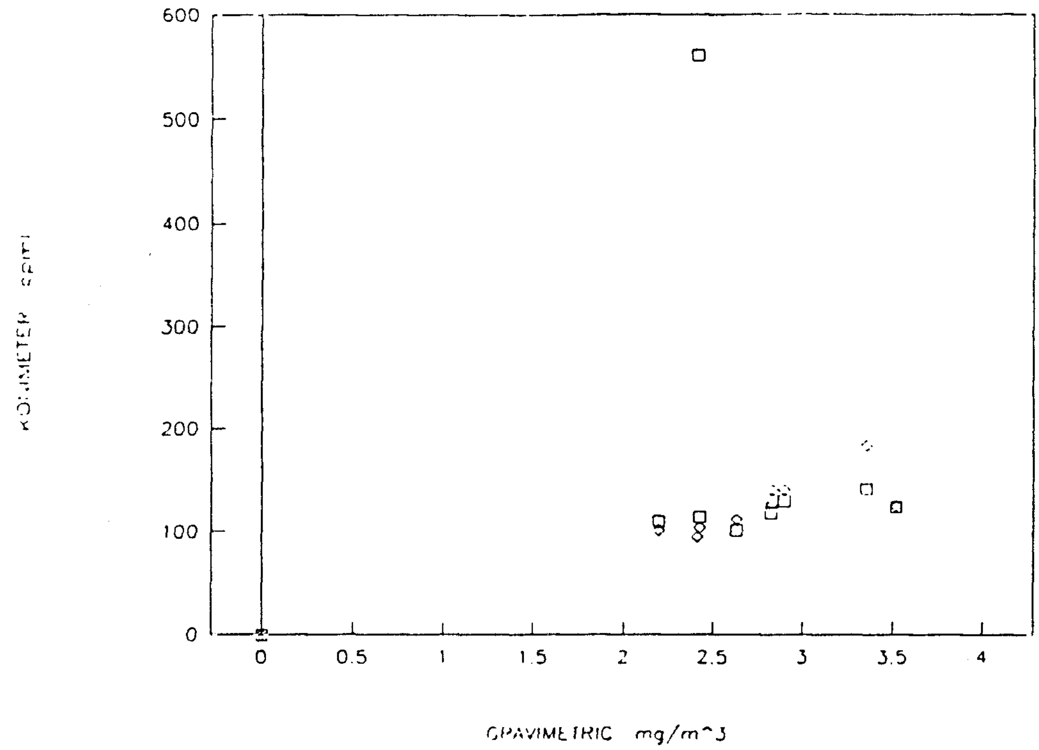


Figure 66 COMPARISON OF GRAVIMETRIC AND KONIMETER SAMPLES STOPE 1 (MINE 1)

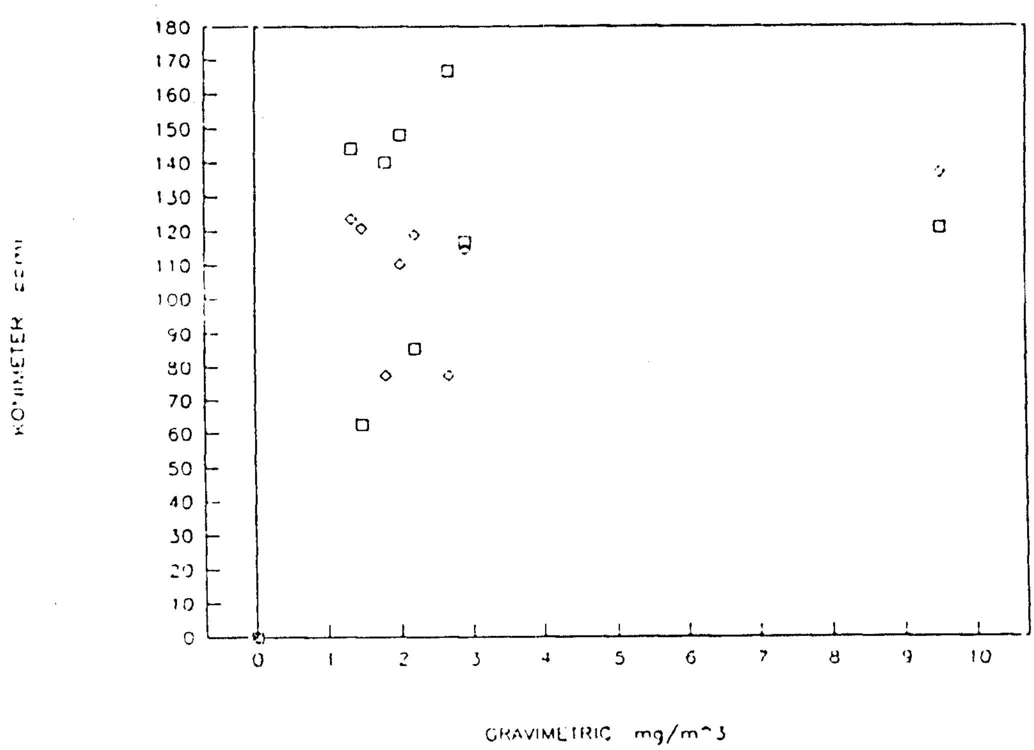


Figure 67 COMPARISON OF GRAVIMETRIC AND KONIMETER SAMPLES STOPE 3 (MINE 1)

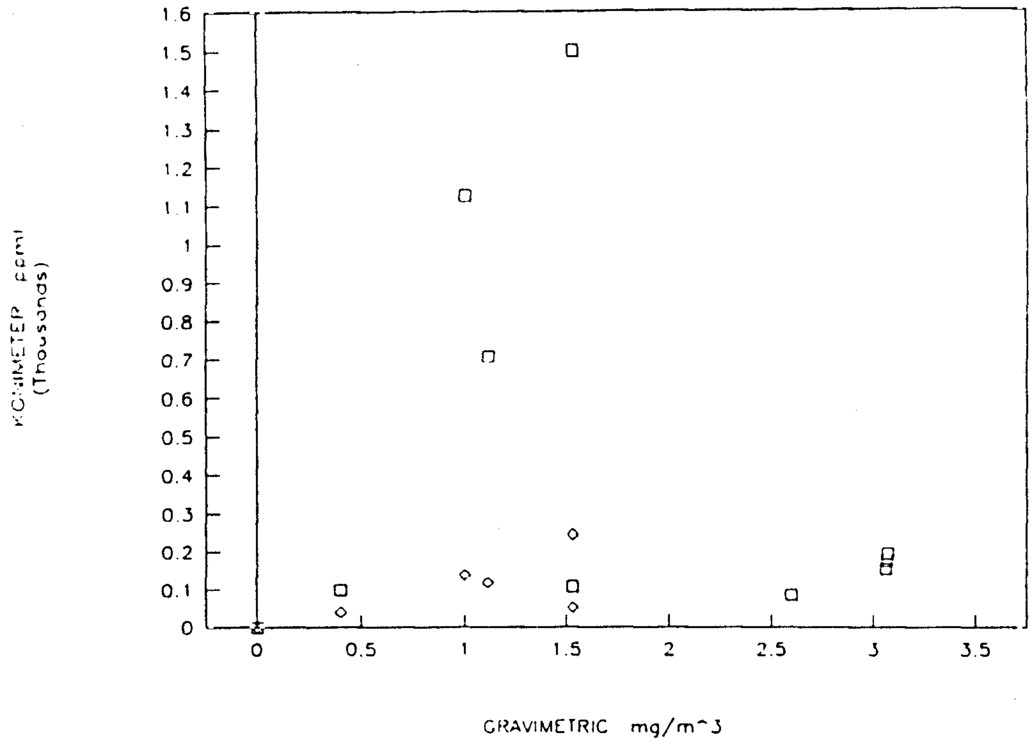


Figure 68 <u>COMPARISON OF GRAVIMETRIC AND KONIMETER SAMPLES - STOPE 4 (MINE 1)</u>

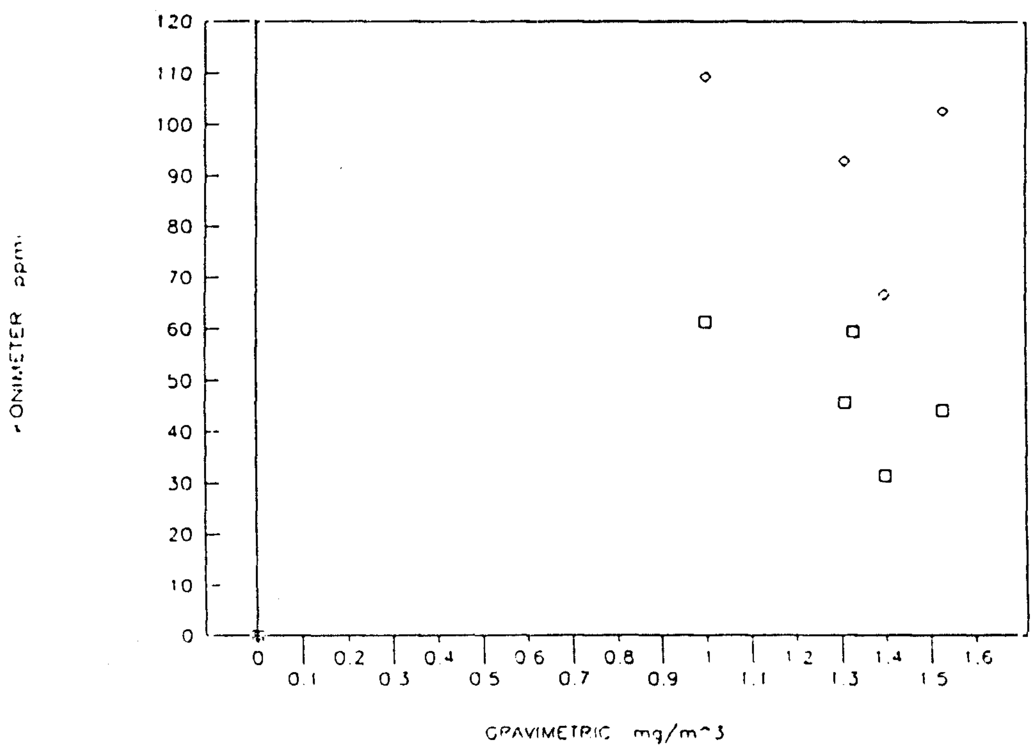


Figure 69 <u>COMPARISON OF GRAVIMETRIC AND KONIMETER SAMPLES - STOPE 5 (MINE 1)</u>

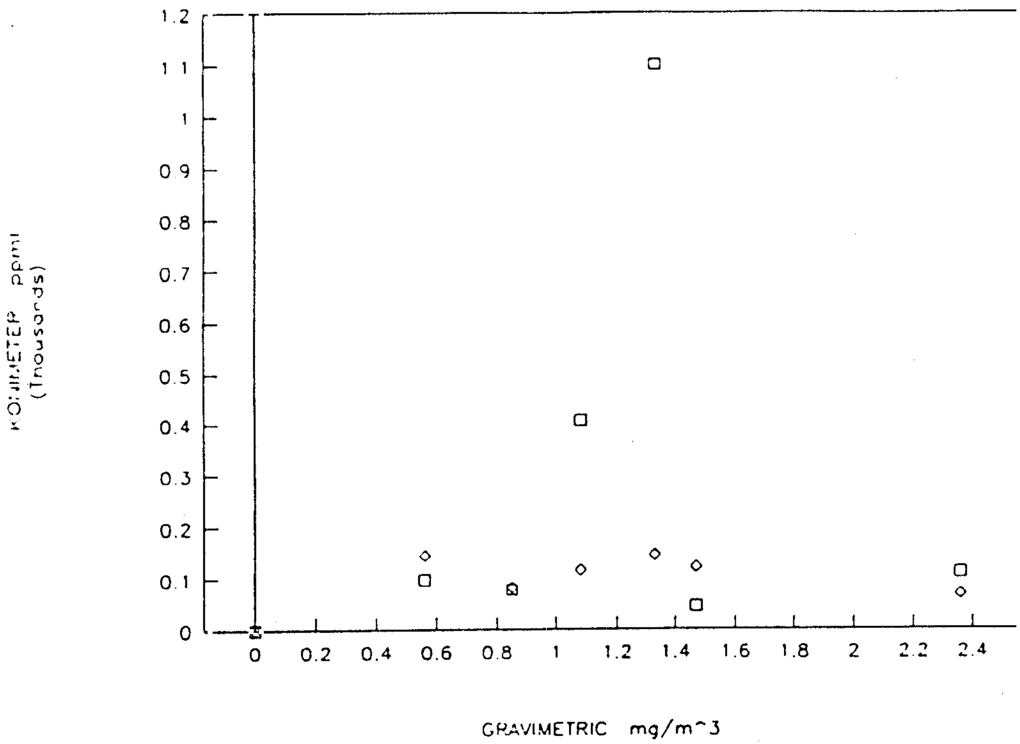


Figure 70 COMPARISON OF GRAVIMETRIC AND KONIMETER SAMPLES - STOPE 6 (MINE 1)

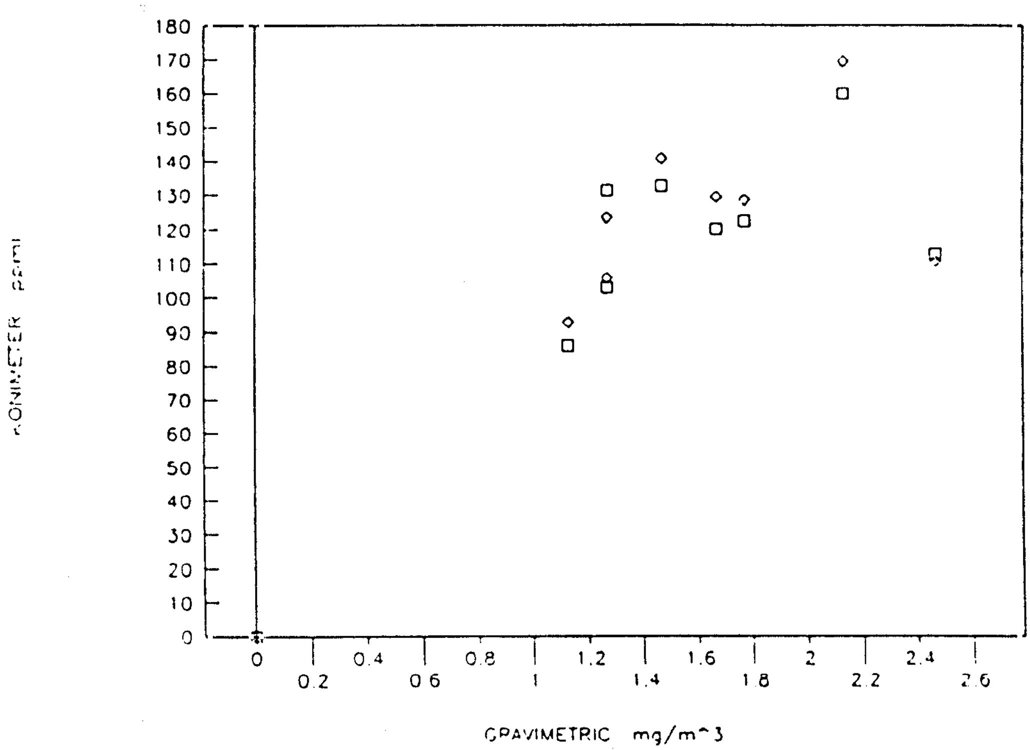


Figure 71 COMPARISON OF GRAVIMETRIC AND KONIMETER SAMPLES - STOPE 7 (MINE 1)

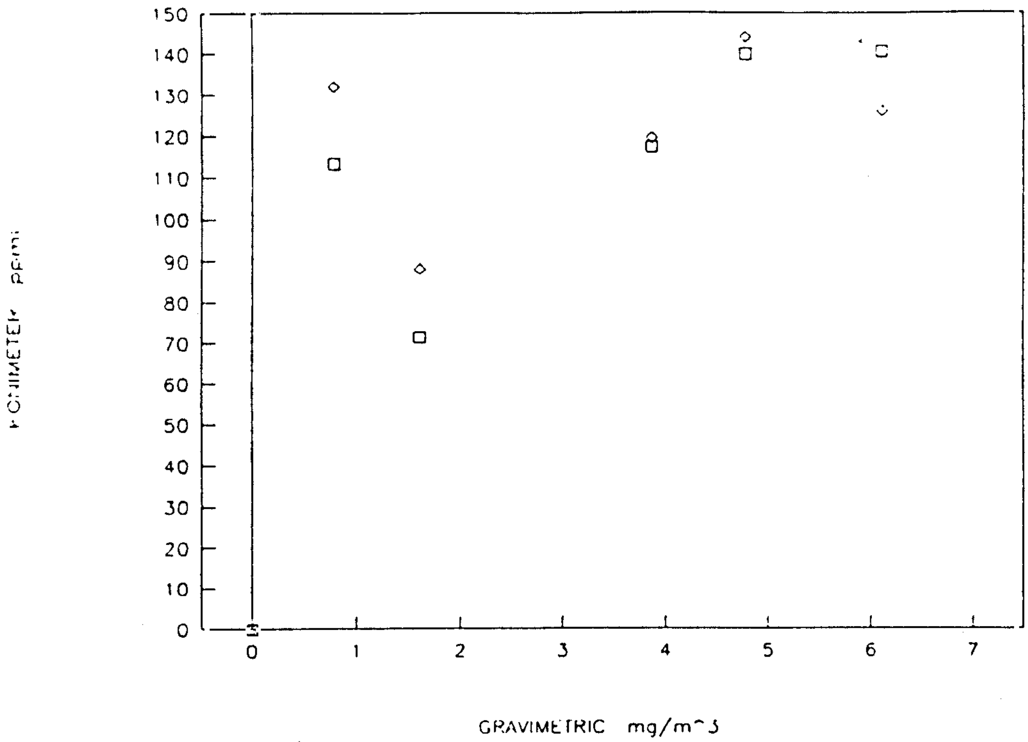


Figure 72 <u>COMPARISON OF GRAVIMETRIC AND KONIMETER SAMPLES - STOPE 8 (MINE 1)</u>

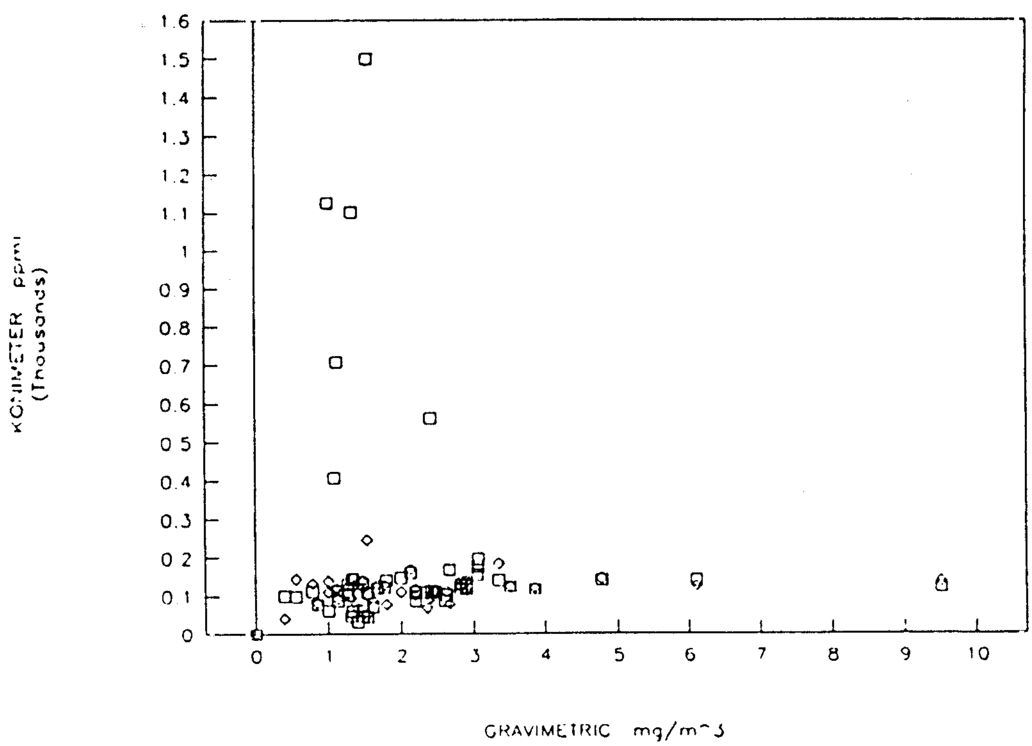


Figure 73 <u>COMPARISON OF GRAVIMETRIC AND KONIMETER SAMPLES - ALL STOPES (MINE 1)</u>

4.4.2 MINE 2

Table 9 RESULTS OF SHORT DURATION SAMPLING - STOPES (MINE 2)

	STOPE 1		STOPE 2		STOPE 3		STOPE 4		STOPE 5		STOPE 6		STOPE 7		STOPE 8		STOPE 9		STOPE 10		STOPE 11		STOPE 12		
POSITION	13 mm	25 mm	13 mm	25 mm	13 mm	25 mm	13 mm	25 mm	13 mm	25 mm	13 mm	25 mm	13 mm	25 mm	13 mm	25 mm	13 mm	25 mm	13 mm	25 mm	13 mm	25 mm	13 mm	25 mm	Averages
	mg/m^3		mg/m^3		mg/m^3		mg/m^3		mg/m^3		mg/m^3		mg/m^3		mg/m^3		mg/m^3		mg/m^3		mg/m^3		mg/m^3		mg/m^3
RETURN	0.259		1.777		1.014		2.301		0.554		0.169		0.203		0.205		0.782		0.346				0.329		0.72
		2.397		4.113		1.841		3.160		1.650		1.423		1.577		0.829		3.078		1.817		1.789		0.829	2.04
FACE	0.615	1.702	0.779	2.314	0.982	1.778	0.769	1.053	0.726	2.809	0.859	2.109	0.681	20.154	1.628	4.145	0.255	4.245	0.134	2.127		20.363	0.133	4.145	
FACE	0.714	1.609	1.068	3.833	1.760	3.122	1.203	4.213	0.361	1.106	1.399	3.216	0.439	3.592	3.467	2.664	1.256	2.547	0.756	3.290		2.984	0.587	2.664	
FACE	0.456	1.678	0.396	1.799	2.867	2.979	0.769	4.161			0.865				0.784	2.192	0.587	3.874	0.469	1.489		1.491	0.228	2.192	
FACE																									
FACE																									
FACE																									
AVE FACE		0.595		0.748		1.870		0.914		0.544		1.041		0.560		1.960		0.699		0.453				0.316	0.88
		1.663		2.649		2.626		3.142		1.958		2.663		11.873		3.000		3.555		2.302		8.279		3.000	3.89
OLD AREA									0.403				0.368												0.38
										5.756				2.147											3.95
OLD AREA																									
OLD AREA																									
AVE OLD AREA									0.403	5.756			0.368	2.147											
INTAKE	0.462		0.406		0.793		0.583		0.252		0.185		0.478		0.583		0.681		0.296		0.169		0.721		0.46
		1.581		1.496		1.249		1.416		1.461		1.500		1.139		1.416		2.600		6.073		1.228		0.735	1.82
INTAKE																									
AVERAGE	0.462	1.581	0.406	1.496	0.793	1.249	0.583	1.416	0.252	1.461	0.185	1.500	0.478	1.139	0.583	1.416	0.681	2.600	0.296	6.073	0.169	1.228	0.721	0.735	
TRAVERSE		0.516		0.292		0.559		0.300		0.537				0.340		0.979				0.762		0.262			0.50
INTE-GRATED						0.330								0.540								0.240		0.041	0.28
FULL SHIFT		0.400		0.090						0.230		0.240						0.430		0.870					0.37

Table 10 **RESULTS OF SHORT DURATION SAMPLING - DEVELOPMENT (MINE 2)**

	DEVEL 1		DEVEL 2		DEVEL 3		DEVEL 4			DEVEL 5		DEVEL 6		
POSITION	13 mm	25 mm	13 mm	25 mm	13 mm	25 mm	13 mm	25 mm	ROTATING SPONGE	13 mm	25 mm	13 mm	25 mm	ROTATING SPONGE
	mg/m³		mg/m³		mg/m³		mg/m³			mg/m³		mg/m³		
RETURN	1.194		1.521		0.825		1.196			0.576		0.991		
		3.789		4.263		3.351		0.902			1.828		1.499	
FACE	1.260		1.079		0.479		0.073			1.382		0.694		
		3.526		2.440		3.342		0.992			2.768		1.756	
INTAKE	1.739		0.639		3.019		0.721			0.518		0.518		
		2.895		3.079		4.091		0.735	0.803				1.904	
						1.176			0.340					
TRAVERSE		1.273											0.791	0.840
INTEGRATED														
FULL SHIFT		0.340		0.340		0.500		0.120					0.370	0.650

LOCALITY		STOPE 2			
Position	Ref.	Dust Concentration mg/m^3		Quartz (%)	Rotating Sponge mg/m^3
		13 mm	25 mm		
Return	R	1,777	4,113		
Face	1	0,779	2,314		
Face	2	1,068	3,833		
Face	3	0,396	1,799		
Face					
Ave. face		0,748	2,649		
Old area Old area Ave. old area					
Intake Intake	4	0,406	1,496		
Traverse Integrated Full shift			0,292 0,091		

SKETCH

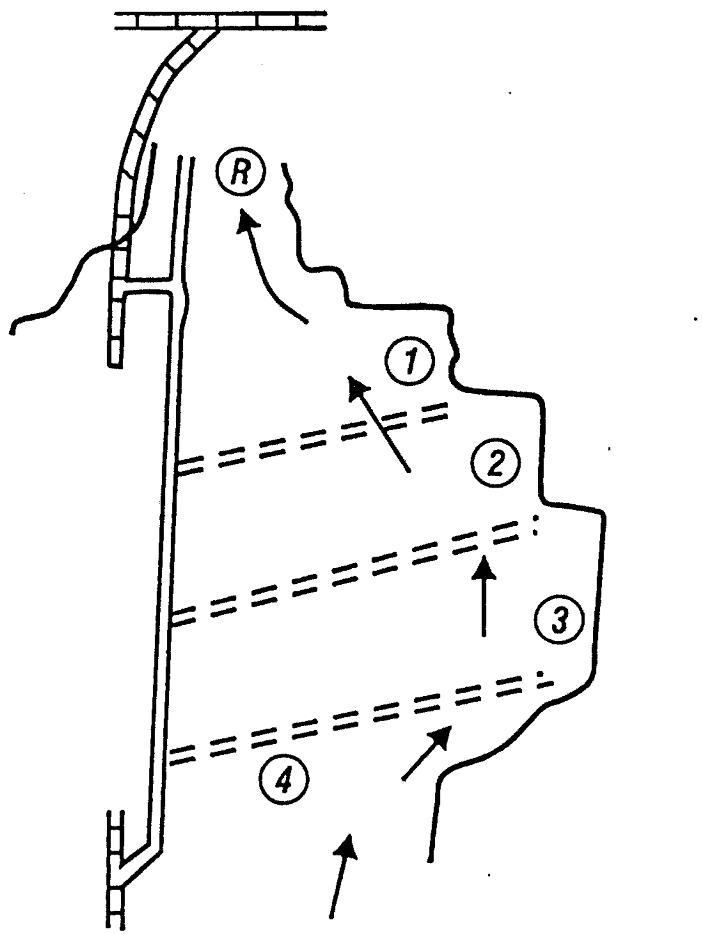


FIGURE 74. SHORT DURATION DUST SAMPLING

MINE 2 - STOPE 2

LOCALITY		STOPE 3			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge
		13 mm	25 mm		
Return	R	1,014	1,841		
Face	1	0,982	1,778		
Face	2	1,276	3.122		
Face	3	2,867	2,979		
Face					
Ave. face		1,708	2,626		mg/m³
Old area Old area Ave. old area					
Intake Intake	4	0,793	1,249		
Traverse Integrated Full shift			0,559 0,330		

SKETCH

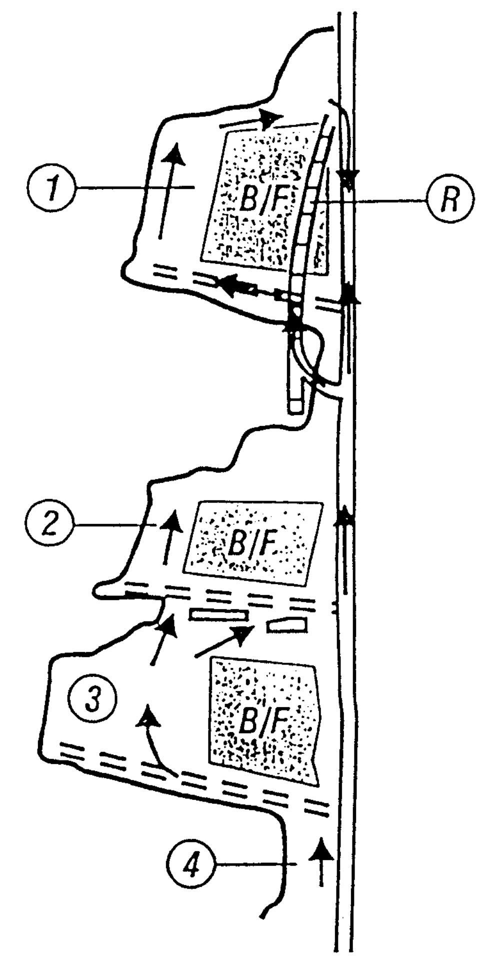


FIGURE 75. SHORT DURATION DUST SAMPLING

MINE 2 - STOPE 3

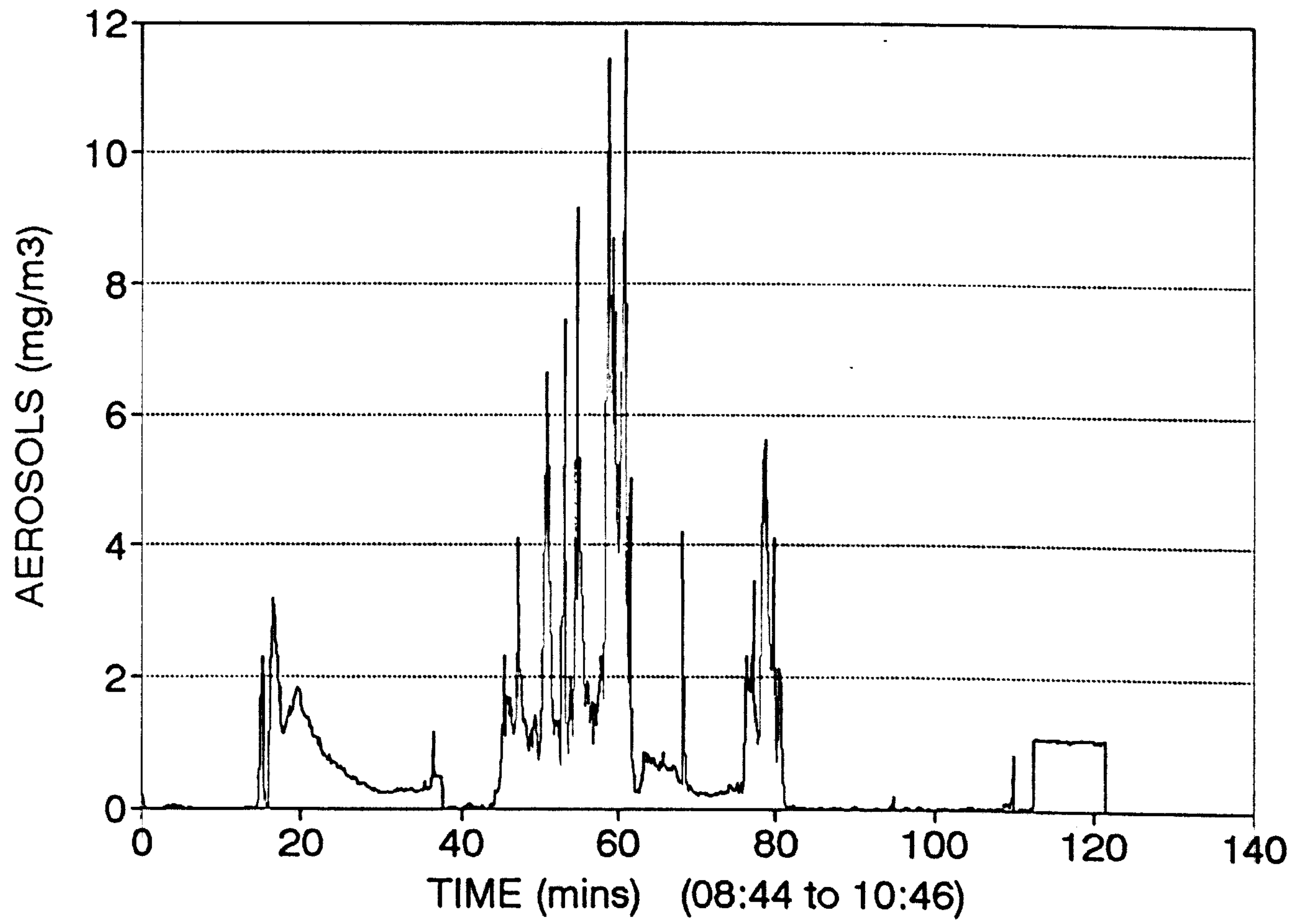


FIGURE 76. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 2 - STOPE 2

LOCALITY		Development 1 and 2			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge mg/m³
		13 mm	25 mm		
Return	R1	1,194	3,789		
	R2	1,521	4,263		
Face	3	1,260	3,526		
Face	4	1,079	2,440		
Face					
Ave. face		1,169	2,983		
Old area					
Old area					
Ave. old area					
Intake	1	1,739	2,895		
Intake	2	0,639	3,070		
Traverse			1,273		
Integrated					
Full shift			0,340		

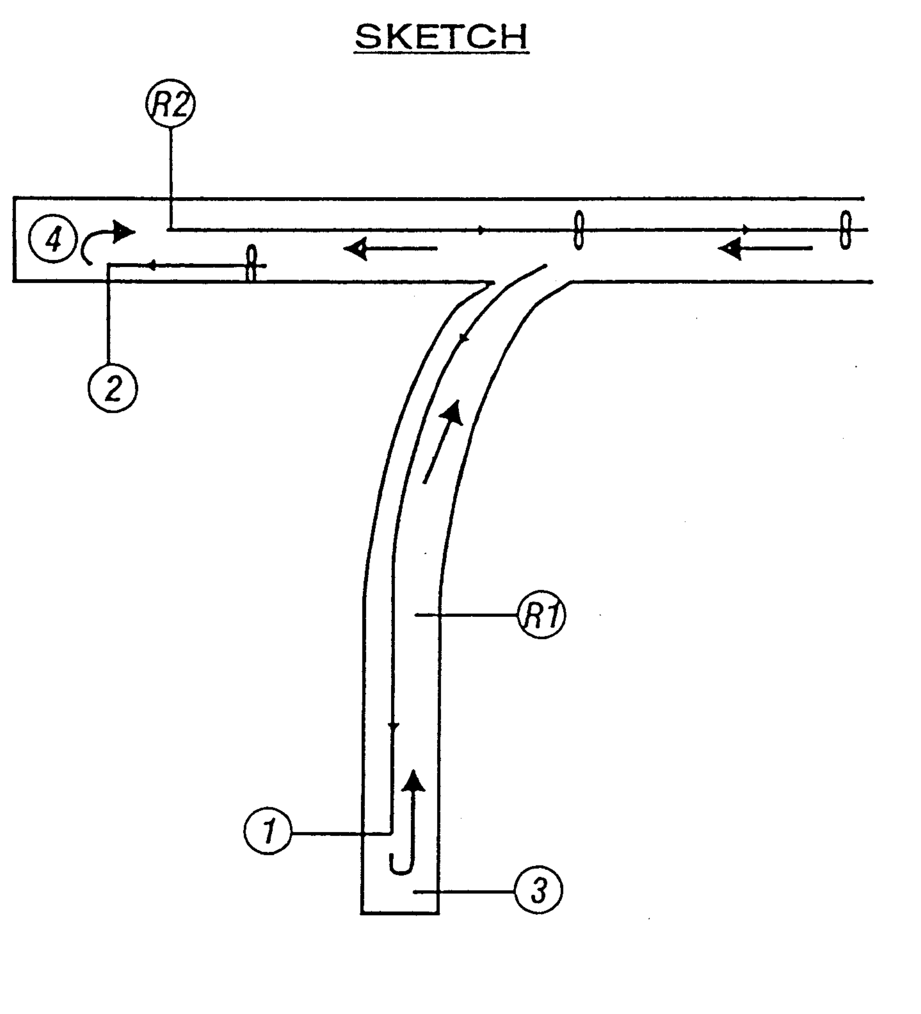


FIGURE 77. SHORT DURATION DUST SAMPLING

MINE 2 - DEVELOPMENT ENDS 1 & 2

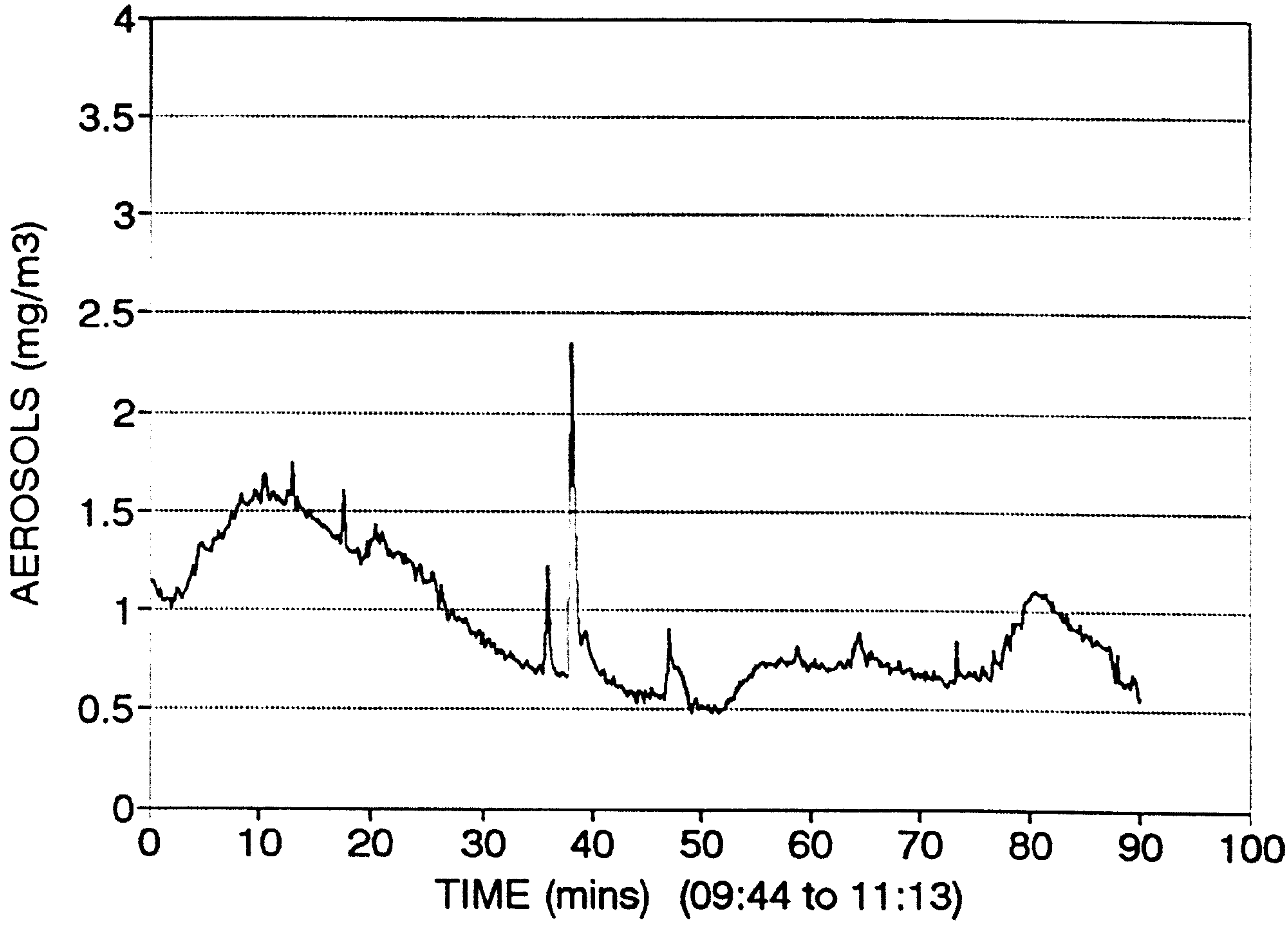


FIGURE 78. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 2 - DEVELOPMENT 1 & 2

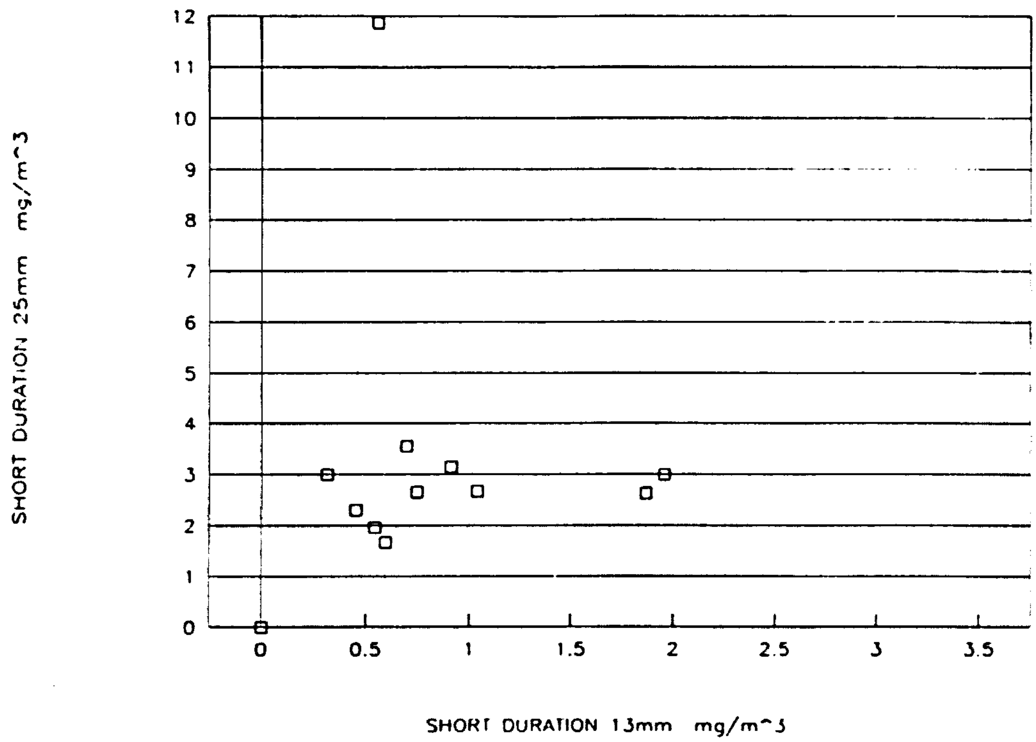


Figure 79 <u>COMPARISON OF AVERAGE STOPE 13 mm AND 25 mm FILTERS: SHORT DURATION (MINE 2)</u>

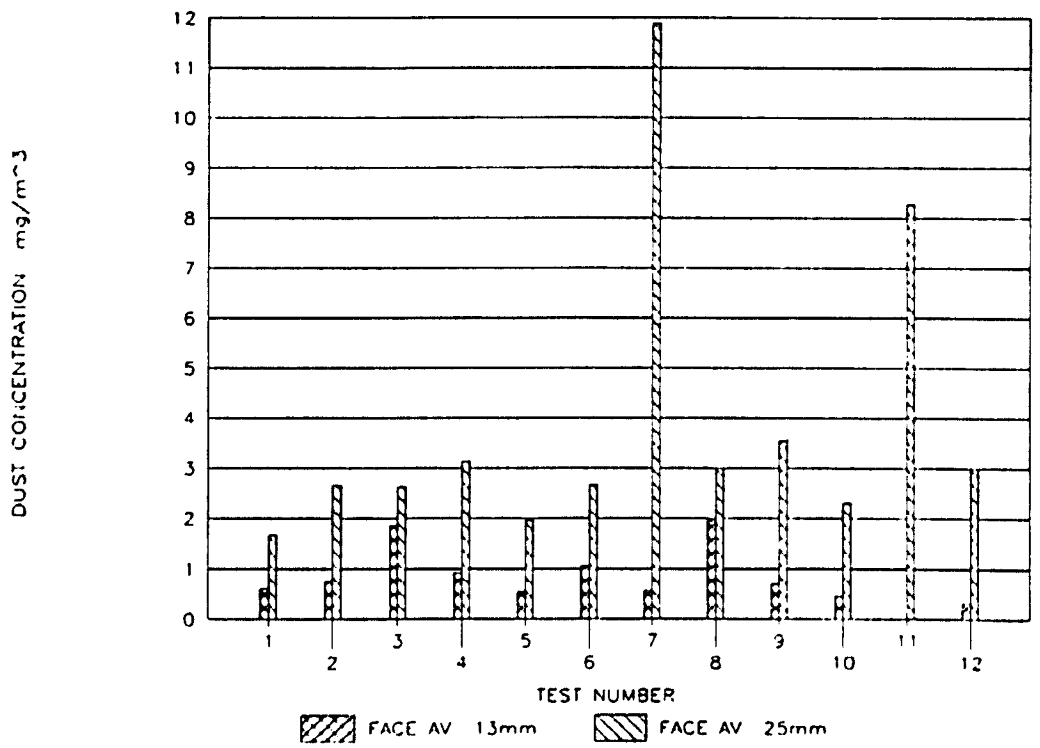


Figure 80 <u>BAR CHART COMPARISON OF AVERAGE STOPE 13 mm AND 25 mm FILTERS: SHORT DURATION (MINE 2)</u>

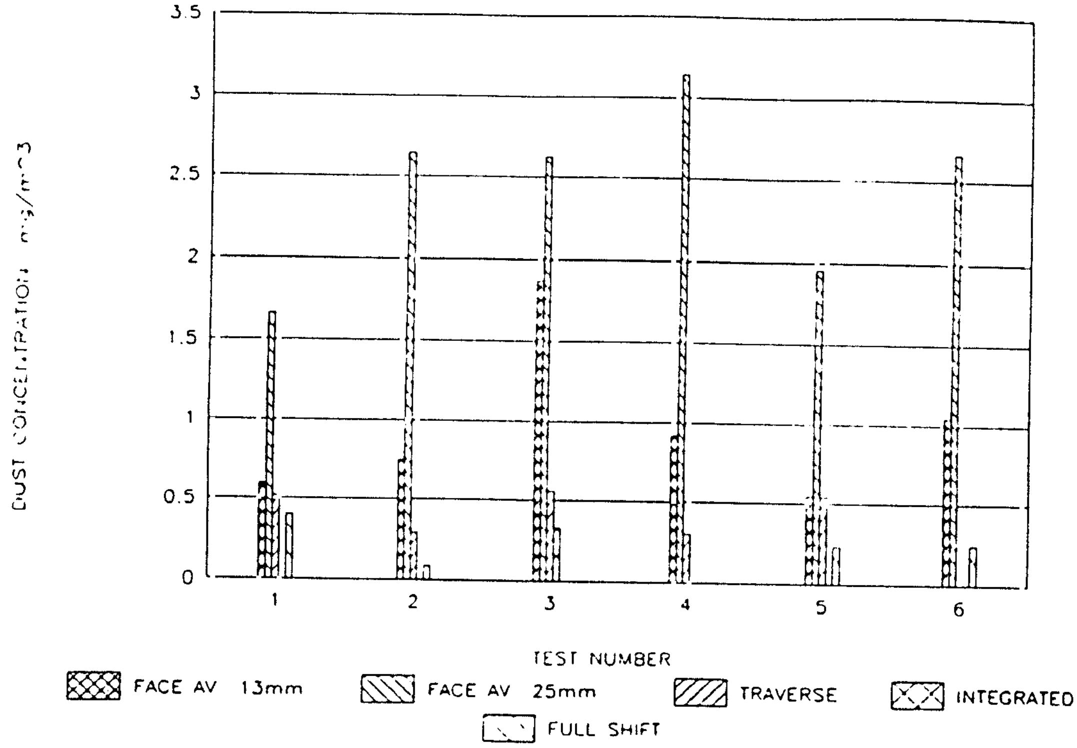


Figure 81 <u>COMPARISON OF ALL SAMPLING MODES FOR THE FIRST SIX STOPES (MINE 2)</u>

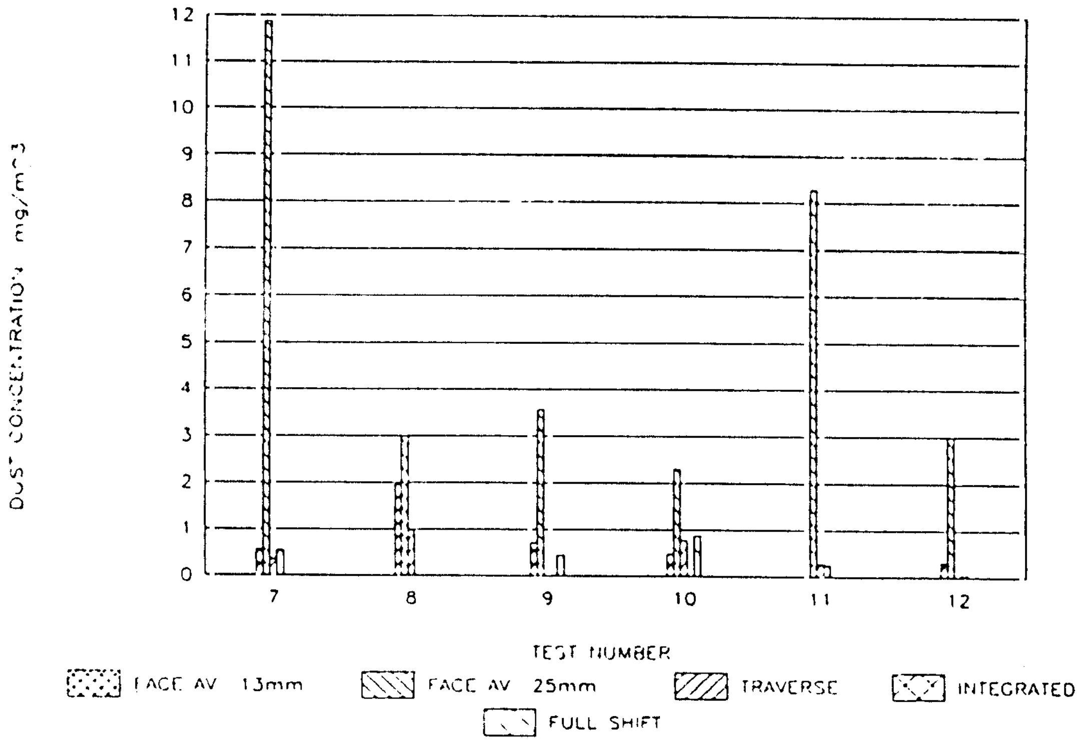


Figure 82 <u>COMPARISON OF ALL SAMPLING MODES FOR THE SECOND SIX STOPES (MINE 2)</u>

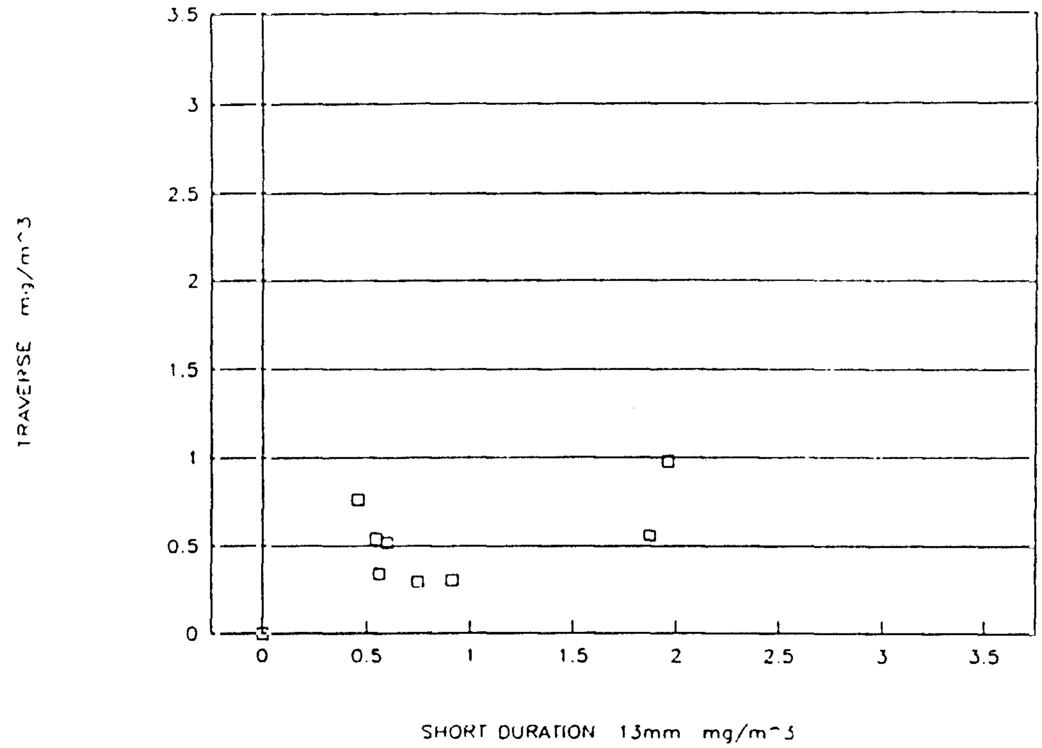


Figure 83 COMPARISON OF AVERAGE SHORT DURATION (13 mm FILTERS) AND TRAVERSE SAMPLES (MINE 2)

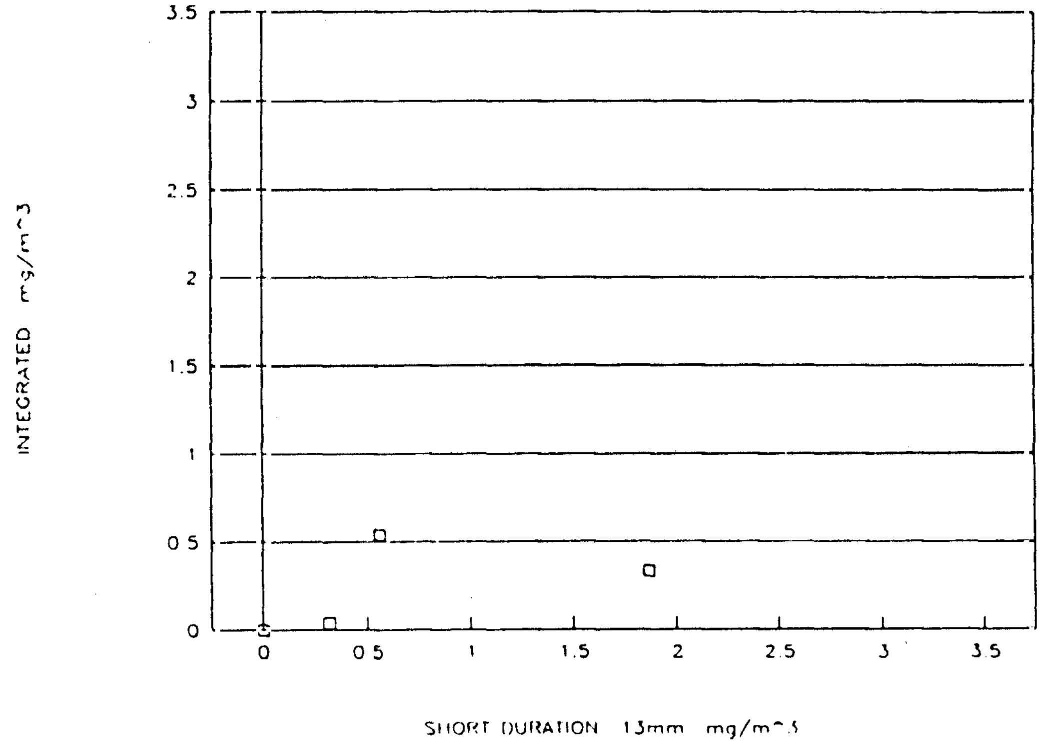


Figure 84 COMPARISON OF AVERAGE SHORT DURATION (13 mm FILTERS) AND INTEGRATED SAMPLES (MINE 2)

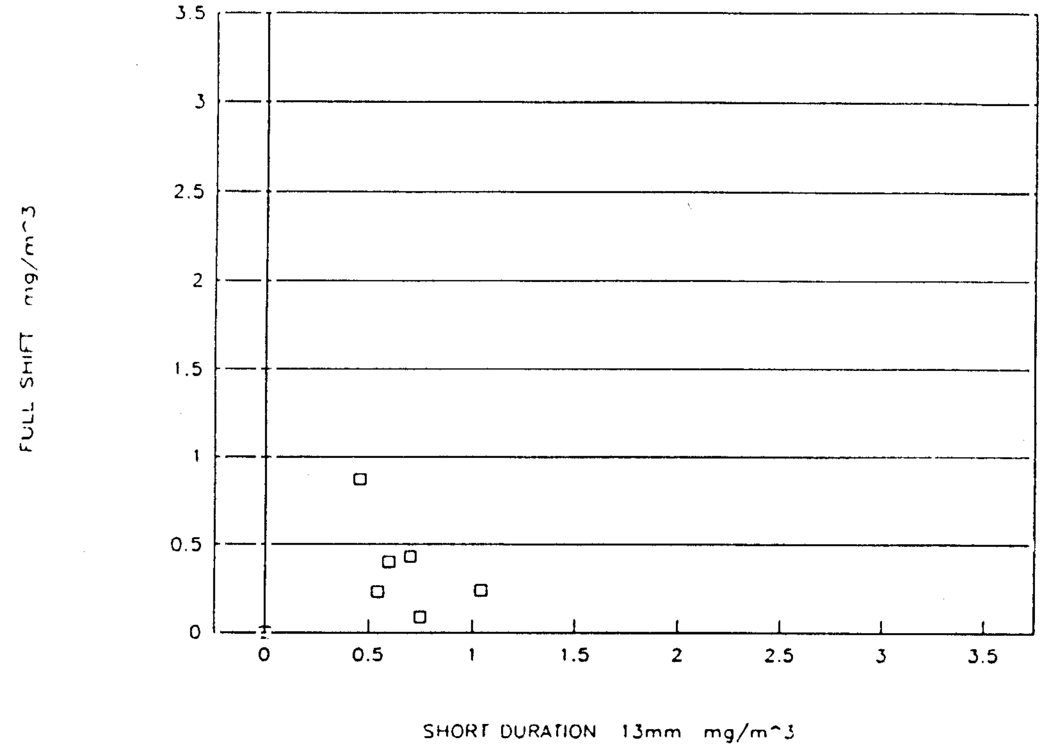


Figure 85 <u>COMPARISON OF AVERAGE SHORT DURATION (13 mm FILTERS) AND FULL SHIFT SAMPLES (MINE 2)</u>

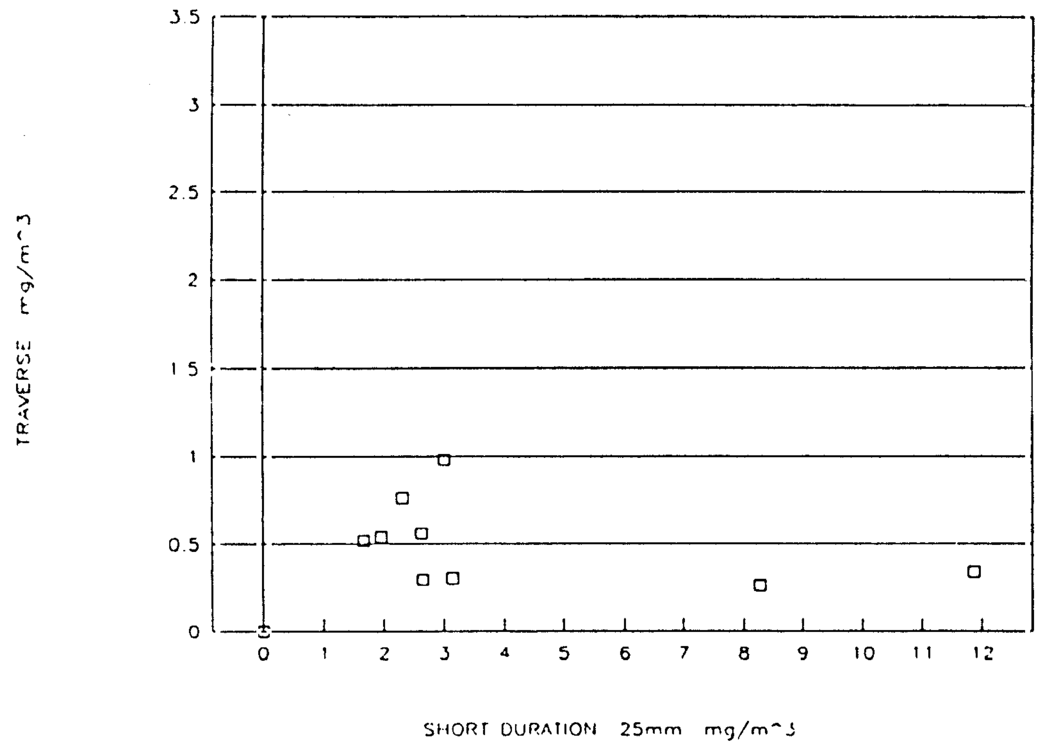


Figure 86 <u>COMPARISON OF AVERAGE SHORT DURATION (25 mm FILTERS) AND TRAVERSE SAMPLES (MINE 2)</u>

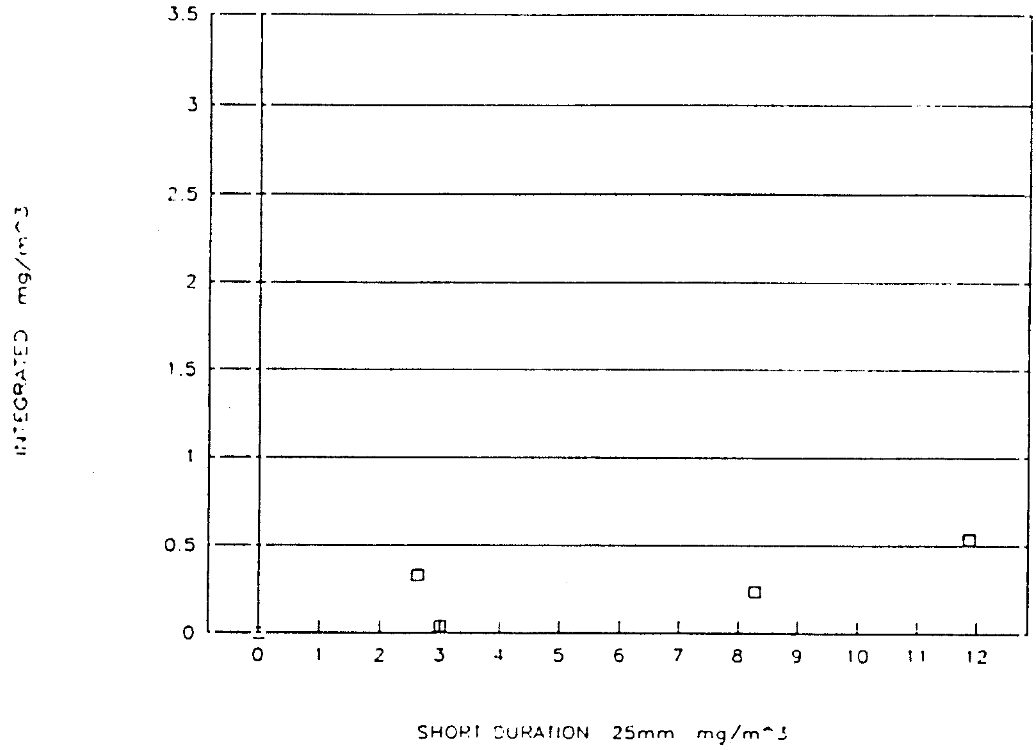


Figure 87 COMPARISON OF AVERAGE SHORT DURATION (25 mm FILTERS) AND INTEGRATED SAMPLES (MINE 2)

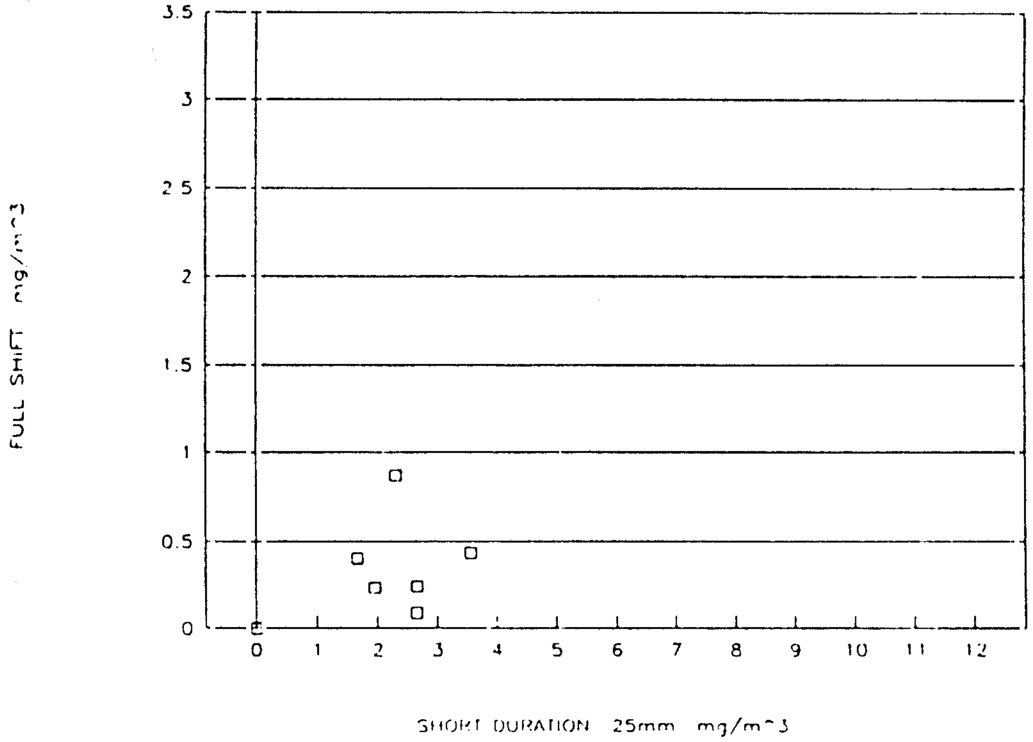


Figure 88 COMPARISON OF AVERAGE SHORT DURATION (25 mm FILTERS) AND FULL SHIFT SAMPLES (MINE 2)

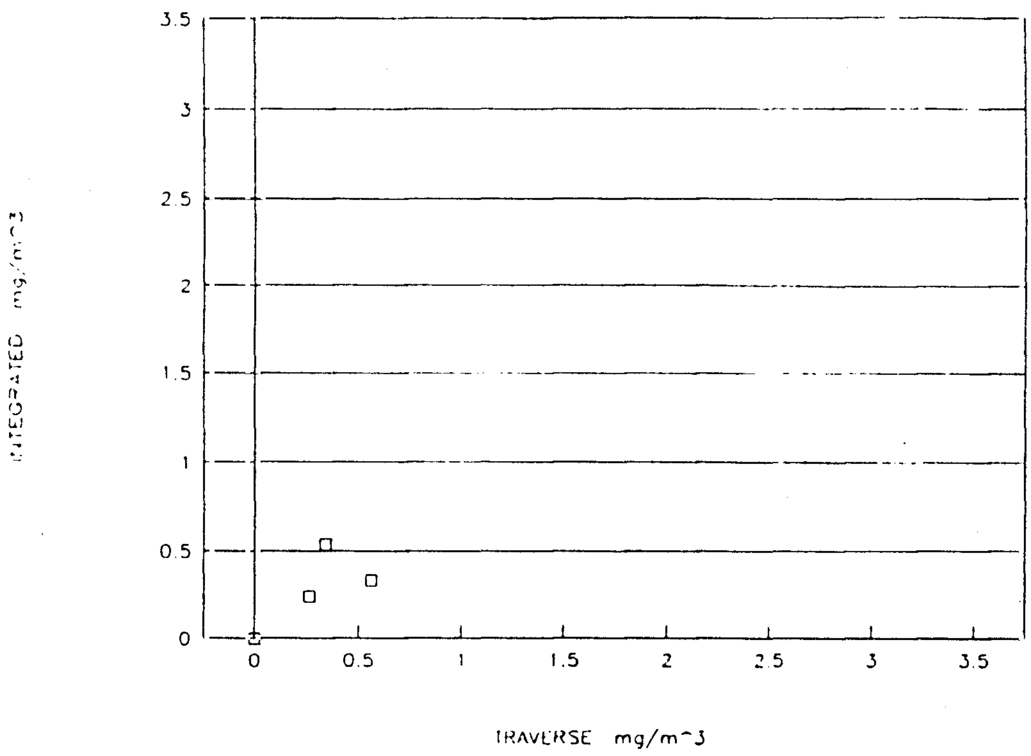


Figure 89 COMPARISON OF TRAVERSE AND INTEGRATED SAMPLES (MINE 2)

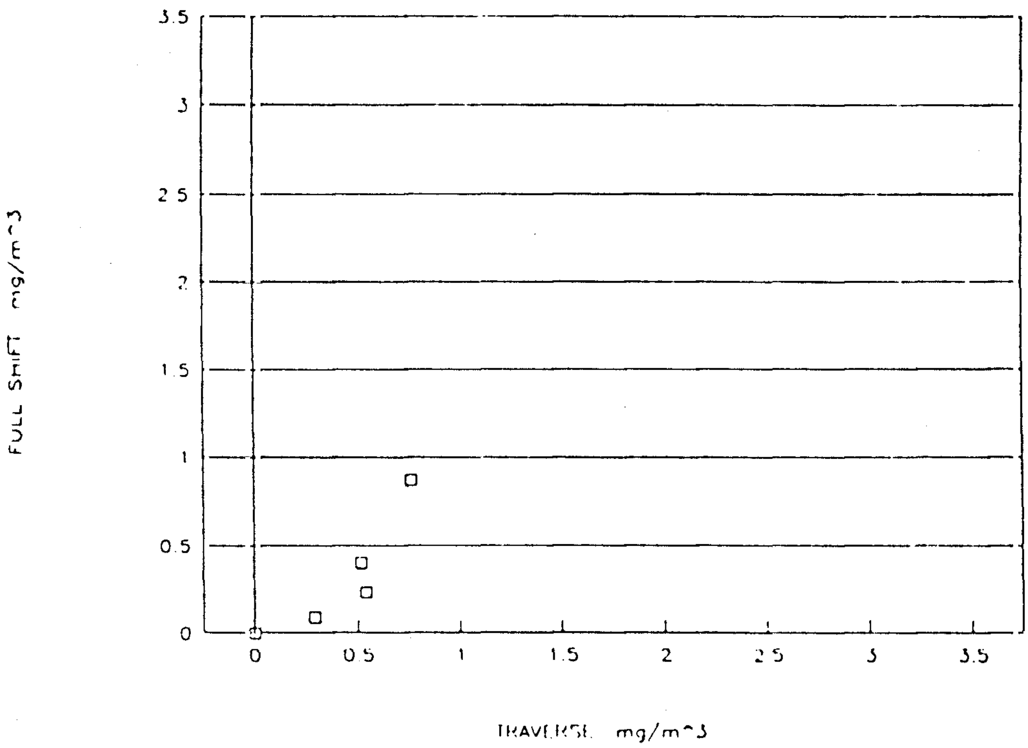


Figure 90 COMPARISON OF TRAVERSE AND FULL SHIFT SAMPLES (MINE 2)

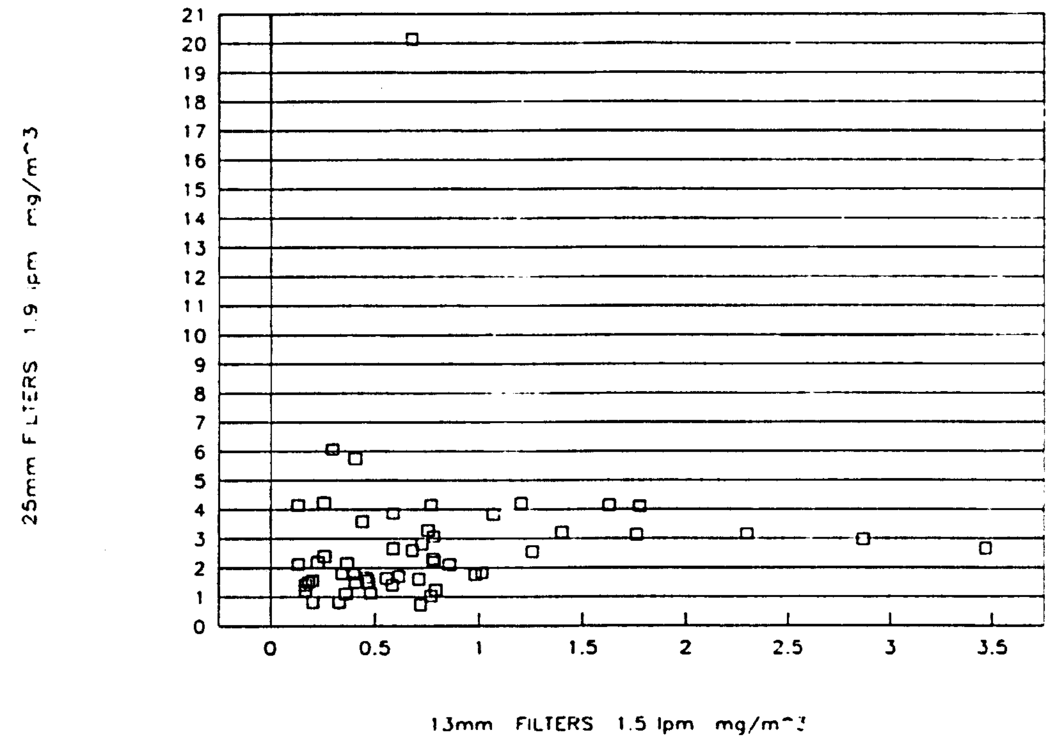


Figure 91 COMPARISON OF ALL COLLECTED SHORT DURATION SAMPLES: 13 mm FILTERS 1.5 ℓpm AND 25 mm FILTERS 1.9 ℓpm (MINE 2)

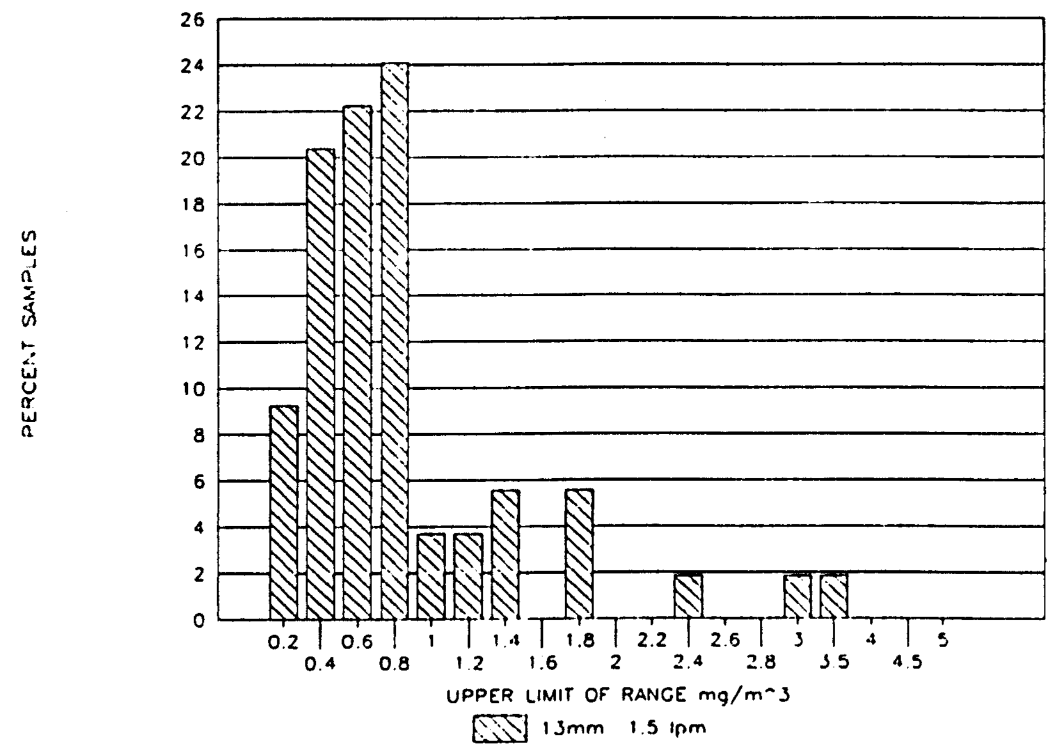


Figure 92 FREQUENCY DISTRIBUTION OF SHORT DURATION 13 mm FILTER SAMPLES COLLECTED AT 1.5 ℓpm (MINE 2)

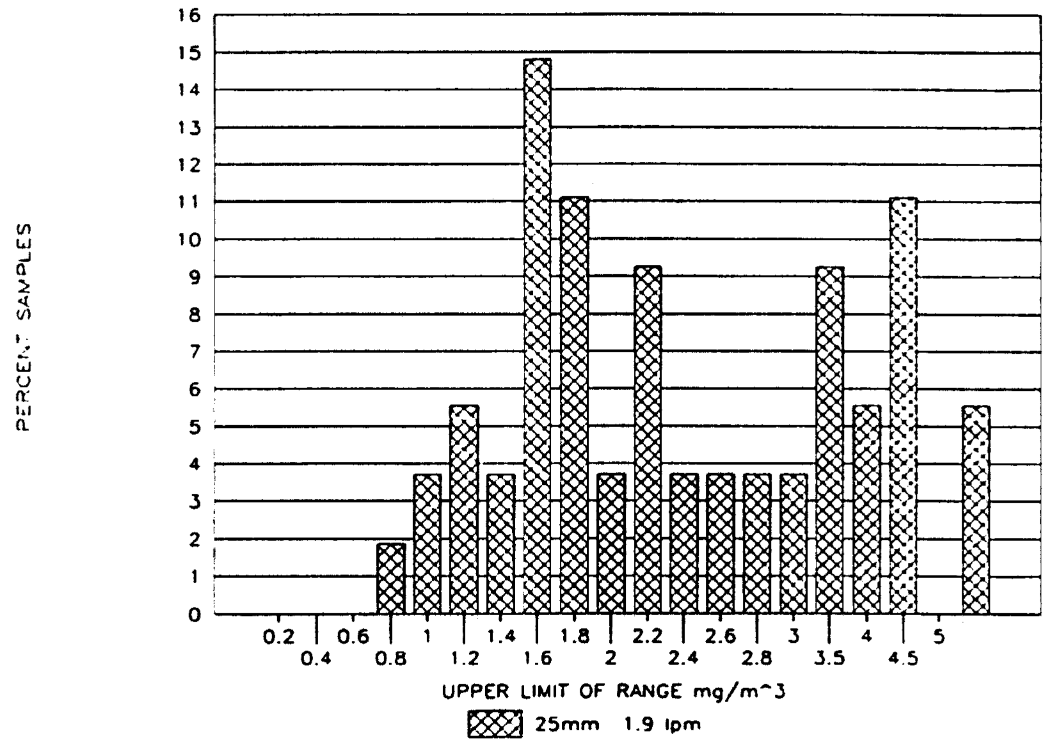


Figure 93 **FREQUENCY DISTRIBUTION OF SHORT DURATION 25 mm FILTER SAMPLES COLLECTED AT 1.9 ℓpm (MINE 2)**

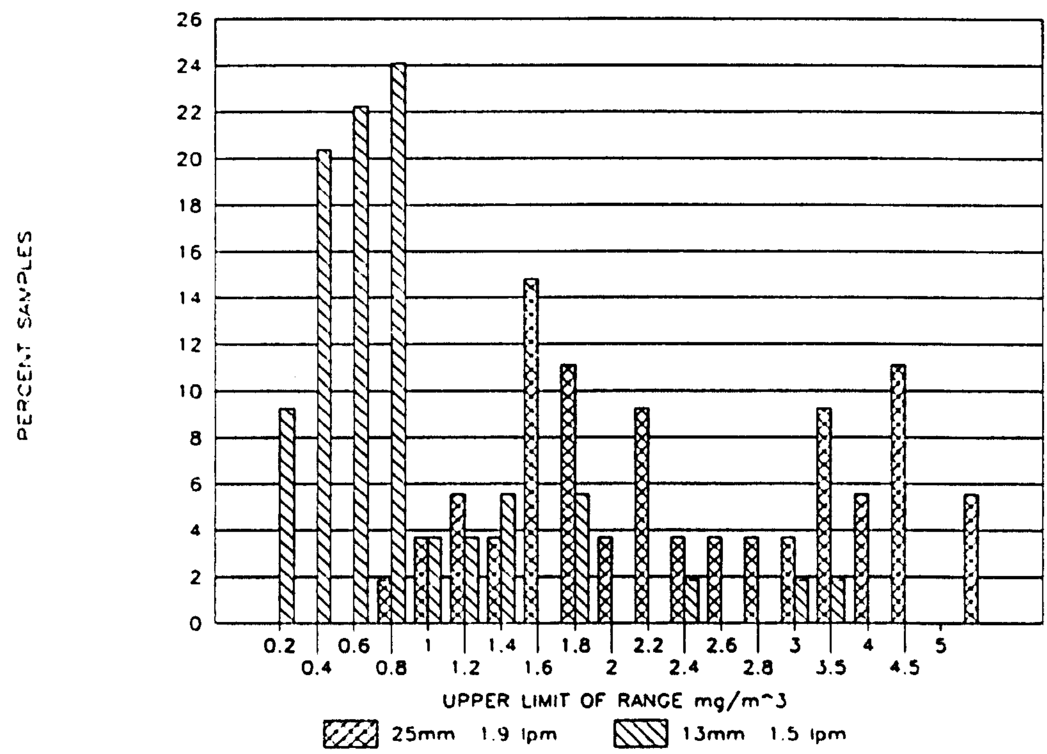


Figure 94 **COMPARISON OF FREQUENCY DISTRIBUTION FOR SHORT DURATION 13 mm FILTER SAMPLES (1.5 ℓpm) AND 25 mm FILTERS (1.9 ℓpm) (MINE 2)**

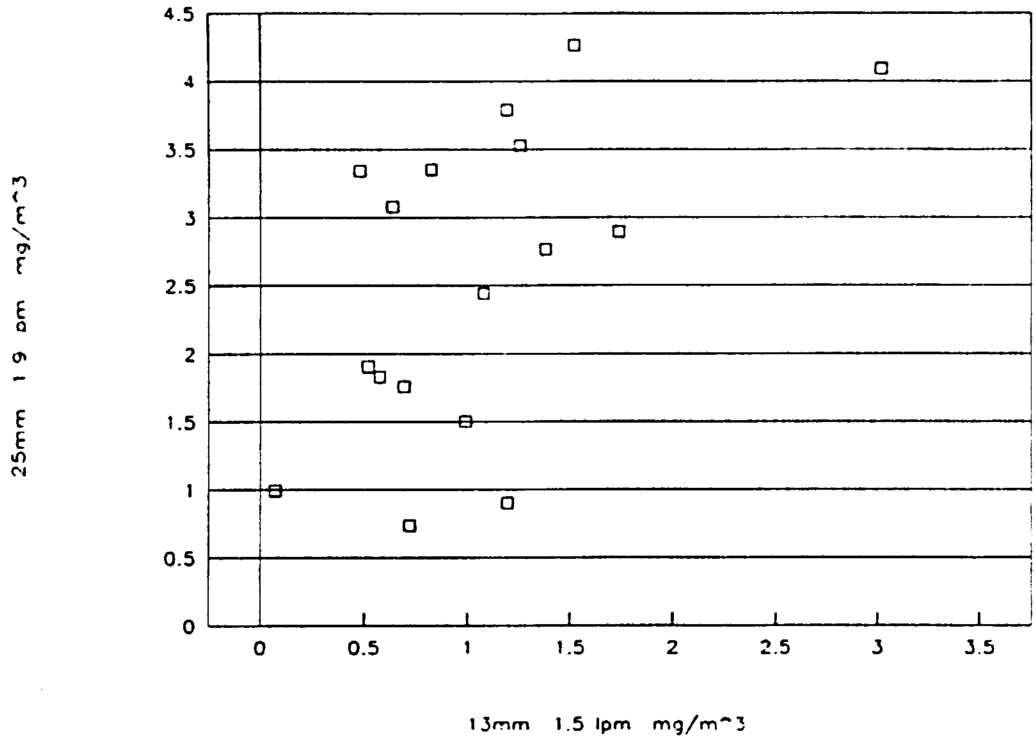


Figure 95 COMPARISON OF 13 mm FILTERS (1.5 ℓpm) AND 25 mm FILTERS (1.9 ℓpm) SHORT DURATION COLLECTED IN DEVELOPMENT ENDS (MINE 2)

4.4.3 MINE 3

Table 11 **RESULTS OF SHORT DURATION SAMPLING - STOPES (MINE 3)**

POSITION	STOPE 1 13mm mg/m^3	STOPE 1 25mm mg/m^3	STOPE 2 13mm mg/m^3	STOPE 2 25mm mg/m^3	STOPE 3 13mm mg/m^3	STOPE 3 25mm mg/m^3	STOPE 3 SiO_2 %	STOPE 4 25mm	STOPE 5 13mm mg/m^3	STOPE 5 25mm mg/m^3	STOPE 5 SiO_2 %	STOPE 6 13mm mg/m^3	STOPE 6 25mm mg/m^3	STOPE 6 SiO_2 %
RETURN	0.872	2.412	0.458	1.447	1.720	2.684		2.834	0.238	3.333		0.256	2.389	
FACE	1.007	3.263	0.633	3.377	2.580	5.316		4.575	0.256	1.886		0.239	2.193	
FACE	0.893	2.368	0.744	29.386	1.160	3.000			1.047	3.947		0.550	1.316	
FACE	0.427	1.474										1.881	2.325	
FACE														
FACE														
FACE														
AVE FACE		0.778		0.689		1.870				0.652			0.817	
		2.388		16.382		4.158		4.575		2.917			1.945	
OLD AREA					1.500	1.474			0.339	2.412				
OLD AREA														
OLD AREA														
AVE OLD AREA					1.500	1.474			0.339	2.412				
INTAKE	0.556	2.675	0.191	2.687	0.807	1.687		0.526	0.411	0.985		0.348	1.617	
INTAKE AVERAGE	0.556	2.675	0.191	2.687	0.807	1.687		0.526	0.411	0.985		0.348	1.617	
TRAVERSE		0.697		0.945		0.934	11.6			0.443	18.2		0.780	22.0
INTEGR-ATED FULL SHIFT		0.241		0.192		0.207		0.509					0.215	

POSITION	STOPE 7 13mm mg/m^3	STOPE 7 25mm mg/m^3	STOPE 7 SiO_2 %	STOPE 8 13mm mg/m^3	STOPE 8 25mm mg/m^3	STOPE 8 SiO_2 %	STOPE 9 13mm mg/m^3	STOPE 9 25mm mg/m^3	STOPE 9 SiO_2 %	STOPE 10 13mm mg/m^3	STOPE 10 25mm mg/m^3	STOPE 10 SiO_2 %	STOPE 11 13mm mg/m^3	STOPE 11 25mm mg/m^3	STOPE 12 13mm mg/m^3	STOPE 12 25mm mg/m^3	STOPE 12 SiO_2 %	STOPE 13 13mm mg/m^3	STOPE 13 25mm mg/m^3	AVERAGES 13mm mg/m^3	AVERAGES 25mm mg/m^3	AVERAGES SiO_2 %
RETURN	0.800	1.930					0.800	1.193		0.267	0.053		0.743	3.346	1.249	1.579		0.852	1.787	0.907	2.081	
FACE	0.882	2.632		0.820	3.158		0.547	2.316		0.906	3.246		0.082	0.977	1.227	1.105		0.733	0.09			
FACE	0.551	2.281		1.087	1.947		0.153	1.474		0.533	3.684		0.871	1.579	1.420	1.675		0.885	0.852			
FACE	0.781	1.754					0.642	3.349		1.087	1.000				1.247	1.000		0.811	0.570			
FACE																						
FACE																						
FACE																						
AVE FACE		0.725			0.944			0.447			0.835			0.467		1.298			0.803	0.779		
		2.222			2.563			2.380			2.310			1.778		1.260			0.500		3.450	
OLD AREA	0.208	2.895		0.827	2.158													0.885	0.948			
				0.820	1.263																	
OLD AREA																						
OLD AREA																						
AVE OLD AREA	0.208	2.895		0.724	1.711													0.885	0.948	0.727	1.888	
INTAKE				1.727	3.158		0.478	0.395		0.700	0.105		0.443	0.789	1.161	2.105		0.907	4.702			
INTAKE																		0.867	0.596			
AVERAGE				1.727	3.158		0.478	0.395		0.700	0.105		0.443	0.789	1.161	2.105		0.887	2.649	0.701	1.610	
TRAVERSE		0.810	11.3		1.082	9.7		0.455	32.6		0.674	18.4		0.569		0.570	22.3				0.722	18.01
INTEGR-ATED FULL SHIFT		0.395	18.1		0.270			0.678			0.242			0.213							0.326	18.10

' Less Than Limits of Weighing

Table 12 RESULTS OF SHORT DURATION SAMPLING - DEVELOPMENT LEVELS (MINE 3)

	DEVEL 1		DEVEL 2	DEVEL 3		DEVEL 4			DEVEL 5		DEVEL 6			AVERAGES	
POSITION	13 mm	25 mm	25 mm	13 mm	25 mm	13 mm	25 mm	QUARTZ	13 mm	25 mm	13 mm		SPONGE	13 mm	25 mm
	mg/m^3			mg/m^3		mg/m^3		PERCENT	mg/m^3		mg/m^3		mg/m^3	mg/m^3	
RETURN	0.387			2.580		0.212			0.522		1.217			0.984	3.917
		2.947			1.474	1.093	1.483			1.316		0.614			
FACE	1.193			0.824		0.480			0.617		1.217			0.866	1.548
		3.632	2.263		0.048		2.158			0.746		0.439			
	1.307			2.479		0.427								1.404	1.691
		2.053			2.440		0.579								
				1.393										1.393	7.105
					7.105										
AVERAGE	1.250			1.565		0.454			0.617		1.217			1.221	3.448
		2.843	2.263		3.198		1.369			0.746		0.439			
INTAKE	0.267			0.067		0.151			0.520		1.027			0.406	1.284
		2.211	1.895		0.088		0.913			2.246		0.351			
TRAVERSE							0.395	25.5		0.107			0.840		0.251
INTEGRATED															
FULL SHIFT		1.012			0.533								0.650		0.773

LOCALITY		STOPE 2			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge
		13 mm	25 mm		
Return	R		1,447		
Face	1		3,377		
Face	2		29,386		
Face	3				
Face					
Ave. face			10,900		mg/m³
Old area Old area Ave. old area					
Intake Intake	4				
Traverse Integrated Full shift			0,945 0,192		

SKETCH

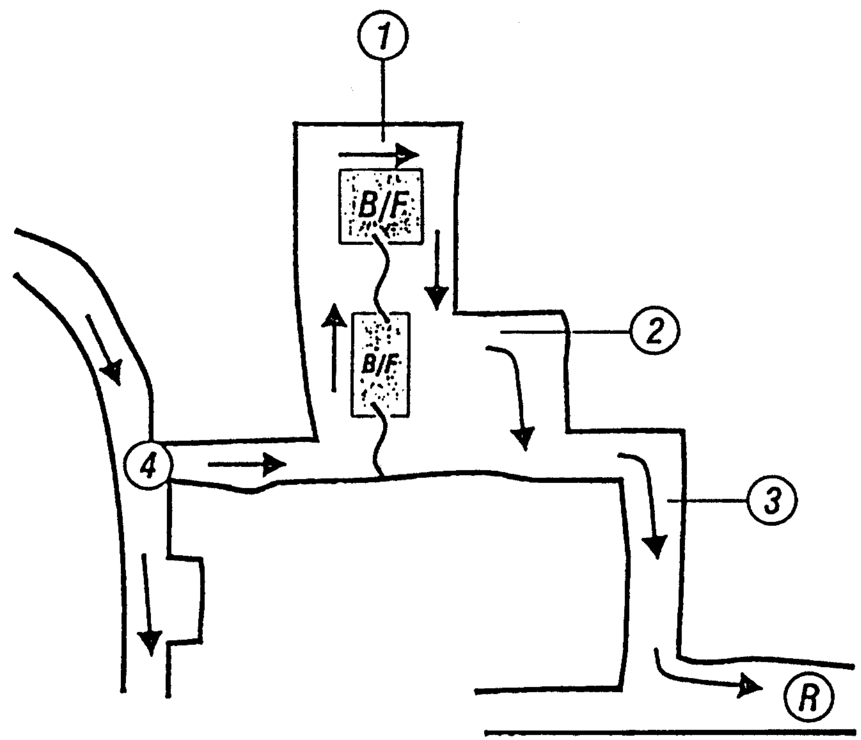


FIGURE 96. SHORT DURATION DUST SAMPLING

MINE 3 - STOPE 2

LOCALITY		STOPE 9			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge
		13 mm	25 mm		
Return	R	0,600	1,193		
Face	1	0,547	2,316		
Face	2	0,153	1,474		
Face	3	0,642	3,349		
Face					
Ave. face		0,447	2,378		mg/m³
Old area Old area Ave. old area					
Intake Intake	4	0,478	0,395		
Traverse Integrated Full shift			0,455 0,678		

SKETCH

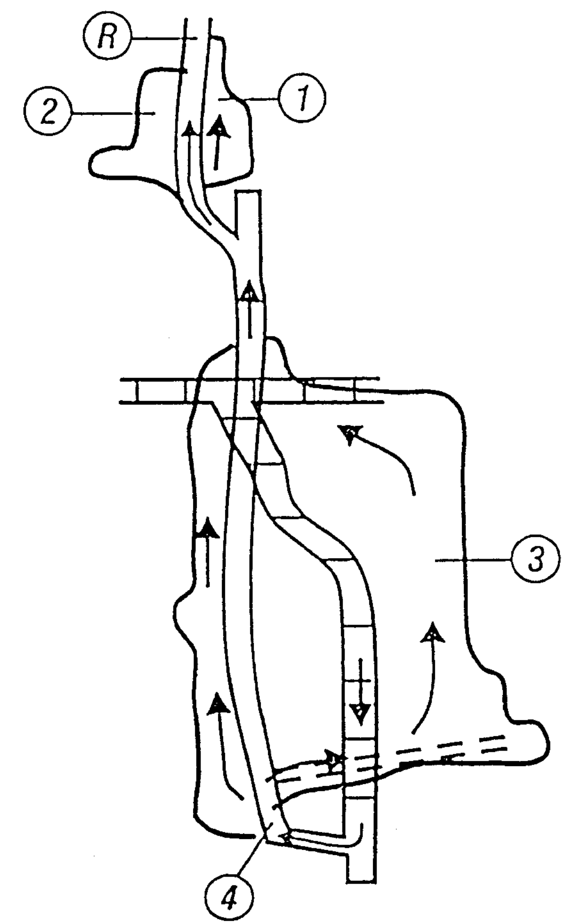


FIGURE 97. SHORT DURATION DUST SAMPLING

MINE 3 - STOPE 9

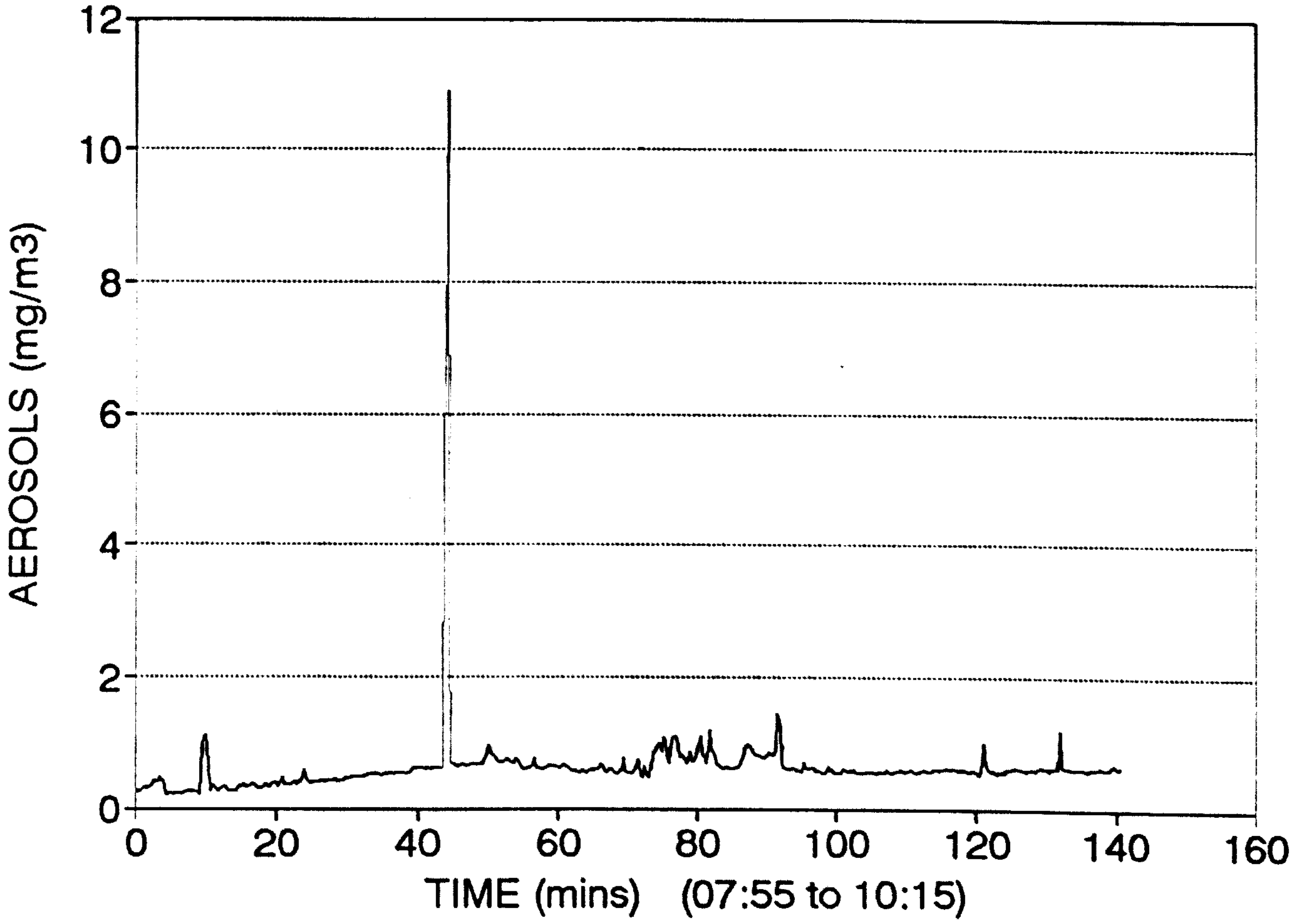


FIGURE 98. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 3 - STOPE 9

LOCALITY		Development 3		
Position	Ref.	Dust Concentration mg/m^3		Quartz (%)
		13 mm	25 mm	
Return	R	2,580	1,474	
Face	1	0,824	0,048	
Face	2	2,479	2,440	
Face	3	1,393	7,105	
Face				
Ave. face		1,565	3,197	
Old area				
Old area				
Ave. old area				
Intake	4	0,067	0,088	
Intake				
Traverse			0,634	
Integrated				
Full shift			0,533	

Rotating Sponge

mg/m^3

SKETCH

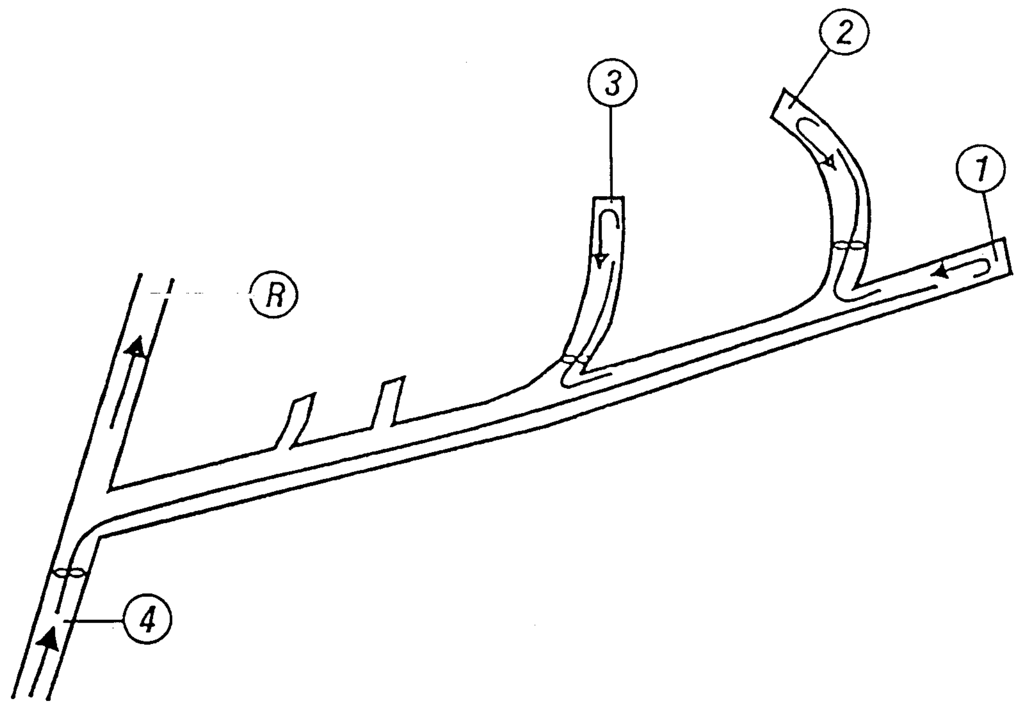


FIGURE 99. SHORT DURATION DUST SAMPLING

MINE 3 - DEVELOPMENT END 3

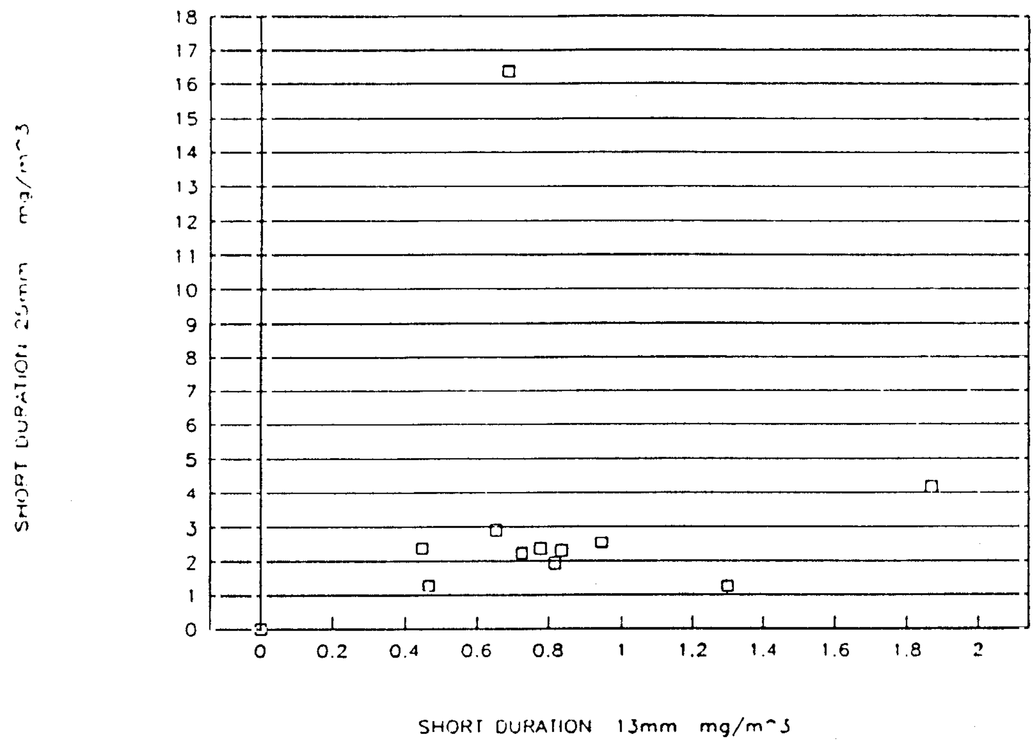


Figure 100 <u>COMPARISON OF AVERAGE SHORT DURATION 13 mm (1.5 ℓpm) AND 25 mm (1.9 ℓpm) SAMPLES (MINE 3) - STOPES</u>

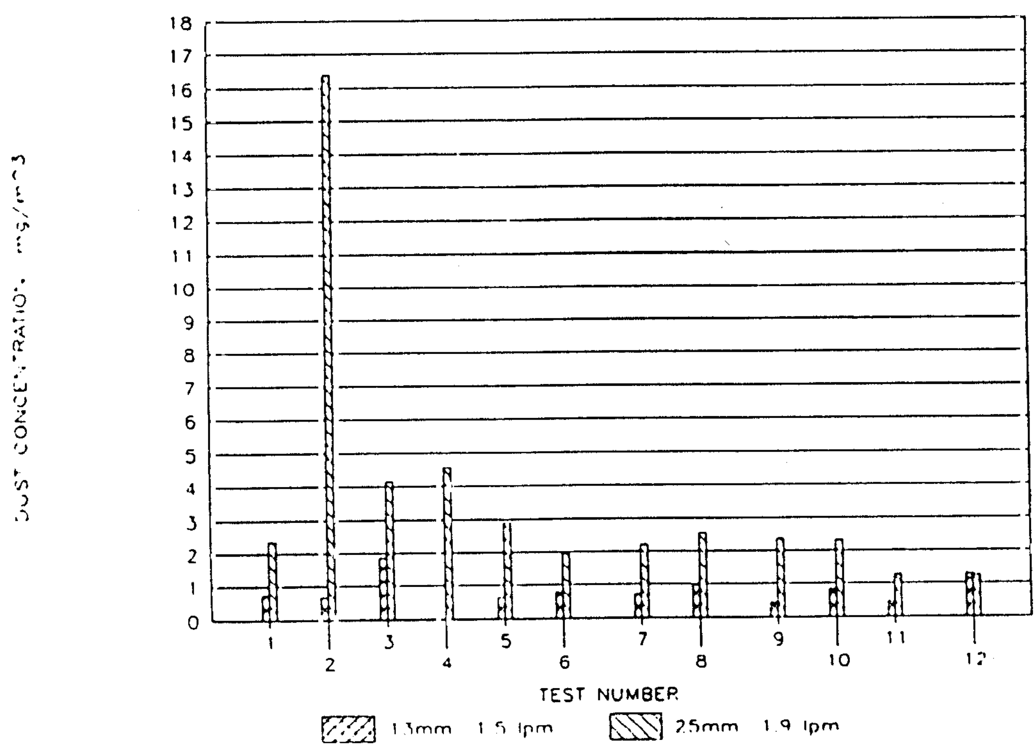


Figure 101 <u>BAR CHART COMPARISONS OF AVERAGE SHORT DURATION 13 mm (1.5 ℓpm) AND 25 mm (1.9 ℓpm) SAMPLES (MINE 3) - STOPES</u>

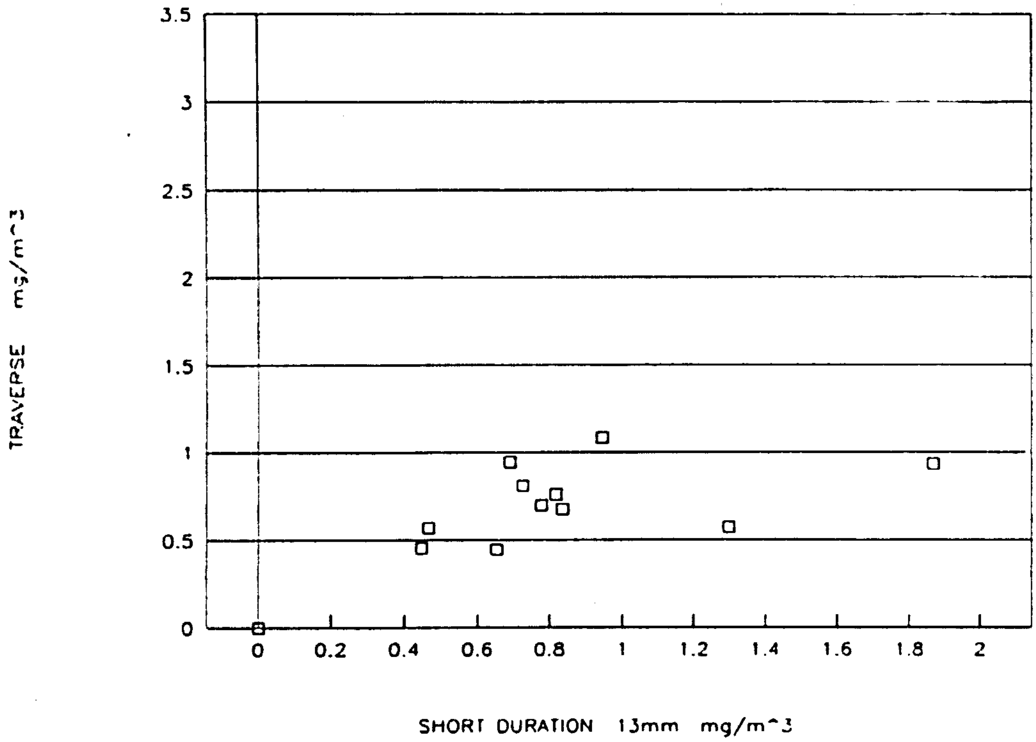


Figure 102 COMPARISON OF 13 mm FILTER SHORT DURATION AND TRAVERSE SAMPLES (MINE 3 - STOPES

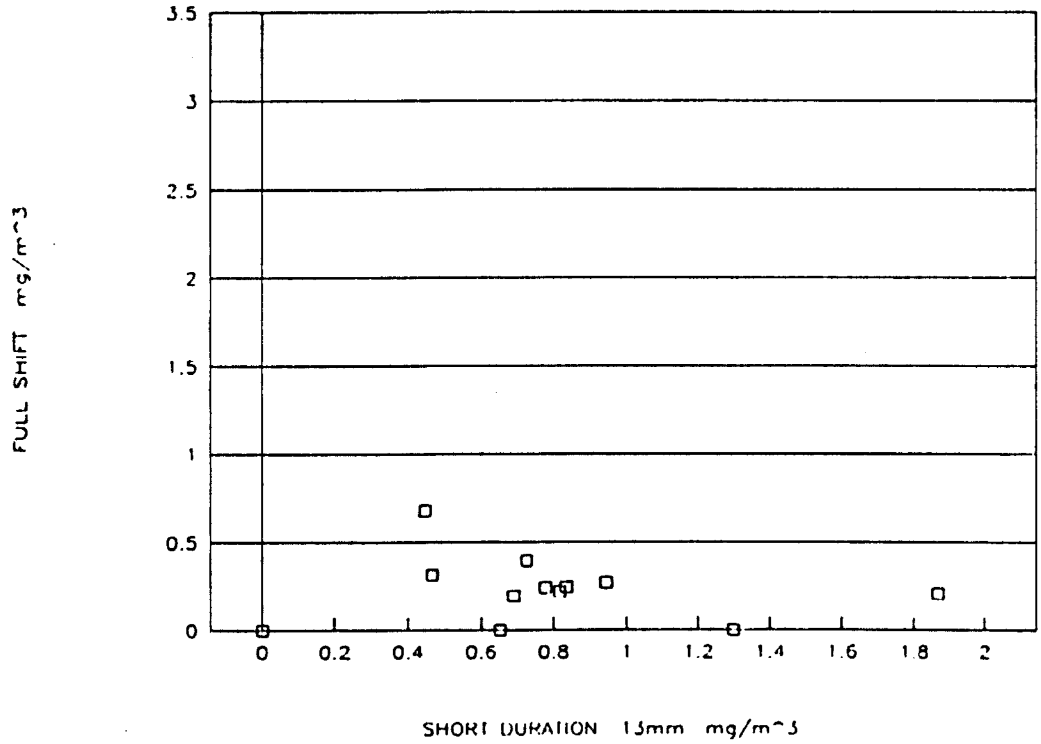


Figure 103 COMPARISON OF 13 mm FILTER SHORT DURATION AND FULL SHIFT (MINE 3) - STOPES

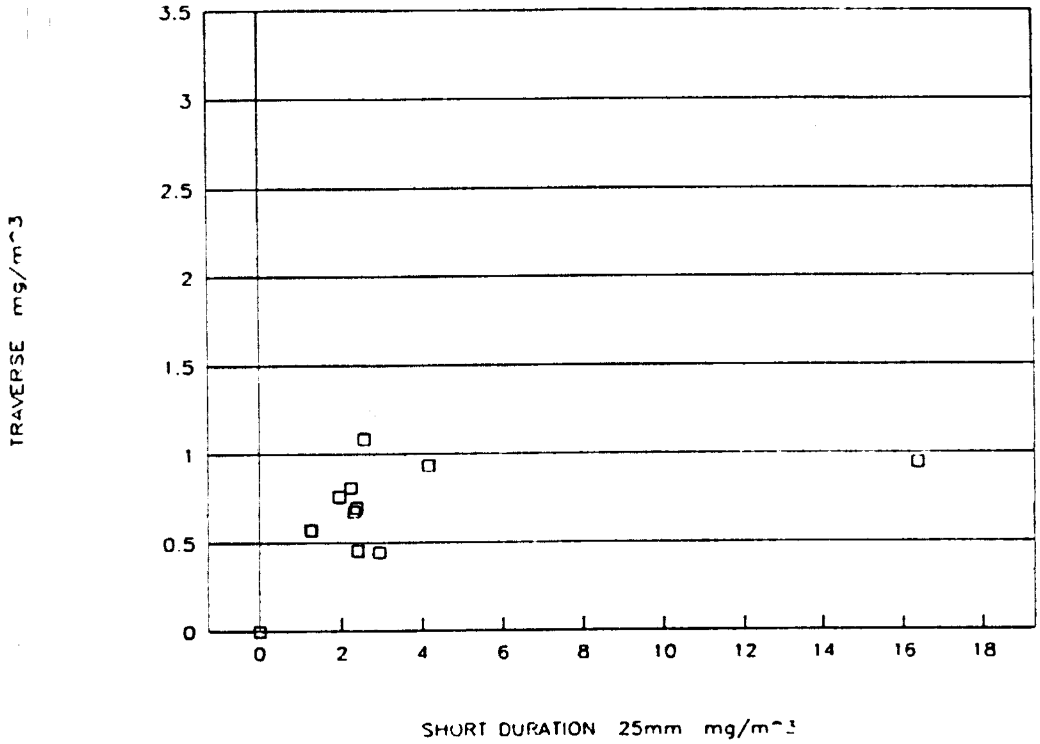


Figure 104 <u>COMPARISON OF 25 mm FILTER SHORT DURATION AND TRAVERSE SAMPLES (MINE 3) - STOPES</u>

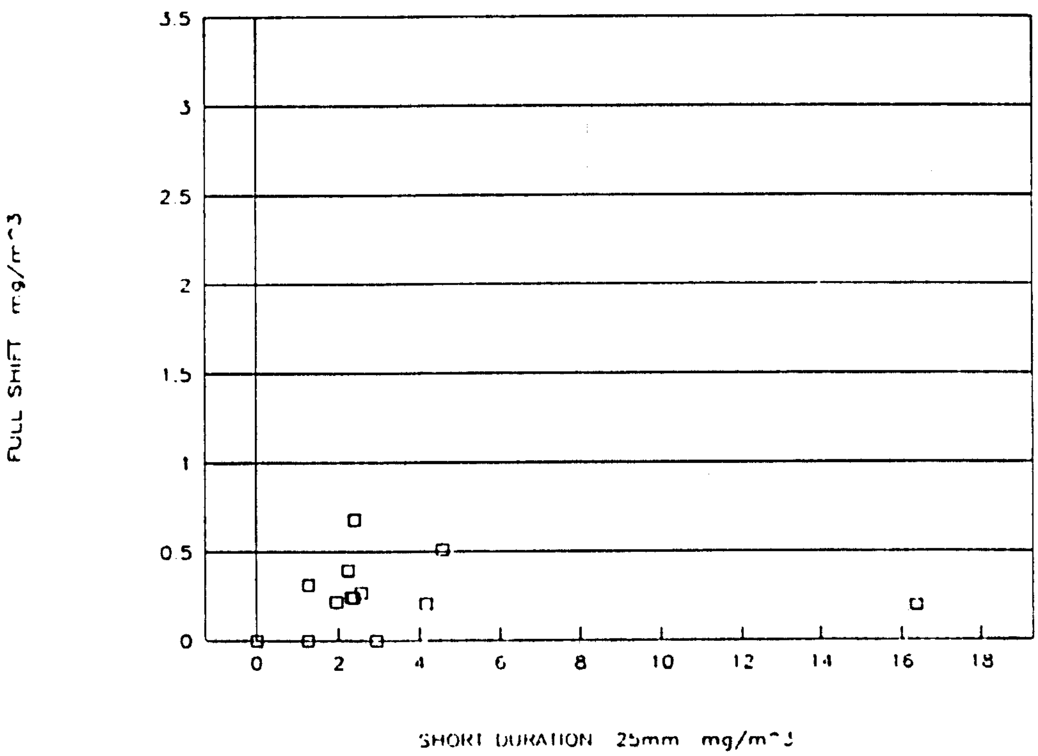


Figure 105 <u>COMPARISON OF 25 mm FILTER SHORT DURATION AND FULL SHIFT SAMPLES (MINE 3) - STOPES</u>

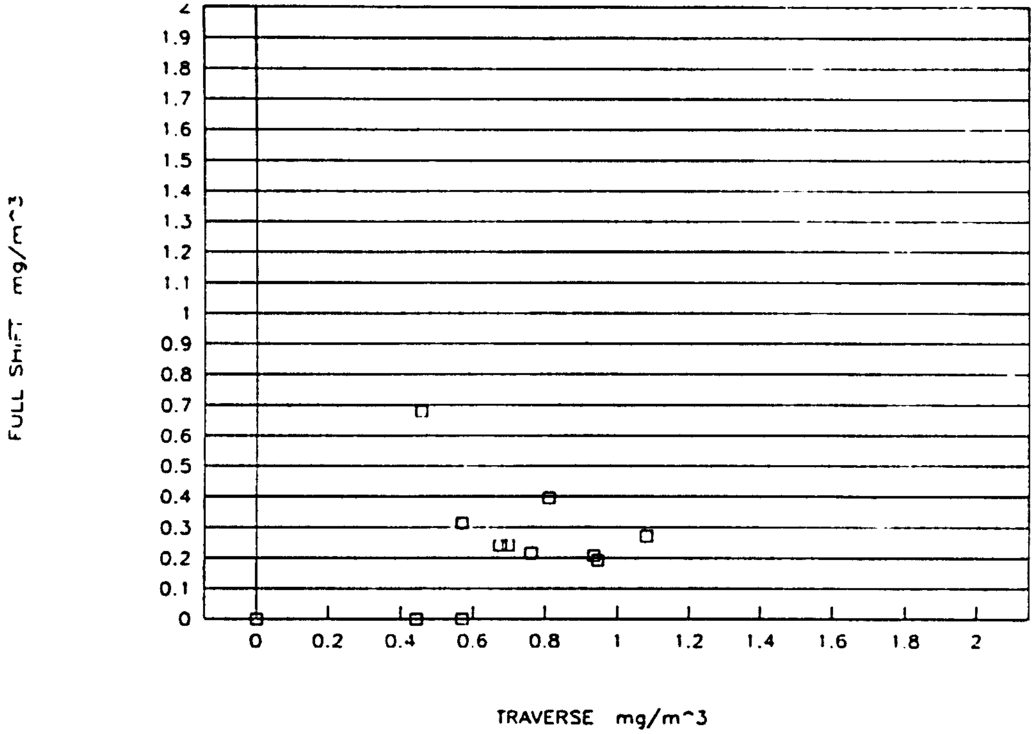


Figure 106 <u>COMPARISON OF TRAVERSE AND FULL SHIFT SAMPLES (MINE 3) - STOPES</u>

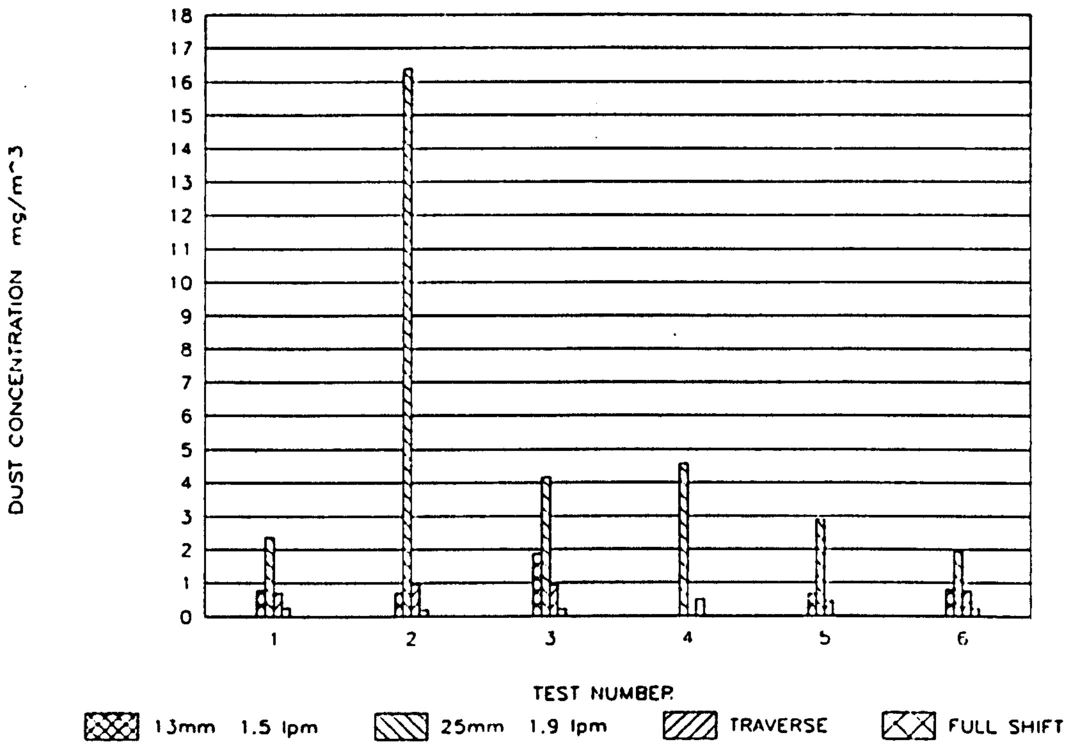


Figure 107 <u>COMPARISON OF ALL SAMPLING MODES FOR THE FIRST SIX STOPE SAMPLES (MINE 3)</u>

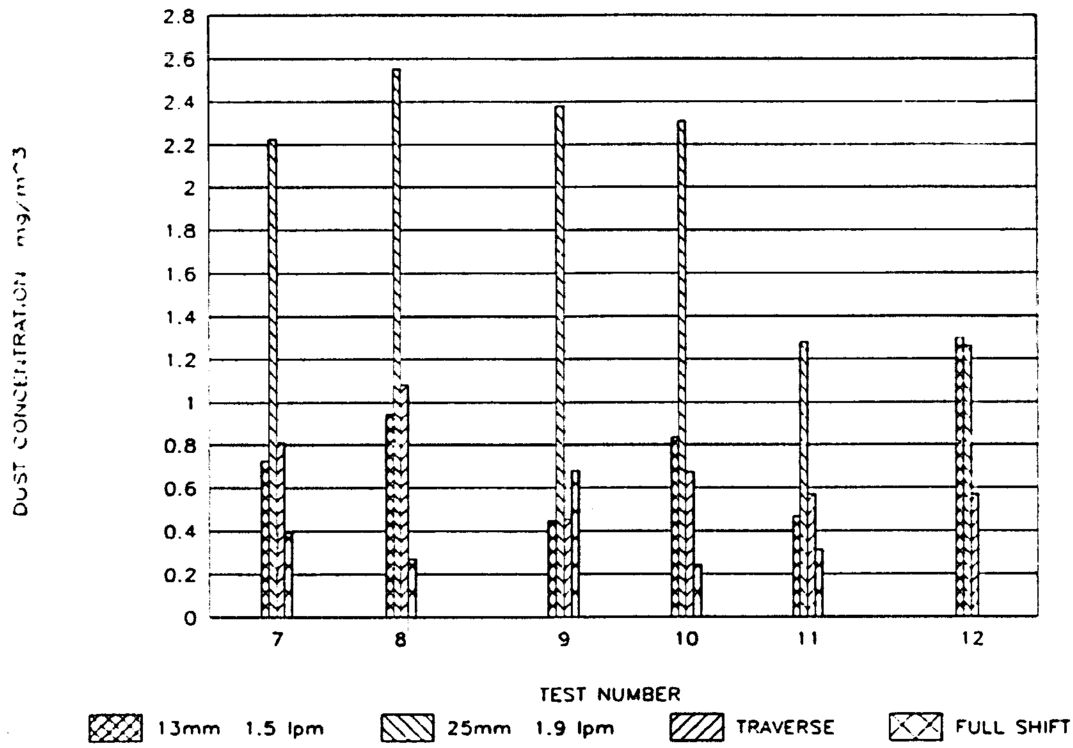


Figure 108 COMPARISON OF ALL SAMPLING MODES FOR THE SECOND SIX STOPE SAMPLES (MINE 3)

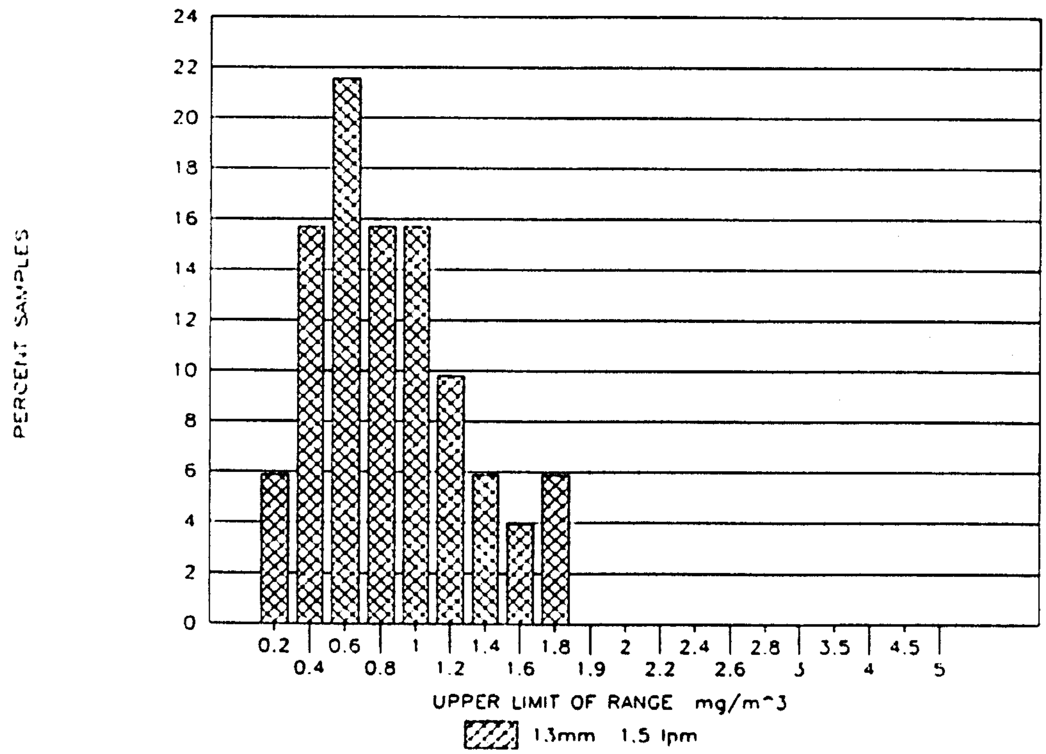


Figure 109 FREQUENCY DISTRIBUTION OF 13 mm SHORT DURATION STOPE SAMPLES (MINE 3)

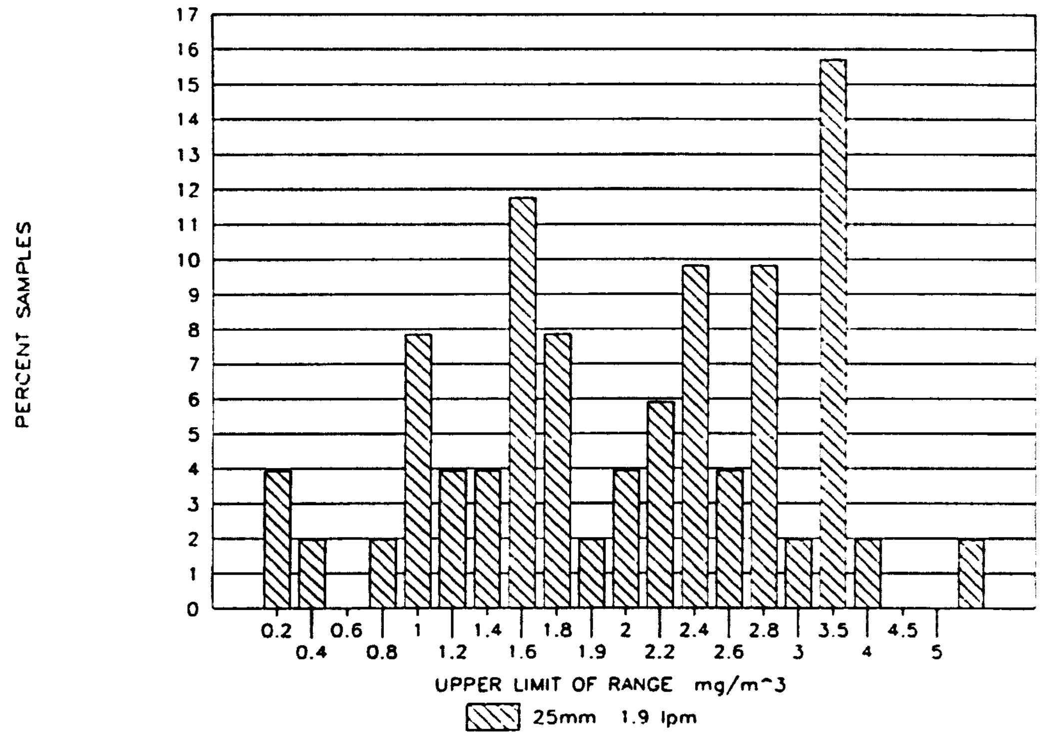


Figure 110 <u>FREQUENCY DISTRIBUTION OF 25 mm SHORT DURATION STOPE SAMPLES (MINE 3)</u>

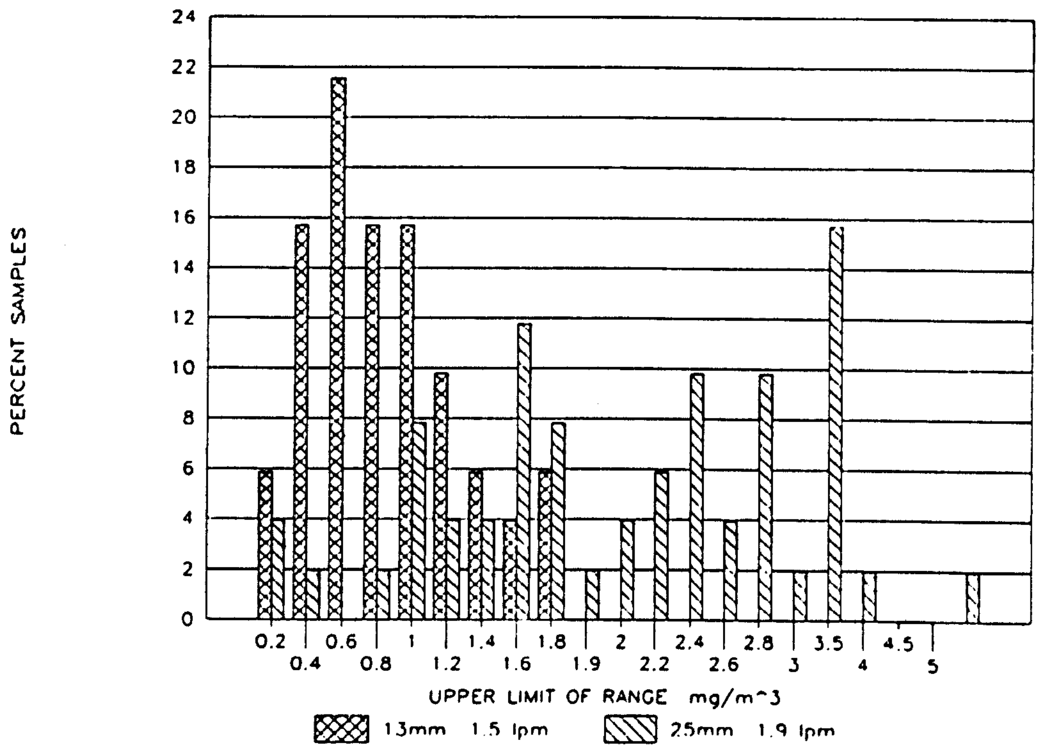


Figure 111 <u>COMPARISON OF FREQUENCY DISTRIBUTION OF 13 mm AND 25 mm SHORT DURATION STOPE SAMPLES (MINE 3)</u>

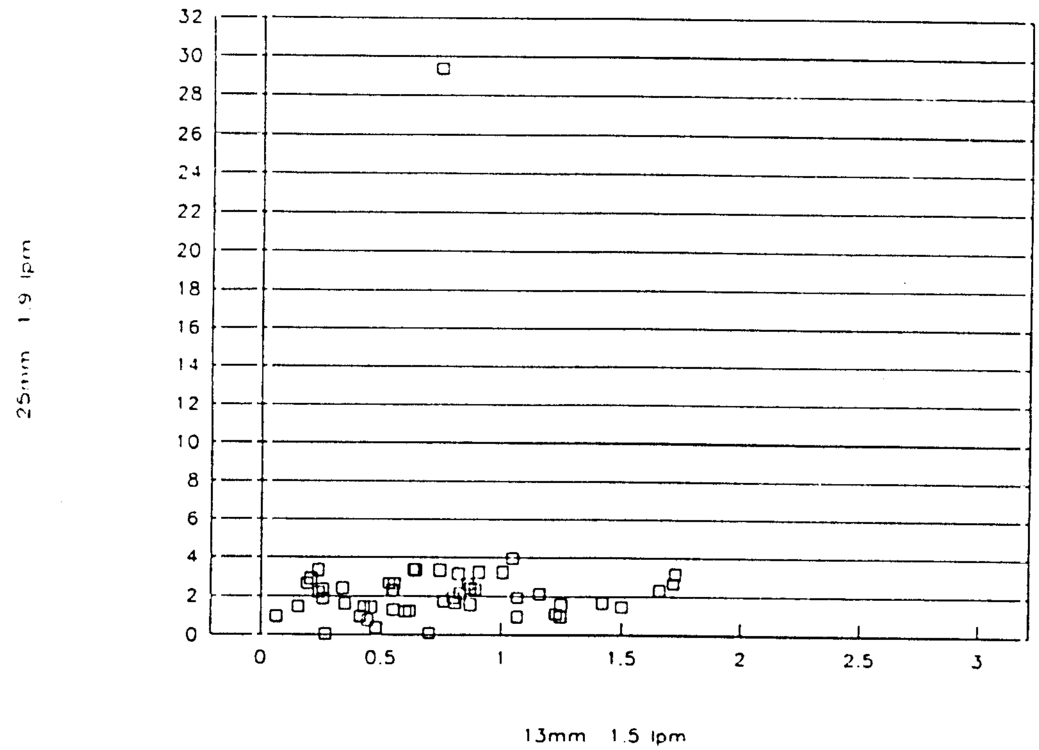


Figure 112 COMPARISON OF ALL 13 mm AND 25 mm SHORT DURATION STOPE SAMPLES (MINE 3)

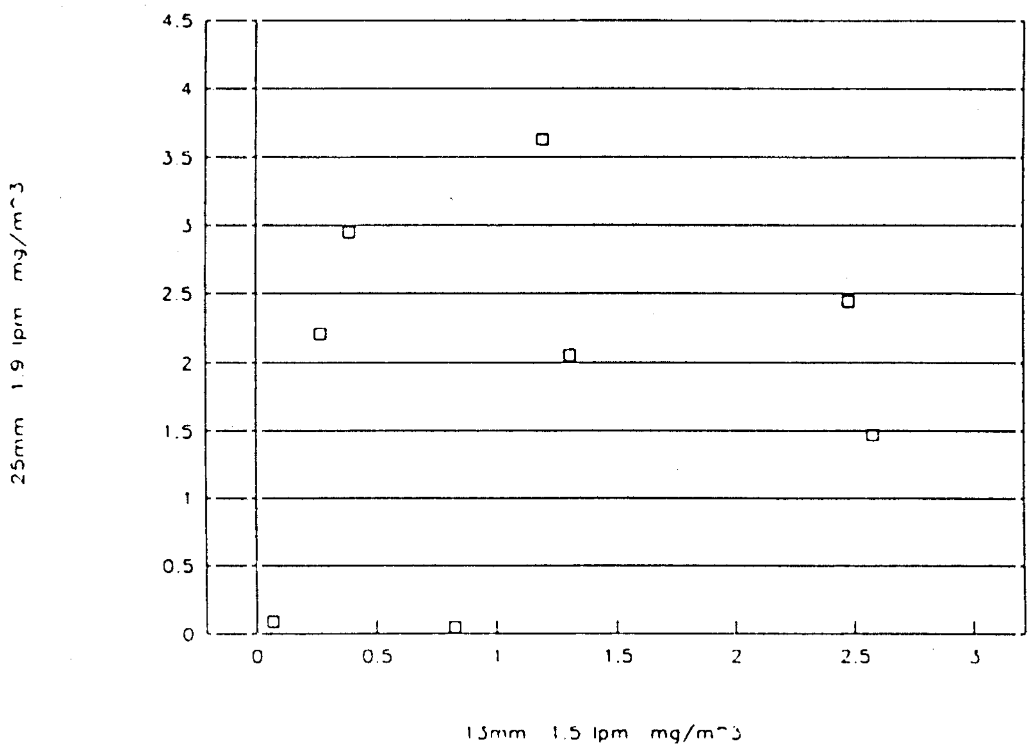


Figure 113 COMPARISON OF 13 mm AND 25 mm SHORT DURATION DEVELOPMENT END SAMPLES (MINE 3)

4.4.4. Mine 4

Table 13 RESULTS OF SHORT DURATION SAMPLING - STOPES (MINE 4)

	STOPE 1			STOPE 2			STOPE 3			STOPE 4				STOPE 5			STOPE 6				STOPE 7				AVERAGES	
	13 mm	25 mm	SPONGE	13 mm	25 mm	SPONGE	13 mm	25 mm	SPONGE	13 mm		25 mm		13 mm	25 mm	SPONGE	13 mm		25 mm		13 mm		25 mm		13 mm	25 mm
POSITION	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³		
	RESP	RESP		RESP	RESP		RESP	RESP		TOTAL	RESP	TOTAL	RESP	RESP	RESP		TOTAL	RESP	TOTAL	RESP	TOTAL	RESP	TOTAL	RESP		
RETURN										0.334							1.355				0.870				0.853	1.163
	2.340						2.690				0.499			0.640				1.000				0.600		0.370		
FACE	2.260						1.970			0.673							1.000				3.560		3.280			
											0.672			1.070				1.090				2.380		1.660		
FACE	1.480						2.030										0.850				1.510					
																		0.670				0.620				
FACE	2.060						2.290																			
FACE																										
FACE																										
FACE																										
AVE FACE	1.933						2.097			0.673	0.672			1.070			0.925	0.880			2.535	1.500	3.3	1.660	1.853	3.280
																										1.402
OLD AREA							3.040			0.061							4.060		1.550		1.480		0.5			
											0.511							4.930		2.020		1.580				
OLD AREA										1.246		0.613														
OLD AREA											1.288															
AVE OLD AREA							3.040			0.654	0.900	0.613					4.060	4.930	1.550	2.020	1.480	1.580	0.5		1.342	2.342
INTAKE	1.500			0.024			1.870			0.378							0.920				1.030		0.3		0.660	0.753
											0.300			0.481				0.544				0.550				
INTAKE AVERAGE	1.500			0.024			1.870			0.378	0.300			0.481			0.920	0.544			1.030	0.550	0.3			
TRAVERSE		0.924	0.876		0.688	0.703		1.041	4.08				0.184			0.6				0.273		0.810				1.020
INTE-GRATED			1.532			1.315			1.11							1.2										1.278
FULL SHIFT		0.765			1.230			1.137					0.359		0.145					0.712		0.395				0.59

Table 14 RESULTS OF SHORT DURATION SAMPLIN(

	DEVEL 1				DEVEL 2			DEVEL 3			DEVEL 4		DEVEL5		DEVEL 6		DEVEL 7	
	13 mm		25 mm		13 mm		25mm	13mm	25mm	SPONGE	13mm	25mm	13mm	25mm	13mm	25mm	13mm	25mm
POSITION	mg/m³		mg/m³		mg/m³		mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³
	TOT	RESP	TOT	RESP	TOT	RESP	RESP	RESP	RESP		RESP	RESP	RESP	RESP	RESP	RESP	RESP	RESP
RETURN																		
		0.808				1.060		0.883			1.567		1.030		1.370		1.367	
																		•
FACE	2.780				4.030													
		1.450				1.180		1.570			0.824		0.536		1.070		1.272	
			1.090															
									0.813									1.579
INTAKE	1.650				1.580													
		1.980				0.840		0.702			0.733		0.812		0.900		1.302	
			0.780															
							•											0.070
TRAVERSE				0.707		•	0.707			0.090				0.315		0.315		0.335
INTEGRATED										0.543								
FULL SHIFT				0.521		•	0.521		0.124			0.124		1.595		1.566		1.560
				1.012														

*Spot Sample

EVELOPMENT ENDS (MINE 4)

DEVEL 8			DEVEL 9			DEVEL 10		DEVEL 11		DEVEL 12		DEVEL 13			DEVEL 14		AVERAGES				
13mm	25mm	SPONGE	13mm	25mm	SPONGE	13mm	25mm	13mm	25mm	13mm	25mm	13mm	25mm	SPONGE	13mm	25mm	13 mm		25 mm		SPONGE
mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³		mg/m³		mg/m³
RESP	RESP		RESP	RESP		RESP	RESP	RESP	RESP	RESP	RESP	RESP	RESP		RESP	RESP	TOT	RESP	TOT	RESP	
1.638			4.390			0.950		0.160		1.970		4.390						1.660			
				0.656							1.350		1.030							1.025	
																	3.405				
			4.391			1.410		1.370		1.650		0.560			1.360			1.560			
3.000																			1.090		
				14.3					0.170				•							4.220	
																	1.615				
1.225			4.754			1.426		0.800		1.580		1.200			0.700			1.354			
																			0.780		
	•			3.745																1.908	
	1.329	0.583		1.329	0.594		0.422		0.352		0.352		0.258	1.298		0.258				0.531	0.706
		3.010			3.014									5.250							2.675
	0.971			0.971			•		•				0.517			0.517				0.856	

LOCALITY		STOPE 1					
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge mg/m³
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		
Return	R		2,340				
Face	1		2,260				
Face	2		1,480				
Face	3		2,060				
Ave. face			1,930				
Old area							
Old area							
Ave. old area							
Intake	4		1,500				
Intake							
Traverse					0,924		0,876
Integrated							1,532
Full shift					0,765		

SKETCH

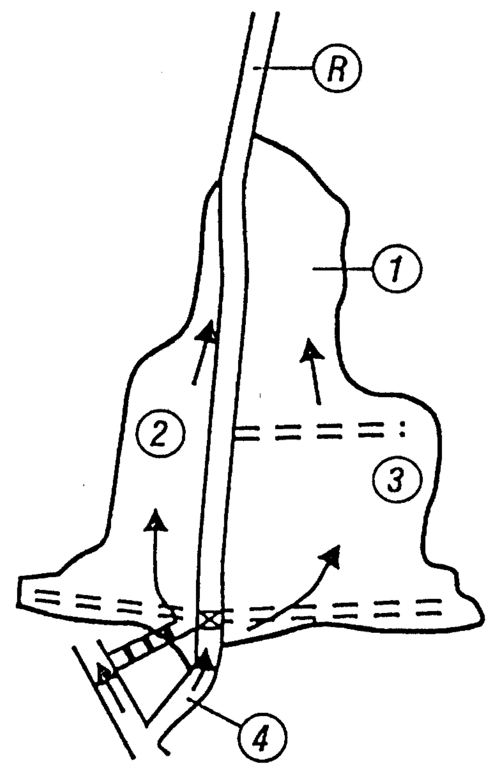


FIGURE 114. SHORT DURATION DUST SAMPLING

MINE 4 - STOPE 1

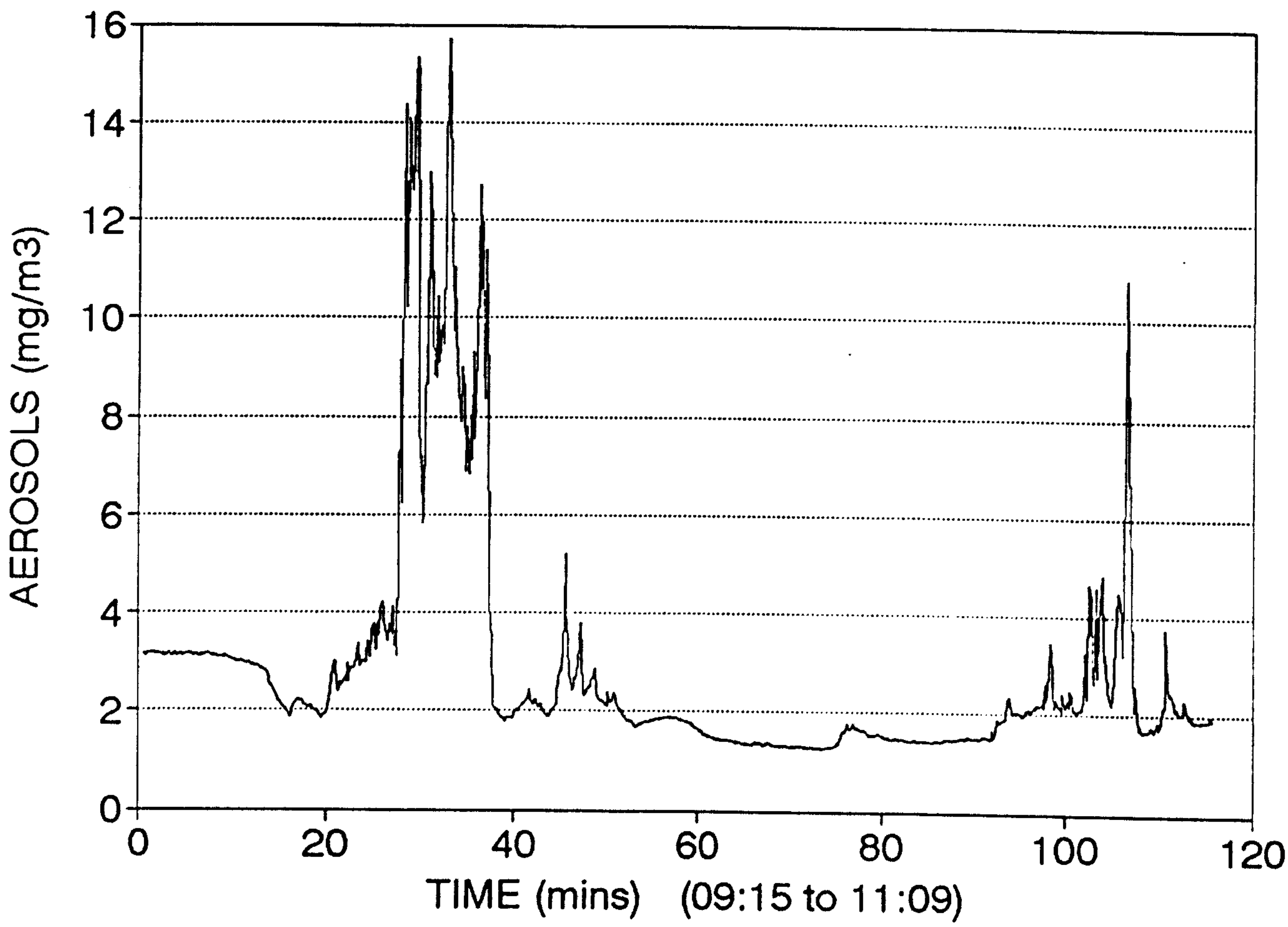


FIGURE 115. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 4 - STOPE 1

LOCALITY		STOPE 4					
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge mg/m³
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		
Return	R	0,334	0,499				
Face	1	0,673	0,672				
Face							
Face							
Ave. face		0,673	0,672				
Old area	2	0,061	0,511				
Old area	3	1,246	1,288	0,613			
Ave. old area		0,654	0,900	0,613			
Intake	4	0,378	0,300				
Intake							
Traverse					0,184		
Integrated							
Full shift					0,359		

SKETCH

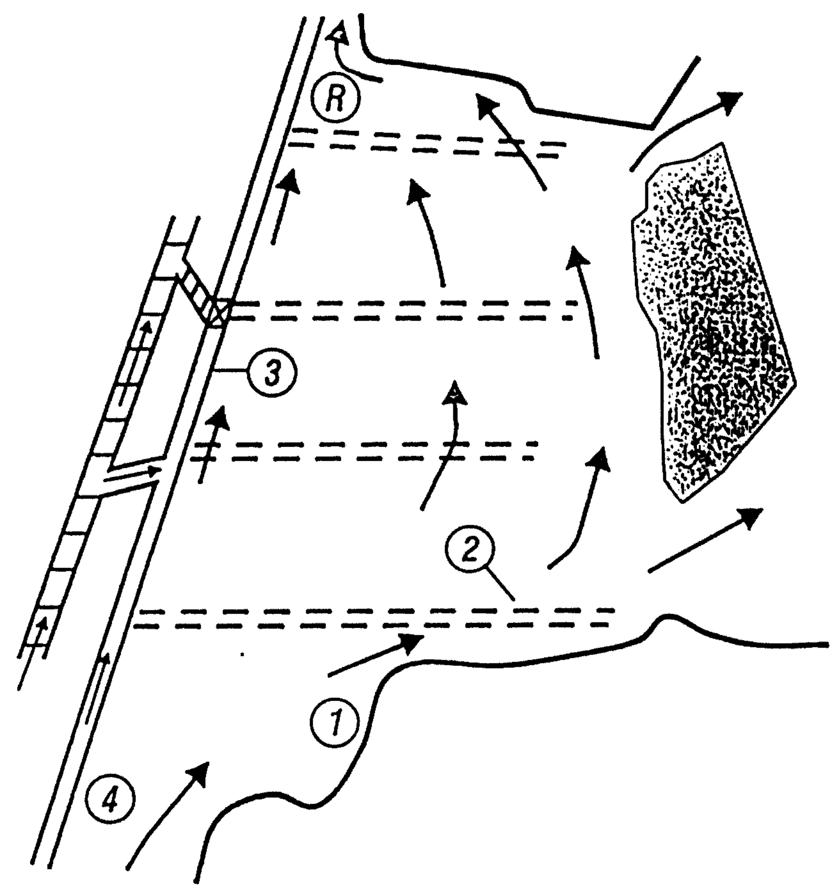


FIGURE 116. SHORT DURATION DUST SAMPLING

MINE 4 - STOPE 4

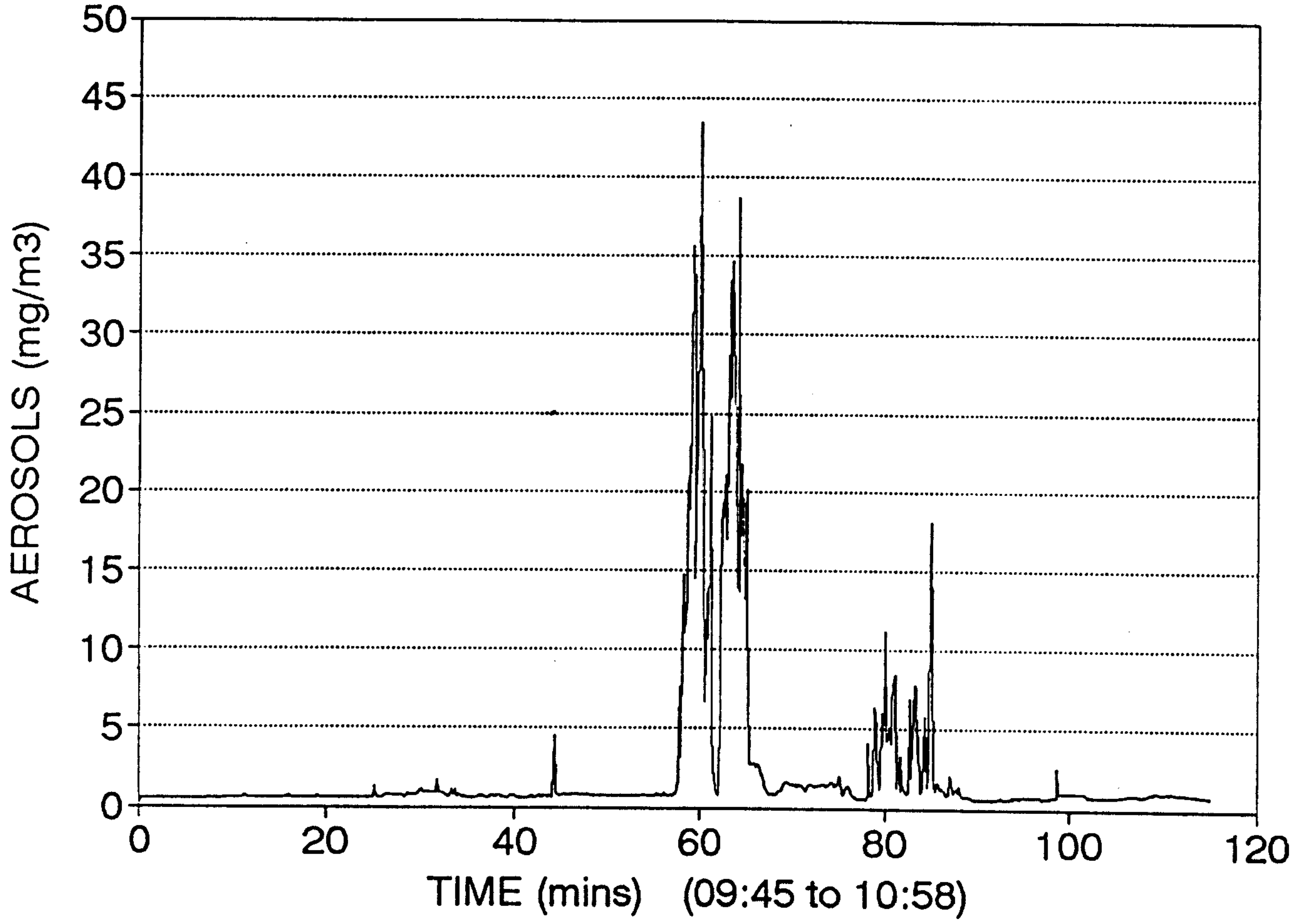


FIGURE 117. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 4 - STOPE 4

LOCALITY		DEVELOPMENT 1					
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		mg/m³
Return	R		0,808				
Face	1	2,780	1,450	1,090			
Face							
Face							
Ave. face		2,780	1,450	1,090			
Old area							
Old area							
Ave. old area							
Intake	2	1,650	1,980	0,780			
Intake							
Traverse					0,707		
Integrated							
Full shift					0,521		

SKETCH

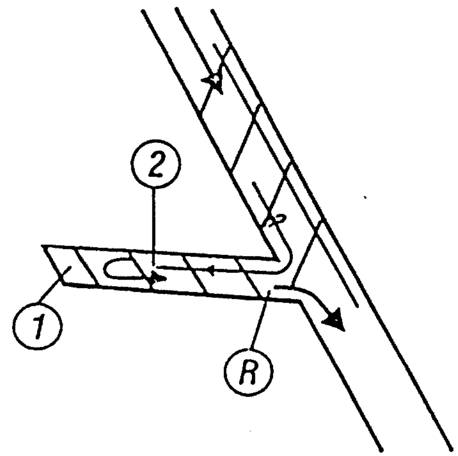


FIGURE 118. SHORT DURATION DUST SAMPLING

MINE 4 - DEVELOPMENT END 1

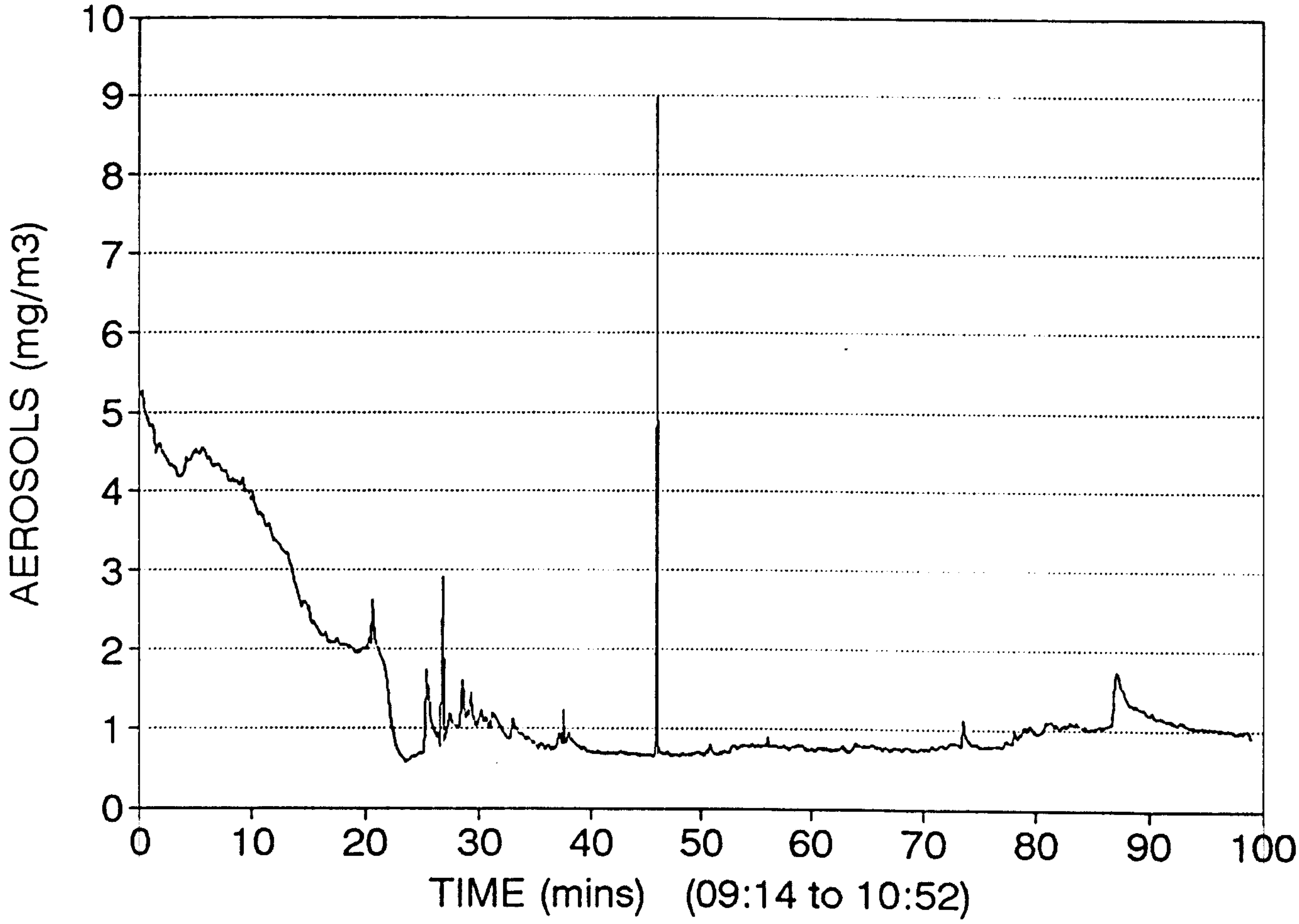


FIGURE 119. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 4 - DEVELOPMENT 1

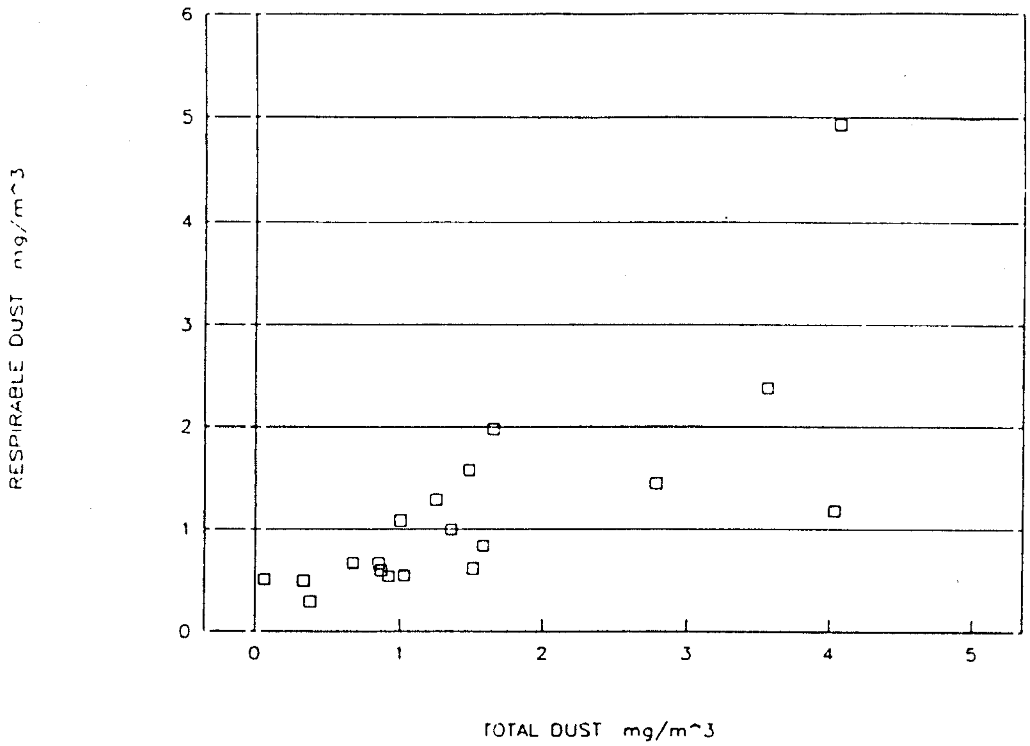


Figure 120 <u>COMPARISON OF 13 mm AND 25 mm SHORT DURATION SAMPLES - DEVELOPMENT END (MINE 4)</u>

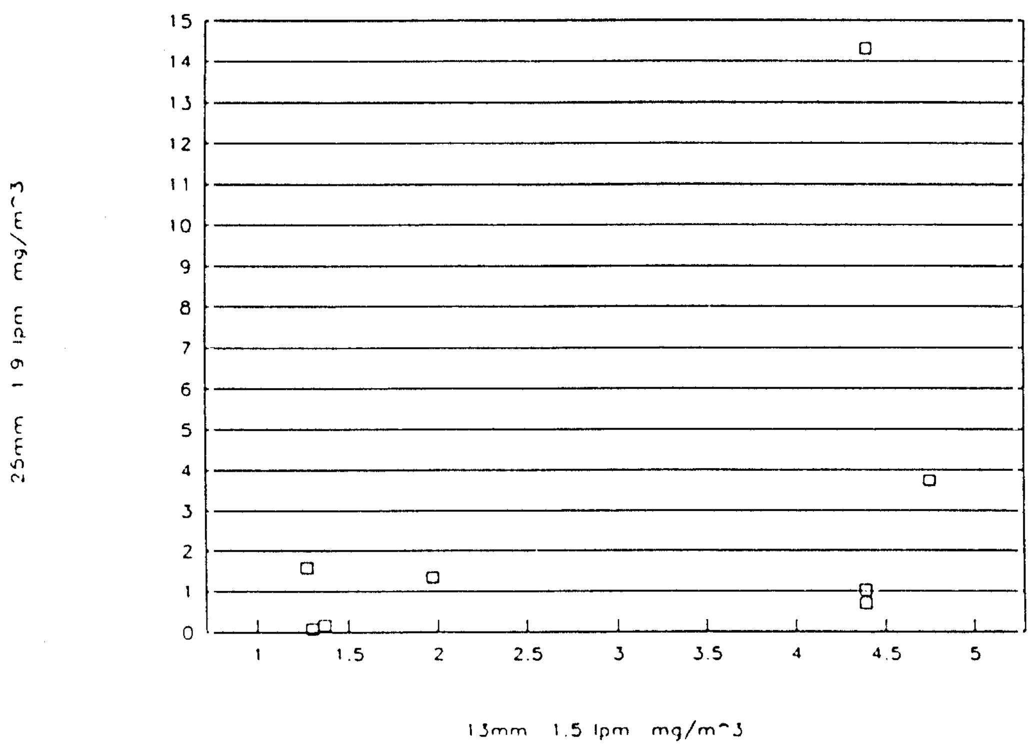


Figure 121 <u>COMPARISON OF TOTAL AND RESPIRABLE DUST SAMPLES FOR 13 mm FILTERS (MINE 4)</u>

4.5 Discussion

A study of Figures 56 - 58, 74 - 78, 96 - 99 and 114 - 119 as well as Figures 140 to 209 in Appendix A shows that short duration sampling can usefully be deployed to provide indications of dust levels in the workplace, both in stopes and development ends. It has also been found to be possible to link particular dust levels to specific operations or activities. If the results of such sampling are entered in standard environmental control reports attention can be directed to unsatisfactory levels and malpractices. This is clearly seen, for example, in Figures 56 to 58. The dust levels from the dust producing activity noted in stope 2 of the first tests (Figure 56) are also reflected in the tyndallometer real-time dust level trace depicted in Figure 57. Because a tyndallometer measures aerosol concentrations, that is all suspended particulates including water vapour, oil mist, dust, etc, direct comparisons with other sampling methods such as gravimetric samples are not always valid, with tyndallometer readings sometimes grossly exceeding the values obtained from other sampling methods. In addition, tyndallometers, in general, do not actually collect dust on a filter so that no actual physical sample is ever available and there is no dust on which pollutant analysis can be performed to establish actual toxicity. Nevertheless, tyndallometers can provide useful information but the results must be treated with a measure of circumspection.

A tyndallometer could be used, by exercising common sense and an understanding of the technique, by experienced personnel for trouble shooting. In the hands of an inexperienced operator readings could be misinterpreted especially if the use of this instrument is attempted on a routine basis because immediate action is required and it is considered that the delay for laboratory evaluations of samples is unacceptable. This is clearly illustrated in the sampling results of Stope 1 of Mine 4 (Figure 114) and the corresponding continuous tyndallometer trace shown in Figure 115. No respirable dust samples collected on the 13 mm filters would be regarded as unsatisfactory when compared to other samples collected by this method. The traverse sample, collected on a 25 mm filter during the same collection period as the tyndallometer, was also acceptable whereas, if the dust levels had been sustained at between 12 to 16 mg/m³ for approximately 15 minutes as indicated by the tyndallometer, the average dust concentration for the traverse sample could have been expected to be over 3 mg/m³.

Since this was not the case, it was possible that it was not mineral dust that had registered on the tyndallometer. If this instrument had been used on a routine basis, considerable effort may conscientiously have been expended in tracing a non-existent dust source for the purpose of controlling dust levels in the workings.

One criticism that has been levelled at short duration samples being used for control dust sampling is that the samples are not real-time and only become available after laboratory assessment. This is true but it is in keeping with occupational hygiene practices, worldwide. There are many instances where samples, such as gas samples, are collected but can only be evaluated when the samples are processed and analysed in a laboratory. As mentioned above, tyndallometer readings can lead to erroneous conclusions and can only be used as a real time monitor with great caution.

Essentially, there are four main reasons to carry out dust sampling: for dust control, for compliance testing, for epidemiological studies (occupational dust exposures) and for risk determination. These latter two reasons will be discussed later. When sampling for control purposes any method that can provide reliable and useful data should be considered for use and could easily include konimeter sampling. With this in mind, parallel sampling with gravimetric samplers (short duration) and konimeters was conducted at Mine 1. Graphical comparisons of these parallel sampling results are shown in Figures 81 to 88. It was not expected that a relationship could be derived between the two methods. The sampling was conducted to establish whether high dust concentrations recorded using short duration gravimetric samplers would be matched with high dust concentrations from konimeters. The results for individual stopes sometimes show apparent good correlation (Figure 66) but the overall results, plotted in Figure 73, indicate a poor relationship. Since the short duration gravimetric samples are capable of providing the required information with regard to the level of dustiness within the workings, it would be preferable to adhere to a single dust sampling system.

Initial indications of success with the technique led to the question of whether different size filters and different flow rates could produce equally acceptable results. The initial proposal featured the use of 13 mm filters for reasons already outlined. This would mean the acquisition of "non-standard" sampling cassettes and using "non-standard" filter diameters with "non-standard" porosity (1,2 μm) filters. Furthermore, to take full advantage of this sampling technique, micro-balances capable of reading 1 μg would also be required. Hence, if standard filters and cassettes could be used with equal success, the implementation of the proposed sampling strategy for workplaces would be easier for mines than if additional equipment had first to be acquired. Accordingly, parallel sampling with 13 mm filters (1,5 ℓpm) was undertaken. Comparison of stope averages are shown in Figures 79, 80, 100 and 101. Comparison of all 13 mm and 25 mm filters results is shown in Figures 91 and 112.

The findings presented above indicate that short duration samples can readily be collected on either 13 mm filters (1,5 ℓpm) or 25 mm filters (1,9 ℓpm) but that dust concentrations of the samples collected on the 25 mm filters are higher than those collected on the 13 mm filters. This bias and the reasons therefore were discussed in Section 3. The stope sample results thus confirm the findings of the sampling battery tests. The same comparison for the two filter sizes was also made in development ends on Mines 2,3 and 4 and are shown graphically in Figures 79, 113 and 120 respectively. In Figures 95 and 113 the dust concentrations were again found to be higher on the 25 mm filters but at the last mine there was no conclusive proof of this (Figure 120). The frequency distribution of the dust concentrations was plotted in Figures 92 and 93 for Mine 2 and Figures 109 and 110 for Mine 3.

The frequency distribution shows that most of the dust collected on the 13 mm filters was of much lower concentration than that collected on the 25 mm filters. The cut off for the higher dust concentrations on the 13 mm filters reinforces the view that there was a mismatch of cyclones and sampling trains for the 13 mm filters resulting in an under sampling. It can be concluded that the use of standard cyclones and 25 mm filters would result in truer and more representative samples than would be possible with 13 mm filters at the lower sampling rate of 1,5 ℓpm.

In addition to the short duration samples integrated samples were also collected. It was considered that, if the dust loads collected with the short duration samples proved to be too light to accurately assess, then integrated samples which use the same filter to collect dust at each measuring point, but the pump is stopped when travelling from one measuring station to the next, may prove to be more useful.

Although it proved to be practical to collect integrated samples, few comparisons between average short duration and integrated samples were made. Available data are compared in Figures 76, 94 and 98, where a bias in favour of the short duration samples is seen. This can be explained by the fact that the integrated samples included samples in intakes, returns and worked out areas whereas the average face short duration samples did not. Integrated samples can provide indications of workplace dustiness but would be of little value in identifying actual places or processes within the workplace where high levels of dust may be generated.

As an alternative to integrated samples, traverse samples could be collected in workplaces. In this type of sampling, a single sample is collected in the workplace by starting the sampling pumps when the working place is entered and stopping it when it is exited. Such samples can also provide workplace dust levels but again would not be suitable to identify places or processes where high dust levels may occur. In addition, because sampling is continuous for about two hours, high dust concentrations will be diluted by excursions into zones where dust levels may be very low. This, in fact, proved to be the case and the findings are presented graphically in Figures 60, 83, 86 and 102. In Figure 86 a comparison is made between average face short duration samples collected on 25 mm filters and traverse samples. The bias towards higher concentrations for short duration samples is not altered with a change in filter diameter.

It was shown in a previous research project (1) that full shift samples did not provide much useful information with regard to workplace exposure or in assisting with the identification of dusty places or processes. In the majority of instances full shift sampling results gave no indication of exposure to high dust levels because the averaging process diminishes peak values and they are therefore "lost". During this investigation, full shift sampling was arranged for the stopes where the other measurements were taken in order to ensure that all sampling was conducted in the same workplace. Comparisons of full shift sampling and average face short duration samples are shown in Figures 62, 85, 88, 103 and 105. Clearly, the expected bias towards higher dust concentrations for the short duration samples is once again evident. This serves to emphasise the fact that sampling strategies/techniques need to be shaped around the sampling objective.

An additional comparison was made between integrated samples and traverse samples. As would be expected the integrated samples displayed higher values than the traverse samples and this can be seen in Figures 63 and 89 although there are few points plotted in Figure 89.

Again, as could be expected, a comparison of integrated samples with full shift samples indicated a bias towards the integrated samples having the highest values. This can be seen in Figure 64.

When compared to full shift samples, the traverse samples could be regarded as a form of short duration sample and could also be expected to return higher dust levels than full shift samples. This proved to be the case as can be seen in Figures 65, 90 and 106.

A further comparison was made at Mine 4 of respirable and total dust samples. It could be argued that, if the level of dustiness in a working place is required and not personal, full-shift samples, total dust could improve accuracy in monitoring, and thereby provide a good measure of conditions because of the anticipated greater dust mass than would be collected for respirable dust samples. The results of the comparison are shown in Figure 121. As expected, the total dust concentrations were found to be higher than the respirable dust concentrations. This contrasts with the findings presented in Section 3 where little difference was found. However, the comparisons reported in Section 3 were made in Return Airways and it is possible that most of the coarse, non-respirable dust fraction had settled out before the dust reached the monitoring sites. This, however, was not the case where the face measurements were made at Mine 4 where coarse dust was closer to the source of generation. For convenience comparisons of all sampling modes are shown in Figures 59, 80, 81, 82, 107 and 108.

With the official abolishment of all konimeter sampling, mines experienced difficulties with gravimetric sampling to establish whether dust decay was adequate at the expiration of re-entry intervals in development ends to permit entry by mining personnel. Using the short duration sampling technique it will be possible to establish if dust levels have reverted to normal by collecting a 10 to 15 minute sample prior to blasting, and then collecting three successive 12 minute samples in the return air of the development end at the conclusion of the re-entry interval. This will show a trend in dust concentrations. This technique has not been fully evaluated but no difficulties are anticipated on the basis of preliminary tests.

Two of many notable recommendations that emerged from the 1959 Johannesburg Pneumoconiosis Conference [3] are:

1. "In the light of present knowledge, dust measurements to assess health hazards should be expressed as the average level of dustiness over an appropriate period of sampling, such as a shift. This measurement may be made by averaging a number of samples, or by using an instrument which automatically averages the dust over the period. Exceptional peaks of dust might also be recorded."

2. "More attention should be paid to designing a dust sampling strategy, bearing in mind the differences between sampling for purposes of dust control and sampling in order to determine the health hazard."

The reasons for collecting dust samples are thus very important and will dictate both the strategy to be followed and the equipment to be deployed.

Prior to the introduction of gravimetric sampling, konimeter sampling was carried out for dust control purposes. The results of konimeter dust sampling, although by no means absolute, were routinely used in determining whether contamination constituted a danger to health, what and where the source of contamination was, and whether actions implemented to control emissions or liberation of undesirable dust concentrations into the work environment were having the desired effect. Such sampling was also used to confirm that satisfactory conditions had been achieved and maintained, to provide records of dust conditions to assist in studying trends and also to assist with the design of ventilating systems.

All dust sampling was centred around control purposes and the philosophy was that, if dust levels can be controlled in the workings, then exposures and doses will be controlled. However, the advent of gravimetric dust sampling heralded the abolishment of official control dust sampling for a large number of mines.

As was found in a previous project[1], and noted in comparisons between full shift samples and short duration samples, there is very little meaningful correlation between results. In reality, little correlation should be expected because the systems are intended for different purposes.

The present investigation has shown that short durations samples, collected gravimetrically with standard equipment on standard settings, are able to provide very useful information on dust conditions at different localities within the workings in both stopes and development ends. It is therefore feasible to use the results of such sampling to compile a workplace risk. Any workers in the workplace would be exposed to this risk but this may not necessarily be the health risk to the workers because this should be determined from full shift samples. By compiling an inventory of workplace risks, workplace conditions may be compared.

The question then to be asked is: How should workplace dust levels measured with the short duration sampling technique be interpreted?

A comparison with an eight hour sample is illustrated below

(×)	Full shift personal sample:	8 hours TWA 0.5 mg/m^3 = 4.0 mg/m^3 -hour
(y)	Short duration sample:	15 minute av 6.0 mg/m^3 = 1.5 mg/m^3 -hour

Assuming steady state, the eight-hour equivalent for (y) would be 0.19 mg/m^3. This appears to be very much lower than the 0.5 mg/m^3 reported for (×).

However, if the same short duration dust concentration were to be measured over an hour instead of 15 minutes, the following would be derived:

(z): one hour at ave 6.0 mg/m^3 gives 6.0 mg/m^3 -hour

Converting to an eight hour equivalent gives 0.75 mg/m^3 and this is then higher than the 0.5 mg/m^3 of case (×).

By extending the monitoring time the projected eight-hour concentration is seen to increase, but the real concentration has remained unchanged. The workplace levels should thus be quoted at face value ie the 15 minute concentration, and the average of the working face levels can be used as a measure of the working places' dustiness.

Average face dust concentrations can be used as an index of workplace conditions and can be used to compare conditions in different workplaces. Analyses of samples should not be necessary if an industry level of 20 percent for quartz content is adopted as was proposed in a previous project (1).

Since the toxic content of an airborne pollutant is used mainly in the determination of personal risk it may not be necessary to determine the toxic content to describe workplace risk. If the toxic content is not disregarded or taken to be some industry average then the implications are that each short duration sample or combination of samples would need to be analysed before the workplace risk can be determined. However, the results presented in the report show that only small masses of dust are collected for short duration samples and that the quartz content of such small masses was found to be, to all intents and purposes, less than the detection limit of 20 μg. Where very much higher quartz concentrations exist the quartz content may be measurable. To ensure that quartz content for a workplace can be ascertained it will become necessary to do so from either a traverse sample or an integrated sample which means the deployment of additional equipment. This would mean both a delay in reporting on dust conditions, which would defeat one of the objectives of short duration sampling, and an escalation in sampling costs.

It has been shown that the correlation between full shift dust concentrations and short duration dust concentrations is poor, with the full shift samples generally returning considerably lower values than the short duration samples since the eight hour averaging process eliminates peak concentrations. For the same reasons full shift quartz levels could be lower than short duration quartz levels. In a previous project (1) it was proposed that an industry average concentration of 20 percent for airborne quartz should be considered. This, however, referred specifically to full shift sampling and may not really be applicable to short duration sampling in workplaces. If it is considered really necessary to define workplace risk in terms of an airborne quartz concentration then, if an average value is to be used to avoid analytical procedures and delays, it may be necessary to specify a concentration different from 20 percent for these samples, and without an in-depth investigation, a recommendation on what value to use cannot be made.

The average quartz concentrations for Mine 1 were well below 20 percent and, as determined from traverse and integrated samples, varied from stope to stope. Some high average face dust concentrations, ascertained from 13 mm filters, have resulted in the average risk of 153 percent for the workplaces measured. If a value of 20 percent for quartz is used, this average escalates to 555 percent and, clearly, if a levy was being based on this risk, the mine would have been disadvantaged by using an industry average. In any event, mines have no control over the airborne quartz content and any levy based on this variable cannot be justified [(1)]. However, reference to Table 7 shows that, if average face dust levels are compared, such comparison will indicate which working places are the dustier, although the differences will not be as striking because there are no multipliers and no squaring functions.

At Mine 3 (see Table 11) the average face quartz concentration was determined from the traverse samples and used to calculate a risk for each stope based on 13 mm and 25 mm filters respectively. The average risk for the stopes monitored was determined from all the individual stope's risks and not from the average dust concentration and average quartz content.

Once again, the 13 mm filters' results proved to be lower than those of the 25 mm filters. This anomaly has already been discussed. As expected, the average risk of workplaces monitored and based on measured quartz content (18,1 percent) is not very different from the risk calculated at 20 percent quartz. The actual average face dust concentrations could be used to compare levels of dustiness in the workplaces but the differences become clearer when a workplace risk is calculated.

Risks for the development ends surveyed at Mine 4 show similar dustiness patterns, with it being possible to compare levels of dustiness in workplaces by referring to average dust concentrations.

It is also clear that mines' dustiness levels could also be compared, provided that samples are collected and analysed strictly according to guidelines set out by the GME.

When the GME's gravimetric dust sampling programme commenced, each mine was divided into areas which were sub-divided into statistical populations. Five percent of the workforce in each statistical population was sampled in each six-monthly sampling cycle. The average exposures for the statistical population were then determined and, once the samples had been analysed for quartz content (usually at the conclusion of the sampling cycle), the AQI for the statistical population was calculated. The "risk" for the statistical population was then calculated from the relationship RISK = 4 $(AQI)^2$ and the risk was then multiplied by the number of persons in the statistical population. Finally, all the products of persons and risk were totalled from each statistical population and divided by the total number of persons in all the statistical populations to give a person weighted risk for a sampling area. A similar procedure was followed for each sampling area and finally for the mine.

A similar concept is now proposed but using the results of short duration samples. For example a mine can be split up into, say, mine overseers' sections. The average dust concentration in each working place in this section would be multiplied by the number of persons in the section. Once again all the products would be totalled for the section and divided by the number of persons to give a person weighted workplace exposure or "risk".

The results from all sections could be used to calculate a mine person weighted workplace exposure or "risk". This system of sampling, i.e short duration, would make it easy for check samples to be conducted and also for appropriate inspectors to conduct their own surveys.

Careful consideration should be given as to whether it is acceptable for mines to conduct their own risk evaluations if any form of levy is to be attached to the risk. With the GME's dust sampling programme there was little choice, but with the proposed workplace sampling it would be possible for independent surveys to be carried out in order to ensure quality control.

If dust sampling is conducted in workplaces for control purposes then the possible role of total dust samples should be considered. Total dust samples do not require cyclones and the equipment would thus be less costly than that required for respirable dust samples. However, as has already been shown in this section as well as in Section 3, the magnitude of total dust samples is affected by settling processes apart from formation processes. Therefore, to be able to make comparisons, uncontrollable variables should be omitted from any calculations. In effect, this means that only respirable dust samples should be collected, provided that all equipment in the sampling train is matched.

Another way of describing the risk in a workplace could be in terms of the amount of pollutant added to the air within the workings. In simple terms this could be the difference between the intake and exit levels of dust. A perusal of the tables of results, however, shows that in many instances exit levels were lower than intake levels. This can be due to settling effects, dilution with other air streams and temporal and spatial displacement. This approach in many instances would thus not be of any use and should therefore not be considered.

Full shift samples can be evaluated in terms of eight-hour Time Weighted Average Threshold Limit Values (TWA - TLV). However, a short duration sample (15 minutes) cannot be evaluated by the same criteria. A Threshold Limit Value is the airborne concentration of a contaminant to which it is believed that most workers may be repeatedly exposed (five days a week; eight hours a day) without developing adverse health effects. They are not sharp lines between "safe" and "unsafe" conditions and are not a gauge of toxicity [4].

One limitation of an eight-hour Time Weighted Average is that it does not take into account situations where there is exposure to a high concentration of contaminant for only a short period of time. A single, high level exposure could in itself result in adverse health effects, even though the eight-hour TWA is below the TLV. This is illustrated below.

Exposure Time Minutes	Contaminant	Concentration ppm	8 hour TWA ppm	TLV ppm
15	Xylene	3 200	100	100

Obviously, the TLV has not been exceeded <u>but</u>, concentrations greater than 900 ppm are immediately dangerous to life or health.

Similarly, eight-hour TWA exposure limits may not be appropriate for controlling pneumoconiosis because lung impairment may be induced by transient peak exposures rather than sustained exposure levels [5]. The concept is illustrated in Figure 122.

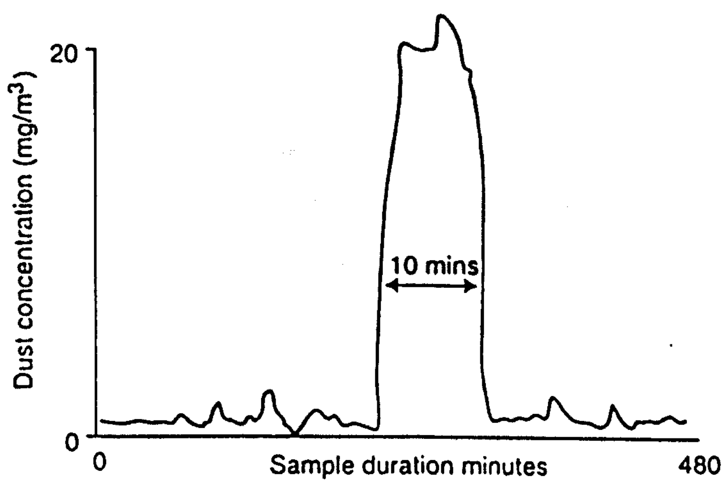


Figure 122 <u>CONTINUOUS DUST LEVEL TRACE WITH TRANSIENT PEAK EXPOSURES</u>

The following comparison can be made

	Exposure	8 hour TWA
(A)	8 hours at 0.5 mg/m^3	0.5 mg/m^3
(B)	10 minutes at 24 mg/m^3	0.5 mg/m^3

Obviously, the eight-hour TWAs are identical and, therefore, provided no additional dust is inhaled for case (B) the dose would be identical . This concept is further illustrated by referring to Figures 53 and 54 where successive 15 minute samples are plotted against average dust concentrations for a two hour period. The comparison was made to evaluate different sampling methods but the results clearly indicate that the "continuous" short time based samples are again capable of detecting peak concentrations which the averaging process eliminates. It is, of course, noted that, when compared to a continuous real time evaluation of dust concentrations, even the 15 minute samples can be regarded as an averaging process. Nevertheless, "continuous " 15 minute samples can reveal peak concentrations, even though the magnitude may be damped.

Dust is an irritant and when inhaled in high concentrations, even for short periods of time, can cause the respiratory tract to overreact and make breathing difficult. In the example set out above, even though the doses are the same, the deposition patterns and rates are vastly different. In case (B) the body (particularly the respiratory tract and lungs) and natural defense mechanisms (production of phlegm and coughing) would be substantially overloaded when compared with case (A). Consequently, (B) would be experiencing a higher health risk than (A) for the same <u>average</u> eight hour dose. The cumulation of exposure to transient peaks of dust could thus be more important in causing lung impairment than exposure to sustained but substantially lower average dust concentrations.

Risk to workers could thus be defined in terms of exposure to transient peaks instead of in terms of average exposure. The technology to identify and evaluate transient peaks realistically and practically (not using a tyndallometer) is still being sought and may well lay in the development of a 15 minute "continuous"sample.

4.6 Conclusions

4.6.1 The 1959 Johannesburg Conference on Pneumoconiosis drew attention to the differences needed for dust sampling strategies aimed at control purposes and those for measuring the health hazard. With the abolishment of all official konimeter sampling, control dust sampling ceased on a large number of mines. As a consequence the levels of dustiness in workplaces were not monitored nor reported. This really must be regarded as an undesirable development. It must, however, be noted that unofficial konimeter sampling was persisted with on some mines by very concerned and conscientious environmental control staff, in spite of severe criticism and discouragement from the DME.

4.6.2 The four essential elements in any occupational hygiene programme are hazard recognition, identification, measurement and control. The latter two elements all but disappeared from the operational functions of a large number of environmental control departments.

4.6.3 Having had a new monitoring system imposed on them, most mines rightly asked what, where and how should health hazards, with regard to airborne dust, be measured with the new monitoring equipment.

This project investigated the possibility of measuring workplace dust levels which could then be used to establish a workplace index or risk which is not to be compared with personal risk. It was found that short duration samples could give very meaningful results both in stopes and development ends. These samples can be related to localities and activities and checks can readily be made. The technique can also be used by various inspectorates wishing to determine levels of dustiness in working places.

Short duration measurements can be used to monitor the maintenance and effectiveness of control measures and to determine trends in workplace dustiness. In addition, the short duration samples can be used to establish a workplace risk and also a mine section risk, which is person weighted, and on which a mine person weighted risk can then be calculated. Improvements in working place dust levels, section risk and ultimately mine risk will be commensurate with the effort expended in reducing and maintaining reduced dust levels. The deployment of the short duration samples will make an independent assessment of mine risk and workplace levels of dustiness possible.

The fact that the results of any dust surveys will not be known at the time of measurement, but will be subject to delays until a laboratory assessment can be made, should not be viewed as a disadvantage, as this would be in keeping with international practices of occupational hygiene investigations where many pollutants require laboratory evaluation. Total and respirable dust samples were investigated and it is concluded that, for uniformity and consistency of measurement respirable dust samples should be used.

4.6.4 Short duration samples were compared with konimeter samples, traverse samples, integrated samples and full shift samples and it is concluded that only the short duration samples should be used to measure workplace dust levels.

Different sample rates and filter diameter and porosity were also investigated and it is recommended that standard 25 mm filters of 0,8 μm porosity be used at a flow rate of 1,9 ℓpm. Other combinations gave results which could be used for purposes of comparison but, because there was a mismatch of cyclones and sampling rates, accuracies were compromised.

Since Threshold Limit Values are used in conjunction with eight hour or full shift exposures, they are not directly applicable to 15 minute samples. In order to determine workplace dust levels it was shown and is recommended that face value readings be used. Where dust levels on filters are too light to assess, they should simply be reported as such (TLA) and the interpretation would be that the concentrations would not present any form of health hazard.

Although the concept of basing a risk on the difference in dust levels between inlet and exit conditions is sound in principle, it has been shown that this may not work in practice and should therefore not be considered.

4.6.5 Tyndallometers could be used for trouble shooting but should not be used for routine measurements. In inexperienced hands incorrect interpretation of readings would result in unnecessary additional investigations.

Where transient peak dust concentrations occur in the workings, if only a fraction of the transient is sampled during the collection of a short duration sample the result will be an elevated concentration. Of course, the transient peak may be missed altogether but an observant environmental official will know when additional samples may need to be collected.

4.6.6 The establishment of workplace risk, using the short duration sampling technique, is entirely possible but determining worker risk is not as clear cut. The eight-hour TWA may not be truly indicative of risk since, as has been indicated, peak exposures over short durations of time could be very harmful. The true risk could lie in the peak exposures and the cumulative effect of these peaks and not of the average exposure. Present techniques and technologies, the use of tyndallometers included, do not readily permit the identification and measurement of such peaks. This could well be the subject of a future research project.

It has been shown that it is possible to determine workplace dust levels using standard gravimetric dust sampling equipment, and hence the reporting of dust concentrations and sampling for control purposes should be re-introduced. Ideally, if integrated dust measurements of all working places in mines could be made along the lines of section evaluations, the results of which could be used for control purposes and at the same time provide dust indices or "risks" which are related to person weighted exposure levels, sampling to establish a dust health hazard would be placed on a more acceptable and meaningful basis. This could form the basis of a future research project. If the philosophy of controlling dust in the first instance to control exposures in the second instance is applied, then conditions in the workings would be kept under control.

5. OCCUPATIONAL DUST SAMPLING

5.1 Introduction

A very important conference on pneumoconiosis was held in Johannesburg, The 1959 Johannesburg Conference in Pneumoconiosis(3), which was attended by the leading authorities of the time. Many forthright recommendations were made and some of the more relevant ones are noted below.

1. In the light of present knowledge, dust measurements to assess health hazards should be expressed as the average level of dustiness over an appropriate period of sampling, such as a shift. This measurement may be made by averaging a number of samples, or by using an instrument which automatically averages the dust over the period. Exceptional peaks of dust concentration might also be recorded.

2. More use should be made of dust sampling instruments with size selecting devices, which collect only the respirable fraction of the dust.

3. More attention should be paid to designing the dust sampling strategy, bearing in mind the difference between sampling for purposes of dust control and sampling in order to determine the health hazard.

4. Further studies should be made of the dust exposure in various occupational groups.

5. Epidemiological studies to determine dose-response relationships in man should be continued and expanded.

6. It is desirable to assess the degree of pathogenicity of various dust mixtures with various amount of free silica.

After nearly 40 years the recommendations may still be regarded as valid but industry does not appear to have taken action on all of them.

The reasons for collecting dust are very important and would dictate the strategy to be used and the equipment to be deployed. As noted in the previous section, the differences between sampling for control purposes and sampling to determine the health hazard should be borne in mind.

While the "snap" or very short duration samples collected in konimeter sampling were useful for determining workplace dust levels and for testing the efficiency of control measures, they could never be equated to full shift exposure. Full shift samples which gave results in terms of a respirable particle count per unit volume (ppmℓ) could be obtained from thermal precipitators. Such investigations were few and far between and mostly undertaken for research purposes and not on a routine basis.

All official konimeter sampling has been abolished and only full shift sampling is conducted using gravimetric samplers according to strategies set out in guidelines by the DME [(2)]. The purpose of this sampling is to provide results from which a risk is calculated after the dust has been analysed for toxic content. Results from a previous project [(1)] have shown large variations in dust levels and large variations in quartz content of the airborne dust from personal sample to personal sample, from one sampling population to the next, from one sampling area to the next and from one sampling cycle to the next. Risk levies based on such randomness can be shown to have little meaning, and the dust sampling strategy to have little relevance. The concept of gravimetric sampling is a good one and offered the opportunity to make a start in compiling and investigating exposure levels for different occupation groups. Unfortunately, this has not been done since the results were reported in "activity" categories and, although a large volume of data has accumulated, no analyses of the data have been presented.

Previous occupational dust surveys, although thorough, were carried out on an industry basis by a very small team, the Pneumoconiosis Research Unit (PRU). The instruments used were konimeters and thermal precipitators, which gave dust concentrations in terms of a particle count (pp mℓ) and Modified Thermal Precipitators (MTP) which gave results in terms of respirable surface area (RSA). Average exposure concentrations were linked to particular occupations. In epidemiological studies these measuring units are no longer internationally accepted and the konimeter and MTP cannot monitor continuously. Continuous monitoring over a full shift is considered to be fundamental to personal exposure monitoring as are exposures in terms of mass concentrations.

At present, estimation of worker exposure still relies heavily on the results of these previous occupational dust surveys conducted nearly 40 years ago and which were not truly personal exposures and which did monitor exposures for all population groups.

Whereas previous surveys were conducted with, what is now apparent, inappropriate instrumentation, Industry is now equipped with gravimetric samplers, developed to measure shift long exposures. The infrastructure is also in place to routinely conduct occupational dust surveys for all occupations and all population groups.

This component of the project was aimed at carrying out occupational dust sampling on selected personnel to determine if differences in eight hour Time Weighted Averages could be detected. During the progress of the project, a Special Interest Group strongly recommended that mine dust sampling records be examined and that comparisons between the mines' results and the project results be drawn up.

At the commencement of this investigation, only two major occupation groups were selected for observation and measurement. The groups selected were supervision and timbering (stope support). However, due to multi skilling practices additional work categories were sampled since the person selected for sampling performed work which was different from his designated work category. This led to fewer samples in the selected categories than was planned for and, rather than discard any samples, additional work categories were included in the report.

5.2 Test Sites

These were the same as described in 4.2.

5.3 Methodology

With the assistance of environmental and human resources personnel, employees in the two selected occupational categories were selected for personal dust sampling and, when the sampling pumps were issued, explanations for the monitoring were given and co-operation to participate was encouraged.

When sampling commenced at the first mine, attempts were made to issue 20 sampling pumps each day. The logistics of issuing so many pumps, record keeping and retrieval of the pumps and noting shift details proved to be impractical. This resulted not only in spoilt samples but in having to recover pumps from such places as change houses, etc. Consequently, although it meant that fewer samples were collected, the number of pumps issued on a daily basis was reduced to a more manageable 10 or 12. This work was conducted at the same time as the short duration sampling and one full shift sample was arranged for the working places where the short duration tests were being conducted.

A recent innovation in mining is the implementation of multi skilling. In this practice, work teams for a particular work place are assembled from a number of employees, for example machine operator, loco driver, winch driver, etc. Although a person may have a specific job description on his record, he may be called upon to perform any task assigned to him for a particular day. On the following day, the same person may be assigned a different job of work and may even perform two different jobs on the same day. What this meant then was that, although persons in the two selected job categories were chosen for sampling, the person may have actually performed any one of a number of jobs. It thus became necessary to interview persons at the completion of the shift to ascertain actual work performed. Consequently, additional jobs or occupation categories entered the analyses.

During the sampling period at a mine, copies of the results of the two most recent sampling cycles were collected for analyses and comparison with project results. Results are reported in terms of "activities" to the DME and hence original data entries had to be scrutinized to establish the occupations for the persons reported on. Unfortunately, due to multi skilling, as explained above, the actual work performed may not have coincided with the designated occupation.

All samples were transported to CSIR: Mining Technology's laboratory for analyses and evaluation. Once mass determination had been completed, all samples were subjected to X-ray Diffraction examination to determine the quartz content.

It was not possible to determine the quartz content of samples for the selected work categories from mine records since the persons selected came from different statistical populations and areas and samples had been combined for analyses.

5.4 Results

5.4.1 Mine 1

The results of CSIR Mining Technology's investigation are set out in Tables 15 and 16 and 16a. Exposure measurements, including quartz analysis, are shown in Table 15 and occupation data are shown in the other two tables. Risk, based on dust and quartz levels, has been calculated for each occupation and a person weighted risk for all occupations sampled has been calculated for actual quartz concentration and for a standard of 20 percent quartz. A summary of averages, maxima and minima and standard deviations based on mine data is given in Table 17.

The breakdown of the mine's results are set out in Tables 18, 18A, 18B, 18C and 18D.

Extractions from mine records on which the analyses were performed are computed in Tables 27 and 27A to 27AA, which can be found in Appendix B.

Graphical analyses of data are shown in Figures 123 to 127.

5.4.2 Mine 2

The summary of CSIR: Mining Technology's results is shown in Table 19 and details of the occupations monitored in Tables 20 and 20A.

A summary of averages, maxima, minima, and standard deviations for mine data is given in Table 21 and occupation details in Tables 22 and 22A. Extractions from mine records are to be found in Tables 28 and 28A to 28I. Graphical presentations of analysis are featured in Figures 128 to 132.

5.4.3 Mine 3

CSIR: Mining Technology's exposure data are summarized in Table 23 and occupation details are set out in Tables 24 and 24A

Analyses are depicted in Figures 133 and 134.

Owing to the software package used by the mine, attempts to extract meaningful data proved to be futile. The selection of statistical populations and persons within the statistical population was puzzling and surprising as were the number of different persons doing similar work but selected as different work categories. In a statistical population coded as "underground mechanized mining", a barman and assistant barman were sampled. Similarly a gardener was sampled.

The selection of, for example, an electrician, electrician's aid, electrician's assistant and a black electrician as different work categories appears to be unjustified.

The complexity of the composition of the sampling strategies and consequent results made it impossible to extract usable and meaningful data for any sort of comparison. Consequently, the results from the mine were not used and are not presented.

5.4.4 Mine 4

CSIR: Mining Technology's data are presented in Tables 25, 26 and 26A. Graphical analyses are shown in Figures 135 and 136. For similar reasons given in section 5.4.3, no data for Mine 4 are presented.

5.4.5 All mines

A comparison of exposures for all mines is shown in Figure 137 and frequency distributions of exposures are shown in Figures 138 and 139.

Table 15 SUMMARY OF CSIR · MINING TECHNOLOGY OCCUPATIONAL EXPOSURE DATA - MINE 1

CONSTRUCTION Exposure			DRILLING Exposure			SUPERVISION Exposure			SUPPORT Exposure			OTHER Exposure			LASHING Exposure			TRANSPORT Exposure		
Actual	TWA	SiO2	Actual	TWA	SiO2	Actual	TWA	SiO2	Actual	TWA	SiO2	Actual	TWA	SiO2	Actual	TWA	SiO2	Actual	TWA	SiO2
mg/m3	mg/m3	%	mg/m3	mg/m3	%	mg/m3	mg/m3	%	mg/m3	mg/m3	%	mg/m3	mg/m3	%	mg/m3	mg/m3	%	mg/m3	mg/m3	%
0.38	0.39	1.6	0.08	0.10	*	1.08	0.70	8.3	0.09	0.10	*	0.07	0.08	*	0.50	0.61	0.9	0.32	0.35	4.0
0.76	0.83	3.6	0.83	0.55	4.4	0.69	0.74	13.6	0.34	0.34	8.3	0.33	0.16	*	0.82	0.95	5.4	0.72	0.74	3.2
0.83	1.02	3.7	1.28	0.62	9.8	0.79	0.89	9.0	0.32	0.37	1.8	0.81	0.90	3.3	0.90	0.99	1.8	1.90	1.73	20.8
1.21	1.13	7.8	1.22	0.68	14.9	0.83	0.89	2.2	0.43	0.45	4.5	1.19	1.31	3.4	1.07	1.18	1.8			
			0.71	0.82	4.8	0.89	0.95	0.9	0.92	0.59	12.7	1.65	1.51	7.1						
			0.75	0.88	9.5	1.11	1.11	12.1	0.57	0.60	2.0	1.72	1.59	10.2						
			0.84	0.91	*	1.76	1.81	4.7	0.54	0.67	7.0									
			1.12	1.21	0.8	2.48	3.86	3.3	0.68	0.72	2.7									
			1.76	1.80	1.0				0.67	0.75	12.8									
			1.58	1.80	4.3				0.69	0.78	2.8									
									0.77	0.79	3.7									
									0.69	0.80	3.7									
									0.71	0.81	7.4									
									0.87	1.01	12.8									
									0.86	1.03	5.1									
									1.15	1.28	15.3									
									1.44	1.39	5.8									
									1.28	1.40	3.2									
									1.61	1.47	22.7									
									1.19	3.12	*									

* Less than detection limit of 20 µg

	CONSTRUCTION			DRILLING			SUPERVISION			SUPPORT			OTHER			LASHING			TRANSPORT			Total
No of People		4			10			8			20			6			4			3		55
AVERAGE	0.79	0.84	4.2	1.02	0.91	5.4	1.20	1.37	6.8	0.79	0.92	7.0	0.96	0.92	4.8	0.82	0.93	2.4	0.98	0.94	9.3	PWM
STD DEV				0.48	0.51	5.0	0.61	1.07	4.7	0.39	0.64	5.8	0.68	0.67	4.0							0.98
MINIMUM				0.08	0.10		0.69	0.70	0.9	0.09	0.10		0.07	0.06								
MAXIMUM				1.76	1.80	14.9	2.48	3.86	13.6	1.61	3.12	22.7	1.72	1.59	10.2							
- STD DEV				0.53	0.41	0.4	0.59	0.30	2.1	0.40	0.29	1.2	0.28	0.25	0.8							
+ STD DEV				1.50	1.42	10.4	1.81	2.44	11.4	1.17	1.56	12.8	1.64	1.60	8.8							

	CONSTRUCTION	DRILLING	SUPERVISION	SUPPORT	OTHER	LASHING	TRANSPORT	
REAL VALUES								*PWM SiO2 %* 6.01
AQI	0.17	0.49	0.93	0.64	0.18	0.19	0.88	
Risk	0.11	0.98	3.43	1.64	0.14	0.14	3.08	
Product	0.45	9.77	27.43	32.71	0.81	0.55	9.23	80.95
								PWM Risk 1.47
VALUES @ 20 %								
AQI	1.68	1.83	2.74	1.84	1.85	1.87	1.88	
Risk	11.32	13.38	29.94	13.59	13.62	13.93	14.08	
Product	45.27	133.83	239.53	271.88	81.72	55.72	42.23	870.17
								PWM Risk 15.82

TABLE 16 DETAILS OF CSIR : MINING TECHNOLOGY OCCUPATIONAL EXPOSURE DATA - MINE 1

Occupation	Actual work done	Conc	Conc TWA
		mg/m3	*mg/m3*
Mach operator assisstant	Construction	0.76	0.83
Construction Team Leader	Construction	1.21	1.13
227 Construc Team Leader	Construction	0.83	1.02
227 Construc Team Leader	Construction	0.36	0.39
214 Machine Operator	Drilling	0.75	0.88
214 Machine operator	Drilling	0.83	0.55
214 Machine operator	Drilling	0.71	0.82
214 Machine operator	Drilling	1.22	0.66
213 Stoping	Drilling	1.58	1.80
M/Timer	Drilling	1.76	1.60
214 Machine operator	Drilling	0.84	0.91
214 Machine operator	Drilling	1.28	0.62
214 Machine	Drilling	0.08	0.10
214 Machine Operator	Drilling	1.12	1.21
214 Stoping	Lashing	0.50	0.61
214 Machine Operator	Lashing	1.07	1.18
214 Machine Operator	Lashing	0.90	0.99
213 Stoping	Lashing	0.82	0.95
213 Stoping	Other	0.81	0.90
213 Cleaner	Other	1.72	1.59
214 Winch Driver	Other	0.33	0.16
214 Machine operator	Other	1.65	1.51
214 Machine operator	Other	1.19	1.31
227 Supervision	Other	0.07	0.06
227 Special Team Leader	Supervision	2.46	3.86
227 Special Team Leader	Supervision	0.83	0.89
227 Special Team Leader	Supervision	0.89	0.95
227 Special Team Leader	Supervision	1.76	1.81
227 Special Team Leader	Supervision	0.79	0.89
227 Special Team Leader	Supervision	1.08	0.70
213 Stoping	Supervision	1.11	1.11
227 Special Team Leader	Supervision	0.69	0.74

TABLE 16 A TABLE 16 CONTINUED

Occupation	Actual work done	Conc	Conc TWA
		mg/m3	mg/m3
213 Stoping	Support	0.09	0.10
213 Stoping	Support	0.57	0.60
U/g labour	Support	1.19	3.12
227 Special Team Leader	Support	1.44	1.39
227 Support	Support	0.86	1.03
227 Special Team Leader	Support	0.92	0.59
227 Special Team Leader	Support	1.61	1.47
213 Support	Support	0.67	0.75
213 Stoping	Support	0.77	0.79
227 Special Team Leader	Support	0.43	0.45
227 Special Team Leader	Support	0.66	0.72
227 Special Team Leader	Support	1.15	1.28
213 Support	Support	0.69	0.76
213 Stoping	Support	0.71	0.81
213 Stoping	Support	0.87	1.01
227 Special Team Leader	Support	1.26	1.40
227 Special Team Leader	Support	0.54	0.67
213 Stoping	Support	0.69	0.80
227 Special Team Leader	Support	0.32	0.37
227 Special Team Leader	Support	0.34	0.34
225 Transport	Transport	1.90	1.73
225 General Team Leader	Transport	0.72	0.74
225 General Team Leader	Transport	0.32	0.35

TABLE 17 SUMMARY OF STATISTICAL DATA FOR MINE OCCUPATIONAL EXPOSURE LEVELS - MINE 1

	CONSTRUCTION		DRILLING		SUPERVISION		SUPPORT		LASHING		TRANSPORT	
	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA
	mg/m3	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*
AVERAGE	0.34	0.44	0.51	0.68	0.29	0.36	0.44	0.62	0.37	0.46	0.29	0.37
STD DEV	0.26	0.44	0.85	1.56	0.23	0.28	0.64	1.54	0.29	0.44	0.27	0.44
MINIMUM	0.01		0.01		0.01		0.01		0.01	0.01	0.02	0.01
MAXIMUM	1.93	2.76	11.95	22.31	0.91	1.32	7.36	18.13	1.89	3.33	1.33	2.49
- STD DEV	0.08	0.00	-0.34	-0.89	0.07	0.07	-0.20	-0.92	0.08	0.02	0.02	-0.07
+ STD DEV	0.61	0.88	1.35	2.24	0.52	0.64	1.08	2.15	0.66	0.90	0.56	0.81
No of People		89		204		34		136		93		56

TABLE 18
SUMMARY OF MINES OCCUPATIONAL EXPOSURE DATA - MINE 1

CONSTRUCTION Exposure		DRILLING Exposure		SUPERVISION Exposure		SUPPORT Exposure		LASHING Exposure		TRANSPORT Exposure	
Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA
mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3
0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.02	0.01
0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.00	0.02	0.02	0.02	0.02
0.02	0.02	0.01	0.01	0.04	0.03	0.02	0.02	0.02	0.02	0.03	0.03
0.02	0.02	0.02	0.02	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.04
0.05	0.05	0.02	0.02	0.04	0.05	0.04	0.04	0.03	0.03	0.05	0.05
0.05	0.06	0.03	0.03	0.06	0.08	0.04	0.05	0.03	0.03	0.05	0.05
0.06	0.05	0.03	0.03	0.07	0.15	0.04	0.05	0.04	0.04	0.05	0.05
0.07	0.07	0.03	0.03	0.07	0.08	0.05	0.06	0.05	0.06	0.05	0.06
0.08	0.08	0.03	0.03	0.09	0.11	0.05	0.04	0.06	0.05	0.07	0.10
0.09	0.10	0.03	0.04	0.10	0.12	0.06	0.05	0.07	0.06	0.07	0.08
0.09	0.10	0.04	0.04	0.13	0.19	0.07	0.07	0.07	0.08	0.08	0.06
0.09	0.14	0.05	0.08	0.18	0.22	0.08	0.11	0.07	0.08	0.09	0.10
0.09	0.13	0.05	0.06	0.20	0.24	0.09	0.09	0.08	0.10	0.09	0.10
0.11	0.13	0.05	0.06	0.20	0.22	0.09	0.09	0.09	0.10	0.10	0.08
0.13	0.14	0.05	0.06	0.23	0.30	0.09	0.11	0.10	0.14	0.10	0.14
0.13	0.16	0.06	0.07	0.24	0.29	0.11	0.13	0.11	0.13	0.11	0.12
0.14	0.15	0.06	0.08	0.26	0.26	0.12	0.12	0.11	0.13	0.12	0.13
0.14	0.15	0.06	0.07	0.27	0.29	0.12	0.14	0.12	0.13	0.13	0.09
0.14	0.16	0.06	0.06	0.27	0.32	0.13	0.13	0.12	0.13	0.14	0.15
0.16	0.20	0.06	0.07	0.27	0.40	0.13	0.13	0.13	0.13	0.14	0.15
0.16	0.15	0.06	0.08	0.29	0.34	0.14	0.17	0.14	0.16	0.14	0.17
0.16	0.18	0.06	0.07	0.32	0.44	0.14	0.17	0.16	0.18	0.15	0.15
0.20	0.24	0.07	0.07	0.34	0.49	0.15	0.18	0.20	0.25	0.15	0.17
0.22	0.24	0.08	0.08	0.39	0.60	0.16	0.18	0.21	0.23	0.18	0.33
0.23	0.27	0.08	0.09	0.44	0.57	0.16	0.19	0.23	0.24	0.20	0.21
0.24	0.24	0.09	0.10	0.47	0.48	0.16	0.19	0.23	0.24	0.20	0.22
0.24	0.34	0.10	0.11	0.48	0.62	0.17	0.19	0.24	0.30	0.21	0.22
0.24	0.30	0.10	0.11	0.54	0.68	0.17	0.19	0.24	0.27	0.22	0.26
0.24	0.37	0.10	0.16	0.55	0.51	0.19	0.21	0.24	0.33	0.24	0.30
0.25	0.26	0.10	0.13	0.56	0.60	0.21	0.27	0.24	0.26	0.25	0.31
0.25	0.27	0.13	0.15	0.63	0.85	0.21	0.31	0.25	0.28	0.26	0.32
0.25	0.23	0.13	0.14	0.64	0.53	0.21	0.27	0.25	0.41	0.28	0.29
0.26	0.33	0.15	0.17	0.68	0.67	0.22	0.31	0.26	0.34	0.28	0.33
0.27	0.31	0.15	0.17	0.91	1.32	0.22	0.26	0.26	0.27	0.29	0.32
0.27	0.31	0.16	0.23			0.24	0.24	0.27	0.32	0.29	0.33
0.27	0.28	0.16	0.22			0.24	0.42	0.27	0.30	0.33	0.32
0.27	0.34	0.17	0.20			0.24	0.26	0.28	0.33	0.35	0.45
0.27	0.34	0.17	0.30			0.24	0.30	0.28	0.32	0.36	0.48
0.27	0.35	0.18	0.25			0.26	0.31	0.28	0.31	0.36	0.40
0.27	0.32	0.18	0.23			0.26	0.33	0.29	0.36	0.38	0.37
0.27	0.32	0.18	0.21			0.26	0.43	0.29	0.34	0.38	0.43
0.28	0.33	0.19	0.26			0.26	0.31	0.30	0.34	0.39	0.47
0.28	0.32	0.20	0.31			0.26	0.35	0.30	0.35	0.39	0.47
0.30	0.58	0.20	0.22			0.26	0.30	0.30	0.35	0.40	0.41
0.30	0.33	0.20	0.22			0.27	0.31	0.32	0.31	0.42	0.59
0.30	0.33	0.20	0.30			0.27	0.35	0.33	0.51	0.42	0.56
0.31	0.31	0.22	0.22			0.27	0.31	0.34	0.39	0.46	0.54
0.31	0.38	0.22	0.26			0.28	0.34	0.34	0.36	0.48	0.59
0.31	0.29	0.22	0.30			0.28	0.32	0.35	0.37	0.53	0.64

TABLE 18 A TABLE 18 CONTINUED

CONSTRUCTION Exposure		DRILLING Exposure		SUPERVISION Exposure		SUPPORT Exposure		LASHING Exposure		TRANSPORT Exposure	
Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA
mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3
0.31	0.36	0.23	0.30			0.28	0.35	0.35	0.44	0.61	0.68
0.31	0.38	0.23	0.26			0.28	0.31	0.36	0.41	0.75	0.86
0.32	0.29	0.23	0.28			0.29	0.32	0.36	0.51	0.82	1.21
0.33	0.39	0.23	0.31			0.29	0.30	0.37	0.42	0.82	1.07
0.34	0.42	0.23	0.27			0.30	0.37	0.37	0.40	1.16	1.78
0.35	0.42	0.24	0.26			0.30	0.31	0.37	0.47	1.33	2.49
0.36	0.42	0.24	0.29			0.30	0.40	0.38	0.41		
0.37	0.44	0.25	0.29			0.30	0.41	0.38	0.47		
0.38	0.50	0.25	0.33			0.30	0.39	0.41	0.45		
0.38	0.37	0.26	0.28			0.31	0.38	0.41	0.49		
0.39	0.48	0.26	0.34			0.31	0.41	0.44	0.56		
0.42	0.43	0.26	0.35			0.31	0.35	0.44	0.48		
0.42	0.46	0.27	0.31			0.31	0.37	0.44	0.45		
0.42	0.48	0.27	0.26			0.32	0.36	0.44	0.47		
0.43	0.47	0.28	0.37			0.32	0.40	0.45	0.52		
0.43	0.49	0.28	0.38			0.32	0.44	0.47	0.61		
0.45	0.49	0.29	0.33			0.32	0.29	0.47	0.49		
0.45	0.64	0.29	0.34			0.33	0.47	0.47	0.54		
0.46	0.64	0.29	0.40			0.33	0.41	0.48	0.57		
0.47	0.54	0.29	0.35			0.33	0.44	0.49	0.59		
0.47	0.52	0.30	0.35			0.33	0.40	0.50	0.60		
0.48	0.92	0.30	0.38			0.34	0.47	0.50	0.63		
0.49	0.56	0.30	0.37			0.35	0.39	0.52	0.60		
0.49	0.54	0.31	0.37			0.36	0.41	0.52	0.58		
0.49	0.57	0.31	0.36			0.36	0.42	0.52	0.65		
0.50	0.57	0.31	0.37			0.36	0.42	0.53	0.64		
0.52	0.63	0.31	0.36			0.36	0.42	0.53	0.81		
0.54	0.58	0.31	0.39			0.37	0.49	0.54	0.59		
0.54	0.62	0.31	0.34			0.38	0.46	0.59	0.59		
0.57	0.51	0.31	0.41			0.39	0.42	0.61	0.49		
0.58	0.67	0.32	0.38			0.40	0.45	0.61	0.74		
0.61	0.70	0.34	0.44			0.40	0.46	0.61	0.66		
0.65	0.73	0.34	0.36			0.40	0.50	0.62	0.73		
0.65	0.92	0.34	0.53			0.40	0.44	0.62	0.78		
0.66	0.77	0.34	0.40			0.41	0.41	0.63	0.77		
0.69	0.75	0.34	0.46			0.41	0.51	0.65	0.99		
0.83	2.21	0.34	0.40			0.43	0.55	0.65	0.73		
0.92	1.56	0.34	0.45			0.43	0.74	0.67	0.68		
1.04	2.11	0.35	0.40			0.44	0.49	0.71	0.89		
1.93	2.76	0.35	0.37			0.44	0.62	0.86	1.45		
		0.35	0.41			0.44	0.46	1.02	1.10		
		0.35	0.54			0.44	0.45	1.14	1.65		
		0.35	0.38			0.44	0.43	1.26	1.86		
		0.35	0.41			0.45	0.53	1.89	3.33		
		0.36	0.44			0.45	0.60				
		0.36	0.59			0.45	0.50				
		0.37	0.46			0.46	0.59				
		0.37	0.48			0.46	0.55				
		0.37	0.41			0.48	0.58				
		0.38	0.45			0.48	0.58				
		0.38	0.43			0.49	0.54				

TABLE 18 B TABLE 18 CONTINUED

CONSTRUCTION Exposure		DRILLING Exposure		SUPERVISION Exposure		SUPPORT Exposure		LASHING Exposure		TRANSPORT Exposure	
Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA
mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3
		0.38	0.42			0.49	0.56				
		0.38	0.42			0.50	0.70				
		0.39	0.48			0.50	0.59				
		0.39	0.50			0.51	0.62				
		0.39	0.50			0.51	0.63				
		0.40	0.44			0.52	0.53				
		0.40	0.41			0.53	0.63				
		0.40	0.47			0.54	0.51				
		0.41	0.43			0.54	0.64				
		0.41	0.43			0.54	0.73				
		0.41	0.48			0.55	0.62				
		0.42	0.46			0.56	0.83				
		0.42	0.43			0.57	0.66				
		0.42	0.52			0.57	0.66				
		0.42	0.50			0.58	0.68				
		0.42	0.49			0.58	0.71				
		0.42	0.44			0.58	0.62				
		0.43	0.74			0.59	0.61				
		0.43	0.50			0.59	0.65				
		0.43	0.52			0.59	0.65				
		0.44	0.46			0.60	0.68				
		0.44	0.48			0.61	0.70				
		0.44	0.47			0.61	0.96				
		0.44	0.51			0.61	0.74				
		0.45	0.52			0.61	0.67				
		0.45	0.48			0.62	0.70				
		0.45	0.55			0.63	0.65				
		0.45	0.51			0.64	0.77				
		0.46	0.52			0.67	0.78				
		0.46	0.53			0.68	0.80				
		0.46	0.51			0.68	0.80				
		0.46	0.57			0.72	0.91				
		0.46	0.50			0.73	1.09				
		0.47	0.50			0.75	0.88				
		0.47	0.56			0.75	0.91				
		0.47	0.56			0.84	1.07				
		0.47	0.56			0.86	1.33				
		0.48	0.52			0.89	1.19				
		0.48	0.49			1.06	1.46				
		0.48	0.49			1.24	1.95				
		0.49	0.58			1.48	2.05				
		0.49	0.61			1.71	3.86				
		0.49	0.63			7.36	18.13				
		0.49	0.50								
		0.49	0.50								
		0.50	0.56								
		0.50	0.55								
		0.51	0.53								
		0.51	0.64								
		0.51	0.56								
		0.52	0.68								

TABLE 18 C TABLE 18 CONTINUED

CONSTRUCTION Exposure		DRILLING Exposure		SUPERVISION Exposure		SUPPORT Exposure		LASHING Exposure		TRANSPORT Exposure	
Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA
mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3
		0.53	0.62								
		0.53	0.53								
		0.53	0.65								
		0.53	0.60								
		0.54	0.65								
		0.54	0.59								
		0.55	0.64								
		0.55	0.69								
		0.55	0.96								
		0.56	0.61								
		0.56	0.59								
		0.56	0.65								
		0.57	0.60								
		0.58	0.64								
		0.58	0.69								
		0.60	0.65								
		0.61	0.78								
		0.61	0.69								
		0.61	0.73								
		0.61	0.64								
		0.61	0.66								
		0.61	0.72								
		0.62	0.82								
		0.64	0.71								
		0.64	0.79								
		0.66	0.86								
		0.67	0.86								
		0.68	0.80								
		0.68	0.80								
		0.69	0.79								
		0.69	0.75								
		0.69	0.73								
		0.71	0.86								
		0.72	0.77								
		0.72	0.94								
		0.72	1.09								
		0.73	0.92								
		0.74	0.87								
		0.75	1.03								
		0.75	0.95								
		0.76	0.77								
		0.76	0.85								
		0.77	0.91								
		0.79	1.30								
		0.80	0.94								
		0.87	1.00								
		0.88	1.29								
		0.92	1.16								
		0.95	1.21								
		0.96	1.59								
		1.04	1.51								

TABLE 18 D TABLE 18 CONTINUED

CONSTRUCTION Exposure		DRILLING Exposure		SUPERVISION Exposure		SUPPORT Exposure		LASHING Exposure		TRANSPORT Exposure	
Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA
mg/m3	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*	*mg/m3*
		1.05	1.21								
		1.18	1.05								
		1.18	2.07								
		1.18	1.68								
		1.19	2.02								
		1.19	1.91								
		1.22	1.29								
		1.26	2.21								
		1.32	2.37								
		1.36	2.78								
		1.38	2.02								
		1.45	2.08								
		1.60	2.33								
		1.83	2.84								
		1.85	3.75								
		11.95	22.31								

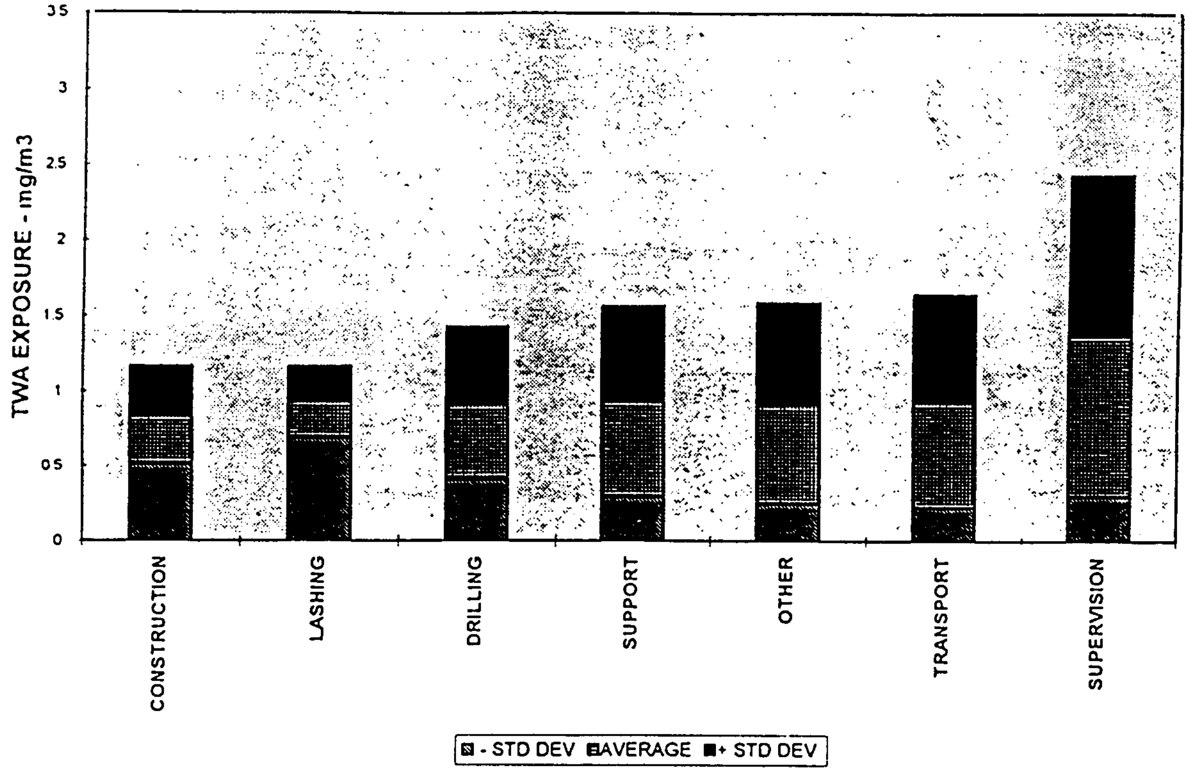


Figure 123 COMPARISON OF OCCUPATIONAL EXPOSURES - CSIR MINING TECHNOLOGY DATA - MINE 1

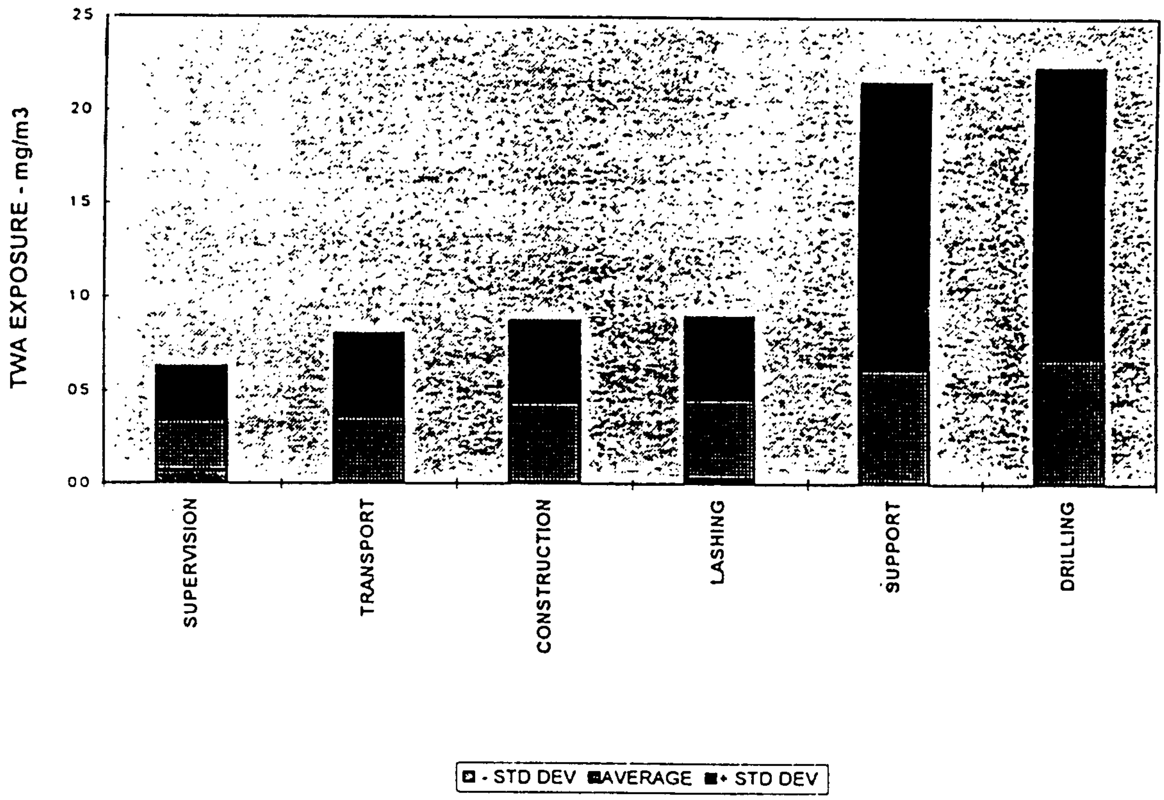


Figure 124 COMPARISON OF OCCUPATIONAL EXPOSURES - MINE DATA - MINE 1

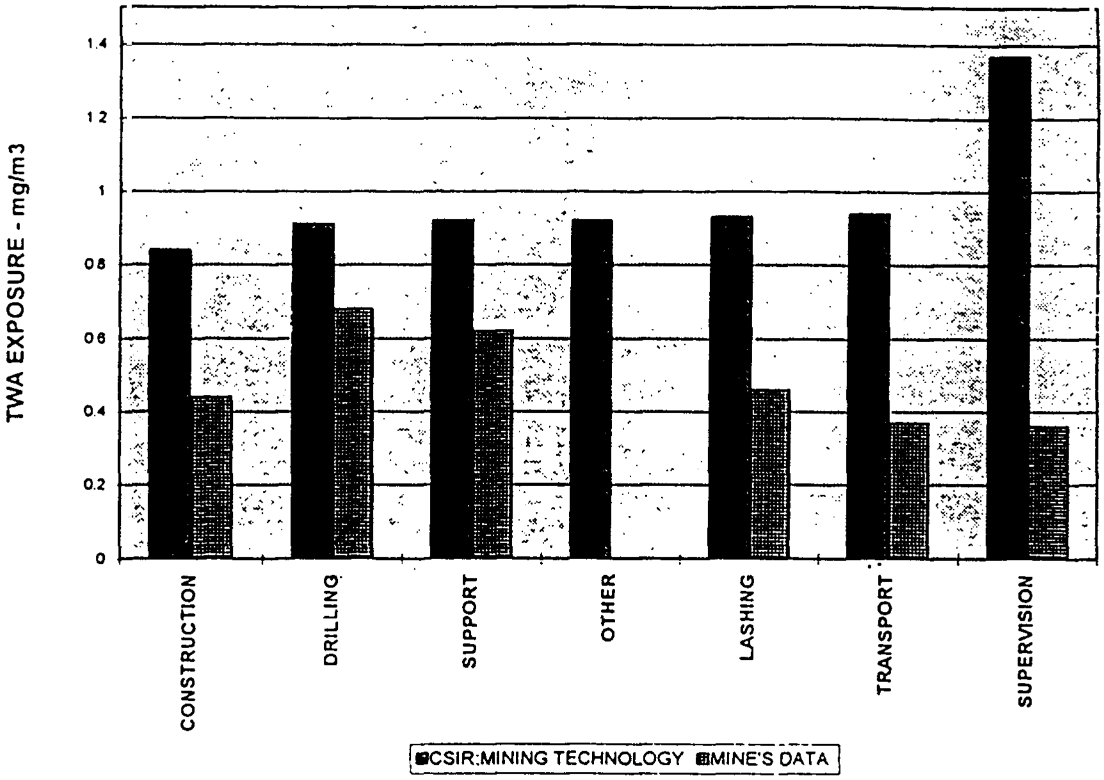


Figure 125 COMPARISON OF AVERAGE OCCUPATIONAL EXPOSURES - CSIR MINING TECHNOLOGY AND MINE DATA - MINE 1

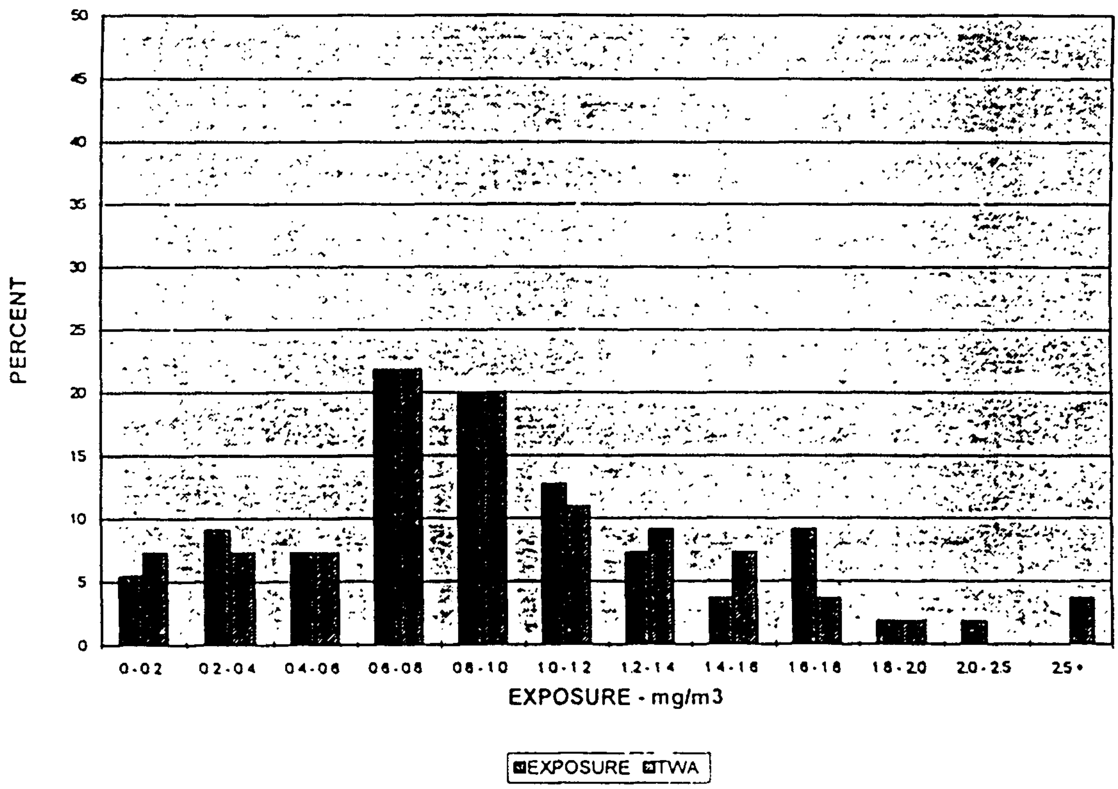


Figure 126 FREQUENCY DISTRIBUTION OF OCCUPATIONAL EXPOSURES - CSIR MINING TECHNOLOGY DATA - MINE 1

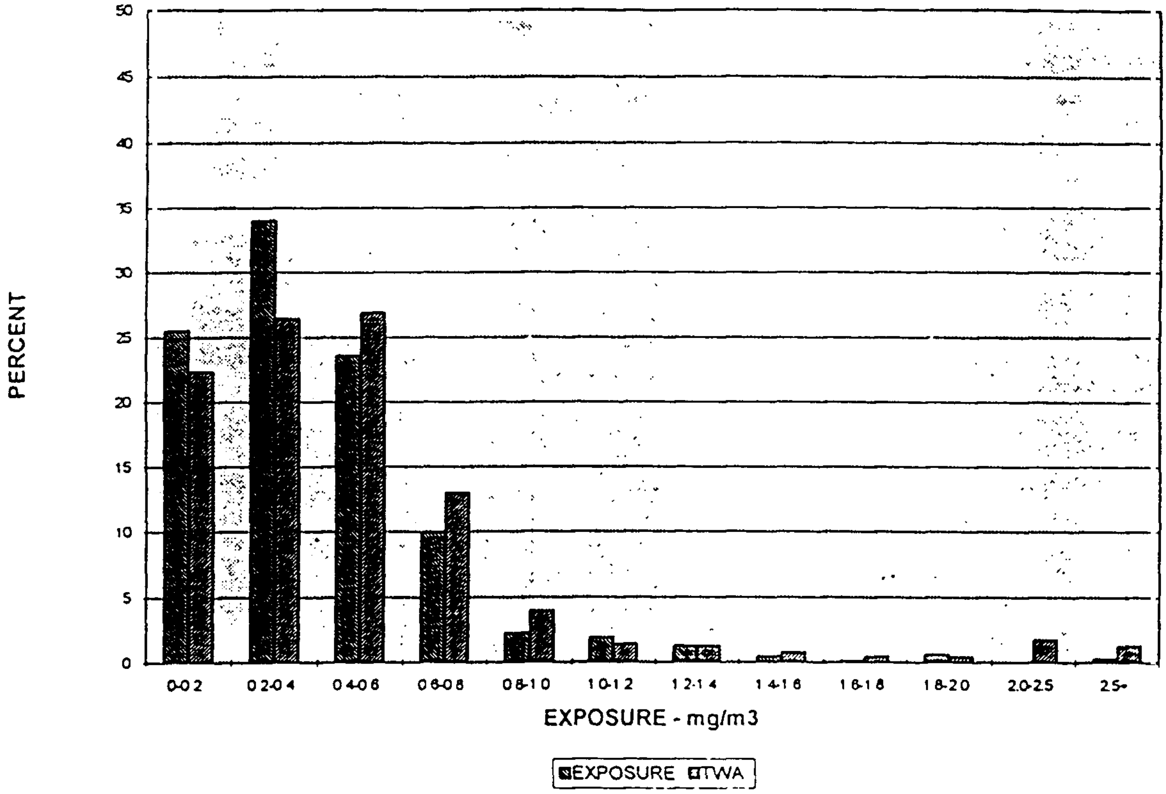


Figure 127 <u>FREQUENCY DISTRIBUTION OF OCCUPATIONAL EXPOSURES MINE DATA - MINE 1</u>

Table 19 SUMMARY OF CSIR : MINING TECHNOLOGY OCCUPATIONAL EXPOSURE DATA
MINE 2

CONSTRUCTION Exposure		DRILLING Exposure		SUPERVISION Exposure		SUPPORT Exposure		OTHER Exposure		LASHING Exposure		TRANSPORT Exposure	
Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA
mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3
0.21	0.24	0.08	0.05	0.02	0.03	0.22	0.25	0.47	0.15	0.17	0.12	0.25	0.18
0.25	0.29	0.32	0.36	0.33	0.17	0.20	0.26	0.31	0.24	0.25	0.30	0.45	0.53
0.36	0.41	0.40	0.44	0.37	0.23	0.30	0.26	0.30	0.27	0.84	0.97	0.51	0.60
0.56	0.50	0.42	0.46	0.47	0.25	0.72	0.26	0.28	0.31				
		0.43	0.49	1.16	0.43	0.23	0.26	0.29	0.32				
		1.35	0.50	0.80	0.54	0.24	0.28	0.42	0.32				
		0.81	0.67	0.74	1.03	0.25	0.29	0.32	0.33				
		0.66	0.79			0.30	0.34	0.50	0.33				
		1.07	1.26			0.37	0.36	0.29	0.34				
						0.95	0.36	0.31	0.35				
						0.34	0.37	0.49	0.37				
						0.69	0.38	0.33	0.37				
						0.40	0.39	0.60	0.44				
						0.36	0.41	0.65	0.49				
						0.38	0.41	0.45	0.49				
						1.24	0.42	0.52	0.51				
						0.38	0.42	0.48	0.54				
						0.38	0.44	0.55	0.63				
						0.41	0.45	0.90	0.76				
						0.44	0.49	0.86	0.96				
						0.47	0.50						
						0.49	0.54						
						0.49	0.54						
						0.51	0.55						
						0.49	0.55						
						0.47	0.56						
						0.52	0.62						
						0.57	0.63						
						0.61	0.70						
						0.62	0.75						
						0.66	0.85						
						0.74	0.86						
						0.97	0.87						
						0.87	1.14						

	CONSTRUCTION	DRILLING	SUPERVISION	SUPPORT	OTHER	LASHING	TRANSPORT	
No of People	4	9	7	34	20	3	3	80

	CONSTRUCTION		DRILLING		SUPERVISION		SUPPORT		OTHER		LASHING		TRANSPORT	
AVERAGE	0.34	0.36	0.62	0.56	0.56	0.38	0.51	0.49	0.47	0.43	0.42	0.46	0.40	0.44
STD DEV			0.40	0.33	0.37	0.33	0.24	0.21	0.18	0.19				
MINIMUM			0.08	0.05	0.02	0.03	0.20	0.25	0.28	0.15				
MAXIMUM			1.35	1.26	1.16	1.03	1.24	1.14	0.90	0.96				
- STD DEV			0.22	0.23	0.18	0.05	0.27	0.28	0.29	0.24				
+ STD DEV			1.02	0.89	0.93	0.71	0.75	0.70	0.65	0.61				

PWM
0.46

NOTE : SiO2 Levels were all less than 5 percent

	CONSTRUCTION	DRILLING	SUPERVISION	SUPPORT	OTHER	LASHING	TRANSPORT	
AQI	0.12	0.19	0.13	0.16	0.14	0.15	0.15	
Risk	0.06	0.14	0.06	0.11	0.08	0.09	0.09	
Product	0.23	1.25	0.45	3.63	1.64	0.28	0.26	7.74

PWM Risk
0.1

TABLE 20 DETAILS OF CSIR : MINING TECHNOLOGY OCCUPATIONAL EXPOSURE DATA - MINE 2

Occupation	Actual work done	Conc	Conc TWA
		mg/m3	*mg/m3*
DEV 11/31 ASG EAST	Construction	0.56	0.50
DEV GENERAL- INST PIPES	Construction	0.21	0.24
PIPE LINER 2/28 FWD WEST	Construction	0.36	0.41
TEAM LDR 11/29	Construction	0.25	0.29
MACH OP 12LVL DEV	Drilling	1.35	0.50
MACH OP 12LVL DEV	Drilling	1.07	1.26
MACH OP-DRILLING	Drilling	0.81	0.67
MACH OP-DRILLING	Drilling	0.43	0.49
MACH OP-DRILLING	Drilling	0.42	0.46
MACH OPRTR	Drilling	0.40	0.44
MACH OPRTR	Drilling	0.32	0.36
MACH OPRTR	Drilling	0.08	0.05
SPANNER 6/23-DRILLING	Drilling	0.66	0.79
DEV 11/30 ASG EAST	Lashing	0.17	0.12
DEV ASST	Lashing	0.25	0.30
DEVELOPMENT 12LVL	Lashing	0.84	0.97
7/36	Other	0.50	0.33
DEV ASST	Other	0.29	0.34
SHIFT BOSS ASST	Other	0.52	0.51
SHIFT BOSS ASST	Other	0.49	0.37
STOPING	Other	0.30	0.27
Stoping	Other	0.90	0.76
STOPING ASST 4/27	Other	0.31	0.35
STOPING ASST 4/27	Other	0.45	0.49
STOPING ASST 4/27	Other	0.48	0.54
STOPING ASST STP 11/29	Other	0.28	0.31
STOPING ASST STP 11/29	Other	0.33	0.37
STOPING ASST STP 11/29	Other	0.29	0.32
STOPING ASST STP 2/30	Other	0.65	0.49
STOPING ASST STP 2/30	Other	0.47	0.15
STOPING ASST STP 3/30	Other	0.55	0.63
STOPING ASST STP 3/30	Other	0.32	0.33
TEAM LDR 6/26	Other	0.86	0.96
WINCH DRIVER	Other	0.60	0.44
WINCH DRIVER	Other	0.31	0.24
WINCH DRVR-IN 3E PANEL	Other	0.42	0.32

TABLE 20 A TABLE 20 CONTINUED

Occupation	Actual work done	Conc	Conc TWA
		mg/m3	mg/m3
M/O's ASST-ACCOMPANYM/O	Supervision	0.02	0.03
MINER (FRANS)	Supervision	0.37	0.23
SUPV 6/24	Supervision	1.16	0.43
TEAM LDR 6/26	Supervision	0.74	1.03
TEAM LEADER 4/27	Supervision	0.47	0.25
TEAM LEADER E PANELS	Supervision	0.33	0.17
TM LDR 7/22	Supervision	0.80	0.54
11/29 Stope timbering shift	Support	0.40	0.39
MACH OP-INST TIM PACKS	Support	0.20	0.26
MINER ASST 12/30	Support	0.36	0.41
Q	Support	0.57	0.63
STOPE ASST 11/30	Support	0.47	0.50
STOPE ASST 12/30	Support	0.49	0.54
STOPE INSTALL PROPS	Support	0.30	0.34
STOPE-CHARGING UP	Support	0.49	0.55
STOPE-CHARGING UP	Support	0.44	0.49
STOPE-SUPPORT	Support	0.61	0.70
STOPING	Support	0.38	0.44
STOPING	Support	0.23	0.26
STOPING	Support	1.24	0.42
STOPING	Support	0.24	0.28
STOPING 10/30 P 1E	Support	0.72	0.26
STOPING 10/33	Support	0.74	0.86
STOPING 12/30	Support	0.38	0.42
STOPING 12/30	Support	0.30	0.26
STOPING 3/28	Support	0.49	0.54
STOPING 3/28	Support	0.34	0.37
STOPING 3/28	Support	0.25	0.29
STOPING 4/26	Support	0.38	0.41
STOPING 4/26	Support	0.95	[illegible]
STOPING 6/23-INST PACKS	Support	0.47	0.56
STOPING 6/23-INST PACKS	Support	0.52	0.62
STOPING 6/23-TRANSPORT PACKS	Support	0.62	0.75
STOPING 7/22 2W-SUPPORT,CHARGING UP	Support	0.97	0.87
STOPING 7/22-TIMBERING	Support	0.87	1.14
STOPING ASST 4/27	Support	0.66	0.85
STOPING ASST11/30	Support	0.51	0.55
STOPING-INST PACKS & HYD PROPS	Support	0.69	0.38
STOPING-TRANS PACKS	Support	0.37	0.36
WINCH DRIVER	Support	0.22	0.25
WINCH DRIVR 11/30	Support	0.41	0.45
DEV LOADER DRIVER	Transport	0.25	0.18
DRIVER ASST-TRANSPORT	Transport	0.45	0.53
DRIVER ASST-TRANSPORT	Transport	0.51	0.60

TABLE 22
SUMMARY OF MINES OCCUPATIONAL EXPOSURE DATA - MINE 2

CONSTRUCTION Exposure		DRILLING Exposure		SUPERVISION Exposure		SUPPORT Exposure		LASHING Exposure		TRANSPORT Exposure	
Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA	Actual	TWA
mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3
0.01	0.01	0.10	0.11	0.01	0.01	0.00	0.20	0.02	0.02	0.01	0.01
0.08	0.08	0.12	0.16	0.03	0.04	0.03	0.04	0.02	0.03	0.02	0.02
0.09	0.10	0.12	0.15	0.03	0.03	0.06	0.07	0.03	0.03	0.04	0.04
0.09	0.11	0.15	0.17	0.04	0.04	0.07	0.08	0.05	0.06	0.05	0.05
0.09	0.09	0.18	0.21	0.05	0.06	0.08	0.09	0.06	0.07	0.07	0.08
0.10	0.11	0.22	0.23	0.05	0.06	0.10	0.11	0.07	0.08	0.08	0.10
0.14	0.14	0.25	0.30	0.06	0.08	0.12	0.13	0.10	0.11	0.09	0.09
0.14	0.14	0.25	0.30	0.08	0.08	0.14	0.30	0.12	0.15	0.12	0.14
0.16	0.06	0.25	0.25	0.08	0.10	0.14	0.15	0.12	0.13	0.13	0.16
0.16	0.20	0.27	0.26	0.09	0.11	0.14	0.15	0.12	0.14	0.19	0.20
0.17	0.18	0.27	0.36	0.10	0.11	0.14	0.15	0.13	0.14	0.22	0.24
0.17	0.20	0.29	0.32	0.12	0.13	0.16	0.17	0.14	0.16	0.25	0.29
0.17	0.21	0.33	0.35	0.13	0.13	0.16	0.18	0.15	0.18	0.25	0.29
0.20	0.23	0.33	0.37	0.13	0.15	0.17	0.18	0.16	0.18	0.26	0.30
0.20	0.19	0.34	0.36	0.14	0.16	0.17	0.35	0.18	0.21	0.29	0.30
0.20	0.22	0.39	0.42	0.14	0.16	0.17	0.20	0.19	0.24	0.30	0.37
0.21	0.23	0.40	0.41	0.14	0.17	0.18	0.19	0.21	0.24	0.31	0.36
0.22	0.24	0.41	0.45	0.15	0.17	0.19	0.21	0.26	0.30	0.31	0.32
0.23	0.27	0.42	0.46	0.15	0.16	0.19	0.24	0.29	0.32	0.33	0.38
0.23	0.24	0.42	0.44	0.15	0.16	0.20	0.24	0.29	0.39	0.35	0.41
0.26	0.30	0.43	0.52	0.16	0.18	0.21	0.21	0.29	0.33	0.35	0.39
0.28	0.29	0.48	0.57	0.16	0.19	0.21	0.41	0.29	0.35	0.37	0.72
0.29	0.29	0.48	1.88	0.17	0.21	0.24	0.24	0.31	0.36	0.41	0.57
0.30	0.36	0.52	0.54	0.17	0.20	0.25	0.29	0.32	0.33	0.42	0.45
0.34	0.37	0.59	0.68	0.17	0.19	0.25	0.25	0.33	0.36	0.42	0.43
0.35	0.36	0.60	0.67	0.19	0.23	0.25	0.26	0.34	0.39	0.44	0.53
0.35	0.38	0.60	0.62	0.21	0.25	0.27	0.27	0.34	0.40	0.49	0.54
0.37	0.38	0.65	0.79	0.22	0.23	0.27	0.32	0.34	0.40	0.52	0.53
0.38	0.39	0.66	0.80	0.23	0.26	0.27	0.28	0.36	0.41	0.54	0.55
0.39	0.44	0.78	0.81	0.23	0.27	0.28	0.28	0.36	0.43	0.56	0.65
0.40	0.41	1.50	1.72	0.24	0.25	0.28	0.29	0.36	0.44	0.57	1.09
0.41	0.41	1.81	1.86	0.25	0.27	0.29	0.32	0.37	0.42	0.57	0.64
0.41	0.46	11.09	0.10	0.25	0.30	0.31	0.31	0.39	0.46	0.85	0.73
0.41	0.49			0.25	0.28	0.32	0.35	0.39	0.56	0.91	0.92
0.42	0.47			0.25	0.29	0.33	0.36	0.40	0.45	1.01	1.05
0.43	0.44			0.26	0.32	0.33	0.33	0.40	0.46	1.10	1.10
0.44	0.49			0.27	0.29	0.34	0.40	0.41	0.44	1.32	1.34
0.45	0.46			0.27	0.32	0.34	0.34	0.42	0.46	1.38	1.38
0.47	0.55			0.27	0.31	0.36	0.39	0.42	0.49	2.02	2.06
0.48	0.58			0.28	0.32	0.37	0.42	0.42	0.49		
0.48	0.50			0.29	0.31	0.37	0.51	0.51	0.61		
0.50	0.59			0.29	0.33	0.38	0.44	0.54	0.80		
0.51	0.54			0.30	0.34	0.40	0.40	0.54	0.62		
0.51	0.60			0.31	0.34	0.40	0.40	0.55	0.57		
0.51	0.51			0.32	0.38	0.41	0.47	0.56	0.65		
0.52	0.53			0.33	0.40	0.41	0.48	0.66	0.72		
0.53	0.66			0.33	0.34	0.42	0.47	0.70	0.78		
0.53	0.66			0.33	0.41	0.42	0.48	0.71	0.85		

TABLE 22 A TABLE 22 CONTINUED

CONSTRUCTION Exposure		DRILLING Exposure		SUPERVISION Exposure		SUPPORT Exposure		LASHING Exposure		TRANSPORT Exposure	
Actual mg/m3	TWA mg/m3	Actual mg/m3	TWA mg/m3	Actual mg/m3	TWA mg/m3	Actual mg/m3	TWA mg/m3	Actual mg/m3	TWA mg/m3	Actual mg/m3	TWA mg/m3
0.54	0.64			0.35	0.56	0.43	0.51	0.77	0.90		
0.59	0.71			0.35	0.40	0.46	0.53	0.83	0.83		
0.62	0.76			0.35	0.39	0.49	0.59	1.02	1.19		
0.62	0.66			0.36	0.37	0.51	0.52	1.08	1.05		
0.63	0.71			0.38	0.40	0.52	0.56	1.44	1.63		
0.63	0.64			0.41	0.49	0.56	0.57	2.01	2.31		
0.68	0.70			0.42	0.52	0.59	0.61				
0.71	0.72			0.42	0.50	0.60	0.62				
0.72	0.72			0.43	0.51	0.66	0.78				
0.73	0.84			0.47	0.53	0.67	0.68				
0.91	0.94			0.48	0.49	0.68	0.81				
1.51	2.41			0.48	0.56	0.68	0.82				
				0.48	0.55	0.72	0.77				
				0.49	0.53	0.75	0.83				
				0.52	0.63	0.75	0.89				
				0.52	0.62	0.83	0.86				
				0.55	0.63	0.85	0.99				
				0.56	0.69	1.36	1.41				
				0.57	0.57	2.81	2.81				
				0.59	0.64						
				0.70	0.77						
				0.79	0.92						
				0.81	0.96						
				0.83	0.93						
				0.86	0.97						
				0.88	0.98						
				0.99	1.09						
				1.14	1.33						
				1.58	1.61						
				1.71	1.88						

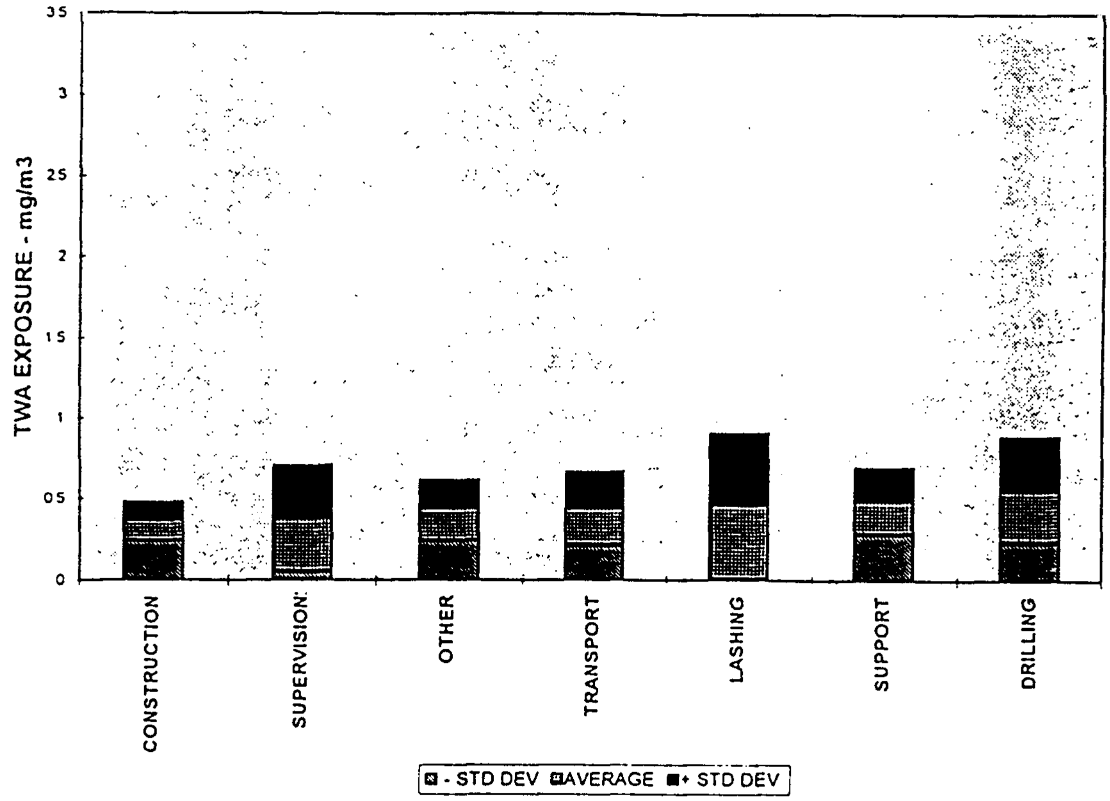


Figure 128 <u>COMPARISON OCCUPATIONAL EXPOSURES - CSIR MINING TECHNOLOGY DATA - MINE 2</u>

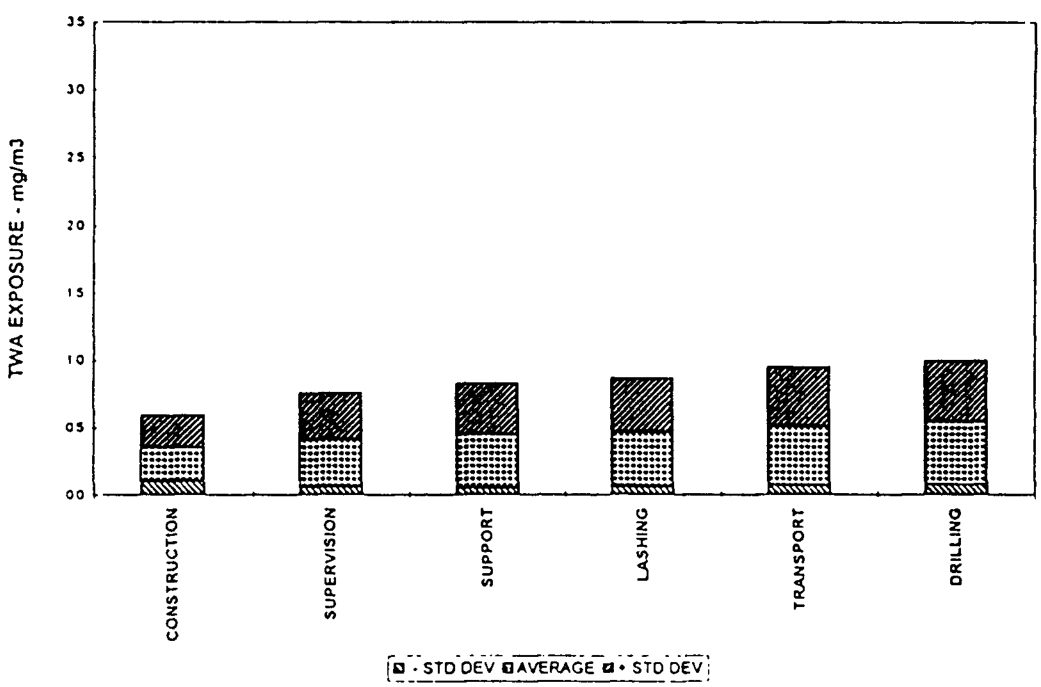


Figure 129 <u>COMPARISONS OF OCCUPATIONAL EXPOSURES - MINE DATA - MINE 2</u>

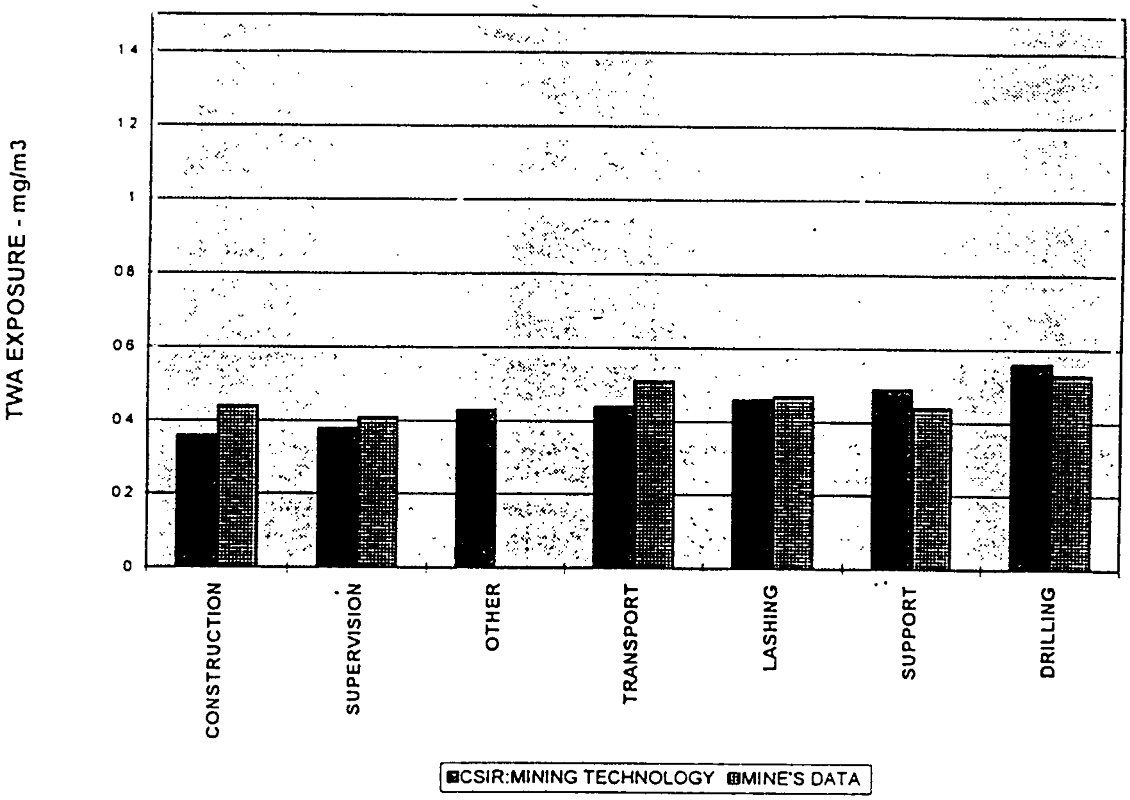


Figure 130 COMPARISON OF AVERAGE OCCUPATIONAL EXPOSURES - CSIR MINING TECHNOLOGY AND MINE DATA - MINE 2

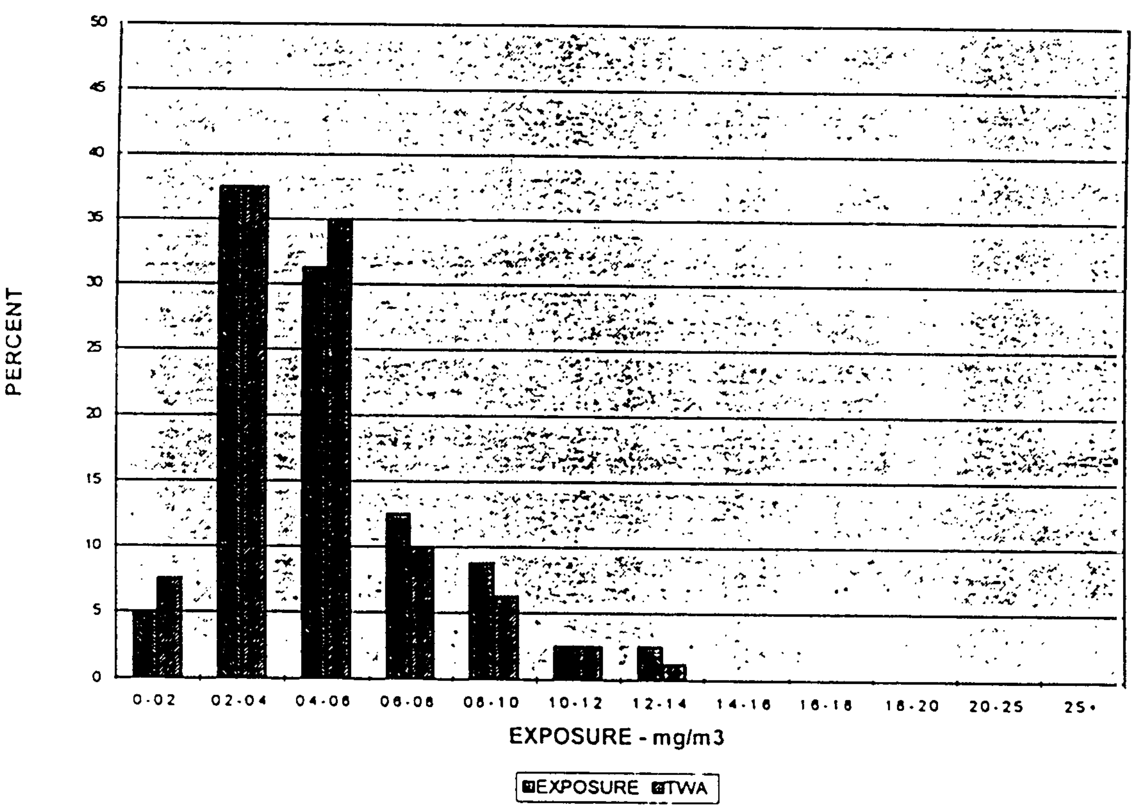


Figure 131 FREQUENCY DISTRIBUTION OF OCCUPATIONAL EXPOSURES - CSIR MINING TECHNOLOGY DATA - MINE 2

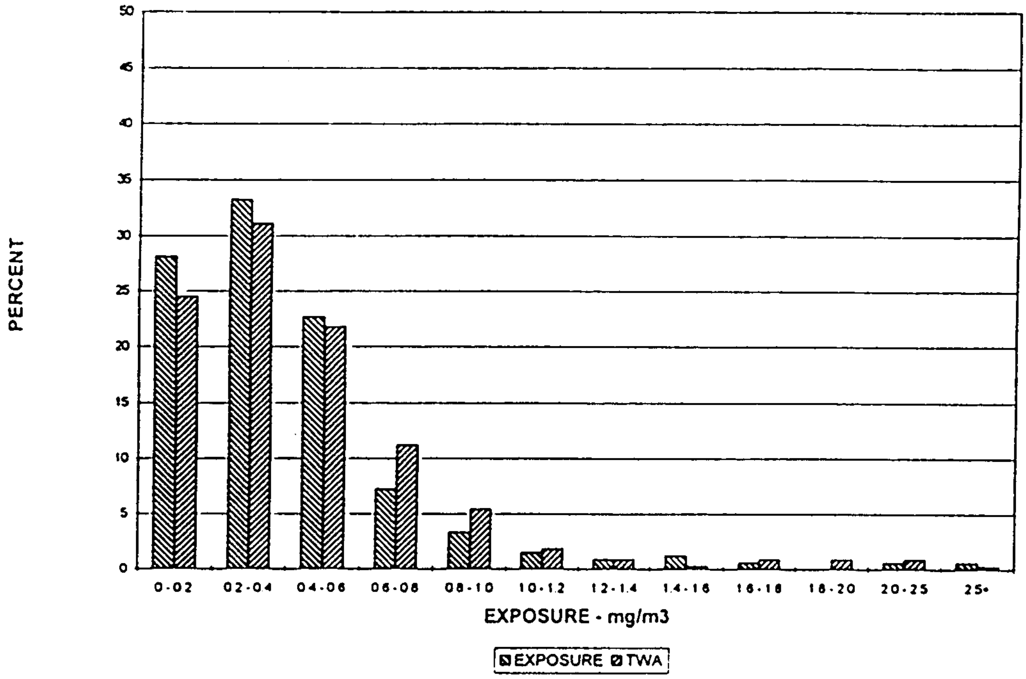


Figure 132 <u>FREQUENCY DISTRIBUTION OF OCCUPATIONAL EXPOSURES - MINE DATA - MINE 2</u>

TABLE 23 SUMMARY OF CSIR : MINING TECHNOLOGY OCCUPATIONAL EXPOSURE DATA - MINE 3

CONSTRUCTION Exposure			DRILLING Exposure			SUPERVISION Exposure			SUPPORT Exposure			OTHER Exposure			LASHING Exposure			TRANSPORT Exposure		
Actual	TWA	SiO2	Actual	TWA	SiO2	Actual	TWA	SiO2	Actual	TWA	SiO2	Actual	TWA	SiO2	Actual	TWA	SiO2	Actual	TWA	SiO2
mg/m3	mg/m3	%	mg/m3	mg/m3	%	mg/m3	mg/m3	%	mg/m3	mg/m3	%	mg/m3	mg/m3	%	mg/m3	mg/m3	%	mg/m3	mg/m3	%
0.07	0.07	*	0.19	0.20	19.9	0.13	0.09	*	0.02	0.02	*	0.08	0.08	*	0.13	0.14	*	0.25	0.28	*
0.29	0.22	8.3	0.40	0.23	25.1	0.25	0.15	15.2	0.05	0.05	*	0.10	0.12	25.9	0.54	0.57	6.6			
0.27	0.28	13.5	0.75	0.36	18.9	0.45	0.28	18.5	0.25	0.13	*	0.14	0.15	15.0						
0.33	0.34	13.3	0.39	0.41	15.7	0.23	0.27	6.0	0.14	0.16	*	0.15	0.17	32.2						
0.41	0.42	10.3	0.35	0.41	14.4	0.36	0.33	13.4	0.19	0.24	24.1	0.31	0.17	*						
0.60	0.67	7.4	0.51	0.55	18.4	0.59	0.37	18.1	0.32	0.25	13.7	0.75	0.20	*						
0.65	0.74	10.0	0.66	0.63	8.4	0.40	0.42	7.4	0.26	0.27	15.2	0.27	0.27	19.6						
			0.69	0.79	9.2	0.45	0.52	3.6	0.35	0.30	32.3	0.27	0.31	7.33						
			0.89	0.88	3.5				0.32	0.30	*	0.26	0.31	19.7						
									0.27	0.31	*	0.31	0.34	32.8						
									0.27	0.31	18.5	0.31	0.34	9.1						
									0.33	0.32	17.3	0.39	0.43	42.7						
									0.35	0.37	10.9	0.31	0.46	22.7						
									0.24	0.39	16.9	0.49	0.47	12.2						
									0.26	0.42	16.0	0.37	0.52	20.0						
									0.35	0.42	6.7	0.32	0.54	11.7						
									0.36	0.42	12.6	0.57	0.61	20.3						
									0.38	0.42	7.0	0.53	0.62	11.2						
									0.30	0.51	19.7	0.81	0.98	5.6						
									0.47	0.56	30.5	1.51	2.63	19.2						
									0.50	0.57	*									
									0.86	0.59	7.5									
									0.63	0.62	30.9									
									0.61	0.70	16.7									
									0.47	0.80	10.5									
									0.69	0.80	9.3									
									0.69	0.82	13.4									
									0.78	0.91	9.2									
									0.82	0.98	15.0									
									0.88	1.01	6.0									
									2.68	3.07	30.9									

* Less than detection limit of 20 μg

	CONSTRUCTION			DRILLING			SUPERVISION			SUPPORT			OTHER			LASHING			TRANSPORT			
No of People		7			9			8			31			20			2			1		78
AVERAGE	0.37	0.39	10.9	0.54	0.50	14.8	0.36	0.30	12.0	0.49	0.55	16.9	0.41	0.48	19.6	0.34	0.35	4.6	0.25	0.28	2.5	PWM
STD DEV	0.20	0.24	2.5	0.23	0.24	6.7	0.15	0.14	6.0	0.47	0.54	8.1	0.32	0.55	9.9							0.48
MINIMUM	0.07	0.07	2.5	0.19	0.20	3.5	0.13	0.09	3.6	0.02	0.02	6.0	0.08	0.08	5.6							
MAXIMUM	0.65	0.74	13.5	0.89	0.88	25.1	0.59	0.52	18.5	2.68	3.07	32.3	1.51	2.63	42.7							
- STD DEV	0.17	0.15	8.4	0.31	0.26	8.1	0.21	0.16	6.0	0.02	0.01	8.8	0.09	-0.06	9.6							
+ STD DEV	0.57	0.63	13.4	0.76	0.73	21.6	0.5'	0.44	18.1	0.95	1.09	25.0	0.74	1.03	29.5							

	CONSTRUCTION	DRILLING	SUPERVISION	SUPPORT	OTHER	LASHING	TRANSPORT	
REAL VALUES								PWM SiO2 %
								15.8
AQI	0.42	0.73	0.36	0.93	0.94	0.07	0.06	
Risk	0.72	2.16	0.52	3.44	3.53	0.02	0.01	
Product	5.02	19.40	4.15	106.68	70.63	0.04	0.01	205.93
								PWM Risk
								2.64
VALUES @ 20 %								
AQI	0.78	0.99	0.61	1.10	0.97	0.70	0.57	
Risk	2.44	3.92	1.46	4.83	3.76	1.98	1.28	
Product	17.10	35.30	11.72	149.80	75.22	3.96	1.28	294.37
								PWM Risk
								3.77

TABLE 24 DETAILS OF CSIR : MINING TECHNOLOGY OCCUPATIONAL EXPOSURE DATA - MINE 3

Occupation	Actual work done	Conc	Conc TWA
		mg/m3	mg/m3
HELPER	Construction	0.33	0.34
SHIFT BOSS	Construction	0.29	0.22
TEAM LEADER	Construction	0.27	0.28
TEAM LEADER	Construction	0.65	0.74
PRODA	Construction	0.41	0.42
PRODA	Construction	0.60	0.67
TEAM LEADER	Construction	0.07	0.07
DRILLING ASSISTANT	Drilling	0.89	0.88
PRODA	Drilling	0.35	0.41
PRODA	Drilling	0.66	0.63
TEAM LEADER	Drilling	0.19	0.20
MINERS ASSISTANT	Drilling	0.75	0.36
TEAM LEADER	Drilling	0.40	0.23
PRODA	Drilling	0.69	0.79
PRODA	Drilling	0.39	0.41
PRODA	Drilling	0.51	0.55
TEAM LEADER	Lashing	0.54	0.57
MINERS ASSISTANT	Lashing	0.13	0.14
MINERS ASSISTANT	Other	0.37	0.52
PRODA	Other	0.27	0.27
PRODA	Other	0.27	0.31
PRODA	Other	0.32	0.54
PRODA	Other	0.31	0.17
TEAM LEADER	Other	0.31	0.46
TEAM LEADER	Other	0.75	0.20
TEAM LEADER	Other	0.53	0.62
PRODA	Other	0.49	0.47
TEAM LEADER	Other	1.51	2.63
TEAM LEADER	Other	0.14	0.15
PRODA	Other	0.31	0.34
TEAM LEADER	Other	0.26	0.31
PRODA	Other	0.81	0.96
PRODA	Other	0.57	0.61
PRODA	Other	0.39	0.43
PRODA	Other	0.15	0.17
TEAM LEADER	Other	0.10	0.12
TEAM LEADER	Other	0.08	0.08
PRODA	Other	0.31	0.34

TABLE 24 A TABLE 24 CONTINUED

Occupation	Actual work done	Conc	Conc TWA
		mg/m3	mg/m3
SHIFT BOSS	Supervision	0.36	0.33
SHIFT BOSS	Supervision	0.25	0.15
TEAM LEADER	Supervision	0.40	0.42
TEAM LEADER	Supervision	0.23	0.27
TEAM LEADER	Supervision	0.13	0.09
TEAM LEADER	Supervision	0.45	0.26
TEAM LEADER	Supervision	0.59	0.37
SUPV TEAM LEADER	Supervision	0.45	0.52
PRODA	Support	0.35	0.42
PRODA	Support	0.88	1.01
TEAM LEADER	Support	0.69	0.80
MINERS ASSISTANT	Support	0.27	0.31
PRODA	Support	0.35	0.30
PRODA	Support	0.25	0.13
TEAM LEADER	Support	0.32	0.30
TEAM LEADER	Support	0.78	0.91
TEAM LEADER	Support	0.35	0.37
TEAM LEADER	Support	0.33	0.32
TEAM LEADER	Support	0.32	0.25
PRODA	Support	0.05	0.05
PRODA	Support	0.63	0.62
TEAM LEADER	Support	0.61	0.70
TEAM LEADER	Support	0.47	0.55
TEAM LEADER	Support	0.82	0.98
PRODA	Support	0.38	0.42
TEAM LEADER	Support	0.30	0.51
TEAM LEADER	Support	0.47	0.80
PRODA	Support	0.24	0.39
PRODA	Support	0.19	0.24
PRODA	Support	0.02	0.02
TEAM LEADER	Support	0.27	0.31
TEAM LEADER	Support	0.26	0.27
TEAM LEADER	Support	0.69	0.82
TEAM LEADER	Support	2.68	3.07
TEAM LEADER	Support	0.86	0.59
TEAM LEADER	Support	0.50	0.57
TEAM LEADER	Support	0.36	0.42
TEAM LEADER	Support	0.26	0.42
PRODA	Support	0.14	0.16
PRODA	Transport	0.25	0.28

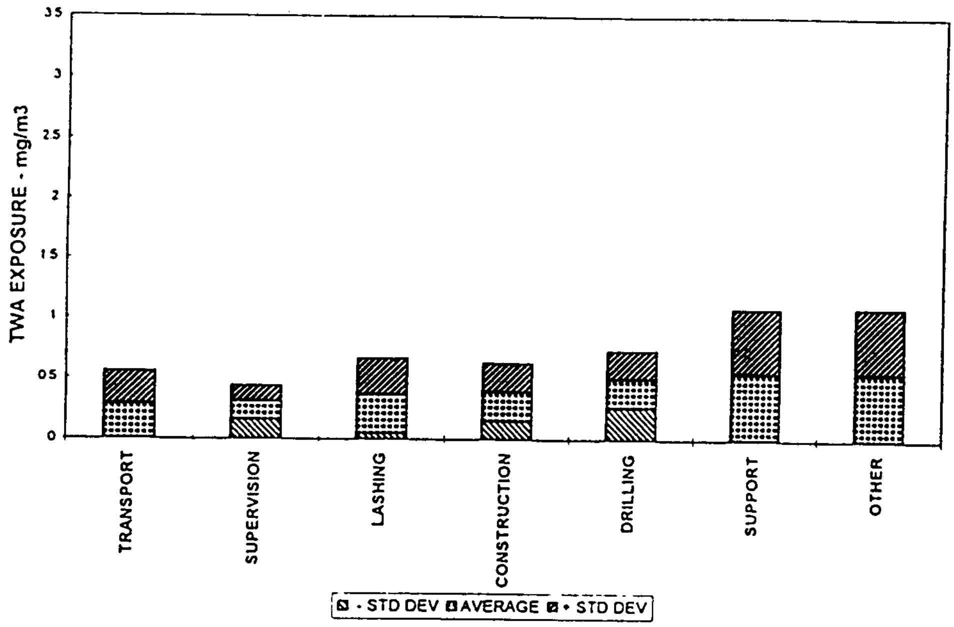


Figure 133 COMPARISON OF OCCUPATIONAL EXPOSURES - CSIR MINING TECHNOLOGY DATA - MINE 3

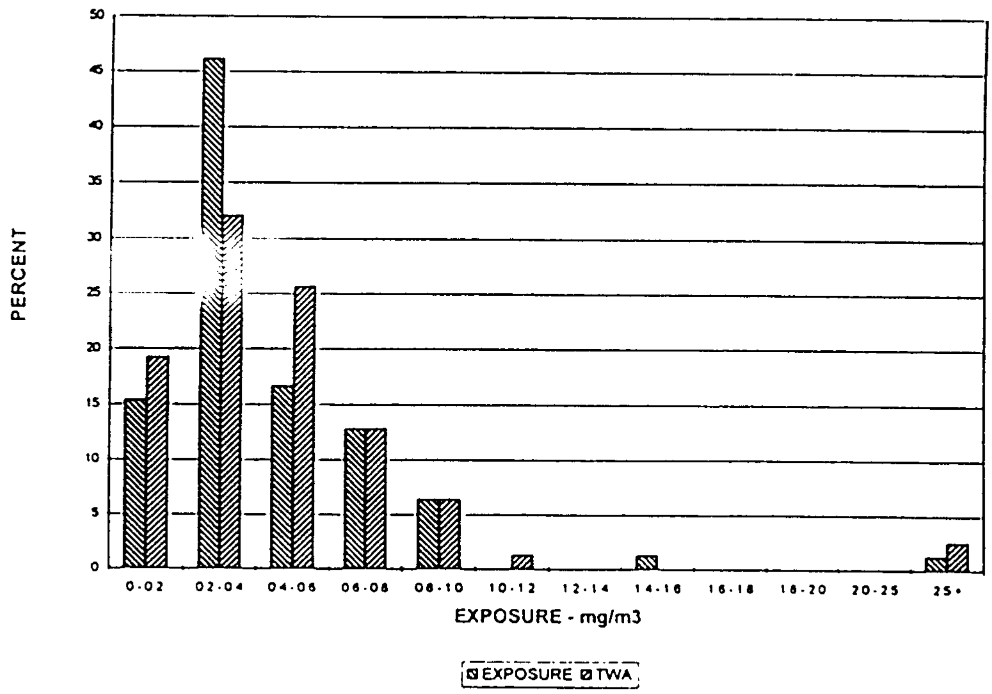


Figure 134 FREQUENCY DISTRIBUTION OF OCCUPATIONAL EXPOSURES - CSIR MINING TECHNOLOGY DATA - MINE 3

TABLE 25 SUMMARY OF CSIR : MINING TECHNOLOGY OCCUPATIONAL EXPOSURE DATA - MINE 4

CONSTRUCTION Exposure			DRILLING Exposure			SUPERVISION Exposure			SUPPORT Exposure			OTHER Exposure			LASHING Exposure			TRANSPORT Exposure		
Actual	TWA	SiO2	Actual	TWA	SiO2	Actual	TWA	SiO2	Actual	TWA	SiO2	Actual	TWA	SiO2	Actual	TWA	SiO2	Actual	TWA	SiO2
mg/m3	mg/m3	%	mg/m3	mg/m3	%	mg/m3	mg/m3	%	mg/m3	mg/m3	%	mg/m3	mg/m3	%	mg/m3	mg/m3	%	mg/m3	mg/m3	%
0.02	0.01	*	0.29	0.34	21.8	0.04	0.04	*	0.05	0.05	*	0.30	0.29	14.1	0.03	0.04	15.2			
0.04	0.04	*	1.53	1.94	*	0.18	0.17	17.6	0.12	0.08	37.4	0.05	0.04	*	0.17	0.16	24.3			
0.05	0.05	*				0.43	0.40	11.0	0.08	0.09	*	0.08	0.07	*	0.27	0.32	12.7			
0.05	0.05	*				0.70	0.59	*	0.13	0.15	11.0	0.14	0.07	*	0.30	0.33	22.5			
0.06	0.08	*				0.57	0.64	7.4	0.15	0.17	18.5	0.08	0.08	*	0.38	0.41	14.9			
0.08	0.07	39.2				0.97	0.88	21.7	0.16	0.17	8.2	0.10	0.09	*	0.40	0.47	10.2			
0.12	0.13	20.7				1.23	1.09	12.7	0.17	0.19	20.1	0.14	0.10	*	0.52	0.59	12.3			
0.12	0.14	37.9				0.98	1.10	15.7	0.22	0.23	17.3	0.13	0.13	45.3	0.61	0.65	8.5			
0.21	0.22	*							0.23	0.24	13.1	0.19	0.22	37.3	1.66	0.68	*			
0.23	0.24	21.8							0.23	0.25	7.4	0.21	0.24	13.9	0.78	0.87	6.5			
0.27	0.32	11.0							0.24	0.27	8.2	0.23	0.25	15.0	0.78	0.98	23.4			
0.33	0.36	10.6							0.30	0.33	20.9	0.33	0.38	37.1	1.34	1.51	9.0			
0.31	0.35	19.1							0.32	0.33	15.8	0.29	0.37	8.9						
0.33	0.38	29.6							0.32	0.39	7.8	0.76	0.37	19.3						
0.39	0.41	9.8							0.35	0.41	32.5	0.36	0.38	12.6						
0.36	0.42	23.8							0.45	0.43	12.6	1.44	1.33	15.1						
0.57	0.48	14.7							0.43	0.45	9.9	1.59	1.40	10.1						
0.46	0.49	18.5							0.47	0.45	15.1	1.87	2.17	30.3						
0.48	0.54	29.9							0.57	0.58	18.0									
0.57	0.57	14.6							1.58	0.58	20.1									
0.52	0.58	10.6							0.53	0.65	7.7									
0.70	0.83	17.7							0.58	0.68	10.4									
0.65	0.88	13.9							0.71	0.78	31.2									
0.84	0.97	1.0							1.00	1.01	21.6									
0.89	1.14	9.8							1.00	1.09	18.8									
2.71	1.54	30.4							1.09	1.08	9.5									
									1.08	1.22	11.8									
									1.42	1.71	2.0									
									3.13	3.39	3.6									
									3.14	3.56	5.5									

* Less than detection limit of 20 µg

	Construction	Drilling	Supervision	Support	Other	Lashing	Transport	Total
No of People	26	2	8	30	18	12	0	96

	CONSTRUCTION			DRILLING			SUPERVISION			SUPPORT			OTHER			LASHING			TRANSPORT		
AVERAGE	0.44	0.43	15.0	0.91	1.14	12.1	0.64	0.59	11.4	0.67	0.70	13.9	0.46	0.44	15.2	0.60	0.58	13.5			
STD DEV	0.53	0.38	11.7				0.41	0.38	7.9	0.78	0.85	9.1	0.57	0.58	14.5	0.48	0.40	7.3			
MINIMUM	0.02	0.01					0.04	0.04		0.05	0.05		0.03	0.04		0.03	0.04				
MAXIMUM	2.71	1.54	39.2				1.23	1.10	21.7	3.14	3.56	37.4	1.87	2.17	45.3	1.66	1.51	24.3			
- STD DEV	-0.09	0.05	3.3				0.22	0.20	3.5	-0.11	-0.15	4.8	-0.11	-0.14	-0.1	0.12	0.18	6.2			
+ STD DEV	0.97	0.81	26.6				1.05	0.97	19.4	1.45	1.55	22.9	1.03	1.02	29.7	1.08	0.98	20.8			

PWM
0.56

PWM SiO2 %
14.14

	Construction	Drilling	Supervision	Support	Other	Lashing	Total
REAL VALUES							
AQI	0.64	1.37	0.67	0.97	0.67	0.78	
Risk	1.66	7.55	1.82	3.77	1.80	2.46	
Product	43.13	15.10	14.54	113.06	32.35	29.46	247.64
VALUES @ 20 %							
AQI	0.86	2.28	1.17	1.40	0.88	1.16	
Risk	2.99	20.85	5.52	7.79	3.11	5.39	
Product	77.70	41.69	44.16	233.73	65.94	64.62	517.85

PWM Risk (real values)	PWM Risk (@ 20 %)
2.58	5.39

TABLE 26 DETAILS OF CSIR : MINING TECHNOLOGY OCCUPATIONAL EXPOSURE DATA - MINE 4

Occupation	Actual work done	Conc	Conc TWA
		mg/m3	mg/m3
TEAM ATTDT-CONSTR TIP	Construction	0.57	0.46
TEAM ASST	Construction	0.57	0.57
TEAM LDR	Construction	0.31	0.35
TEAM LDR	Construction	0.48	0.54
TEAM LEADER	Construction	0.05	0.06
TEAM LEADER	Construction	0.99	1.14
TEAM LEADER	Construction	0.05	0.05
TEAM LEADER	Construction	0.52	0.58
TEAM LEADER	Construction	0.12	0.14
TEAM ASST	Construction	0.02	0.01
TEAM ASST	Construction	0.33	0.38
TEAM LEADER	Construction	0.05	0.05
TEAM LEADER	Construction	0.04	0.04
TEAM LEADER	Construction	0.70	0.83
TEAM ASST	Construction	0.27	0.32
TEAM ASST	Construction	0.84	0.97
TEAM LEADER	Construction	0.39	0.41
TEAM LEADER	Construction	0.65	0.88
TEAM LEADER	Construction	0.06	0.07
TEAM ASST	Construction	0.21	0.22
TEAM ASST	Construction	0.46	0.48
TEAM LEADER	Construction	0.35	0.42
TEAM ASST	Construction	0.12	0.13
TEAM ASST	Construction	0.23	0.24
TEAM LEADER	Construction	0.33	0.35
TEAM LEADER	Construction	2.71	1.54
TEAM ATTDT	Drilling	0.29	0.34
TEAM LEADER	Drilling	1.53	1.94
TEAM ASST	Lashing	0.27	0.32
TEAM ASST	Lashing	0.03	0.04
TEAM ATTDT	Lashing	1.66	0.66
TEAM LEADER	Lashing	0.52	0.59
TEAM ASST	Lashing	0.36	0.41
TEAM ASST	Lashing	0.78	0.87
TEAM LEADER	Lashing	0.30	0.33
TEAM ASST	Lashing	0.61	0.65
TEAM ASST	Lashing	0.17	0.16
TEAM ASST	Lashing	1.34	1.51
TEAM LEADER	Lashing	0.40	0.47
TEAM LEADER	Lashing	0.78	0.96

TABLE 26 A TABLE 26 CONTINUED

Occupation	Actual work done	Conc	Conc TWA
		mg/m3	mg/m3
TM LDR -STOPING	Other	0.26	0.29
TEAM LDR STOPE 15N19	Other	0.76	0.37
TEAM ASST	Other	0.14	0.10
TEAM ASST	Other	0.19	0.22
STOPE TIMBER	Other	0.36	0.38
TEAM HELPER	Other	0.14	0.07
TEAM ATTDT	Other	1.44	1.33
TEAM LEADER	Other	0.08	0.08
TEAM LEADER	Other	0.13	0.13
TEAM LEADER	Other	1.59	1.40
TEAM ASST	Other	0.06	0.07
TEAM ASST	Other	0.10	0.09
TEAM ASST	Other	0.23	0.25
TEAM LEADER	Other	0.03	0.04
TEAM LEADER	Other	1.87	2.17
TEAM LEADER	Other	0.29	0.37
TEAM LEADER	Other	0.33	0.36
TEAM LEADER	Other	0.21	0.24
TM LDR-STOPING	Supervision	0.57	0.64
TEAM LDR	Supervision	0.04	0.04
TEAM LDR	Supervision	0.18	0.17
TEAM LDR	Supervision	0.96	1.10
TEAM LDR	Supervision	1.23	1.09
TEAM LEADER	Supervision	0.43	0.40
TEAM LEADER	Supervision	0.97	0.66
TEAM LEADER	Supervision	0.70	0.59
TEAM ATTDT-SUPPORT	Support	1.00	1.01
TEAM ATTDT-SUPPORT	Support	0.32	0.33
TEAM ATTDT-SUPPORT	Support	0.23	0.25
TEAM ATTDT-SUPPORT/CLEAN	Support	1.00	1.08
TEAM LDR-SUPPORT	Support	0.32	0.38
TEAM LDR	Support	0.56	0.66
TEAM ATTDT	Support	3.14	3.56
TEAM ATTDT	Support	0.43	0.45
TEAM ATTDT	Support	0.47	0.45
TEAM LDR	Support	1.42	1.71
TEAM LDR	Support	0.23	0.24
TEAM ASST	Support	0.45	0.43
TEAM ASST	Support	0.08	0.08
TEAM ASST	Support	0.57	0.56
TEAM ASST	Support	1.08	1.22
TEAM ASST	Support	1.56	0.58
TEAM LEADER	Support	0.24	0.27
TEAM LEADER	Support	0.22	0.23
TEAM LEADER	Support	0.12	0.08
TEAM ATTENDANT	Support	0.30	0.33
TEAM ASST	Support	0.53	0.63
TEAM LEADER	Support	0.35	0.41
TEAM ASST	Support	0.05	0.05
TEAM ASST	Support	0.17	0.19
TEAM ASST	Support	0.71	0.76
TEAM ASST	Support	3.13	3.39
TEAM ASST	Support	1.09	1.08
TEAM ASST	Support	0.16	0.17
TEAM ASST	Support	0.13	0.15
TEAM ASST	Support	0.15	0.17

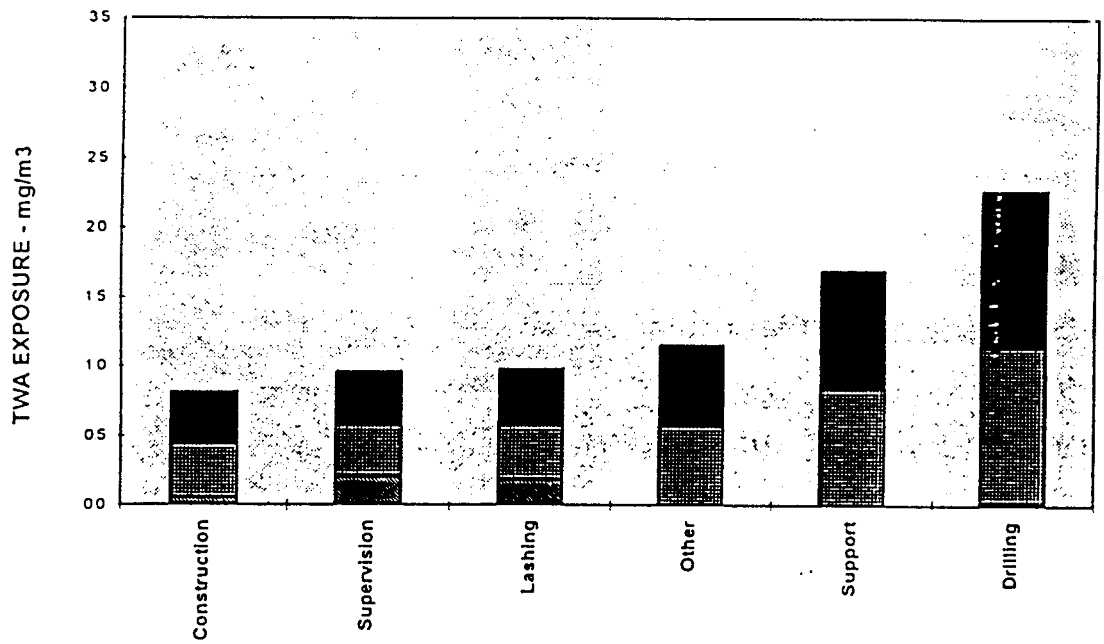


Figure 135 COMPARISON OF OCCUPATIONAL EXPOSURES - CSIR MINING TECHNOLOGY DATA - MINE 4

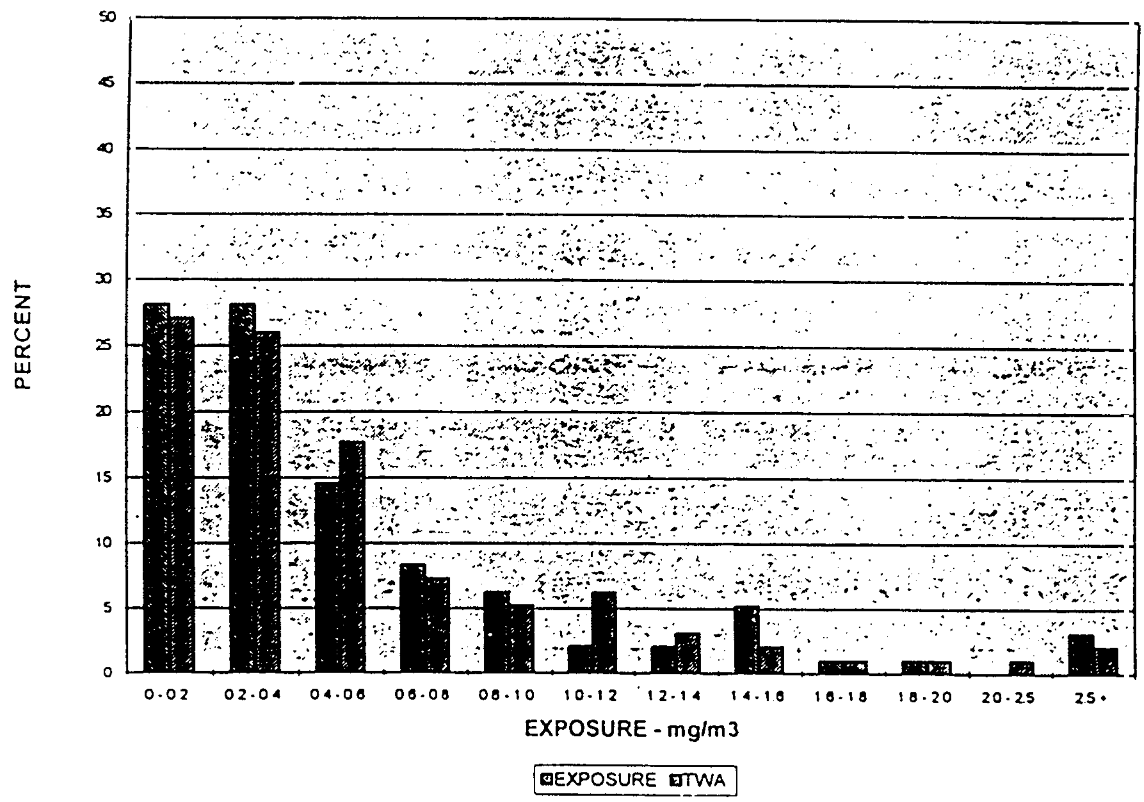


Figure 136 FREQUENCY DISTRIBUTION OF OCCUPATIONAL EXPOSURES - CSIR: MINING TECHNOLOGY DATA, MINE 4

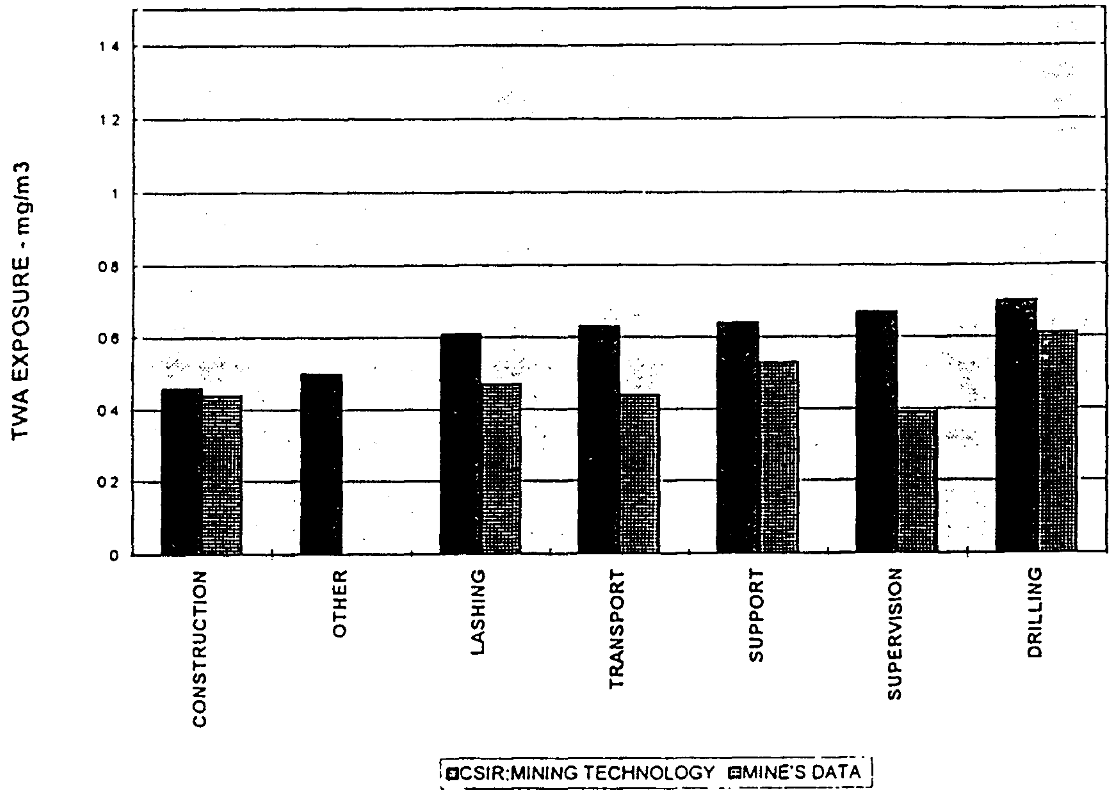


Figure 137 COMPARISON OF OCCUPATIONAL EXPOSURE DATA- ALL MINES SURVEYED- CSIR MINING TECHNOLOGY AND MINE DATA

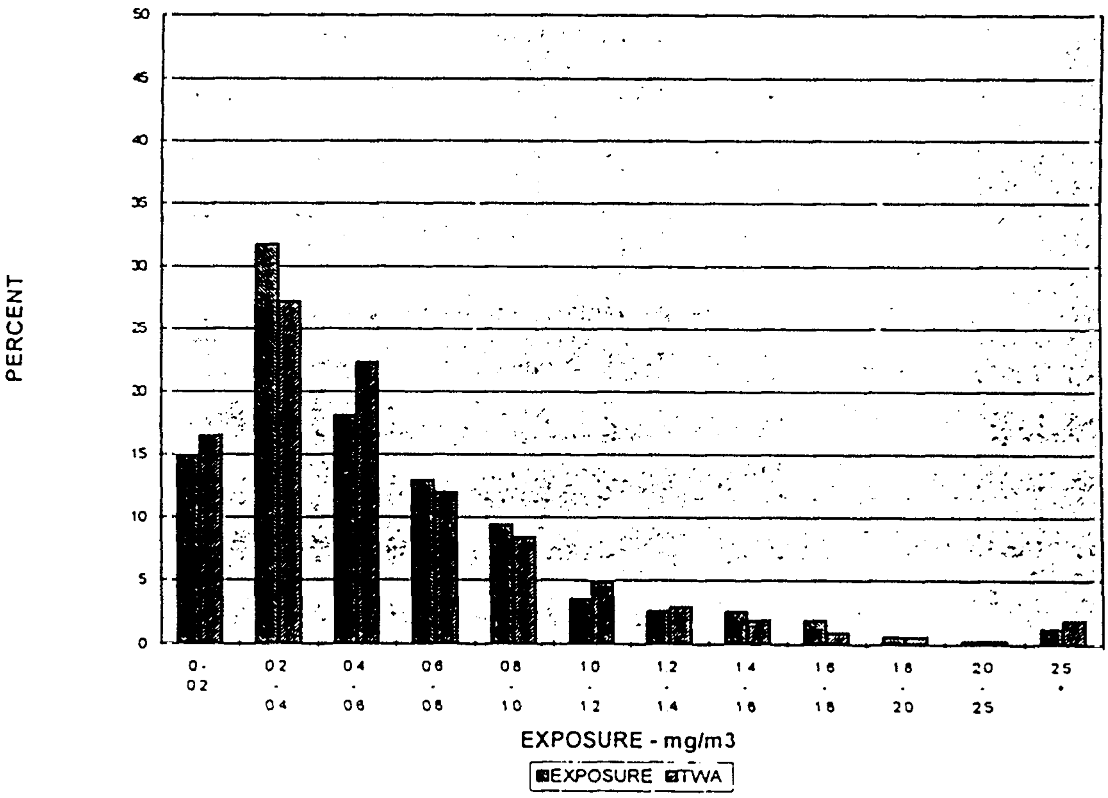


Figure 138 FREQUENCY DISTRIBUTION OF OCCUPATIONAL EXPOSURES - ALL MINES SURVEYED - CSIR MINING TECHNOLOGY DATA

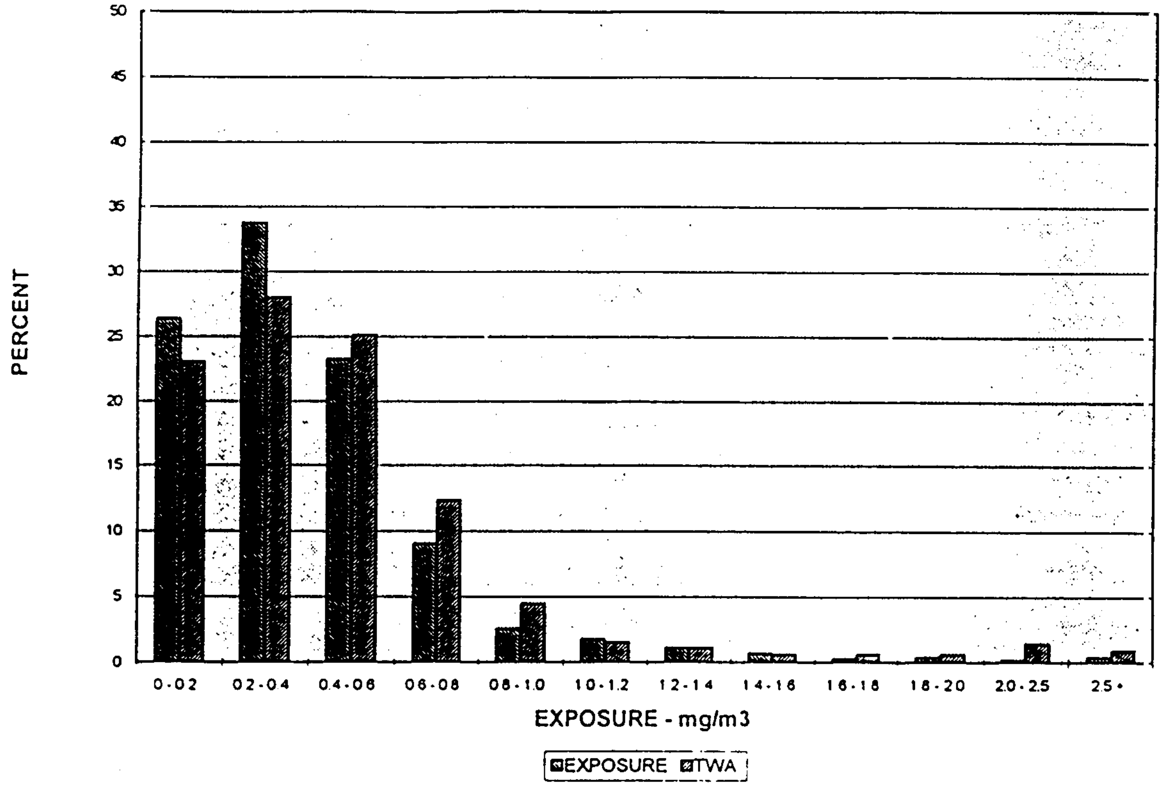


Figure 139 <u>FREQUENCY DISTRIBUTION OF OCCUPATIONAL EXPOSURES - ALL MINES SURVEYED - MINE DATA</u>

5.5 Discussion

The advent of multiskilling ensured that more worker categories were sampled than was originally intended. Instead of only two major occupational categories, namely supervision and stope support (timbering), an additional four major categories were sampled and these were transport, drilling, lashing and construction. In addition, a category called "other", where workers did not fit any of these first six occupations, also had to be used in some instances. As a consequence fewer samples than planned were collected in the two categories selected for the study. It became obvious that a direct comparison with the results reported by mines would be of little value since, irrespective of the actual work performed on the day of sampling, the results were reported on the basis of the original selection, since failure to do so would result in a deviation from the approved sampling strategy.

In order to fully comply with the approved sampling strategy, it may have necessitated many repeat samples to obtain results for the selected occupations, and hence samples would not have been collected on the agreed sampling dates. This would have meant spending considerably increased effort and time to correct the emerging picture of results to one approaching compatibility with the approved strategy.

From the tables of extractions from mine records, (which were originally unsorted), it is obvious that the reporting procedures are not set up for rapid extraction of relevant data. Although the numbers of CSIR: Mining Technology's samples were less than those planned for, the data have nevertheless been analysed on a mine by mine basis and then collectively. The results have been compared with mine results where possible.

In compiling results it also became evident that, in some instances there are differences between actual dust exposure levels and eight-hour Time Weighted Averages. It is understood that TWAs were selected by the DME so that comparisons could be made with internationally accepted TLVs and that inter-mine comparisons may become possible. Some comparisons were made between TWA exposures and actual exposures.

An inspection of Figure 123 shows that, even though based on a relatively small population sample, the possibility of detecting differences in TWA exposure levels for different occupations groups does exist. For convenience, the exposures have been ranked on the basis of average exposures for the occupation groups investigated. There is a detectable difference from lowest to highest.

The results of the analysis on the mine's data are shown in Figure 124 where ranking has again been done. This time the order has been changed, and drilling was found to have the highest eight hour TWA. Results are based on a larger population sample than Miningtek's data.

A comparison between CSIR: Mining Technology's results and the mine's results is shown in Figure 125, where CSIR: Mining Technology's results are ranked. Differences between the two sets of results are clearly discernable as are the exposure rankings. Only the averages are shown for the sake of clarity.

It is known that the mine uses rotating sponge samples in their gravimetric dust sampling programme and, as has been pointed out in a previous project [(1)], these samples tend to yield lower results than standard sampling trains. This is the most plausible explanation for the considerable discrepancy between the sets of results.

Frequency distributions of actual exposures and TWA exposures were done for both CSIR: Mining Technology's and the mine's results. These are shown in Figures 126 and 127. The bulk of the CSIR: Mining Technology's results are found in the 0,6 to 1,2 mg/m^3 range and the bulk of the mine's results are in the 0 - 0,6 mg/m^3 range. In the concentration ranges greater than 1,2 mg/m^3, CSIR: Mining Technology's data shows observable numbers of samples whereas the mine data show a quite sharp reduction in samples in the concentration ranges greater than 0,8 mg/m^3. There may be a plausible explanation for this, the most obvious being the difference in performance of sampling instruments.

Neither CSIR: Mining Technology's nor the mine's data displayed bias towards actual exposures or TWA exposures for the complete range. The Person Weighted TWA for the occupations studied was calculated as 0.98 mg/m^3. (CSIR: Mining Technology results.)

The results shown in Table 15 indicate that personal quartz concentrations fell in the range of less than 5 percent to 22 percent, which is slightly higher than the range found for the short duration tests. The person weighted mean (PWM) quartz content for all occupations monitored was calculated as 6,0 percent and the person weighted mean risk, based on actual quartz concentration, was found to be 1,65. When a standard quartz content of 20 percent is used, the PWM risk increases considerably to over 15 percent because of the large difference in quartz concentrations used to calculate risk. Risk was calculated from the relationship Risk = $4(AQI)^2$ where AQI = (Quartz fraction of dust) / TLV (0.1), except where the quartz content is less than five percent, when a TLV of 5 mg/m^3 is applicable [(2)]. The ranking of the different occupation risks based on measured quartz levels followed a similar pattern to the TWA ranking at the top and bottom of the rankings and in this instance the occupation risk could have been ranked in terms of TWA, making an actual quartz analysis unnecessary. Recording measurements in terms of occupations instead of activities and then ranking the results, even without quartz analyses, would assist in focusing on occupations with unsatisfactory results and in identifying individuals with high exposures. Of course, peak concentrations and localities where high dust concentrations occurred could not be identified but the potential would exist to instigate an in-depth investigation. Workplace dust records would be of assistance in this connection.

Although a clearer picture of risk would emerge by using quartz concentrations in the calculation, especially a standard value, mine risk should not be evaluated in terms of personal concentrations but rather in terms of workplace risk. Evaluation of workplace conditions will assist in focussing attention where it is required to improve conditions, whereas this cannot be done directly from personal samples. Furthermore, improvements in workplace conditions would be able to be seen in any calculation of risk based on such measurements whereas, with the averaging process of the GME's present dust sampling programme, improvements in TWA dust concentrations for a number of employees would not significantly improve any mine risk.

At Mine 1 the use of a standard quartz concentration instead of actual quartz concentrations would certainly adversely affect the risk, as calculated, but would render comparisons of risk between occupation groups more equitable since the uncontrollable variable of widely fluctuating quartz concentrations would be eliminated from all calculations. Rankings based on TWA and on risk where a standard quartz concentration is used are identical, as expected. In addition, there would be an element of cost saving involved if samples do not need to be analysed and it would be a simple matter for any mine to compile an ongoing data base of occupational dust exposures as results become available since there would be none of the delays incurred while waiting for analysis results. Such a data base would also be useful as part of the mine's occupational health programme since the results can be passed directly to the occupational medicine department for use in exposure estimations.

The ranked results of CSIR: Mining Technology's data for Mine 2 is shown in Figure 128 and for the mine in Figure 129. A comparison of average exposures for CSIR: Mining Technology and the mine is shown in Figure 130. In these results, drilling exhibits the highest exposures for both sets of data and, similarly, construction and supervision have returned the lowest results for both sets of data. Agreement between the two sets of results is close with the same type of instrument being used for data collection by CSIR: Mining Technology and the mine. Once again frequency distributions of actual and TWA exposures were plotted for CSIR: Mining Technology and mine data and these are shown in Figures 131 and 132 respectively. The majority of CSIR: Mining Technology's results were in the 0.2 to 0.6 mg/m^3 range with a sharp cut off at 1.4 mg/m^3. Most of the mine's samples were in the 0 to 0.6 mg/m^3 with the tail of the curve extending to 2.5 mg/m^3. This again represents a higher number of samples in the lower concentration ranges then was obtained by CSIR: Mining Technology.

A comparison of actual exposures and TWA exposures for Mine 2 (see Figures 131 and 132) shows no specific bias towards one or other method of evaluation over the full range. The TWA exposures for Mine 2 are seen to be considerably lower than those recorded for Mine 1. The calculation of the Person Weighted TWA of 0.46 mg/m^3 for the occupations studied confirms this (CSIR: Mining Technology results).

All the samples at Mine 2 yielded quartz concentrations of less than five percent and therefore the TLV of 3 mg/m³ was applied. The rankings based on TWA values and risk were identical, again making sample analysis unnecessary. The risks calculated for the different occupation groups were also considerably lower than those for Mine 1, even when compared to the risk based on actual quartz concentrations for Mine 1.

The analyses for Mine 3 are shown in Figures 133 and 134. Dust levels are similar to those measured in Mine 2 with a person weighted average concentration of 0.48 mg/m³ (CSIR: Mining Technology results) but the ranking order changed with "support" experiencing the highest exposure averages, drilling moving to second highest and transport to lowest. The frequency distribution shown in Figure 134 indicates than the majority of the exposures occurred in the 0,2 to 0,4 mg/m³ range and no bias towards actual exposures or TWA exposures (over the full range).

For reasons already set out the occupational exposure data from the mine could not be analysed.

Rankings based on risk calculations compiled from actual quartz concentrations differ from those based on TWA concentrations but are identical to TWA rankings when a standard value of 20 percent is used. There is no appreciable difference between the PWM risk based on actual quartz concentrations (PWM quartz average 15.8 percent) and that based on a quartz concentration of 20 percent since the quartz concentration used in the respective calculations are reasonably close, unlike the situation in Mine 1. Reference to the short duration test results also show that the average quartz concentration measured for the working places was 18 percent, and again that there was little difference in workplace risk when calculated from either the actual average or a standard value. The simple arithmetic average quartz concentration is 12 percent which is lower than that found for the short duration samples. The reason could be that, as for dust concentrations, pollutant concentrations are affected by the duration of the sample, with time having a strong influence on the averaging process.

The results of occupational dust sampling for Mine 4 are presented graphically in Figures 135 and 136. Only CSIR: Mining Technology's data were used for analyses because the mine's data were not in a form that could readily be used. The average dust concentration is higher than those for the previous two mines and is seen in the person weighted average of 0,56 mg/m³ (CSIR: Mining Technology results). In this analysis "drilling" again had the highest exposure, with "construction" the lowest. As seen in Figure 136 most of the exposures occurred in the ranges 0 to 0,4 mg/m³ with no bias either towards actual average exposures or TWA exposures (over the full range).

Once again the rankings based on TWA and on risk calculation from a 20 percent quartz standard are very similar and, since the average quartz concentration (PWM) was found to be 14,1 percent, the PWM risk at 20 percent quartz was also found to be higher at 5,39 than the PWM of 2.58 based on actual quartz concentrations.

There are clearly discernible differences in occupational exposures, whichever evaluation technique is used.

A comparison of quartz concentrations obtained from workplace samples (21 percent) again shows that concentrations based on longer sampling intervals (eight hour personal samples) were again lower (14.1 percent).

The usable data from the four mines were used to produce the comparison of occupations shown in Figure 137, where only CSIR: Mining Technology's results are ranked. Data from only two mines could be used for the comparison. CSIR: Mining Technology results show that "drilling" exposures were highest with "supervision" second and "construction" the lowest. Mine data indicate drilling highest with support second highest and supervision lowest.

Occupational exposure data accumulated by CSIR: Mining Technology for the four mines were pooled and a frequency distribution of exposure ranges was computed. Figure 138 shows the plot of the frequency distribution where a log normal distribution is seen and the majority of samples are found in the 0,2 - 0,4 mg/m³ range. No overall bias toward TWA or actual exposures can be found. A similar analysis was performed on the results for the two mines where data could be extracted and the frequency distribution is shown in Figure 139. A log normal distribution is also evident but, although most of the samples are found in the 0,2 - 0,4 mg/m³ range, a far higher percentage of the samples are found in the 0 - 0,6 mg/m³ ranges than is the case for

CSIR: Mining Technology results and with fewer exposures in ranges greater than this. This is in keeping with previous findings [1].

The results of the samples collected in the occupation categories studied, indicates that differences in average exposures are detectable, but that ranking orders may be mine specific whether they are based on TWA exposures or risk. CSIR: Mining Technology data were collected under controlled conditions; mine data were collected routinely but the compilation process rendered some of the data unusable for analysis. It was anticipated that full shift samples, or personal samples, could be grouped in occupation categories to determine an occupation risk that could be used to compare risk between occupations. Intra mine differences, although small in some cases, are nevertheless discernable but, as has been shown, inter mine differences can be substantial. On one mine, although based on considerably different sample numbers, there was very good agreement between CSIR: Mining Technology and the mine's results. The differences in average dust concentrations between CSIR: Mining Technology results and the second mine with usable data can be ascribed to differences in sampling characteristics of the sampling instruments used and has been described in another report [1].

The results are encouraging for future work in occupational dust exposure and makes possible an in-depth study of results submitted to the GME over the past few years, although a considerable effort may be required to be able to extract usable data. It would also be important to keep occupation categories to a meaningful number in order not to end up with a similar situation to the Western Australian mining industry [6]. In a total workforce of 30 000, 403 job codes were established. Inevitably, this will result in undersampling of some jobs and gross oversampling of others. This type of situation tends to mask job categories where exposure levels are such that attention should be focused on them. Grouping of job categories with increasing multi-skilling of the workforce is made very difficult. This is a situation which will have to be carefully addressed in the South African mining industry and which could cause difficulties when estimates of life long exposures are based on current measurements.

Some of the reasons to conduct dust sampling have already been discussed in the previous section. The reasons for the sampling will dictate the strategy and equipment. The full shift sampling conducted by Industry has only been used to calculate a mine risk.

for levy purposes and not for epidemiology studies, which is what such sampling is usually used for.

In general, TLVs were set on the basis of population estimates, whether of animal or human populations [7]. Thus it is most appropriate to consider exposures in terms of exposed populations rather than exposed individuals. The objective of studying exposures of occupational groups fits in well with this concept. Having considered the population, one can then look for individuals who, because of special circumstances, may be at greater risk.

The general approach to exposure assessment for epidemiological studies is significantly different from that generally used by occupational hygienists to assess the presence of a recognised hazard by the use of exposure limits. The principal source of this difference is that the epidemiological study is performed to detect a hazard and determine the nature of any dose-response relationship, whereas compliance testing is performed with the presumption that the dose-response relationship is known and built into the exposure limit. These differences have important implications for sampling strategy.

The objective of epidemiological studies is to determine if exposure to a toxic material affects human risk through adverse health effects, such as a loss of pulmonary function or the risk of lung cancer. Epidemiologists study health risks in groups of workers with different exposures. This project explored the feasibility of sampling different occupation groups to determine if epidemiological studies could be carried out. This has been shown to be possible and epidemiologists would then be able to compare the relative risk of effects among different occupation groups who may be similar in all respects except their exposure levels.

For some epidemiological studies [7], the population of TWA exposure levels that are of interest for each worker is all work shifts within a working lifetime. For such an exposure population, random sampling is only a theoretical concept, but it may be possible to sample randomly from a "pseudo-population" that is assumed to be representative of the entire population. For example, if a certain three month period could be assumed to be fully representative of the exposure distribution for the entire working lifetime, a random sample of 10 shifts from a possible 65 (say) during that quarter would be interpreted as a random sample of the working lifetime. However, a more realistic interpretation of such a sample is that it represents the hypothetical exposure which would be expected during a working lifetime if the worker continued to do the same work, under the same conditions that existed during the quarter actually sampled. Relevant conditions include such determining factors as production levels, environmental conditions and the level of expertise of the employee insofar as it affects his ability to avoid exposure to a contaminated environment.

Classically, epidemiological studies have made little use of quantative data on exposures to assign subjects to exposure groups [7]. Surrogates were used to indicate potential exposure to a given pollutant. The most common are: "current job title", "longest held job title", "duration of work in an exposed job or work area" and "total duration of work". Essentially, this makes use of a "record of service". In making such assignments, two major difficulties can be encountered, ie misclassification and confounding. Misclassification is putting employees in the wrong exposure category; multi skilling could impact heavily here. Confounding is observing an apparent positive relationship between an exposure and an effect, which is actually caused by an exposure to another un-measured agent, for example cigarette smoking.

Previous occupational dust exposure studies were conducted nearly 40 years ago and estimates of exposures using the surrogate technique are still based on these results even though sampling was done with konimeters and thermal precipitators and not all work or population groups were monitored.

Over the last decade great progress has been made with sampling equipment that can deliver meaningful full-shift exposure levels. Continuation with full-shift monitoring is essential if a living data base on exposures for different occupations is to be established as part of ongoing epidemiological studies.

Dust monitoring techniques have improved and the compilation of an exposure data base is a distinct possibility, but it must be recognised that the purpose of the data base is to enhance dose-response knowledge. Utilising air sampling data in historical cohort studies can be considered to be something of a jigsaw puzzle where, from limited samples, a picture of the cumulative exposure of groups of workers or individuals is pieced together. This is exacerbated when service records are incomplete and there are long breaks between periods of employment. Dust sampling should ideally run in parallel with biological monitoring. Emphasis needs to be placed on the detection of subtle physiological changes which can be considered predictors of the disease [7]. This is where biological monitoring can be useful. At present, early indications of incipient disease are controversial. Dust sampling programmes should be operated in collaboration with medical programmes that are developing biological monitoring systems. It is also a requirement of the Mine Health and Safety Act that medical surveillance is linked to environmental exposure with the objective of reducing the risk of disease. Full shift monitoring for occupational groups can play an important role in this objective.

5.6 Conclusions

The results of this investigation have shown that it is possible to conduct occupational dust sampling and detect discernable differences in average exposure levels and risk between different groups. Inter mine differences for a given occupation group are also detectable and exposure levels may thus be mine specific. Although a limited number of occupations were monitored, the results indicate that it would be possible to combine data on an industry basis to produce exposure profiles.

Difficulty was experienced in extracting relevant data from some mine records due largely to the computer software used in the gravimetric dust sampling programme. This matter would need serious consideration before any large scale analysis of existing data for occupational dust compilation could be embarked on. If these difficulties cannot be resolved, a substantial percentage of samples collected over the past few years will be rendered unusable. The introduction of multi skilling in mines will make the collection of samples for a specific occupation difficult and could impact heavily on attempts to compile occupation exposure profiles and also on attempts to estimate dose for such employees at some time in the future. Overseas experience has shown that to be effective great care must be exercised when the number of job categories is decided. With an unrealistically high number of job categories, some categories can be oversampled and others undersampled, which will lead inevitably to bias in the results.

Where frequency distributions for the different exposure ranges were made, the mine results indicate a preponderance of samples in the lowest exposure ranges. These results show even lower concentrations than were found for the Industry results presented previously [1]. Although only two mines are being considered, the mine's results were nevertheless lower than those obtained by CSIR: Mining Technology, but CSIR: Mining Technology's samples were probably collected under more controlled conditions than those of the mines'.

Risks for each occupation, based on actual quartz analyses and on an "industry average" of 20 percent, show variations from mine to mine for given occupations and also that where quartz concentrations were low, using an industry average would obviously result in much higher risk values. Previously, the quartz content was needed to calculate a mine risk (not an occupational or personal risk) but actual analyses may not be required for full shift samples for future epidemiological studies. It may be acceptable to use an industry average but consultation with epidemiologists would be needed to resolve this issue in a practical way.

Particulate and dust concentrations are known to vary widely in three dimensions of space and in time. When and where to collect a sample depends upon the objective of the sampling. Questions that may be asked of a dust sample could be:

a) will the sample give information which will enable the prediction of exposures in the future, assuming no major changes in the operation?
b) will the sample give information which will assist in controlling the operation? and,
c) if the only purpose of the sample is to estimate the exposure of the worker on the day and at the time sampled, will this information be of value in the protection of his health?

The 1959 Johannesburg Pneumoconiosis Conference drew clear distinctions between sampling for control purposes and sampling for epidemiological needs and declared a need to conduct occupational dust sampling. The introduction of personal gravimetric sampling had the potential for the commencement of the compilation of a data base of occupational exposures but unfortunately this was not the case. However, by restructuring the sampling strategy, occupational dust sampling can be introduced for the long overdue embarkation of meaningful epidemiological studies in the major mining industry of the world.

Two separate studies have shown that different sampling systems and equipment ie. conventional pump and filter and rotating sponge type, do give differences in results. For usable industry results, this issue would need to be resolved since failure to do so would result in a seriously flawed data base from which no conclusions could ever be drawn.

Whereas the sampling pumps can be made to operate at a constant flow rate, irrespective of the load of the filter, this does not accurately mirror the inhalation rate of the worker throughout the shift as this can vary considerably depending on exertion. Serious discrepancies in representative dust inhalation loads would occur when the worker is inhaling deeply and rapidly in a transient high concentration of dust. The technology exists to be able to link the pump's performance to the pulse rate of the wearer of the pump, and in pursuance of greater accuracy and reality the development of this approach should be given serious consideration.

An acknowledged limitation of an eight-hour TWA is that it does not take into account situations where there is exposure to a high concentration of contaminants for only a short period of time. Significant short duration peak concentrations will be averaged out and the health hazard underestimated. In the previous section it was proposed that short duration samples be used for sampling in workplaces, ie control sampling, and that the full shift samples be used for personal sampling which can be used for occupational dust records. This separation of objectives could address the shortcomings of full shift samples since workplace risk could be described in terms of short duration samples.

There are still many unanswered questions with regard to exposure to dust and certainly a closer liaison between occupational hygiene and occupational medicine practioners is called for. The biological effects of exposure to dust, and in particular to quartz, through better monitoring techniques and strategies, including the evaluation of short term peak exposures, could be more realistically linked to more representative exposure levels. However, a great deal of research still needs to be done before a better understanding of the exposure-dose-response process can be gained. Some questions that still need addressing are [7]

a) what are the mechanistic linkages between exposure and health risk, and might they be influenced by exposure variability?,

b) how might exposure variability dictate the evaluation of exposures to toxic pollution?,

c) what is the likely impact of short term (i.e. < 15 minutes) peak concentrations on the health risk?, and

d) what is the likely impact of day-to-day variables in exposure on the health risk?

Both exposure and toxic content variability have been unquestionably demonstrated in a previous project [1] and been confirmed in the literature. With better monitoring and evaluation techniques, as well as a closer collaboration between occupational hygiene and occupational medicine, the answers to these and many more questions should emerge with time.

At present, estimations of worker exposure still rely heavily on studies done nearly 40 years ago with instruments that are now known to be incorrect for this type of study. The infrastructure and instrumentation is now in place in Industry to at last be able to participate in meaningful occupational dust sampling. The results of this sampling could in turn be used to predict life-time working exposures that could be used to implement an intervention policy to prevent any worker from reaching a certifiable level of disease. Of course, dust sampling should never be a substitute for control measures which is why control sampling and occupational sampling should be ongoing with the data bases continually being updated.

The statistical power of the data base will increase with an increase in the number of samples, but ultimately the purpose of all the dust sampling conducted is to assist in making the workplace as dust free as possible to minimise the health risk due to exposure.

6. OVERALL CONCLUSIONS AND RECOMMENDATIONS

Prior to the introduction of the gravimetric dust sampling, all dust sampling conducted by mines had been for the purpose of identifying localities and operations where unsatisfactory dust levels occurred. This information was then used to implement control measures to reduce dust levels. The philosophy adopted was that if workplace exposure levels are controlled then personal exposure levels would also be controlled.

Few definitive studies were carried out on occupational dust exposure levels, mainly due to the lack of suitable instrumentation that would give full shift exposures in terms of the dust mass concentrations. The development of reliable gravimetric dust sampling equipment presented the means to collect vast numbers of full shift samples for occupational dust surveys and epidemiological studies. However, in the context of South African mining, the full shift samples were classified in terms of "activities" and used to calculate a "risk" on which a compensation levy was based. In the process of converting to gravimetric dust sampling, control dust sampling was abolished.

Shortcomings of the present gravimetric dust sampling programme were highlighted in a previous research project [1] where attention was drawn to the need for control dust sampling as well as for occupational dust sampling. Initial trials with a technique known as short duration sampling was proposed for determining workplace dust levels and a proposal was made to conduct limited occupational dust sampling under controlled conditions.

Before control or occupational dust sampling commenced some technical aspects were investigated. These were the effects of pump orientation, filter size and porosity, sample flow rates, shielding and the choice of respirable or total dust samples.

None of the above factors was found to have any significant or practical bearing on the results of short duration gravimetric dust sampling.

The results presented in this report show that short duration dust sampling is feasible and that localities and operations where high dust levels emanate can be identified. Short duration dust sampling can be used to determine where control measures need to be implemented and what the effectiveness of such measures is.

Workplace risk can also be calculated from average working face dust levels on the basis of either a measured average quartz concentration or on a standard quartz concentration. By sampling all workplaces on a regular basis a "mine risk" can be determined. The technique allows results to be recorded on environmental survey reports and also provides inspectors with a realistic and practical methodology to conduct checks. Furthermore, independent dust surveys can be carried out in a meaningful way.

Limited full shift samples were collected for two chosen occupations - supervision and timbering (support). Because of the introduction of multi skilling additional occupations were sampled. Comparisons were made between CSIR: Mining Technology's results and mine results. It was found that differences in exposure levels for different occupations are discernible and that, generally, the mine's results are lower than those of CSIR: Mining Technology. If the results of gravimetric dust sampling from 1992 to date could be assessed it is anticipated that a very substantial data base on occupational dust exposure levels could be compiled. The results of this investigation could be made available to mine occupational medical practioners for dose-response references. With the size of the Industry in existence in South Africa, should the proposed data analyses study be carried out, the world's largest mining occupational dust exposure data base could be created.

The principal recommendations are:

1. Short duration dust sampling should be introduced to identify localities or operations where unsatisfactory dust levels are emanating.

2. Short duration dust sampling should be used to test the effectiveness of dust control measures.

3. Short duration samples should be used to determine workplace "risk" and, additionally, "mine risk".

4. Full shift gravimetric dust sampling should be continued, but structured to embrace the principal of occupational dust sampling - the results of which should be used to update the Industry data base on an ongoing basis.

5. Full shift gravimetric dust sampling should not be used to calculate risk for levy purposes.

6. The data submitted to the DM&E should be analysed in terms of occupational exposures.

7. There is evidence to suggest, as found in both this project and a previous project, that certain dust samplers do not give acceptable results. These samplers should be re-evaluated in terms of collection efficiencies because Industry statistics could be considerably adversely affected by the apparently erroneous results from such samplers.

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8. ACKNOWLEDGEMENTS

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APPENDIX A

SHORT DURATION SAMPLING AND TYNDALLOMETER SURVEYS FOR STOPES AND DEVELOPMENT ENDS AT FOUR UNDERGROUND MINES.

FIGURES 140 TO 209

LOCALITY		STOPE 1		
Position	Ref.	Dust Concentration mg/m^3		Konimeter Count p/ml
Return	1	2,07	2,20	158 - 90 - 82 106 - 90 - 106
Face	2	2,72	2,13	86 - 134 - 122 124 - 58 - 128
Face	3	3,49	3,21	114 - 96 - 112 252 - 154 - 142
Face	4	2,15	4,88	112 - 132 - 126 148 - 104 - 120
Face	5	2,79	2,47	88 - 114 - 100 108 - 124 - 102
Face				
Face				
Ave. face		2,79	3,17	130 - 110 - 114
Old area	6	2,19	2,64	108 - 400+ - 76
Old area				102 - 82 - 98
Old area				
Ave. old area		2,19	2,64	105 - 250 - 87
Intake	7	2,60	3,64	106 - 132 - 148 124 - 114 - 180
Intake	8	2,79	2,87	148 - 190 - 186 298 - 200 - 172
Traverse			3,97	
Integrated		0,97	0,64	
Full shift				

SKETCH

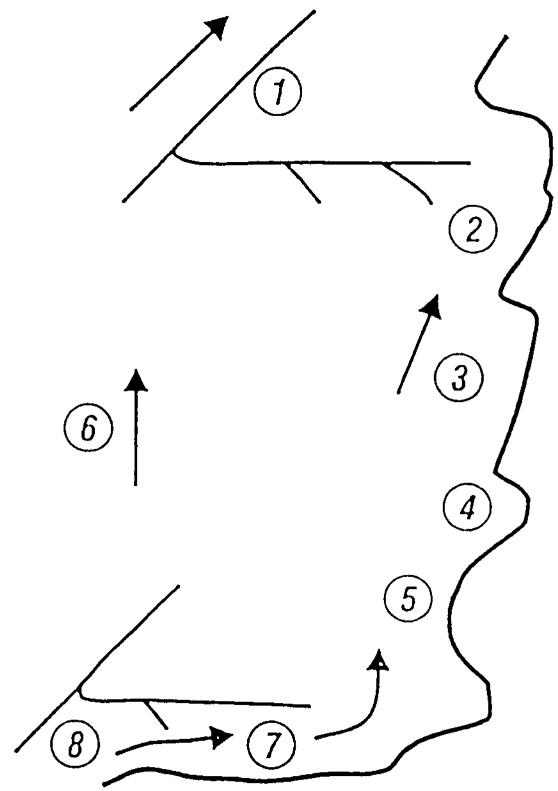

FIGURE 140. SHORT DURATION DUST SAMPLING

MINE 1 - STOPE 1

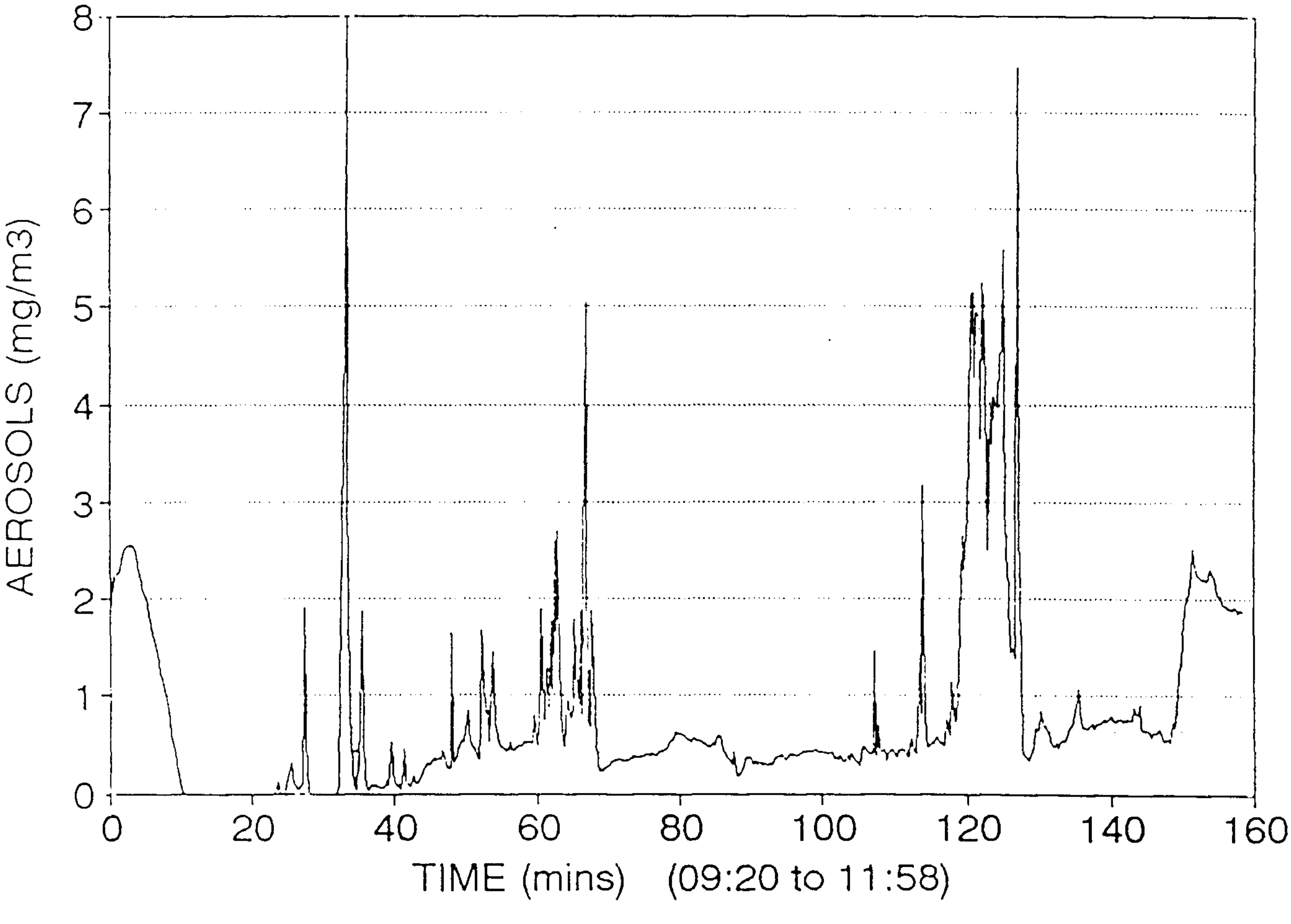

FIGURE 141. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 1 - STOPE 1

LOCALITY		STOPE 3	
Position	Ref.	Dust Concentration mg/m^3	Konimeter Count p/ml
Return	1	1,47	56 - 70 - 62 124 - 118 - 120
Face	2	1,80	140 - 148 - 132 76 - 92 - 84
Face	3	2,00	156 - 150 - 138 126 - 104 - 100
Face	4	1,33	130 - 148 - 154 124 - 110 - 136
Face	5	9,52	118 - 132 - 112 120 - 122 - 104
Face	6	2,20	100 - 96 - 112 138 - 130 - 142
Face	7	2,00	88 - 76 - 92 136 - 116 - 118
Ave. face		3,14	120 - 118 - 118
Old area Old area Old area Ave. old area			
Intake	8	2,67	178 - 162 - 160 90 - 68 - 74
Intake			
Traverse Integrated Full shift		1,03 1,26	

SKETCH

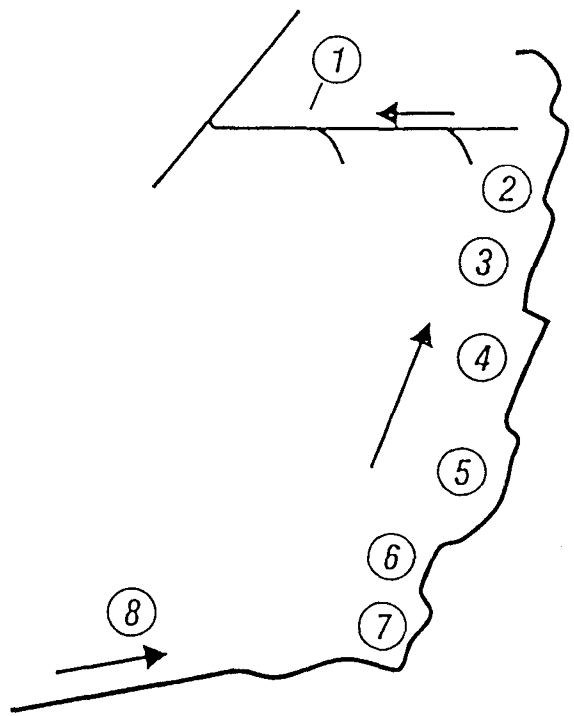

FIGURE 142. SHORT DURATION DUST SAMPLING

MINE 1 - STOPE 3

LOCALITY		STOPE 4	
Position	Ref.	Dust Concentration mg/m^3	Konimeter Count p/ml
Return	1	1,53	140 - 112 - 60 46 - 44 - 68
Face	2	1,53	400+ - 400+ - 400+ 253 - 234 - 246
Face	3	1,00	400+ - 400+ - 378 152 - 136 - 130
Face	4	0,40	116 - 108 - 72 48 - 42 - 30
Face			
Face			
Face			
Ave. face		0,98	228 - 220 - 196
Old area	5	3,07	184 - 198 - 212
Old area	6	3,06	166 - 154 - 146
Old area			
Ave. old area		3,07	176 - 176 - 180
Intake	7	2,60	112 - 94 - 52
Intake			
Traverse		1,86	
Integrated		1,26	
Full shift			

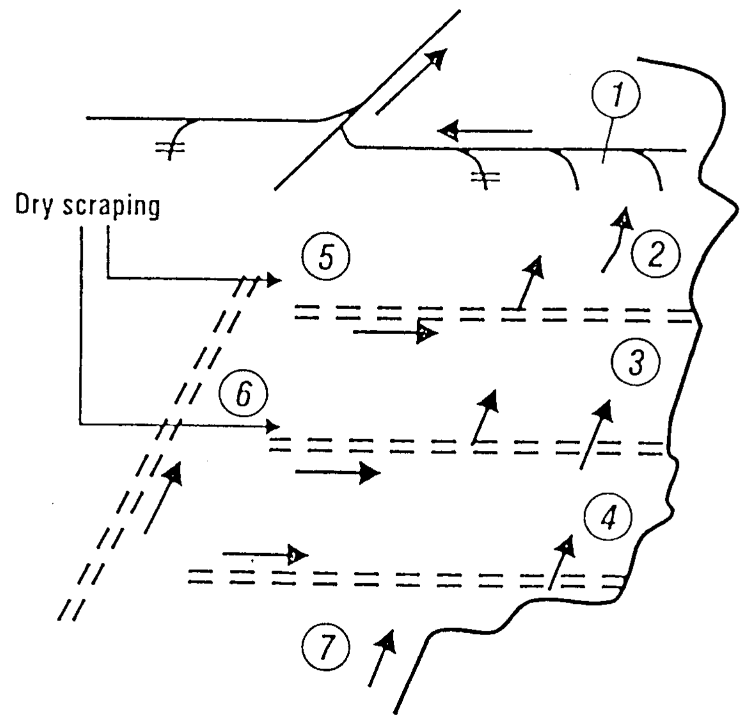

FIGURE 143. SHORT DURATION DUST SAMPLING

MINE 1 - STOPE 4

LOCALITY		STOPE 5	
Position	Ref.	Dust Concentration mg/m^3	Konimeter Count p/ml
Return	1	140	46 - 30 - 18 70 - 68 - 62
Face	2	1,00	70 - 64 - 50 116 - 112 - 100
Face	3	1,53	60 - 44 - 28 128 - 94 - 86
Face			
Face			
Face			
Face			
Ave. face		1,27	94 - 78 - 66
Old area			
Old area			
Old area			
Ave. old area			
Intake	4	1,33	130 - 32 - 16
Intake			
Traverse		0,89	
Integrated		1,63	
Full shift			

SKETCH

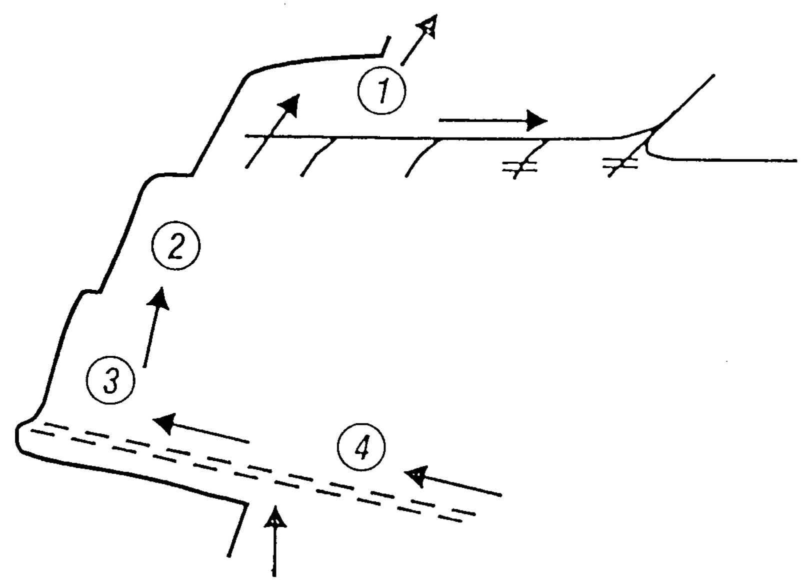

FIGURE 144. SHORT DURATION DUST SAMPLING

MINE 1 - S\ ?E 5

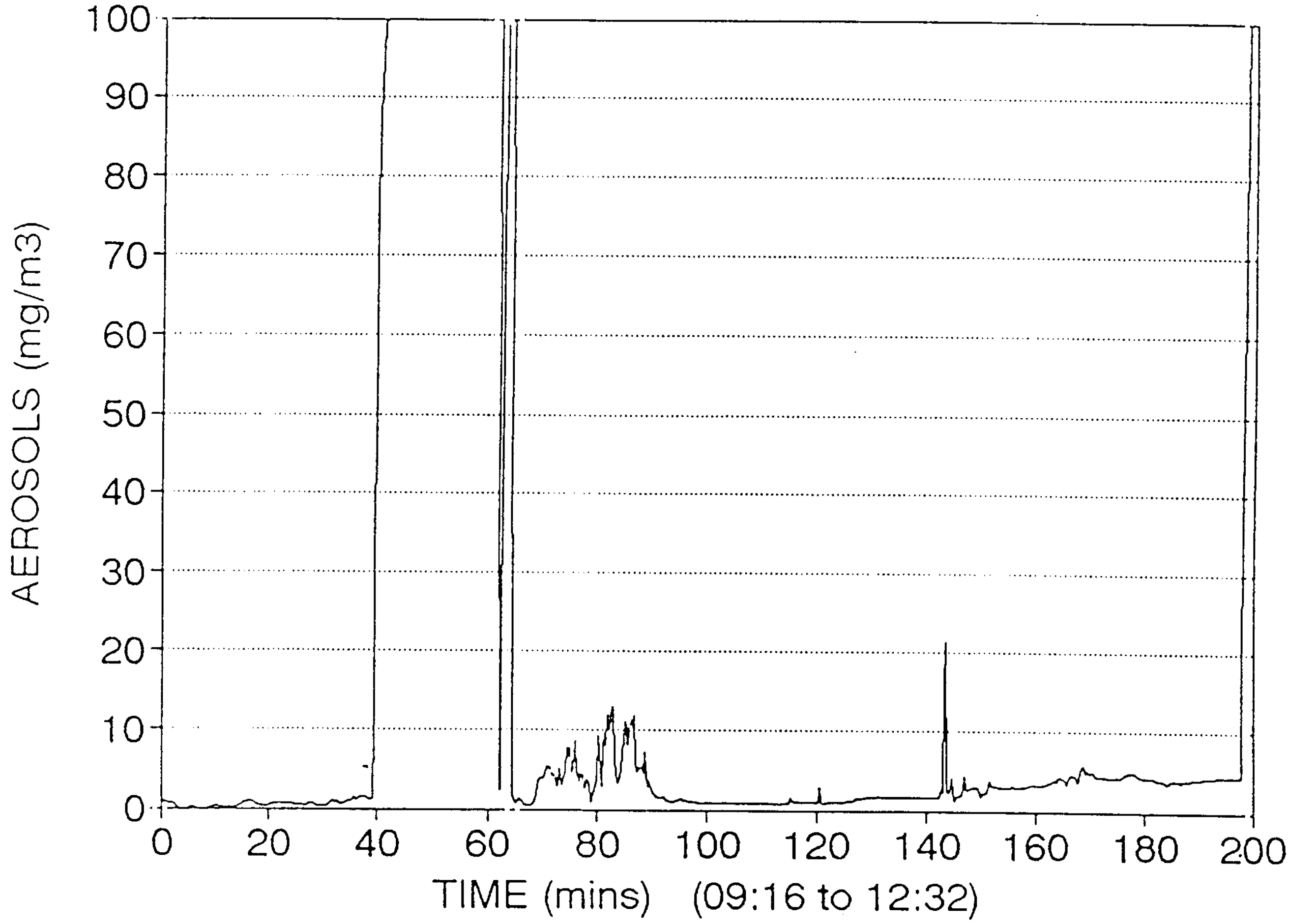

FIGURE 145. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 1 - STOPE 5

LOCALITY		STOPE 6	
Position	Rcf.	Dust Concentration mg/m^3	Konimeter Count p/ml
Return	1	0,85	114 - 66 - 54 66 - 88 - 92
Face	2	1,47	86 - 20 - 30 180 - 72 - 112
Face	3	1,33	302 - 400+ - 400+ 146 - 158 - 130
Face	4	0,67	90 - 132 - 74 106 - 44 - 112
Face			
Face			
Face			
Ave. face		1,16	152 - 138 - 144
Old area	5	0,56	86 - 116 - 92
Old area			152 - 96 - 184
Old area			
Ave. old area		0,56	120 - 106 - 138
Intake	6	2,36	146 - 86 - 100 72 - 66 - 66
Intake			
Traverse		0,98	
Integrated		1,45	
Full shift		0,76	

SKETCH

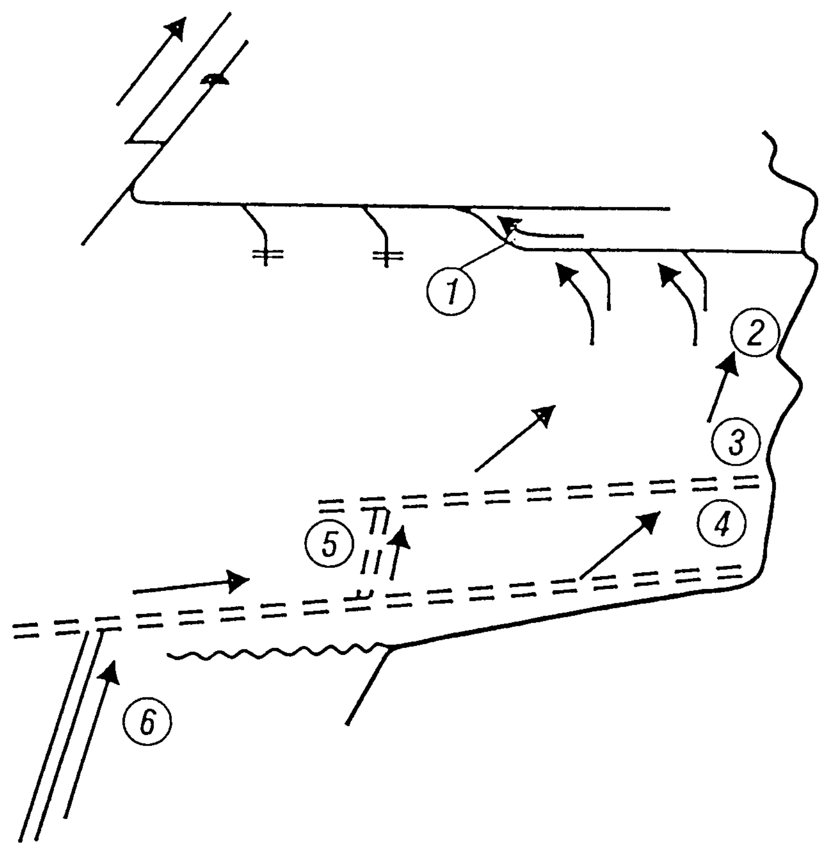

FIGURE 146. SHORT DURATION DUST SAMPLING

MINE 1 - ST E 6

LOCALITY		STOPE 7	
Position	Ref.	Dust Concentration mg/m^3	Konimeter Count p/ml
Return	1	1,13	86 - 90 - 82 100 - 104 - 94
Face	2	2,47	138 - 114 - 86 148 - 92 - 92
Face	3	1,67	148 - 112 - 100 126 - 134 - 128
Face	4	2,13	174 - 142 - 164 160 - 172 - 176
Face	5	1,47	142 - 114 - 104 180 - 156 - 124
Face			
Face			
Ave. face		1,94	140 - 124 - 114
Old area			
Old area			
Old area			
Ave. old area			
Intake	6	1,27	148 - 128 - 118 136 - 114 - 120
Intake			72 - 68 - 84 68 - 100 - 96
Traverse		1,09	
Integrated		1,47	
Full shift		0,86	

SKETCH

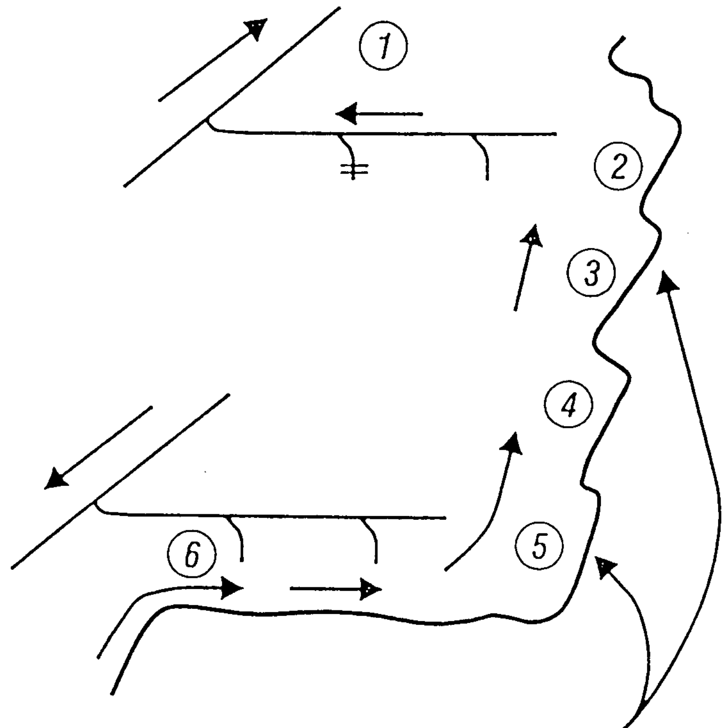

FIGURE 147. SHORT DURATION DUST SAMPLING

MINE 1 - STOPE 7

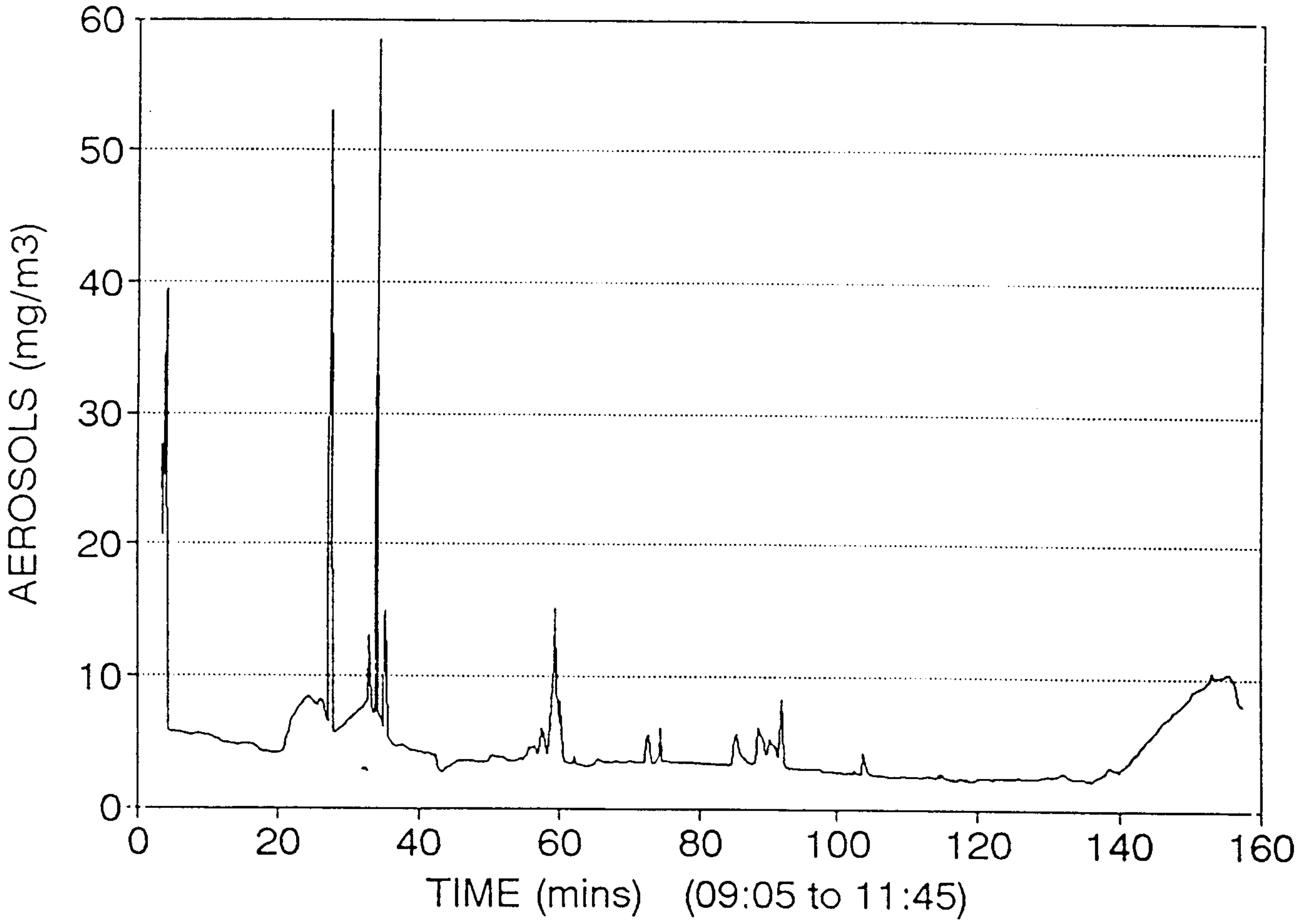

FIGURE 148. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 1 - STOPE 7

LOCALITY		STOPE 9	
Position	Ref.	Dust Concentration mg/m^3	Konimeter Count p/ml
Return		-	
Face	1	2,60	
Face	2	2,87	
Face	3	2,53	
Face			
Face			
Face			
Ave. face		2,67	
Old area			
Old area			
Old area			
Ave. old area			
Intake	4	2,33	
Intake			
Traverse		1,26	
Integrated		1,87	
Full shift			

SKETCH

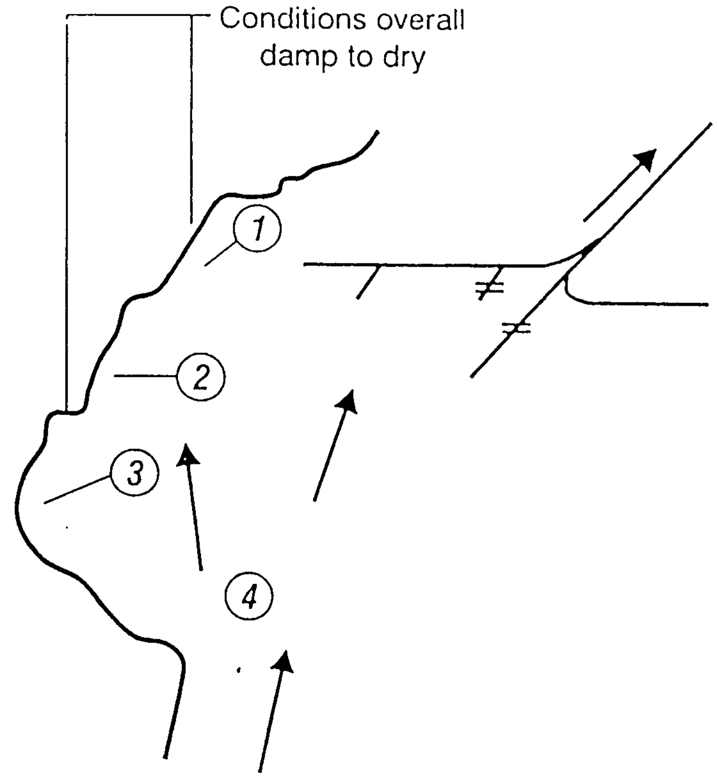

FIGURE 149. SHORT DURATION DUST SAMPLING

MINE 1 - STOPE 9

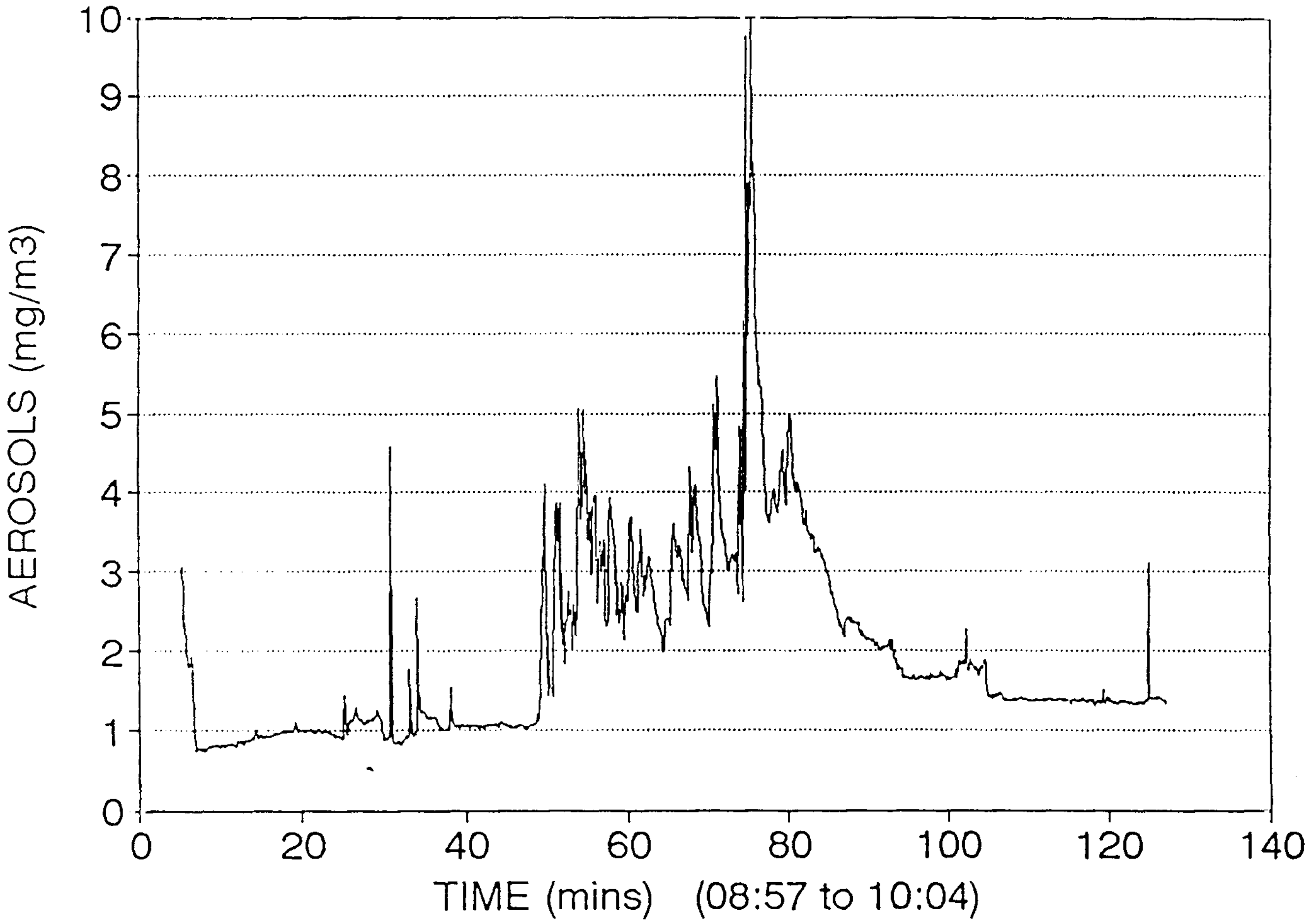

FIGURE 150. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 1 - STOPE 9

LOCALITY		STOPE 1			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge
		13 mm	25 mm		
Return	R	0,259	2,397		
Face	1	0,615	1,702		
Face	2	0,714	1,609		
Face	3	0,456	1,678		
Face					
Ave. face		0,595	1,663		mg/m³
Old area Old area Ave. old area					
Intake Intake	4	0,462	1,561		
Traverse Integrated Full shift			0,516 0,400		

SKETCH

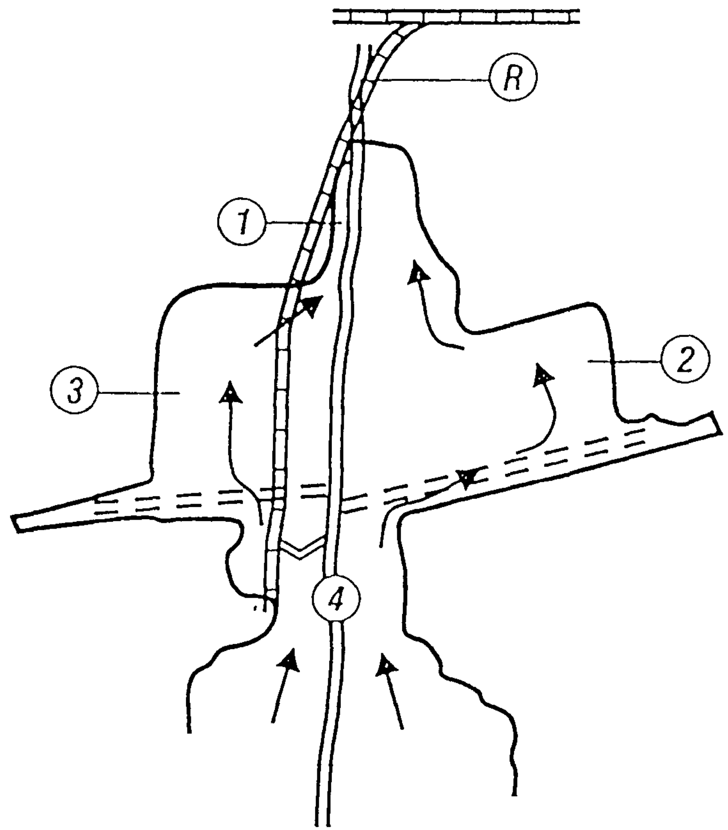

FIGURE 151. SHORT DURATION DUST SAMPLING

MINE 2 - STOPE 1

LOCALITY		STOPE 4			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge
		13 mm	25 mm		
Return	R	2,301	3,160		
Face	1	0,769	1,053		
Face	2	1,203	4,213		
Face	3	0,769	4,161		
Face					
Ave. face		0,914	3,142		mg/m³
Old area Old area Ave. old area					
Intake Intake	4	0,583	1,416		
Traverse Integrated Full shift			0,300		

SKETCH

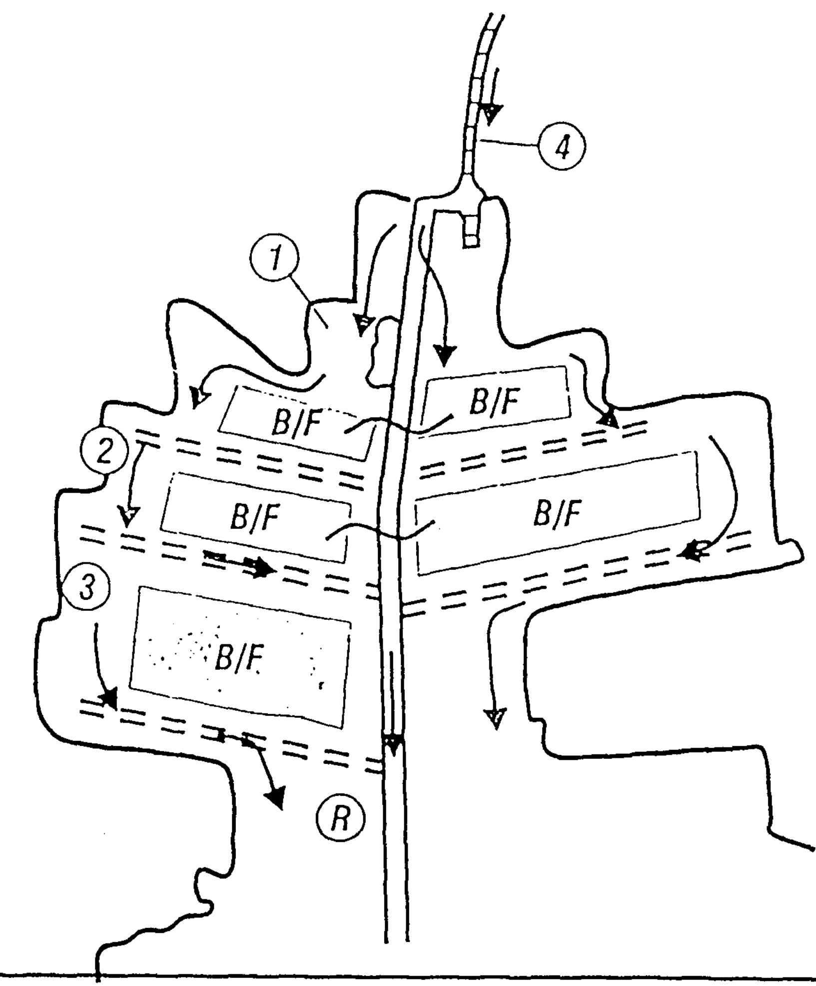

FIGURE 152. SHORT DURATION DUST SAMPLING

MINE 2 - 'OPE 4

LOCALITY		STOPE 5			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge mg/m³
		13 mm	25 mm		
Return	R	0,554	1,650		
Face	1	0,726	2,809		
Face	2	0,361	1,106		
Face					
Face					
Ave. face		0,544	1,958		
Old area	3	0,403	5,756		
Old area					
Ave. old area		0,403	5,756		
Intake	4	0,252	1,461		
Intake					
Traverse			0,537		
Integrated					
Full shift			0,230		

SKETCH

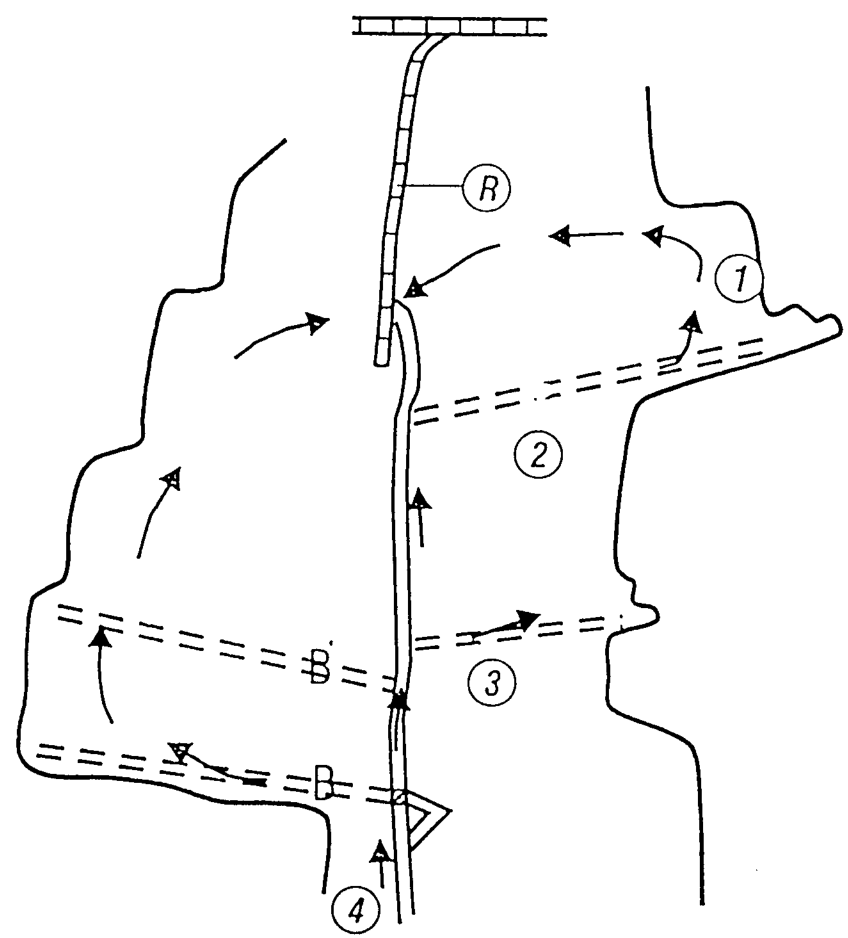

FIGURE 153. SHORT DURATION DUST SAMPLING

MINE 2 - STOPE 5

LOCALITY		STOPE 6			
Position	Ref.	Dust Concentration mg/m^3		Quartz (%)	Rotating Sponge mg/m^3
		13 mm	25 mm		
Return	R	0,169	1,423		
Face	1	0,859	2,104		
Face	2	1,399	3,216		
Face	3	0,865	-		
Face					
Ave. face		1,041	2,663		
Old area					
Old area					
Ave. old area					
Intake	4	0,185	1,500		
Intake					
Traverse			-		
Integrated					
Full shift			0,240		

SKETCH

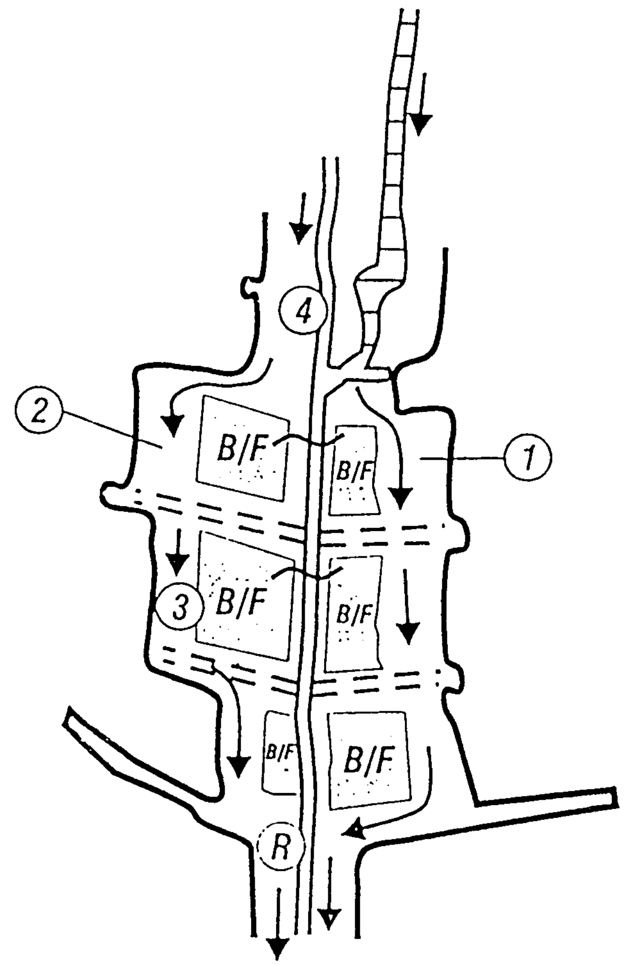

FIGURE 154. SHORT DURATION DUST SAMPLING

MINE 2 - ( )PE 6

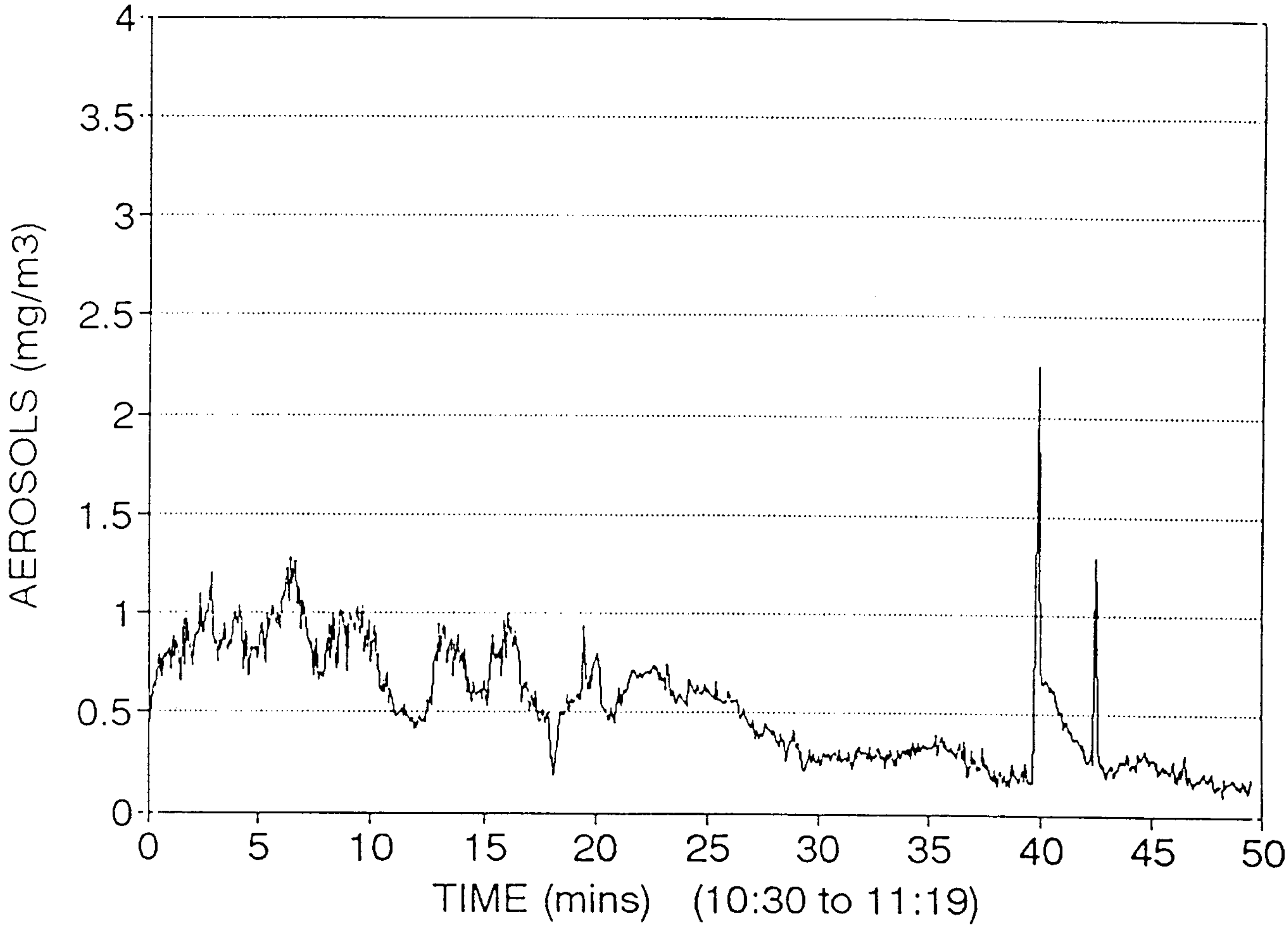

FIGURE 155. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 2 - STOPE 6

LOCALITY		STOPE 7			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge mg/m³
		13 mm	25 mm		
Return	R	0,203	1,577		
Face	1	0,681	20,154		
Face	2	0,439	3,592		
Face					
Face					
Ave. face		0,560	11,873		
Old area	3	0,368	2,147		
Old area					
Ave. old area					
Intake	4	0,478	1,139		
Intake					
Traverse			0,340		
Integrated					
Full shift			0,540		

SKETCH

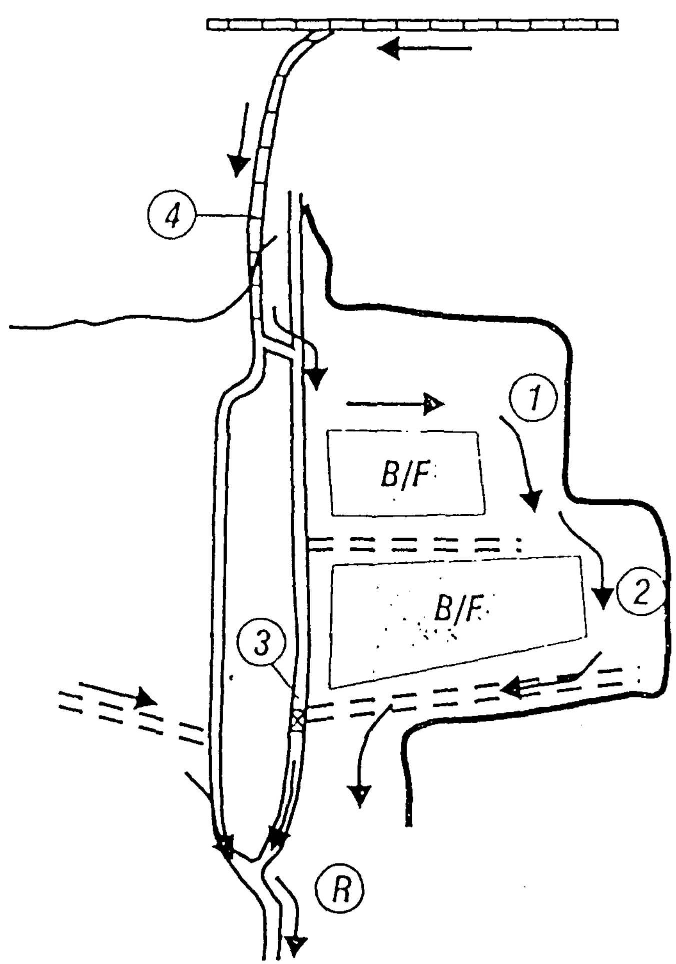

FIGURE 156. SHORT DURATION DUST SAMPLING

MINE 2 - STOPE 7

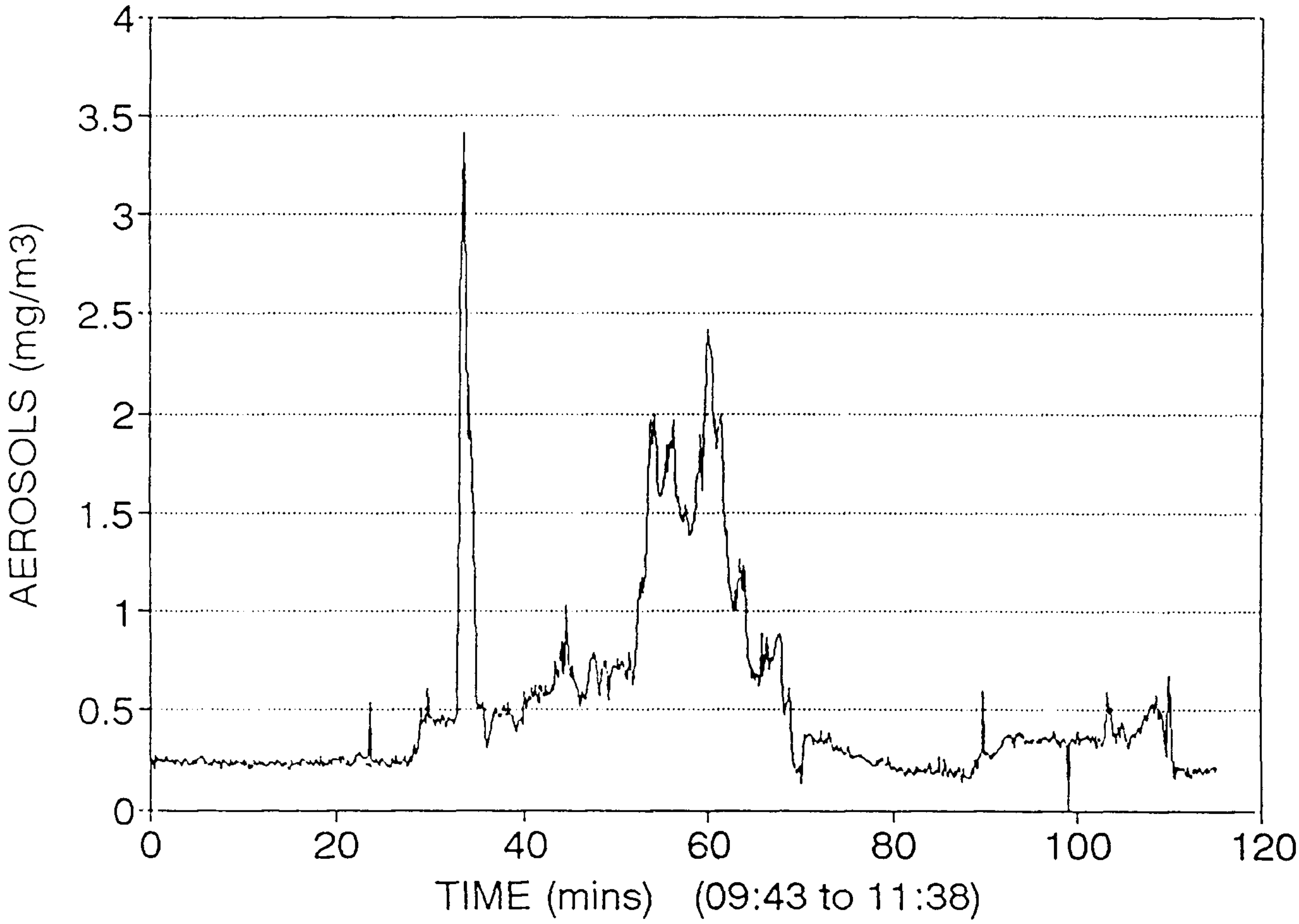

FIGURE 157. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 2 - STOPE 7

LOCALITY		STOPE 8			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge
		13 mm	25 mm		mg/m³
Return	R	0,205	0,829		
Face	1	1,628	4,145		
Face	2	3,467	2,664		
Face	3	0,784	2,192		
Face					
Ave. face		1,960	3,000		
Old area					
Old area					
Ave. old area					
Intake	4	0,260	0,917		
Intake					
Traverse			0,979		
Integrated			-		
Full shift					

SKETCH

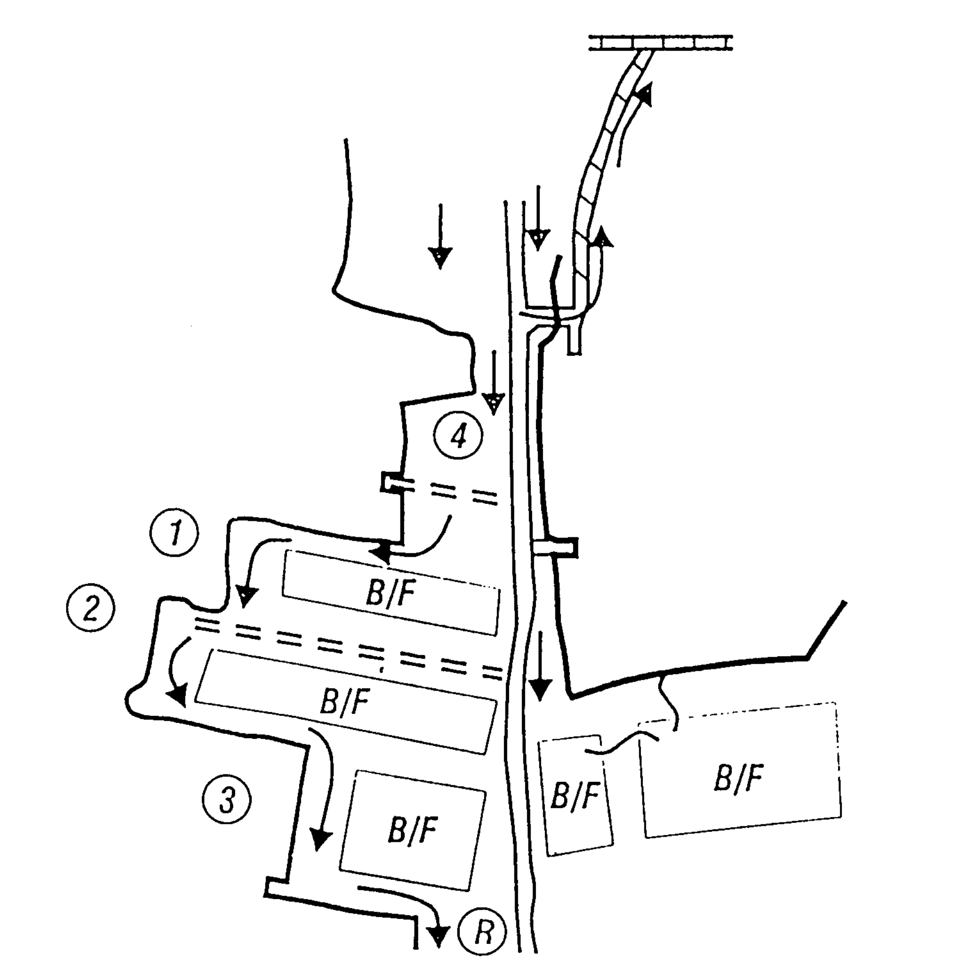

FIGURE 158. SHORT DURATION DUST SAMPLING

MINE 2 - STOPE 8

LOCALITY		STOPE 9			
Position	Ref.	Dust Concentration mg/m^3		Quartz (%)	Rotating Sponge mg/m^3
		13 mm	25 mm		
Return	R	0,782	3,078		
Face	1	0,255	4,245		
Face	2	1,256	2,547		
Face	3	0,587	3,874		
Face					
Ave. face		0,699	3,555		
Old area Old area Ave. old area					
Intake Intake	4	0,681	2,600		
Traverse Integrated Full shift			- 0,430		

SKETCH

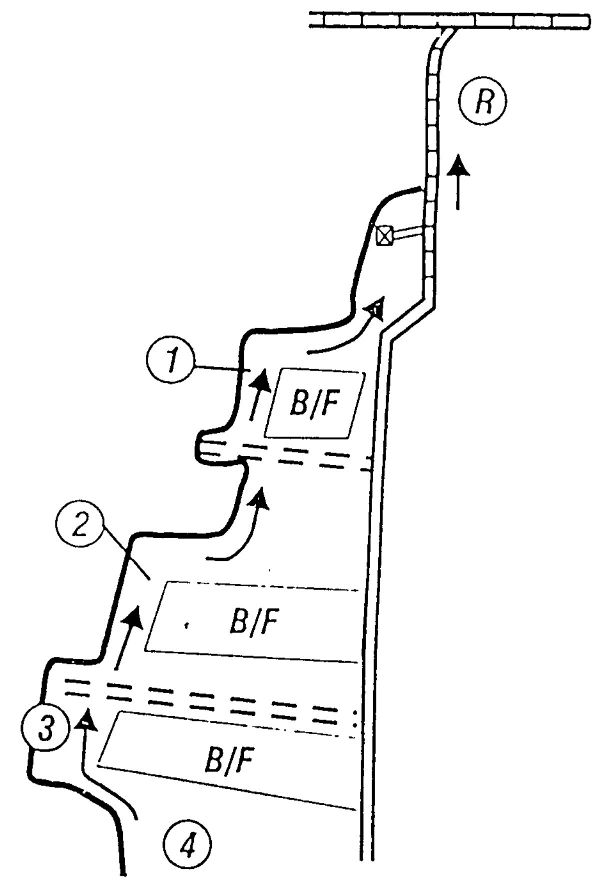

FIGURE 159. SHORT DURATION DUST SAMPLING

MINE 2 - STOPE 9

LOCALITY		STOPE 10			
Position	Ref.	Dust Concentration mg/m^3		Quartz (%)	Rotating Sponge
		13 mm	25 mm		
Return	R	0,346	1,819		
Face	1	0,134	2,127		
Face	2	0,756	3,290		
Face	3	0,469	1,489		
Face					
Ave. face		0,453	2,302		mg/m^3
Old area Old area Ave. old area					
Intake Intake	4	0,296	6,073		
Traverse Integrated Full shift			0,762 0,870		

SKETCH

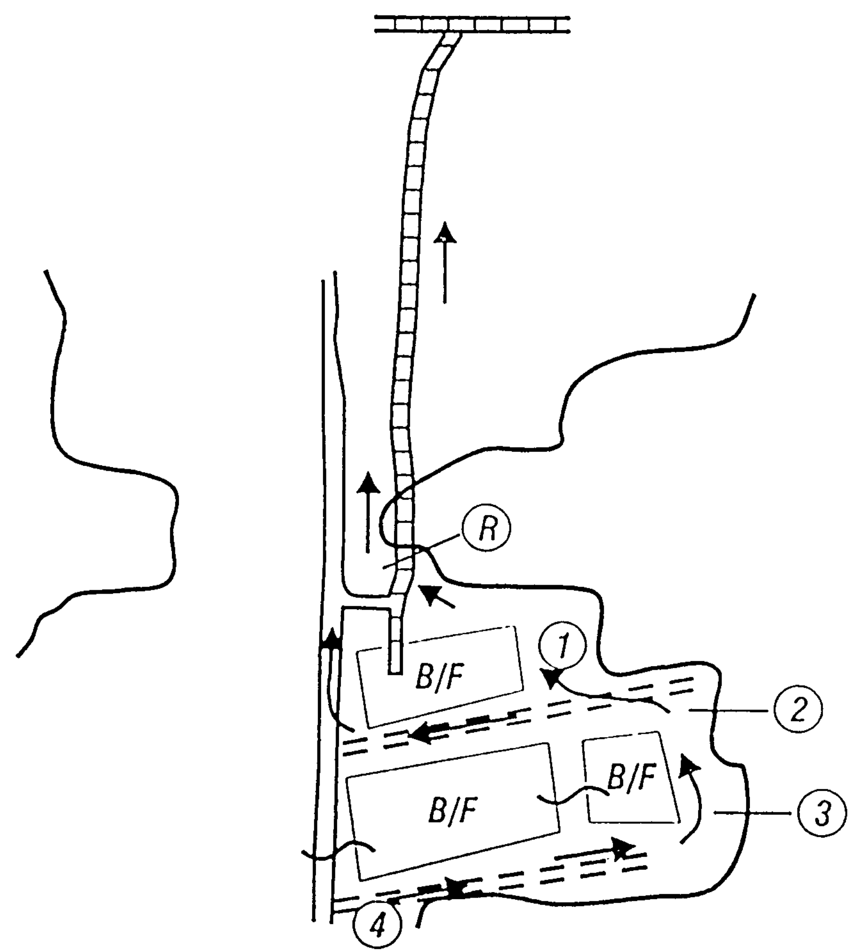

FIGURE 160. SHORT DURATION DUST SAMPLING

MINE 2 - .OPE 10

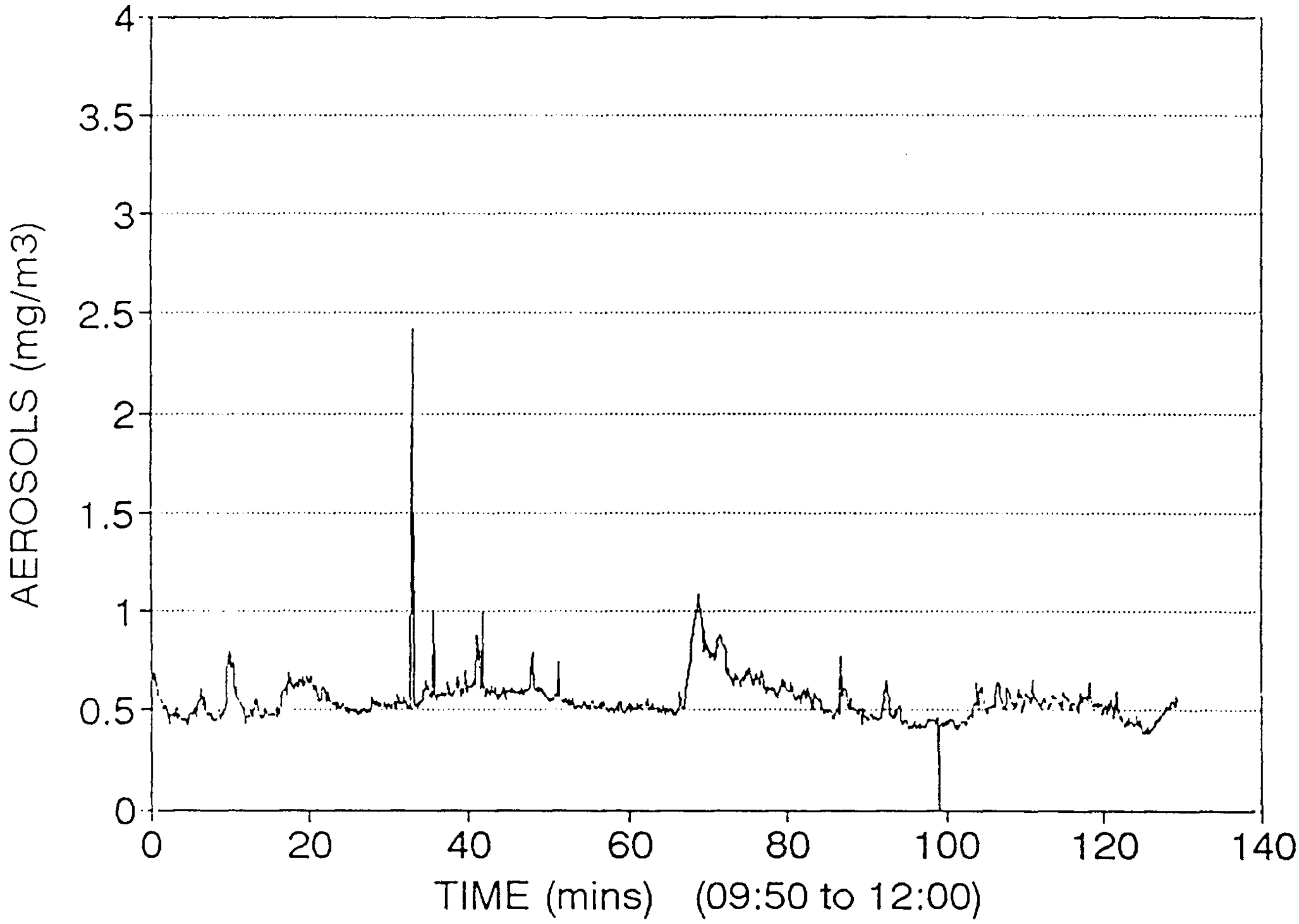

FIGURE 161. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 2 - STOPE 10

LOCALITY		STOPE 11			
Position	Ref.	Dust Concentration mg/m^3		Quartz (%)	Rotating Sponge mg/m^3
		13 mm	25 mm		
Return	R		1,789		
Face	1		20,363		
Face	2		2,984		
Face	3		1,491		
Face					
Ave. face			8,279		
Old area Old area Ave. old area					
Intake Intake	4	0,169	1,228		
Traverse Integrated Full shift			0,262 0,240		

SKETCH

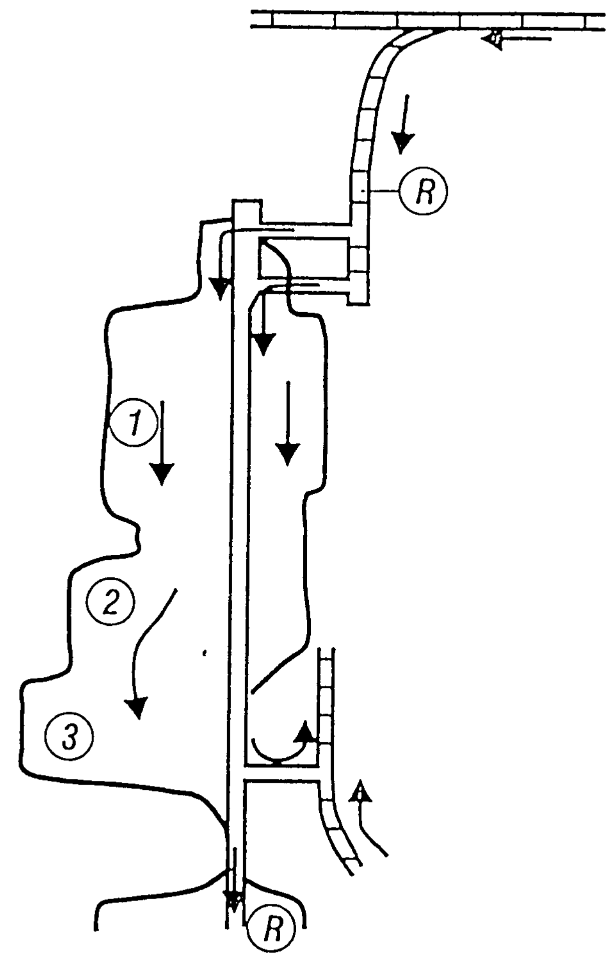

FIGURE 162. SHORT DURATION DUST SAMPLING

MINE 2 - ·OPE 11

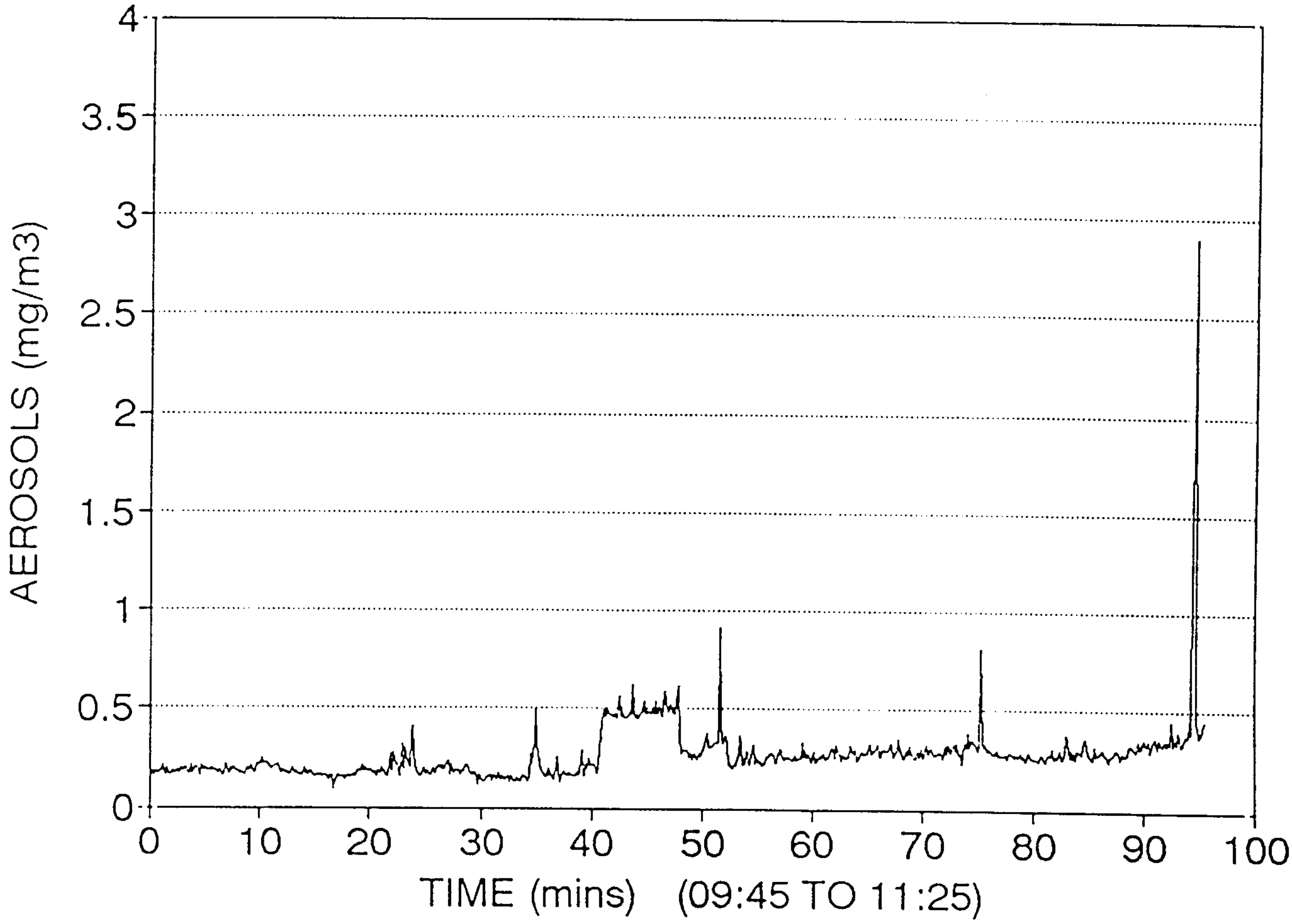

FIGURE 163. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 2 - STOPE 11

LOCALITY		STOPE 12			
Position	Ref.	Dust Concentration mg/m^3		Quartz (%)	Rotating Sponge
		13 mm	25 mm		
Return	R	0,329	3,187		
Face	1	0,133	3,721		
Face	2	0,387	4,098		
Face	3	0,228	3,502		
Face					
Ave. face		0,249	3,774		mg/m^3
Old area Old area Ave. old area					
Intake Intake	4	0,721	0,735		
Traverse Integrated Full shift			- 0,041		

SKETCH

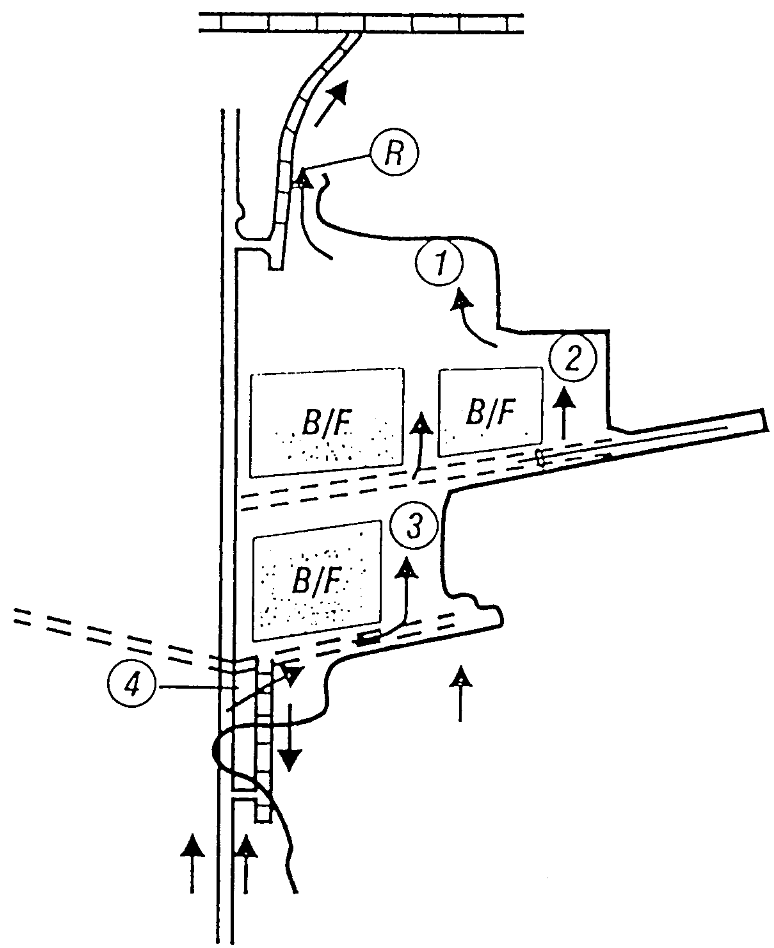

FIGURE 164. SHORT DURATION DUST SAMPLING

MINE 2 - STOPE 12

LOCALITY		STOPE 1			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge mg/m³
		13 mm	25 mm		
Return	R		2,412		
Face	1		3,263		
Face	2		2,368		
Face	3		1,474		
Face					
Ave. face			2,368		
Old area					
Old area					
Ave. old area					
Intake	4		2,675		
Intake					
Traverse			0,697		
Integrated					
Full shift			0,241		

SKETCH

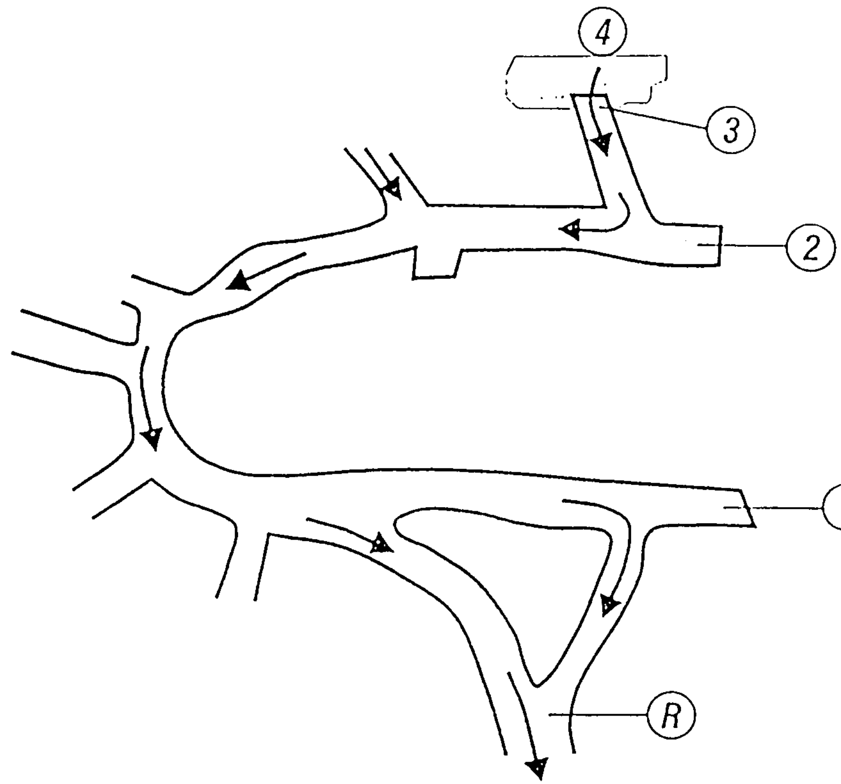

FIGURE 167. SHORT DURATION DUST SAMPLING

MINE 3 - STOPE 1

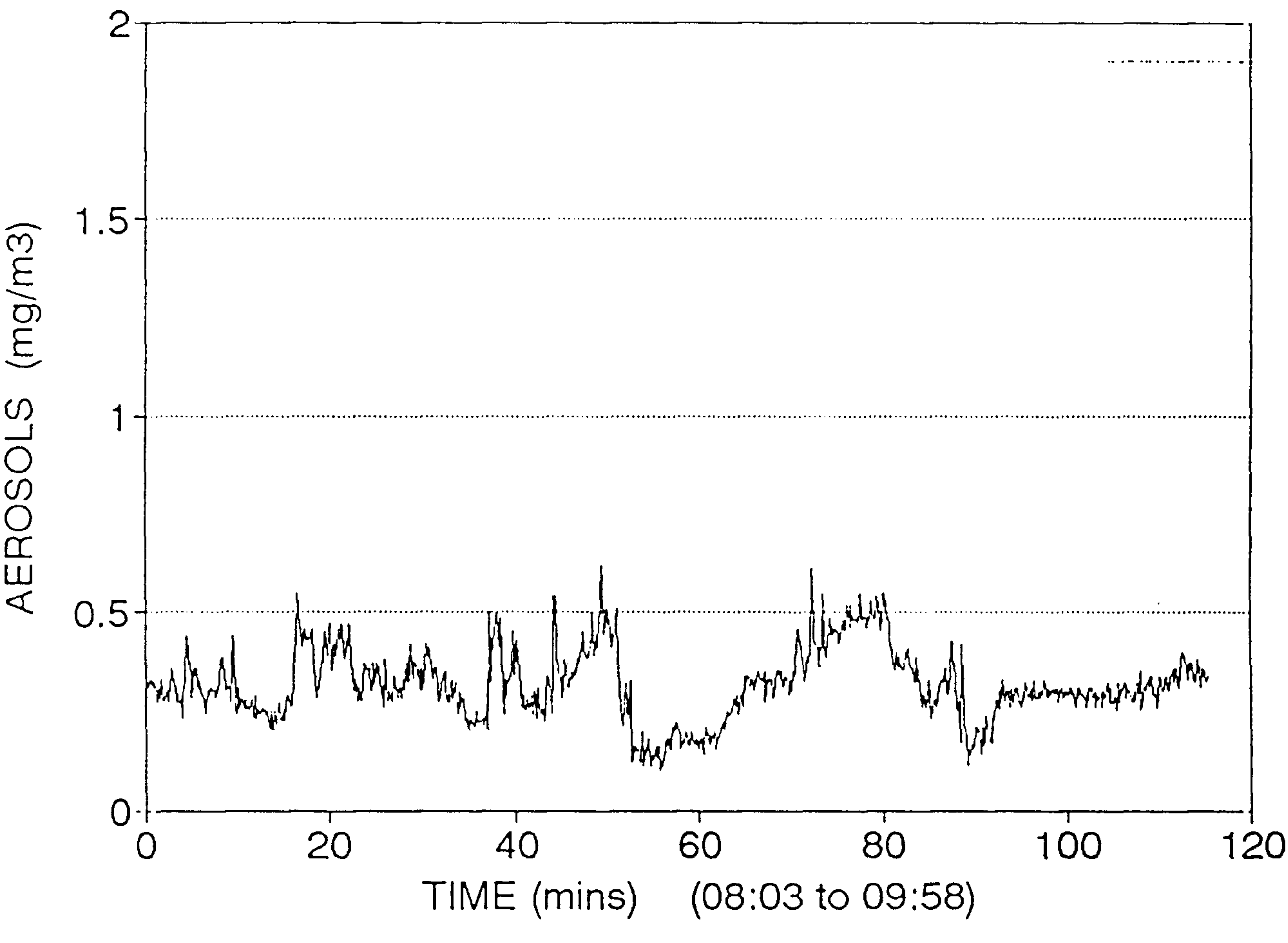

FIGURE 168. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 3 - STOPE 1

LOCALITY		STOPE 3			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge mg/m³
		13 mm	25 mm		
Return	R		2,684		
Face	1		5,316		
Face	2		3,000		
Face	3		3 804		
Face					
Ave. face			4,040		
Old area Old area Ave. old area	5		1,474		
Intake Intake	4	16,886	1,667		
Traverse Integrated Full shift			0,934 0,207		

SKETCH

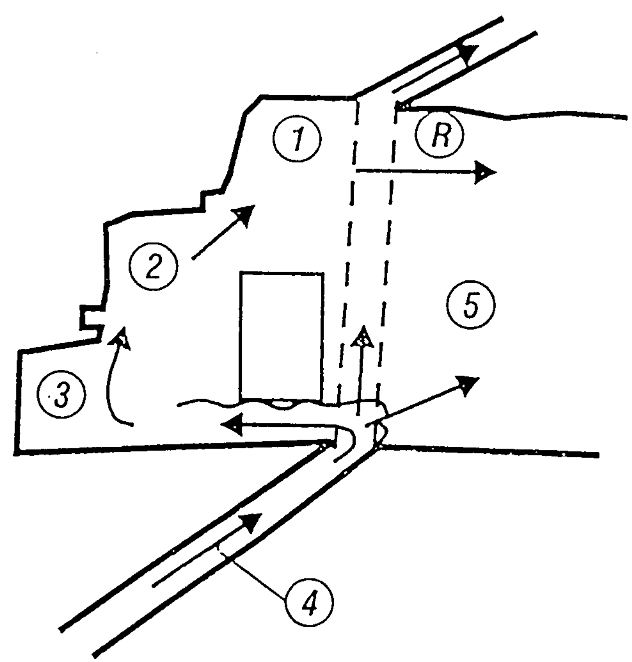

FIGURE 169. SHORT DURATION DUST SAMPLING

MINE 3 - STOPE 3

LOCALITY		STOPE 4			
Position	Ref.	Dust Concentration mg/m^3		Quartz (%)	Rotating Sponge
		13 mm	25 mm		
Return	R		2,834		
Face	1		4,575		
Face					
Face					
Face					
Ave. face			4,575		mg/m^3
Old area Old area Ave. old area					
Intake Intake	2	:	0,526		
Traverse Integrated Full shift			0,509		

SKETCH

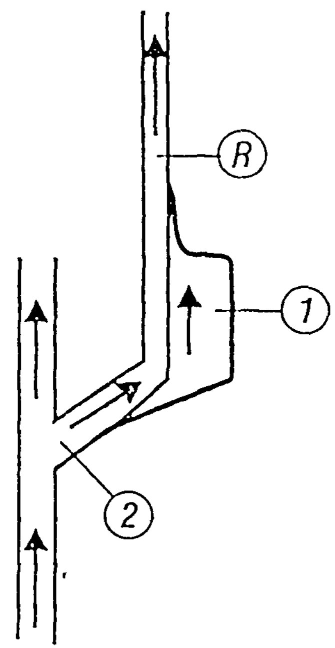

FIGURE 170. SHORT DURATION DUST SAMPLING

MINE 3 - STOPE 4

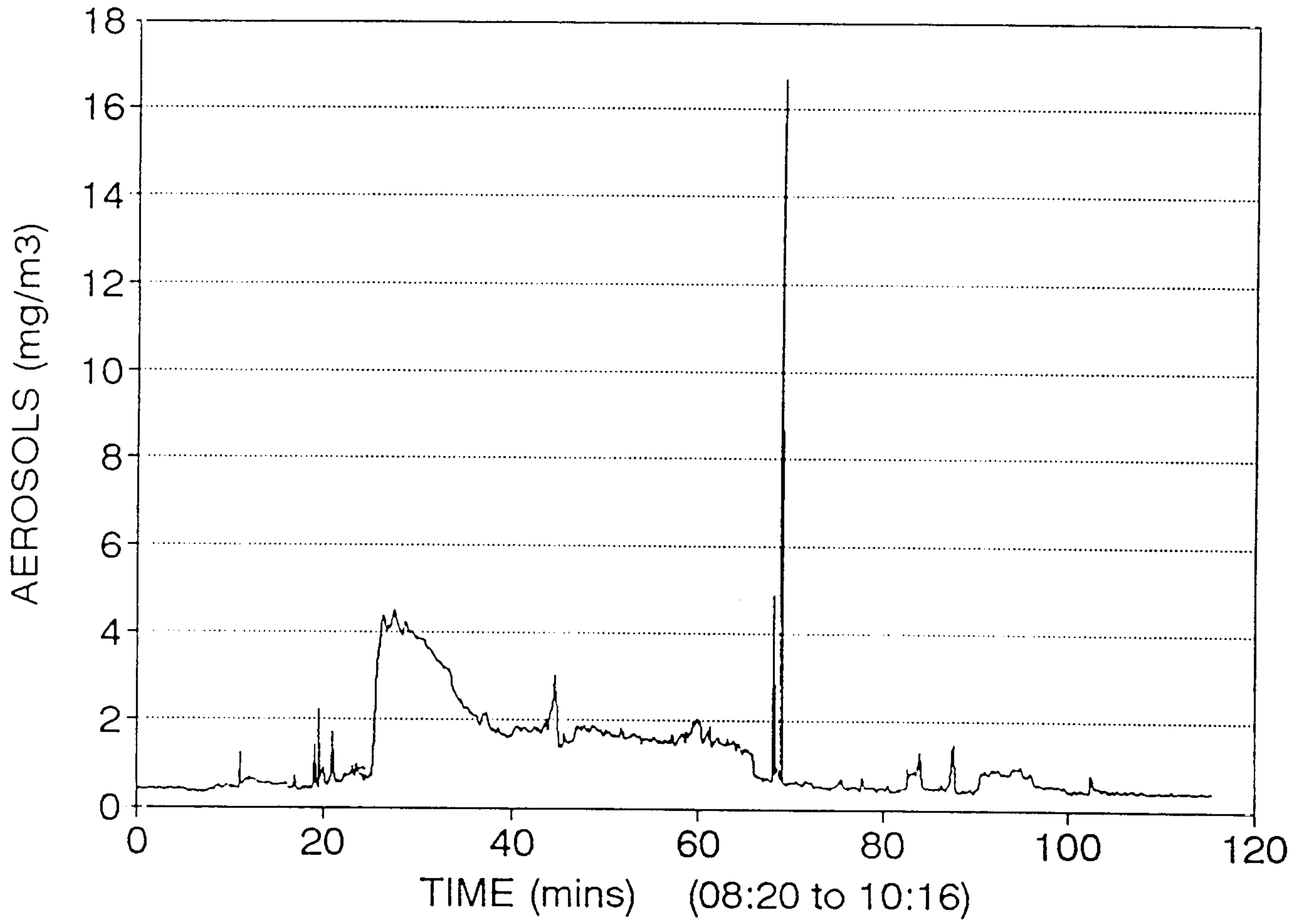

FIGURE 171. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 3 - STOPE 4

LOCALITY		STOPE 5			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge
		13 mm	25 mm		
Return	R	0,236			
Face	1	0,256	1,886		
Face	2	1,047	3,947		
Face					
Face					
Ave. face		0,651	2,916		mg/m³
Old area Old area Ave. old area	3	0,339	2,412		
Intake Intake	4	0,411	0,965		
Traverse Integrated Full shift			0,443	16,20	

SKETCH

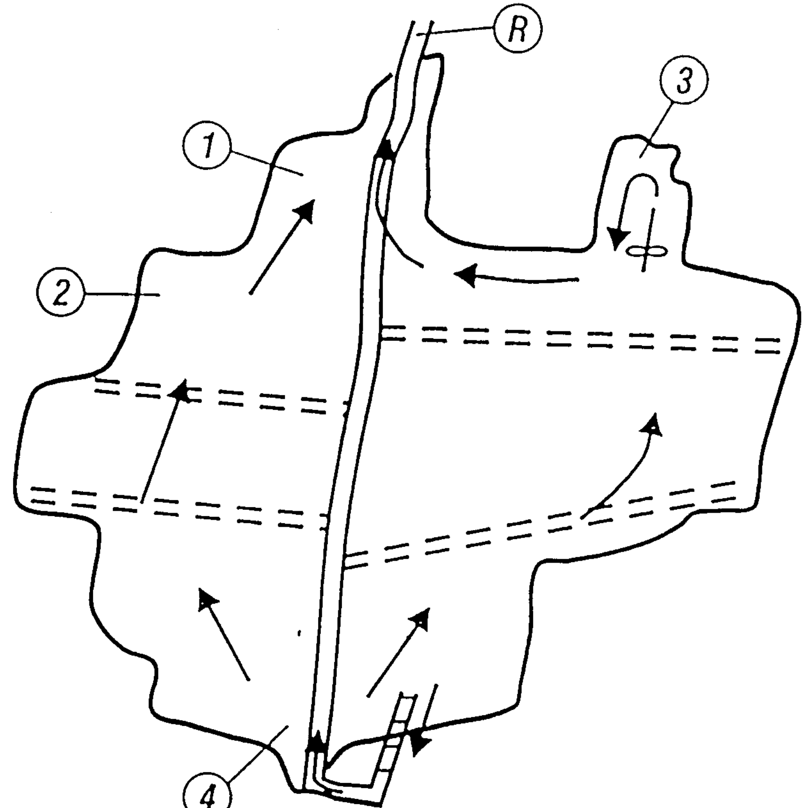

FIGURE 172. SHORT DURATION DUST SAMPLING

MINE 3 - STOPE 5

LOCALITY		STOPE 6			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge mg/m³
		13 mm	25 mm		
Return	R	0,256	2,389		
Face	1	0,239	2,193		
Face	2	0,550	1,316		
Face	3	1,661	2,325		
Face					
Ave. face		0,810	1,940		
Old area					
Old area					
Ave. old area					
Intake	4	0,348	1,617		
Intake					
Traverse			0,760	22,00	
Integrated					
Full shift			0,215		

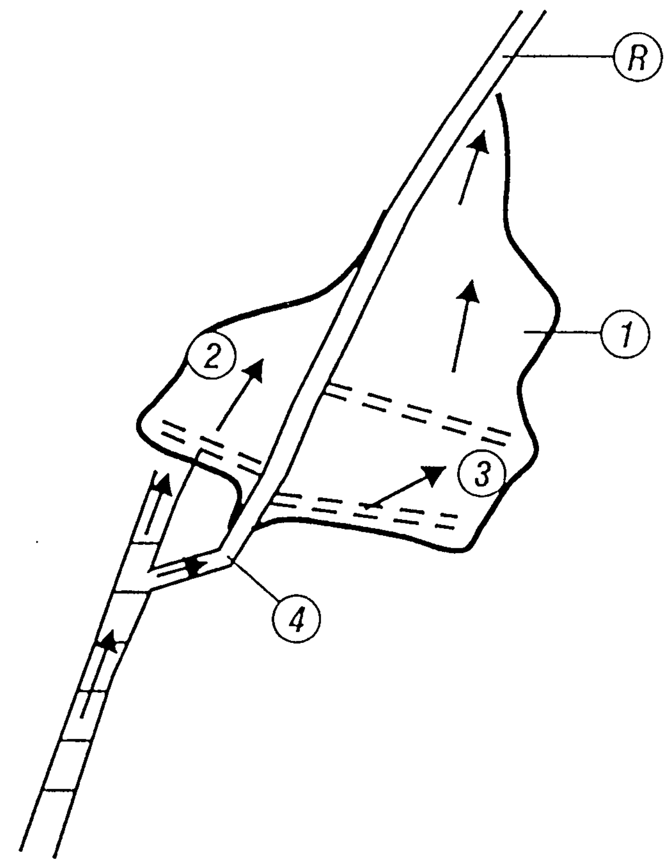

FIGURE 173. SHORT DURATION DUST SAMPLING

MINE 3 - STOPE 6

LOCALITY		STOPE 7			
Position	Ref.	Dust Concentration mg/m^3		Quartz (%)	Rotating Sponge
		13 mm	25 mm		mg/m^3
Return	R	0,800	1,930		
Face	1	0,862			
Face	2	0,551	2,281		
Face	3	0,761	1,754		
Face					
Ave. face		0,723	2,017		
Old area Old area Ave. old area					
Intake Intake	4		0,207		
Traverse Integrated Full shift			0,810 0,395	11,30 18,10	

SKETCH

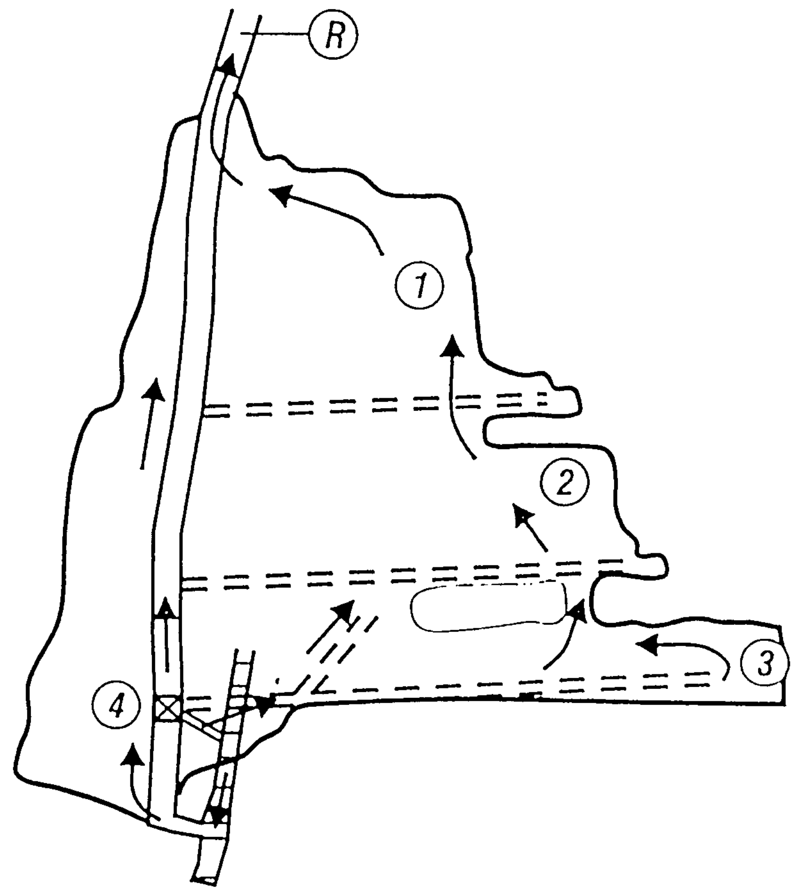

FIGURE 174. SHORT DURATION DUST SAMPLING

MINE 3 - STOPE 7

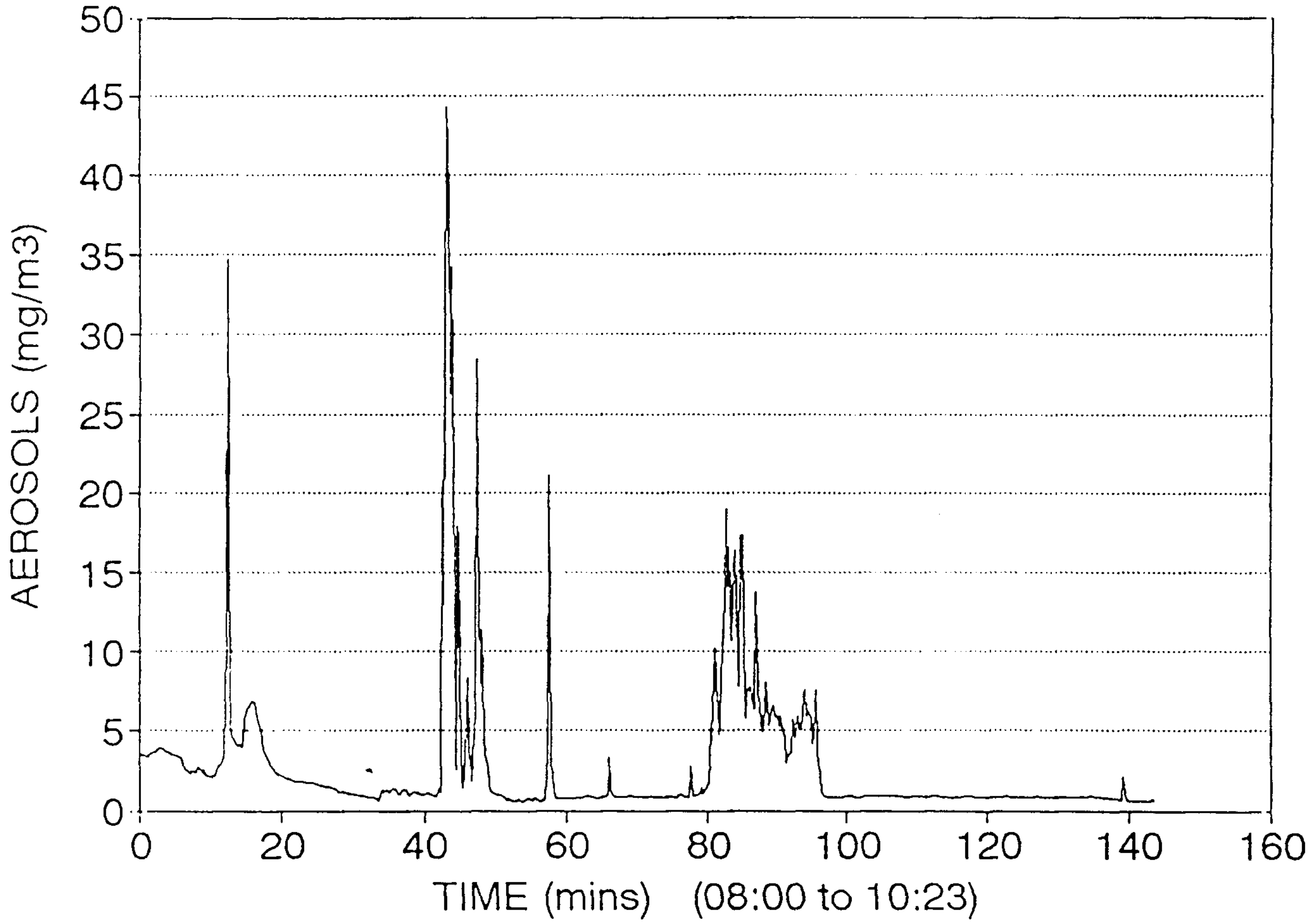

FIGURE 175. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 3 - STOPE 7

LOCALITY		STOPE 8			
Position	Ref.	Dust Concentration mg/m^3		Quartz (%)	Rotating Sponge mg/m^3
		13 mm	25 mm		
Return					
Face	1	0,820	3,158		
Face	2	1,067	1,947		
Face					
Face					
Ave. face		0,944	2,551		
Old area	3	0,827	2,158		
Old area	4	0,620	1,263		
Ave. old area		0,712	1,710		
Intake	5	1,727	3,158		
Intake					
Traverse			1,082	9,70	
Integrated					
Full shift			0,270		

SKETCH

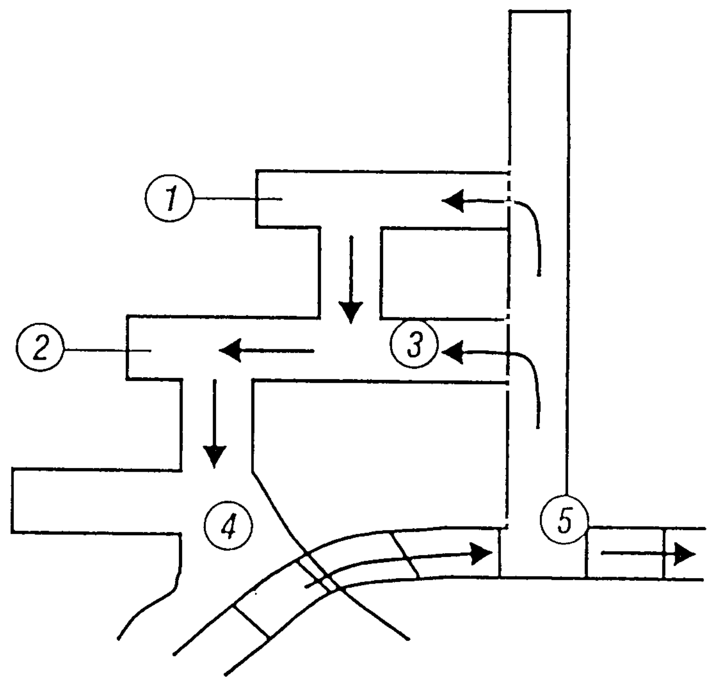

FIGURE 176. SHORT DURATION DUST SAMPLING

MINE 3 - STOPE 8

LOCALITY		STOPE 10			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge
		13 mm	25 mm		
Return	R	0,267	0,053		
Face	1	0,906	3,246		
Face	2	0,533	2,684		
Face	3	1,067	1,000		
Face					
Ave. face		0,835	2,310		mg/m³
Old area Old area Ave. old area					
Intake Intake	4	0,700	0,105		
Traverse Integrated Full shift			0,670 0,242	18,40	

SKETCH

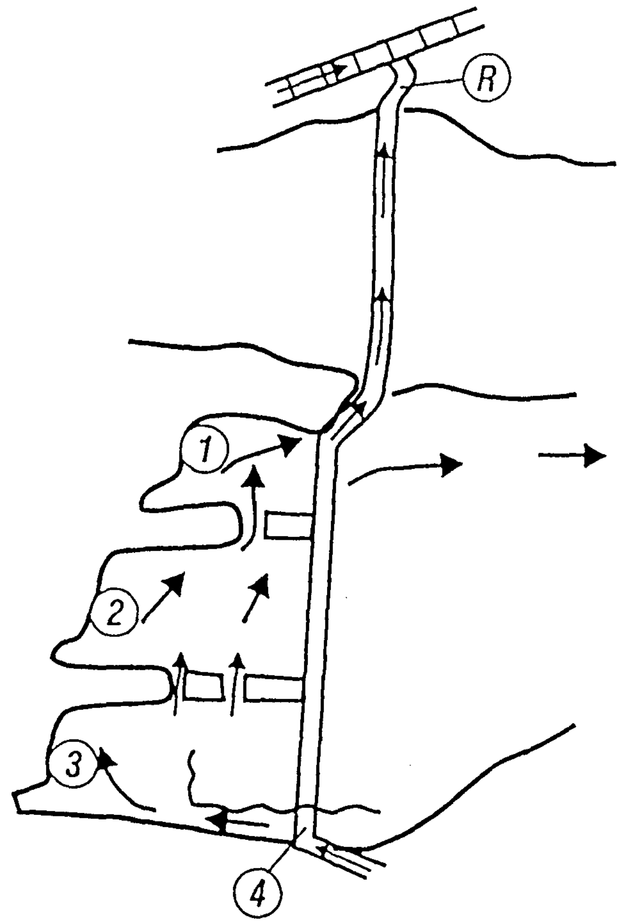

FIGURE 177. SHORT DURATION DUST SAMPLING

MINE 3 - STOPE 10

LOCALITY		STOPE 11			
Position	Ref.	Dust Concentration mg/m^3		Quartz (%)	Rotating Sponge mg/m^3
		13 mm	25 mm		
Return	R	0,743	3,346		
Face	1	0,062	0,977		
Face	2	0,871	1,579		
Face					
Face					
Ave. face		0,462	1,278		
Old area					
Old area					
Ave. old area					
Intake	3	0,443	0,789		
Intake					
Traverse			0,569		
Integrated					
Full shift			0,313		

SKETCH

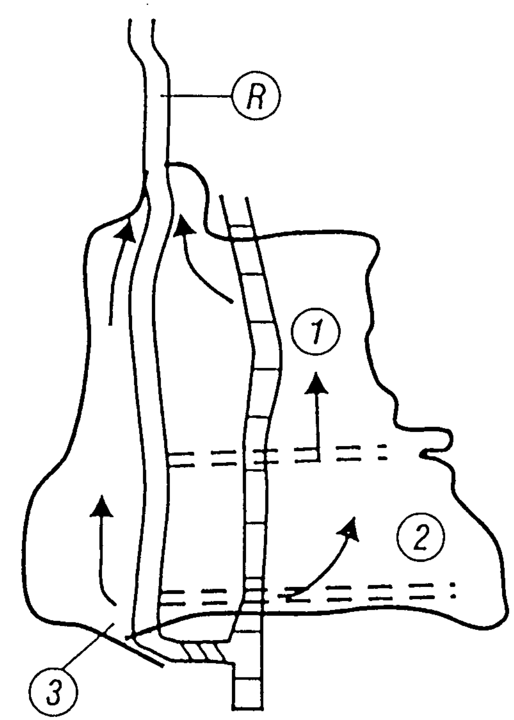

FIGURE 178. SHORT DURATION DUST SAMPLING

MINE 3 - STOPE 11

LOCALITY		STOPE 12			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge
		13 mm	25 mm		mg/m³
Return	R	1,249	1,579		
Face	1	1,227	1,105		
Face	2	1,420	1,675		
Face	3	1,247	1,000		
Face					
Ave. face		1,298	1,260		
Old area					
Old area					
Ave. old area					
Intake	4	1,161	2,105		
Intake					
Traverse			0,570	22,30	
Integrated					
Full shift					

SKETCH

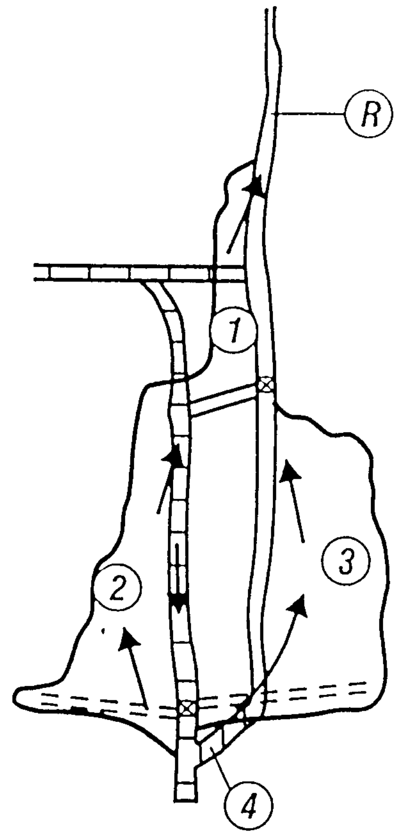

FIGURE 179. SHORT DURATION DUST SAMPLING

MINE 3 - STOPE 12

LOCALITY		STOPE 13			
Position	Ref.	Dust Concentration mg/m^3		Quartz (%)	Rotating Sponge
		13 mm	25 mm		mg/m^3
Return	R	0,852	1,767		
Face	1	0,733	0,088		
Face	2	0,865	0,852		
Face	3	0,811	0,570		
Face					
Ave. face		0,803	0,503		
Old area	4	0,865	0,948		
Old area					
Ave. old area					
Intake	5	0,907	4,702		
Intake	6	0,867	0,596		
Traverse			0,344		
Integrated					
Full shift			0,242		

SKETCH

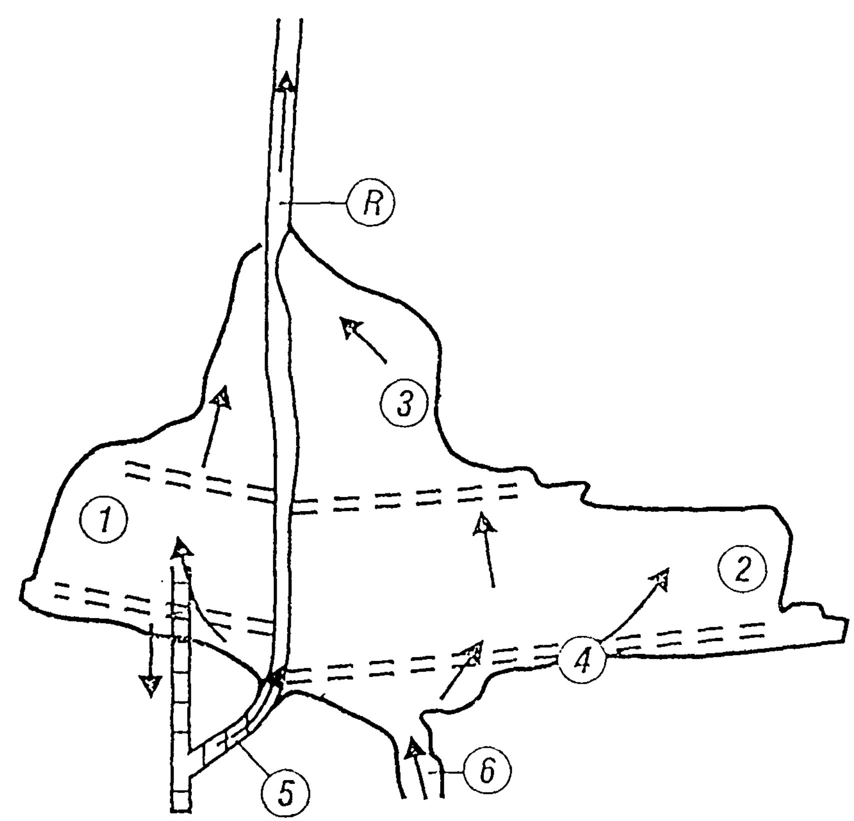

FIGURE 180. SHORT DURATION DUST SAMPLING

MINE 3 - STOPE 13

LOCALITY		Development 1			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge
		13 mm	25 mm		
Return	R		2,947		
Face	1		3,632		
Face	2	1,307	2,053		
Face					
Face					
Ave. face		1,307	2,843		mg/m³
Old area Old area Ave. old area					
Intake Intake	3	0,267	2,211		
Traverse Integrated Full shift			1,012		

SKETCH

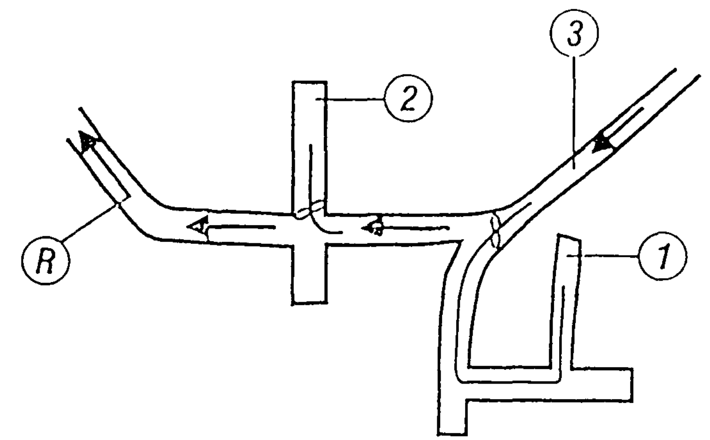

FIGURE 181. SHORT DURATION DUST SAMPLING

MINE 3 - DEVELOPMENT END 1

LOCALITY		Development 2			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge mg/m³
		13 mm	25 mm		
Return					
Face	1		2,263		
Face					
Face					
Face					
Ave. face			2,263		
Old area					
Old area					
Ave. old area					
Intake	2		1,895		
Intake					
Traverse					
Integrated					
Full shift					

SKETCH

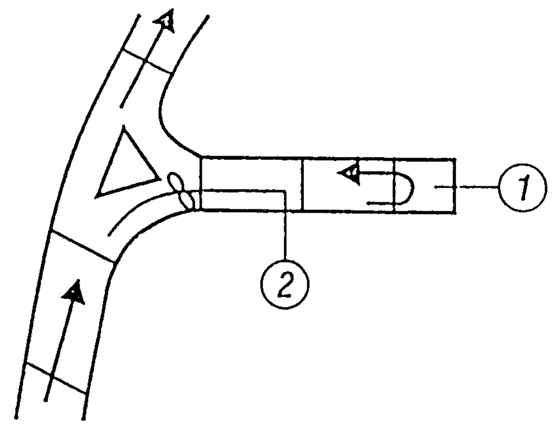

FIGURE 182. SHORT DURATION DUST SAMPLING

MINE 3 - DEVELOPMENT END 2

LOCALITY		Development 4			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge
		13 mm	25 mm		
Return	R1	0,212	1,483		
	R2	1,093	.		
Face	1	0,480	2,158		
Face	2	0,427	0,579		
Face					
Face					
Ave. face		0,454	1,368		mg/m³
Old area					
Old area					
Ave. old area					
Intake	3	0,293	1,439		
Intake	4	0,009	0,386		
Traverse			0,395	25,50	
Integrated					
Full shift					

SKETCH

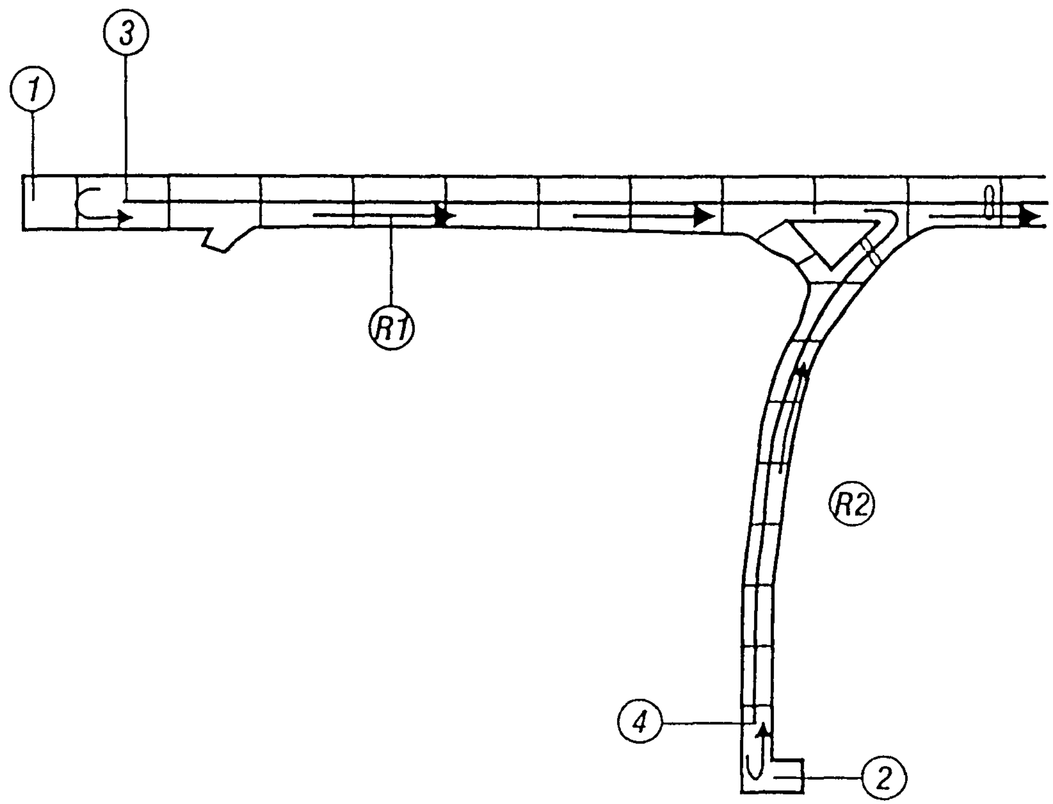

FIGURE 183. SHORT DURATION DUST SAMPLING

MINE 3 - DEVELOPMENT END 4

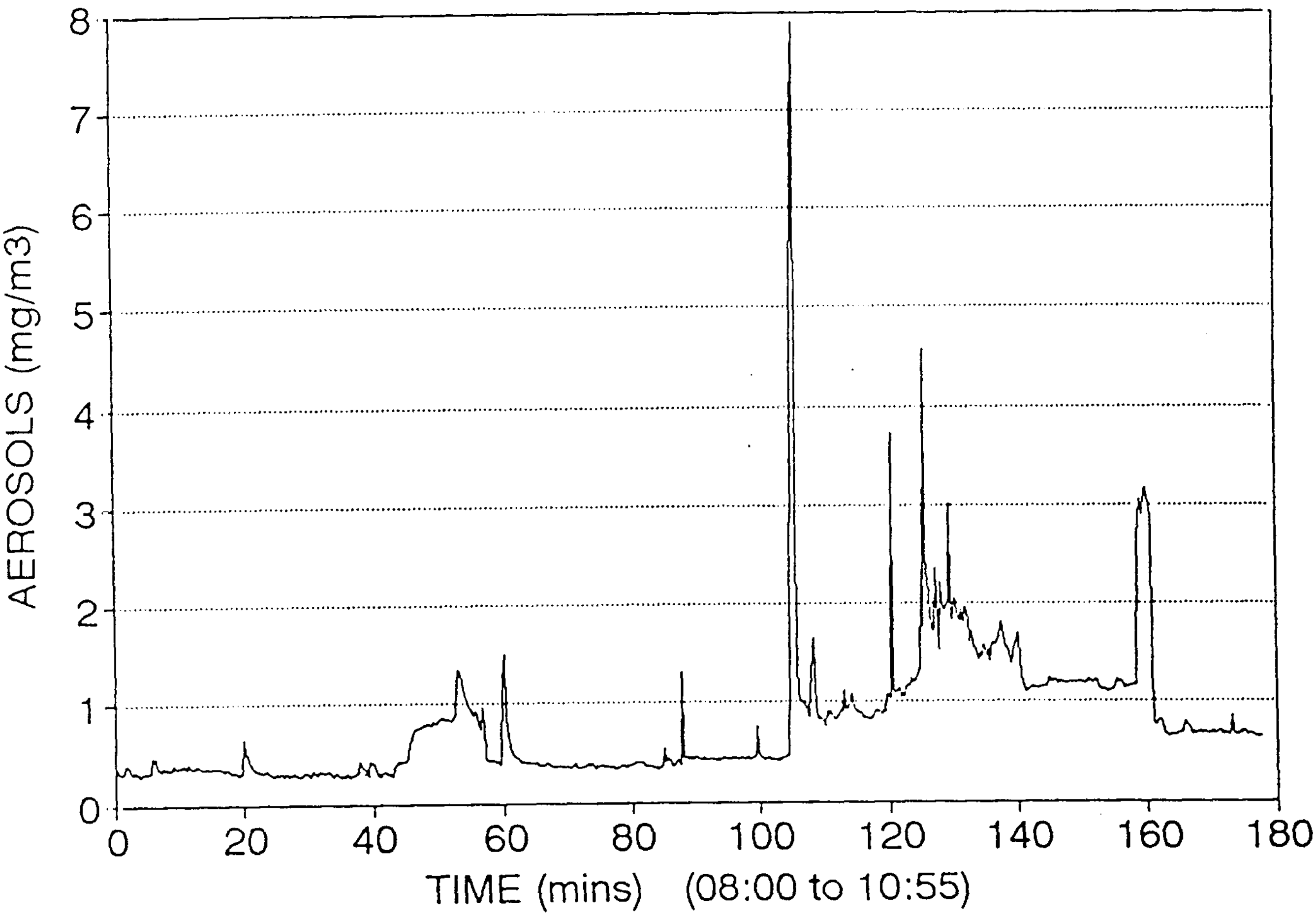

FIGURE 184. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 3 - DEVELOPMENT END 4

LOCALITY		Development 5 and 6			
Position	Ref.	Dust Concentration mg/m³		Quartz (%)	Rotating Sponge mg/m³
		13 mm	25 mm		
Return	R1	0,522	1,316		
	R2	1,217	0,614		
Face	1	0,617	0,746		
Face	2	1,217	0,439		
Face					
Face					
Ave. face		0,917	0,593		
Old area					
Old area					
Ave. old area					
Intake	3	0,520	2,246		
Intake	4	1,027	0,351		
Traverse			0,107		
Integrated					
Full shift					

SKETCH

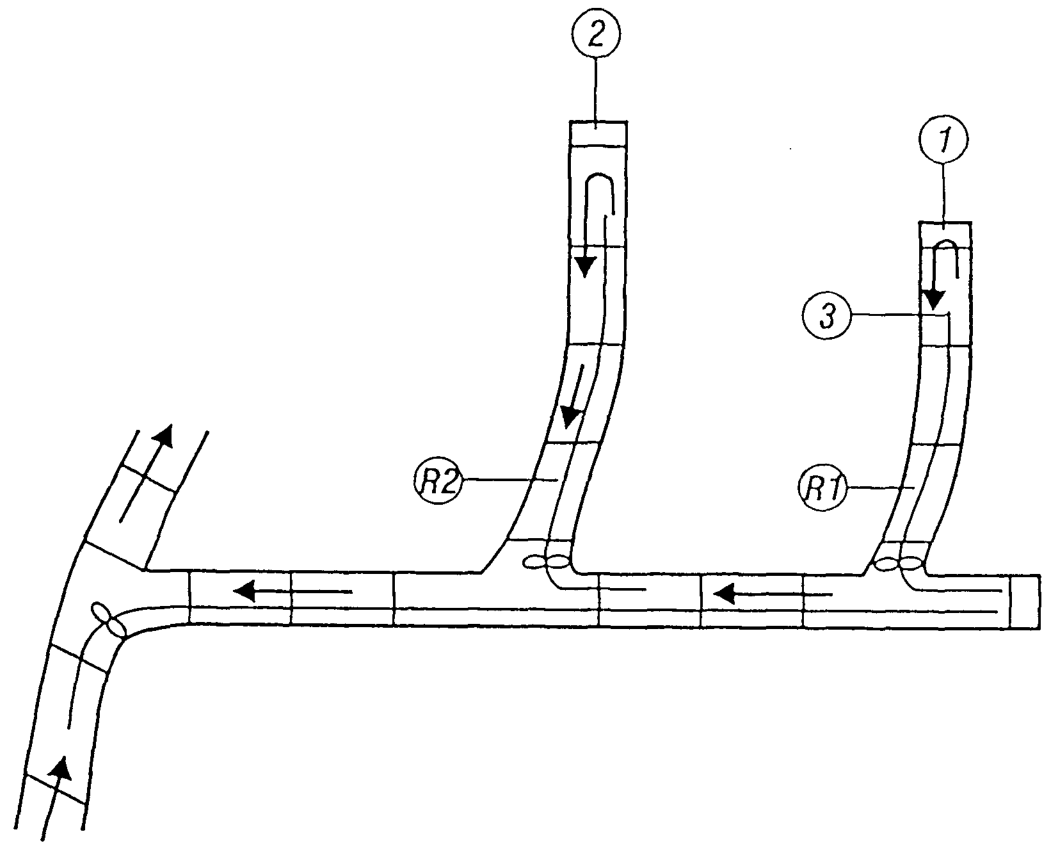

FIGURE 185. SHORT DURATION DUST SAMPLING

MINE 3 - DEVELOPMENT ENDS 5 & 6

LOCALITY		STOPE 2					
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge mg/m³
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		
Return	R						
Face	1						
Face	2						
Face							
Ave. face							
Old area							
Old area							
Ave. old area							
Intake	3		0,024				
Intake							
Traverse					0,688	20,30	0,703
Integrated							1,315
Full shift					1,730		

SKETCH

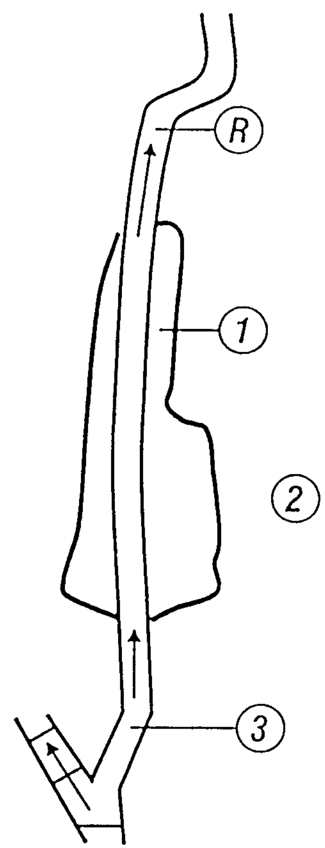

FIGURE 186. SHORT DURATION DUST SAMPLING

MINE 4 - STOPE 2

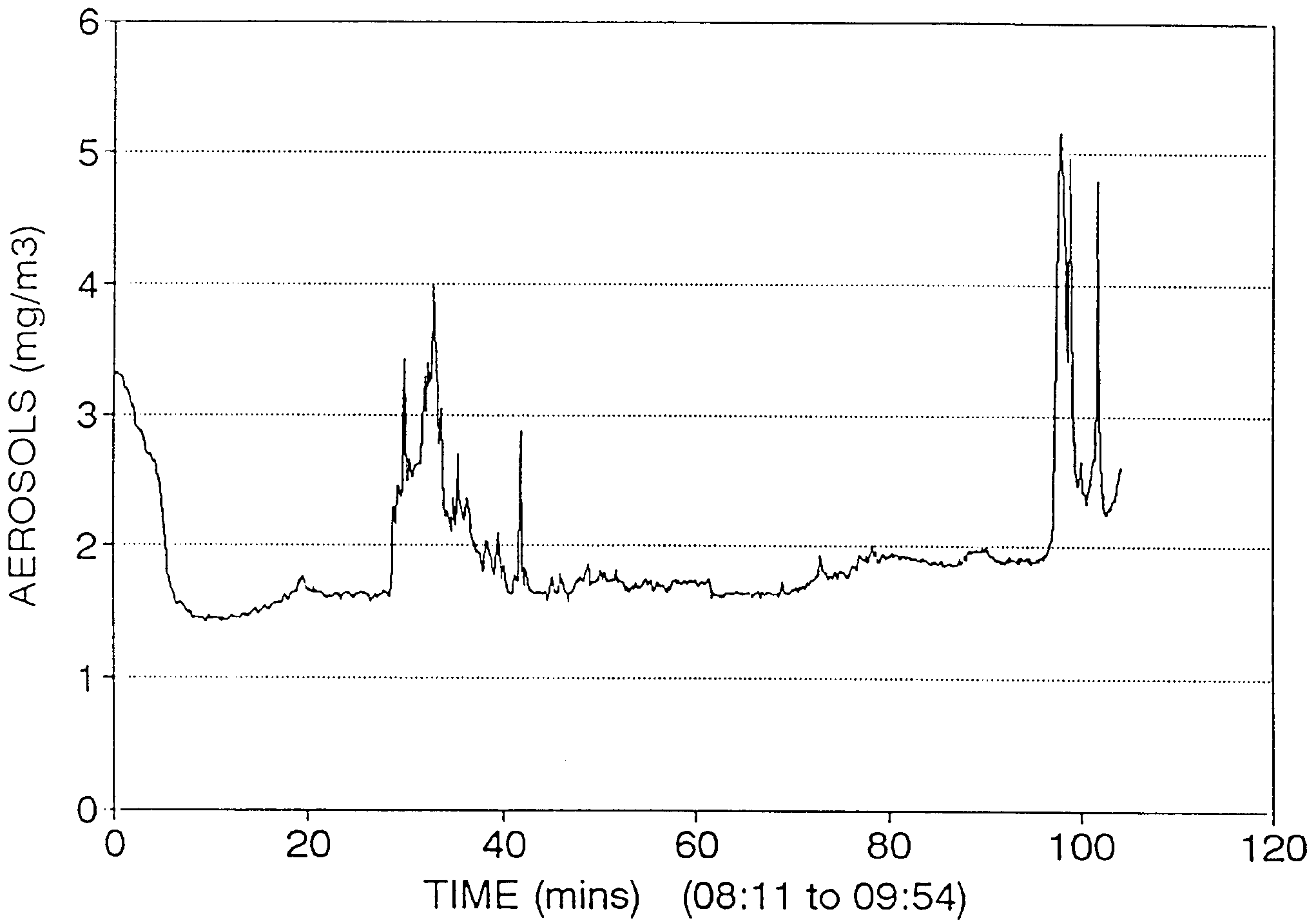

FIGURE 187. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 4 - STOPE 2

LOCALITY		STOPE 3					SKETCH
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge mg/m³
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		
Return	R		2,690				
Face	1		1,970				
Face	2		2,030				
Face	3		2,290				
Ave. face			2,070				
Old area Old area Ave. old area	4		3,040				
Intake Intake	5		1,870				
Traverse Integrated Full shift					1,041 0,137	20,10	4,080 1,111

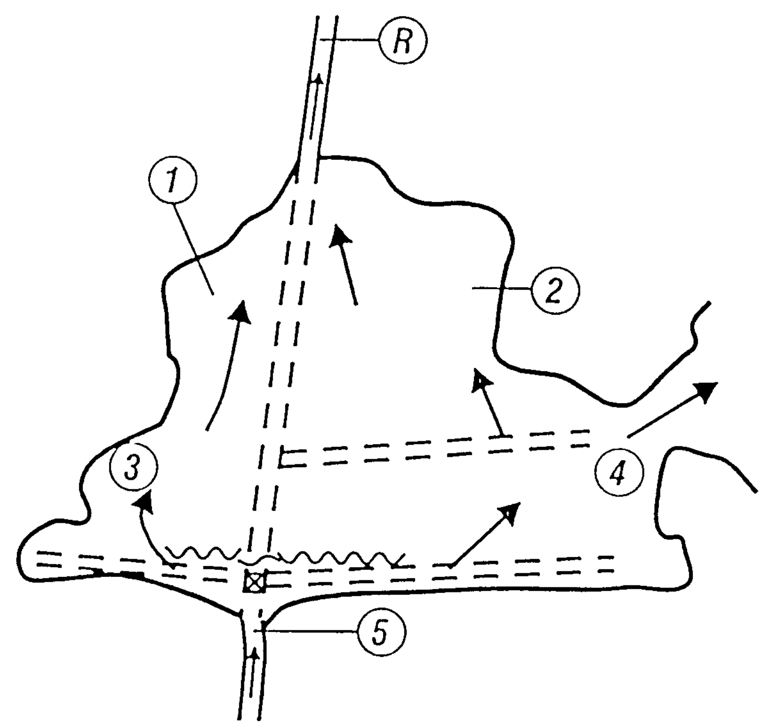

FIGURE 188. SHORT DURATION DUST SAMPLING

MINE 4 - STOPE 3

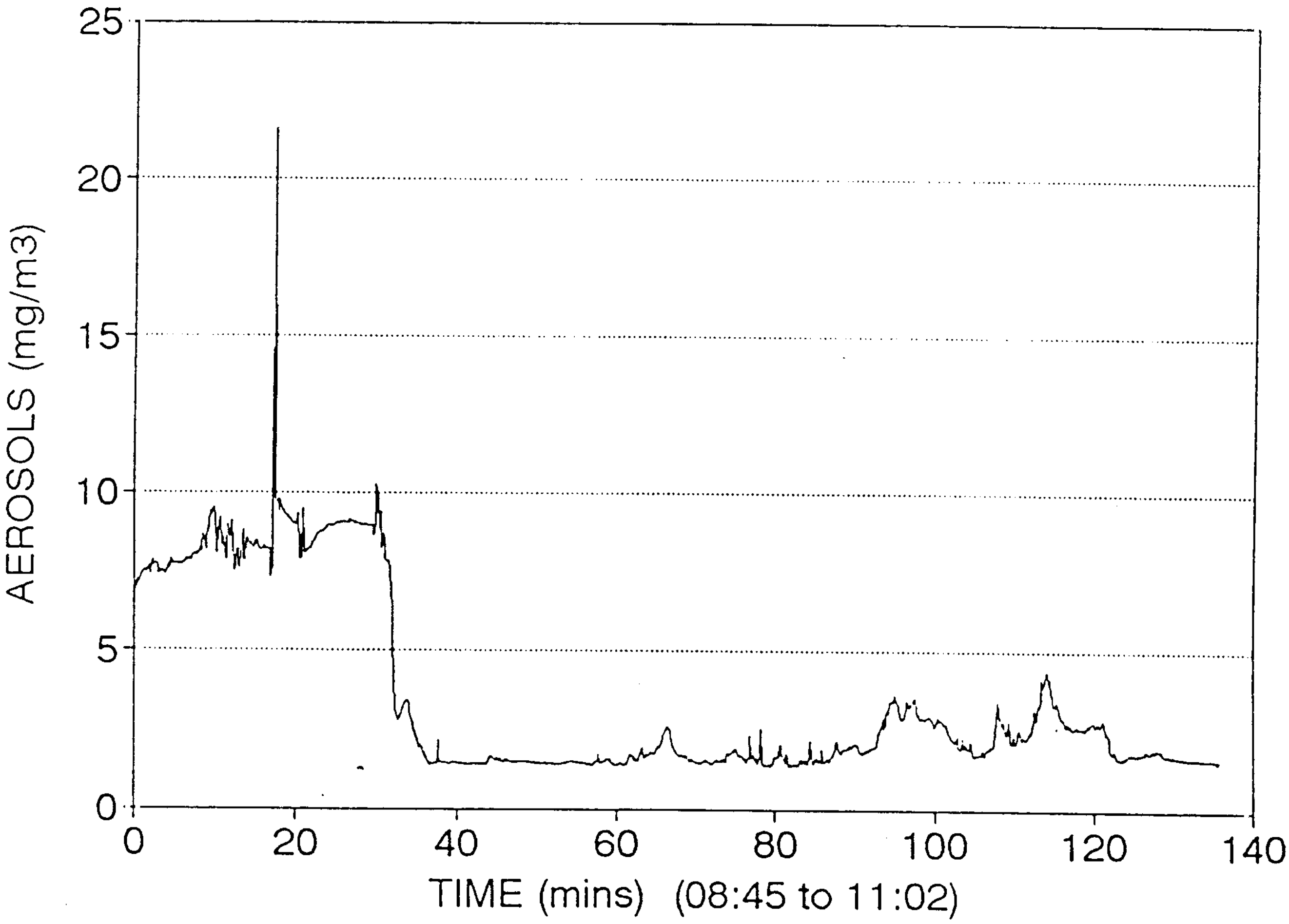

FIGURE 189. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 4 - STOPE 3

LOCALITY		STOPE 5					
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		mg/m³
Return	R		0,640				
Face	1		1,070				
Face							
Face							
Ave. face			1,070				
Old area							
Old area							
Ave. old area							
Intake	2		0,481				
Intake							
Traverse							0,623
Integrated							1,154
Full shift					0,145		

SKETCH

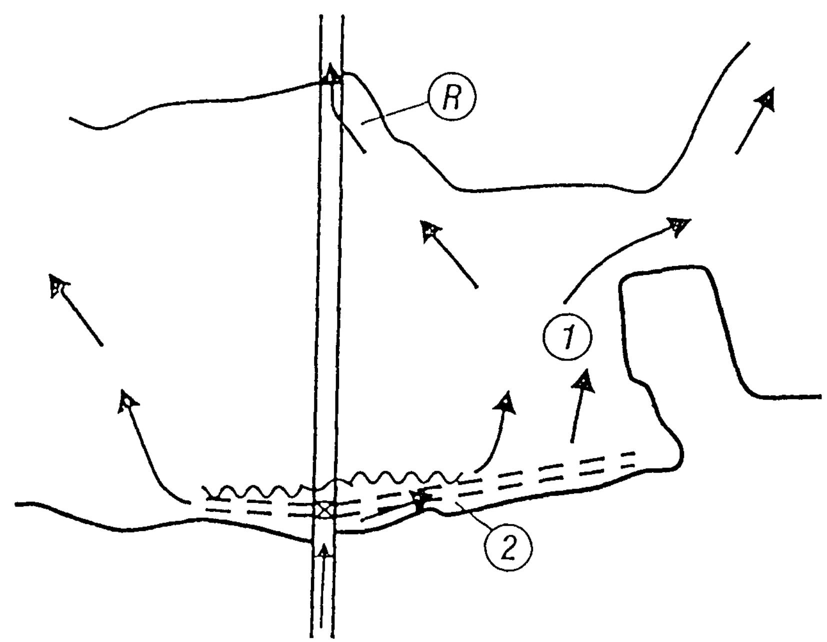

FIGURE 190. SHORT DURATION DUST SAMPLING

MINE 4 - STOPE 5

LOCALITY		STOPE 6						SKETCH
Position	Ref.	Dust Concentration mg/m3				Quartz (%)	Rotating Sponge	
		13 mm Ø		25 mm Ø				
		Total	Res	Total	Res		mg/m3	
Return	R	1,355	1,000					
Face	1	1,000	1,090					
Face	2	0,850	0,670					
Face								
Ave. face		0,920	0,880					
Old area	3	4,060	0,481	1,550	2,020			
Old area								
Ave. old area								
Intake	4	0,920	0,544					
Intake								
Traverse					0,273			
Integrated								
Full shift					0,712	31,20		

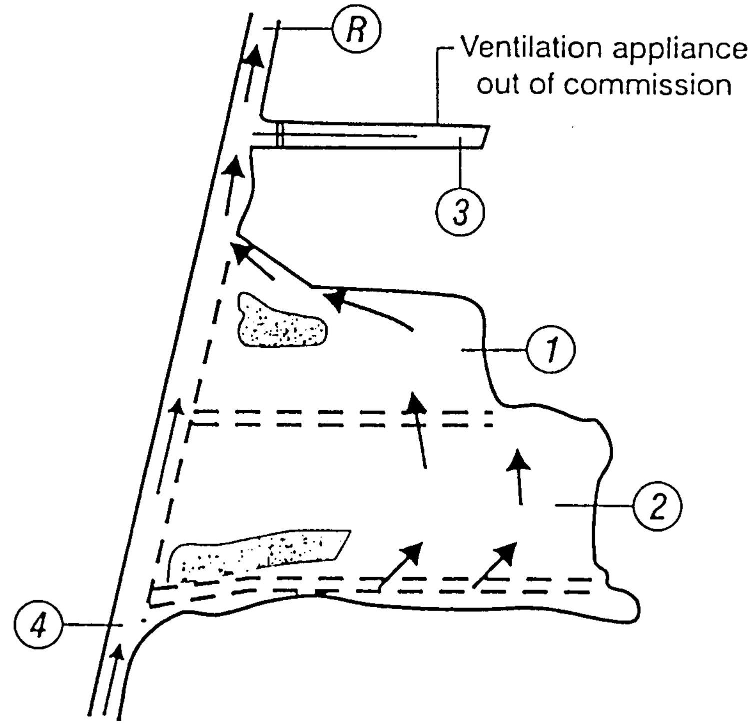

FIGURE 191. SHORT DURATION DUST SAMPLING

MINE 4 - STOPE 6

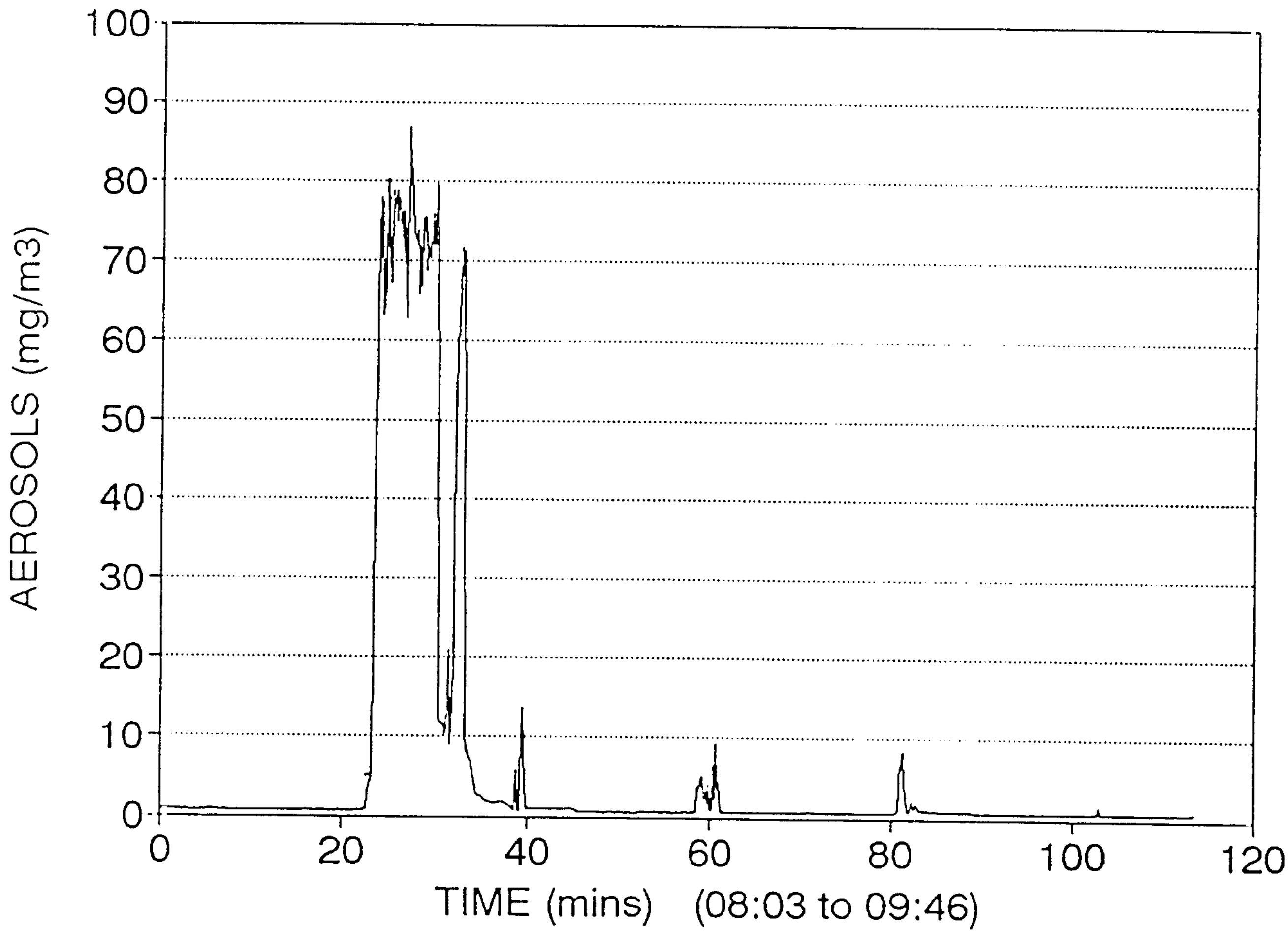

FIGURE 192. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 4 - STOPE 6

LOCALITY		STOPE 7					
Position	Ref.	Dust Concentration mg/m^3				Quartz (%)	Rotating Sponge
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		mg/m^3
Return	R	0,870	0,600		0,370		
Face	1	3,560	2,380	3,280	1,660		
Face	2	1,510	0,620				
Face							
Ave. face		2,030		1,640	0,870		
Old area	3	1,480	1,580	0,520			
Old area							
Ave. old area							
Intake	4	1,030	0,550	0,310			
Intake							
Traverse							
Integrated							
Full shift							

SKETCH

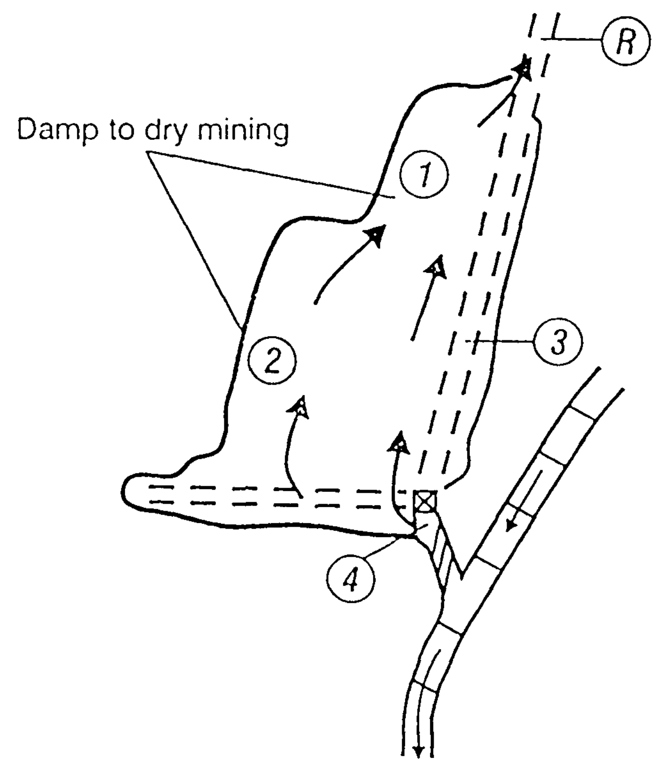

FIGURE 193. SHORT DURATION DUST SAMPLING

MINE 4 - STOPE

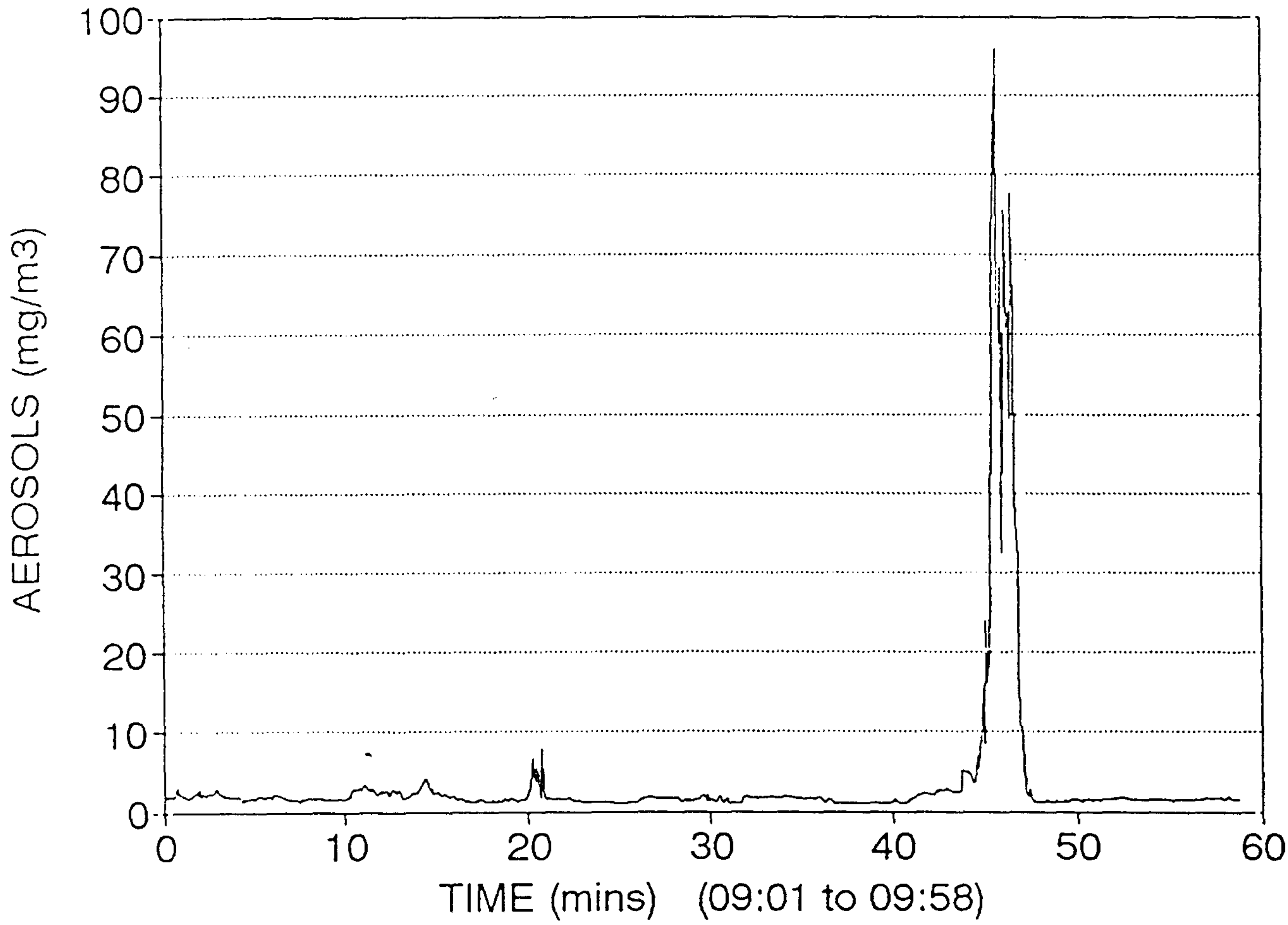

FIGURE 194. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 4 - STOPE 7

LOCALITY		DEVELOPMENT 2					
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge mg/m³
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		
Return	R		1,060				
Face	1	4,030	1,180				
Face							
Face							
Ave. face		4,030	1,180				
Old area							
Old area							
Ave. old area							
Intake	2	1,580	0,840				
Intake							
Traverse					0,707		
Integrated							
Full shift					0,521	10,60	

SKETCH

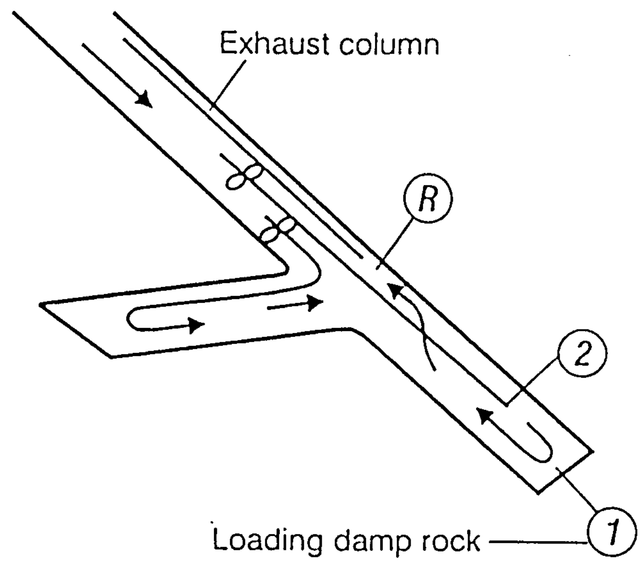

FIGURE 195. SHORT DURATION DUST SAMPLING

MINE 4 - DEVELOP'¯NT END 2

LOCALITY		DEVELOPMENT 3					
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge mg/m³
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		
Return	R		0,883				
Face	1		1,570		0,813		
Face							
Face							
Ave. face			1,570		0,813		
Old area							
Old area							
Ave. old area							
Intake	2		0,702				
Intake							
Traverse							0,090
Integrated							0,543
Full shift					0,124	37,10	

SKETCH

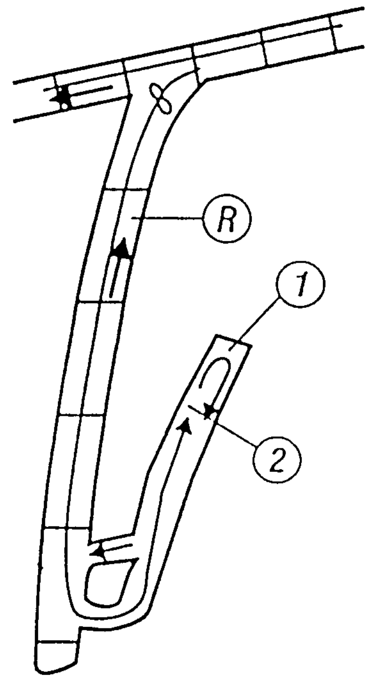

FIGURE 196. SHORT DURATION DUST SAMPLING

MINE 4 - DEVELOPMENT END 3

LOCALITY		DEVELOPMENT 4					
Position	Ref.	Dust Concentration mg/m^3				Quartz (%)	Rotating Sponge
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		mg/m^3
Return	R		1,567				
Face	1		0,824				
Face							
Face							
Ave. face			0,924				
Old area Old area Ave. old area							
Intake Intake	2		0,733				
Traverse Integrated Full shift					0,124		

SKETCH

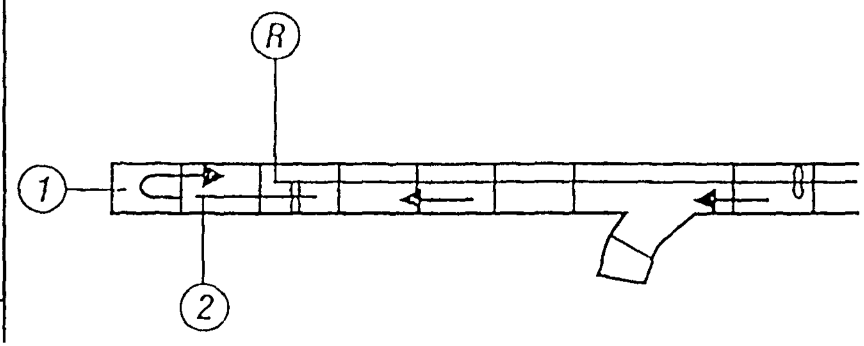

FIGURE 197. SHORT DURATION DUST SAMPLING

MINE 4 - DEVE`^PMENT END 4

LOCALITY		DEVELOPMENT 5					
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge mg/m³
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		
Return	R		1,030				
Face	1		0,536				
Face							
Face							
Ave. face			0,536				
Old area Old area Ave. old area							
Intake Intake	2		0,812				
Traverse Integrated Full shift					0,315 1,595		

SKETCH

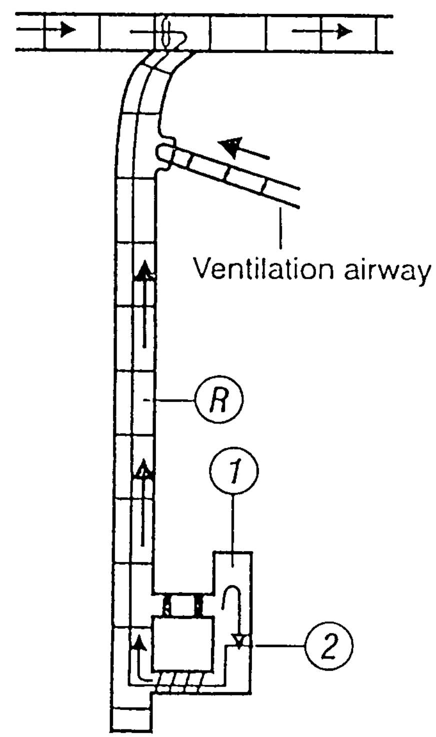

FIGURE 198. SHORT DURATION DUST SAMPLING

MINE 4 - DEVELOPMENT END 5

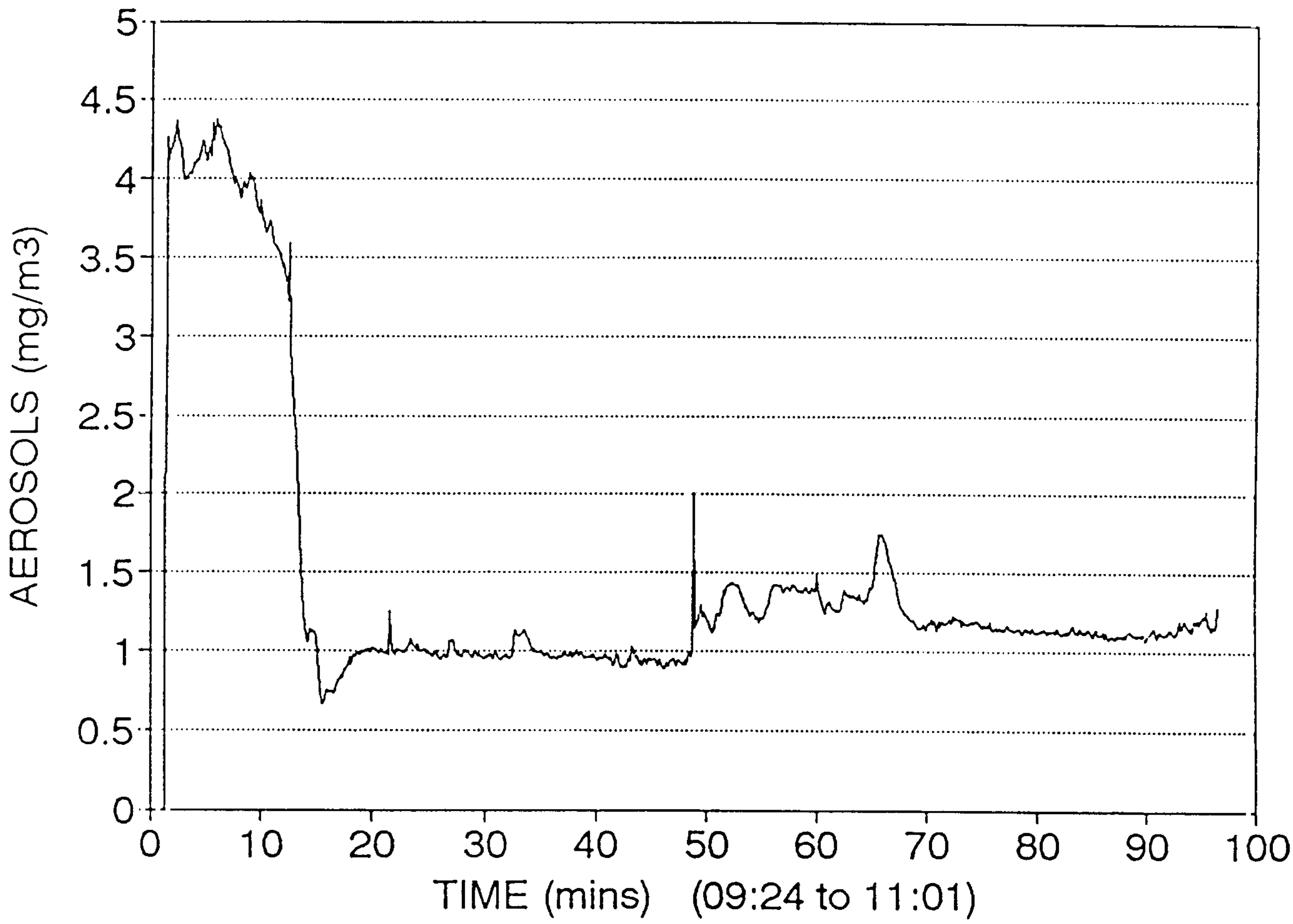

FIGURE 199. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 4 - DEVELOPMENT ENDS 5 & 6

LOCALITY		DEVELOPMENT 6					
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge mg/m³
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		
Return	R		1,370				
Face	1		1,070				
Face							
Face							
Ave. face			1,070				
Old area							
Old area							
Ave. old area							
Intake	2		0,900				
Intake							
Traverse					0,315		
Integrated							
Full shift					1,595		

SKETCH

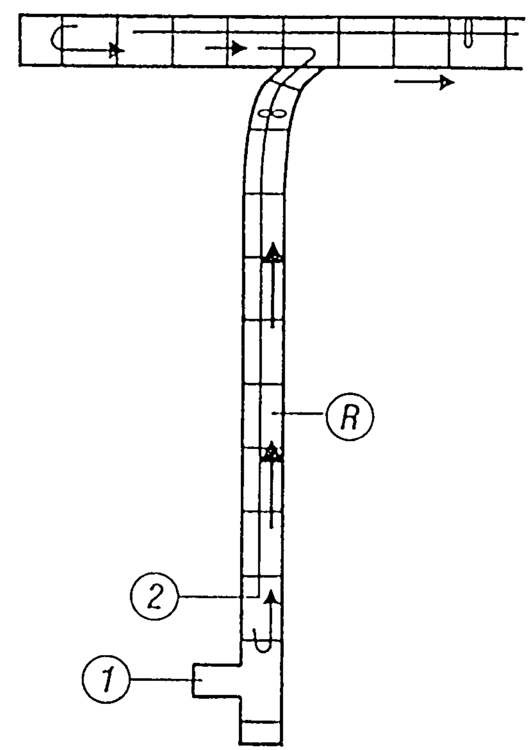

FIGURE 200. SHORT DURATION DUST SAMPLING

MINE 4 - DEVELOPMENT END 6

LOCALITY		DEVELOPMENT 7					
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		mg/m³
Return	R		1,367				
Face	1		1,272		1,579		
Face							
Face							
Ave. face			1,272		1,579		
Old area							
Old area							
Ave. old area							
Intake	2		1,302		0,070		
Intake							
Traverse					0,335		0,960
Integrated							1,560
Full shift					1,590	22,00	

SKETCH

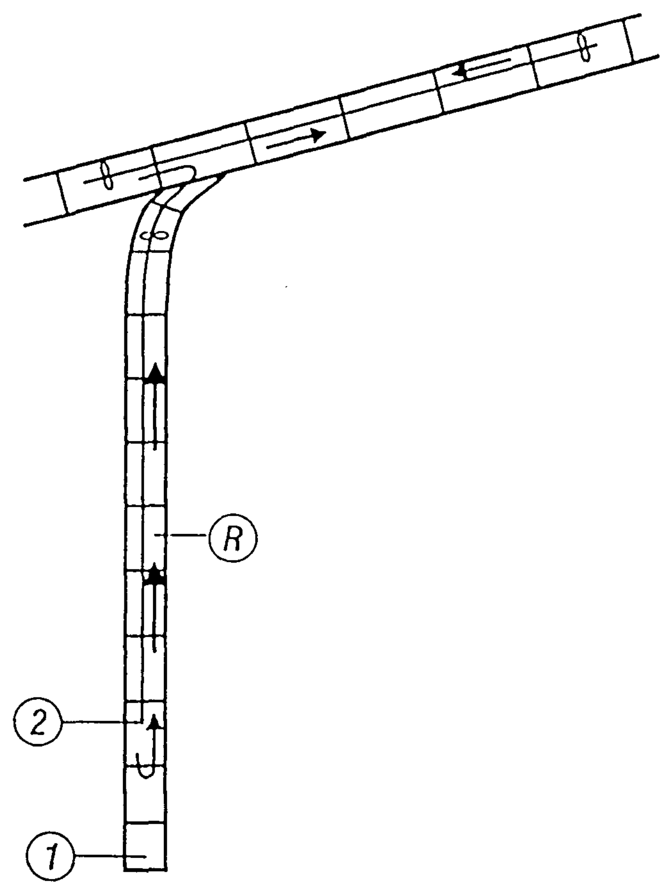

FIGURE 201. SHORT DURATION DUST SAMPLING

MINE 4 - DEVELOPMENT END 7

LOCALITY		DEVELOPMENT 8					
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge mg/m³
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		
Return	R		1,638				
Face	1		3,000				
Face							
Face							
Ave. face			3,000				
Old area							
Old area							
Ave. old area							
Intake	2		1,226				
Intake							
Traverse					1,329		0,593
Integrated							3,010
Full shift					0,971	21,70	

SKETCH

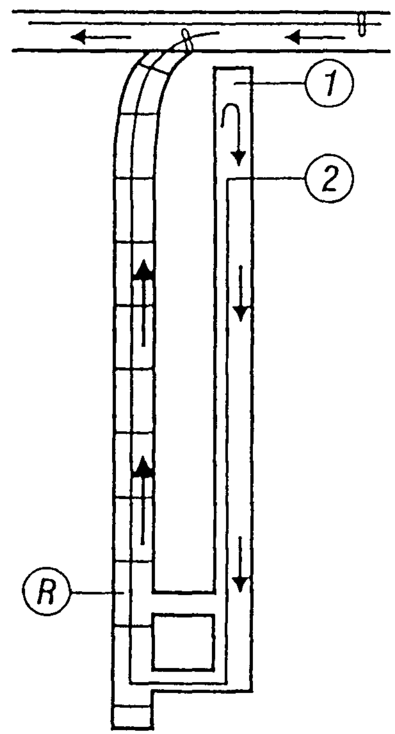

FIGURE 202. SHORT DURATION DUST SAMPLING

MINE 4 - DEVELOPMENT END 8

LOCALITY		DEVELOPMENT 9					
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge mg/m³
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		
Return	R		4,390		0,695		
Face	1		4,391		14,318		
Face							
Face							
Ave. face			4,391		14,318		
Old area							
Old area							
Ave. old area							
Intake	2		4,754		3,745		
Intake							
Traverse					1,329		
Integrated							
Full shift					9,971		

SKETCH

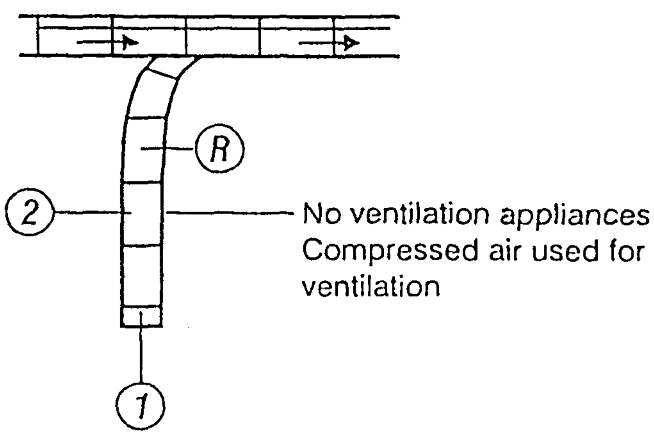

FIGURE 203. SHORT DURATION DUST SAMPLING

MINE 4 - DEVELOPMENT END 9

LOCALITY		DEVELOPMENT 10					
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge mg/m³
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		
Return	R		0,950				
Face	1		1,410				
Face							
Face							
Avc. face			1,410				
Old area Old area Avc. old area							
Intake Intake	2		1,426				
Traverse Integrated Full shift					0,422		

SKETCH

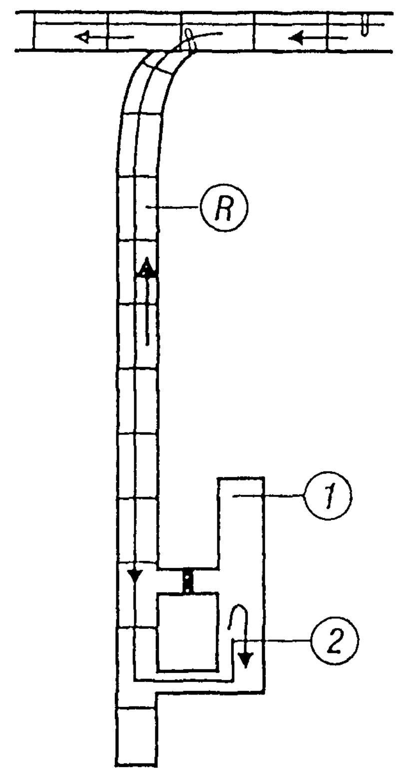

FIGURE 204. SHORT DURATION DUST SAMPLING

MINE 4 - DEVELOPMENT END 10

LOCALITY		DEVELOPMENT 11					
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		mg/m³
Return	R		0,160				
Face	1		1,370		0,170		
Face							
Face							
Ave. face			1,370		0,170		
Old area							
Old area							
Ave. old area							
Intake	2		0,800				
Intake							
Traverse					0,352		
Integrated							
Full shift							

SKETCH

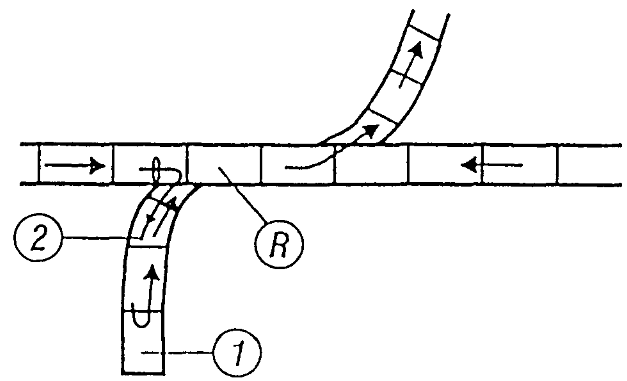

FIGURE 205. SHORT DURATION DUST SAMPLING

MINE 4 - DEVELOPMENT END 11

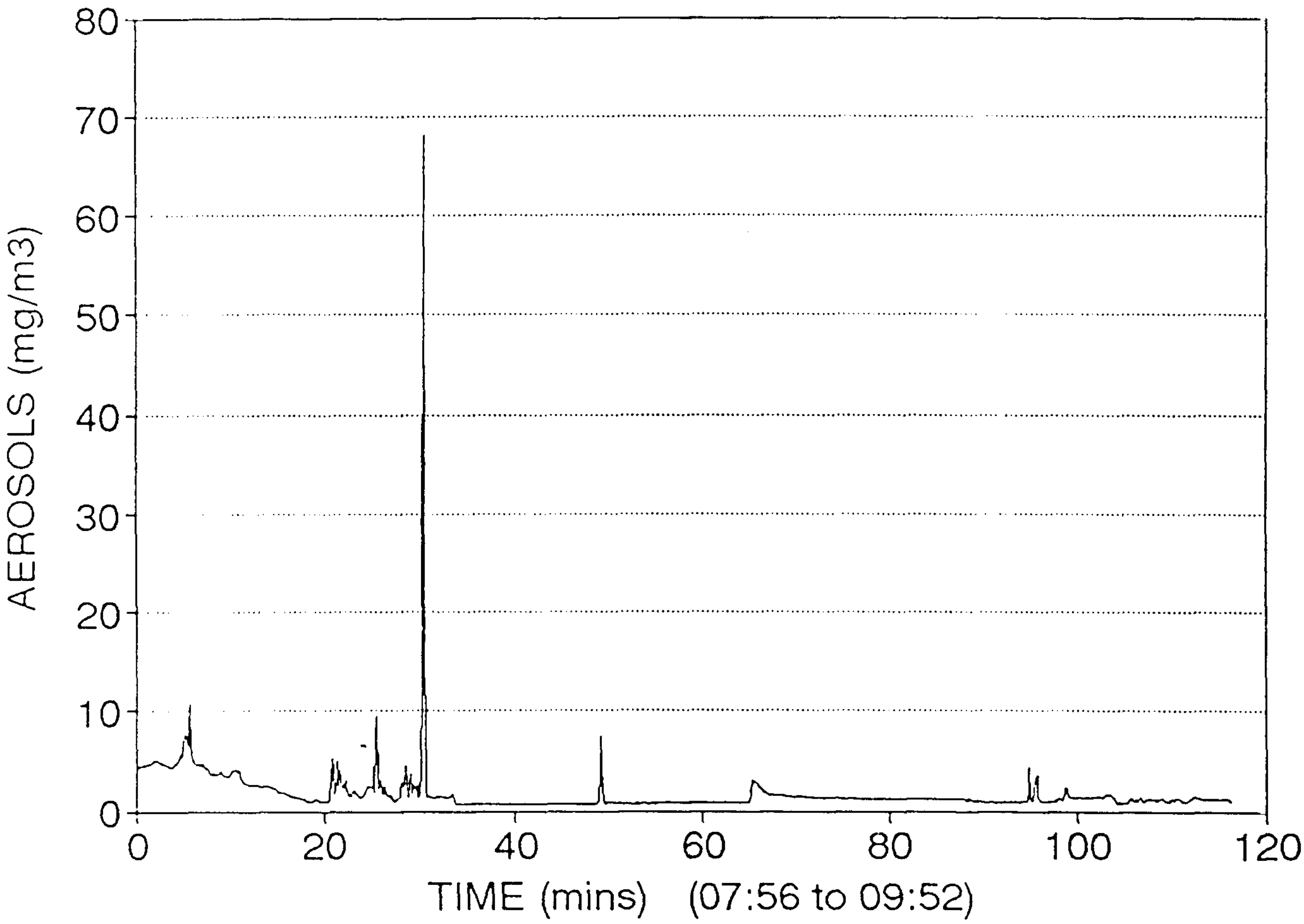

FIGURE 206. SHORT DURATION DUST SAMPLING

TYNDALLOMETER SURVEY MINE 4 - DEVELOPMENT ENDS 11 & 12

LOCALITY		DEVELOPMENT 12						SKETCH
Position	Ref.	Dust Concentration mg/m³				Quartz (%)	Rotating Sponge mg/m³	
		13 mm Ø		25 mm Ø				
		Total	Res	Total	Res			
Return	R		1,970		1,359			
Face	1		1,850					
Face								
Face								
Ave. face			1,950					
Old area Old area Ave. old area								
Intake Intake	2		1,580					
Traverse Integrated Full shift					0,352			

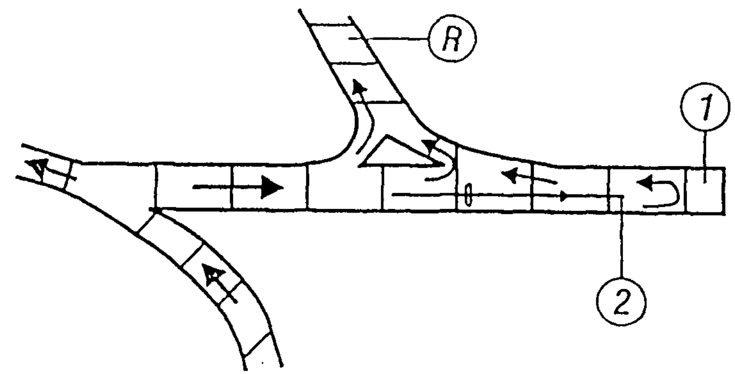

FIGURE 207. SHORT DURATION DUST SAMPLING

MINE 4 - DEVE`PMENT END 12

LOCALITY		DEVELOPMENT 13					
Position	Ref.	Dust Concentration mg/m3				Quartz (%)	Rotating Sponge
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		mg/m3
Return	R		4,290		1,030		
Face	1		0,560				
Face							
Face							
Ave. face			0,560				
Old area							
Old area							
Ave. old area							
Intake	2		1,200				
Intake							
Traverse					0,258		1,288
Integrated							5,250
Full shift					0,517		

SKETCH

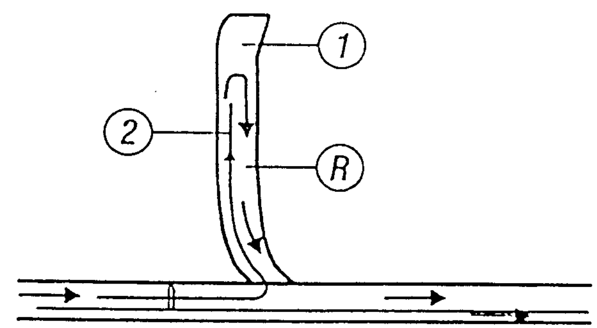

FIGURE 208. SHORT DURATION DUST SAMPLING

MINE 4 - DEVELOPMENT END 13

LOCALITY		DEVELOPMENT 14					
Position	Ref.	Dust Concentration mg/m^3				Quartz (%)	Rotating Sponge
		13 mm Ø		25 mm Ø			
		Total	Res	Total	Res		mg/m^3
Return							
Face	1		1,360				
Face							
Face							
Ave. face			1.360				
Old area							
Old area							
Ave. old area							
Intake	2		0,700				
Intake							
Traverse					0,258		1,288
Integrated							5,250
Full shift					0,517		

SKETCH

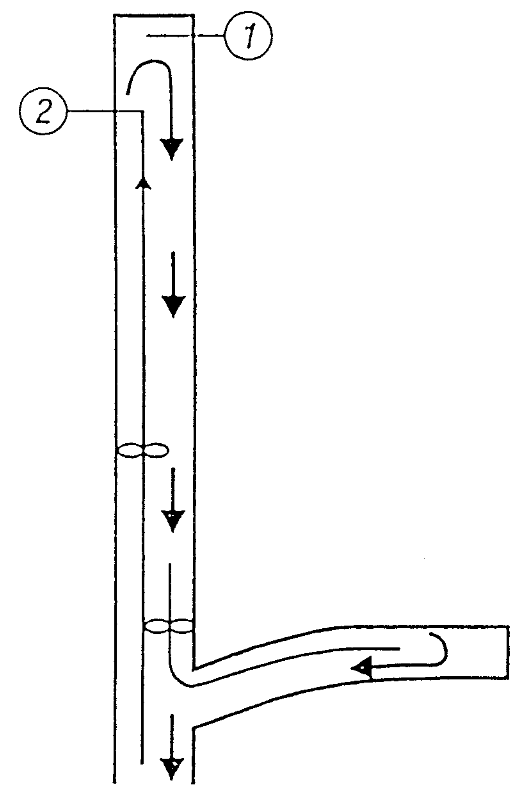

FIGURE 209. SHORT DURATION DUST SAMPLING

MINE 4 - DEVELOPMENT END 14

APPENDIX B

DETAILS OF MINES' OCCUPATIONAL EXPOSURE DATA - MINE 1

TABLES 27 AND 27A TO 27 AA

TABLE 27
DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC mg/m3	CONC TWA mg/m3
CONSTRUCTION	CONSTRUCTION	0.05	0.06
CONSTRUCTION	CONSTRUCTION	0.11	0.13
CONSTRUCTION	CONSTRUCTION	0.24	0.34
CONSTRUCTION	CONSTRUCTION	0.66	0.77
CONSTRUCTION	CONSTRUCTION	0.69	0.75
CONSTRUCTION T/L	CONSTRUCTION	0.49	0.56
CONSTRUCTION T/LEADER	CONSTRUCTION	0.02	0.02
CONSTRUCTION T/LEADER	CONSTRUCTION	0.06	0.05
CONSTRUCTION T/LEADER	CONSTRUCTION	0.07	0.07
CONSTRUCTION T/LEADER	CONSTRUCTION	0.09	0.10
CONSTRUCTION T/LEADER	CONSTRUCTION	0.09	0.10
CONSTRUCTION T/LEADER	CONSTRUCTION	0.23	0.27
CONSTRUCTION T/LEADER	CONSTRUCTION	0.24	0.30
CONSTRUCTION T/LEADER	CONSTRUCTION	0.24	0.37
CONSTRUCTION T/LEADER	CONSTRUCTION	0.25	0.23
CONSTRUCTION T/LEADER	CONSTRUCTION	0.27	0.31
CONSTRUCTION T/LEADER	CONSTRUCTION	0.27	0.28
CONSTRUCTION T/LEADER	CONSTRUCTION	0.27	0.35
CONSTRUCTION T/LEADER	CONSTRUCTION	0.31	0.29
CONSTRUCTION T/LEADER	CONSTRUCTION	0.31	0.38
CONSTRUCTION T/LEADER	CONSTRUCTION	0.33	0.39
CONSTRUCTION T/LEADER	CONSTRUCTION	0.43	0.49
CONSTRUCTION T/LEADER	CONSTRUCTION	0.45	0.64
CONSTRUCTION T/LEADER	CONSTRUCTION	0.46	0.64
CONSTRUCTION T/LEADER	CONSTRUCTION	0.48	0.92
CONSTRUCTION T/LEADER	CONSTRUCTION	0.49	0.57
CONSTRUCTION T/LEADER	CONSTRUCTION	0.50	0.57
CONSTRUCTION T/LEADER	CONSTRUCTION	0.58	0.67
CONSTRUCTION T/LEADER	CONSTRUCTION	0.65	0.73
CONSTRUCTION T/LEADER	CONSTRUCTION	0.65	0.92
CONSTRUCTION T/LEADER	CONSTRUCTION	0.83	2.21
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.01	0.00
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.02	0.01
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.02	0.02
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.05	0.05
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.09	0.14
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.13	0.14
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.13	0.16
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.14	0.16
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.16	0.20
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.16	0.15
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.16	0.18
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.20	0.24
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.24	0.24
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.25	0.26
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.25	0.27
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.27	0.31
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.27	0.34
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.27	0.34
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.27	0.32
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.28	0.33
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.28	0.32

TABLE 27 A TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		mg/m3	mg/m3
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.30	0.33
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.30	0.33
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.31	0.38
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.32	0.29
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.34	0.42
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.35	0.42
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.37	0.44
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.38	0.50
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.38	0.37
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.39	0.48
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.42	0.43
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.45	0.49
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.47	0.54
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.47	0.52
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.49	0.54
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.52	0.63
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.54	0.62
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.57	0.51
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.61	0.70
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.92	1.56
CONSTRUCTION TEAM LEADER	CONSTRUCTION	1.04	2.11
CONSTRUCTION TEAM LEADER	CONSTRUCTION	1.93	2.76
CONSTRUCTION TEAM LEADER	CONSTRUCTION	0.31	0.31
CONSTRUCTION WORKS	CONSTRUCTION	0.08	0.08
CONSTRUCTION WORKS	CONSTRUCTION	0.14	0.15
CONSTRUCTION WORKS	CONSTRUCTION	0.26	0.33
CONSTRUCTION WORKS	CONSTRUCTION	0.31	0.36
CONSTRUCTION WORKS	CONSTRUCTION	0.54	0.58
INSTALLING PIPES	CONSTRUCTION	0.09	0.13
PIPE INSTALER	CONSTRUCTION	0.42	0.46
PIPE INSTALER	CONSTRUCTION	0.42	0.48
PIPE INSTALLATION	CONSTRUCTION	0.36	0.42
PIPE INSTALLER	CONSTRUCTION	0.22	0.24
PIPE INSTALLER	CONSTRUCTION	0.30	0.58
PIPE INSTALLER	CONSTRUCTION	0.43	0.47
SEALING OF ALL WORKING	CONSTRUCTION	0.14	0.15
SEALING OF ALL WORKINGS	CONSTRUCTION	0.27	0.32

TABLE 27 B TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		mg/m3	mg/m3
DRILLING	DRILLING	1.60	2.33
DRILLING	DRILLING	1.83	2.84
MACHIME OPERATOR	DRILLING	0.62	0.82
MACHINE OPERATOR	DRILLING	0.01	0.00
MACHINE OPERATOR	DRILLING	0.01	0.01
MACHINE OPERATOR	DRILLING	0.01	0.01
MACHINE OPERATOR	DRILLING	0.02	0.02
MACHINE OPERATOR	DRILLING	0.02	0.02
MACHINE OPERATOR	DRILLING	0.03	0.03
MACHINE OPERATOR	DRILLING	0.03	0.03
MACHINE OPERATOR	DRILLING	0.03	0.03
MACHINE OPERATOR	DRILLING	0.03	0.03
MACHINE OPERATOR	DRILLING	0.03	0.04
MACHINE OPERATOR	DRILLING	0.04	0.04
MACHINE OPERATOR	DRILLING	0.05	0.08
MACHINE OPERATOR	DRILLING	0.05	0.06
MACHINE OPERATOR	DRILLING	0.05	0.06
MACHINE OPERATOR	DRILLING	0.05	0.06
MACHINE OPERATOR	DRILLING	0.06	0.07
MACHINE OPERATOR	DRILLING	0.06	0.08
MACHINE OPERATOR	DRILLING	0.06	0.07
MACHINE OPERATOR	DRILLING	0.06	0.06
MACHINE OPERATOR	DRILLING	0.06	0.07
MACHINE OPERATOR	DRILLING	0.06	0.08
MACHINE OPERATOR	DRILLING	0.06	0.07
MACHINE OPERATOR	DRILLING	0.07	0.07
MACHINE OPERATOR	DRILLING	0.08	0.08
MACHINE OPERATOR	DRILLING	0.08	0.09
MACHINE OPERATOR	DRILLING	0.09	0.10
MACHINE OPERATOR	DRILLING	0.10	0.11
MACHINE OPERATOR	DRILLING	0.10	0.11
MACHINE OPERATOR	DRILLING	0.10	0.16
MACHINE OPERATOR	DRILLING	0.10	0.13
MACHINE OPERATOR	DRILLING	0.13	0.15
MACHINE OPERATOR	DRILLING	0.13	0.14
MACHINE OPERATOR	DRILLING	0.15	0.17
MACHINE OPERATOR	DRILLING	0.15	0.17
MACHINE OPERATOR	DRILLING	0.16	0.23
MACHINE OPERATOR	DRILLING	0.16	0.22
MACHINE OPERATOR	DRILLING	0.17	0.20
MACHINE OPERATOR	DRILLING	0.17	0.30
MACHINE OPERATOR	DRILLING	0.18	0.25
MACHINE OPERATOR	DRILLING	0.18	0.23
MACHINE OPERATOR	DRILLING	0.18	0.21
MACHINE OPERATOR	DRILLING	0.19	0.26
MACHINE OPERATOR	DRILLING	0.20	0.31
MACHINE OPERATOR	DRILLING	0.20	0.22
MACHINE OPERATOR	DRILLING	0.20	0.22

TABLE 27 C TABLE 27 CONTINUED DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
MACHINE OPERATOR	DRILLING	0.20	0.30
MACHINE OPERATOR	DRILLING	0.22	0.22
MACHINE OPERATOR	DRILLING	0.22	0.26
MACHINE OPERATOR	DRILLING	0.22	0.30
MACHINE OPERATOR	DRILLING	0.23	0.30
MACHINE OPERATOR	DRILLING	0.23	0.26
MACHINE OPERATOR	DRILLING	0.23	0.28
MACHINE OPERATOR	DRILLING	0.23	0.31
MACHINE OPERATOR	DRILLING	0.23	0.27
MACHINE OPERATOR	DRILLING	0.24	0.26
MACHINE OPERATOR	DRILLING	0.24	0.29
MACHINE OPERATOR	DRILLING	0.25	0.29
MACHINE OPERATOR	DRILLING	0.25	0.33
MACHINE OPERATOR	DRILLING	0.26	0.28
MACHINE OPERATOR	DRILLING	0.26	0.34
MACHINE OPERATOR	DRILLING	0.26	0.35
MACHINE OPERATOR	DRILLING	0.27	0.31
MACHINE OPERATOR	DRILLING	0.27	0.26
MACHINE OPERATOR	DRILLING	0.28	0.37
MACHINE OPERATOR	DRILLING	0.28	0.38
MACHINE OPERATOR	DRILLING	0.29	0.33
MACHINE OPERATOR	DRILLING	0.29	0.34
MACHINE OPERATOR	DRILLING	0.29	0.40
MACHINE OPERATOR	DRILLING	0.29	0.35
MACHINE OPERATOR	DRILLING	0.30	0.35
MACHINE OPERATOR	DRILLING	0.30	0.38
MACHINE OPERATOR	DRILLING	0.30	0.37
MACHINE OPERATOR	DRILLING	0.31	0.37
MACHINE OPERATOR	DRILLING	0.31	0.36
MACHINE OPERATOR	DRILLING	0.31	0.37
MACHINE OPERATOR	DRILLING	0.31	0.36
MACHINE OPERATOR	DRILLING	0.31	0.39
MACHINE OPERATOR	DRILLING	0.31	0.34
MACHINE OPERATOR	DRILLING	0.31	0.41
MACHINE OPERATOR	DRILLING	0.32	0.38
MACHINE OPERATOR	DRILLING	0.34	0.44
MACHINE OPERATOR	DRILLING	0.34	0.36
MACHINE OPERATOR	DRILLING	0.34	0.53
MACHINE OPERATOR	DRILLING	0.34	0.40
MACHINE OPERATOR	DRILLING	0.34	0.46
MACHINE OPERATOR	DRILLING	0.34	0.40
MACHINE OPERATOR	DRILLING	0.34	0.45
MACHINE OPERATOR	DRILLING	0.35	0.40
MACHINE OPERATOR	DRILLING	0.35	0.37
MACHINE OPERATOR	DRILLING	0.35	0.41
MACHINE OPERATOR	DRILLING	0.35	0.54
MACHINE OPERATOR	DRILLING	0.35	0.38
MACHINE OPERATOR	DRILLING	0.35	0.41

TABLE 27 D TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		mg/m3	mg/m3
MACHINE OPERATOR	DRILLING	0.36	0.44
MACHINE OPERATOR	DRILLING	0.36	0.59
MACHINE OPERATOR	DRILLING	0.37	0.46
MACHINE OPERATOR	DRILLING	0.37	0.48
MACHINE OPERATOR	DRILLING	0.37	0.41
MACHINE OPERATOR	DRILLING	0.38	0.45
MACHINE OPERATOR	DRILLING	0.38	0.43
MACHINE OPERATOR	DRILLING	0.38	0.42
MACHINE OPERATOR	DRILLING	0.38	0.42
MACHINE OPERATOR	DRILLING	0.39	0.48
MACHINE OPERATOR	DRILLING	0.39	0.50
MACHINE OPERATOR	DRILLING	0.39	0.50
MACHINE OPERATOR	DRILLING	0.40	0.44
MACHINE OPERATOR	DRILLING	0.40	0.41
MACHINE OPERATOR	DRILLING	0.40	0.47
MACHINE OPERATOR	DRILLING	0.41	0.43
MACHINE OPERATOR	DRILLING	0.41	0.43
MACHINE OPERATOR	DRILLING	0.41	0.48
MACHINE OPERATOR	DRILLING	0.42	0.46
MACHINE OPERATOR	DRILLING	0.42	0.43
MACHINE OPERATOR	DRILLING	0.42	0.52
MACHINE OPERATOR	DRILLING	0.42	0.50
MACHINE OPERATOR	DRILLING	0.42	0.49
MACHINE OPERATOR	DRILLING	0.42	0.44
MACHINE OPERATOR	DRILLING	0.43	0.74
MACHINE OPERATOR	DRILLING	0.43	0.50
MACHINE OPERATOR	DRILLING	0.43	0.52
MACHINE OPERATOR	DRILLING	0.44	0.46
MACHINE OPERATOR	DRILLING	0.44	0.48
MACHINE OPERATOR	DRILLING	0.44	0.47
MACHINE OPERATOR	DRILLING	0.44	0.51
MACHINE OPERATOR	DRILLING	0.45	0.52
MACHINE OPERATOR	DRILLING	0.45	0.48
MACHINE OPERATOR	DRILLING	0.45	0.55
MACHINE OPERATOR	DRILLING	0.45	0.51
MACHINE OPERATOR	DRILLING	0.46	0.52
MACHINE OPERATOR	DRILLING	0.46	0.53
MACHINE OPERATOR	DRILLING	0.46	0.51
MACHINE OPERATOR	DRILLING	0.46	0.57
MACHINE OPERATOR	DRILLING	0.46	0.50
MACHINE OPERATOR	DRILLING	0.47	0.50
MACHINE OPERATOR	DRILLING	0.47	0.56
MACHINE OPERATOR	DRILLING	0.47	0.56
MACHINE OPERATOR	DRILLING	0.47	0.56
MACHINE OPERATOR	DRILLING	0.48	0.52
MACHINE OPERATOR	DRILLING	0.48	0.49
MACHINE OPERATOR	DRILLING	0.48	0.49
MACHINE OPERATOR	DRILLING	0.49	0.58

TABLE 27 E TABLE 27 CONTINUED DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		mg/m3	mg/m3
MACHINE OPERATOR	DRILLING	0.49	0.61
MACHINE OPERATOR	DRILLING	0.49	0.63
MACHINE OPERATOR	DRILLING	0.49	0.50
MACHINE OPERATOR	DRILLING	0.49	0.50
MACHINE OPERATOR	DRILLING	0.50	0.56
MACHINE OPERATOR	DRILLING	0.50	0.55
MACHINE OPERATOR	DRILLING	0.51	0.53
MACHINE OPERATOR	DRILLING	0.51	0.64
MACHINE OPERATOR	DRILLING	0.51	0.56
MACHINE OPERATOR	DRILLING	0.52	0.68
MACHINE OPERATOR	DRILLING	0.53	0.62
MACHINE OPERATOR	DRILLING	0.53	0.53
MACHINE OPERATOR	DRILLING	0.53	0.65
MACHINE OPERATOR	DRILLING	0.53	0.60
MACHINE OPERATOR	DRILLING	0.54	0.65
MACHINE OPERATOR	DRILLING	0.54	0.59
MACHINE OPERATOR	DRILLING	0.55	0.64
MACHINE OPERATOR	DRILLING	0.55	0.69
MACHINE OPERATOR	DRILLING	0.55	0.96
MACHINE OPERATOR	DRILLING	0.56	0.61
MACHINE OPERATOR	DRILLING	0.56	0.59
MACHINE OPERATOR	DRILLING	0.56	0.65
MACHINE OPERATOR	DRILLING	0.57	0.60
MACHINE OPERATOR	DRILLING	0.58	0.64
MACHINE OPERATOR	DRILLING	0.58	0.69
MACHINE OPERATOR	DRILLING	0.60	0.65
MACHINE OPERATOR	DRILLING	0.61	0.78
MACHINE OPERATOR	DRILLING	0.61	0.69
MACHINE OPERATOR	DRILLING	0.61	0.73
MACHINE OPERATOR	DRILLING	0.61	0.64
MACHINE OPERATOR	DRILLING	0.61	0.66
MACHINE OPERATOR	DRILLING	0.61	0.72
MACHINE OPERATOR	DRILLING	0.64	0.71
MACHINE OPERATOR	DRILLING	0.64	0.79
MACHINE OPERATOR	DRILLING	0.66	0.86
MACHINE OPERATOR	DRILLING	0.67	0.86
MACHINE OPERATOR	DRILLING	0.68	0.80
MACHINE OPERATOR	DRILLING	0.68	0.80
MACHINE OPERATOR	DRILLING	0.69	0.79
MACHINE OPERATOR	DRILLING	0.69	0.75
MACHINE OPERATOR	DRILLING	0.69	0.73
MACHINE OPERATOR	DRILLING	0.71	0.86
MACHINE OPERATOR	DRILLING	0.72	0.77
MACHINE OPERATOR	DRILLING	0.72	0.94
MACHINE OPERATOR	DRILLING	0.72	1.09
MACHINE OPERATOR	DRILLING	0.73	0.92
MACHINE OPERATOR	DRILLING	0.74	0.87
MACHINE OPERATOR	DRILLING	0.75	1.03

TABLE 27 F   TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL
EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		mg/m3	mg/m3
MACHINE OPERATOR	DRILLING	0.75	0.95
MACHINE OPERATOR	DRILLING	0.76	0.77
MACHINE OPERATOR	DRILLING	0.76	0.85
MACHINE OPERATOR	DRILLING	0.77	0.91
MACHINE OPERATOR	DRILLING	0.79	1.30
MACHINE OPERATOR	DRILLING	0.80	0.94
MACHINE OPERATOR	DRILLING	0.87	1.00
MACHINE OPERATOR	DRILLING	0.88	1.29
MACHINE OPERATOR	DRILLING	0.92	1.16
MACHINE OPERATOR	DRILLING	0.95	1.21
MACHINE OPERATOR	DRILLING	0.96	1.59
MACHINE OPERATOR	DRILLING	1.04	1.51
MACHINE OPERATOR	DRILLING	1.05	1.21
MACHINE OPERATOR	DRILLING	1.18	1.05
MACHINE OPERATOR	DRILLING	1.18	2.07
MACHINE OPERATOR	DRILLING	1.18	1.68
MACHINE OPERATOR	DRILLING	1.19	2.02
MACHINE OPERATOR	DRILLING	1.19	1.91
MACHINE OPERATOR	DRILLING	1.22	1.29
MACHINE OPERATOR	DRILLING	1.26	2.21
MACHINE OPERATOR	DRILLING	1.32	2.37
MACHINE OPERATOR	DRILLING	1.36	2.78
MACHINE OPERATOR	DRILLING	1.38	2.02
MACHINE OPERATOR	DRILLING	1.45	2.08
MACHINE OPERATOR	DRILLING	1.85	3.75
MACHINE OPERATOR	DRILLING	11.95	22.31

TABLE 27 G TABLE 27 CONTINUED DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		[illegible]	[illegible]
LASHER	LASHING	0.01	0.01
LASHER	LASHING	0.02	0.02
LASHER	LASHING	0.02	0.02
LASHER	LASHING	0.03	0.03
LASHER	LASHING	0.03	0.03
LASHER	LASHING	0.04	0.04
LASHER	LASHING	0.05	0.06
LASHER	LASHING	0.06	0.05
LASHER	LASHING	0.07	0.08
LASHER	LASHING	0.09	0.10
LASHER	LASHING	0.10	0.14
LASHER	LASHING	0.11	0.13
LASHER	LASHING	0.12	0.13
LASHER	LASHING	0.12	0.13
LASHER	LASHING	0.13	0.13
LASHER	LASHING	0.14	0.16
LASHER	LASHING	0.16	0.18
LASHER	LASHING	0.24	0.30
LASHER	LASHING	0.24	0.26
LASHER	LASHING	0.25	0.28
LASHER	LASHING	0.25	0.41
LASHER	LASHING	0.26	0.27
LASHER	LASHING	0.27	0.32
LASHER	LASHING	0.27	0.30
LASHER	LASHING	0.29	0.36
LASHER	LASHING	0.29	0.34
LASHER	LASHING	0.30	0.34
LASHER	LASHING	0.30	0.35
LASHER	LASHING	0.34	0.39
LASHER	LASHING	0.34	0.36
LASHER	LASHING	0.36	0.41
LASHER	LASHING	0.37	0.42
LASHER	LASHING	0.37	0.40
LASHER	LASHING	0.37	0.47
LASHER	LASHING	0.38	0.41
LASHER	LASHING	0.41	0.45
LASHER	LASHING	0.41	0.49
LASHER	LASHING	0.44	0.56
LASHER	LASHING	0.44	0.48
LASHER	LASHING	0.44	0.45
LASHER	LASHING	0.48	0.57
LASHER	LASHING	0.49	0.59
LASHER	LASHING	0.50	0.60
LASHER	LASHING	0.50	0.63
LASHER	LASHING	0.59	0.59
LASHER	LASHING	0.61	0.74
LASHER	LASHING	0.62	0.73
LASHER	LASHING	0.62	0.78

TABLE 27 H TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		mg/m3	mg/m3
LASHER	LASHING	0.65	0.73
LASHER	LASHING	0.71	0.89
LASHER	LASHING	1.26	1.86
LASHING	LASHING	0.03	0.03
LASHING	LASHING	0.07	0.06
LASHING	LASHING	0.07	0.08
LASHING	LASHING	0.08	0.10
LASHING	LASHING	0.11	0.13
LASHING	LASHING	0.20	0.25
LASHING	LASHING	0.21	0.23
LASHING	LASHING	0.23	0.24
LASHING	LASHING	0.23	0.24
LASHING	LASHING	0.24	0.27
LASHING	LASHING	0.24	0.33
LASHING	LASHING	0.26	0.34
LASHING	LASHING	0.28	0.33
LASHING	LASHING	0.28	0.32
LASHING	LASHING	0.28	0.31
LASHING	LASHING	0.30	0.36
LASHING	LASHING	0.32	0.31
LASHING	LASHING	0.33	0.51
LASHING	LASHING	0.35	0.37
LASHING	LASHING	0.35	0.44
LASHING	LASHING	0.36	0.51
LASHING	LASHING	0.38	0.47
LASHING	LASHING	0.44	0.47
LASHING	LASHING	0.45	0.52
LASHING	LASHING	0.47	0.61
LASHING	LASHING	0.47	0.49
LASHING	LASHING	0.47	0.54
LASHING	LASHING	0.52	0.60
LASHING	LASHING	0.52	0.58
LASHING	LASHING	0.52	0.65
LASHING	LASHING	0.53	0.64
LASHING	LASHING	0.53	0.81
LASHING	LASHING	0.54	0.59
LASHING	LASHING	0.61	0.49
LASHING	LASHING	0.61	0.66
LASHING	LASHING	0.63	0.77
LASHING	LASHING	0.65	0.99
LASHING	LASHING	0.67	0.68
LASHING	LASHING	0.86	1.45
LASHING	LASHING	1.02	1.10
LASHING	LASHING	1.14	1.65
LASHING	LASHING	1.89	3.33

TABLE 27 I TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL
EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC mg/m3	CONC TWA mg/m3
ARTISAN AID	OTHER	0.10	0.11
ASSISTANT MACHINE OPERATOR	OTHER	0.45	0.77
ASST FITTER	OTHER	0.07	0.09
ASST LOCO DRIVER	OTHER	0.62	0.68
ASST MACHINE OPERATOR	OTHER	0.23	0.28
ASST MACHINE OPERATOR	OTHER	0.38	0.42
ASST MACHINE OPERATOR	OTHER	0.41	0.43
ASST MACHINE OPERATOR	OTHER	0.45	0.51
ASST PUMP OPERATOR	OTHER	0.09	0.12
BACKFILL OPERATOR	OTHER	0.05	0.05
BACKFILL OPERATOR	OTHER	0.06	0.06
BACKFILL OPERATOR	OTHER	0.28	0.30
BANKSMAN ASST	OTHER	0.19	0.21
BARRER	OTHER	0.04	0.04
BARRER	OTHER	0.05	0.06
BARRER	OTHER	0.09	0.11
BARRER	OTHER	0.22	0.23
BARRER	OTHER	0.26	0.33
BARRER	OTHER	0.28	0.37
BARRER	OTHER	0.32	0.56
BARRER	OTHER	0.36	0.63
BARRER	OTHER	0.39	0.47
BARRER	OTHER	0.50	0.55
BARRER	OTHER	0.56	0.64
BARRER	OTHER	0.56	0.74
BARRER	OTHER	0.58	0.71
BELL RING OPERATOR	OTHER	0.21	0.25
BELL RINGER	OTHER	0.12	0.13
BELL RINGER	OTHER	0.15	0.15
BELL RINGER	OTHER	0.35	0.34
BELL RINGER	OTHER	0.37	0.47
BELL RINGER	OTHER	0.51	0.54
BELL RINGER	OTHER	1.06	1.19
BELT LVL OPERATOR	OTHER	0.01	0.01
BLACKSMITH ASSISTANT	OTHER	0.02	0.02
BLACKSMITH ASST	OTHER	0.06	0.06
BLACKSMITH ASST	OTHER	0.17	0.16
BOILERMAKER AID	OTHER	0.04	0.04
BOILERMAKER AID	OTHER	0.09	0.08
BOILERMAKER AIDE	OTHER	0.04	0.06
BOILERMAKER AIDE	OTHER	0.09	0.12
BOILERMAKER AIDE	OTHER	0.26	0.28
BOILERMAKER AIDE	OTHER	0.32	0.36
BOILERMAKER AIDE	OTHER	0.39	0.52
BOILERMAKER AIDE	OTHER	0.44	0.44
BOILERMAKER ASSISTANT	OTHER	0.18	0.20
BOILERMAKER ASST	OTHER	0.07	0.07
BOILERMAKER ASST	OTHER	0.08	0.08

TABLE 27 J TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		[illegible]	[illegible]
BOILERMAKER ASST	OTHER	0.08	0.07
BOILERMAKER ASST	OTHER	0.10	0.10
BOILERMAKER ASST	OTHER	0.21	0.33
BOILERMAKER ASST	OTHER	0.24	0.21
BOILERMAKER ASST	OTHER	0.25	0.26
BOILERMAKER ASST	OTHER	0.28	0.24
BOILERMAKER ASST	OTHER	0.31	0.34
BOILERMAKER ASST	OTHER	0.33	0.39
CHECKER	OTHER	0.02	0.02
CHECKER	OTHER	0.03	0.03
CHEMICAL SPRAY	OTHER	0.14	0.13
CLEANER	OTHER	0.01	0.01
CLEANER	OTHER	0.11	0.11
CLEANER	OTHER	0.33	0.33
CLEANER	OTHER	0.34	0.68
CLEANER	OTHER	0.68	0.91
CLEANING	OTHER	0.01	0.00
CLEANING	OTHER	0.02	0.01
CLEANING	OTHER	0.28	0.25
CLEANING	OTHER	0.31	0.39
CLEANING	OTHER	0.49	0.53
CLEANING	OTHER	0.63	0.65
CLEANING	OTHER	0.77	0.82
CLEANING CHANGE HOUSE	OTHER	0.12	0.12
CLEANING DAM	OTHER	0.20	0.23
CLEANING DAM	OTHER	0.22	0.23
CLEANING DAM	OTHER	0.23	0.28
CLEANING DAM	OTHER	0.30	0.61
CLEANING DRAINS	OTHER	0.10	0.11
CLEANING FILER BAGS	OTHER	0.11	0.12
CLEANING FILTER BAGS	OTHER	0.05	0.07
CLEANING FILTER BAGS	OTHER	0.23	0.31
CLEANING FILTER BAGS	OTHER	0.26	0.26
CLEANING FILTER BAGS	OTHER	0.30	0.34
CLEANING FILTER BAGS	OTHER	0.31	0.34
CLEANING FILTER BAGS	OTHER	0.33	0.40
CLEANING FILTER BAGS	OTHER	0.38	0.48
CLEANING FILTER BAGS	OTHER	0.39	0.49
CLEANING FILTER BAGS	OTHER	0.42	0.57
CLEANING PUMPS	OTHER	0.15	0.15
CLEANING PUMPS	OTHER	0.25	0.25
CLEANING PUMPS	OTHER	0.35	0.35
CLEANING SECTION	OTHER	0.18	0.20
CLEANING SECTION	OTHER	0.24	0.21
CLEANING SECTION	OTHER	0.34	0.39
CLEANING SECTION	OTHER	0.37	0.46
CLEANING SECTION	OTHER	0.41	0.48
CLEANING SHAFT	OTHER	0.10	0.12

TABLE 27 K TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		mg/m3	mg/m3
CLEANING SHAFT	OTHER	0.24	0.29
CLEANING SHAFT	OTHER	0.29	0.36
CLEANING STASION	OTHER	0.17	0.19
CLEANING STATION	OTHER	0.07	0.07
CLEANING STATION	OTHER	0.10	0.12
CLEANING STATION	OTHER	0.12	0.12
CLEANING STATION	OTHER	0.15	0.16
CLEANING STATION	OTHER	0.20	0.32
CLEANING STATION	OTHER	0.25	0.23
CLEANING STATION	OTHER	0.30	0.37
CLEANING STATION	OTHER	0.31	0.37
CLEANING STATION	OTHER	0.31	0.30
CLEANING STATION	OTHER	0.33	0.33
CLEANING STATION	OTHER	0.35	0.36
CLEANING STATION	OTHER	0.46	0.45
CLEANING STORE	OTHER	0.05	0.05
CLEANING STORE	OTHER	0.06	0.06
CLEANING STORE	OTHER	0.32	0.42
CLEANING STORE	OTHER	0.39	0.37
CLEANING STORES	OTHER	0.40	0.41
CLEANING SUB STATION	OTHER	0.02	0.02
CLEANING SUB STATION	OTHER	0.18	0.19
CLOSING CAGE DOORS	OTHER	0.14	0.16
CLOSING DOORS	OTHER	0.38	0.47
DOOR ATTENDANT	OTHER	0.06	0.06
DRILL SHARP ASST	OTHER	0.28	0.29
ELECTRIAN ASST	OTHER	0.37	0.46
ELECTRICIAN AIDE	OTHER	0.07	0.08
ELECTRICIAN AIDE	OTHER	1.30	2.18
ELECTRICIAN ASSISTANT	OTHER	0.51	0.69
ELECTRICIAN ASST	OTHER	0.12	0.14
ELECTRICIAN ASST	OTHER	0.23	0.25
ELECTRICIAN ASST	OTHER	0.31	0.28
FILTER BAG CLEANER	OTHER	0.03	0.02
FITTER AID	OTHER	0.08	0.09
FITTER AID	OTHER	0.09	0.08
FITTER AID	OTHER	0.10	0.19
FITTER AID	OTHER	0.12	0.23
FITTER AID	OTHER	0.13	0.26
FITTER AID	OTHER	0.21	0.40
FITTER AID	OTHER	0.43	0.45
FITTER AIDE	OTHER	0.60	0.82
FITTER AIDE	OTHER	1.11	1.35
FITTER ASSISTANT	OTHER	0.30	0.31
FITTER ASST	OTHER	0.08	0.08
FITTER ASST	OTHER	0.22	0.21
FITTER ASST	OTHER	0.32	0.26
FITTER ASST	OTHER	0.32	0.50

TABLE 27 L TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		[illegible]	[illegible]
FITTER ASST	OTHER	0.56	0.78
GENERAL LABOURER	OTHER	0.24	0.24
GENERAL LABOURER	OTHER	0.38	0.45
GENERAL LABOURER	OTHER	0.46	0.54
GENERAL T/LEADER	OTHER	0.40	0.52
HOISTING ENGINE	OTHER	0.03	0.03
INSTALLING CABLE	OTHER	0.03	0.03
INSTALLING LIGHTS	OTHER	0.16	0.18
INSTALLING LIGHTS	OTHER	0.19	0.20
INSTALLING LIGHTS	OTHER	0.29	0.37
LAUNDRY	OTHER	0.04	0.04
LAUNDRY T/LEADER	OTHER	0.05	0.05
LOADER	OTHER	0.54	0.68
LOADER DRIVER	OTHER	0.26	0.26
LOADER DRIVER	OTHER	0.34	0.30
LOADER DRIVER	OTHER	0.53	0.52
LOADING	OTHER	0.41	0.53
LOADING	OTHER	0.41	0.51
LOADING	OTHER	0.54	0.57
LOADING REEF	OTHER	0.53	0.65
LOCO FITTER	OTHER	0.07	0.06
MACHANICAL LOADER	OTHER	0.24	0.28
MACHANICAL LOADER	OTHER	0.39	0.38
MACHANICAL LOADER	OTHER	0.80	0.94
MACHENICAL LOADER	OTHER	0.21	0.23
MACHENICAL LOADING	OTHER	0.42	0.50
MACHINE ASST	OTHER	0.31	0.50
MACHINE ASST	OTHER	0.36	0.47
MACHINE ASST	OTHER	0.40	0.44
MACHINE ASST	OTHER	0.46	0.51
MACHINE ASST	OTHER	0.49	0.64
MACHINE EQUIP OPERATOR	OTHER	0.49	0.63
MACHINE OPERATOR ASSISTANT	OTHER	0.25	0.31
MACHINE OPERATOR ASSISTANT	OTHER	0.45	0.60
MACHINE OPERATOR ASSISTANT	OTHER	1.57	2.91
MACHINE OPERATOR ASST	OTHER	0.01	0.01
MACHINE OPERATOR ASST	OTHER	0.07	0.08
MACHINE OPERATOR ASST	OTHER	0.12	0.14
MACHINE OPERATOR ASST	OTHER	0.50	0.65
MACHINE OPERATOR ASST	OTHER	0.58	0.66
MACHINE OPRATOR ASST	OTHER	0.14	0.13
MACHINECAL LOADER	OTHER	0.86	1.10
MACHINICAL LOADER	OTHER	0.12	0.14
MACHINICAL LOADER	OTHER	0.14	0.17
MACHINICAL LOADER	OTHER	0.29	0.39
MECH EQUIP OPERATOR	OTHER	0.05	0.05
MECH EQUIP OPERATOR	OTHER	0.06	0.06
MECH EQUIP OPERATOR	OTHER	0.37	0.40

TABLE 27 M TABLE 27 CONTINUED DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
[illegible]	[illegible]	[illegible]	[illegible]
MECH EQUIP OPERATOR	OTHER	0.45	0.58
MECHANIAL LOADER	OTHER	0.41	0.46
MECHANICAL EQUIP OPERATOR	OTHER	0.21	0.23
MECHANICAL LOADER	OTHER	0.00	0.00
MECHANICAL LOADER	OTHER	0.03	0.03
MECHANICAL LOADER	OTHER	0.04	0.04
MECHANICAL LOADER	OTHER	0.04	0.04
MECHANICAL LOADER	OTHER	0.05	0.05
MECHANICAL LOADER	OTHER	0.08	0.09
MECHANICAL LOADER	OTHER	0.09	0.09
MECHANICAL LOADER	OTHER	0.10	0.11
MECHANICAL LOADER	OTHER	0.14	0.17
MECHANICAL LOADER	OTHER	0.15	0.14
MECHANICAL LOADER	OTHER	0.16	0.19
MECHANICAL LOADER	OTHER	0.16	0.18
MECHANICAL LOADER	OTHER	0.17	0.18
MECHANICAL LOADER	OTHER	0.17	0.19
MECHANICAL LOADER	OTHER	0.20	0.21
MECHANICAL LOADER	OTHER	0.22	0.27
MECHANICAL LOADER	OTHER	0.25	0.31
MECHANICAL LOADER	OTHER	0.25	0.30
MECHANICAL LOADER	OTHER	0.27	0.31
MECHANICAL LOADER	OTHER	0.28	0.32
MECHANICAL LOADER	OTHER	0.31	0.48
MECHANICAL LOADER	OTHER	0.31	0.36
MECHANICAL LOADER	OTHER	0.32	0.34
MECHANICAL LOADER	OTHER	0.34	0.39
MECHANICAL LOADER	OTHER	0.36	0.38
MECHANICAL LOADER	OTHER	0.36	0.42
MECHANICAL LOADER	OTHER	0.37	0.46
MECHANICAL LOADER	OTHER	0.37	0.42
MECHANICAL LOADER	OTHER	0.37	0.42
MECHANICAL LOADER	OTHER	0.40	0.46
MECHANICAL LOADER	OTHER	0.41	0.46
MECHANICAL LOADER	OTHER	0.41	0.52
MECHANICAL LOADER	OTHER	0.42	0.51
MECHANICAL LOADER	OTHER	0.42	0.54
MECHANICAL LOADER	OTHER	0.45	0.48
MECHANICAL LOADER	OTHER	0.45	0.46
MECHANICAL LOADER	OTHER	0.45	0.63
MECHANICAL LOADER	OTHER	0.46	0.48
MECHANICAL LOADER	OTHER	0.47	0.48
MECHANICAL LOADER	OTHER	0.48	0.83
MECHANICAL LOADER	OTHER	0.49	0.56
MECHANICAL LOADER	OTHER	0.49	0.52
MECHANICAL LOADER	OTHER	0.55	0.56
MECHANICAL LOADER	OTHER	0.61	1.02
MECHANICAL LOADER	OTHER	0.62	0.77

TABLE 27 N   TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL
EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC mg/m3	CONC TWA mg/m3
MECHANICAL LOADER	OTHER	0.99	1.08
MECHANICAL LOADING	OTHER	0.34	0.39
MECHANICAL LOADING	OTHER	0.41	0.47
MECHANICAL LOADING	OTHER	0.56	0.58
MINER ASST	OTHER	0.26	0.27
MINER ASST	OTHER	0.75	0.79
MINERS ASST	OTHER	0.59	0.65
ONSETTER'S ASST	OTHER	0.03	0.03
ONSETTER'S ASST	OTHER	0.06	0.04
PAINTER	OTHER	0.10	0.10
PAINTING	OTHER	0.51	0.62
PAINTING LOCO	OTHER	0.49	0.48
PARADE CHECKER	OTHER	0.03	0.03
PLANT ARTISAN	OTHER	0.15	0.18
PLANT ATTENDANT	OTHER	2.41	4.16
PUMP ASSISTANT OPERATOR	OTHER	0.15	0.26
PUMP ASSISTANT OPERATOR	OTHER	0.19	0.19
PUMP ASST	OTHER	0.28	0.38
PUMP ASST	OTHER	0.37	0.39
PUMP ATTENDANT	OTHER	0.02	0.01
PUMP ATTENDANT	OTHER	0.02	0.01
PUMP ATTENDANT	OTHER	0.02	0.02
PUMP ATTENDANT	OTHER	0.04	0.04
PUMP ATTENDANT	OTHER	0.09	0.08
PUMP ATTENDANT	OTHER	0.23	0.24
PUMP ATTENDANT	OTHER	0.34	0.36
PUMP ATTENDENT	OTHER	0.24	0.27
PUMP CLEANER	OTHER	0.49	0.23
PUMP OPERATOR	OTHER	0.01	0.00
PUMP OPERATOR	OTHER	0.02	0.03
PUMP OPERATOR	OTHER	0.03	0.02
PUMP OPERATOR	OTHER	0.04	0.04
PUMP OPERATOR	OTHER	0.04	0.04
PUMP OPERATOR	OTHER	0.05	0.05
PUMP OPERATOR	OTHER	0.05	0.05
PUMP OPERATOR	OTHER	0.06	0.07
PUMP OPERATOR	OTHER	0.06	0.08
PUMP OPERATOR	OTHER	0.06	0.06
PUMP OPERATOR	OTHER	0.08	0.12
PUMP OPERATOR	OTHER	0.10	0.10
PUMP OPERATOR	OTHER	0.12	0.15
PUMP OPERATOR	OTHER	0.14	0.18
PUMP OPERATOR	OTHER	0.14	0.18
PUMP OPERATOR	OTHER	0.14	0.19
PUMP OPERATOR	OTHER	0.15	0.14
PUMP OPERATOR	OTHER	0.15	0.19
PUMP OPERATOR	OTHER	0.15	0.17
PUMP OPERATOR	OTHER	0.15	0.14

TABLE 27 O TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL
EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
PUMP OPERATOR	OTHER	0.16	0.20
PUMP OPERATOR	OTHER	0.16	0.17
PUMP OPERATOR	OTHER	0.17	0.15
PUMP OPERATOR	OTHER	0.17	0.26
PUMP OPERATOR	OTHER	0.18	0.18
PUMP OPERATOR	OTHER	0.19	0.32
PUMP OPERATOR	OTHER	0.22	0.25
PUMP OPERATOR	OTHER	0.22	0.38
PUMP OPERATOR	OTHER	0.26	0.28
PUMP OPERATOR	OTHER	0.27	0.37
PUMP OPERATOR	OTHER	0.27	0.36
PUMP OPERATOR	OTHER	0.27	0.27
PUMP OPERATOR	OTHER	0.27	0.27
PUMP OPERATOR	OTHER	0.28	0.31
PUMP OPERATOR	OTHER	0.28	0.36
PUMP OPERATOR	OTHER	0.29	0.33
PUMP OPERATOR	OTHER	0.29	0.30
PUMP OPERATOR	OTHER	0.29	0.30
PUMP OPERATOR	OTHER	0.31	0.36
PUMP OPERATOR	OTHER	0.31	0.33
PUMP OPERATOR	OTHER	0.32	0.54
PUMP OPERATOR	OTHER	0.33	0.33
PUMP OPERATOR	OTHER	0.36	0.42
PUMP OPERATOR	OTHER	0.37	0.45
PUMP OPERATOR	OTHER	0.38	0.33
PUMP OPERATOR	OTHER	0.39	0.53
PUMP OPERATOR	OTHER	0.40	0.56
PUMP OPERATOR	OTHER	0.41	0.55
PUMP OPERATOR	OTHER	0.42	0.42
PUMP OPERATOR	OTHER	0.45	0.37
PUMP OPERATOR	OTHER	0.45	0.61
PUMP OPERATOR	OTHER	0.48	0.52
PUMP OPERATOR	OTHER	0.50	0.57
PUMP OPERATOR	OTHER	0.53	0.71
PUMP OPERATOR	OTHER	0.54	0.63
PUMP OPERATOR	OTHER	0.85	0.83
PUMP OPERATOR	OTHER	0.92	1.78
PUMP OPERATOR	OTHER	2.26	3.78
PUMP OPERATOR ASST	OTHER	0.26	0.34
PUMP OPERATOR ASST	OTHER	0.31	0.33
PUMP OPERATOR ASST	OTHER	0.33	0.47
PUMP SUPERVISION	OTHER	0.30	0.41
PUMP SUPERVISOR	OTHER	0.40	0.51
REPAIR LOCO	OTHER	0.19	0.22
REPAIRED WINCH	OTHER	0.20	0.25
REPAIRED LOCO	OTHER	0.23	0.24
REPAIRING LOADER	OTHER	0.24	0.29
REPAIRING LOCO	OTHER	0.07	0.10

TABLE 27 P TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		[illegible]	[illegible]
REPAIRING LOCO	OTHER	0.14	0.15
REPAIRING LOCO	OTHER	0.54	0.71
REPAIRING LOCO	OTHER	1.32	1.65
RIGGER AID	OTHER	0.17	0.22
RIGGER AID	OTHER	0.32	0.43
SAMPLING ASST	OTHER	0.01	0.01
SAMPLING ASST	OTHER	0.02	0.01
SAMPLING ASST	OTHER	0.02	0.01
SAMPLING ASST	OTHER	0.07	0.06
SANITATION	OTHER	0.12	0.13
SANITATION	OTHER	0.16	0.17
SANITATION	OTHER	0.16	0.19
SANITATION	OTHER	0.24	0.26
SECURITY GUARD	OTHER	0.02	0.01
SECURITY GUARD	OTHER	0.04	0.04
SECURITY GUARD	OTHER	0.06	0.02
SECURITY GUARD	OTHER	0.06	0.06
SECURITY GUARD	OTHER	0.10	0.08
SECURITY GUARD	OTHER	0.14	0.11
SECURITY GUARD	OTHER	0.16	0.16
SERVICE LOCO	OTHER	0.23	0.32
SERVICE LOCO	OTHER	0.26	0.28
SERVICE LOCO	OTHER	0.29	0.27
SERVICE PUMP CHAMBER	OTHER	0.29	0.32
SERVICING LOCO	OTHER	0.08	0.08
SERVICING LOCO	OTHER	0.12	0.21
SERVICING LOCO	OTHER	0.27	0.29
SERVICING PUMPS	OTHER	0.22	0.22
SERVICING PUMPS	OTHER	0.23	0.25
SHAFT OBSERVATION	OTHER	0.33	0.36
SHIFT BOSS ASST	OTHER	0.07	0.07
SHIFT CONTROLLER	OTHER	0.08	0.10
SHIFT CONTROLLER	OTHER	0.08	0.11
SHIFT CONTROLLER	OTHER	0.10	0.13
SHIFT CONTROLLER	OTHER	0.14	0.21
SHIFT CONTROLLER	OTHER	0.53	0.76
SHIFT CONTROLLER	OTHER	0.69	0.93
SHIFT CONTROLLER	OTHER	0.73	1.04
SKIP LOADER	OTHER	0.09	0.11
SPECIAL BARRER	OTHER	0.02	0.02
SPECIAL BARRER	OTHER	0.04	0.04
SPECIAL BARRER	OTHER	0.09	0.09
SPECIAL BARRER	OTHER	0.09	0.10
SPECIAL BARRER	OTHER	0.18	0.22
SPECIAL BARRER	OTHER	0.19	0.21
SPECIAL BARRER	OTHER	0.19	0.23
SPECIAL BARRER	OTHER	0.25	0.30
SPECIAL BARRER	OTHER	0.30	0.35

TABLE 27 Q TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL
EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		mg/m3	mg/m3
SPECIAL BARRER	OTHER	0.33	0.47
SPECIAL BARRER	OTHER	0.34	0.42
SPECIAL BARRER	OTHER	0.41	0.43
SPECIAL BARRER	OTHER	0.43	0.48
SPECIAL BARRER	OTHER	0.47	0.48
SPECIAL BARRER	OTHER	0.48	0.59
SPECIAL BARRER	OTHER	0.52	0.65
SPECIAL BARRER	OTHER	0.53	0.64
SPECIAL BARRER	OTHER	0.53	0.86
SPECIAL BARRER	OTHER	0.57	0.59
SPECIAL BARRER	OTHER	0.66	0.71
SPECIAL BARRER	OTHER	0.78	0.77
SPECIAL BARRER	OTHER	0.79	1.07
SPECIAL BARRER	OTHER	1.01	1.26
SPECIAL BARRER	OTHER	1.12	1.89
SPECIAL BARRER	OTHER	3.14	5.46
SPECIAL OPERATOR	OTHER	0.31	0.37
STONE SORTER	OTHER	2.42	2.84
STONE SORTING	OTHER	3.83	6.26
STOPING	OTHER	0.16	0.18
STOPING	OTHER	0.18	0.20
STORE MAN	OTHER	0.09	0.10
STORE MAN	OTHER	0.33	0.46
STORE MAN	OTHER	0.54	0.51
STORE SUPERVISOR	OTHER	0.04	0.04
STOREMAN	OTHER	0.09	0.09
SURVEY ASST	OTHER	0.03	0.02
SWEEPING	OTHER	0.43	0.46
TEA MAKER	OTHER	0.01	0.01
TEA MAKER	OTHER	0.02	0.02
TEA MAKER	OTHER	0.03	0.03
TEA MAKER	OTHER	0.04	0.04
TEA MAKER	OTHER	0.04	0.05
TEA MAKER	OTHER	0.05	0.05
TEA MAKER	OTHER	0.07	0.07
TEA MAKER	OTHER	0.10	0.09
TEA MAKER	OTHER	0.10	0.10
TEA MAKER	OTHER	0.12	0.12
TEA MAKER	OTHER	0.15	0.16
TIP INSPECTION	OTHER	0.14	0.16
TIP INSPECTION	OTHER	0.20	0.20
TIP INSPECTION	OTHER	0.35	0.38
TORCH CUTTING	OTHER	0.63	0.82
TRAMMING	OTHER	0.02	0.02
TRAMMING	OTHER	0.04	0.03
TRAMMING	OTHER	0.04	0.06
TRAMMING	OTHER	0.05	0.07
TRAMMING	OTHER	0.06	0.07

TABLE 27 R TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL
EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC mg/m3	CONC TWA mg/m3
TRAMMING	OTHER	0.09	0.09
TRAMMING	OTHER	0.09	0.08
TRAMMING	OTHER	0.09	0.08
TRAMMING	OTHER	0.10	0.12
TRAMMING	OTHER	0.10	0.12
TRAMMING	OTHER	0.11	0.13
TRAMMING	OTHER	0.12	0.14
TRAMMING	OTHER	0.13	0.14
TRAMMING	OTHER	0.13	0.14
TRAMMING	OTHER	0.17	0.19
TRAMMING	OTHER	0.17	0.20
TRAMMING	OTHER	0.17	0.19
TRAMMING	OTHER	0.19	0.18
TRAMMING	OTHER	0.19	0.18
TRAMMING	OTHER	0.20	0.27
TRAMMING	OTHER	0.21	0.20
TRAMMING	OTHER	0.21	0.25
TRAMMING	OTHER	0.22	0.25
TRAMMING	OTHER	0.22	0.26
TRAMMING	OTHER	0.23	0.28
TRAMMING	OTHER	0.24	0.29
TRAMMING	OTHER	0.24	0.28
TRAMMING	OTHER	0.25	0.30
TRAMMING	OTHER	0.25	0.27
TRAMMING	OTHER	0.25	0.29
TRAMMING	OTHER	0.25	0.30
TRAMMING	OTHER	0.25	0.26
TRAMMING	OTHER	0.25	0.31
TRAMMING	OTHER	0.26	0.30
TRAMMING	OTHER	0.26	0.28
TRAMMING	OTHER	0.27	0.32
TRAMMING	OTHER	0.27	0.28
TRAMMING	OTHER	0.28	0.33
TRAMMING	OTHER	0.29	0.32
TRAMMING	OTHER	0.30	0.41
TRAMMING	OTHER	0.30	0.38
TRAMMING	OTHER	0.31	0.31
TRAMMING	OTHER	0.32	0.34
TRAMMING	OTHER	0.32	0.33
TRAMMING	OTHER	0.33	0.37
TRAMMING	OTHER	0.33	0.38
TRAMMING	OTHER	0.33	0.42
TRAMMING	OTHER	0.37	0.38
TRAMMING	OTHER	0.39	0.47
TRAMMING	OTHER	0.39	0.58
TRAMMING	OTHER	0.39	0.47
TRAMMING	OTHER	0.40	0.42
TRAMMING	OTHER	0.40	0.51

TABLE 27 S TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		mg/m3	mg/m3
TRAMMING	OTHER	0.41	0.47
TRAMMING	OTHER	0.43	0.42
TRAMMING	OTHER	0.43	0.44
TRAMMING	OTHER	0.43	0.44
TRAMMING	OTHER	0.43	0.45
TRAMMING	OTHER	0.44	0.45
TRAMMING	OTHER	0.44	0.52
TRAMMING	OTHER	0.45	0.49
TRAMMING	OTHER	0.45	0.49
TRAMMING	OTHER	0.47	0.48
TRAMMING	OTHER	0.48	0.51
TRAMMING	OTHER	0.48	0.53
TRAMMING	OTHER	0.48	0.61
TRAMMING	OTHER	0.49	0.57
TRAMMING	OTHER	0.49	0.54
TRAMMING	OTHER	0.50	0.53
TRAMMING	OTHER	0.51	0.58
TRAMMING	OTHER	0.52	0.68
TRAMMING	OTHER	0.52	0.58
TRAMMING	OTHER	0.53	0.57
TRAMMING	OTHER	0.54	0.57
TRAMMING	OTHER	0.54	0.73
TRAMMING	OTHER	0.56	0.68
TRAMMING	OTHER	0.56	0.58
TRAMMING	OTHER	0.58	0.64
TRAMMING	OTHER	0.59	0.71
TRAMMING	OTHER	0.61	0.77
TRAMMING	OTHER	0.62	0.69
TRAMMING	OTHER	0.63	0.71
TRAMMING	OTHER	0.65	0.77
TRAMMING	OTHER	0.65	0.65
TRAMMING	OTHER	0.70	0.81
TRAMMING	OTHER	0.71	0.75
TRAMMING	OTHER	0.74	0.73
TRAMMING	OTHER	0.75	1.27
TRAMMING	OTHER	0.76	0.92
TRAMMING	OTHER	0.77	0.92
TRAMMING	OTHER	0.77	0.87
TRAMMING	OTHER	0.78	0.89
TRAMMING	OTHER	0.80	1.13
TRAMMING	OTHER	0.81	1.16
TRAMMING	OTHER	0.82	1.02
TRAMMING	OTHER	0.84	0.97
TRAMMING	OTHER	0.84	1.13
TRAMMING	OTHER	0.84	0.91
TRAMMING	OTHER	0.92	1.10
TRAMMING	OTHER	0.94	1.33
TRAMMING	OTHER	0.99	1.24

TABLE 27 T TABLE 27 CONTINUED DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
TRAMMING	OTHER	1.01	1.22
TRAMMING	OTHER	1.09	1.72
TRAMMING	OTHER	1.26	1.32
TRAMMING	OTHER	1.35	1.75
TRAMMING	OTHER	1.95	2.07
VENT ASSISTANT	OTHER	0.34	0.37
VENT ASSISTANT	OTHER	0.57	0.60
VENT ASST	OTHER	0.01	0.01
VENT ASST	OTHER	0.02	0.02
VENT ASST	OTHER	0.03	0.03
VENT ASST	OTHER	0.05	0.05
VENT ASST	OTHER	0.06	0.06
VENT ASST	OTHER	0.06	0.07
VENT ASST	OTHER	0.10	0.11
VENT ASST	OTHER	0.11	0.15
VENT ASST	OTHER	0.11	0.14
VENT ASST	OTHER	0.11	0.14
VENT ASST	OTHER	0.12	0.12
VENT ASST	OTHER	0.12	0.18
VENT ASST	OTHER	0.13	0.14
VENT ASST	OTHER	0.13	0.16
VENT ASST	OTHER	0.13	0.18
VENT ASST	OTHER	0.13	0.14
VENT ASST	OTHER	0.14	0.17
VENT ASST	OTHER	0.14	0.15
VENT ASST	OTHER	0.14	0.17
VENT ASST	OTHER	0.15	0.17
VENT ASST	OTHER	0.16	0.19
VENT ASST	OTHER	0.16	0.17
VENT ASST	OTHER	0.16	0.23
VENT ASST	OTHER	0.18	0.18
VENT ASST	OTHER	0.18	0.22
VENT ASST	OTHER	0.18	0.18
VENT ASST	OTHER	0.19	0.15
VENT ASST	OTHER	0.19	0.21
VENT ASST	OTHER	0.19	0.22
VENT ASST	OTHER	0.20	0.22
VENT ASST	OTHER	0.20	0.23
VENT ASST	OTHER	0.20	0.29
VENT ASST	OTHER	0.21	0.21
VENT ASST	OTHER	0.21	0.23
VENT ASST	OTHER	0.23	0.27
VENT ASST	OTHER	0.24	0.26
VENT ASST	OTHER	0.27	0.27
VENT ASST	OTHER	0.27	0.30
VENT ASST	OTHER	0.31	0.30
VENT ASST	OTHER	0.32	0.34
VENT ASST	OTHER	0.33	0.34

TABLE 27 U TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		mg/m3	mg/m3
VENT ASST	OTHER	0.41	0.53
VENT ASST	OTHER	0.43	0.51
VENT ASST	OTHER	0.44	0.47
VENT ASST	OTHER	0.46	0.51
VENT ASST	OTHER	0.49	0.59
VENT ASST	OTHER	0.66	0.72
VENT ASST	OTHER	1.06	1.11
VENT SURVEY	OTHER	0.03	0.03
VENTILATION ASST	OTHER	0.08	0.09
VENTIlATION ASST	OTHER	0.16	0.16
VENTILATION ASST	OTHER	0.41	0.46
WASHING STORE	OTHER	0.26	0.32
WASTE SORTING	OTHER	0.04	0.04
WELDER	OTHER	0.07	0.07
WELDING	OTHER	0.09	0.08
WELDING	OTHER	0.09	0.08
WINCH DRIVER	OTHER	0.17	0.18
WINCH DRIVER	OTHER	0.21	0.24
WINCH DRIVER	OTHER	0.22	0.40
WINCH DRIVER	OTHER	0.29	0.36
WINCH DRIVER	OTHER	0.64	0.72
WINCH DRIVER	OTHER	0.66	0.76

TABLE 27 V TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL
EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		mg/m3	mg/m3
SPECIAL TEAM LEADER	SUPERVISION	0.04	0.05
SPECIAL TEAM LEADER	SUPERVISION	0.09	0.11
SPECIAL TEAM LEADER	SUPERVISION	0.23	0.30
SPECIAL TEAM LEADER	SUPERVISION	0.32	0.44
SPECIAL TEAM LEADER	SUPERVISION	0.34	0.49
SPECIAL TEAM LEADER	SUPERVISION	0.91	1.32
SPECIAL TL	SUPERVISION	0.63	0.85
SUPERVISION	SUPERVISION	0.01	0.00
SUPERVISION	SUPERVISION	0.02	0.02
SUPERVISION	SUPERVISION	0.04	0.03
SUPERVISION	SUPERVISION	0.04	0.04
SUPERVISION	SUPERVISION	0.06	0.08
SUPERVISION	SUPERVISION	0.07	0.15
SUPERVISION	SUPERVISION	0.07	0.08
SUPERVISION	SUPERVISION	0.10	0.12
SUPERVISION	SUPERVISION	0.18	0.22
SUPERVISION	SUPERVISION	0.20	0.24
SUPERVISION	SUPERVISION	0.20	0.22
SUPERVISION	SUPERVISION	0.24	0.29
SUPERVISION	SUPERVISION	0.26	0.26
SUPERVISION	SUPERVISION	0.27	0.29
SUPERVISION	SUPERVISION	0.27	0.32
SUPERVISION	SUPERVISION	0.27	0.40
SUPERVISION	SUPERVISION	0.29	0.34
SUPERVISION	SUPERVISION	0.39	0.60
SUPERVISION	SUPERVISION	0.47	0.48
SUPERVISION	SUPERVISION	0.48	0.62
SUPERVISION	SUPERVISION	0.54	0.68
SUPERVISION	SUPERVISION	0.55	0.51
SUPERVISION	SUPERVISION	0.56	0.60
SUPERVISION	SUPERVISION	0.64	0.53
SUPERVISION	SUPERVISION	0.68	0.67
SUPERVISOR	SUPERVISION	0.13	0.19

TABLE 27 W   TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL
EXPOSURE DATA - MINE 1
DETAILS OF MINE'S OCCUPATIONAL

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		[illegible]	[illegible]
SUPPORT	SUPPORT	0.01	0.00
SUPPORT	SUPPORT	0.01	0.00
SUPPORT	SUPPORT	0.02	0.02
SUPPORT	SUPPORT	0.03	0.03
SUPPORT	SUPPORT	0.04	0.04
SUPPORT	SUPPORT	0.04	0.05
SUPPORT	SUPPORT	0.04	0.05
SUPPORT	SUPPORT	0.05	0.06
SUPPORT	SUPPORT	0.05	0.04
SUPPORT	SUPPORT	0.06	0.05
SUPPORT	SUPPORT	0.07	0.07
SUPPORT	SUPPORT	0.09	0.09
SUPPORT	SUPPORT	0.09	0.09
SUPPORT	SUPPORT	0.09	0.11
SUPPORT	SUPPORT	0.12	0.12
SUPPORT	SUPPORT	0.12	0.14
SUPPORT	SUPPORT	0.13	0.13
SUPPORT	SUPPORT	0.13	0.13
SUPPORT	SUPPORT	0.14	0.17
SUPPORT	SUPPORT	0.14	0.17
SUPPORT	SUPPORT	0.15	0.18
SUPPORT	SUPPORT	0.16	0.18
SUPPORT	SUPPORT	0.16	0.19
SUPPORT	SUPPORT	0.16	0.19
SUPPORT	SUPPORT	0.17	0.19
SUPPORT	SUPPORT	0.17	0.19
SUPPORT	SUPPORT	0.19	0.21
SUPPORT	SUPPORT	0.21	0.27
SUPPORT	SUPPORT	0.21	0.31
SUPPORT	SUPPORT	0.21	0.27
SUPPORT	SUPPORT	0.22	0.31
SUPPORT	SUPPORT	0.22	0.26
SUPPORT	SUPPORT	0.24	0.24
SUPPORT	SUPPORT	0.24	0.42
SUPPORT	SUPPORT	0.24	0.26
SUPPORT	SUPPORT	0.24	0.30
SUPPORT	SUPPORT	0.26	0.31
SUPPORT	SUPPORT	0.26	0.33
SUPPORT	SUPPORT	0.26	0.43
SUPPORT	SUPPORT	0.26	0.31
SUPPORT	SUPPORT	0.26	0.35
SUPPORT	SUPPORT	0.26	0.30
SUPPORT	SUPPORT	0.27	0.31
SUPPORT	SUPPORT	0.27	0.35
SUPPORT	SUPPORT	0.28	0.34
SUPPORT	SUPPORT	0.28	0.32
SUPPORT	SUPPORT	0.28	0.35
SUPPORT	SUPPORT	0.28	0.31

TABLE 27 X TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL
EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		mg/m3	mg/m3
SUPPORT	SUPPORT	0.29	0.32
SUPPORT	SUPPORT	0.29	0.30
SUPPORT	SUPPORT	0.30	0.37
SUPPORT	SUPPORT	0.30	0.31
SUPPORT	SUPPORT	0.30	0.40
SUPPORT	SUPPORT	0.30	0.41
SUPPORT	SUPPORT	0.30	0.39
SUPPORT	SUPPORT	0.31	0.38
SUPPORT	SUPPORT	0.31	0.41
SUPPORT	SUPPORT	0.31	0.35
SUPPORT	SUPPORT	0.31	0.37
SUPPORT	SUPPORT	0.32	0.36
SUPPORT	SUPPORT	0.32	0.40
SUPPORT	SUPPORT	0.32	0.29
SUPPORT	SUPPORT	0.33	0.47
SUPPORT	SUPPORT	0.33	0.41
SUPPORT	SUPPORT	0.33	0.44
SUPPORT	SUPPORT	0.33	0.40
SUPPORT	SUPPORT	0.34	0.47
SUPPORT	SUPPORT	0.35	0.39
SUPPORT	SUPPORT	0.36	0.41
SUPPORT	SUPPORT	0.36	0.42
SUPPORT	SUPPORT	0.36	0.42
SUPPORT	SUPPORT	0.36	0.42
SUPPORT	SUPPORT	0.37	0.49
SUPPORT	SUPPORT	0.38	0.46
SUPPORT	SUPPORT	0.39	0.42
SUPPORT	SUPPORT	0.40	0.45
SUPPORT	SUPPORT	0.40	0.46
SUPPORT	SUPPORT	0.40	0.50
SUPPORT	SUPPORT	0.40	0.44
SUPPORT	SUPPORT	0.41	0.41
SUPPORT	SUPPORT	0.41	0.51
SUPPORT	SUPPORT	0.43	0.55
SUPPORT	SUPPORT	0.43	0.74
SUPPORT	SUPPORT	0.44	0.49
SUPPORT	SUPPORT	0.44	0.62
SUPPORT	SUPPORT	0.44	0.46
SUPPORT	SUPPORT	0.44	0.45
SUPPORT	SUPPORT	0.44	0.43
SUPPORT	SUPPORT	0.45	0.53
SUPPORT	SUPPORT	0.45	0.60
SUPPORT	SUPPORT	0.45	0.50
SUPPORT	SUPPORT	0.46	0.59
SUPPORT	SUPPORT	0.46	0.55
SUPPORT	SUPPORT	0.48	0.58
SUPPORT	SUPPORT	0.48	0.58
SUPPORT	SUPPORT	0.49	0.54

TABLE 27 Y TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL
EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC mg/m3	CONC TWA mg/m3
SUPPORT	SUPPORT	0.49	0.56
SUPPORT	SUPPORT	0.50	0.70
SUPPORT	SUPPORT	0.50	0.59
SUPPORT	SUPPORT	0.51	0.62
SUPPORT	SUPPORT	0.51	0.63
SUPPORT	SUPPORT	0.52	0.53
SUPPORT	SUPPORT	0.53	0.63
SUPPORT	SUPPORT	0.54	0.51
SUPPORT	SUPPORT	0.54	0.64
SUPPORT	SUPPORT	0.54	0.73
SUPPORT	SUPPORT	0.55	0.62
SUPPORT	SUPPORT	0.56	0.83
SUPPORT	SUPPORT	0.57	0.66
SUPPORT	SUPPORT	0.57	0.66
SUPPORT	SUPPORT	0.58	0.68
SUPPORT	SUPPORT	0.58	0.71
SUPPORT	SUPPORT	0.58	0.62
SUPPORT	SUPPORT	0.59	0.61
SUPPORT	SUPPORT	0.59	0.65
SUPPORT	SUPPORT	0.59	0.65
SUPPORT	SUPPORT	0.60	0.68
SUPPORT	SUPPORT	0.61	0.70
SUPPORT	SUPPORT	0.61	0.96
SUPPORT	SUPPORT	0.61	0.74
SUPPORT	SUPPORT	0.61	0.67
SUPPORT	SUPPORT	0.62	0.70
SUPPORT	SUPPORT	0.63	0.65
SUPPORT	SUPPORT	0.64	0.77
SUPPORT	SUPPORT	0.67	0.78
SUPPORT	SUPPORT	0.68	0.80
SUPPORT	SUPPORT	0.68	0.80
SUPPORT	SUPPORT	0.72	0.91
SUPPORT	SUPPORT	0.75	0.88
SUPPORT	SUPPORT	0.75	0.91
SUPPORT	SUPPORT	0.84	1.07
SUPPORT	SUPPORT	0.86	1.33
SUPPORT	SUPPORT	0.89	1.19
SUPPORT	SUPPORT	1.06	1.46
SUPPORT	SUPPORT	1.24	1.95
SUPPORT	SUPPORT	1.48	2.05
SUPPORT	SUPPORT	1.71	3.86
SUPPORT	SUPPORT	7.36	18.13
TIMBER ASSISTANT	SUPPORT	0.32	0.44
TIMBER ASSTANT	SUPPORT	0.08	0.11
TIMBER ASSTANT	SUPPORT	0.73	1.09
TIMBERING	SUPPORT	0.11	0.13
TIMBERMAN	SUPPORT	0.27	0.31

TABLE 27 Z TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL
EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
LOCO DRIVER	TRANSPORT	0.03	0.03
LOCO DRIVER	TRANSPORT	0.09	0.10
LOCO DRIVER	TRANSPORT	0.15	0.17
LOCO DRIVER	TRANSPORT	0.20	0.21
LOCO DRIVER	TRANSPORT	0.22	0.26
LOCO DRIVER	TRANSPORT	0.35	0.45
LOCO DRIVER	TRANSPORT	0.36	0.40
LOCO DRIVER	TRANSPORT	0.38	0.37
LOCO DRIVER	TRANSPORT	0.39	0.47
LOCO DRIVER	TRANSPORT	0.75	0.86
LOCO DRIVER	TRANSPORT	1.33	2.49
LOCO DRIVER ASST	TRANSPORT	0.48	0.59
LOCO DRIVER ASST	TRANSPORT	0.82	1.21
TRANSPORT	TRANSPORT	0.02	0.01
TRANSPORT	TRANSPORT	0.02	0.02
TRANSPORT	TRANSPORT	0.04	0.04
TRANSPORT	TRANSPORT	0.05	0.05
TRANSPORT	TRANSPORT	0.05	0.05
TRANSPORT	TRANSPORT	0.05	0.05
TRANSPORT	TRANSPORT	0.05	0.06
TRANSPORT	TRANSPORT	0.07	0.10
TRANSPORT	TRANSPORT	0.07	0.08
TRANSPORT	TRANSPORT	0.08	0.06
TRANSPORT	TRANSPORT	0.09	0.10
TRANSPORT	TRANSPORT	0.10	0.08
TRANSPORT	TRANSPORT	0.10	0.14
TRANSPORT	TRANSPORT	0.11	0.12
TRANSPORT	TRANSPORT	0.12	0.13
TRANSPORT	TRANSPORT	0.13	0.09
TRANSPORT	TRANSPORT	0.14	0.15
TRANSPORT	TRANSPORT	0.14	0.15
TRANSPORT	TRANSPORT	0.14	0.17
TRANSPORT	TRANSPORT	0.15	0.15
TRANSPORT	TRANSPORT	0.18	0.33
TRANSPORT	TRANSPORT	0.20	0.22
TRANSPORT	TRANSPORT	0.21	0.22
TRANSPORT	TRANSPORT	0.24	0.30
TRANSPORT	TRANSPORT	0.25	0.31
TRANSPORT	TRANSPORT	0.26	0.32
TRANSPORT	TRANSPORT	0.28	0.29
TRANSPORT	TRANSPORT	0.28	0.33
TRANSPORT	TRANSPORT	0.29	0.32
TRANSPORT	TRANSPORT	0.29	0.33
TRANSPORT	TRANSPORT	0.33	0.32
TRANSPORT	TRANSPORT	0.36	0.48
TRANSPORT	TRANSPORT	0.38	0.43
TRANSPORT	TRANSPORT	0.39	0.47
TRANSPORT	TRANSPORT	0.40	0.41

TABLE 27 AA   TABLE 27 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL
EXPOSURE DATA - MINE 1

DESCRIPTION	ACTUAL WORK DONE	CONC	CONC TWA
		mg/m3	mg/m3
TRANSPORT	TRANSPORT	0.42	0.59
TRANSPORT	TRANSPORT	0.42	0.56
TRANSPORT	TRANSPORT	0.46	0.54
TRANSPORT	TRANSPORT	0.53	0.64
TRANSPORT	TRANSPORT	0.61	0.68
TRANSPORT	TRANSPORT	0.82	1.07
TRANSPORT	TRANSPORT	1.16	1.78

APPENDIX C

DETAILS OF MINES' OCCUPATIONAL EXPOSURE DATA - MINE 2

TABLES 28 AND 28A - 28I

TABLE 28
DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 2

OCCUPATION	ACTUAL WORK DONE	CONC	CONC TWA
		[illegible]	[illegible]
Construction Assistant	Construction	0.17	0.18
Construction Assistant	Construction	0.14	0.14
CONTRACTION ASSISTANT	Construction	0.53	0.66
Railroad Contractors	Construction	0.45	0.46
TEAM LEADER (CONCOR)	Construction	0.20	0.19
STOPING ASSISTANT	Construction	0.62	0.76
STOPING ASSISTANT	Construction	0.16	0.20
Stoping Assistant	Construction	0.23	0.27
Stoping Assistant	Construction	0.09	0.10
Stoping Assistant	Construction	0.09	0.11
Stoping Assistant	Construction	0.62	0.66
Stoping Assistant	Construction	0.53	0.66
Stoping Assistant	Construction	0.73	0.84
Stoping Assistant	Construction	0.20	0.23
Stoping Assistant	Construction	0.54	0.64
Stoping Assistant	Construction	0.59	0.71
Stoping Assistant	Construction	0.63	0.71
Stoping Assistant	Construction	0.44	0.49
Stoping Assistant	Construction	0.17	0.20
Stoping Assistant	Construction	0.41	0.46
Stoping Assistant	Construction	0.41	0.49
Stoping Assistant	Construction	0.39	0.44
Stoping Assistant	Construction	0.48	0.58
Stoping Assistant	Construction	0.30	0.36
Stoping Assistant	Construction	0.50	0.59
Stoping Assistant	Construction	0.42	0.47
Stoping Assistant	Construction	0.47	0.55
Stoping Assistant	Construction	0.17	0.21
Stoping Assistant	Construction	0.28	0.29
Stoping Assistant	Construction	1.51	2.41
Stoping Assistant	Construction	0.51	0.60
Stoping Assistant	Construction	0.43	0.44
Stoping Assistant	Construction	0.16	0.06
Stoping Assistant	Construction	0.23	0.24
Stoping Assistant	Construction	0.10	0.11
Stoping Assistant	Construction	0.51	0.54
Stoping Assistant	Construction	0.34	0.37
Stoping Assistant	Construction	0.01	0.01
Stoping Assistant	Construction	0.09	0.09
Stoping Assistant	Construction	0.26	0.30
Stoping Assistant	Construction	0.20	0.22
Stoping Assistant	Construction	0.21	0.23
Stoping Assistant	Construction	0.37	0.38
Stoping Assistant	Construction	0.72	0.72
Stoping Assistant	Construction	0.14	0.14
Stoping Assistant	Construction	0.08	0.08
Stoping Assistant	Construction	0.35	0.38
Stoping Assistant	Construction	0.40	0.41
Stoping Assistant	Construction	0.63	0.64
Stoping Assistant	Construction	0.68	0.70
Stoping Assistant	Construction	0.48	0.50

TABLE 28 A TABLE 28 CONTINUED DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 2

OCCUPATION	ACTUAL WORK DONE	CONC	CONC TWA
		[illegible]	[illegible]
Stoping Assistant	Construction	0.29	0.29
Stoping Assistant	Construction	0.71	0.72
Stoping Assistant	Construction	0.52	0.53
Stoping Assistant	Construction	0.41	0.41
Stoping Assistant	Construction	0.35	0.36
Stoping Assistant	Construction	0.38	0.39
Stoping Assistant	Construction	0.91	0.94
Stoping Assistant	Construction	0.22	0.24
Stoping Assistant	Construction	0.51	0.51

TABLE 28 B TABLE 28 CONTINUED DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 2

OCCUPATION	ACTUAL WORK DONE	CONC	CONC TWA
		[illegible]	[illegible]
Machine Operator	Drilling	0.25	0.30
Machine Operator	Drilling	0.27	0.36
MACHINE OPERATOR	Drilling	0.65	0.79
MACHINE OPERATOR	Drilling	0.48	1.88
MACHINE OPERATOR	Drilling	0.15	0.17
Machine Operator	Drilling	0.39	0.42
Machine Operator	Drilling	0.60	0.62
Machine Operator	Drilling	0.25	0.25
Machine Operator	Drilling	0.42	0.46
Machine Operator	Drilling	0.34	0.36
Rockdrill Operator	Drilling	0.22	0.23
Machine Assistant	Drilling	0.43	0.52
Machine Assistant	Drilling	0.60	0.67
Machine Assistant	Drilling	0.25	0.30
Machine Assistant	Drilling	0.12	0.15
Machine Assistant	Drilling	0.10	0.11
Machine Assistant	Drilling	0.18	0.21
Machine Assistant	Drilling	0.27	0.26
Machine Assistant	Drilling	0.12	0.16
Machine Assistant	Drilling	1.50	1.72
Machine Assistant	Drilling	0.41	0.45
Machine Assistant	Drilling	0.48	0.57
Machine Assistant	Drilling	0.59	0.68
Machine Assistant	Drilling	0.29	0.32
MACHINE ASSISTANT	Drilling	0.66	0.80
MACHINE ASSISTANT	Drilling	1.61	1.86
Machine Operator Assistant	Drilling	0.42	0.44
Machine Operator Assistant	Drilling	0.78	0.81
Machine Operator Assistant	Drilling	0.33	0.35
Machine Operator Assistant	Drilling	0.33	0.37
Rock Assistant	Drilling	0.52	0.54
Rock Drill Assistant	Drilling	11.09	0.10
Rockdrill Assistant	Drilling	0.40	0.41

TABLE 28 C TABLE 28 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 2

OCCUPATION	ACTUAL WORK DONE	CONC	CONC TWA
Stope Assistant	Lashing	0.32	0.33
Stope Assistant	Lashing	0.66	0.72
STOPING	Lashing	0.06	0.07
STOPING	Lashing	0.29	0.32
STOPING	Lashing	0.14	0.16
STOPING	Lashing	0.18	0.21
STOPING	Lashing	0.51	0.61
STOPING	Lashing	0.12	0.15
STOPING	Lashing	0.37	0.42
STOPING ASSISTANT	Lashing	0.13	0.14
Stoping Assistant	Lashing	0.33	0.36
Stoping Assistant	Lashing	0.55	0.57
Stoping Assistant	Lashing	0.16	0.18
Stoping Assistant	Lashing	0.21	0.24
Stoping Assistant	Lashing	0.05	0.06
Stoping Assistant	Lashing	0.03	0.03
Stoping Assistant	Lashing	0.29	0.39
Stoping Assistant	Lashing	1.02	1.19
Stoping Assistant	Lashing	0.36	0.43
Stoping Assistant	Lashing	0.15	0.18
Stoping Assistant	Lashing	0.54	0.80
Stoping Assistant	Lashing	0.34	0.40
Stoping Assistant	Lashing	0.77	0.90
Stoping Assistant	Lashing	0.41	0.44
Stoping Assistant	Lashing	0.42	0.49
Stoping Assistant	Lashing	0.29	0.33
Stoping Assistant	Lashing	0.34	0.39
Stoping Assistant	Lashing	0.40	0.46
Stoping Assistant	Lashing	0.40	0.45
Stoping Assistant	Lashing	0.29	0.35
Stoping Assistant	Lashing	0.02	0.03
Stoping Assistant	Lashing	0.02	0.02
Stoping Assistant	Lashing	0.19	0.24
Stoping Assistant	Lashing	0.36	0.44
Stoping Assistant	Lashing	2.01	2.31
Stoping Assistant	Lashing	0.12	0.14
Stoping Assistant	Lashing	0.39	0.56
Stoping Assistant	Lashing	0.10	0.11
Stoping Assistant	Lashing	0.07	0.08
Stoping Assistant	Lashing	0.56	0.65
Stoping Assistant	Lashing	0.42	0.46
Stoping Assistant	Lashing	0.26	0.30
Stoping Assistant	Lashing	0.36	0.41
Stoping Assistant	Lashing	0.83	0.83
Stoping Assistant	Lashing	0.70	0.78
Stoping Assistant	Lashing	1.44	1.63
Stoping Assistant	Lashing	0.42	0.49
Stoping Assistant	Lashing	1.08	1.05

TABLE 28 D TABLE 28 CONTINUED DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 2

OCCUPATION	ACTUAL WORK DONE	CONC	CONC TWA
		[illegible]	[illegible]
Stoping Assistant	Lashing	0.71	0.85
Stoping Assistant	Lashing	0.12	0.13
Stoping Assistant	Lashing	0.39	0.46
Stoping Assistant	Lashing	0.31	0.36
Stoping Assistant	Lashing	0.34	0.40
Stoping Assistant	Lashing	0.54	0.62

TABLE 28 E TABLE 28 CONTINUED DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 2

OCCUPATION	ACTUAL WORK DONE	CONC	CONC TWA
		mg/m3	mg/m3
DEV. TEAM LEADER	Supervision	0.52	0.62
SHAFT TEAM LEADER	Supervision	0.12	0.13
Shift Boss	Supervision	0.33	0.34
Shift Supervisor	Supervision	1.58	1.61
TEAM LEADER	Supervision	0.23	0.26
TEAM LEADER	Supervision	0.14	0.16
TEAM LEADER	Supervision	0.05	0.06
TEAM LEADER	Supervision	0.48	0.56
TEAM LEADER	Supervision	0.14	0.17
TEAM LEADER	Supervision	0.15	0.16
TEAM LEADER	Supervision	0.17	0.21
Team Leader	Supervision	0.13	0.13
Team Leader	Supervision	0.29	0.31
Team Leader	Supervision	0.55	0.63
Team Leader	Supervision	0.04	0.04
Team Leader	Supervision	0.25	0.28
Team Leader	Supervision	0.16	0.19
Team Leader	Supervision	0.27	0.32
Team Leader	Supervision	0.21	0.25
Team Leader	Supervision	0.24	0.25
Team Leader	Supervision	1.14	1.33
Team Leader	Supervision	0.27	0.29
Team Leader	Supervision	0.48	0.55
Team Leader	Supervision	0.86	0.97
Team Leader	Supervision	0.38	0.40
Team Leader	Supervision	0.17	0.20
Team Leader	Supervision	0.27	0.31
Team Leader	Supervision	0.06	0.08
Team Leader	Supervision	0.08	0.08
Team Leader	Supervision	0.35	0.40
Team Leader	Supervision	0.17	0.19
Team Leader	Supervision	0.42	0.52
Team Leader	Supervision	0.99	1.09
Team Leader	Supervision	0.25	0.29
TEAM LEADER	Supervision	0.70	0.77
TEAM LEADER	Supervision	0.03	0.04
TEAM LEADER	Supervision	0.28	0.32
TEAM LEADER	Supervision	0.56	0.69
TEAM LEADER	Supervision	0.47	0.53
TEAM LEADER	Supervision	0.32	0.38
TEAM LEADER	Supervision	0.81	0.96
TEAM LEADER	Supervision	0.30	0.34
TEAM LEADER	Supervision	0.52	0.63
TEAM LEADER	Supervision	0.22	0.23
TEAM LEADER	Supervision	0.83	0.93
TEAM LEADER	Supervision	1.71	1.88
TEAM LEADER	Supervision	0.43	0.51
TEAM LEADER	Supervision	0.25	0.27
TEAM LEADER	Supervision	0.19	0.23
TEAM LEADER	Supervision	0.15	0.16
TEAM LEADER	Supervision	0.05	0.06
TEAM LEADER	Supervision	0.16	0.18

TABLE 28 F TABLE 28 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL
EXPOSURE DATA - MINE 2

OCCUPATION	ACTUAL WORK DONE	CONC	CONC TWA
		[illegible]	[illegible]
TEAM LEADER	Supervision	0.10	0.11
TEAM LEADER	Supervision	0.01	0.01
TEAM LEADER	Supervision	0.29	0.33
TEAM LEADER	Supervision	0.42	0.50
TEAM LEADER	Supervision	0.33	0.40
TEAM LEADER	Supervision	0.31	0.34
Team Leader	Supervision	0.41	0.49
Team Leader	Supervision	0.09	0.11
Team Leader	Supervision	0.08	0.10
Team Leader	Supervision	0.14	0.16
Team Leader	Supervision	0.35	0.39
Team Leader	Supervision	0.13	0.15
Team Leader	Supervision	0.33	0.41
Team Leader	Supervision	0.15	0.17
Team Leader	Supervision	0.79	0.92
Team Leader	Supervision	0.35	0.56
TEAM LEADER	Supervision	0.23	0.27
Team Leader	Supervision	0.25	0.30
Team Leader	Supervision	0.88	0.98
Team Leader	Supervision	0.26	0.32
Team Leader	Supervision	0.59	0.64
Team Leader	Supervision	0.57	0.57
Team Leader	Supervision	0.49	0.53
Team Leader	Supervision	0.03	0.03
Team Leader	Supervision	0.36	0.37
Team Leader	Supervision	0.48	0.49

TABLE 28 G TABLE 28 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL
EXPOSURE DATA - MINE 2

OCCUPATION	ACTUAL WORK DONE	CONC	CONC TWA
TIMBER ASSISTANT	Support	0.33	0.33
TIMBER ASSISTANT	Support	0.40	0.40
TIMBER ASSISTANT	Support	0.16	0.17
Timber Assistant	Support	0.42	0.47
Timber Assistant	Support	0.19	0.21
Timber Assistant	Support	0.52	0.56
Timber Assistant	Support	0.24	0.24
Timber Assistant	Support	0.51	0.52
TIMBER MAN	Support	0.16	0.18
Timberman	Support	0.25	0.29
Timberman	Support	0.27	0.27
Timberman	Support	0.31	0.31
Timberman Assistant	Support	0.06	0.07
Power Pack Operator	Support	0.12	0.13
Power Packer	Support	0.72	0.77
Prop Jacker	Support	0.25	0.25
Stoping Assistant	Support	0.21	0.21
Stoping Assistant	Support	0.56	0.57
Stoping Assistant	Support	0.59	0.61
Stoping Assistant	Support	0.14	0.15
Stoping Assistant	Support	0.40	0.40
Stoping Assistant	Support	0.28	0.29
Stoping Assistant	Support	1.36	1.41
Stoping Assistant	Support	0.27	0.28
Stoping Assistant	Support	0.25	0.26
Stoping Assistant	Support	0.67	0.68
Stoping Assistant	Support	0.14	0.15
Stoping Assistant	Support	0.34	0.34
Stoping Assistant	Support	0.60	0.62
Stoping Assistant	Support	0.28	0.28
Stoping Assistant	Support	2.81	2.81
Stoping Assistant	Support	0.21	0.41
Stoping Assistant	Support	0.14	0.30
Stoping Assistant	Support	0.00	0.20
Stoping Assistant	Support	0.17	0.35
Stoping Asstant	Support	0.32	0.35
Stoping Asstistant	Support	0.83	0.86
Stopping Assistant	Support	0.34	0.40
Stopping Assistant	Support	0.37	0.51
Stopping Assistant	Support	0.08	0.09
Stopping Assistant	Support	0.36	0.39
STOPING ASSISTANT	Support	0.37	0.42
STOPING ASSISTANT	Support	0.33	0.36
STOPING ASSISTANT	Support	0.41	0.47
STOPING ASSISTANT	Support	0.68	0.82
STOPING ASSISTANT	Support	0.75	0.83
STOPING ASSISTANT	Support	0.43	0.51
STOPING ASSISTANT	Support	0.14	0.15
STOPING ASSISTANT	Support	0.85	0.99
STOPING ASSISTANT	Support	0.49	0.59
STOPING ASSISTANT	Support	0.42	0.48
STOPING ASSISTANT	Support	0.68	0.81

TABLE 28 H TABLE 28 CONTINUED
DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 2

OCCUPATION	ACTUAL WORK DONE	CONC	CONC TWA
STOPING ASSISTANT	Support	0.29	0.32
STOPING ASSISTANT	Support	0.19	0.24
STOPING ASSISTANT	Support	0.46	0.53
STOPING ASSISTANT	Support	0.41	0.48
STOPING ASSISTANT	Support	0.27	0.32
STOPING ASSISTANT	Support	0.66	0.78
STOPING ASSISTANT	Support	0.20	0.24
STOPING ASSISTANT	Support	0.17	0.20
STOPING ASSISTANT	Support	0.18	0.19
STOPING ASSISTANT	Support	0.07	0.08
STOPING ASSISTANT	Support	0.17	0.18
STOPING ASSISTANT	Support	0.10	0.11
STOPING ASSISTANT	Support	0.03	0.04
STOPING ASSISTANT	Support	0.38	0.44
STOPING ASSISTANT	Support	0.75	0.89

TABLE 28 I TABLE 28 CONTINUED DETAILS OF MINE'S OCCUPATIONAL EXPOSURE DATA - MINE 2

OCCUPATION	ACTUAL WORK DONE	CONC	CONC TWA
		[illegible]	[illegible]
Loco Dirver	Transport	1.01	1.05
Loco Driver	Transport	0.56	0.65
Loco Driver	Transport	0.41	0.57
Loco Driver	Transport	0.85	0.73
Loco Driver	Transport	0.57	0.64
Loco Driver	Transport	0.42	0.45
LOCO DRIVER	Transport	0.08	0.10
LOCO DRIVER	Transport	0.44	0.53
LOCO DRIVER	Transport	0.33	0.38
LOCO DRIVER	Transport	0.35	0.41
LOCO DRIVER	Transport	0.02	0.02
LOCO DRIVER	Transport	0.01	0.01
LOCO DRIVER	Transport	0.07	0.08
LOCO DRIVER	Transport	0.25	0.29
LOCO DRIVER	Transport	0.13	0.16
LOCO DRIVER	Transport	0.22	0.24
LOCO DRIVER	Transport	0.12	0.14
LOCO DRIVER	Transport	0.31	0.36
Loco Driver	Transport	0.30	0.37
Loco Driver	Transport	0.25	0.29
Loco Driver	Transport	0.26	0.30
Loco Driver	Transport	0.37	0.72
Loco Driver	Transport	0.57	1.09
Loco Driver	Transport	0.19	0.20
Loco Driver	Transport	0.31	0.32
Loco Driver	Transport	0.04	0.04
Loco Driver	Transport	0.35	0.39
Loco Driver	Transport	2.02	2.06
Loco Driver	Transport	0.49	0.54
Loco Driver	Transport	0.42	0.43
Loco Driver	Transport	1.38	1.38
Loco Driver	Transport	0.05	0.05
Loco Driver	Transport	0.09	0.09
Loco Driver	Transport	0.91	0.92
Loco Driver	Transport	0.54	0.56
Loco Driver	Transport	0.29	0.30
Loco Driver	Transport	1.32	1.34
Loco Driver	Transport	1.10	1.10
Loco Driver	Transport	0.52	0.53