Chapter 3

PARAMETRIC STUDIES OF DUST DISTRIBUTION

3.1 INTRODUCTION

In order to develop an effective dust control technique it was necessary to have a thorough understanding of the airflow characteristics and respirable dust behaviour in a longwall face. A review of the literature showed that only very limited data existed on dust cloud characterisation at a longwall face. Furthermore, the large variations in the dust concentration profiles at different longwall faces and the physical differences in the longwall faces, ventilation plan and operating procedures made the data inapplicable at Australian longwall faces. Thus a need existed for detailed and extensive dust sampling at longwall faces in Australia, both to develop a fundamental data set on spatial and temporal variations in dust levels and to understand respirable dust behaviour in order to develop effective dust control techniques. In addition, information on the size distribution of mine respirable dust was required as the effectiveness of many dust control techniques is particle size dependent.

The generation and transportation of airborne dust is governed mainly by the velocity and the movement pattern of the ventilating air in longwall faces. Thus, it is important to know the air velocity distribution in the face to design a dust control technique. The air velocity profiles may vary from mine to mine due to variations in face geometry, dimensions, type of ventilation system used, height of seam and type of supports used. Experimental studies can however, provide a qualitative understanding of the average air flow conditions in a longwall face.

Hence, extensive field investigations were conducted in four operating longwall faces in the Southern district of New South Wales, Australia. The experiments were designed to determine the influence of various parameters on respirable dust concentration levels and behaviour of dust. Average and instantaneous respirable dust concentration profiles along and across the longwall face were determined, as were air velocity profiles. Data on the face layout, time study of the activities at the face, and size distribution of respirable dust were collected for analysis of the relevant dust behaviour with respect to various face conditions.

3.2 OBJECTIVES OF FIELD INVESTIGATIONS

Experiments were designed to obtain basic data on the concentration levels and behaviour of respirable dust in a longwall face. The primary objectives of these preliminary investigations were to:

- (i) identify major dust sources along the longwall face;
- (ii) identify the major factors affecting dust distribution profiles along the face;
- (iii) determine instantaneous dust concentration profiles along and across the longwall face for better understanding of the real-time behaviour of dust;
- (iv) determine the air velocity profiles in the longwall face;
- (v) determine the size distribution of respirable dust;
- (vi) obtain the basic data for mathematical modelling of the dust behaviour in a longwall face and control techniques, and
- (vii) plan new approaches for dust control in the longwall face.

3.3 DESIGN OF UNDERGROUND EXPERIMENTS

The determination of the transient dust profiles at a longwall face required comprehensive planning and execution of underground experiments. Specific aspects which were considered included the types of samples to be collected, selection of proper instruments and detailed sampling and time study plans to correlate the dust concentration with the different activities at the face. Interpretation of the respirable dust survey data required face details from all the longwall faces because the parameters and geometry of the longwall faces differed from one mine to another. To achieve the objectives mentioned in previous section, two types of surveys were conducted, namely time averaged gravimetric sampling surveys and instantaneous respirable dust concentration surveys.

Gravimetric samplers are routinely used by mine operators to determine compliance with dust standards. The gravimetric dust samples provide information on the average airborne dust levels along the face over the entire sampling period. They were also necessary for studying the size distribution of airborne dust in the face. The dust samplers are normally worn by mine personnel, but during these surveys discussed here, they were fixed at predetermined locations along the longwall face.

The instantaneous respirable airborne dust concentration profiles on a continuous basis at a predetermined point can be used to determine the relationship between the dust level, the location of the shearer and shearer activities under given airflow conditions. The information is useful in characterising the temporal behaviour of the respirable dust in relation to mining activities at the face.

3.3.1 Field instrumentation

(a) Gravimetric dust survey instrumentation

The 'Du Pont P-2500' sampling instrument, commonly referred to as personal sampler, was used for measuring the average respirable dust concentration along the longwall face (Hewitt, 1986b; Breslin, Page and Jankowski, 1983). The instrument is shown in Figure 3.1. The sampler consists of an air pump, a 25 mm cassella cyclone and a filter cassette. The air flow range of the instrument is from 1 to 2.5 l/min. The pump used to draw the air into the sampling system was battery powered, weighed less than one kilogram, and had overall dimensions of approximately 18cm x 10cm x 5cm. The cyclone and filter assembly, commonly referred to as the 'sampling head' was connected to the sampling pump by a 3 mm diameter tube.

Figure 3.1 Du Pont personal dust sampler, Model P-2500.

The instrument is designed to be capable of sampling the dust environment a miner is exposed to during his working shift by mounting it on the miner, but has the flexibility of being used as a stationary instrument to obtain measurements of the general dust environment where it is located.

The following set of auxiliary instruments were also used during the surveys:

(i) Charging unit;
(ii) Flowmeter to calibrate the instrument;
(iii) Precision weighing balance;
(iv) Dessicator - to remove moisture.

(b) Instantaneous dust survey instrumentation

A 'Hund' (TM-digital µP, 1991; Hewitt and Aziz, 1993) instantaneous sampler was used to monitor the instantaneous respirable dust concentration on a continuous basis in the longwall face. It uses a wide angle light scattering system to measure the respirable dust concentration in the airflow passing through its light beam. It has the capability of measuring respirable dust concentration without the preliminary separation of coarse particles. A light emitting display shows the respirable dust concentration as the current value for the preceding seconds or as the specified time weighted average. The measuring range of the instrument is from 0 to 100 mg/m^3. It is portable, battery powered, weighs 980 gm and has overall dimensions of 193mm x 102mm x 46mm (Figure 3.2). The battery of the instrument, if used continuously, lasts for about 5 to 6 hours.

The Hund continuously records fluctuations in dust levels and calculates a running average that is updated every second. It can be used to measure single and average values for random measuring periods. During these field surveys, average concentration measurements were taken every 15 seconds. The instrument was

Figure 3.2(a) Hund instantaneous dust sampling instrument.

Figure 3.2(b) A schematic figure showing measuring chamber with infrared beam opening (after TM-digital μP, 1991).

calibrated regularly to ensure the accuracy of the collected data. The performance of the instrument has been evaluated both in the laboratory (Thompson et al, 1981; Williams, 1983) and in the field (Hwang et al, 1988).

(c) Other instrumentation

A vane anemometer was used to measure the air velocity in the longwall face. A Malvern micron size particle analyser (Malvern Instruments, 1990) was also used to determine the dust size distribution. Cascade impactors are commonly used to obtain the in-situ size distribution of airborne dust, but because of their susceptibility to overloading, they are inconvenient for large scale data collection in mines. Instruments commonly used in the laboratory for size distribution measurement of respirable particles are Coulter Counter, Microtrac Small Particle Analyzer and Scanning Electron Microscope. These instruments use electrical sensing, light scattering and microscopic principles respectively for measuring size distribution (Dumm and Hogg, 1987; Grayson and Peng, 1986).

3.3.2 Sampling procedure

(a) Average gravimetric dust survey

Sampling stations were located along the face to obtain data on time-averaged gravimetric dust concentration levels (Figure 3.3). The first sampling station was positioned in the intake roadway at the crib room. This was to obtain information on intake air dust contamination in a longwall section due to dust generated at out-bye transport roadways. Another sampling station was set up in the return airway. The other six sampling stations were placed at an equal distance from each other between the intake and return sampling stations.

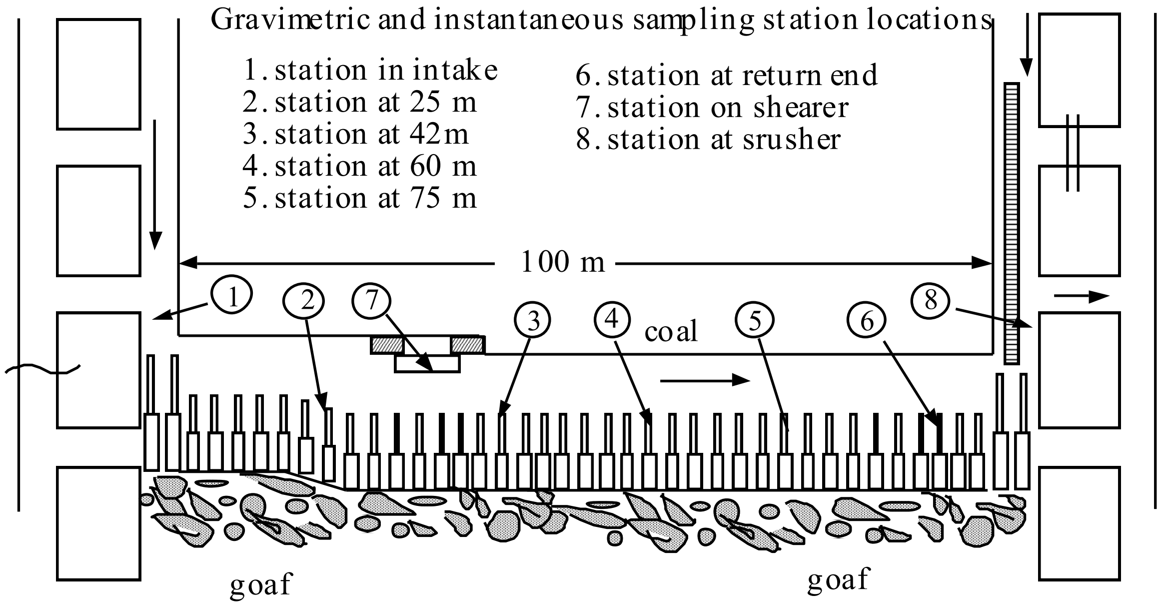

Figure 3.3 Respirable dust sampling locations along the longwall face A.

The sampling instruments at the face were hung from the shield's canopy over the spill plate/ walkway in the miners' breathing zone. The cyclone was attached to the sampling pump to eliminate errors associated with high face velocities. The pumps were calibrated every alternate day in the laboratory using a calibration flowmeter to ensure the accuracy of the data. Sampling was performed over a period of 15 continuous working shifts to eliminate the effects of shift practices. As mentioned earlier, the air velocities along the face were also measured using vane anemometers.

In the laboratory, new filters, preweighed to a precision of 0.001 mg, were mounted in the cyclones. The Du Pont pump flow was adjusted to 1.9 l/min before commencing the experiments. On the site, the cyclones were connected to the sampling pumps by 3 mm diameter tubing. After sampling, the filters were precision weighed again on an electronic microbalance to within 0.001 mg in the laboratory. The samples were desiccated before being weighed to remove any moisture that might have been absorbed. An ionising unit, called a static master, was also used to eliminate static charges on all filters before weighing. The samples were reweighed after drying for 24 hours and the net weight of the respirable dust concentration determined.

Although the sampling time required depends strongly on the dust concentration being measured, it should include at least 30 minutes of cutting time to obtain a sufficient sample (Foster-Miller Associates, Inc., 1982). During these investigations, the samplers were operated for a full shift and the weight of dust collected was determined after the shift. The time-averaged gravimetric dust concentrations over the entire sampling period were calculated on the basis of the mass collected on the filters, the sampling time and the pump flow rate.

The concentration of respirable dust was calculated using the following formula:

$$x = \frac{m_2 - m_1}{r.t} 1000$$

where, x = concentration of respirable dust (mg/m^3)

m_1 = mass of filter before use (mg)

m_2 = mass of loaded filter after use (mg)

r = air flow rate through sampling pump (l/min)

t = sampling time (min.)

(b) Instantaneous dust surveys

(i) Dust profiles along the face : In the longwall mining system, the major dust generating source, the shearer, not only moves as it cuts the coal but its movement can be either with, or against, the direction of airflow in the face. The dust concentration at any given point is a function of the shearer activities at that time, the position of the sampling point, the direction of shearer movement, the air velocity and quantity passing through the face, and other face activities. In order to correlate the instantaneous dust concentration along the longwall face with respect to the shearer position and face activities, two types of instantaneous dust survey methods were used, a moving and a stationary instrument method.

In the moving instrument method, the Hund sampler was moved at a fixed distance from the shearer as it travelled along the face. In different experiments, the position of the moving Hund was changed to obtain dust concentration profiles at different positions relative to the shearer. These positions included the rear operator's location, the mid-point of the shearer, and 5 m, 10 m, and 20 m downwind of the shearer. During the surveys, the Hund was kept on the walkway side of the face and readings were taken at a height of 1.3 - 1.7 m, which was considered to be the most likely inhalation position of the face crew. Averaged instantaneous dust concentration values were read approximately every 15 seconds.

In the stationary instrument sampling method, the Hund monitor was positioned at a fixed location at the face. Dust profiles were obtained at several fixed locations along the face while the shearer was operating. Typically, in one experiment, the sampling station was located near the return end of the face to determine the instantaneous dust concentration levels at the tailgate operator's position during a complete cutting, cleaning and sumping cycle.

(ii) Dust profiles around the shearer : To determine the dust concentration profiles around the shearer the following procedure was followed. The Hund instrument was fixed at a location and, as the shearer approached the sampling point, both the dust levels and distances from the shearer were recorded. Recordings were based on the time and the shearer's tramming speed. The tram rate was calculated from taking the shearer's passage time at 5-shield intervals, i.e. at shields 10, 15, 20, 25, etc. For example, as the shearer approached the sampling station, dust concentration readings were taken every 5 seconds, beginning 10 minutes prior to the shearer's arrival. At an average tramming speed of 5 m/min, this would put the shearer approximately 50 m upwind or downwind of the sampling station. After the shearer had passed the sampling location, dust levels were recorded for an additional 5 minutes. Respirable dust profiles were thus obtained for about 70 m reflecting concentrations on the intake and return side of the shearer.

In the case of cutting with ventilation, sampling commenced when the shearer was about 50 m upwind of the sampling station and continued until the shearer had passed and was 20 m downwind of the sampler. In case of cutting against ventilation, readings commenced when the shearer was 20 m downwind of the sampling position and continued until it had passed and was 50 m upwind side of the sampler.

(iii) Miscellaneous data : Instantaneous sampling was carried out for the entire cycle which consisted of one cutting, one sumping and one flitting operation, over about 30 to 60 minutes depending on the face conditions. Production of coal during this period was between 300 and 800 tonnes. During all surveys, dust concentration measurements were taken in the walkway adjacent to the shearer. To correlate the instantaneous respirable dust concentration values with the activities of the shearer and its location, a time study of shearer activities was conducted at the same time. These included tailgate cutting, sumping, cutting time, travelling rate, shearer cutting

direction, face stoppages, support movement and shearer location relative to each sampling station. The information on the shearer activities during every cutting cycle was necessary as cutting cycle times are different for different cuts /faces. Other face details such as coal seam thickness, type of supports, air velocity, etc. were also noted.

(iv) Support generated dust: : To measure the support generated dust, one Hund instrument was carried at a constant distance of 3 m on the upwind side of the moving supports and another Hund instrument was carried at a constant distance on the downwind side of the moving supports. The distance between the moving supports and downwind sampling instrument was kept at 1 m, 5 m, and 10 m during different experiments. Dust concentrations were read approximately every 4 seconds. The difference between the readings of the two instruments gives the level of dust generated by support movement.

(iv) Dust profiles across the section of the face : The ideal procedure to obtain dust gradients across the face is to position 10-15 instantaneous sampling instruments across the face and to collect the readings simultaneously for 20 - 30 minutes. Owing to resources limitation, two instruments were used and the following procedure was adopted to obtain this data. First, the whole cross section of the face was divided into 9 - 15 arbitrary sections. The two instantaneous samplers were located approximately 1.0 to 1.5 m distant apart in one section of the face. The location of the instruments was changed to different sections of the face in different experiments to obtain dust gradients in parts. For example, during experiment 1, one sampler was located over the panline while the second one was positioned in the front walkway, i.e. between the spill plate and front legs. During the second experiment, the first sampler was located over the spill plate while the second one was positioned in the back walkway, i.e. in between the two rows of legs. Similarly several other experiments were

conducted to collect dust gradients across all sections of the face. Data from all sections was used to determine the dust gradient across the full section of the face.

Four longwall faces each with a poor dust compliance record were selected for the field investigations. They are referred to as longwall faces 'A', 'B', 'C' and 'D'. The main characteristics of the faces are listed in Table 3.1 and brief description of the faces and the results of the field studies are provided in the following sections.

Table 3.1. Main characteristics of the longwall faces - parametric studies

Face	Seam thickness (m)	Face length (m)	Cutting direction	Ventilation	Air velocity (m/s)
A	2.1 - 2.5	100	with ventilation	homotropal	2.0 - 2.2
B	2.2 - 2.7	200	against ventilation	antitropal	3.3 - 3.8
C	2.1 - 2.5	150	with ventilation	homotropal	1.8 - 2.1
D	1.9 - 2.2	200	against ventilation	antitropal	2.6 - 2.8

3.4 RESULTS OF INVESTIGATIONS IN LONGWALL FACE 'A'

Longwall face A was operating in the Bulli Seam in the Southern district of NSW, Australia. The working height was between 2.1 and 2.5 m and the main properties of the seam were as follows: thickness 2.1 - 3.2 m, moisture 1.0 - 1.1%, volatile matter 26%, Hardgrove Grindability Index 69 - 80. The longwall face length was 100 m and the length of the panel was 1250 m. A EDW-300-L Eichoff double ended ranging drum shearer and 2 x 460 tonnes split base two legged shields were used in this face. The diameter and width of the cutting drums were 1.2 m and 0.9 m respectively. The average tram speed of the shearer while cutting was approximately 7 m/min.

The cutting sequence was uni-directional with cutting from tailgate to maingate in the direction of ventilation. The roof supports were advanced on the intake side of the shearer immediately after cutting. A homotropal ventilation system was used and the face air velocity varied between 2.0 and 2.2 m/s. The average daily production from the face was about 5 400 tonnes and the annual production was approximately 1.6 million tonnes.

3.4.1 Average dust concentration profiles

Average dust concentration survey results from some experiments are given in Table 3.2 showing dust levels at different stations along the longwall face. During each of the experiments the shearer completed between 3 and 6 full cuts in each shift, producing between 900 and 2 000 tonnes. From these, typical average dust concentration profiles along longwall face A were determined and are shown in Figures 3.4 and 3.5. The data shows that the concentration varies with the location of the sampling point. The dust concentration at the beginning of the face is low because of the homotropal ventilation system and there is a general increase in dust concentration from intake to return. The dust level at the return end station is highest because all the dust generated has to pass through this station, as opposed to other sampling stations which are downwind for only some part of the cutting process. These profiles differ from those in U.S. mines, because of the bleeder ventilation system used.

As this face is homotropally ventilated, the dust generated at the stage loader goes directly into the return airway. Thus, the stage loader dust did not add to longwall face dust levels, but did overload the rock dusting requirements in the return airway. To measure this dust generation, one sampling station was located in the return airway on the return side of the stage loader. Therefore the results presented in the last column of

Table 3.2. Average dust concentration levels along the face (in mg/m^3)

Sl.No.	face intake	17th Chock	42nd Chock	65th Chock		Production (tonnes)	Shearer	Boot End (crusher)
1	0.08	0.97	1.74	2.10		1400	2.93	-
2	0.17	1.30	1.63	2.07		1600	3.53	17.46
3	0.16	0.63	0.99	1.64		800	2.37	6.80
4	-	1.09	3.46	4.06		2000	2.20	12.48
5	0.38	0.37	0.75	1.33		500	0.49	3.81
6	0.19	0.80	1.68	2.55		1500	1.73	9.84
7	0.28	0.49	1.27	1.52		800	1.93	3.33
8	0.16	0.37	2.15	2.76		2000	2.43	7.65
9	0.14	0.75	2.38	3.83		2000	-	14.30
10	0.41	1.68	2.88	5.27		2600	3.95	6.90
11	0.19	0.90	1.72	2.52		1600	-	8.9
12	-	0.83	2.40	4.96		2000	3.11	-
13	-	1.07	2.95	5.60		2500	6.05	98.52
14	0.15	1.03	2.22	4.94		2200	2.99	-

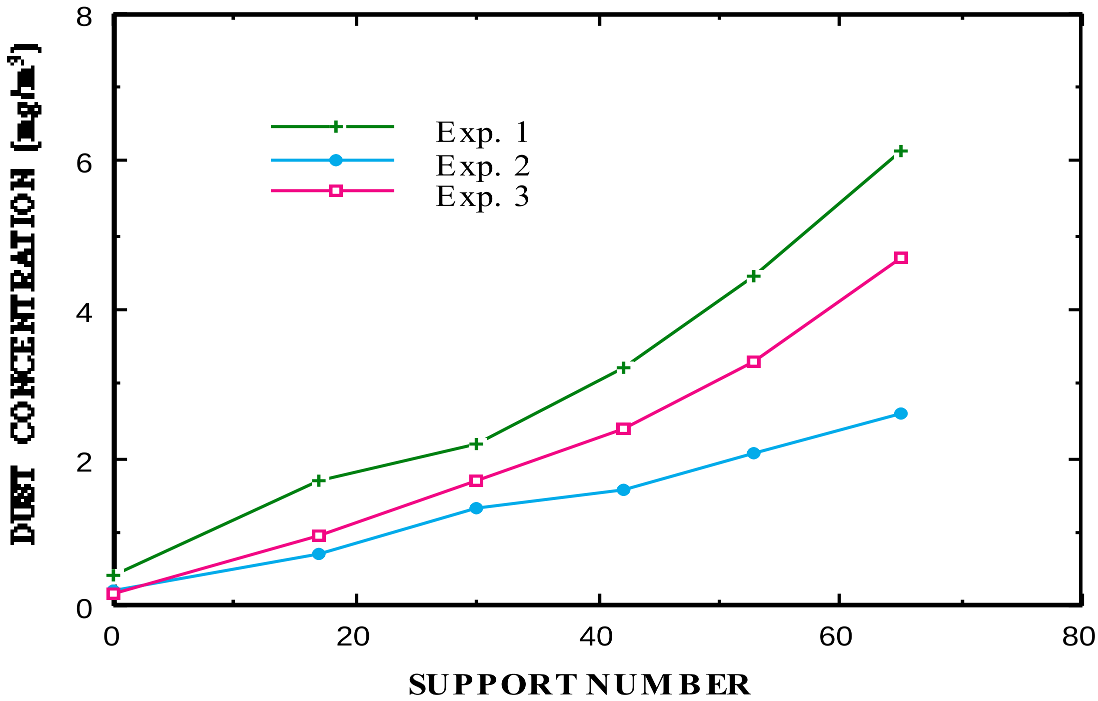

Figure 3.4 Average gravimetric airborne respirable dust concentration p
along the longwall face A for experiments 1, 2 and 3.

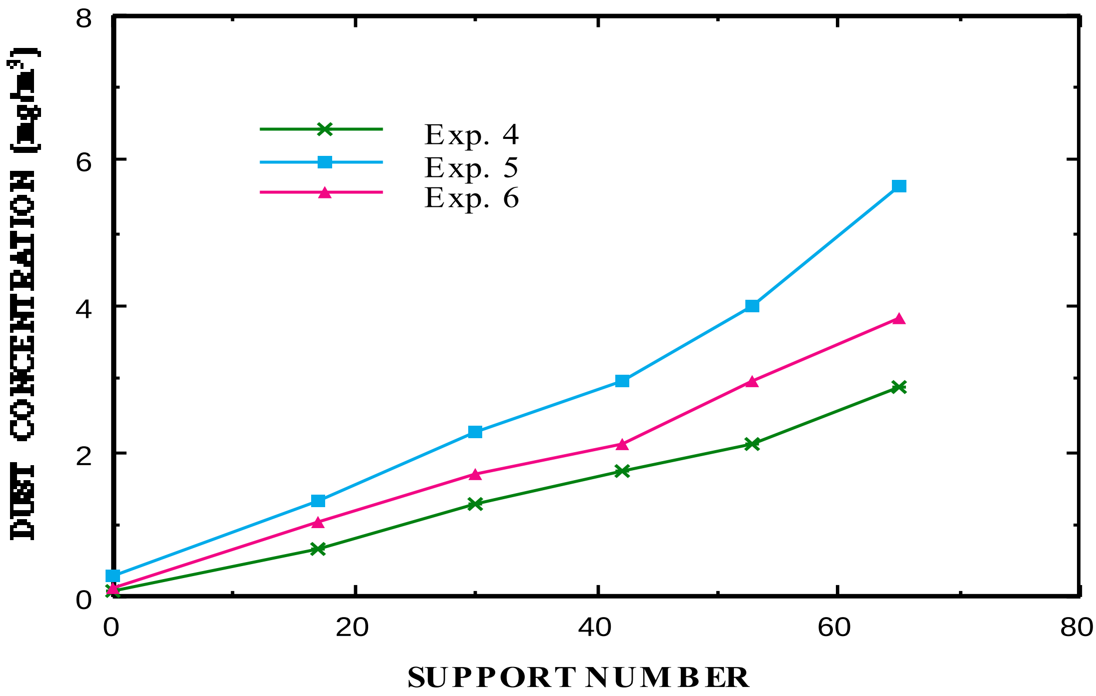

Figure 3.5 Average gravimetric airborne respirable dust concentration p
along the longwall face A for experiments 4, 5 and 6.

Table 3.2 relate to the return side of the stage loader and represents only the dust generated at the stage loader and do not indicate the total longwall face dust levels. Figures 3.6 and 3.7 shows the relationship between production and dust level along the longwall face. The figures indicate that the dust levels exceeded the statutory limit of 3 mg/m^3 when the production per shift was more than 2 000 tonnes.

Measurement of airborne dust by personal samplers is a commonly accepted means of monitoring worker's exposure to hazardous dust in the work place. While such routine measurements provide a direct measurement of the average exposure over a complete shift, they do not provide information on variations of concentration in time and space as the worker proceeds with his duties. Full shift gravimetric samplers are usually not adequate to determine specific dust sources, and therefore, these results cannot be used to determine the effect of different operating practices on spatial variations in dust levels at different locations.

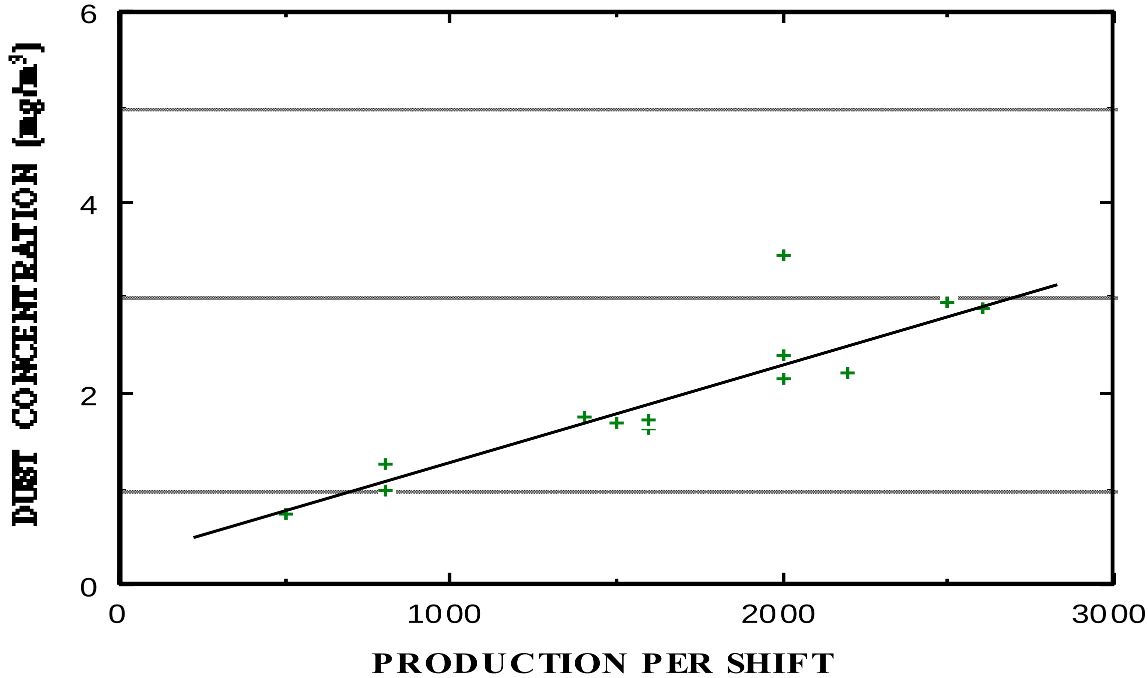

Figure 3.6 Average respirable dust concentration values at 42nd cho longwall face A for 14 experiments with different rates of production.

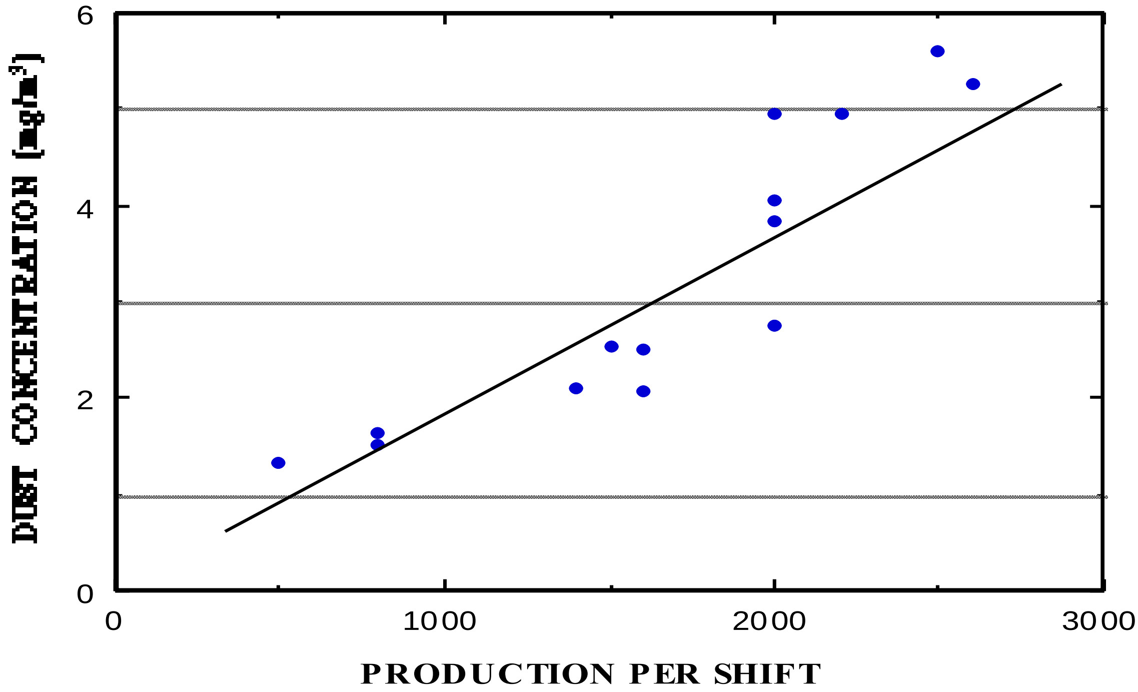

Figure 3.7 Average respirable dust concentration values at 65th ch longwall face A for 14 experiments with different rates of production.

3.4.2 Instantaneous dust concentration profiles

(i) Dust profiles near the return end of the face: The instantaneous sampling survey results of the first series of experiments in longwall face A at the return end sampling station are shown in Table 3.3 and Figures 3.8 - 3.9, along with the activities of the shearer indicated on the X axis. The instantaneous dust concentration levels during different cutting cycles show that the profiles are somewhat similar, but not identical. Once the shearer was on the downwind side of the Hund, dust levels at the sampling station decreased rapidly. It took between 3 and 5 minutes before most of the dust generated by the shearer upwind of the sampling station was carried past the sampling station. The figures shows that during most of the cutting cycle, the dust concentration was more than 3 mg/m^3. Further analysis of figures indicates that even

during the sumping operation at the tailgate entry, the dust concentration was higher than the allowable limit.

Table 3.3. Instantaneous dust concentration levels during a cutting cycle

Time	Dust level (mg/m^3)					Remarks
(min.)	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5	(for Exp. 5)
1	8.15	10.14	6.23	16.36	7.68	cutting
2	4.60	14.89	13.76	25.78	10.78	"
3	6.25	6.35	16.40	10.05	18.27	"
4	19.27	18.63	9.16	22.21	20.35	"
5	6.50	12.51	6.95	12.15	6.57	"
6	23.5	10.99	9.50	9.65	12.30	"
7	16.21	6.35	6.87	4.24	11.31	"
8	7.39	20.98	13.52	6.21	8.05	"
9	23.12	18.24	12.46	11.05	5.99	"
10	20.01	14.76	6.54	11.95	10.17	"
11	4.55	11.10	9.75	12.52	7.78	"
12	22.87	8.67	10.56	25.83	8.92	"
13	30.21	17.40	5.25	8.10	10.98	"
14	9.24	15.25	6.91	40.29	11.82	"
15	25.3	4.41	8.71	7.30	15.22	"
16	44.35	8.95	13.71	6.05	11.18	"
17	18.29	17.14	3.21	21.89	21.27	"
18	8.90	11.25	5.76	11.72	10.87	"
19	8.35	5.25	6.50	2.76	9.59	"
20	5.10	2.41	5.47	4.65	16.37	"
21	6.20	3.95	3.05	2.99	10.20	"
22	4.35	5.98	4.76	2.16	3.30	cleaning
23	3.33	2.86	3.59	5.45	3.43	"
24	4.11	2.19	4.36	2.83	3.16	"
25	3.65	4.20	2.30	2.99	2.80	"
26	4.89	3.32	4.18	3.22	2.12	"
27	2.75	4.06	3.19	4.19	3.20	"
28	4.22	3.19	2.76	2.74	6.26	"
29	2.61	2.16	2.11	8.11	3.27	"
30	3.21	2.56	2.28	12.55	4.26	"
31	7.82	8.12	6.57	11.50	2.88	"
32	9.04	7.42	6.86	7.50	7.35	sumping
33	13.67	9.71	8.92	6.10	9.65	"
34	8.02	7.29	9.12		7.76	"
35	7.49	9.39	6.12		8.26	"
36	5.60				5.89	"

37					7.82	"

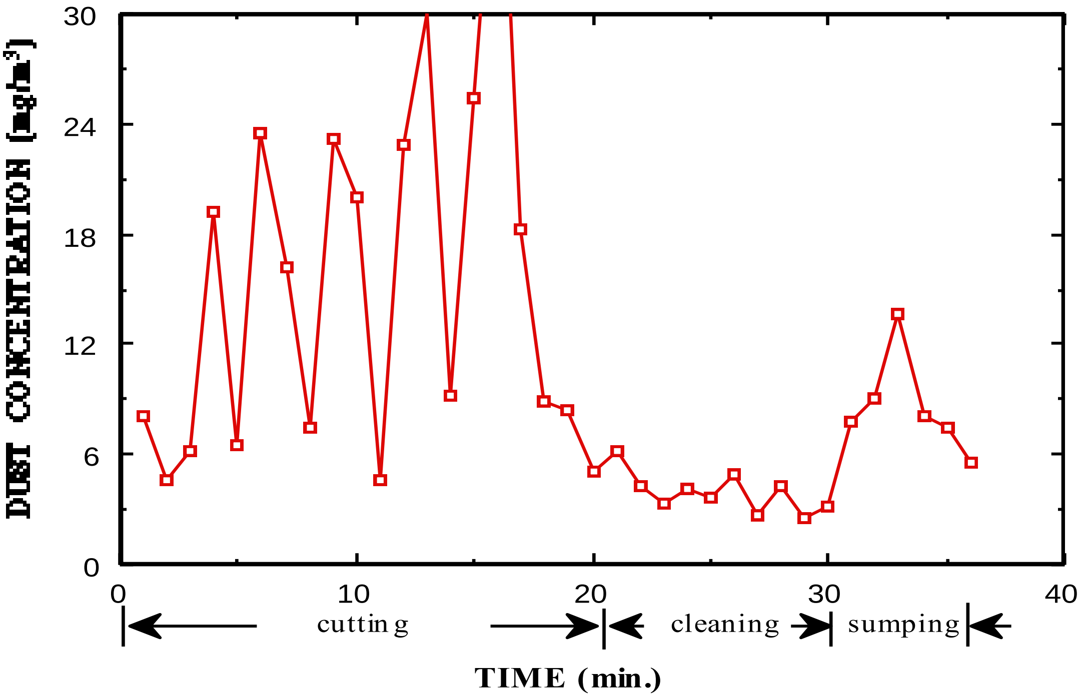

Figure 3.8 Instantaneous respirable dust concentration at return end samp station during a cutting cycle in longwall face A for experiment

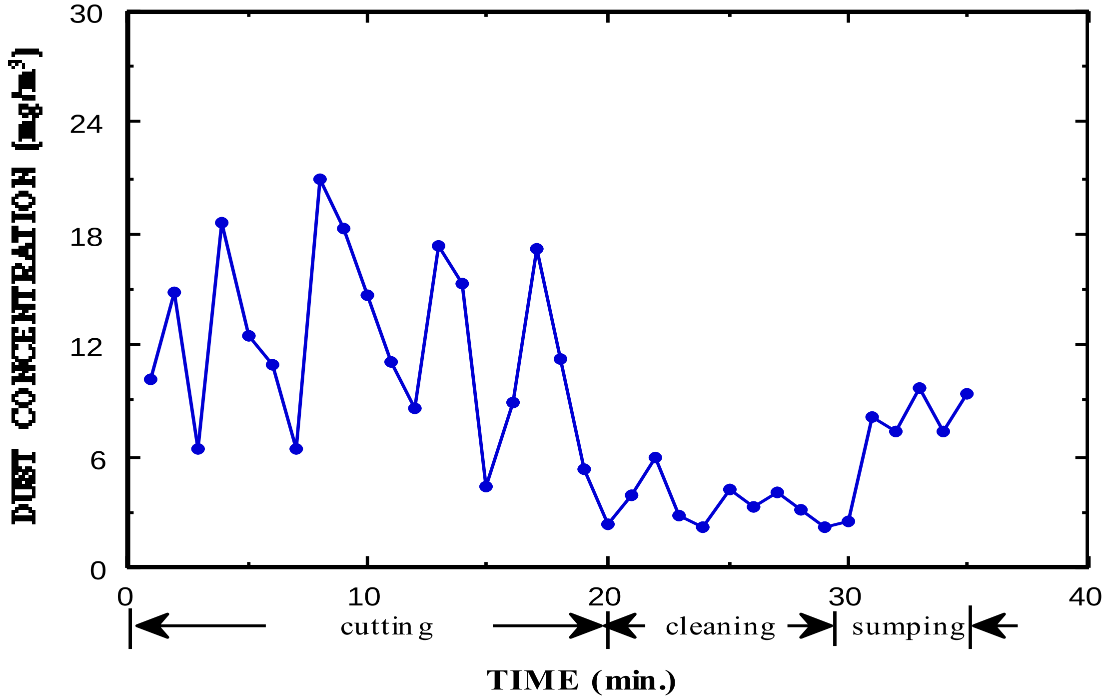

Figure 3.9 Instantaneous respirable dust concentration at return end sam
station during a cutting cycle in longwall face A for experiment

A plot of instantaneous respirable dust levels at the stage loader is shown in Figure 3.10. As a homotropal ventilation system was used in this face, the dust generated at this location did not contribute to the longwall face dust concentration, but overloaded the rock dusting requirements in the return airway. However, results show that a large amount of respirable dust was generated at the stage loader. Therefore, it is very important to control the dust generation at the stage loader and at other intake dust sources in antitropally ventilated faces.

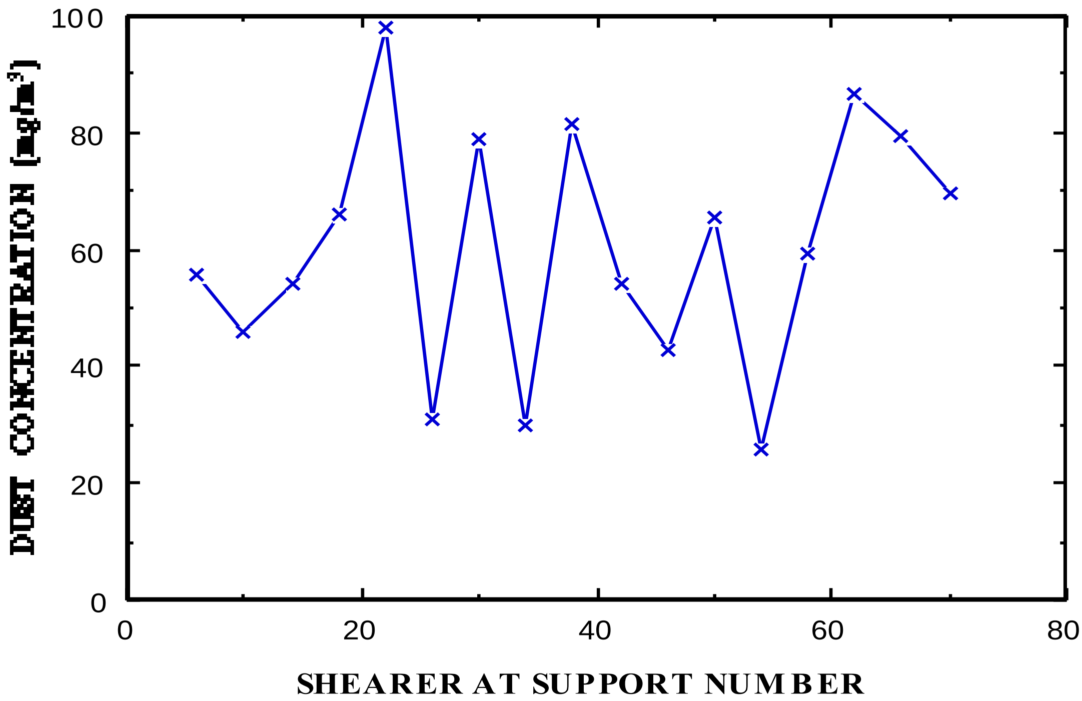

Figure 3.10 Instantaneous respirable dust concentration at crusher/stage during a cutting cycle in longwall face A.

(ii) Dust profiles around the shearer: Respirable dust concentration profiles around the shearer, a major dust source, are given in Figures 3.11 and 3.12. These figures show clearly the pattern in which the dust emanates from the shearer which is the major dust source. A very high dust concentration zone was observed near the cutting

drums but was beyond the surveyor's reach. As the distance from the shearer increased, the

Figure 3.11 Instantaneous respirable dust concentration profile around shearer during cutting cycle in longwall face A for experiment 1.

Figure 3.12 Instantaneous respirable dust concentration profile around shearer during cutting cycle in longwall face A for experiment 2.

airborne dust in the high concentration zone gradually dispersed into the whole ventilation space. Analysis shows that the dust concentration decreased continuously from the midpoint of the shearer to the downstream side and reached the lowest level at 5 to 10 m downstream of the lead drum. After this point, the dust concentration increased gradually until it reached its highest level, which was generally 3 to 4 times higher than that around the leading drum operator.

Figures 3.11 and 3.12 show very high dust concentration levels at the rear/upwind drum operator's position. To check these unusual high dust levels when cutting in the direction of ventilation, a sampling survey with a moving instrument was conducted. During this survey, the instrument was positioned at the upwind drum operator's position throughout the cutting cycle. The results of this survey for one complete cycle are given in Figure 3.13. The very high dust concentration levels obtained at the shearer's rear drum were due primarily to the effect of the 'boiling' over of dust caused by misdirected water sprays at the rear of the shearer. Support movement upwind of the rear operators was also found to be one of the contributing factors. As indicated in Figure 3.13, the dust concentration levels around chocks 18 and 31 were very high. An analysis of time data showed that, at these locations, the shearer was cutting a small rock band which produced large amounts of dust.

Figures 3.14 and 3.15 show the dust concentration at the lead/main drum operator's position, and at a distance 5 m downwind of the shearer during the entire cutting cycle. Most of the time the dust levels were within the statutory limit of 3 mg/m^3. These figures suggest that the best location for the downwind drum operator would be 4 m ahead of the shearer to reduce his dust exposure levels.

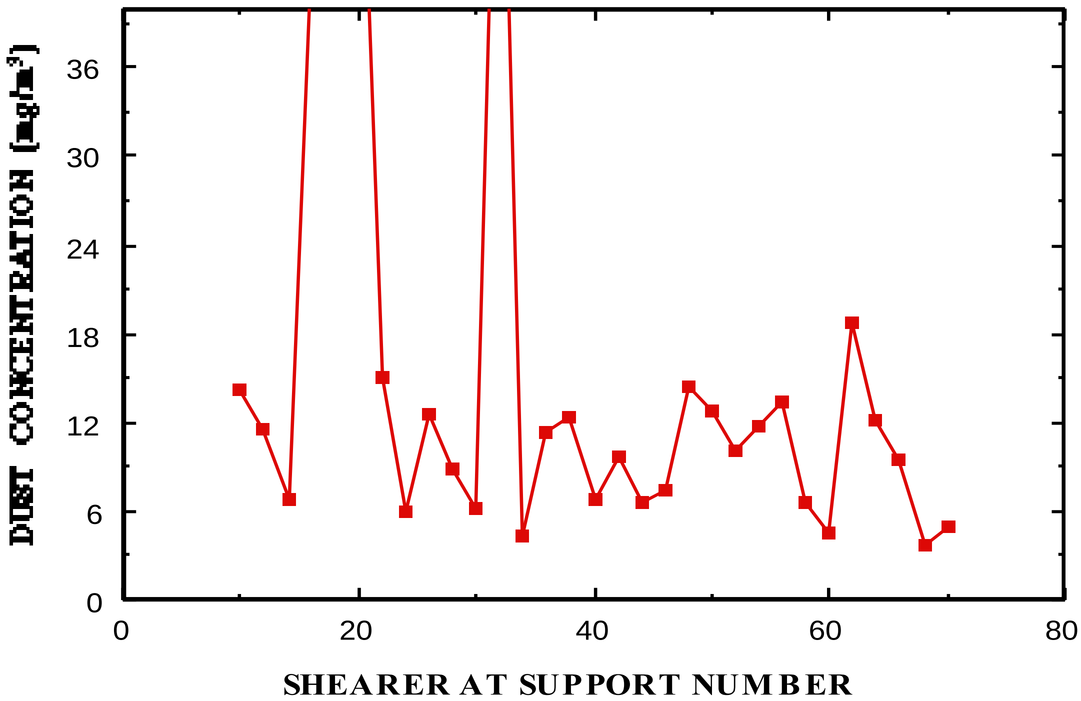

Figure 3.13 Instantaneous respirable dust concentration at upwind cuttin
operator's position during a cutting cycle in longwall face A.

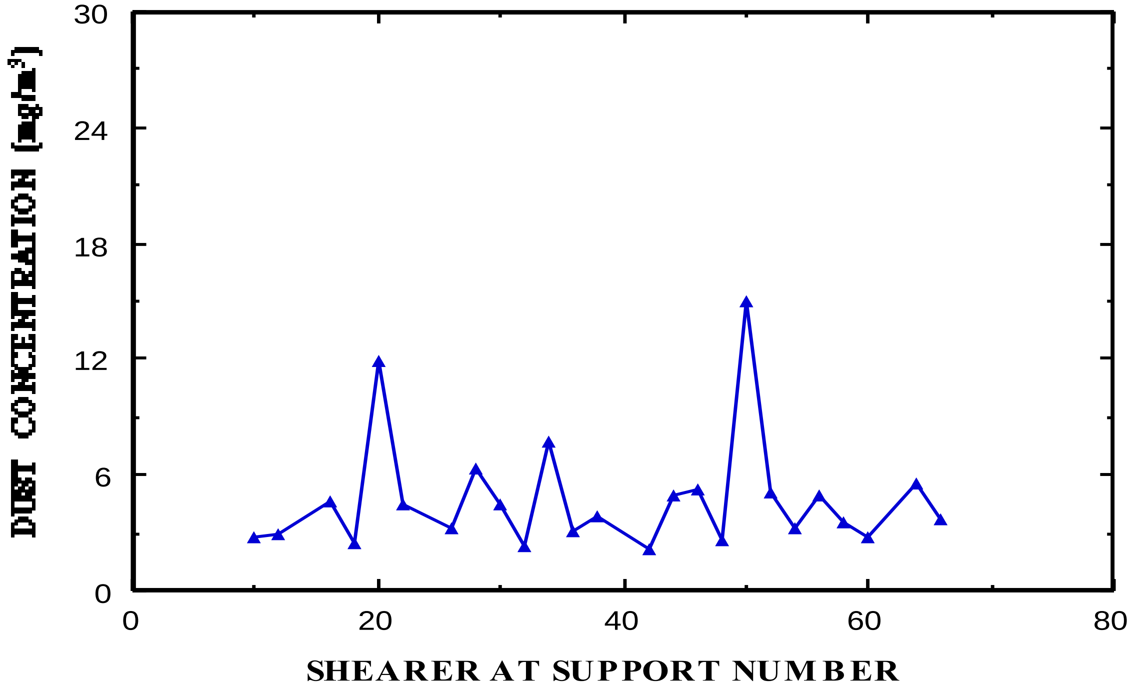

Figure 3.14   Instantaneous respirable dust concentration at downwind operator's position during a cutting cycle in longwall face A

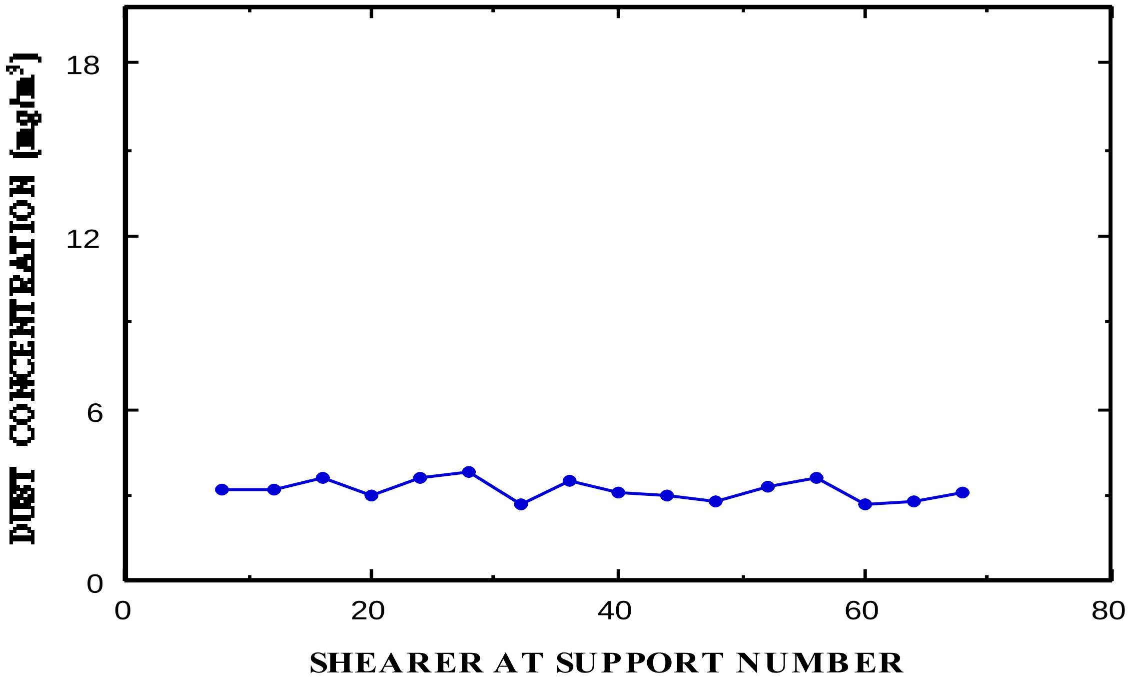

Figure 3.15 Instantaneous respirable dust concentration at 5 m downs of shearer during a cutting cycle in longwall face A.

(iii) Support generated dust profiles: Typical support generated dust concentration profiles along the face at 1 m, 5 m and 10 m downwind of the support movement are shown in Table 3.4 and Figure 3.16. The difference between the upwind and downwind concentration levels during support movement gives the dust generated by supports, which is shown as the shaded area in the plots. The dust generation varies significantly along the face. For example, in figure 3.16(a), the dust concentration downwind of the supports ranged between 38.5 and 7.5 mg/m^3. The average upwind dust concentration was 0.9 mg/m^3 and the downwind dust concentration was 17.10 mg/m^3, with the overall average support generated dust concentration being 16.20 mg/m^3.

The dust level in walkway decreased as the distance to the moving supports increased. The average dust concentration at 1 m downwind of the moving supports was 17.1 mg/m^3, at 5 m it was 8.8 mg/m^3 and at 10 m downwind the dust level was only 3.7 mg/m^3. This is because the primary ventilating airflow dilutes and diffuses the

Table 3.4. Dust generation during support movement

Support No.	Dust level (mg/m^3)			
	upwind	downwind -at a distance of		
		1 m	5 m	10 m
10	0.80	10.50	7.10	3.50
12	0.65	16.8	6.50	4.30
14	0.72	28.2	6.80	2.90
16	1.10	8.50	11.30	3.80
18	1.20	15.30	14.40	5.70
20	0.69	25.40	10.50	5.20
22	0.82	16.90	12.90	2.90
24	0.83	28.50	6.50	4.30
26	0.92	20.10	7.20	3.20
28	0.85	14.30	8.50	3.10
30	1.05	9.50	10.80	2.60
32	1.18	7.20	15.20	2.80
34	0.72	16.10	12.60	4.20
36	0.88	13.50	8.20	6.30
38	0.67	12.20	11.60	3.80
40	1.19	18.50	8.60	2.50
42	0.92	11.50	4.50	3.70
44	0.99	26.50	13.10	4.00
46	1.05	22.00	7.80	4.60
48	1.21	38.50	4.30	3.20
50	1.10	30.20	8.20	6.50
52	0.97	10.50	6.30	2.80
54	0.81	7.90	7.50	2.40
56	0.75	12.50	8.00	3.10
58	0.80	18.40	11.00	2.80
60	0.86	19.20	7.10	3.50
62	0.70	7.30	5.20	2.20
64	0.50	10.30	6.30	3.43

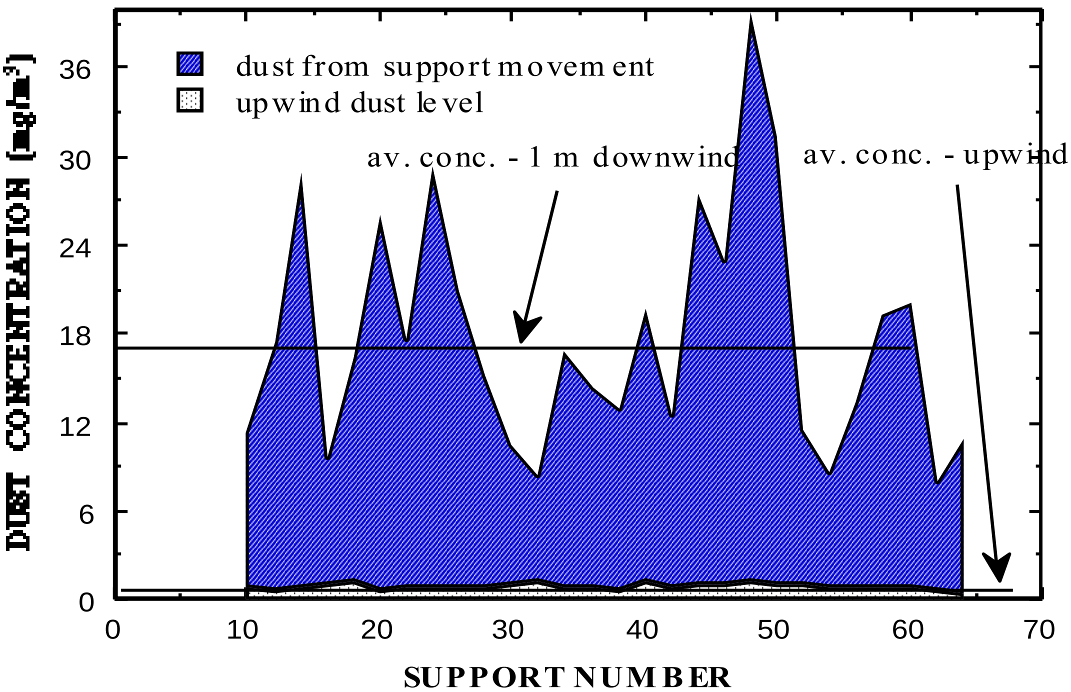

Figure 3.16(a) Instantaneous respirable dust concentration at 1 m downwi
of support movement in longwall face A.

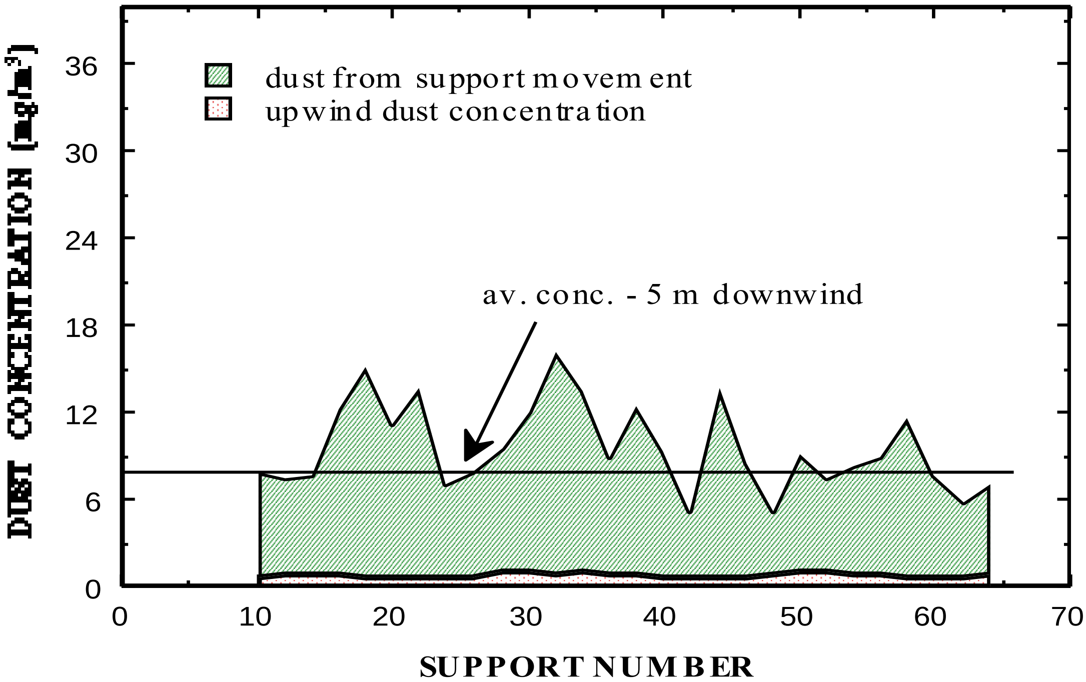

Figure 3.16(b) Instantaneous respirable dust concentration at 5 mdownw of support movement in longwall face A.

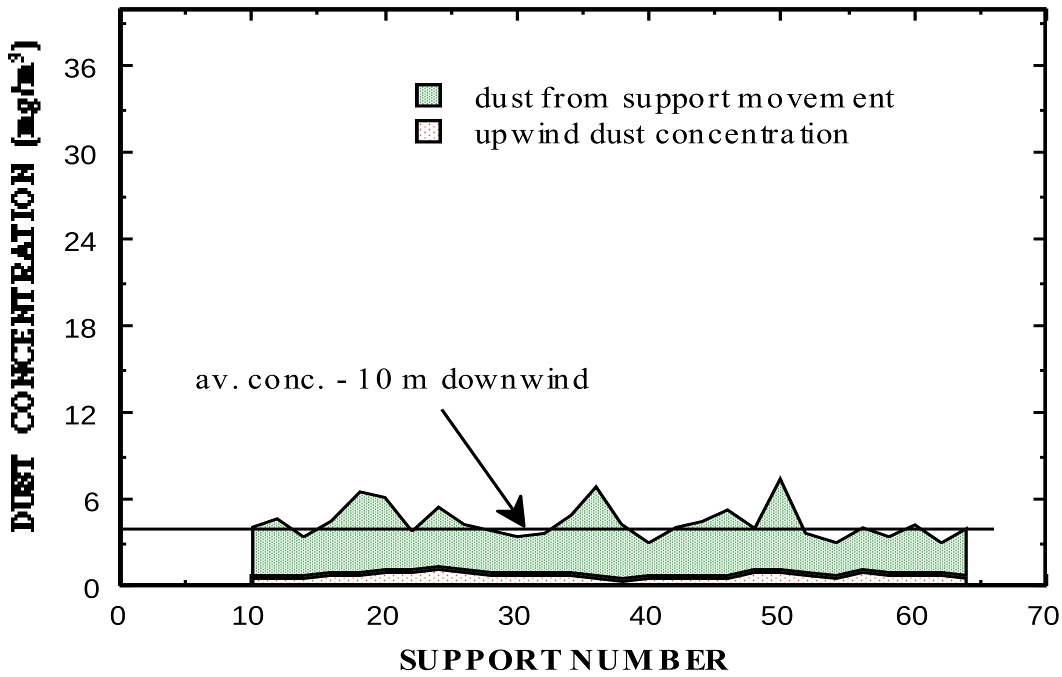

Figure 3.16(c) Instantaneous respirable dust concentration at 10 m downw of support movement in longwall face A.

dust generated by supports towards the face side. It can be inferred from these results that the contribution of support generated dust to the shearer operator's dust exposure varied depending on the distance between the shearer and support movement.

3.4.3 Respirable dust size distribution

The size distribution of respirable dust samples from longwall face 'A' was measured using a laser particle analyser. The results are shown in Figures 3.17 and 3.18 as histograms of weight percentage frequency against particle size. In these graphs the total percentage represents 100% and integration of the data results in the cumulative percentage curves. A plot of the cumulative percent of undersize by weight versus particle diameter in microns produced a typical S-type curve as shown in Figure 3.19. The median is readily observed from figure 3.19 as occuring at approximately 3.8 microns diameter. The size data for experiment 1, plotted on a log-normal scale, is shown in Figure 3.20. The size distribution of respirable dust found in this study are in general agreement with other studies (Ramani, Qin and Jankowski, 1992).

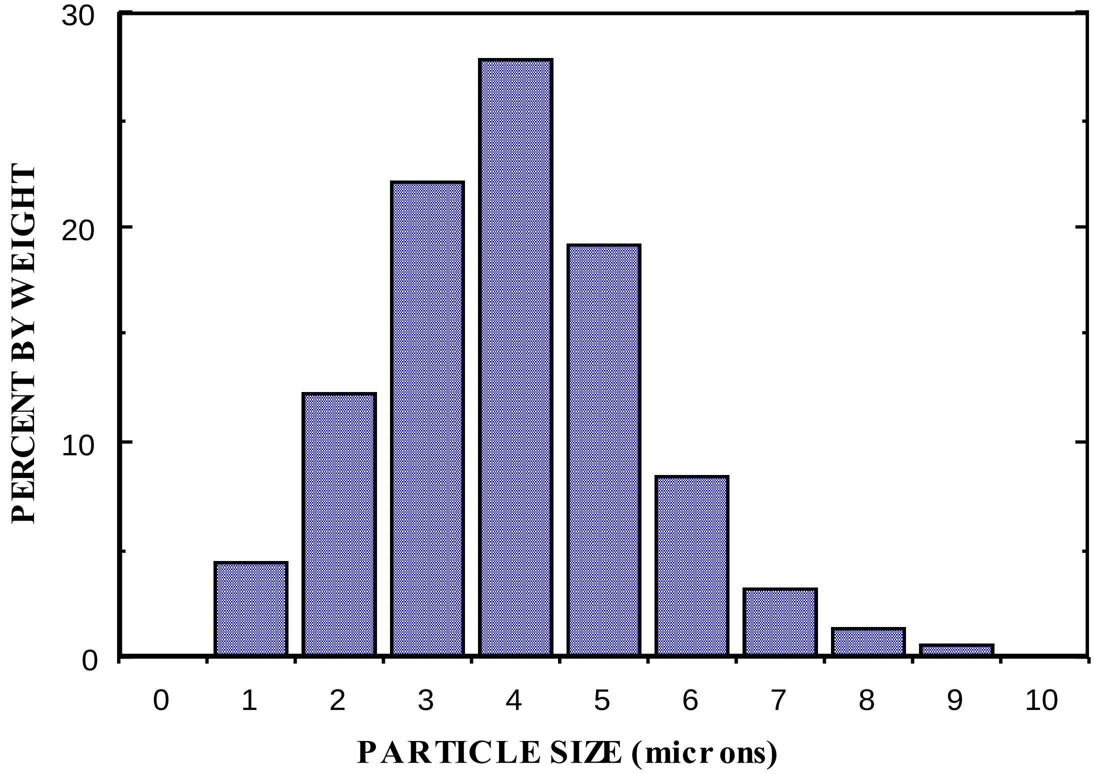

Figure 3.17 Particle size distribution of airborne respirable dust sampl collected from longwall face A for experiment 1.

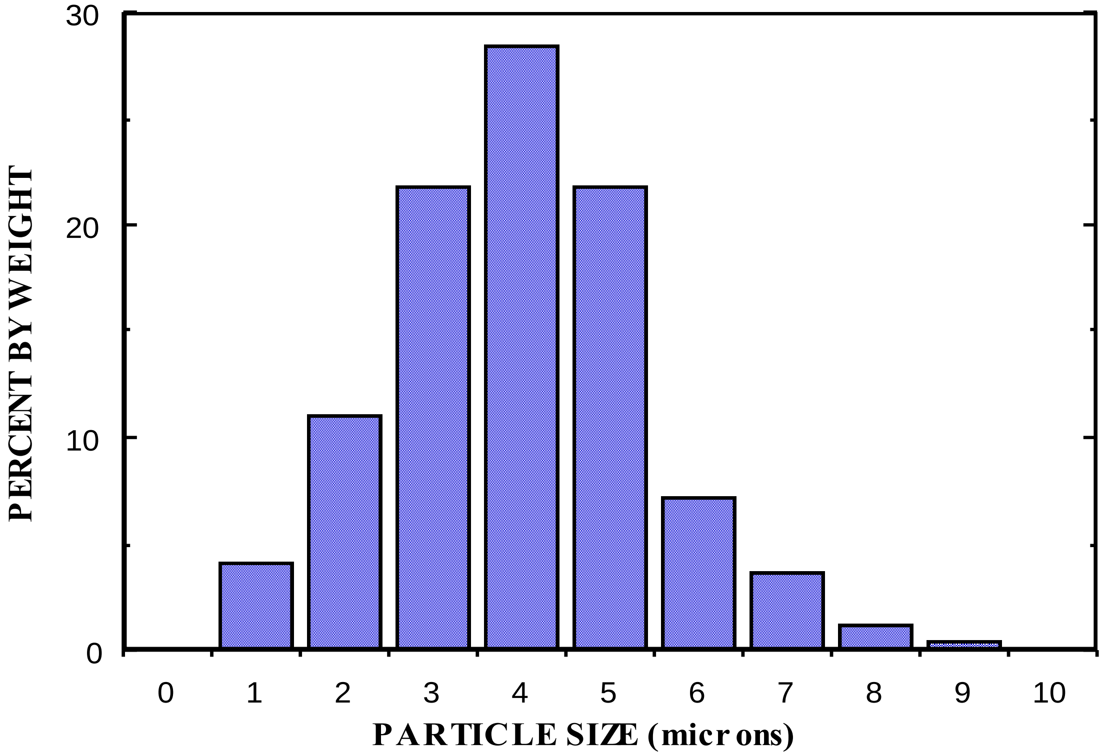

Figure 3.18 Particle size distribution of airborne respirable dust sample collected from longwall face A for experiment 2.

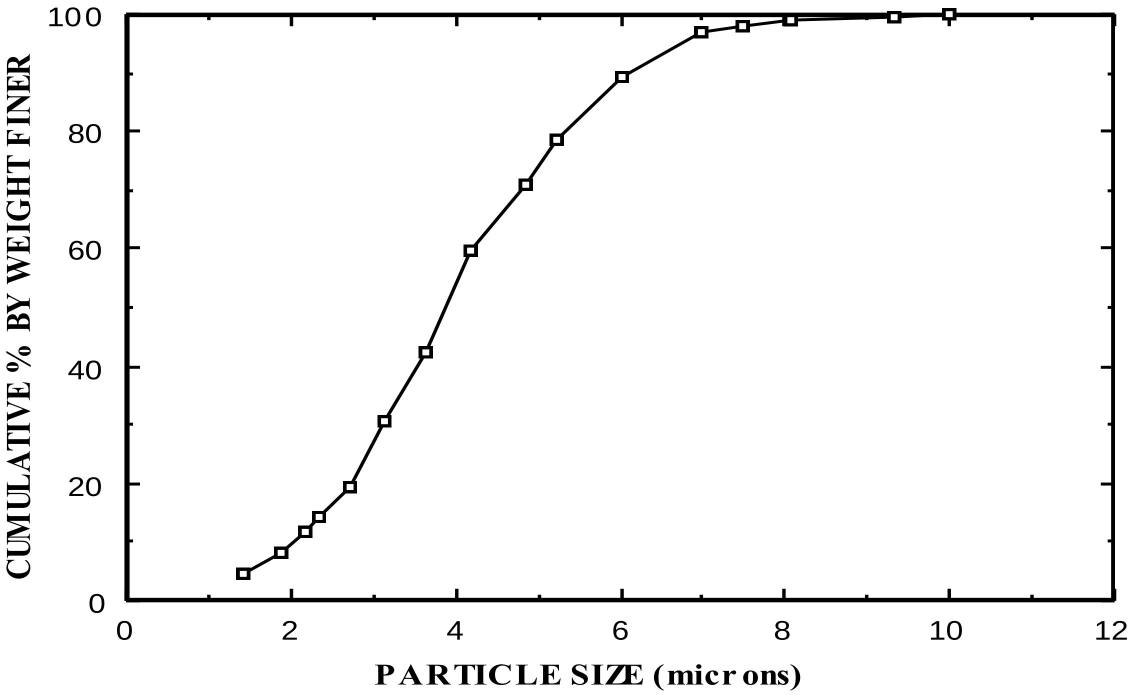

Figure 3.19 Typical cumulative particle size distribution of respirabl
samples collected from longwall face A.

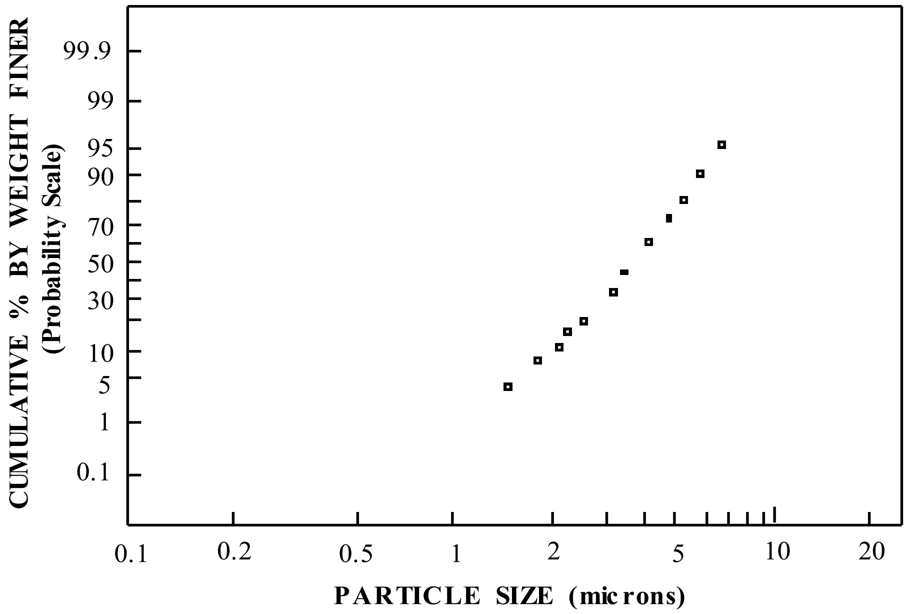

Figure 3.20 Typical cumulative particle size distribution of respirable dust samples collected from longwall face A on log-probability scale.

3.5 RESULTS OF INVESTIGATIONS IN LONGWALL FACE 'B'

Longwall face B was operating in the Bulli seam in the Southern district of NSW, Australia. The working height was between 2.2 and 2.7 m, the longwall face length 200 m and the length of the panel 1900 m. Anderson AM-500 double ended ranging drum shearer and Gullick 4 x 1000 tonnes four legged chock shields were used in this face. The diameter and width of the cutting drums were 1.8 m and 0.8 m respectively. The average tram speed of the shearer while cutting was approximately 7 m/min.

The cutting sequence was uni-directional with cutting from tailgate to maingate against the direction of ventilation. The roof supports were advanced on the return side of the shearer immediately after cutting. The ventilation system was antitropal and the face air velocity varied between 3.5 and 4.3 m/s. The daily production from the face was about 6 800 tonnes and the annual production was approximately 1.9 million tonnes.

3.5.1 Instantaneous dust concentration profiles

(i) Dust profiles near the return end of the face: The instantaneous sampling survey results of the experiments in longwall face B for one complete cutting cycle are shown in Figures 3.21 - 3.23. The activities of the shearer are indicated on the X axis. In figure 3.23 dust concentration profiles at two cutting speeds are presented. The average dust concentration was 9.7 mg/m^3 at 14 m/min cutting speed and 4.3 mg/m^3 at 7 m/min cutting speed. Results show that at high cutting speed dust levels are 2 to 2.5 times higher during both the cutting and cleaning phases of the cut cycle.

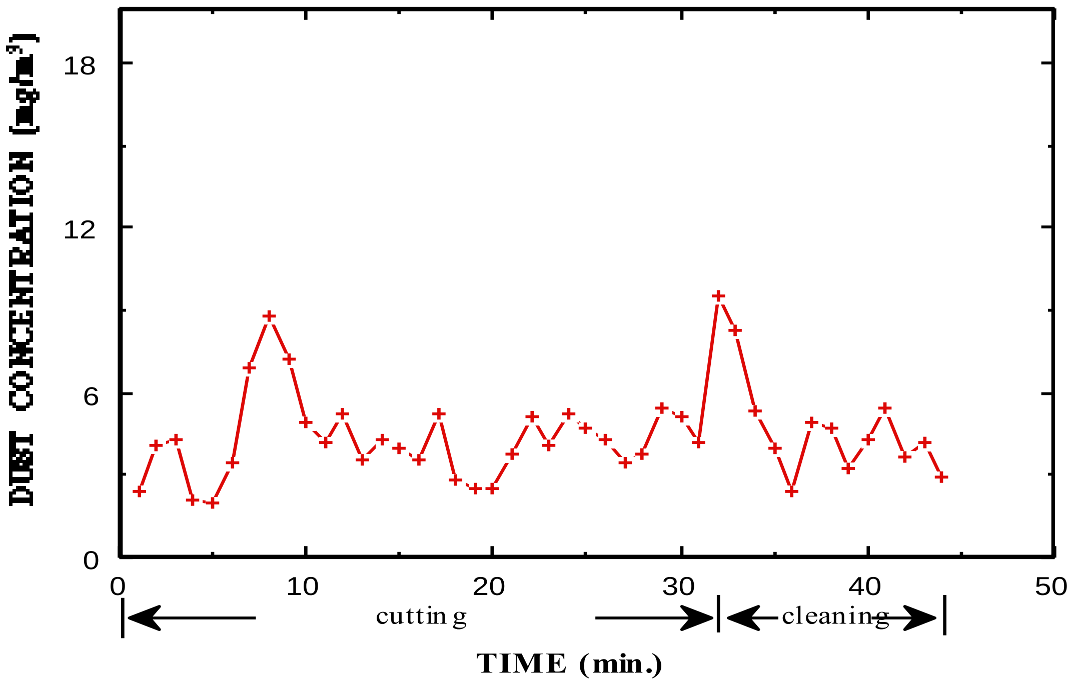

Figure 3.21 Instantaneous respirable dust concentration at return end sam
station during a cutting cycle in longwall face B for experiment

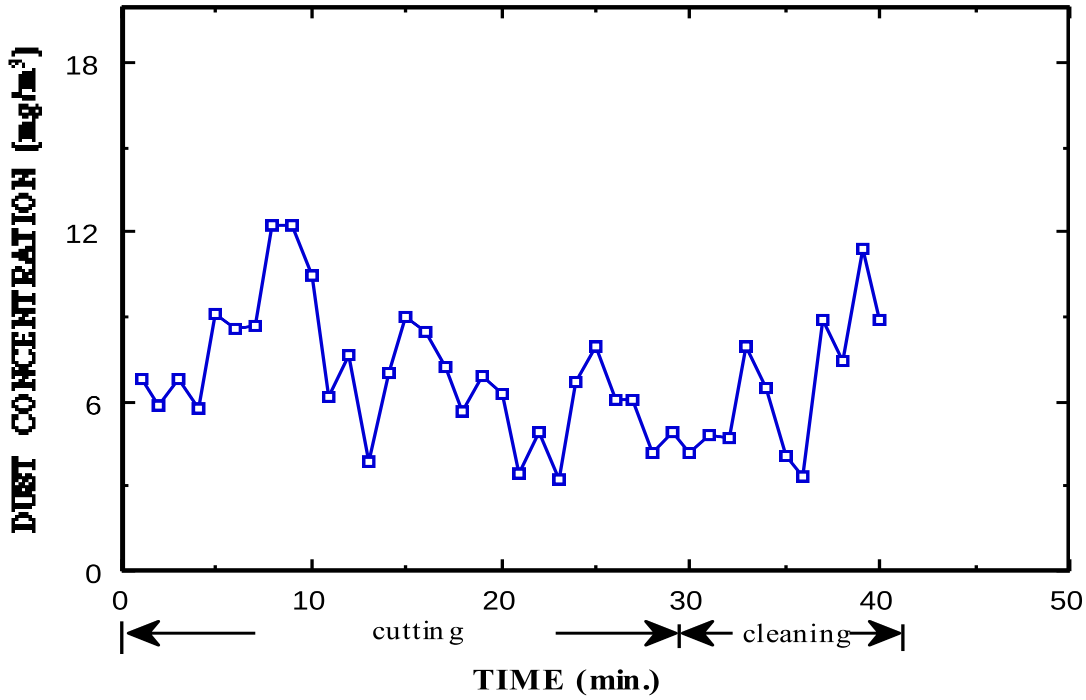

Figure 3.22 Instantaneous respirable dust concentration at return end san
station during a cutting cycle in longwall face B for experiment

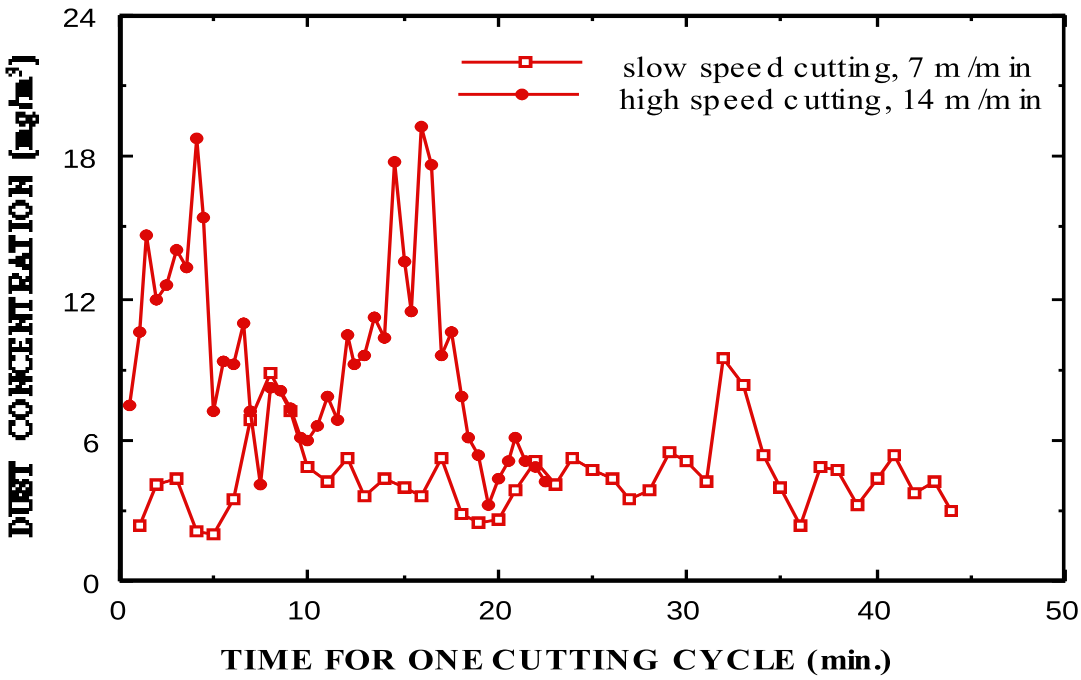

Figure 3.23 Instantaneous respirable dust concentration at return end sampling station during a cutting cycle in longwall face B with two cutting speeds.

<u>*(ii) Dust profiles at other sampling stations along the face*</u>: Dust concentration data at different locations along the face are shown in Figure 3.24. The dust peaks sampled near the maingate have short widths because these stations were upwind of the shearer most of the time. Towards the return end sampling station, however, the peaks of dust levels become wider. The average dust concentration levels at the 30th, 60th, 90th and 120th chock positions were 1.8, 3.2, 4.2 and 5.6 mg/m^3 respectively.

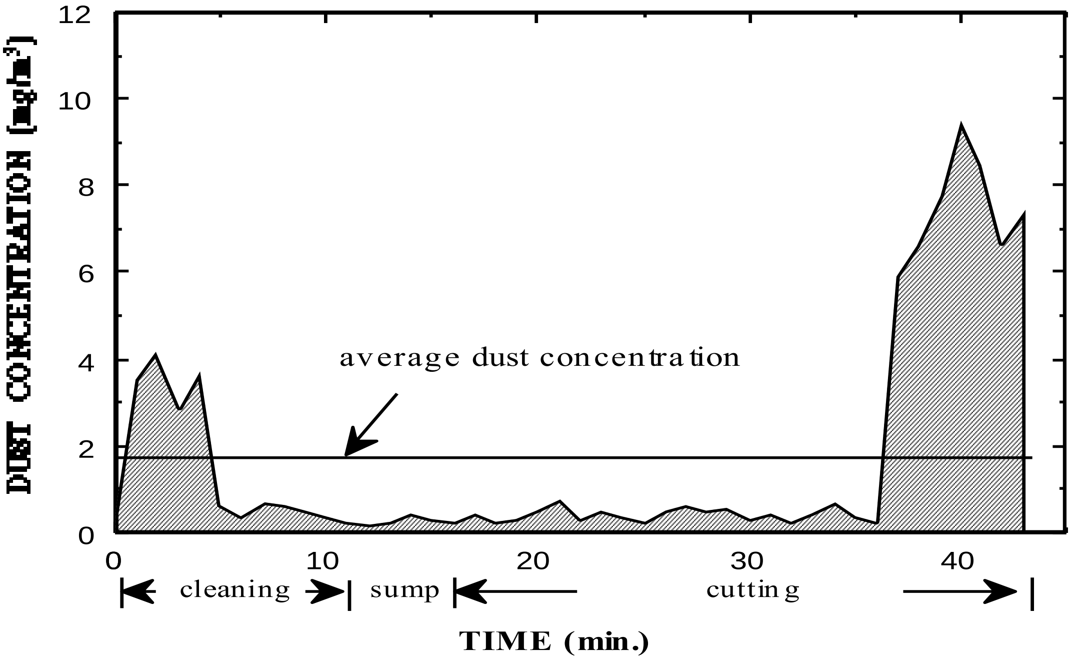

Figure 3.24(a) Instantaneous respirable dust concentration at 30th chock sampling station during a cut cycle in longwall face B (when cutting against ventilation).

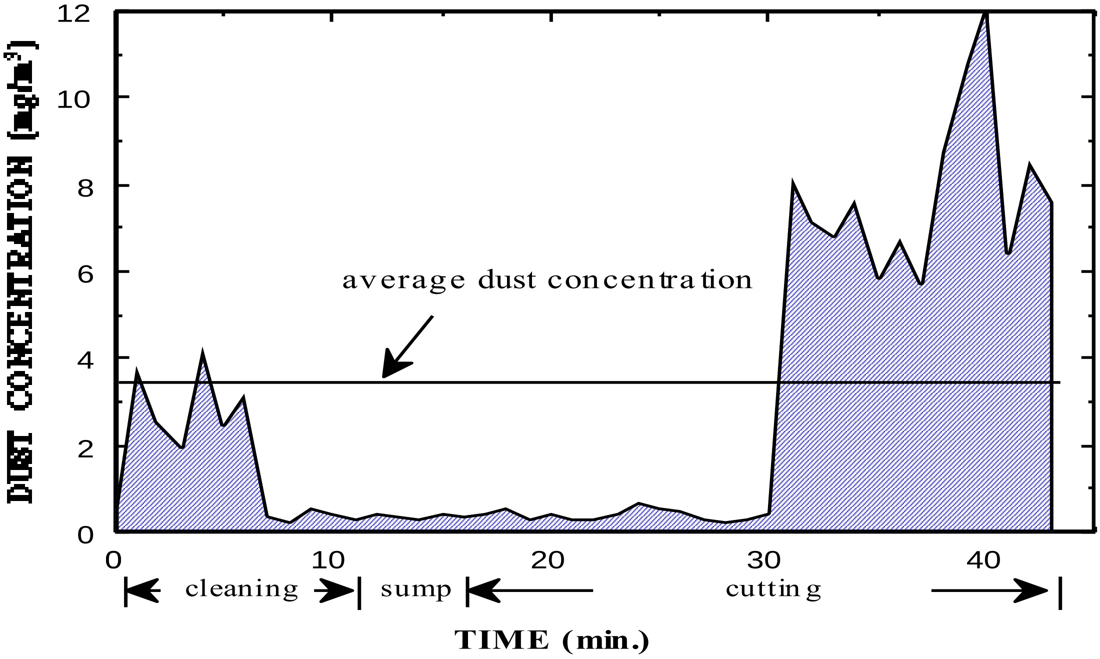

Figure 3.24(b) Instantaneous respirable dust concentration at 60th c
sampling station during a cut cycle in longwall face B
(when cutting against ventilation).

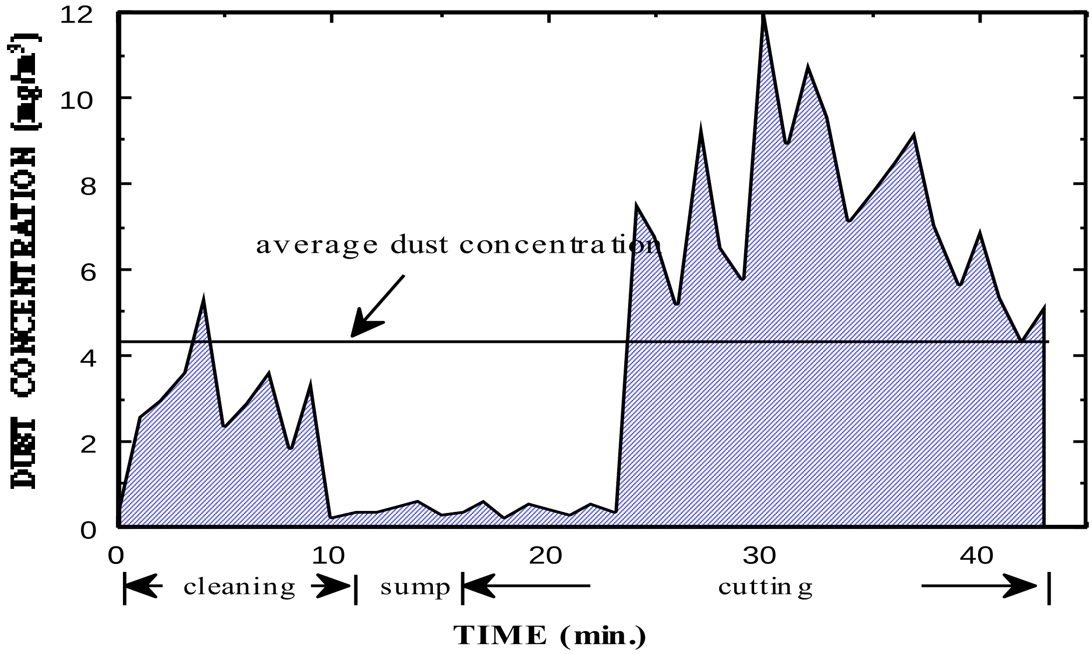

Figure 3.24(c) Instantaneous respirable dust concentration at 90th ch
samplingstation during a cut cycle in longwall face B
(when cutting against ventilation).

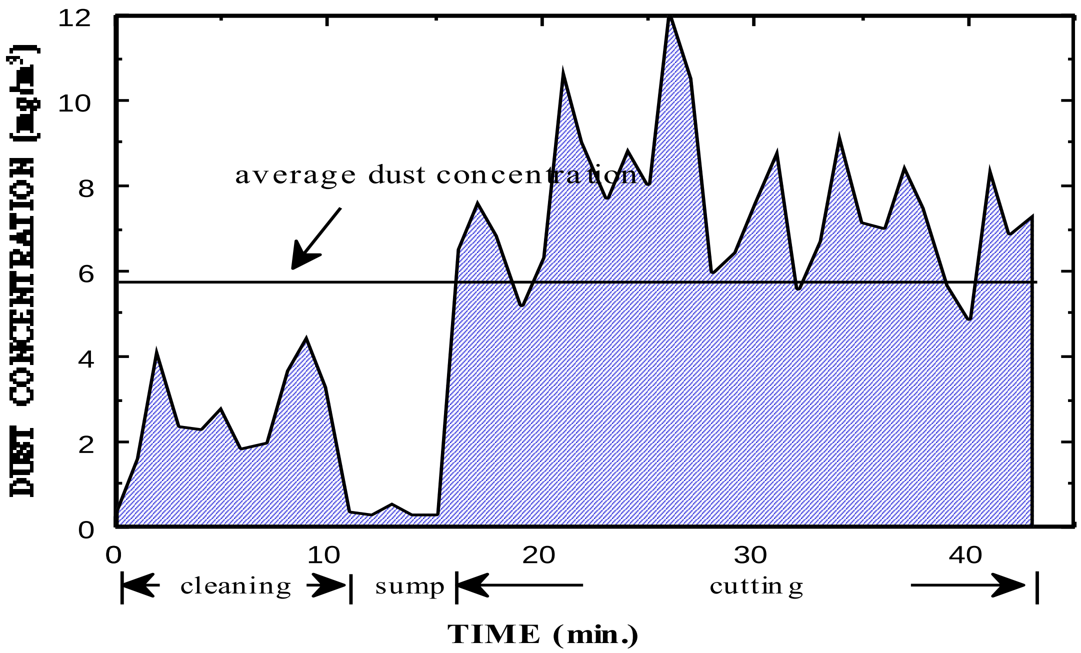

Figure 3.24(d) Instantaneous respirable dust concentration at 120th c
sampling station during a cut cycle in longwall face B
(when cutting against ventilation).

(iii) Dust profiles around the shearer: Typical respirable dust concentration profiles around the shearer are given in Figures 3.25 and 3.26. It can be seen that the pattern of dust profiles differ from those of in longwall face A, particularly in the vicinity of the shearer. Dust produced by the upstream lead drum quickly dispersed into the walkway over the shearer. The dust levels around the shearer increased rapidly from about 1.0 m on the return side of the shearer upstream/lead drum exposing both the operators to high dust concentration. This can be attributed to the cutting sequence which, in this case, was against the ventilation.

Figure 3.25 Instantaneous respirable dust concentration profile around shearer during cutting cycle in longwall face B for experiment 1.

Figure 3.26 Instantaneous respirable dust concentration profile around shearer during cutting cycle in longwall face B for experiment 2.

(iv) Dust profiles across the section of the face: Table 3.5 and Figure 3.27 shows a comparison of instantaneous dust concentration profiles at four different locations across the section of the face. The average concentrations were 5.9 mg/m^3 over the panline, 3.7 mg/m^3 in the front walkway, 5.4 mg/m^3 over the spill plate and 2.8 mg/m^3 in the back walkway. Perhaps the most surprising aspect is that these differences exist even after 50 m downwind of the shearer. A typical average dust concentration gradient across the section of the longwall face at the miner's breathing height (0.4 m below roof) is given in Figure 3.28. These figures demonstrate that large dust gradients exist, not only around the shearer, but also across the section of the longwall face. The dust profiles show that correct siting of sampling stations is crucial to the successful evaluation of dust control techniques.

Table 3.5. Dust levels at different locations across the longwall face

Time (min.)	Dust level (mg/m^3)			
	AFC	spill plate	front walkway	back walkway
1	6.50	5.49	5.20	3.70
2	6.70	5.90	4.40	3.20
3	6.70	5.80	4.50	3.63
4	5.30	4.90	3.70	2.93
5	6.75	6.00	4.25	3.20
6	5.25	6.80	4.00	3.05
7	6.44	4.30	3.40	2.17
8	4.35	6.40	3.25	2.79
9	5.20	4.50	3.86	2.90
10	7.60	5.80	4.24	3.21
11	6.50	7.10	3.80	2.90
12	5.77	4.80	3.90	3.10
13	4.38	4.70	3.30	2.40
14	5.79	5.25	3.18	2.50
15	5.45	4.80	3.40	2.80
16	4.90	5.50	3.40	2.80
17	6.10	6.40	3.90	3.20
18	9.30	5.60	4.20	2.70
19	5.53	4.72	4.30	2.84
20	5.00	6.10	3.30	2.90
21	5.90	4.95	3.50	2.60
22	6.34	5.70	3.90	3.20
23	4.80	5.30	3.44	2.90
24	5.50	5.00	3.80	2.70
25	6.32	4.80	3.67	3.10

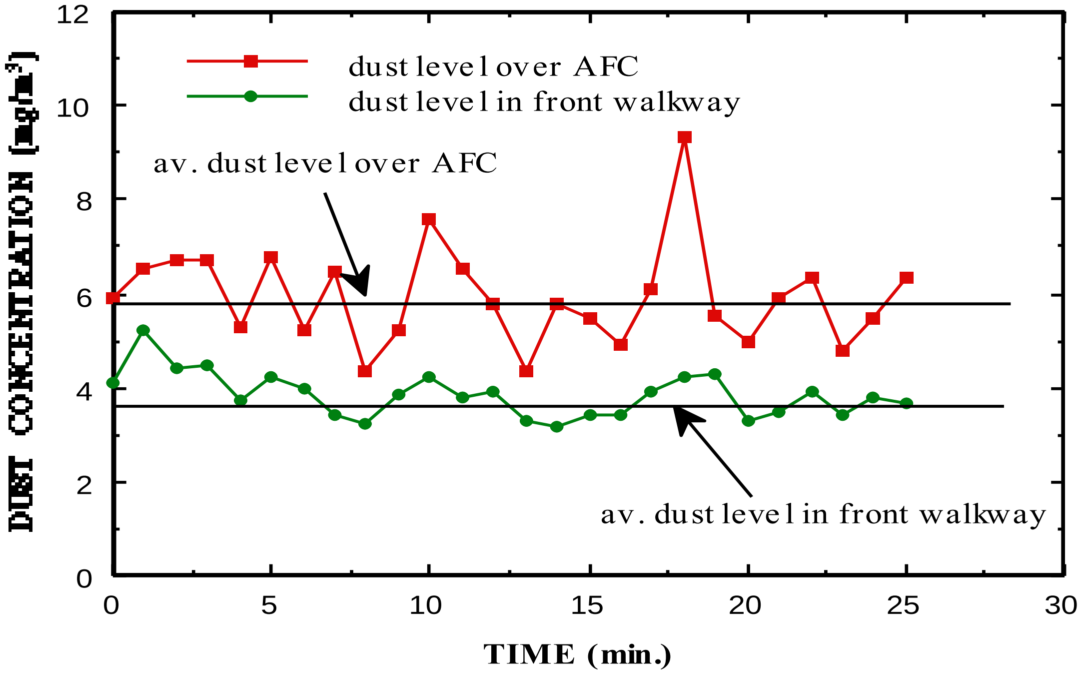

Figure 3.27(a) Instantaneous respirable dust concentration at two differe locations across the longwall face B (0.4 mbelow roof).

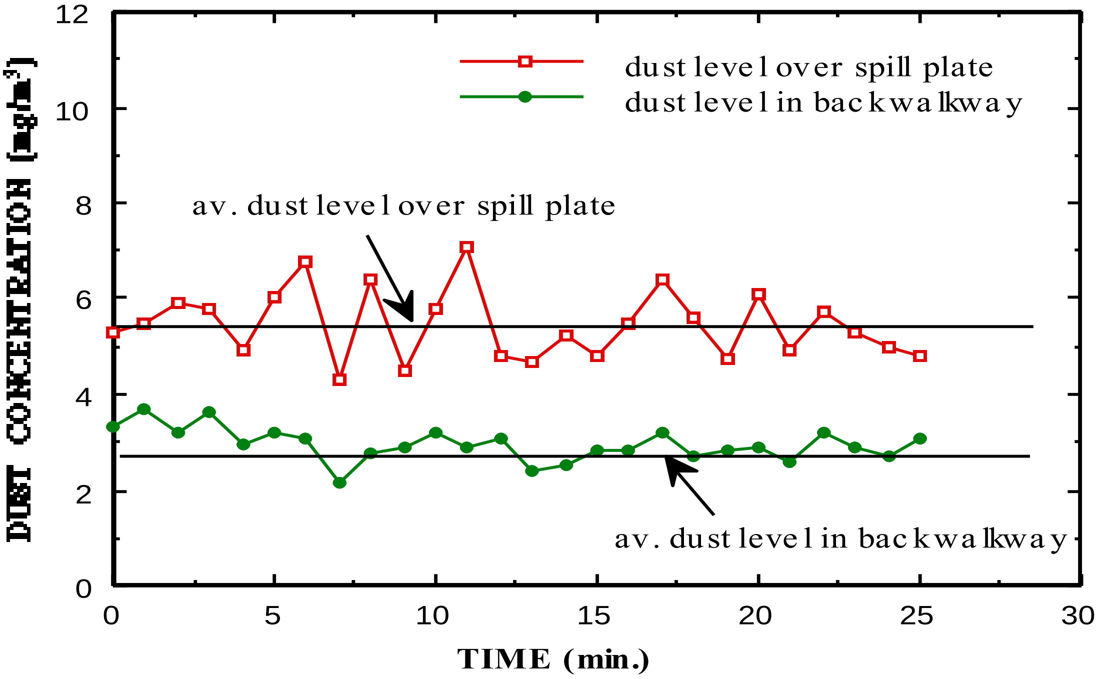

Figure 3.27(b) Instantaneous respirable dust concentration at two diffe
locations across the longwall face B (0.4 m below roof).

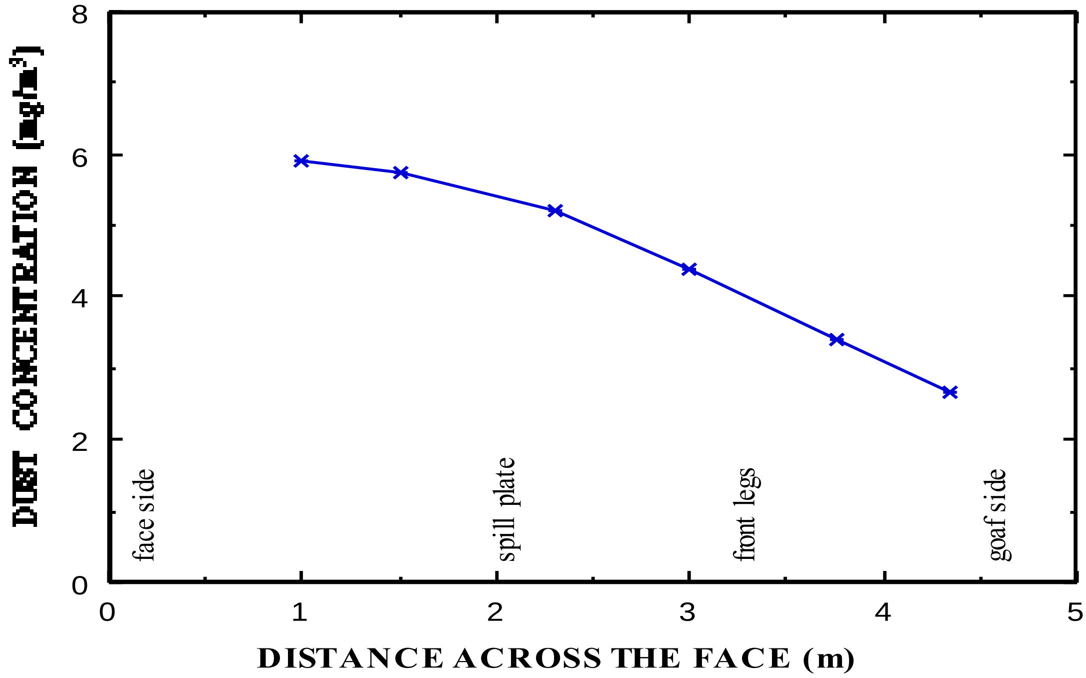

Figure 3.28 Typical respirable dust concentration profile across the lon face B at miner's breathing height (0.4 m below the roof).

3.5.2 Respirable dust size distribution

The particle size distribution of respirable dust samples from longwall face B is shown in Figures 3.29 - 3.30. A comparison of particle size distribution between dust samples from faces B and A is shown in Tables 3.6 - 3.7. It can be seen that the size distribution of dust from face B is quite different from that of face A. There are more fines in the dust sample from face B than that of face A. The cutting sequence, which is against the ventilation in this face, is one of the contributing factors to the high percentage of fines in the respirable dust. The median dust particle diameter of the respirable dust was approximately 3.45 microns. Figure 3.31 is a plot of the particle size against the cumulative weight percentage of particles smaller than that size on a log-normal scale.

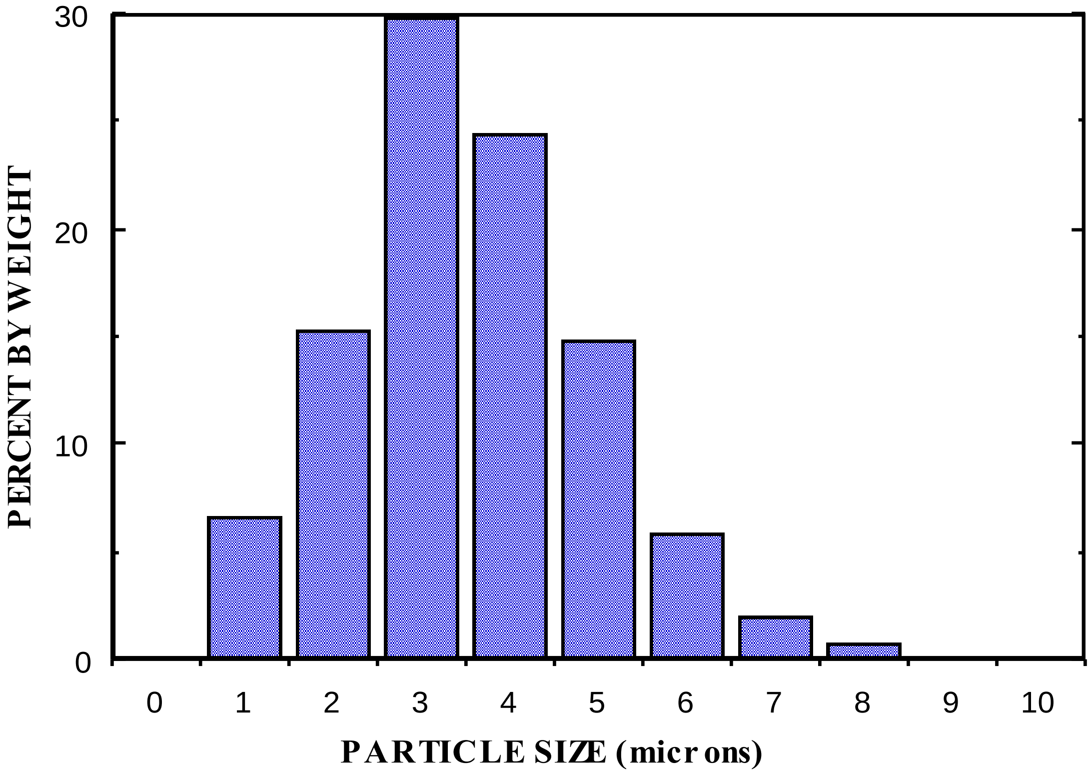

Figure 3.29 Particle size distribution of airborne respirable dust samp
collected from longwall face B for experiment 1.

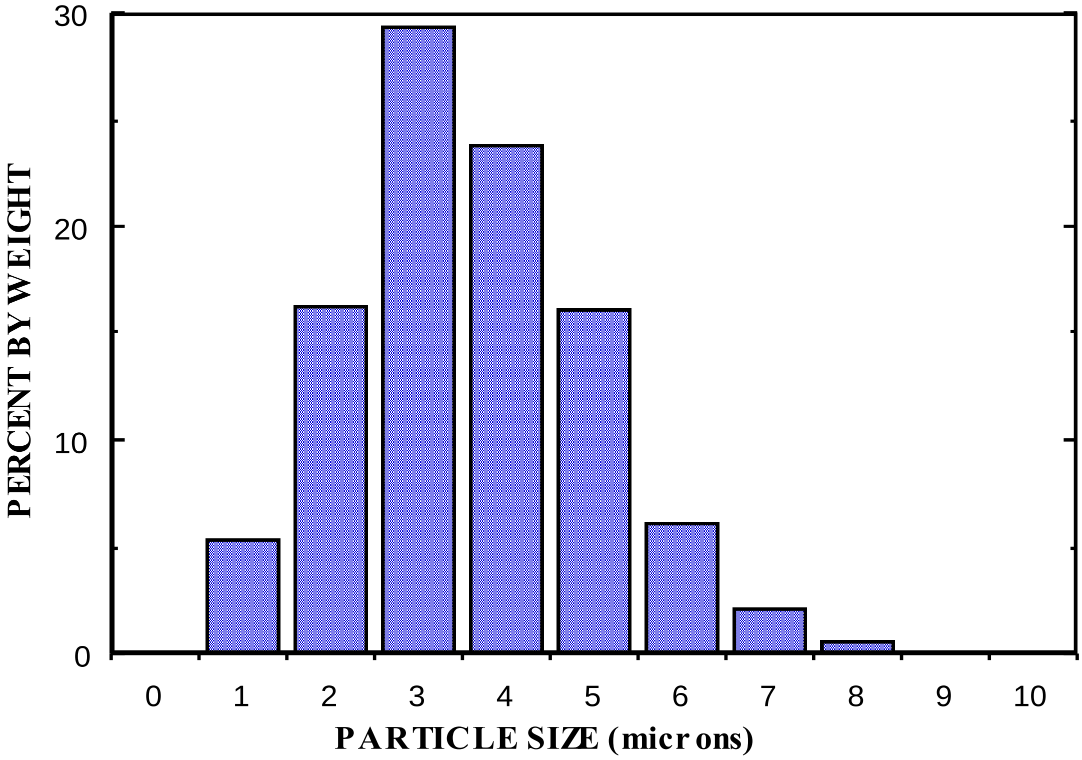

Figure 3.30 Particle size distribution of airborne respirable dust sampl
collected from longwall face B for experiment 2.

Table 3.6. Respirable dust size distribution

particle size (microns)	Face B		Face A	
	Exp. 1	Exp. 2	Exp. 1	Exp. 2
1	6.70	5.40	4.50	4.20
2	15.30	16.30	12.30	11.00
3	29.80	29.40	22.10	21.80
4	24.50	23.90	27.80	28.50
5	14.90	16.10	19.20	21.80
6	5.80	6.20	8.50	7.30
7	2.00	2.10	3.30	3.70
8	0.80	0.60	1.40	1.20
9	0.00	0.00	0.60	0.50
10	0.00	0.00	0.00	0.00

Table 3.7. Respirable dust particle cumulative size distribution

particle size (microns)	Face B		Face A	
	Exp. 1	Exp. 2	Exp. 1	Exp. 2
1.22	3.00	2.50	2.80	2.30
1.88	8.80	8.20	8.30	7.50
2.18	11.96	10.97	11.90	10.70
2.71	25.30	24.51	19.40	17.50
3.13	39.80	38.45	30.40	28.60
3.62	55.50	54.50	42.60	40.80
4.19	69.90	67.85	59.90	57.50
4.84	80.30	78.50	70.80	69.90
5.21	84.60	84.50	78.50	80.70
6.02	93.67	94.10	89.30	90.20
6.97	98.90	98.90	96.70	96.50
7.49	99.20	99.40	98.00	98.30
8.05	99.60	99.70	99.10	99.30
10.00	100	100	100	100

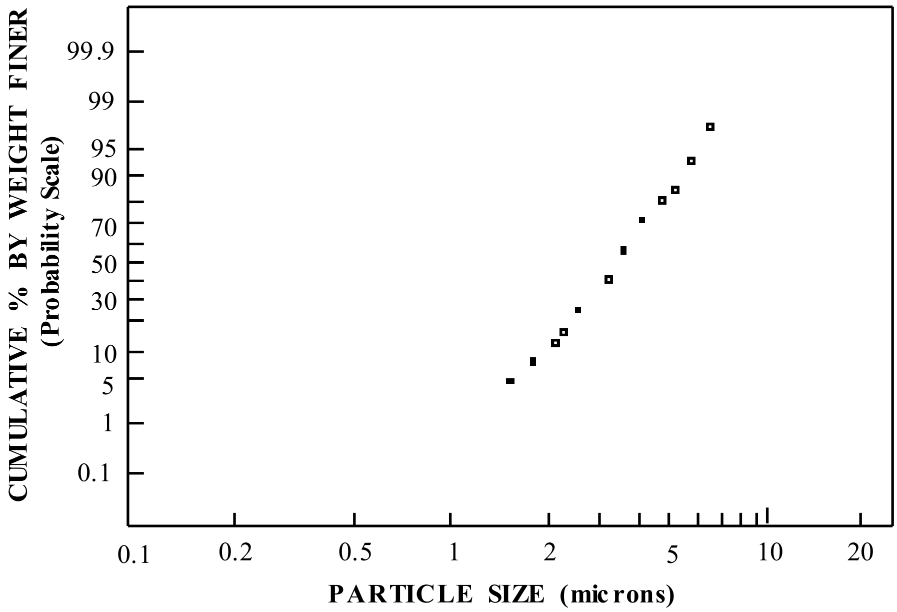

Figure 3.31 Typical cumulative particle size distribution of respirable dust samples collected from longwall face B on log-probability scale.

3.6 RESULTS OF INVESTIGATIONS IN LONGWALL FACE 'C'

Longwall face C was operating in the Bulli seam in the Southern district of NSW, Australia. The working height was between 2.1 and 2.5 m, the longwall face length 150 m and the length of the panel 1300 m. Anderson AM 500 double ended ranging drum shearer and 4 x 600 tonnes Meco four legged chocks were used in this face. The diameter and width of the cutting drums were 1.6 m and 0.9 m respectively. The average tram speed of the shearer, while cutting, was approximately 6.5 m/min. The cutting sequence was uni-directional with cutting from tailgate to maingate in the direction of ventilation. The roof supports were advanced on the intake side of the shearer immediately after cutting. A homotropal ventilation system was used and the face air velocity varied between 1.9 and 2.1 m/s. The daily production from the face was about 4,500 tonnes and the annual production was approximately 1.6 million tonnes.

3.6.1 Instantaneous dust concentration profiles

(i) Dust profiles near the return end of the face: Instantaneous dust concentration profiles at the return end sampling station at the face over one complete cutting cycle are shown in Figures 3.32 and 3.33. The results show that the rate of dust generation by the shearer was variable, reflected in the varying heights of the peaks. A large number of smaller peaks represents secondary dust sources such as support advance, face spalling, rock cutting and roof collapse in the goaf. More specifically, in figure 3.32 there is a peak at the 23rd minute, which a time study attributes to the shearer cutting a fallen rock boulder and generating large amounts of dust. This figure also reinforces the fact that dust generated during the sumping phase contributes significantly to the miners' dust exposure.

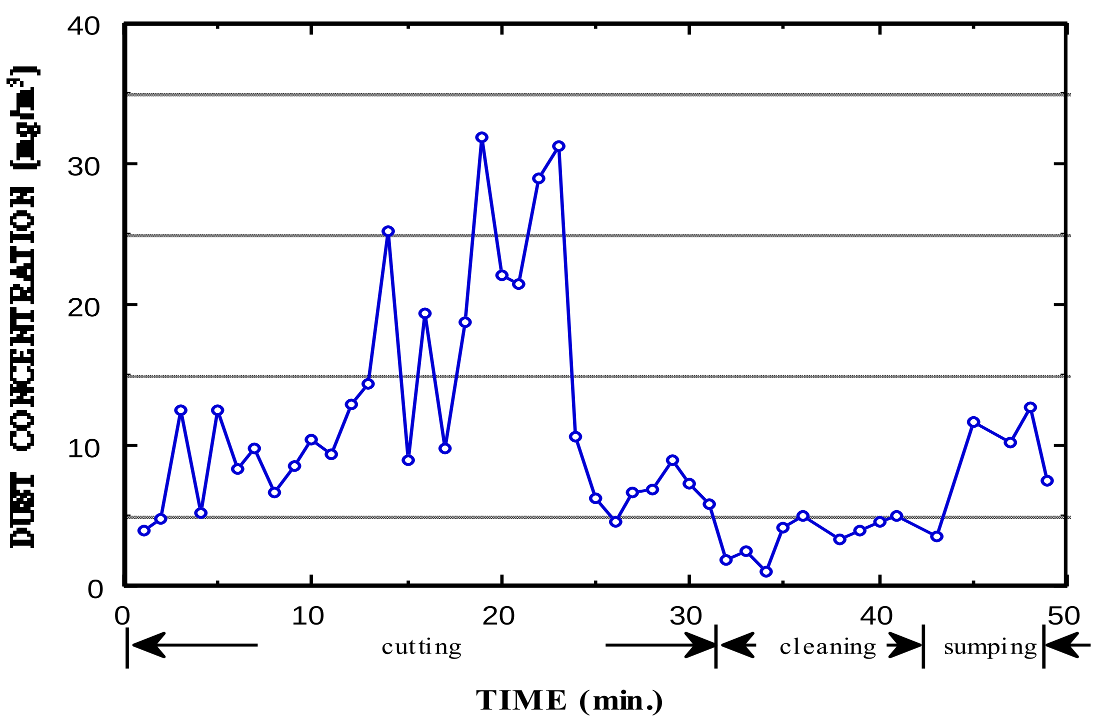

Figure 3.32 Instantaneous respirable dust concentration at return end san
station during a cutting cycle in longwall face C for experiment

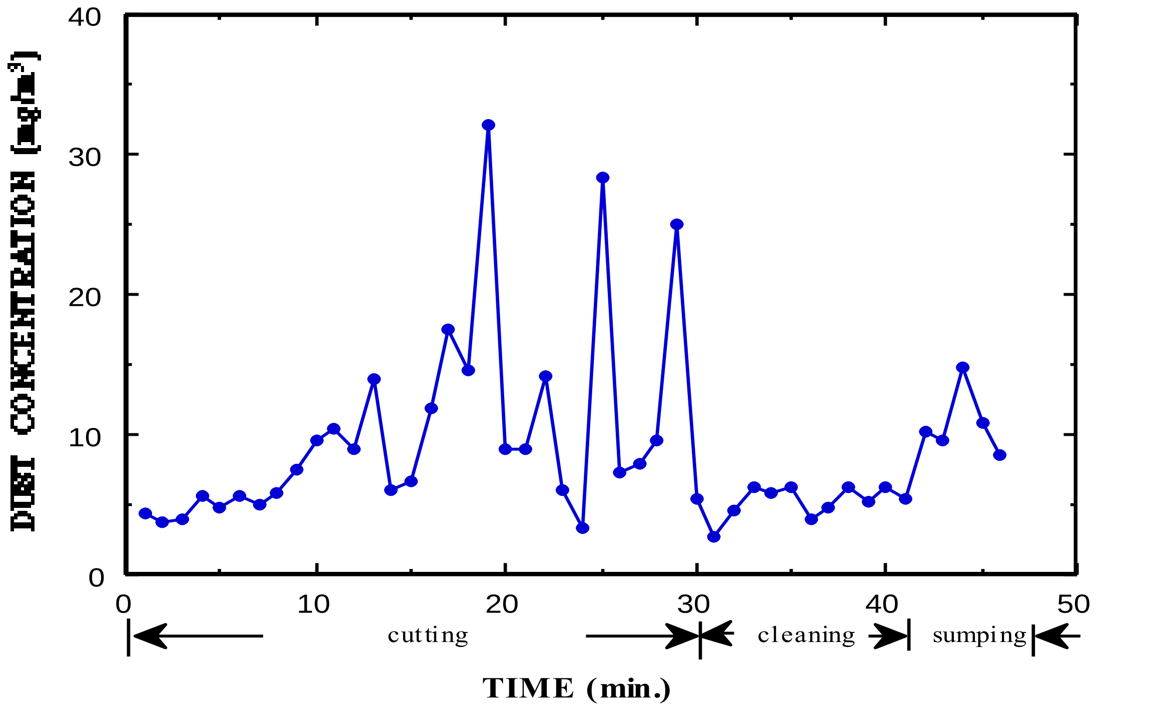

Figure 3.33 Instantaneous respirable dust concentration at return end sa
station during a cutting cycle in longwall face C for experimen

(ii) Dust profiles at other sampling stations along the face: Dust concentration data at different sampled locations along the face are shown in Figure 3.34. The dust peaks near the maingate are narrow, indicating that they are of short duration, because the sampling stations were upwind of the shearer most of the time. Towards the tailgate, however, the peaks become progressively wider. In the last sampling station, which is near the tailgate and is downwind of the shearer for most of the time, the observed dust peaks are the widest, indicating longer dust exposure.

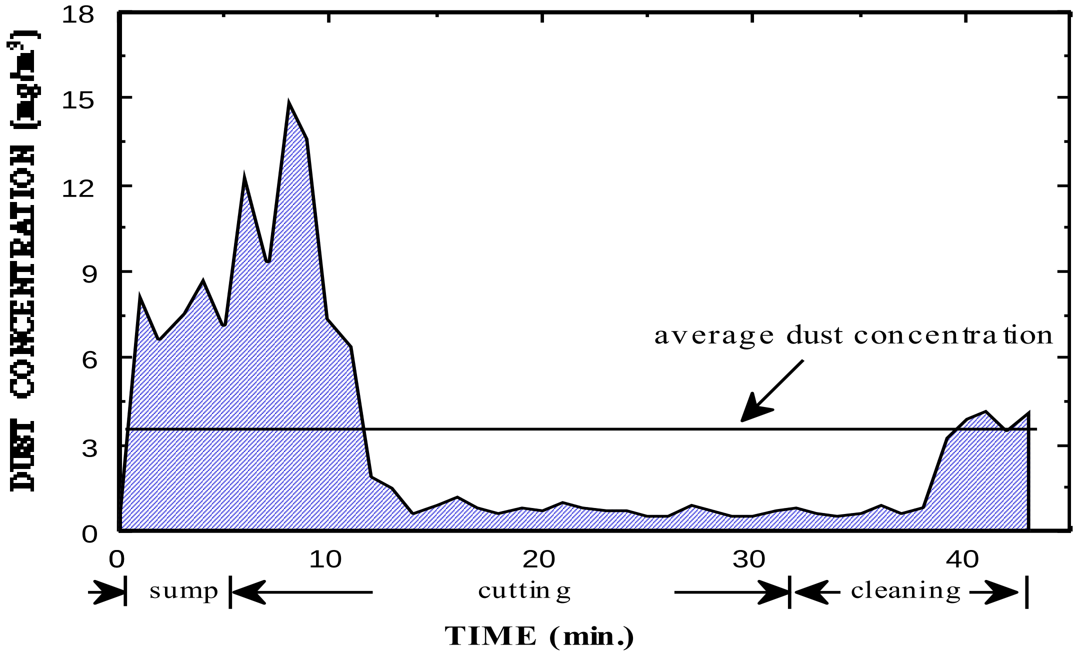

Figure 3.34(a) Instantaneous respirable dust concentration at 25th ch sampling station during a cut cycle in longwall face C (when cutting with ventilation).

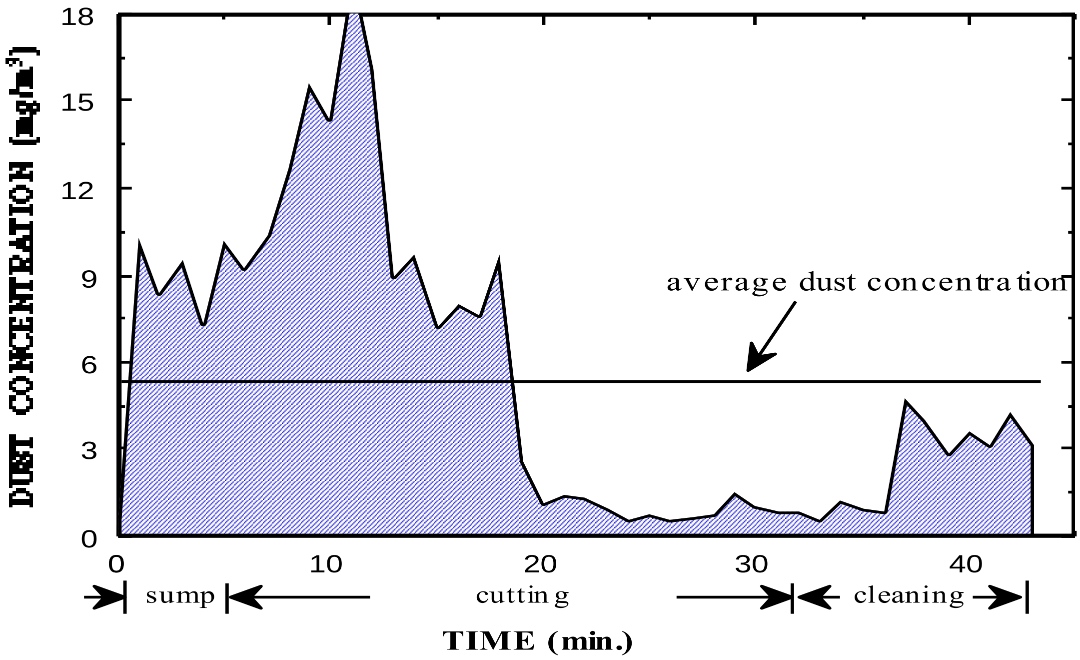

Figure 3.34(b) Instantaneous respirable dust concentration at 50th ch sampling station during a cut cycle in longwall face C (when cutting with ventilation).

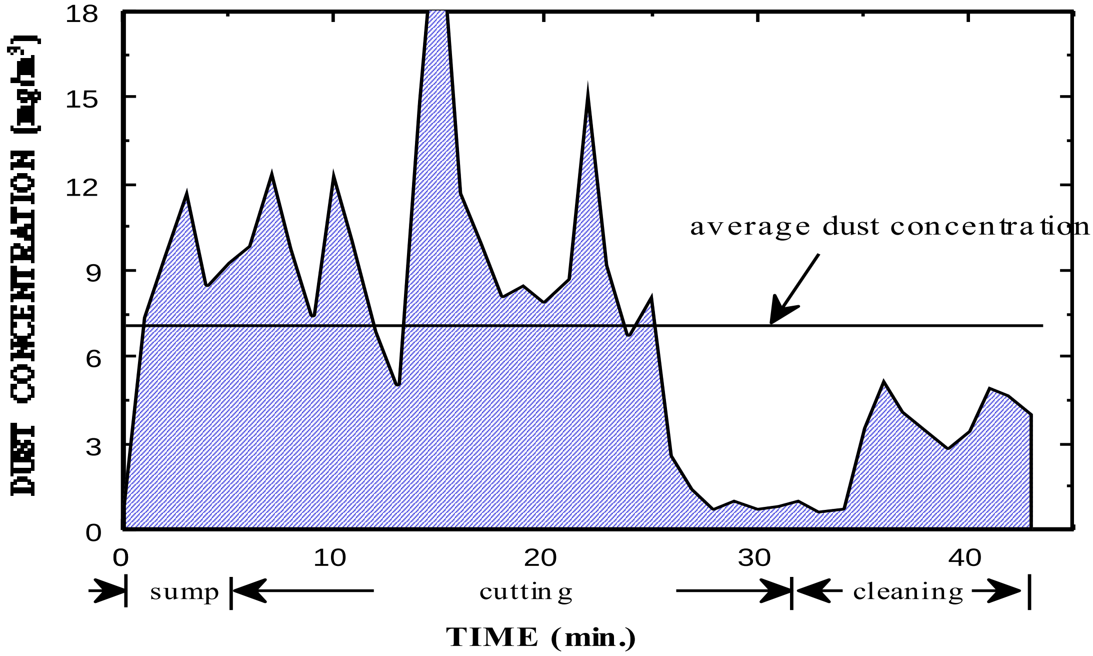

Figure 3.34(c) Instantaneous respirable dust concentration at 75th ch
sampling station during a cut cycle in longwall face C
(when cutting with ventilation).

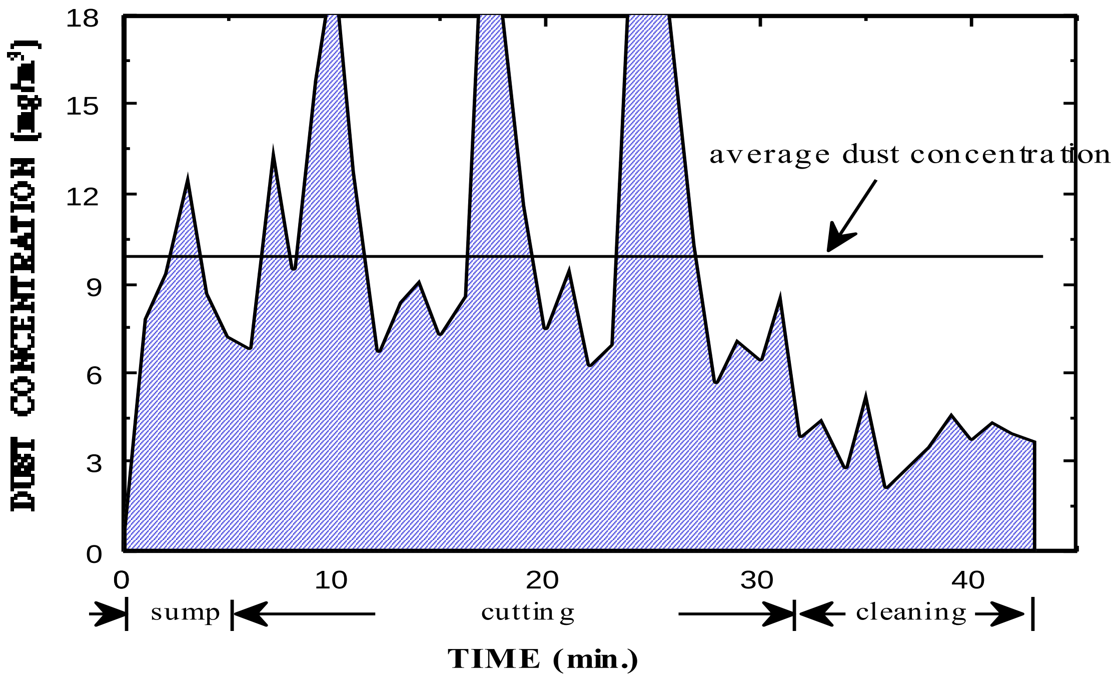

Figure 3.34(d) Instantaneous respirable dust concentration at 100th ch
sampling station during a cut cycle in longwall face C
(when cutting with ventilation).

(iii) Dust profiles around the shearer: Respirable dust concentration profiles around the shearer are given in Figures 3.35 and 3.36. Analysis of the figures show that they differ from those of in longwall faces A and B, especially in the vicinity of the shearer. The dust concentration level was lowest between 5 and 8 m downwind of the shearer's lead drum position and increased from there onwards towards the return end of the face. However, the dust concentration around the trailing upwind drum operator's position was higher than expected. This can be attributed to poor installation of water sprays on the shearer and the upwind support movement.

Figure 3.35   Instantaneous respirable dust concentration profile around shearer during cutting cycle in longwall face C for experiment 1.

Figure 3.36 Instantaneous respirable dust concentration profile around shearer during cutting cycle in longwall face C for experiment 2.

(iv) Support generated dust profiles: Dust generated by support movement along the face is profiled in Figure 3.37. The average dust concentration at 1 m downwind of the moving supports was 7.6 mg/m^3 and at 5 m it was 3.5 mg/m^3. These figures show that although support generated dust was less as a component of overall shearer operator's dust exposure than in face A, it still represented a significant proportion of total dust exposure.

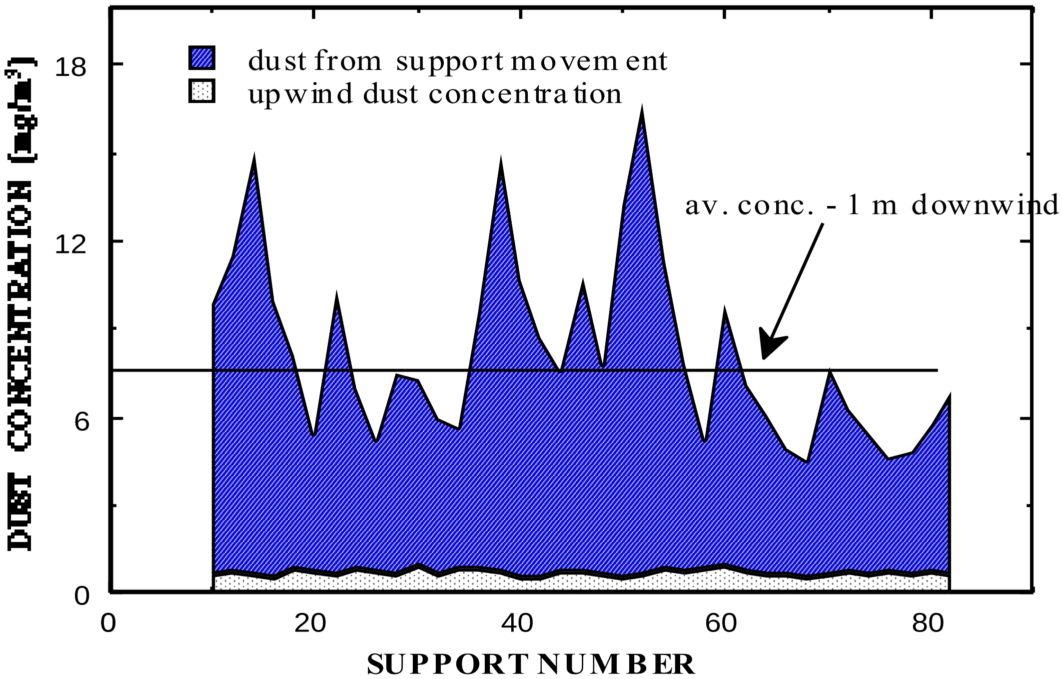

Figure 3.37(a) Instantaneous respirable dust concentration at 1 m downwi
of support movement in longwall face C.

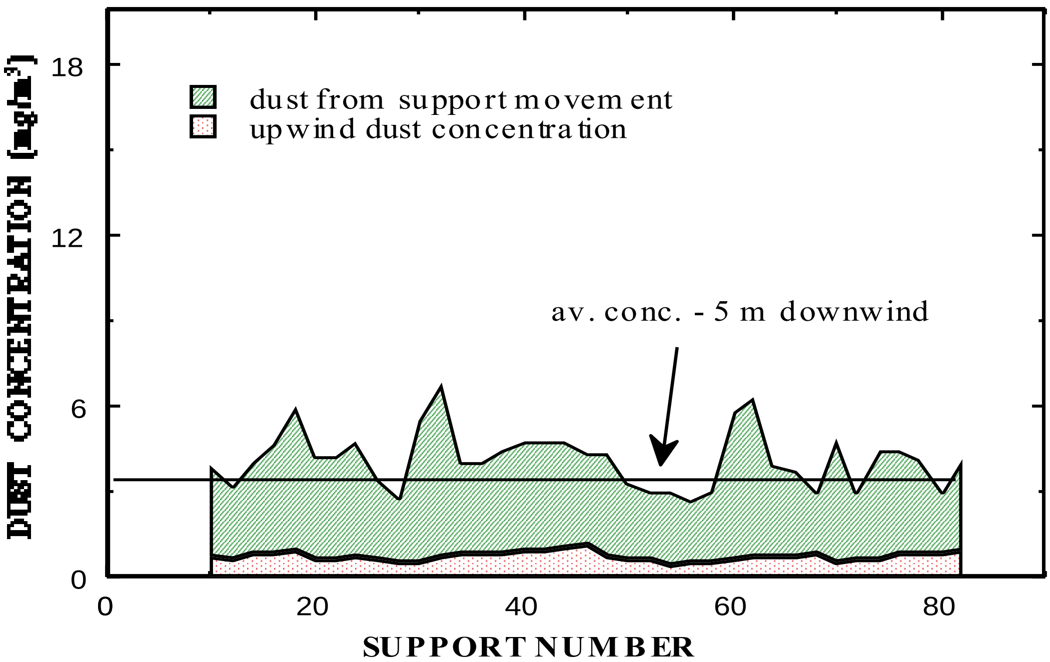

Figure 3.37(b)   Instantaneous respirable dust concentration at 5 mdownw
of support movement in longwall face C.

(v) Dust profiles across the section of the face: Two typical instantaneous dust concentration profiles at two different locations across the face are shown in Figure 3.38(a). The average concentration, over approximately 15 min, were 10.5 mg/m^3 over the panline and 6.1 mg/m^3 in the walkway. Overall, the two profiles appear to be different; for example, at the 8th minute on the x-axis, when the panline concentrations were 24.4 mg/m^3, no measurement exceeded 8 mg/m^3 in the walkway. Dust profiles at different locations across the section of the face, given in Figure 3.38(b), show that the average dust level over the spill plate was 9.3 mg/m^3 and 4.3 mg/m^3 in the back walkway. Figure 3.39 shows the average dust gradient, across the section of the face, at a height of 1.5 m and demonstrates that there are high dust gradients across the section of the longwall face.

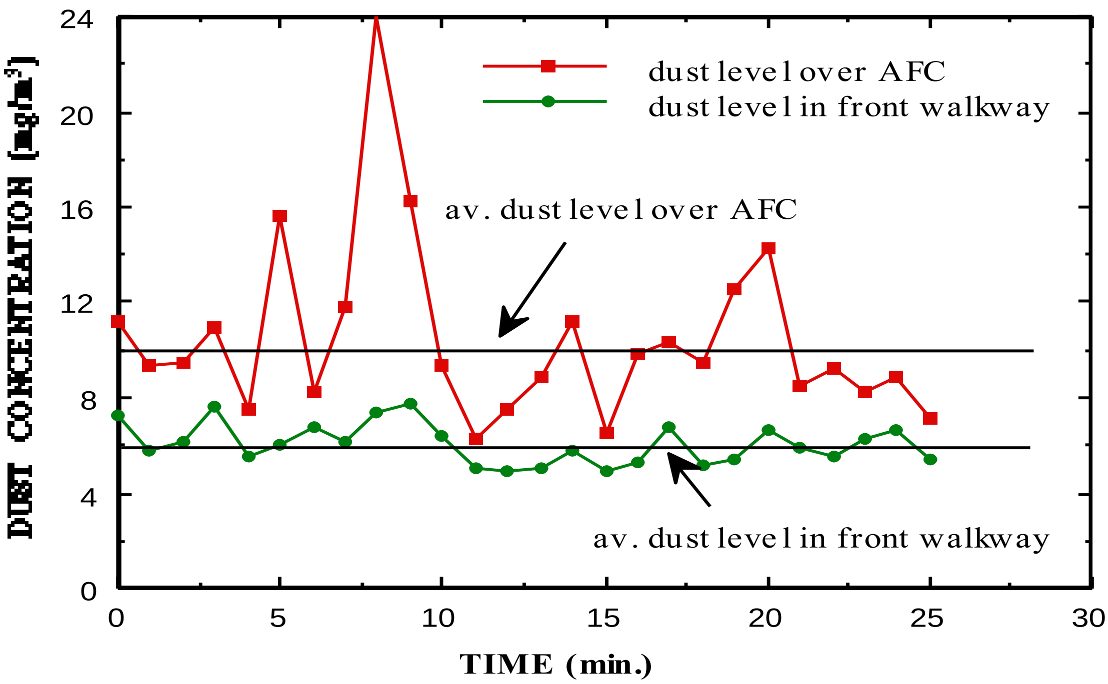

Figure 3.38(a) Instantaneous respirable dust concentration at two different locations across the longwall face C (0.4 m below roof).

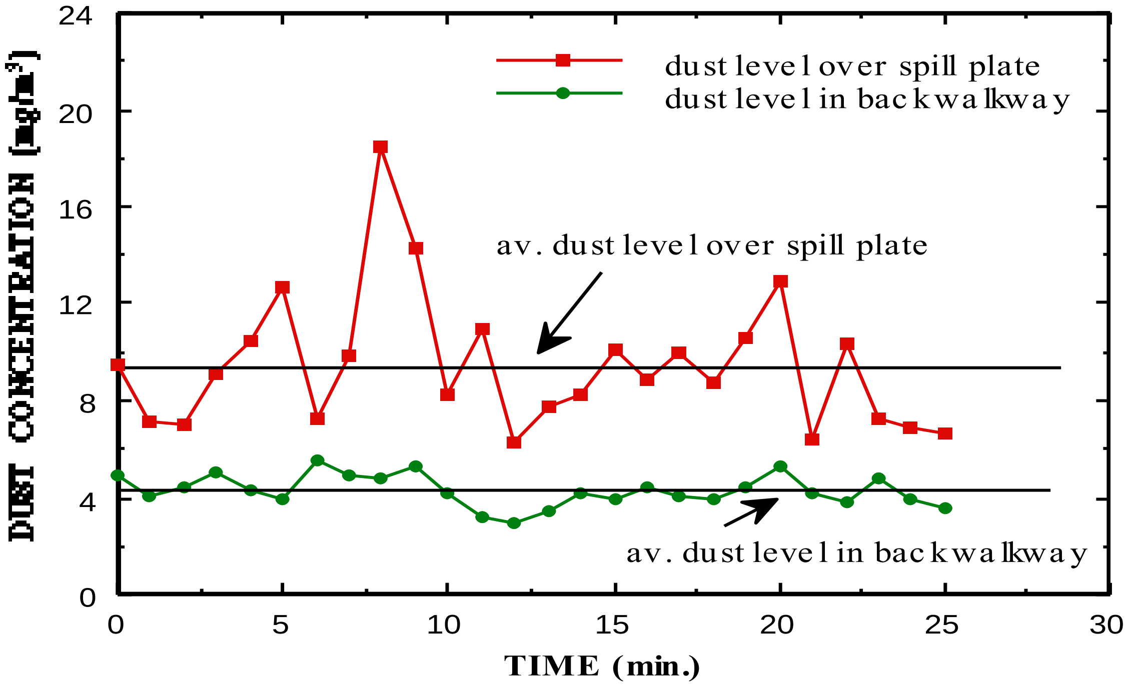

Figure 3.38(b) Instantaneous respirable dust concentration at two di locations across the longwall face C (0.4 mbelow roof).

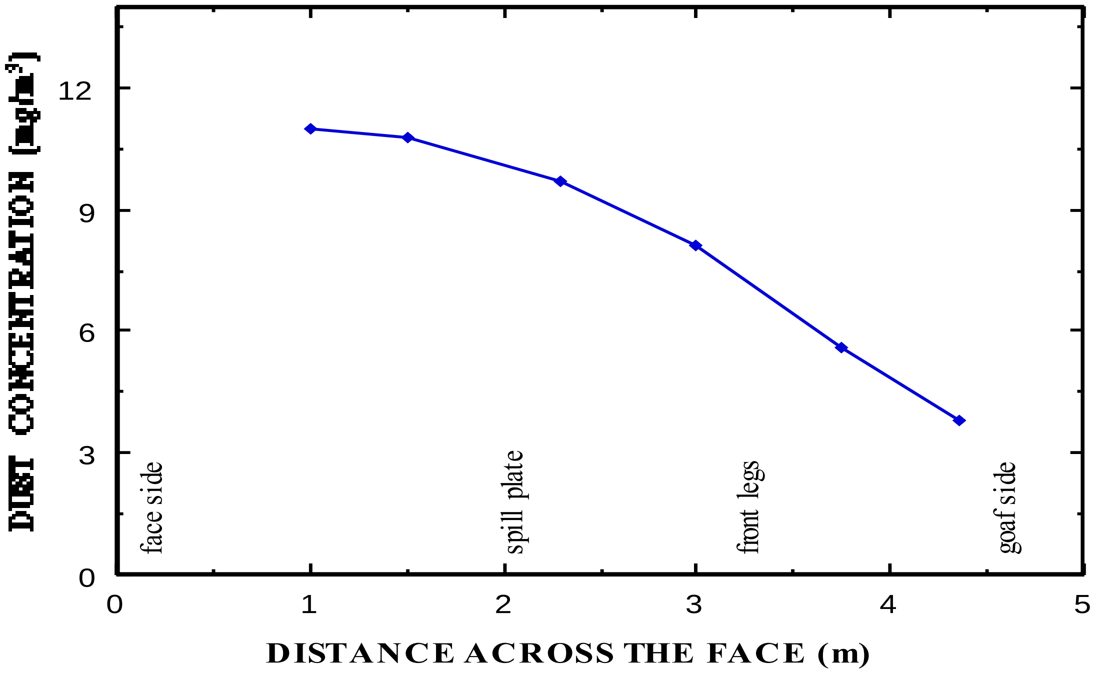

Figure 3.39 Typical respirable concentration profile across the longw face C at miner's breathing height (0.4 m below the roof).

3.6.2 Air velocity patterns

Air velocities measured with an anemometer along the face are presented in Figure 3.40. The decreased air velocity at the second station is the result of air from the tailgate entry being pushed into the back of the supports and settling down after some distance. Overall, there was not much variation along the face. There was no bleeder entry in this face, and therefore air leakage into the goaf was negligible. It is the air leakage component which made these air velocity profiles different from those of the Qin (1992) for U.S. longwall faces using a bleeder entry ventilation system. Air velocity measurements across the face, at different heights, are shown in Figure 3.41, which shows that air velocity was not uniform across the face. It was highest over the AFC area and lowest in the walkway, where it is half of that in the AFC area. This variation must be taken into account during the development of a dust control technique, as it affects the respirable dust behaviour and dispersion.

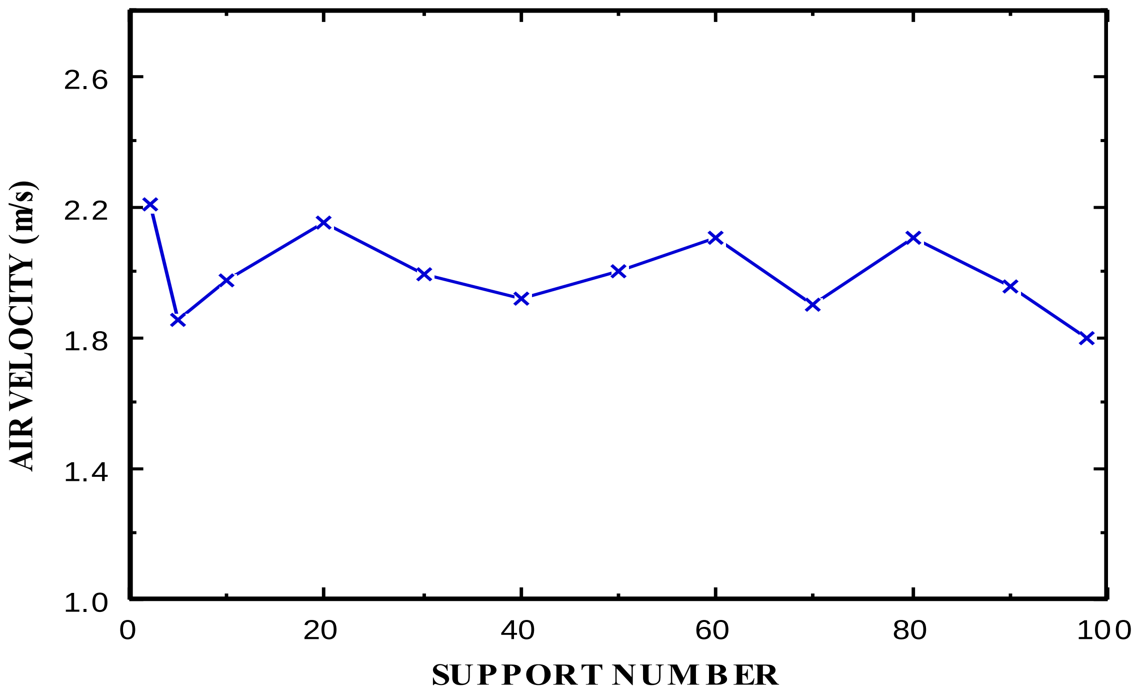

Figure 3.40 Air velocity over AFC along the longwall face C.

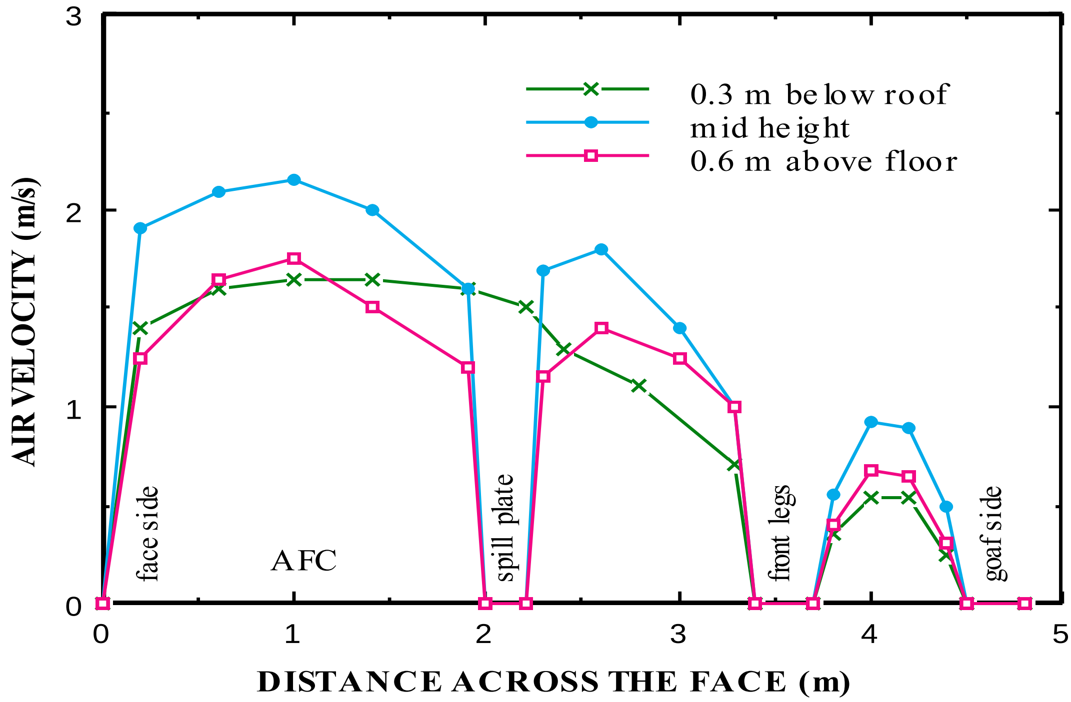

Figure 3.41 Air velocity profiles across the longwall face C at three he

3.7 RESULTS OF INVESTIGATIONS IN LONGWALL FACE 'D'

Longwall face D was operating in the Bulli seam in the Southern district of NSW, Australia. The working height was between 2.2 and 2.5 m, the longwall face length was 200 m and the length of the panel was 1650 m. A 500 KW Mitsui Miike double ended ranging drum shearer and Dowty 4 x 680 tonnes four legged chock shields were used in this face. The diameter and width of the cutting drums were 1.6 m and 1.0 m respectively. The average tram speed of the shearer while cutting was approximately 7 m/min. The cutting sequence was uni-directional with cutting from tailgate to maingate against the direction of ventilation. The roof supports were advanced on the return side of the shearer immediately after cutting. Antitropal ventilation system was used and the face air velocity varied between 2.6 and 2.8 m/s.

The daily production from the face was about 7200 tonnes and the annual production was approximately 2.1 million tonnes.

3.7.1 Instantaneous dust concentration profiles

(i) Dust profiles near the return end of the face: The results of the instantaneous sampling surveys for one complete cutting cycle are shown in Figures 3.42 and 3.43. The shearer activities are indicated on the X axis. Each point shown is the average of four readings. These figures show the dust exposure during each phase of the mining cycle and indicate that the dust level during the cutting phase was always above the statutory limit of 3 mg/m^3. It is also evident that the return end operators were only exposed to dust during the cutting and cleaning phases of the cycle. Dust produced during the sumping phase went directly into the return airway because the ventilation system is antitropal and cutting was against the airflow.

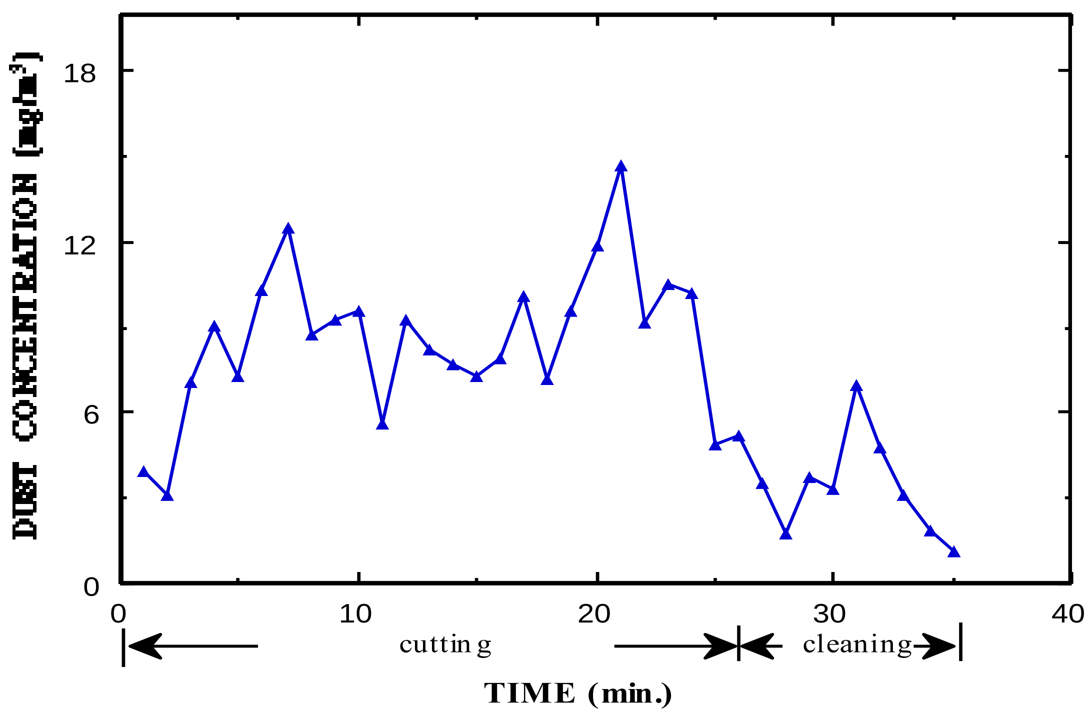

Figure 3.42 Instantaneous respirable dust concentration at return end sar
station during a cutting cycle in longwall face D for experimen

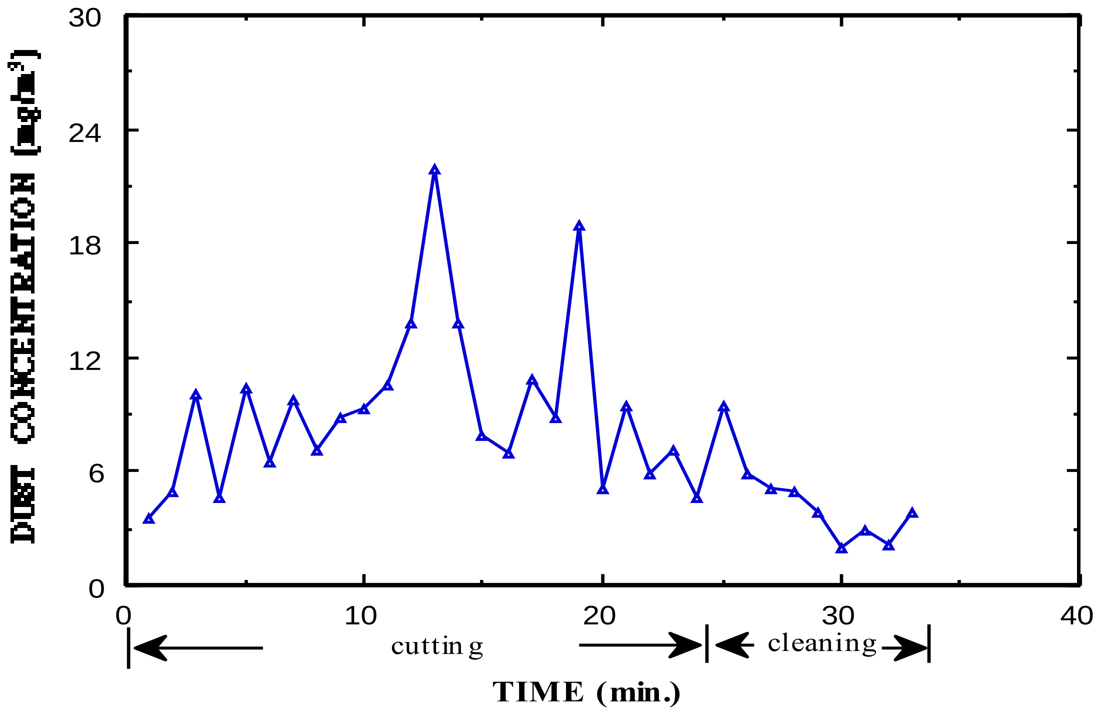

Figure 3.43 Instantaneous respirable dust concentration at return end sar
station during a cutting cycle in longwall face D for experimen

(ii) Dust profiles around the shearer: Respirable dust concentration profiles around the shearer are given in Figures 3.44 to 3.45. It can be seen that in face 'D', where cutting was against the ventilation, dust produced by the upstream lead drum quickly dispersed into the walkway over the shearer, thereby exposing both operators to high dust concentration levels. The pattern of these dust profiles is different from those of in longwall faces A and C.

Figure 3.44 Instantaneous respirable dust concentration profile around shearer during cutting cycle in longwall face D for experiment 1.

Figure 3.45 Instantaneous respirable dust concentration profile around shearer during cutting cycle in longwall face D for experiment 2.

3.7.2 Respirable dust size distribution

The size distribution of respirable dust samples in longwall face 'D' is shown in Figures 3.46 and 3.47. It can be seen that the size distribution of respirable dust from face D was similar to that in face B. The median diameters for experiments 1 & 2 in face D are 3.6 and 3.45 respectively. Figure 3.48 is a plot of the log of the particle size against the cumulative weight /mass percent of particles smaller than that size.

3.7.3 Air velocity patterns

Air velocities along the face, measured with an anemometer, are presented in Figure 3.49. Although in this face the air velocity was slightly high, the general pattern of air velocity along the face was the same as that in face 'C'. Analysis of results shows that air velocity did not vary much along the face and indicates that there was negligible air leakage into the goaf. Air velocity measurements across the face, at different heights, are shown in Figure 3.50. These results also confirm the fact that the velocity was not uniform across the section of the face.

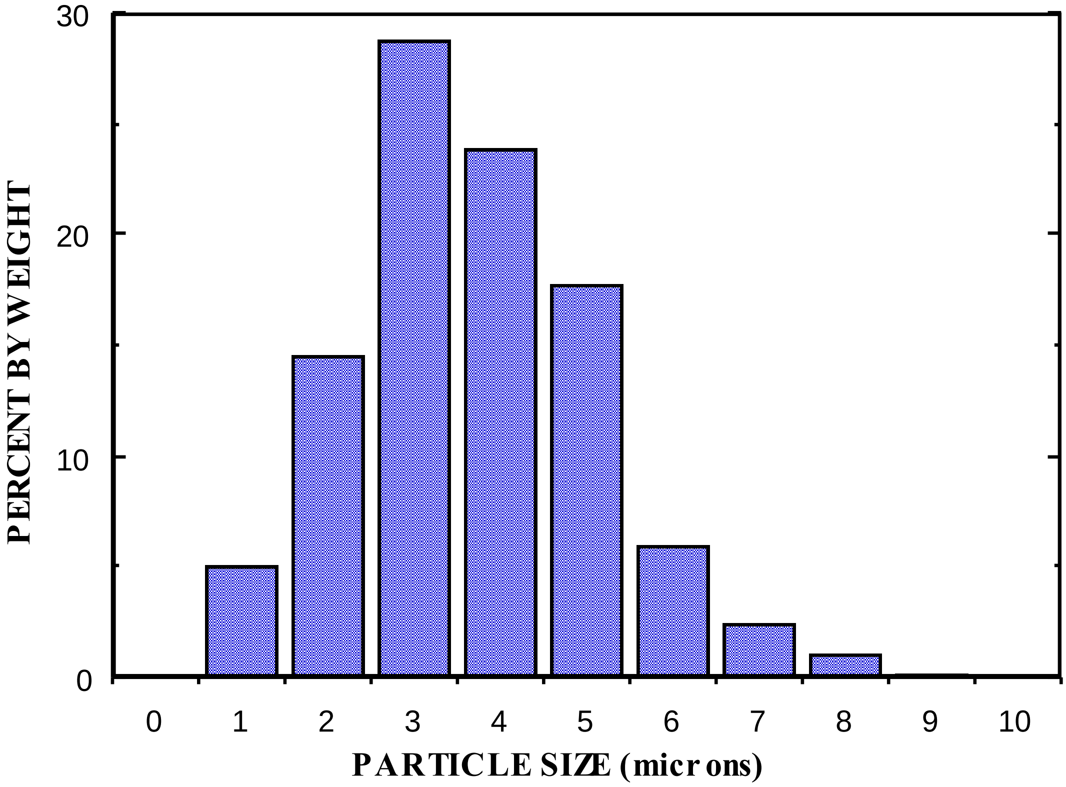

Figure 3.46 Particle size distribution of airborne respirable dust samples collected from longwall face D for experiment 1.

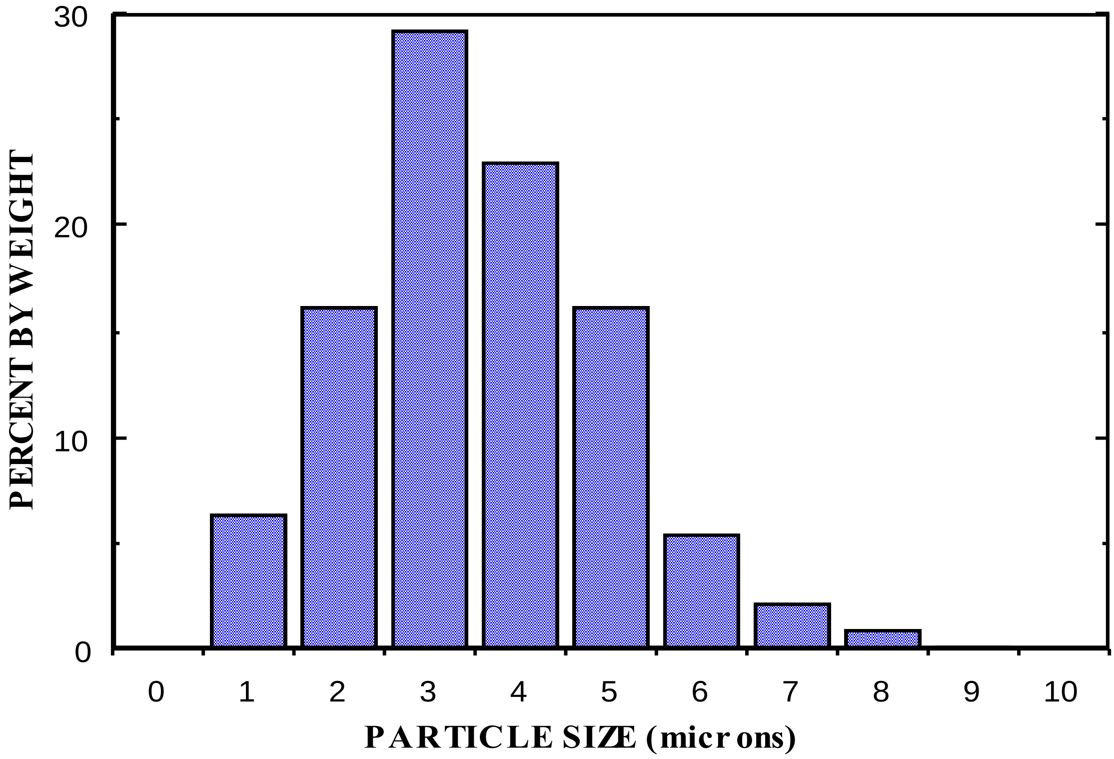

Figure 3.47 Particle size distribution of airborne respirable dust san
collected from longwall face D for experiment 2.

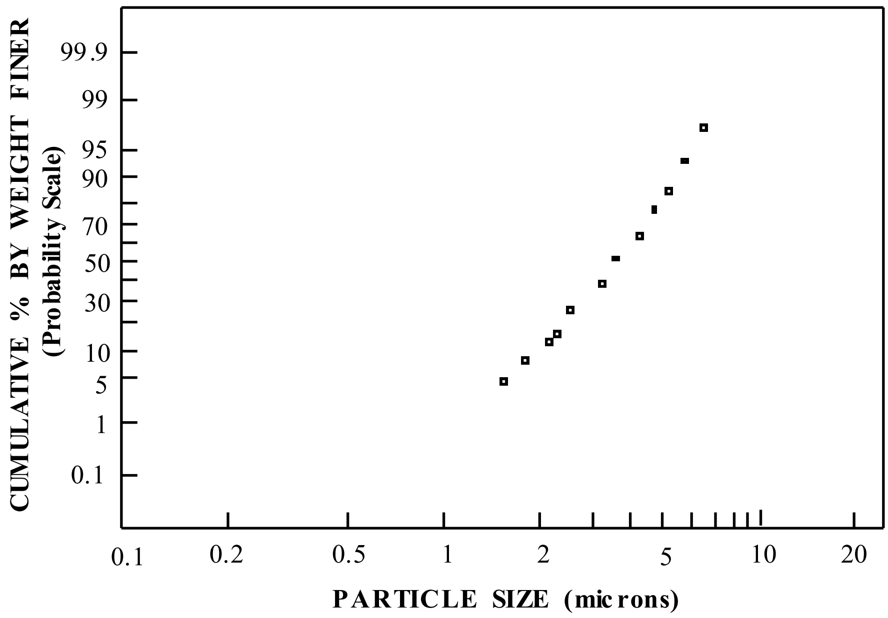

Figure 3.48 Typical cumulative particle size distribution of respirable dust samples collected from longwall face D on log-probability scale.

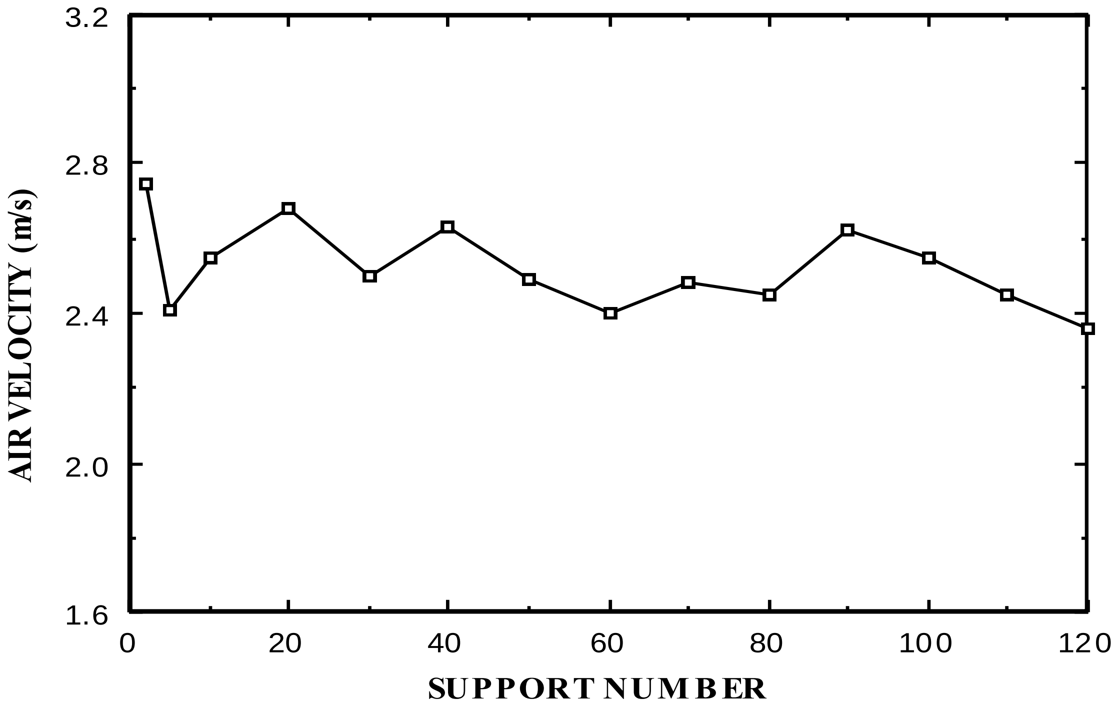

Figure 3.49 Air velocity over AFC along the longwall face D.

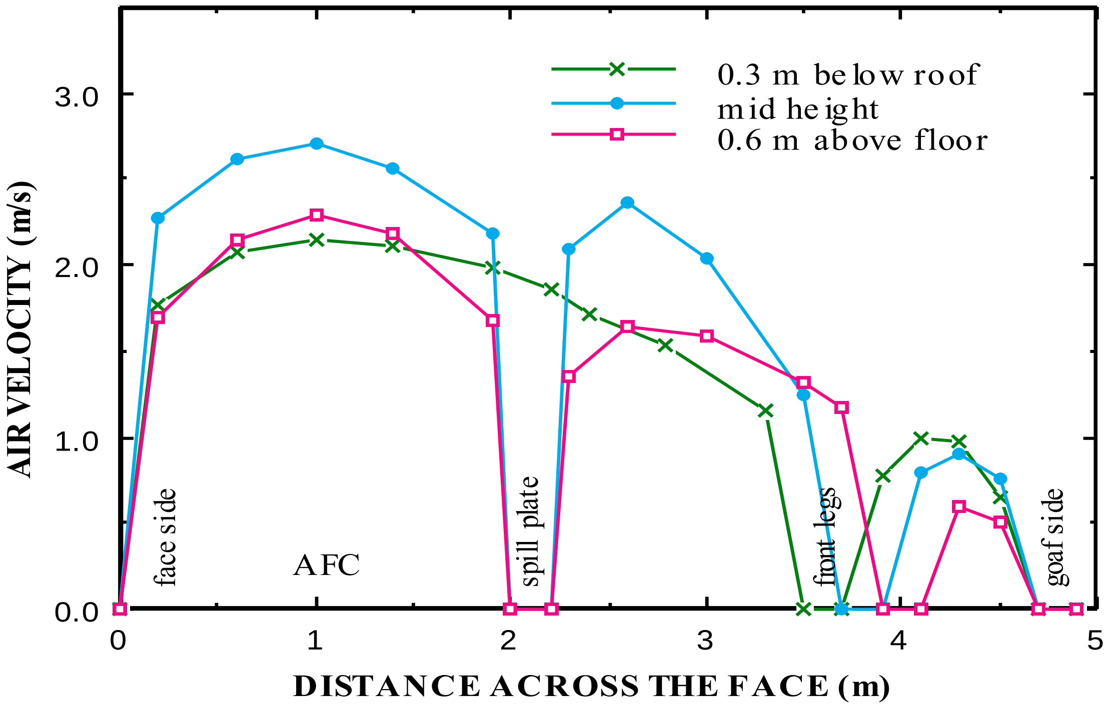

Figure 3.50 Air velocity profiles across the longwall face D at three he

3.8 COMPARISON AND SUMMARY

High respirable airborne dust levels at the working face is a difficult problem associated with longwall mining. There is only very limited fundamental data available to characterise the respirable dust behaviour at longwall faces. To augment this data, and to obtain data from Australian longwall faces in this research, field experiments were performed in four longwall faces in the Southern district of New South Wales. The shift average gravimetric dust data shows that respirable dust concentration increased with distance to the return end of the longwall face. However, the large variations in the dust gradients, measured over a period of 14 consecutive shifts in the same longwall face, indicates that the relationship between the dust level and the distance from the intake end was complex and not easily generalised owing to the large number of factors involved. In addition, as the average dust concentration levels could not be correlated with face activities, it was decided to conduct instantaneous dust sampling surveys in subsequent experiments to give a clearer picture of respirable dust conditions at the face.

The instantaneous dust concentration profiles show that the dust distribution patterns were different during different cutting operations in a cycle e.g. the cutting, cleaning and sumping. Badly positioned water sprays on the shearer were found to increase dust concentration at the rear drum operator's position. A comparison of dust data showed that respirable dust concentration levels and patterns were variable from one face to another. For example in face 'A', the dust level was around 11 mg/m^3 and in longwall face 'B' it was around 5 mg/m^3. Studies in face 'B' confirmed that higher cutting speed resulted in higher dust levels all along the longwall face. Respirable dust profiles around the shearer showed that cutting against the ventilation system dispersed more dust into the shearer operator's position than when cutting with ventilation.

However, when cutting at the maingate with the ventilation during which the drum makes a number of partial sumping cuts, produced a significant proportion of the total respirable dust.

It should be noted that the instantaneous dust concentration plots did not indicate the average shift dust concentration as they were set up to operate only during the cutting process. Therefore the high, but short, peaks of concentration should not be interpreted as the worst dust conditions, but their duration should be included in the interpretation of results. An increase in the width, hence duration, of the peaks signifies an increase in average dust concentration. Studies in faces 'A' and 'C' showed support movement significantly contributed to miners' dust exposure at the longwall faces.

Air velocity and quantity data showed that there was no significant air leakage into the goaf. A comparison of air velocity, quantity and respirable dust levels in the faces showed that low air velocity /quantity was associated with high dust concentration levels in faces A & C. Air velocity profiles across the face showed that air velocity was not uniform across the face; it was highest over the AFC area and lowest in the walkway. A comparison of air velocity with dust levels across the face indicated that the dispersion and distribution of respirable dust depended largely on the airflow patterns. Therefore, the variation in air velocity across the face should be taken into account during the development of a dust control technique, as it affects the respirable dust behaviour and dispersion. The size distribution of airborne respirable dust samples was found to be quite different from mine to mine.

These studies also showed that there are high dust level gradients around the shearer and across the section of the longwall face and indicated that the correct siting of sampling stations is crucial in successful evaluation of dust control techniques. These experimental studies have been useful in identifying some of the important parameters affecting dust transport and in characterizing dust cloud behaviour at longwall faces. The studies have also provided a data base for the development of dust control techniques to minimise the miners' exposure to dust. The knowledge of dust behaviour under numerous conditions, obtained during this study, formed the basis of the development of the multi-scrubber dust control system discussed in chapter 4.