Safety In Mines Research Advisory Committee

SIMRAC

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Final Report

Title: MECHANICAL MINER ENVIRONMENTAL CONTROL: EVALUATION OF VENTILATION AND DUST CONTROL SYSTEMS IN A VENTILATION SIMULATION TUNNEL

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Executive Summary

The continuous high dust levels at the continuous miner (CM) operator's position prompted the DME to set up a directive enforcing a 5 mg/m^3 dust-concentration level at the position of the CM operator. In this regard, two committees were established (the Dust Working Group and the Industry Dust Steering Committee) to urgently address the dust problem. From the work of these committees a project was formulated under SIMRAC auspices with the title of "Underground Mechanical Miner Environmental Control". The primary objective of this project was to control the environment to ensure that dust and methane levels were within the regulating requirements. The mining industry, through the SIMRAC process, assigned the CSIR-Miningtek (Kloppersbos Research Centre) to test and evaluate ventilation systems to ensure compliance with the new dust standard and the existing methane standard.

The project was conducted in two phases, the first on surface at the newly built ventilation tunnel at the Kloppersbos Research Centre and the second phase being the underground evaluation of the proposed systems. This report discusses the results of the first phase of the work at Kloppersbos. In order to achieve the objectives, evaluations were done on an existing system. These resulted in certain recommendations for application in the coal mine. A number of laboratory tests were conducted in the newly built ventilation simulation tunnel at the Kloppersbos test site. The tunnel simulates a long heading similar to an underground environment. This test facility enabled the research team to carry out extensive simulation tests on ventilation and dust-control systems in deep headings. Five different ventilation and spray systems, viz. jet fan (small and large), force column, force-exhaust system, mobile exhaust and scoop brattice ventilation system, were tested. The more than 100 tests resulted in some interesting findings and recommendations for further evaluation in an underground mine.

The ventilation simulation tunnel has proved to be an invaluable tool in the development and evaluation of ventilation and dust-control systems and their components. The evaluation of the systems has resulted in the following main developments: a new spray nozzle, a directional spray system, a physical air curtain and changes to the scrubber inlet and outlet.

Further evaluation of auxiliary ventilation systems has highlighted the complexities involved in ventilating for both dust and methane where force ventilation is the primary method of methane dilution. The findings of the surface tests will be evaluated in underground collieries

as the second phase of the project. The Kloppersbos studies were aimed at evaluating individual components and combinations of ventilation equipment. The results of the individual and combined tests led to the following recommendations, which will be implemented on the dedicated 12 HM9 for underground test work at Matla No. 3 mine:

- Fitted with new spray nozzle (1,6 mm inlet and 2,0 mm outlet)
- Kloppersbos directional spray system introduced (spray configuration)
- Air movers fitted over flight conveyor
- Extended scrubber intake, with inlet cone fitted
- Physical air curtain introduced.

List of abbreviations, symbols and terms

Abbreviations

SIMRAC	Safety in Mines Research Advisory Committee
DME	Department of Minerals and Energy
CM	Continuous Miner
USBM	United States Bureau of Mines
USA	United States of America
LTR	Last Through Road
CDC	Colliery Dust Control Services

Symbols

mg/m^3	milligrams per cubic metre
ℓ/min	litres per minute
ℓ	litre
m	metre
mm	millimetres
kPa	kilopascal
kW	kilowatts
m/s	metres per second
m^3/s	cubic metres per second

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1 Introduction

The 1995 report of the Leon Commission of Inquiry into Safety and Health in the South African Mining Industry (Leon et al., 1995) led to the promulgation of the Mine Health and Safety Act of 1996. It is hoped that the Act will lead to a significant improvement in the health and safety profile of the South African mining industry (Green Paper: Minerals and Mining Policy for South Africa, 1998).

A directive of the South African Department of Minerals and Energy (DME) (1997) to reduce the dust-concentration level to below 5 mg/m^3 at the operator's cab position on continuous mining machines resulted in a dedicated research project entitled "Underground Mechanical Miner Environment Control." The project was planned in two phases. The first phase involved tests on a continuous miner (CM) model in a ventilation tunnel at the Kloppersbos Research Centre. The evaluation of these findings in an underground mine section will be the main objective of the second phase of the project. The systems tested needed to comply with two main criteria, viz. adequate methane gas dilution at the face and keeping the respirable dust concentration levels below 5 mg/m^3.

The objective of the work focused on obtaining a balance between dust-capture effectiveness and maintaining good ventilation conditions at the coal face to keep the methane levels low. Previously, the United States Bureau of Mines (USBM) had commissioned the research and development of a modified water-spray system which would direct intake air across the front of a CM to prevent the build-up of methane gas and to suppress dust. The sprayfan system was found to be more effective and cheaper than the earlier fan systems, so much so that by 1987 it was in operation over 300 CMs in American coal mines. The South African mining industry has been using sprayfan systems extensively since 1992, but without any guidance on the correct installation and operating procedures. Also, due to the differences in the mining conditions and the operations of the mines in South Africa and in the USA, it was difficult to judge the effectiveness of the dust-control systems developed abroad. Ultimately, this resulted in the inability of our mines to bring the dust levels down. This report discusses a new standard spray system developed at Kloppersbos, the results of the tests on combinations of ventilation systems and recommendations made for further testing underground in South African mines.

The newly built ventilation tunnel at Kloppersbos was used to evaluate the components of ventilation and dust-control systems such as scrubbers, spray fan systems and auxiliary ventilation systems, or any combination thereof. This report also discusses the proposed modifications required to existing CMs and the operation of the various ventilation systems tested in the tunnel, as the first phase of the project.

2 Test Tunnel

The test tunnel has a corrugated iron and steel structure. It is 3,5 m to 3,8 m high and has a road width of 6,5 m. The heading, split and the last through road (LTR) are 40 m, 20 m and 50 m in length respectively. The influence of airflow in the LTR under various conditions can be measured in the tunnel. The velocity can be varied from 0,5 m/s to 4,0 m/s in the LTR through inlet damper control on a twin-inlet centrifugal exhaust fan.

A continuous miner model was built and fitted with dust-control systems such as a wet fan scrubber system (11 m^3/s capacity), a directional water-spray system and a number of air movers. The water-spray system has the following main components:

- four blocks of directional sprays on the top (each block consisting of three sprays)
- two blocks on the bottom at each side of the cutting head (each block consisting of three sprays)
- one block with two sprays on the bottom of the cutter boom to the right
- one block with two sprays on the spade directing to the right
- one L-shaped block on the side (total of six sprays).

Three air movers were positioned in front of the operator, in front of the scrubber and on the top of the conveyor. Each of the spray blocks and air movers can be controlled to optimize dust control and air movement in the face area. A D35 Meyers piston pump with a maximum capacity of 3 000 kPa (140 ℓ/min) was used for all the tests. A smoke generator was used for visual evaluation of the ventilation and dust-control systems. To evaluate the force-and-exhaust systems, spiral ducting of 570 mm and 760 mm diameter was used.

3 Description of Experiments

A number of water-spray systems were evaluated by comparing their individual flow patterns, water flow volume (ℓ/min), water pressure, airflow volume and face air velocity. The ventilation systems were evaluated on the basis of the air velocity at the operator and at the face, the airflow volume from auxiliary ventilation and the dust-suppression ability of the system.

Two methods of evaluation were used in the tests. The first was measuring the air velocities across the face and at the operator position using anemometers. The second was visual evaluation using smoke to elucidate the behaviour of airborne coal dust and identify the airflow directions. The tests were also recorded on video to allow for further comparison (Kloppersbos Ventilation Test Video, 1998).

Two cutting cycles were simulated. The first position of the CM (Figure 3) represents the second-pass cut on the right-hand side of the face under maximum allowable conditions in a long heading. The second position of the CM (Figure 3) represents the second-pass cut on the left-hand side of the face. All tests were conducted with the boom of the CM raised to the middle of the face level (± 2,0 m high).

4 Results

4.1 Water-spray system

For the optimum spray system, a balance between dust-capture effectiveness and maintaining good ventilation conditions at the face to keep the methane levels to a minimum was sought. Several nozzle types were selected with varying spray configurations. Hollow-cone nozzles were chosen to be used for all the tests. The decision was based upon the optimal air-moving and dust-suppressing characteristics of such nozzles.

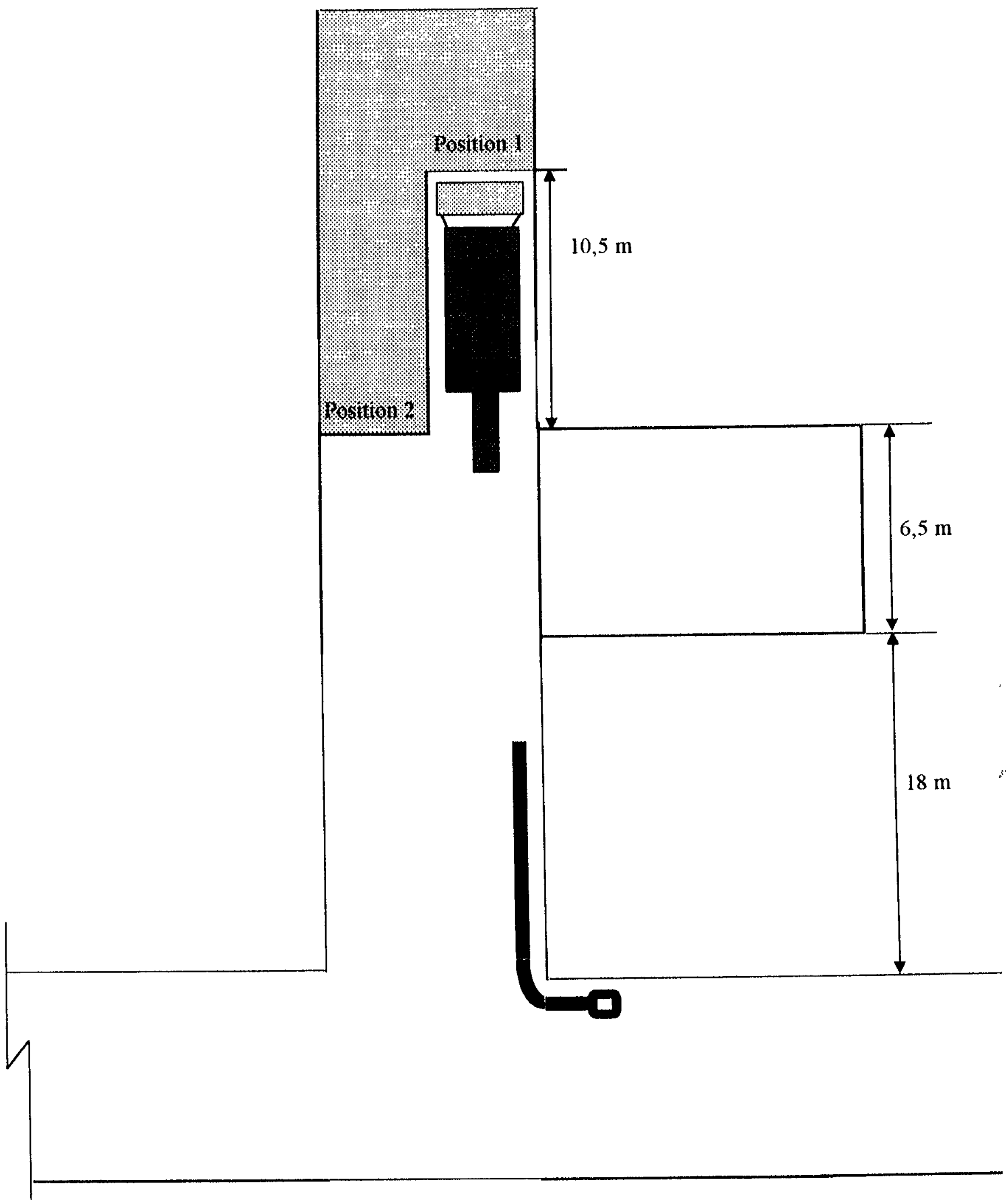

Figure 3: Layout of the ventilation tunnel showing positions of the CM

The selection of a water-spray system was based on previous experience and the system was evaluated visually and by means of face airflow measurements. A frontal view of the selected system is shown in Figures 4.1a and 4.1b. The system consists of four top and two bottom spray blocks. Both the top and bottom blocks on the right have one nozzle directed 30° from the horizontal to the right and two nozzles to the left (see Figure 4.1a).

A number of different nozzle sizes were tested and the system performance for various pump pressure settings is given in Table 4.1. Figure 4.1c shows the performance of the spray system with various spray nozzles. Despite improvement in the coal-wetting ability, high rollback was observed at high pressures. Tests with 1,6 mm (outlet size) hollow-cone nozzles indicated a major improvement in both air movement and dust wetting when compared with 1,0 mm nozzles.

Generally, after careful visual observations and analyses of the video recording of factors such as velocity across the face, wetting ability and amount of atomization, a 1,6 mm inlet and 2,0 mm outlet was adjudged to be the best alternative.

Positioning the three air movers over the conveyor of the CM and using a spray configuration with a total of 28 hollow-cone nozzles gave an effective spray system. Good air movement across the face (> 1,0 m/s) and wetting of the coal at a pressure of 2 000 kPa and a water flow of 110 ℓ/min were observed. With an increase in the water pressure, greater movement of airflow was observed, but at pressures greater than 2 000 kPa, atomization and rollback of mist towards the operator were increased. The overall observations under different test conditions for all the nozzles are shown in a tabular form in Appendix A (Tables A1-1, A1-2 and A1-3).

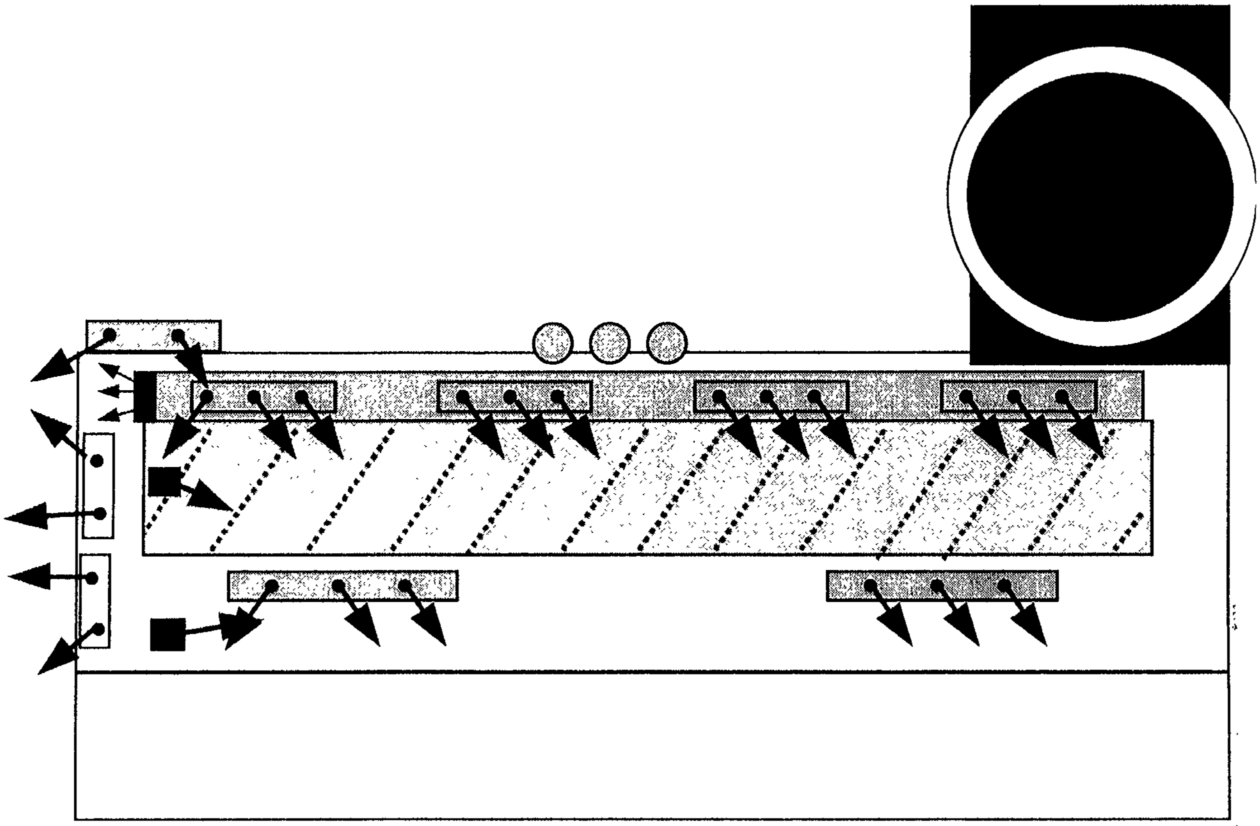

Figure 4.1a: Front view of the continuous miner with the nozzle configuration

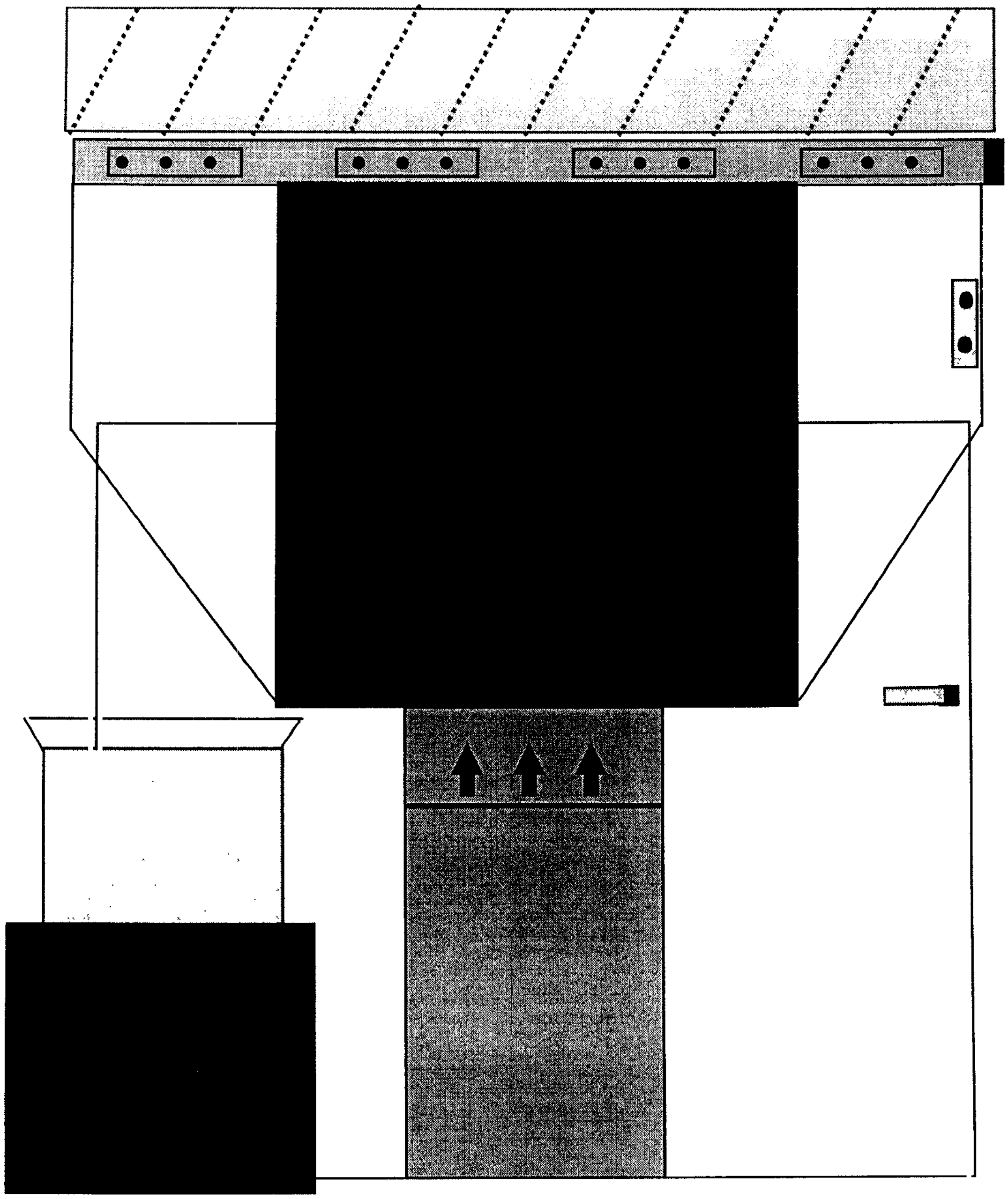

Figure 4.1b: Top view of the continuous miner with the nozzle configuration

Table 4.1
Hollow-cone nozzle types tested in the Kloppersbos ventilation tunnel

Inlet Diameter (mm)	Outlet Diameter (mm)	Water Pressure (kPa)	Water Flow (ℓ/min)	Face Velocity (m/s)
1,0	1,0	900	40	0,1
		1 500	50	0,2
		2 000	64	0,5
		3 000	85	1,0
		4 000	100	1,2
1,0	1,6	800	60	0,9
		1 000	71	1,0
		1 500	87	1,0
		2 000	100	1,0
		2 800	120	1,8
1,6	2,0	1 000	85	0,5
		1 500	100	1,2
		2 000	118	1,3
		2 400	120	1,4
2,0	1,6	1 000	70	0,4
		1 500	100	0,4
		2 000	112	0,4
		2 400	120	0,5
2,5	2,0	500	80	0,1
		1 000	120	0,2
		1 300	130	0,2

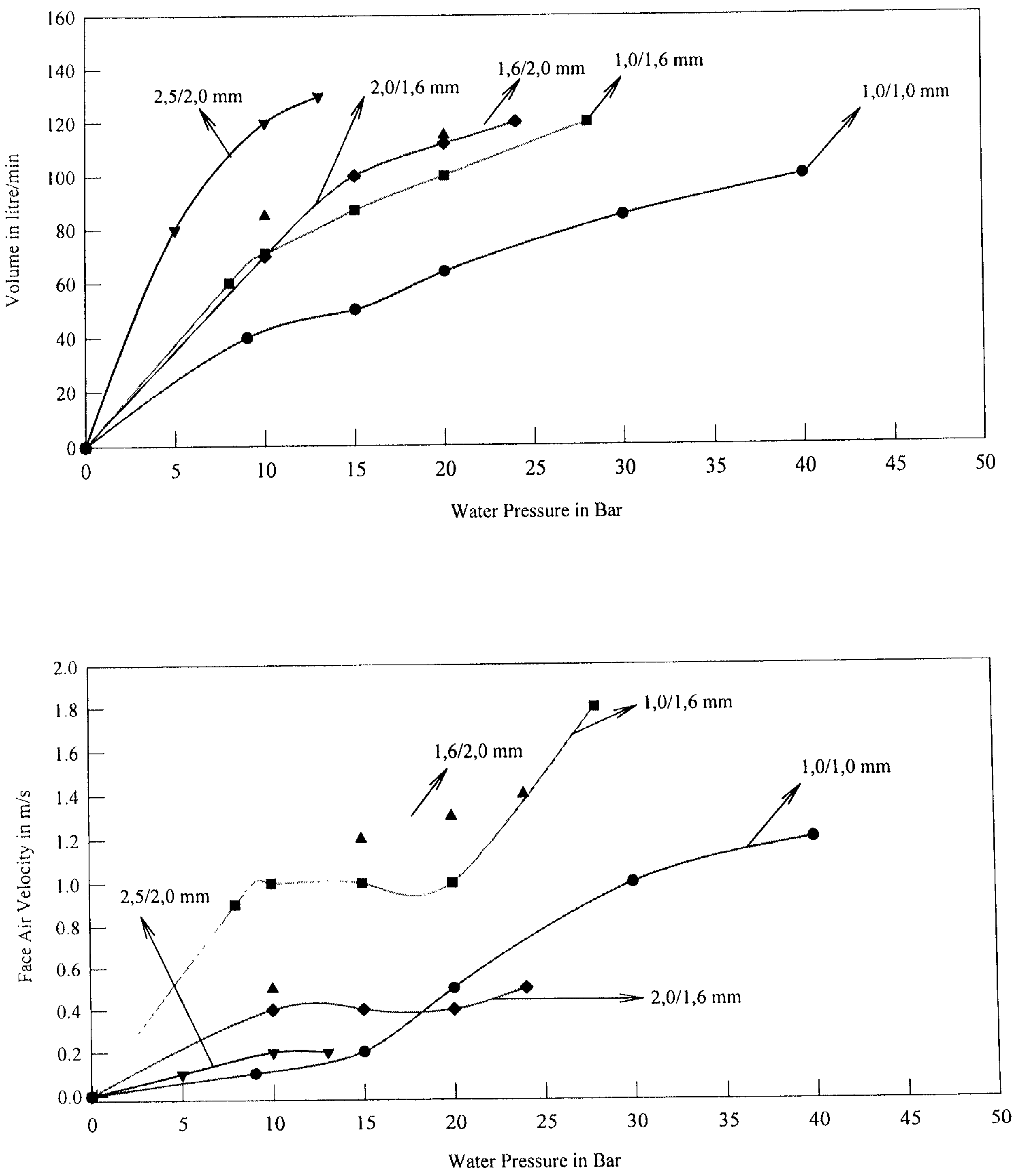

Figure 4.1c: Plot of the baseline tests on hollow-cone spray nozzles at varying pressures

4.2 Kloppersbos standard spray system

The spray system and the spray nozzle configurations were developed at Kloppersbos after extensive testing. A three-dimensional view of the standard spray configuration system on the CM is shown in Figures 4.2a and 4.2b. The Kloppersbos spray configuration as installed on the machine consists of a number of water spray blocks, air movers and an on-board scrubber. The system consists of a total of 34 sprays, including three air movers. The detailed descriptions of the individual components as shown on the drawings are as follows:

- On-board scrubber: A wet fan scrubber capable of handling an air quantity of 10 m^3/s -12 m^3/s, fitted with an inlet cone.
- Water supply to the machine: Maintains a water pressure of 2 000 kPa (20 bar) and a water flow rate of 110 ℓ/min.
- Type of nozzles: Standard hollow-cone nozzles with a single inlet diameter of 1,6 mm and an outlet diameter of 2,0 mm.
- Position A on drawing: Three air movers spraying downwards at an angle greater than 45° from the horizontal onto the conveyor to prevent dust rollback and to wet the coal on the flight conveyor.
- Position B on drawing: Four top spray blocks situated above the cutter drum. A total of 12 directional water sprays is used to move air across the face from right to left towards the scrubber intake.
- Position C on drawing: L-shaped spray block installed on the right-hand side of the machine, approximately 1 m from the hinge of the boom. Three spray blocks, each consisting of two water sprays (a total of six), ensure air movement to the front of the machine.
- Position D on drawing: One spray block consisting of two water sprays installed on the spade, directing air to the left of the machine underneath the boom.
- Position E on drawing: One spray block consisting of two water sprays connected to the bottom of the cutter boom, directing air towards the left of the machine underneath the boom.

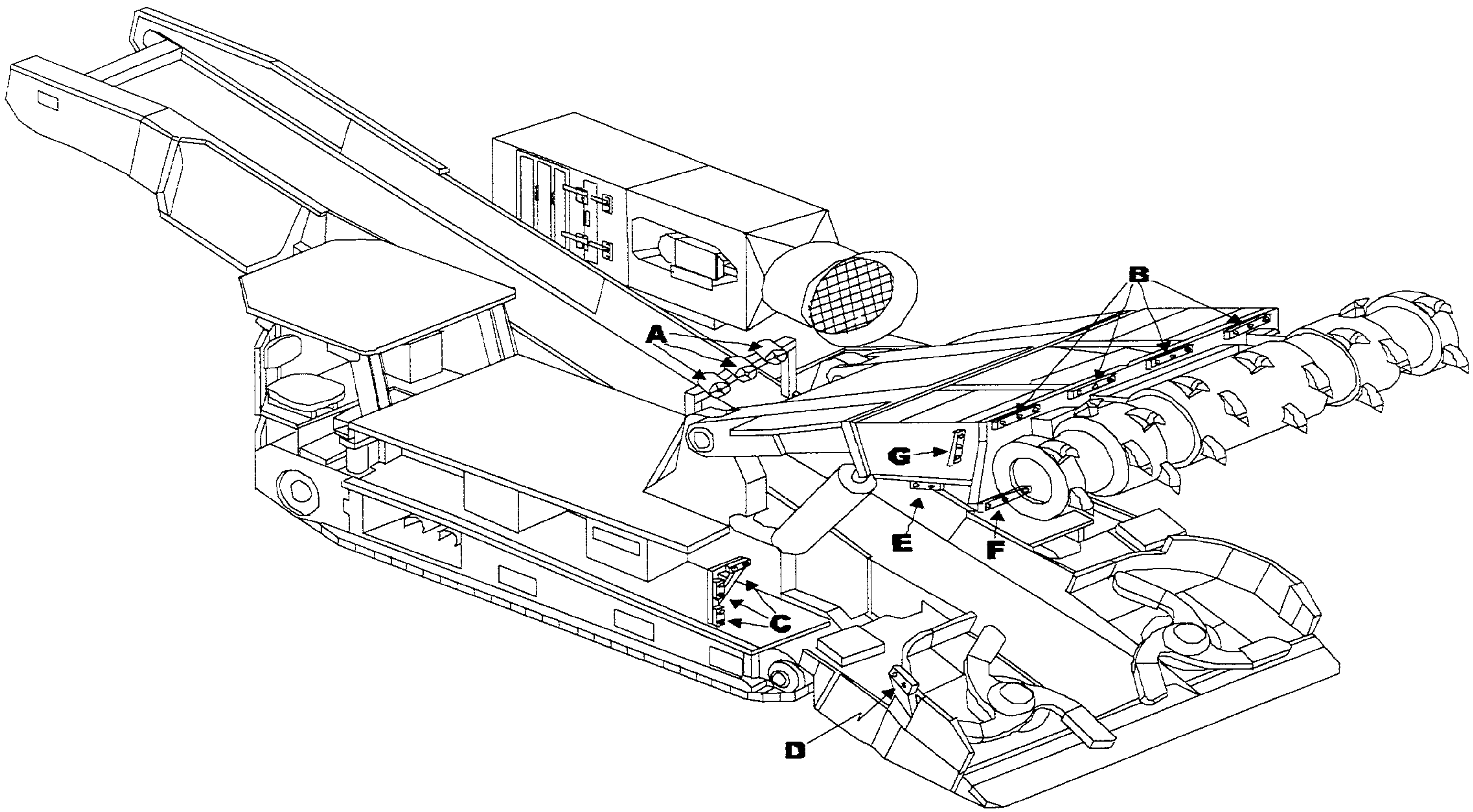

Figure 4.2a: Kloppersbos standard spray configuration (driver-side view)

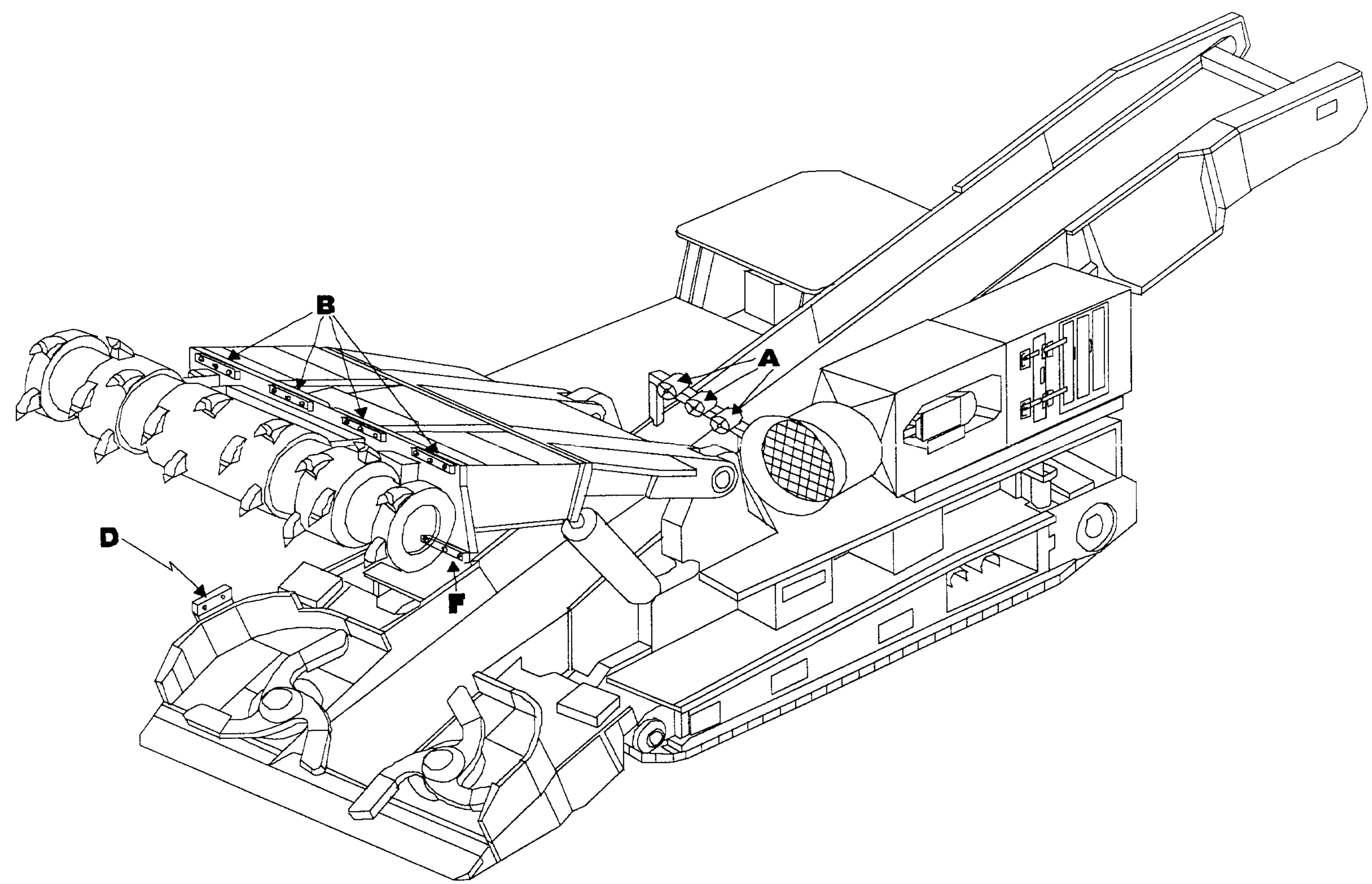

Figure 4.2b: Kloppersbos standard spray configuration (scrubber-side view)

- Position F on drawing: Two bottom directional spray blocks, each consisting of three sprays installed underneath the cutting head on the left and right sides of the head to ventilate under the cutting drum.
- Position G on drawing: Four water sprays directed to the left to prevent dust rollby.

4.3 Scrubber configuration

Tests were conducted with and without a scrubber deflector plate. These tests demonstrated the influence of the deflector plate on air movement around the machine, recirculation and the dust-capture efficiency of the scrubber. Optimum results were obtained with the scrubber discharge deflected towards the wall and the roof. This configuration reduces both the airflow towards the right-hand side and the forward air velocities towards the LTR.

Further tests were conducted with the scrubber at different inlet distances (3,5 m, 4,5 m and 5,5 m) from the face. Extending the inlet from 5,5 m to 4,5 m from the face improved the ventilation conditions at the face by increasing the dilution of methane (Table 4.3). Further extension of the scrubber inlet made no significant difference. It is possible that multiple inlets may further enhance the capture of dust out by the machine at floor level.

Table 4.3
Test results for scrubber configuration

Test No.	Sprays	Air Movers	Scrubber Inlet from Face		Air Velocity (m/s)	
	On/Off	**On/Off**	**On/Off**	**Metres**	**Operator**	**Face**
1	Off	Off	On	4,5	0,6	NAM
2	On	Off	On	4,5*	0,9	NAM
3	On	Off	On	4,5*	1,10	0,7
4	On	Off	On	4,5*	1,1	0,8
5	On	On/Off	On	5,5	1,3	1,0

* Jet Fan on; NAM – no air movement

Extending the scrubber inlet by 1,0 m, fitting an inlet cone and directing the outlet-air deflector plates towards the side and the roof gave excellent results. The above results reiterate the conclusions obtained in the earlier SIMRAC studies (Hole, B J and Glehn, F H, 1996).

4.4 Physical air curtain

A physical air curtain was installed over the scrubber to reduce recirculation and dust rollback. The results obtained indicated that an open area above the screen did not influence the system's operational effectiveness. It was further found that the curtain should not be closer than 0,5 m from the scrubber inlet and 1,0 m from the operator. Furthermore, the air curtain must be so positioned as not to influence the operator's line of sight. The results of the physical air curtain tests with the 570 mm force column are shown in a tabular form in Appendix A (Table A2). From the observations, it can be inferred that the addition of the physical air curtain greatly improved conditions at the operator's position as the smoke was contained in front of the curtain. Even when the auxiliary ventilation device was 25 m from the face, the air velocity over the operator was higher than the legal requirement, with very good conditions in terms of methane and dust (Table 4.4).

Table 4.4
Results of the 570 mm force column (axial fan) and half-curtain system at position 1

Test #	Sprays	Air Movers	Column from Face	Scrubber	Air Velocity (m/s)	
	On/Off	**On/Off**	**metres**	**On/Off**	**Operator**	**Face**
1	Off	Off	11,0	On	10,3	4,9
2	On	Off	16,0	On	3,2	1,3
3	On	Off	21,0	On	0,7	2,1
4	On	On	21,0*	On	0,7	2,1
5	On	On	25,5*	On	0,5	2,1

4.5 Ventilation systems

The auxiliary ventilation systems evaluated included the following:

- Force ventilation system with either a 570 or a 760 mm column
- Mobile exhaust system
- Force and mobile exhaust system
- Force and exhaust scoop brattice systems.

4.5.1 Force ventilation systems

The observations made from the tests with the 5,5 kW jet fan and 570 mm column are shown in a tabular form in Appendix A (Table A3-1).

The tests on the force column system using the axial fan and the 570 mm column with a single 760 mm discharge column used at the discharge (to give low velocity) were carried out at different distances from the face (Appendix A, Tables A3-2, A3-3 and A3-4). In all the tests, rollback was observed over the scrubber and the left-hand side of the machine due to the energy imbalance at the face. Use of an axial fan instead of a jet fan did not make any significant difference.

The test results for the force ventilation system at position 1 and position 2 are shown in tabular form in Tables 4.5.1a and 4.5.1b. A 15 kW axial-flow fan was used and its volume flow rate was controlled so as to ensure an air quantity of 5 m^3/s delivered at various evaluation positions at different distances from the face (Appendix A, Table A3-3). The results of the tests with the 760 mm (holed) column at the discharge to reduce the velocity to 7 m/s with the scrubber running are shown in Appendix A (Table A3-3). Appendix A, Table A3-4, summarizes the tests on force ventilation at position 2.

Optimum results for the 760 mm force system at position 1 were obtained with the column discharge 15 to 20 m from the face. At face position 2, optimum results were obtained with the column extended past the operator's position, i.e. between 12 m and 15 m from the face at position 1. With the 760 mm force column, it was observed that a lower discharge velocity allows the column to work more effectively closer to the face when at position 1. It is more sensitive than the 570 mm force discharge column in terms of distance from the face. Optimum operation was found to be at 15 m for position 1. At position 2, the recommendation as for the 570 mm column remains the same.

Table 4.5.1a

Results of force ventilation system (760 mm column) at position 1

Test #	Sprays	Air Movers	Column from Face	Scrubber	Air Velocity (m/s)	
	On/Off	On/Off	Metres	On/Off	Operator	Face
1	On	On	10,2	On	7,1	2,3
2	On	On	15,0	On	2,6	0,8
3	On	On	20,0	On	1,4	1,1
4	On	On	25,0	On	1,0	1,2
5*	On	On	10,5	On	5,8	1,9
6*	On	On	16,0	On	0,6	0,4
7*	On	On	15,5	On	1,0	0,7
8*	On	On	20,5	On	1,0	1,1

* Force column discharge velocity is reduced to 7,0 m/s.

Table 4.5.1b

Results of force ventilation system (760 mm column) at position 2

Test #	Sprays	Air Movers	Column from Face	Scrubber	Air Velocity (m/s)		
	On/Off	On/Off	Metres	On/Off	Operator	Pos-1	Pos-2
1	Off	On	20,0	On	SAM	0,2	0,5
2	On	On	15,0	On	0,2	0,5	0,4
3	On	On	25,0	On	SAM	NAM	0,6
4*	On	On	11,0	On	Turbulent	1,1	0,2
5*	On	On	16,0	On	Turbulent	0,4	0,6
6*	On	On	21,0	On	Turbulent	0,2	0,8
7*	On	On	No	On	0,2	NAM	1,0
8*	On	On	No	On	0,8	NAM	0,4
9	On	On	No	On	Turbulent	NAM	1,3

*15 kW force fan and average discharge velocity of 20,0 m/s; SAM - small air movement; NAM - no air movement.

Tests on 5,5 and 7,5 kW jet fans indicated that this system is not able to ventilate a 35 m heading at position 1. Further tests showed that fitting the jet fan with an entrainment intake with a column gives similar results to a normal force fan with a column. Also, jet fans alone are not able to ventilate position 1 when the machine is in operation at position 2 and is further than 27 m from the face.

4.5.2 Force and mobile exhaust system

The mobile exhaust system tested is defined as a scrubber system fitted with an exhaust column (760 mm diameter) which discharges clean air directly into the return (downwind of the working) and moves along with the CM as it advances. In Appendix A (Table A4-1) a number of different evaluations of the system are shown.

As the mobile exhaust alone cannot ventilate both positions 1 and 2, a combination of forcing systems was used together with the mobile exhaust system.

4.5.2.1 Force brattice and mobile exhaust

The results of the tests with the mobile exhaust and force brattice system are shown in Tables 4.5.2.1a and 4.5.2.1b and in Appendix A (Table A4-2). This was one of the cleanest systems observed, from a dust perspective, at both positions of the CM. The dust conditions at the operator's position were also good. However, poor methane dilution at the right-hand corner of face position 1 is suspected.

Table 4.5.2.1a
Results of mobile exhaust and force brattice system at position 1

Test #	Sprays	Air Movers	Brattice from Face	Fan Capacity (kW)	Scrubber	Air Velocity (m/s)	
	On/Off	On/Off	Metres	5,5/11,0	On/Off	Operator	Face
1	On	On	8,0	Off	On	0,9	1,4
2	On	On	8,0	5,5	On	1,7	0,9
3	On	On	11,0	Off	On	1,0	1,5
4	On	On	11,0	5,5	On	1,2	1,3
5	On	On	No	11,0	On	0,9	1,6
6*	On	On	No	5,5	On	1,4	1,5

*Test was conducted with scrubber only (without the exhaust column).

Similarly, the results for the mobile exhaust with the force brattice when the machine is in position 2 are summarized in Table A4-2 (Appendix A).

Table 4.5.2.1b
Results of mobile exhaust and force brattice

Test #	Sprays	Air Movers	Brattice from Face	Fan Capacity (kW)	Scrubber	Air Velocity (m/s)		
	On/Off	**On/Off**	**Metres**	**5,5/11**	**On/Off**	**Operator**	**Pos-1**	**Pos-2**
1	On	On	11,0	Off	On	0,4	NAM	0,8
2	On	On	11,0	5,5	On	1,6	NAM	0,2
3	On	On	No	5,5	On	0,5	NAM	0,8
4	On	On	No	11	On	2,0	NAM	1,0

NAM – no air movement

Unfortunately, the implementation of this system in underground mines will have great practical disadvantages unless the CM body is redesigned.

4.5.2.2 760 mm Force column and mobile exhaust

At 25 m from the face, the mobile exhaust force system was the best combination for this set of tests. However, it was not as good as only having a force column at 25 m from the face. The test observations for the mobile exhaust system at positions 1 and 2 are shown in Appendix A (Tables A4-2 and A4-3) and the summarized results are shown in Tables 4.5.2.2a and 4.5.2.2b.

Table 4.5.2.2a
Results of 760 mm force and mobile exhaust system at position 1

Test #	Sprays	Air Movers	Column from Face	Scrubber	Air Velocity (m/s)	
	On/Off	**On/Off**	**Metres**	**On/Off**	**Operator**	**Pos–1**
5	Off	Off	10,0	On	7,4	3,1
6	On	Off	15,0	On	4,2	1,9
7	On	Off	20,0	On	2,4	1,1
8	On	On	25,0	On	2,1	0,8
9	On	On	16,0	On	0,6	0,4

At position 2, both a 5,5 and a 11 kW jet fan were used as the auxiliary ventilation device.

Table 4.5.2.2b
Results of mobile exhaust (760 mm) system at position 2

Test #	Sprays	Air Movers	Column from Face	Fan Capacity (kW)	Scrubber	Air Velocity (m/s)		
	On/Off	**On/Off**	**Yes/No**	**5,5/11**	**On/Off**	**Operator**	**Pos-1**	**Pos-2**
1	On	On	No	Off	On	0,4	NAM	1,1
2	On	On	No	11	On	2,3	NAM	1,4
3	On	On	No	5,5	On	0,4	NAM	1,2
4	On	On	11,0	11	On	0,2	2,0	0,6
5	On	On	16,0	11	On	0,2	0,4	0,6
6	On	On	21,0	11	On	0,2	NAM	1,2
7	On	On	25,0	11	On	0,3	NAM	1,2
8	On	On	11,0	5,5	On	0,2	1,6	0,4
9	On	On	16,0	5,5	On	0,2	NAM	0,8
10	On	On	21,0	5,5	On	Turbulent	0,8	0,9
11	On	On	25,0	11	On	1,2	NAM	1,6
12	On	On	No	Off	On	0,4	NAM	0,8

With the column 25 m from face position 1, no air movement was observed at this position, indicating that a risk of methane build-up can result. Both jet fans (5,5 and 11 kW) failed to ventilate face position 1 without columns extending their outlet.

4.5.2.3 570 mm Force column and mobile exhaust

The system consists of a 570 mm force column giving 5 m^3/s and a 760 mm column (9,5 m^3/s) mobile exhaust. This system is extremely sensitive, as the energy balance is critical. The results of the force-exhaust system at positions 1 and 2 are shown in Tables 4.5.2.3a and 4.5.2.3b.

If the force system is too close, there is dust rollback over the scrubber and operator. The air balance is sensitive in position 1 and is optimum at 15 m to 20 m from the face. In position 2, the force system at 12 m to 20 m from the face ventilates both positions 1 and 2. The summarized test observations for the force-exhaust system are shown in Appendix A (Tables A4-4 and A4-5).

Table 4.5.2.3a
Results of 570 mm force column and mobile exhaust system at position 1

Test #	Sprays	Air Movers	Column from Face	Scrubber	Air Velocity (m/s)	
	On/Off	On/Off	Metres	On/Off	Operator	Pos–1
1	On	Off	11,0	On	10,5	4,3
2	On	Off	15,5	On	5,4	3,6
3	On	On	21,5	On	4,3	1,3
4	Off	Off	25,5	On	3,4	1,6

Table 4.5.2.3b
Results of 570 mm force column and mobile exhaust system at position 2

Test #	Sprays	Air Movers	Column from Face	Scrubber	Air Velocity (m/s)	
	On/Off	On/Off	Metres	On/Off	Operator	Pos–1
113	On	On	11,0	On	0,2	P1 – 1,6 P2 – 0,4
114	On	On	16	On	0,2	P1 – NAM P2 – 0,8
115	On	On	21	On	Turbulent	P1 – NAM P2 – 0,9
116	On	On	25,5	On	1,2	P1 – NAM P2 – 1,6

The air short circuits to the scrubber inlet and does not ventilate position 1 at 16 m from the face.

4.5.3 Force and exhaust scoop brattice systems

Both scoop force and exhaust brattice systems were evaluated. The exhaust scoop brattice system resulted in good dust conditions as the whole heading was bathed in slow-flowing fresh air. However, the system was sensitive to the brattice falling behind and needs to be close to the face to ensure methane dilution. It does not ventilate position 1 when position 2 is being cut. Test results are given in Table 4.5.3 and in Appendix A (Table A5). The force scoop brattice system needs to be as close as possible to the machine in position 1. It results in good dust conditions at the operator with fresh air flowing over the operator. If the brattice falls behind, however, there is poor visibility at the face and poor methane dilution. When cutting position 2, the brattice needs to be as close as possible to position 1.

Table 4.5.3
Results of scoop brattice system at position 1

Test #	Sprays	Air Movers	Brattice from Face	Scrubber	Air Velocity (m/s)	
	On/Off	On/Off	Metres	On/Off	Operator	Face
1	On	Off	9,0	Off	0,5	1,0
2	On	Off	9,0	On	1,6	0,7
3	On	Off	12,0	On	1,5	0,9
4	Off	On	12,0	On	1,6	0,9
5	On	On	12,0	Off	SAM	1,0
6	On	On	12,0	On	1,5	1,1
7	On	On	9,0	Off	0,2	1,0
8	On	On	9,0	On	1,6	1,1

SAM – small air movement

5 Conclusions

The ventilation simulation tunnel has proved to be an invaluable tool in the development and evaluation of dust-control systems and their components. The evaluation of the systems has resulted in the following main developments: a new spray nozzle, a directional spray system, a physical air curtain and changes to the scrubber inlet and outlet.

Further evaluation of auxiliary ventilation systems has highlighted the complexities of ventilating for dust and methane where force ventilation is the primary method of methane dilution. The findings of the surface tests will be evaluated in underground collieries as the second phase of the project. The Kloppersbos studies were aimed at evaluating individual components and combinations of ventilation equipment. The results of the individual and combined tests led to the following recommendations, which will be implemented on the dedicated 12 HM9 for underground test work at Matla No. 3 mine:

- Fitted with new spray nozzle (1,6 mm inlet and 2,0 mm outlet)
- Kloppersbos directional spray system introduced
- Air movers fitted over flight conveyor
- Scrubber intake extended, with inlet cone fitted
- Physical air curtain introduced.

6 References

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Appendix A

Table A1-1

Nozzle test observations

Test	Velocity at face (m/s)	Observations
1 mm Hollow-cone nozzle		
1	Negligible	▪ Volume flow much too low to have any effect on air movement and will not be able to suppress the dust ▪ Nozzle too small at low pressures; insufficient volume of water to wet coal
2	Slight	▪ Severe rollback; water suppression Blanket improved; volume still inadequate to wet coal
3	1,0	▪ Considerable improvement over test 2 ▪ Turbulence on face good; severe rollback at flight conveyor ▪ Coal-wetting ability improved
4	1,2	▪ Considerable improvement over test 2 ▪ Turbulence on face good; severe rollback at flight conveyor ▪ Coal-wetting ability improved
5	0,5	▪ Volume flow much too low to have any effect on air movement and will not be able to suppress the dust ▪ Nozzle too small at low pressures; insufficient volume of water to wet coal
1,6 mm Hollow-cone nozzle		
1	0,9	▪ Air moves back; no rollback
2	1,0	▪ Severe rollback through flight conveyor ▪ Smoke slow to clear; rollback behind cutter head
3	1,0	▪ Improvement over previous test ▪ Rollback through flight conveyor still a problem
4	1,0	▪ Flight conveyor problem; visual rollback at conveyor from under cutting arm ▪ Rollback not so severe; smoke contained in headway
5	1,8	▪ Rollback considerably lower ▪ Water spray contained closer to face
2 mm Hollow-cone nozzle		
1	0,50	▪ Slight rollback; no air movement
2	1,2	▪ Rollback quicker; good wetting
3	1,3	▪ Same as previous test – only quicker
4	1,40	▪ Air direction fluctuating; good atomization

1,6 mm Hollow-cone nozzle: Two spray blocks off		
1	1,0	▪ Rollback reduced; rollback past operator
2	1,0	▪ Airflow pattern very similar throughout ▪ Air under cutter arm on right and exiting on left; also flight conveyor rollback a major problem
4	1,0	▪ Spray pattern from nozzles differs considerably from one nozzle to another

Table A1-2
Nozzle test observations

2,5 mm / 2,0 mm Hollow-cone nozzle					
Test	**Column distance from face (m)**	**Velocity in m/s**		**Special conditions**	**Observations**
		Operator	**Face**		
27	15	4,2	1,2	Water pressure decreased to 8 bar	▪ Much less rollback – more laminar flow ▪ Operator not affected by rollback, but by scrubber recirculation
30	15	0,0	0,1	All ventilation & scrubber systems off; new nozzle – 2,5 mm inlet with 2,0 mm outlet; 80 ℓ/min; 500 kPa	▪ Water quantity and pressure too low ▪ Rollback and swirling over operator ▪ No rollback through flight conveyor
31	15	0,0	0,2	H_2O pressure at 1 000 kPa 120 ℓ/min	▪ More rollback but none through flight conveyor ▪ Very good wetting ability at face
32	15	4,1	>1,1	Jet fan & scrubber on; new nozzles (2,5 mm inlet)	▪ Good wetting ability – very poor capture efficiency due to excessive turbulence, swirling and rollback from the full width of the face, back over the operator ▪ End of tests with this nozzle size ▪ Also rollback through flight conveyor (excessive)

Table A1-3

Nozzle test observations

2,0 / 1,6 mm Nozzles					
Test	Column distance from face (m)	Velocity in m/s		Special conditions	Observations
		Operator	Face		
55		± 0,7	± 0,4	New nozzle size (2,0 mm inlet / 1,6 mm outlet) H_2O at 1 000 kPa 62 ℓ/min	▪ Even at 1 000 kPa, severe atomization observed – to the extent that excessive rollback and turbulence occurred ▪ Poor wetting and air-moving ability ▪ It appears that when the inlet diameter is larger than the outlet, it enhances atomization, and vice versa
56		0,6	0,4	H_2O pressure at 1 500 kPa 100 ℓ/min	▪ Severe atomization observed – to the extent that excessive rollback and turbulence occurred ▪ Improved wetting and air-moving ability ▪ It appears that when the inlet diameter is larger than the outlet, it enhances atomization, and vice versa
57		0,6	0,4	H_2O pressure at 2 000 kPa 110 ℓ/min	▪ Severe atomization observed ▪ Excessive rollback and turbulence occurred ▪ Improved wetting and air-moving ability ▪ It appears that when the inlet diameter is larger than the outlet, it enhances atomization, and vice versa
58 (a)		± 0,6	± 0,4	H_2O pressure at 2 500 kPa 120 ℓ/min	▪ Severe atomization observed ▪ Excessive rollback and turbulence occurred ▪ Improved wetting and air-moving ability ▪ It appears that when the inlet diameter is larger than the outlet, it enhances atomization, and vice versa

Table A2

Half-curtain test results with 570 mm force column

Test	Column distance from face (m)	Velocity in m/s Operator	Face	Special conditions	Observations
67	11,0	10,3	4,9	Half-curtain fitted	▪ Severe rollback through flight conveyor and over scrubber ▪ Energy imbalance in face
68	16,0	3,2	1,3	Half-curtain fitted	▪ Considerably better ▪ No rollback through flight conveyor ▪ Face clears more quicker; operator in clean air ▪ Only contamination is recirculating scrubber air
69	21,0	0,7	2,1	Half-curtain fitted	▪ All smoke contained behind curtain ▪ Operator clear ▪ Smooth flow across face ▪ No turbulence
70	21,0	0,7	2,1	Small vents cut into curtain at top	▪ Same as for test 69
71	25,5	0,5	2,1	Small vents cut into curtain at top	▪ Similar to test 70 – maybe slightly better ▪ Once again, no rollback

Table A3-1

Force system tests with 5,5 kW jet fan and 570 mm column

Test	Column distance from face (m)	Velocity in (m/s)		Special conditions	Observations
		Operator	Face		
12	12	14	2,4	-	▪ Severe rollback over the operator
13	12	12,8	2,7	Scrubber volume reduced to 5,5 m^3/s	▪ Even more rollback past the operator and around the scrubber
14	12	5,1	2,6	Scrubber volume reduced to 3,3 m^3/s	▪ Some rollback around the operator and scrubber (slightly less than with test 13)
15	12	12,2	10,2	Scrubber off	▪ Air coming predominantly along flight conveyor – air movement (face sweeping) right to left
16	12	5,4	2,4	Scrubber volume reduced to 5,8 m^3/s	▪ Very similar to test 15 ▪ For first time, rollback occurred on the right-hand side – force fan too far back ▪ Severe turbulence and swirling at operator
18	12	5,0	1,0	Water sprays off	▪ Although rollback occurred, it did not reach the operator's position ▪ Whole face filled with smoke – poor visibility ▪ Less energy on face – therefore improvement in dust conditions
19	18	0,8	0,2	Water sprays off	▪ Still rollback, but much smoother flow in heading – velocity at face too low
20	18	1,6	1,1	Water sprays on	▪ Best system so far; operator virtually in clean air ▪ Rollback limited to conveyor and captured by scrubber
21	15	4,4	1,2	Water sprays on	▪ Excessive rollback through flight conveyor and over the operator ▪ More rollback observed over the operator than with test 20
22	15	4,5	1,0	Water sprays off	▪ Less rollback through the throat of the conveyor ▪ Scrubber catches any rollback which it does not do with the water sprays operating ▪ No rollback on the side of the scrubber, but slight rollback above scrubber

23	15	2,8	2,4	Scrubber volume reduced to 3,3 m^3/s	▪ Excessive rollback and turbulence; much smoke rolling over operator and bypassing scrubber ▪ Recirculation as smoke entrained by force air stream ▪ Repeat of test 23 with water sprays off – very poor conditions
24	15	4,3	1,0	Scrubber extended to 1,0 m	▪ Rollback still occurred through flight conveyor ▪ Operator's position seems to be clear (rollback stops just in front of the operator's position) ▪ Scrubber volume too high – excessive recirculation can be more clearly seen
26	15	4,5	1,0	Scrubber inlet further extended to 1,9 m	▪ It appears that the additional extension is too small, too close to the face to capture the dust ▪ Rollback observed past the inlet ▪ Worse than previous test
33	21	3,0	1,1	Scrubber inlet extended to 1,0 m	▪ Right-hand side of face clean ▪ Only rollback is through flight conveyor which is excessive and contaminates driver's position ▪ The difference between the result of this test and those of the 15,0 m test is that the scrubber inlet is extended, and the force column is 3 m further away from the face
34	21	3,0	1,1	Scrubber inlet extended to 1,0 m Deflector plate on	▪ Rollback through flight conveyor, but only slight to operator ▪ With three air movers operating in the flight conveyor, no rollback was observed through it ▪ No rollback passed the scrubber
35	21	2,1	0,8	Scrubber inlet extended to 1,0 m Deflector plate on Scrubber volume reduced to 3,3 m^3/s	▪ Very low capture efficiency ▪ Rollback over the scrubber and via the conveyor ▪ With venturi's on, less rollback via the flight conveyor but still over the scrubber ▪ Not recommended
36	25,5	0,6	1,1	Scrubber inlet extended to 1,0 m Deflector plate on Scrubber volume	▪ Rollback through flight conveyor but with venturi's on, no rollback anywhere ▪ Rollback via flight conveyor did not reach the operator's position

				reduced to 3,3 m^3/s	▪ Slightly worse than test 35
37	30,5	1,5	1,0	Scrubber inlet extended to 1,0 m Deflector plate on Scrubber volume reduced to 3,3 m^3/s	▪ Air movers on – slight rollback above the scrubber and below the CM; visibility at face very poor; test worse than previous test ▪ Air movers off – rollback through conveyor and slightly over the operator. Plenty of rollback over the scrubber and under the CM; visibility at face very poor; velocities at face low ▪ With only jet fan operating, face velocity was 0,2 m/s. With air movers on, velocity at face was 1,1 m/s

Table A3-2
Axial fan with force column (760 mm)

Test	Column distance from face (m)	Velocity at operator (m/s)	Velocity at face (m/s)	Special conditions	Observations
63	10,2	7,1	2,3	Exhaust column removed; Position 1	▪ Blowing occurred past scrubber ▪ Right side of machine clear ▪ Rollback through flight conveyor chain controlled ▪ Too much turbulence in face
64	15	2,6	0,8	Position 1	▪ Blowing still occurring on left side at ± the same rate as in test 63; air reaching face ▪ Operator's position relatively clean ▪ Unable to quantify recirculation components
65	20	1,4	1,1	Position 1	▪ Limited rollback and turbulence ▪ Operator virtually clean ▪ Good system – compares well with axial fan / jet fan tests with higher discharge velocities
66	25,0	1,0	1,2	Position 1	▪ Almost similar to test 65, but perhaps slight deterioration observed at operator ▪ However, it appears that due to more recirculation, the overlap is more polluted than with the other tests

Table A3-3
Axial fan with force column (760 mm) holed

Test	Column distance from face (m)	Velocity at operator (m/s)	Velocity at face (m/s)	Special conditions	Observations
76	11	5,8	1,9	No half-curtain	▪ Blow-by (rollback) occurring around scrubber ▪ Operator's position relatively clean ▪ Best results so far under similar conditions, i.e. with discharge column 11 m from face
77	15	1,0	0,7	No half-curtain	▪ Best results for a force system at this discharge distance so far ▪ No rollback to operator observed
78	20	1,0	1,1	No half-curtain	▪ Not as good as test 77, but rollback controlled ▪ Not enough air reaching the face ▪ Fresh air turned back at ± 14 m ▪ Air from slit and holes also turned back ▪ Some air reaching face

Table A3-4
Force system and 570 mm column at position 2

Test	Column distance from face (m)	Velocity in m/s		Special conditions	Observations
		Operator	Face		
95	20	SAM	P1 – 0,20 P2 – 0,50	Scrubber and directional sprays running; m/c position 2; force quantity 5 m^3/s @ 11 m/s	▪ Small amount of recirculation observed ▪ Operator's position relatively clear ▪ Low velocity over face at position 1
96	15	SAM (0,2)	P1 – 0,5 P2 – 0,4	Machine at pos. 2 Scrubber and jet fan	▪ Some rollback observed on right side (open) ▪ Operator's position relatively clear ▪ Turbulent air movement occurring at pos. 1
97	25	SAM	P1 - NAM P2 -0,6	Machine at pos. 2 Jet fan	▪ Position 1 not ventilated for CH_4 control ▪ Blow-by occurring on right of scrubber over operator ▪ Not a good system
98	11	Turbulent	P1 – 1,1 P2 – 0,20	Machine at pos. 2 Axial fan (15 kW)	▪ Good ventilation conditions at positions 1 and 2 ▪ No recirculation observed over the operator ▪ Good system
99	16	Turbulent	P1 – 0,4 P2 – 0,6	Machine at pos. 2 Axial fan	▪ Operator's position clear ▪ Slight recirculation observed over the operator; good system
100	21	Turbulent	P1 – 0,2 P2 – 0,8	Machine at pos. 2 Axial fan (15 kW)	▪ Too much turbulence around the operator's position ▪ More recirculation observed than with other distances ▪ Not a satisfactory system for these conditions
101	No	0,2	P1 – NAM P2 – 1,0	Outlet of scrubber to LTR =15,3 m Scrubber on, sprays on Force system off	▪ Large portion of air reaching LTR ▪ Position 1 not ventilated
102	No	0,8	P1 – NAM P2 –0,40	Scrubber on Directional spray system on Jet fan (5,5 kW) positioned in LTR	▪ Jet fan ineffective, irrespective of its position or direction ▪ Position 1 poorly ventilated ▪ Too much recirculation past operator

					▪ Not a good system
103		Turbulent	P1 – NAM P2 – 1,3	Scrubber and 11 kW jet fan suspended Machine at pos. 2	▪ Rollback to operator ▪ Position 1 not ventilated ▪ Turbulence created around machine ▪ Poorest system in position 2

Table A4-1
Mobile exhaust system at position 1

Test	Velocity in m/s		Special conditions	Observations
	Operator	Face		
37b	1,0	0,9	Position 1	▪ Clear conditions at operator ▪ Still rollback past scrubber and flight conveyor but not affecting operator's cabin ▪ Face velocity slightly less ▪ With conveyor venturi's on, rollback stopped ▪ Whole right-hand side of face clear
45	0,6	0	Sprays off Scrubber inlet extended (1 m) Jet fan off	▪ Severe short-circuiting to fan ▪ Slow air movement on right side ▪ Small air movement under cutter arm ▪ Face contaminated and visibility very poor ▪ Not recommended without H_2O running, i.e. should not be used in headings where no cutting is done
46	0,9	0	Sprays off & inlet cone fitted Jet fan off	▪ Severe short-circuiting to fan; bi-directional air movement at face ▪ Better air movement on right-hand side ▪ Visibility at face poor; not good for CH_4 dilution ▪ Scrubber fan increased by 1 m^3/s
47	1,1	0,7	Air movers off Sprays on Jet fan off	▪ Good undirectional flow over face ▪ Rollback occurring through flight conveyor ▪ No rollback at operator; a good system
48	1,1	0,8	Sprays on Air movers on Jet fan off	▪ Rollback through flight chain controlled ▪ None reaching operator ▪ Scrubber fan volume = 9,36 m^3/s
50	1,30	1,0	Without scrubber extension Sprays on Air movers on Jet fan off	▪ Without flight chain air movers, rollback was severe ▪ Once turned on, rollback was reduced considerably ▪ Good ventilation flow across the whole face ▪ Blow-past may still occur if area below scrubber is closed off ▪ Scrubber volume = 9,54 m^3/s
38	2,2	0,4	With jet fan – no ducting	▪ Air movers on – rollback over scrubber and under

				machine – very little over operator; poor visibility ▪ Air movers off – rollback over scrubber and under machine which affects area around operator ▪ Rollback at conveyor; slightly poor face visibility ▪ Air flow very turbulent – difficult to measure velocities accurately ▪ Velocities of jet fan around 13 to 17 m/s with scrubber fan operating

Table A4-2
Mobile exhaust and scoop brattice system

Test	Scoop Brattice distance from face (m)	Velocity in m/s		Special conditions	Observations
		Operator	Face		
111	11 m back from face pos. 1	0,4	P1 – NAM P2 – 0,80	Machine at position 2 No jet fan	▪ Operator's position very clean ▪ No rollback from LHS and flight conveyor ▪ Pos. 2 invisible; no or less air movement at pos. 1 ▪ Pos. 2 cleans quickly, except takes time to suck out the smoke from pos. 1
112	11 m back from face pos. 1	1,6	P1 – NAM P2 – 0,20	Machine at position 2 Jet fan (5,5, kW) used	▪ Very poor system ▪ Operator's position invisible ▪ Face velocity poor; high chance of methane accumulation ▪ Lot of mist at the operator
117	No brattice	0,4	P1 – NAM P2 – 0,80	Machine at position 2	▪ Operator's position clean ▪ Lot of recirculation ▪ Pos. 1 invisible; poor system
118	No brattice	0,5	P1 – NAM P2 – 0,80	Machine at position 2 Jet fan (5,5, kW) used between roof and floor	▪ Operator exposed to smoke ▪ Less smoke at pos. 1 when compared to test 117 ▪ Observed recirculation ▪ Face turbulence observed at pos. 2 ▪ Smoke leaking from bottom of CM on left-hand side
119	No brattice	2,0	P1 – NAM P2 – 1,0	Machine at oosition 2 Jet fan (11 kW) used between roof and floor	▪ Operator position: smoke present ▪ Not a good system; heading is full of escaped smoke ▪ Less air movement at pos. 1 ▪ High operator velocity
120	8 m back from face pos. 1	0,9	P1 – 1,4	Machine at position 1	▪ Operator clean; cleans quickly ▪ Good face velocity and good system

121	8 m back from face pos. 1	1,7	P1 – 0,90	Machine at position 1 Jet fan (5,5, kW) used	▪ Operator clean ▪ Smoke at the right-hand side of pos. 1 still persists; takes longer time to clean ▪ Turbulence in face area; air short-circuiting
122	11 m back from face pos. 1	1,0	P1 – 1,50	Machine at position 1	▪ Operator clean ▪ Turbulence occurred in face area ▪ Face velocity is fine
123	11 m back from face pos. 1	1,2	P1 – 1,30	Machine at position 1 Jet Fan (5,5, kW) used	▪ Operator is clean; heading is clean ▪ Good ventilation system ▪ No smoke comes from bottom of CM
124	No scoop brattice	0,9	P1 – 1,60	Machine at position 1 Jet Fan (11 kW) used	▪ Operator is clean; heading is clean ▪ Good ventilation system ▪ No different from test 123, except air quantity may matter
125	No scoop brattice	1,4	P1 – 1,50	Machine at position 1 Scrubber only Jet Fan (5,5, kW) used	▪ Face ventilation is good; recirculation taking place ▪ Operator affected ▪ Heading is full of smoke ▪ Not a good system

Table A4-3
Axial fan (15 kW) with force column (570 mm) discharge (760 mm) and mobile exhaust (760 mm)

Test	Column distance from face (m)	Velocity in m/s		Special conditions	Observations
		Operator	Face		
59 (a)	10,0	7,4	3,1	Diffuser only fitted	▪ Excessive rollback through flight conveyor and over operator ▪ Too much energy in face ▪ Rollback on left-hand side past scrubber on the floor, causing some recirculation
58 (b)	10,2	7,2	3,2	1 x 760 mm force column discharge 570 mm column	▪ Rollback past operator's position ▪ System recirculating (spray fan) ▪ Blow-by occurring past scrubber ▪ Too much energy in face
59 (b)	15,0	4,2	1,9	1 x 760 mm force column 570 mm force column	▪ Rollback up to fan outlet ▪ Recirculation taking place at spray fan; with flight chain sprays operating, rollback controlled in that area ▪ Air short-circuiting to fan ▪ Operator's position reasonably clear
60	20	2,4	1,1	1 x 760 mm force column 570 mm column	▪ Rollback to 17 m from face ▪ Recirculation taking place at spray fan ▪ Operator's position relatively clean; better than previous test ▪ Rollback on left-hand side of scrubber almost eliminated ▪ Rollback over scrubber
61	25	2,1	0,8	1 x 760 mm force column 570 mm force column	▪ Heavy rollback on left-hand side of machine extending to 21 m ▪ Operator's position in relatively clean air ▪ Recirculation still taking place at spray fan

Table A4-4

Mobile exhaust and jet fan and force column 570mm

Test	Column distance from face (m)	Velocity in m/s		Special conditions	Observations
		Operator	Face		
51	11	10,5	4,3	Scrubber extended and cone fitted Air movers on	▪ Severe rollback past operator ▪ Top right-hand corner of face not getting air ▪ Too much turbulence in face; air being blown past scrubber ▪ Air movers made no difference; poor dust control ▪ Good CH_4 dilution except for top right-hand corner
52	15,5	5,4	3,6	Air movers on	▪ Severe rollback almost as far as force column outlet ▪ Turning on air movers appeared not to reduce severity ▪ Still no good air movement at right-hand corner ▪ Too much turbulence
53	21,5	4,3	1,3	Air movers on	▪ Rollback occurring on left and right of machine and through flight conveyor ▪ Rollback extends as far as the outlet of the force fan ▪ Air now appears to reach top right-hand corner of face ▪ Too much turbulence
54	25,5	3,4	1,6	Air movers on	▪ Rollback 21 m – excessive through flight conveyor and over drum, despite air movers operating ▪ Severe rollback around machine, particularly through flight conveyor; air reaching top right-hand corner

Table A4-5
Mobile exhaust and force system (570 mm)

Test	Column distance from face (m)	Velocity in m/s		Special conditions	Observations
		Operator	Face		
38b	± 35 m	2,2	1,0	Jet fan only Air movers off	▪ Same as for test 37, but with slightly high face velocities ▪ Slightly less rollback than test 37 ▪ Good conditions at the operator; no recirculation
39	± 35 m	0,3	1,2	Jet fan only Throttled scrubber ($5,2\ m^3/s$) Air movers off	▪ Once again operator in clean air, although rollback is more severe ▪ The face is also not so clear as with test 38 (b) ▪ Not as good as test 38(b); no recirculation observed
40	11	11,6	4,4	Jet fan Column 570 mm Air movers on	▪ Discharge air short-circuit to scrubber ▪ Severe turbulence, swirling and rollback at face ▪ Excessive energy at face ▪ Dust-capture efficiency will be very poor even with venturi sprays on; flight conveyor sprays on, still rollback through it ▪ Not recommended
41	15,5	4,8	3,1	Jet fan Column 570 mm Air movers off	▪ Rollback so excessive through flight conveyor that air movers do not stop it ▪ Operator's cabin contaminated ▪ Still far too much energy at face
42	20,5	3,9	1,2	Jet fan Column 570 mm Air movers off	▪ Still excessive rollback through flight conveyor, even to the extent that the air movers cannot cope with it ▪ Operator's cabin seems to be fairly clear, except for some swirling around, especially above the cabin
43	25,5	3,2	1,3	Jet fan Column 570 mm Air movers off	▪ Best of all the force/exhaust systems, but not as good as when only force column is 25,0 m from the face
49	25,5	3,4	1,4	Jet fan Column 570 mm Air movers on	▪ Severe rollback past machine – extending 20 m and out of heading ▪ Rollback also on left of machine and through flight conveyor

					▪ Opening air movers made difference on flight conveyor ▪ Too much energy in the face area ▪ A poor system for dust ▪ Good CH_4 dilution
113	11	0,2	P1– 1,6 P2– 0,4	Jet fan Column 570 mm Discharge velocity = 20,2 m/s Machine position 2	▪ Operator clean ▪ Smoke escapes to position 1, will go till 9 m from face and returns back ▪ Position 1, smoke conditions good
114	16	0,2	P1– NAM P2– 0,8	Jet fan Column 570 mm Discharge velocity = 20,3 m/s Machine position 2	▪ Operator clean ▪ Position 1 clean ▪ Most of the smoke goes through the scrubber ▪ At 9 m from face, escaped smoke and turns back to the face
115	21	Turbulent	P1– 0,8 (2 m from face) P2– 0,9	Jet fan Column 570 mm Discharge velocity = 20,3 m/s Machine position 2	▪ Smoke observed at operator's position ▪ Not a good system ▪ Smoke did not reach position 1 ▪ Not recommended
116	25,5	1,2	P1– NAM P2– 1,6	Jet fan Column 570 mm Discharge velocity = 20,3 m/s Machine position 2	▪ Operator's position: lot of smoke ▪ Not a good system ▪ Lot of mist at the operator, suggesting rollback ▪ Position 1 clean because most of the smoke did not reach past the 9 m mark from the face

Table A5

Scoop brattice tests

Test	Brattice distance from face (m)	Velocity in m/s		Special conditions	Observations
		Operator	Face		
87	9,0	0,2	1,0	Directional water spray system only, no scrubber, air movers off	▪ Smoke clearing very slowly ▪ Operator's position clear, but would probably be contaminated over time as machine advances; face visibility very poor
88	9,0	1,6	0,7	Scrubber on, air movers off, sprays on	▪ No pollution at operator; a good system ▪ Below-average face velocity ▪ No recirculation
89	12,0	1,5	0,9	Scoop moved back 3 m from outlet of scrubber, no scrubber, air movers off Directional water spray system	▪ Nil visibility at face ▪ Operator's position badly polluted ▪ Not a good system; Air movers off
90	12,0	1,6	0,9	Scoop moved back 3 m from outlet of scrubber, no scrubber, air movers off Directional water spray system	▪ Some recirculation taking place ▪ Operator's position clear
91	12,0	SAM	1,0	Directional water spray system LTR, exhaust brattice Scrubber off, air movers off	▪ Nil visibility at face ▪ Operator's position badly polluted ▪ Not a good system
92	12,0	1,5	1,1	Return brattice 3 m back at LTR, brattice made as exhaust Scrubber on, air movers on	▪ Some recirculation taking place ▪ Operator's position clear, a good system
93	9,0	0,2	1,0	Scrubber off Brattice extended to scrubber outlet, only water on At LTR brattice made as exhaust	▪ Operator's position clear ▪ Turbulence at the face making the face visibility poor; scrubber off
94	9,0	1,6	1,1	Scrubber off Brattice extended to scrubber outlet; Only water on At LTR brattice made as exhaust	▪ Operator's position clear ▪ Slight recirculation from the left-hand side of the scrubber

Safety In Mines Research Advisory Committee

SIMRAC

DRAFT

Final Report

Title: MECHANICAL MINER ENVIRONMENTAL CONTROL: INTEGRATED HOOD SYSTEM

Author/s: J J L DU PLESSIS; B K BELLE

Research Agency: CSIR MINING TECHNOLOGY

Project No: COL 518
Date: DEC. 1998

Executive Summary

High dust levels at the continuous miner operator's position prompted the DME to set up a directive enforcing a 5 mg/m^3 dust-concentration level at the position of the CM operator. In this regard, two committees were established, the Dust Working Group and the Industry Working Group on Mechanical Miner Ventilation and Dust Control, to address the dust problem. Through the activities of the Committees a project was formulated under the auspices of SIMRAC. The primary objective of this project was to control the environment to ensure the effective dilution of dust and methane to within the regulation requirements.

The project was conducted in two phases, firstly in a surface ventilation tunnel at Kloppersbos and secondly, by means of underground evaluations of various systems. The integrated hood system was evaluated as part of the second phase and the evaluation tests were conducted at SASOL's Twistdraai Colliery.

The average dust-concentration levels at the CM operator position for the smaller scrubber system as tested are shown below:

- Sampling period average 6,082 mg/m^3
- System sampling average 6,102 mg/m^3

Peak methane levels exceeding the maximum permissible level were observed. In one of the tests, the peak methane level reached the maximum sampler level of 4 % CH_4. Subsequent repairs to the high-pressure pump resulted in a drop in the CH_4 levels to well below 1,4 % CH_4.

The average dust-concentration levels at the CM operator position for the bigger scrubber system as tested are shown below:

- Sampling period average 7,452 mg/m^3
- System sampling average 7,845 mg/m^3

The methane concentrations were well within the 1,4 % CH_4 per volume concentration levels in most of the tests.

The most critical problem areas identified during the tests at Twistdraai Colliery included:

- maintenance of machine systems, including integrated hood, water sprays and scrubber
- consistency in water flow rate
- auxiliary ventilation position, operation and control
- awareness of and need for training.

The outcome of this project has shown that dust levels below 5 mg/m^3 are achievable, although with greater difficulty than was encountered during the work conducted at Matla Colliery.

The sensitivity of the dust levels measured to water flow rates and pressures has again been demonstrated. During the later part of the evaluations, a centrifugal pump used in line, at the feeder breaker, proved as effective as the piston-type pump mounted on the machine for providing water flow at the correct pressure and flow rate.

This observation is important, as this system is easy to maintain as well as allowing quick and easy inspections of a critical element of the dust-suppression system.

Glossary of abbreviations, symbols and terms

Abbreviations

CM	Continuous Miner
TWA-CONC	Time-weighted average dust concentration
SSA	System Sample Average
LTR	Last Through Road
DME	Department of Minerals and Energy

Symbols

mg/m^3	milligrams per cubic metre
ℓ/min	litres per minute
μm	micrometre
m^3/s	cubic metres per second
kPa	kilopascal

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  Jan du Plessis, CSIR-Miningtek, Kloppersbos

  Kobus van Zyl, CSIR-Miningtek, Kloppersbos

  Sarel W. Pretorius, Sarel Stofmonster

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1 Introduction

The 1995 report of the Leon Commission of Inquiry into Safety and Health in the South African Mining Industry (Leon et al., 1995) led to the promulgation of the Mine Health and Safety Act of 1996. In this report, the reasons for the current fatality, injury and disease rates in the mining industry are investigated. It is hoped that the Act will lead to a significant improvement in the health and safety profile of the South African mining industry (Green Paper: Minerals and Mining Policy for South Africa, 1998).

The issues of public health and safety have been dealt with around the world, through the intervention of governments. A directive of the South African Department of Minerals and Energy (DME Directive, 1997) to reduce the dust-concentration level to below 5 mg/m^3 at the operator's cab position on continuous heading machines resulted in a dedicated research project entitled "Underground Mechanical Miner Environment Control". The project was planned in two phases. The first phase involved tests on a continuous miner model in a ventilation tunnel at the Kloppersbos Research Centre (Du Plessis and Belle, 1998). The evaluation of these findings in an underground mine section was the main objective of the second phase of the project. The systems tested needed to comply with two main criteria, viz., adequate methane gas dilution at the face and keeping the respirable dust concentration level down to less than 5 mg/m^3.

This report discusses the second phase of the mechanical miner environmental control underground work at Section 15 of Twistdraai Central Colliery. The system that was evaluated consisted of the following main machine-mounted dust-control systems:

- Directional spray system
- New spray nozzles fitted
- Air movers
- Integrated hood system
- Auxiliary ventilation was provided by a 7,5 kW jet fan used together with an induction ring and 570 mm diameter spiral ventilation ducting.

Tests were conducted to determine the respirable dust concentrations at the intake, operator's cab position (remote-control machine) and the return of the section. Furthermore, the methane concentration was monitored to ensure compliance with the 1,4 % CH_4 per volume requirements. This report describes the tests, the test conditions and the results of the two (integrated hood) systems evaluated.

2 Method and instrumentation

2.1 Method

All the tests were conducted in a bord-and-pillar CM section. Figure 2.1a shows the typical deployment of the dust-monitoring instruments in the test section. The respirable dust-concentration levels in the headings were determined by placing gravimetric respirable dust samplers along with the Hund tyndallometers. The samplers were positioned in the section intake, at the operator's cabin position and in the section return. The air quantities and the direction of airflow were determined using anemometers and smoke tubes.

The mining sequence utilized, adhering to the 12 m rule, and the subsequent mining blocks (referred to as cuts 1 to 14) are shown in Figure 2.1b. In Table 2.1, the mining conditions in which the tests were conducted are shown. A total of 15 tests were conducted for evaluating the integrated hood system. The first five tests were conducted with a smaller scrubber; during the second series of tests, a larger scrubber was fitted. Jet fans were used as the auxiliary ventilation device and they were kept on the floor with an entrainment ring and column fitted to induce airflow.

Table 2.1

Description of conditions in section

Description	Specification
Panel Number	15
Depth, m	175
Height, m	4,5 – 4,9
Bord Width, m	6,5 – 7,0

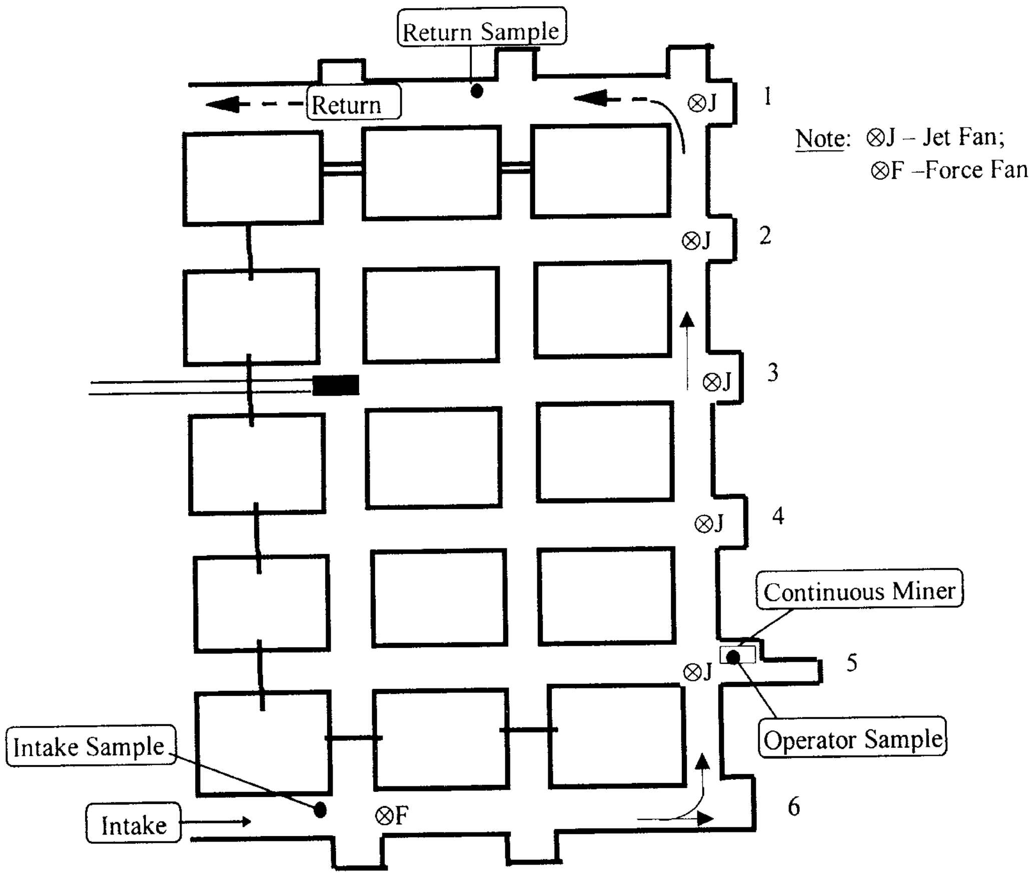

Figure 2.1a: General layout of test section 15 at Twistdraai

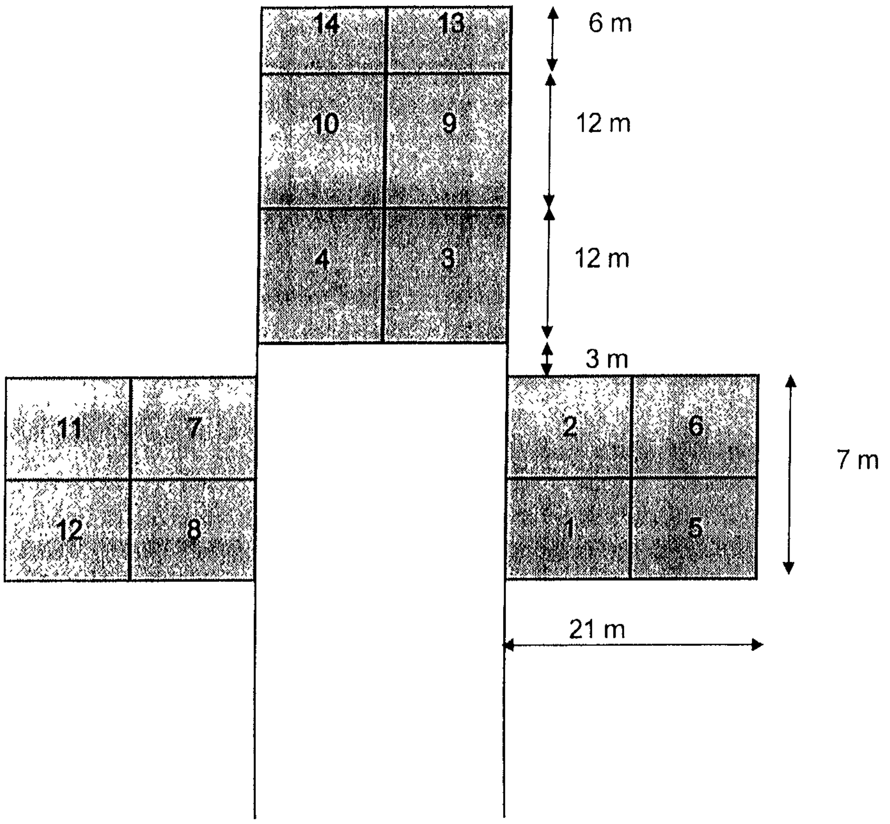

Figure 2.1b: 12 m Cutting Sequence

2.2 Instrumentation

2.2.1 Dust monitoring

The sampling set-up is shown in Figure 2.2.1a. The set-up contains two gravimetric samplers, viz. a BGI sampler and a Cowl sampler, plus a Hund tyndallometer. Gravimetric samplers were used to determine the average respirable dust concentrations during different operations. A pair of samplers, consisting of BGI and Cowl samplers, was positioned at the section intake, the CM operator (Figure 2.2.1b) and the section return. The average gravimetric respirable dust concentration was used to convert the Hund readings to mass concentrations (mg/m^3). The gravimetric samplers consist of an air pump that draws 2,2 ℓ/min of air through a mini-cyclone, which separates the airborne dust and collects only respirable dust (<7 μm) on a pre-weighed filter disc. At the stipulated flow rate of 2,2 ℓ/min, the instrument conforms to the new USA, UK and European respirable dust curve with a 50 % cut point (d_{50}) of 4 μm. The dust samples were then weighed and the procedure for determining the particulate mass was followed according to DME guidelines.

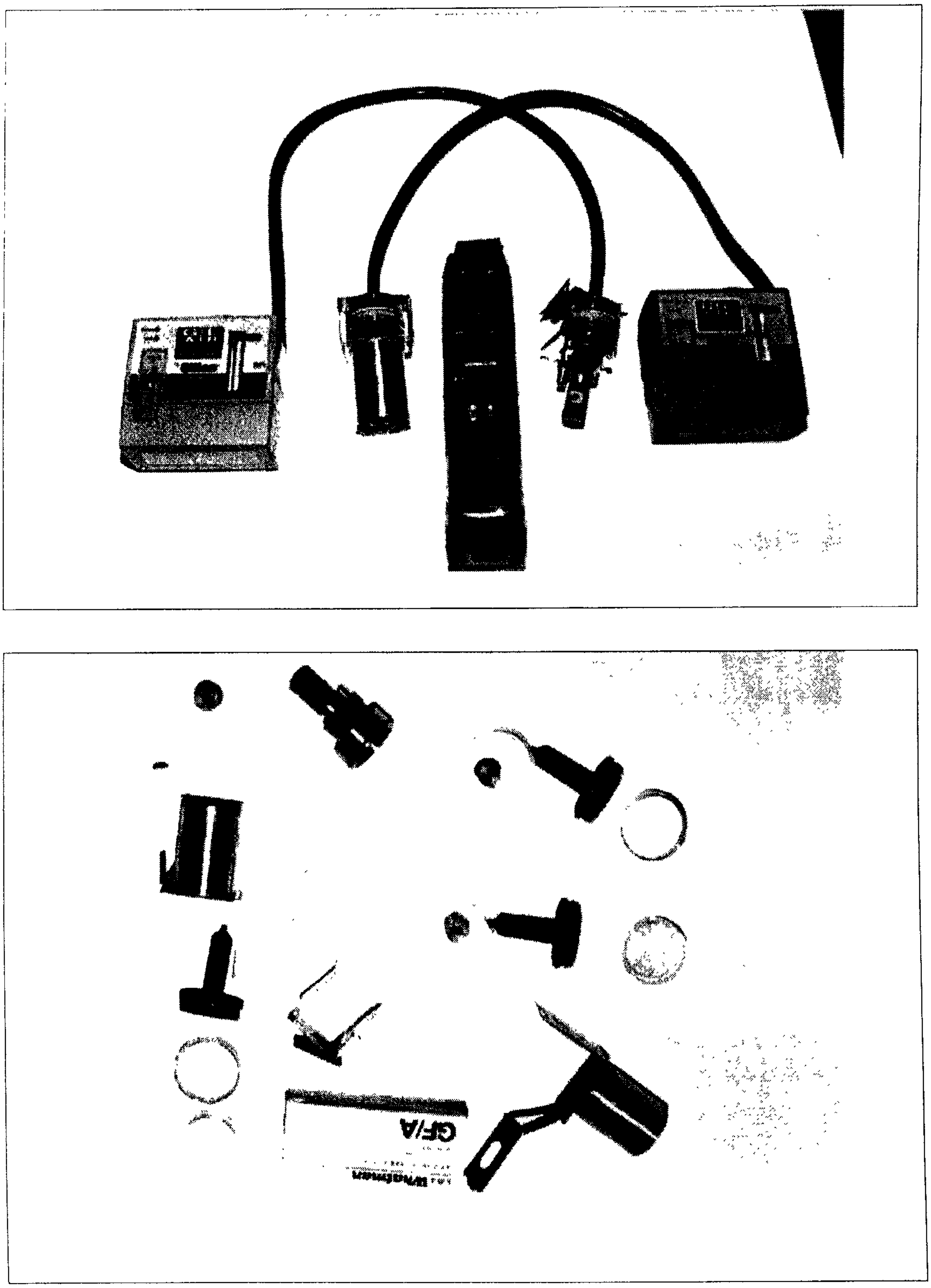

Figure 2.2.1a: The sampling set-up

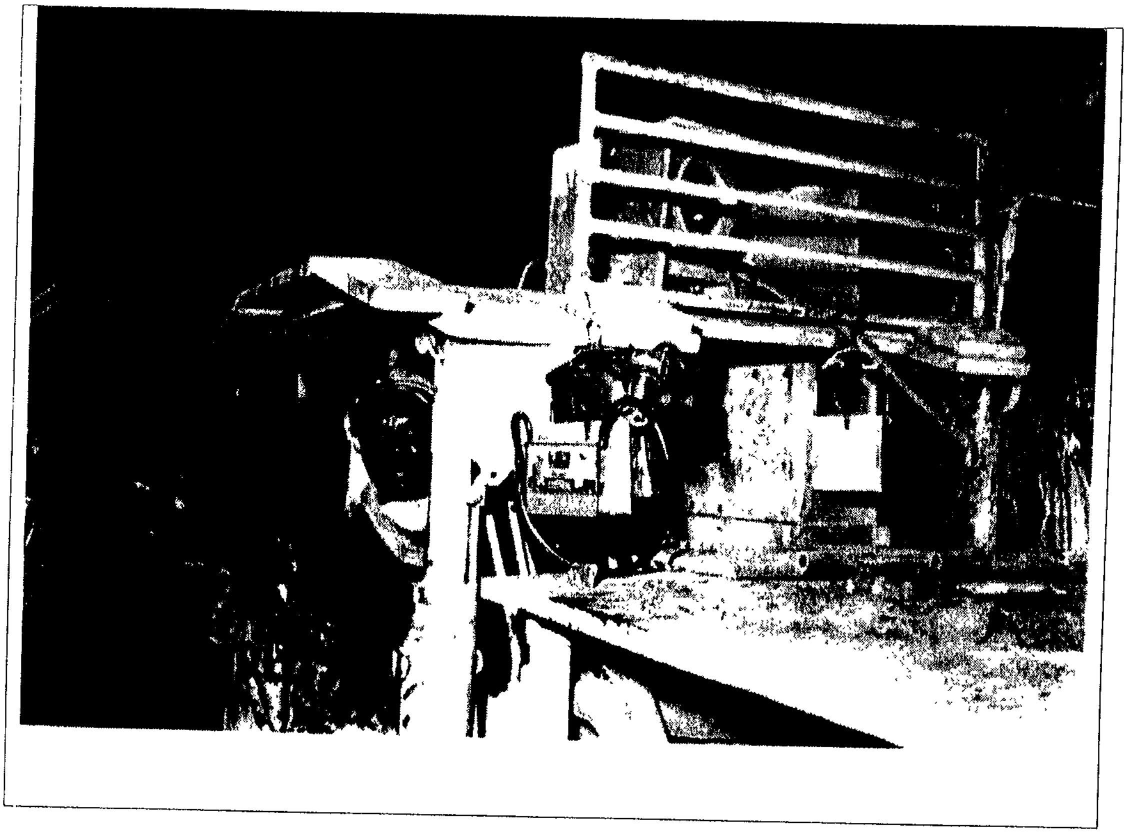

Figure 2.2.1b: Position of samplers at the operator's position

2.2.2 Methane monitoring

A system developed by CSIR-Miningtek to monitor methane levels every ten seconds was used in order to obtain a reliable indication of the methane levels during a shift. The system consists of a main box and methane sensors (Figure 2.2.2). The main box contains the system battery and a logger unit. The methane sensors, which have a range of 0 % to 4 % methane by volume in air, are connected via screened armoured cables to the main box. The sensor elements are supplied with a protective hood to prevent excessive water and dust from reaching the sensor head. During the test period, two methane sensors were placed directly behind the cutting drum to monitor the methane levels. These data were used to evaluate the effectiveness with which a ventilation system could dilute the methane liberated from the face. For all the tests carried out underground and for reporting purposes, the cutting sequence as shown in Figure 2.1b was followed.

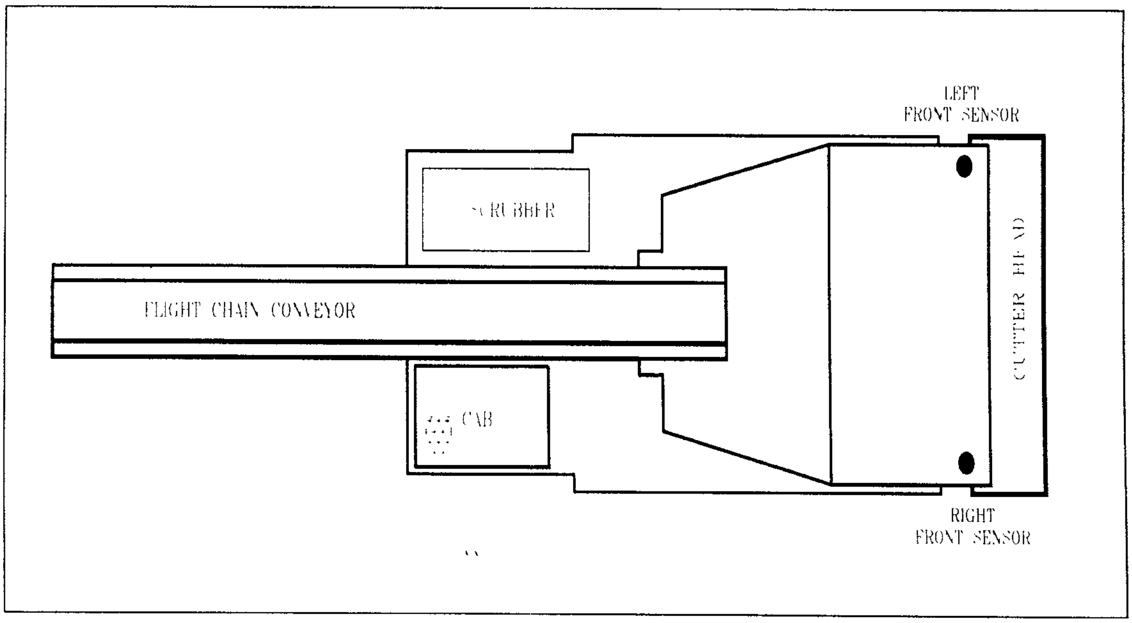

Figure 2.2.2: Position of methane sensors on the CM

2.3 Data analysis

2.3.1 Evaluation of dust-concentration level

The dust concentrations presented throughout this report reflect gravimetric dust measurements taken over a specific sampling period. These results should not be taken to be full-shift compliance samples (TWA-CONC), but as engineering measurements. Real-time dust-sampling results allow the comparison of face-area dust concentrations under different ventilation and mining conditions.

Using the mass of dust collected on the filters, the sample dust concentration is obtained as follows:

$$\text{Sample Dust Concentration (SC)} = \frac{(C_f - C_i)}{Fl \times T} \qquad \textbf{(1)}$$

where:	SC	=	sample dust concentration measured in mg/m^3
	C_i	=	corrected initial filter mass in mg
	C_f	=	corrected final filter mass containing dust in mg
	Fl	=	sample flow rate in m^3/min
	T	=	sampling time in min

The time-weighted average dust concentration (TWA-CONC) is obtained as follows (DME Guideline, 1994):

$$\text{TWA-CONC} = \frac{(SC \times T)}{480} \qquad \textbf{(2)}$$

where:	SC	=	sample dust concentration measured in mg/m^3
	T	=	sampling time in min

A new way of evaluating the dust-concentration values for each system, called the System Sample Average dust concentration (SSA), is proposed.

Essentially the SSA is calculated as follows:

$$\text{System Sample Average } (SSA_j) = \frac{\sum_{i=0}^{i=n} SC_{ij} \times T_{ij}}{\sum_{i=0}^{i=n} T_{ij}} \qquad (3)$$

where:

where:	SSA_j	=	System Sample Average dust concentration for a system measured in mg/m^3
	SC	=	sample dust concentration measured in mg/m^3
	T	=	sampling time in min
	i	=	test number; i= 1 to n
	j	=	test system number; j = 1 to n

2.3.2 Evaluation of methane data

Methane concentration varies in the cutting zone due to differential air movement over the cutter head. To establish a worst-case scenario, the maximum level recorded per time interval is used as a representative value for that time interval. As peak methane liberation occurs during the cutting cycles of a shift, the data recorded during these cutting cycles are extracted from the recorded shift data. From these data two values are calculated to reflect the methane conditions during the shift. These are the maximum levels recorded during the shift and the average of the peak values recorded. During the coal-cutting cycle, methane levels are a series of highs and lows as the CM sumps and shears. To avoid a false sense of security, the peak values of these highs and lows are isolated. Peak value is defined as a value that has higher values than the preceding and following time intervals. In this report, the maximum level and average of peak values for each test are shown in tabular form.

2.4 System description

The water spray system as developed at Kloppersbos was altered. The top and front views of the spray configuration are shown in Figures 2.4a and 2.4b. The spray configuration consists of a number of water spray blocks, air movers and an on-board scrubber connected to an integrated hood system. The system consists of a total of 41 water sprays and four air movers. The details of the individual components and the design specifications as shown on the drawings are as follows

- On-board scrubber:
  - a) Wet fan scrubber capable of handling between 6,0 and 8,0 m^3/s (referred to as the small scrubber).
  - b) Wet fan scrubber capable of handing an air quantity between 10 m^3/s and 12 m^3/s (referred to as the large scrubber).

- Water supply to the machine: Maintain water pressure between 1 500 and 2 000 kPa (15 and 20 bars) and a water flow rate of 100 and 120 ℓ/min to the water spray system and 40-60 ℓ/min to the scrubber.

- Type of nozzles: Standard hollow-cone nozzles with a single inlet diameter of 1,6 mm and an outlet diameter of 2,0 mm with a flow rate of 3,5 ℓ/min at 2 000 kPa.

- Position A on drawing: Four air movers spraying downwards (> 45° from vertical) onto the conveyor to wet the coal and to prevent dust rollback through the flight conveyor.

- Position B on drawing: Five top spray blocks situated above the cutter drum. A total of 15 directional water sprays to move air across the face from right to left.

- Position C on drawing: L-shaped spray block installed on right-hand side of machine. Three spray blocks, each consisting of two water sprays (a total of six), ensuring air movement to the front of the machine.

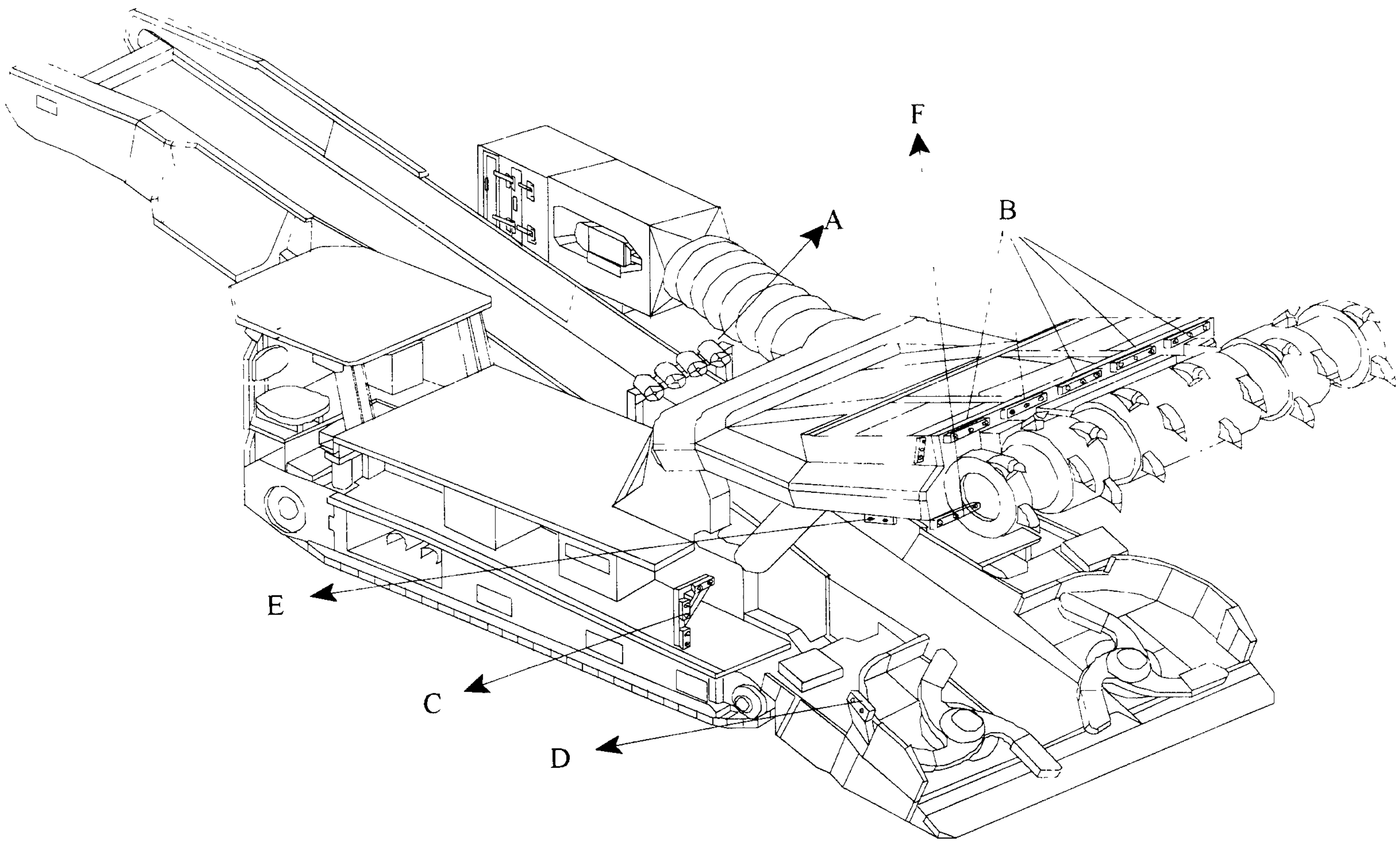

Figure 2.4a: Spray configuration (driver-side view)

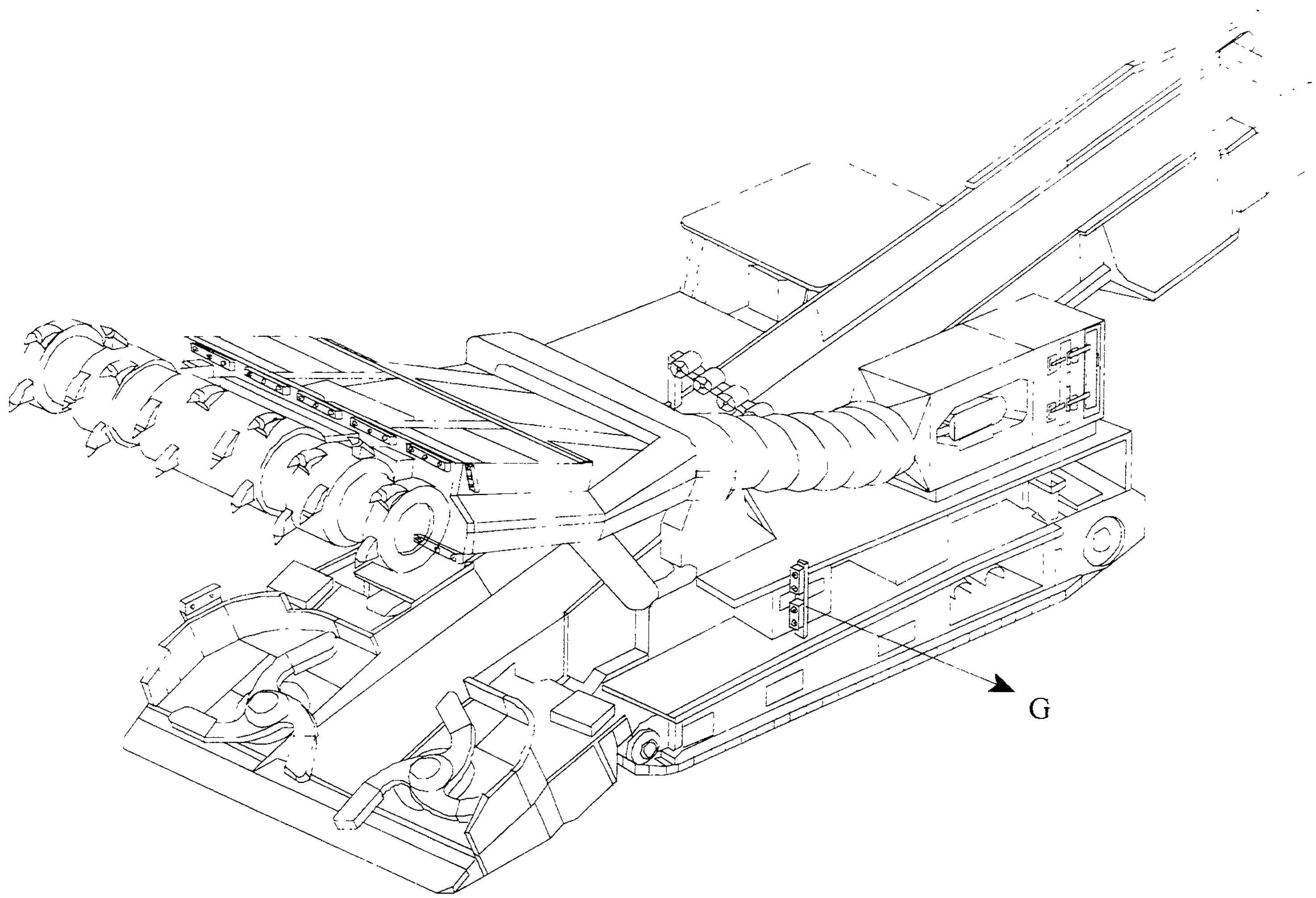

Figure 2.4b: Spray configuration (scrubber-side view)

- Position D on drawing: One spray block consisting of two water sprays installed on spade, directing air to the left of the machine underneath the boom.

- Position E on drawing: One spray block consisting of two water sprays connected to the bottom of the cutter boom, directing air towards the left of the machine underneath the boom (45 ° to horizontal).

- Position F on drawing: Two bottom directional spray blocks, each consisting of three sprays, installed underneath the cutting head on the left and right sides of the head to ventilate underneath the cutting drum.

- Position G on drawing: Four water sprays directed to the left to prevent dust rollby.

When the machine was being prepared, and before evaluation could start, a number of alterations to the dust-suppression system fitted by the manufacturer were found to be required. They included:

- Closing of more than 20 water sprays
- Movement of spray blocks
- Realignment of air movers
- Changing of nozzles
- Removal of air-balancing plates to integrated hood inlets.

All these changes were necessary to conform to the design specifications. Furthermore, permission was requested to use a jet fan together with an entrainment ring and column. Exemption from the 12 m rule to mine at 25 m was granted to this mine. This resulted in the jet fan-column outlet being a maximum distance of 25 m away from the face.

3 Test details and results

The results of the underground tests, are summarized in a tabular form, followed by discussions.

3.1 Test results: smaller scrubber

3.1.1 Methane concentration results

Table 3.1.1 summarizes the methane levels during the underground tests with the smaller scrubber.

Table 3.1.1

Methane concentrations: smaller scrubber tests

Test Nr.	Peak Value	Av. Value	Variance	Comments
3	1,30	0,33	0,054	Low peaks observed, just-steady increase in CH_4 over shift
4	0,62	0,22	0,011	Low peaks observed, just-steady increase in CH_4 over shift
5	0,64	0,18	0,012	Low peaks observed, just-steady increase in CH_4 over shift

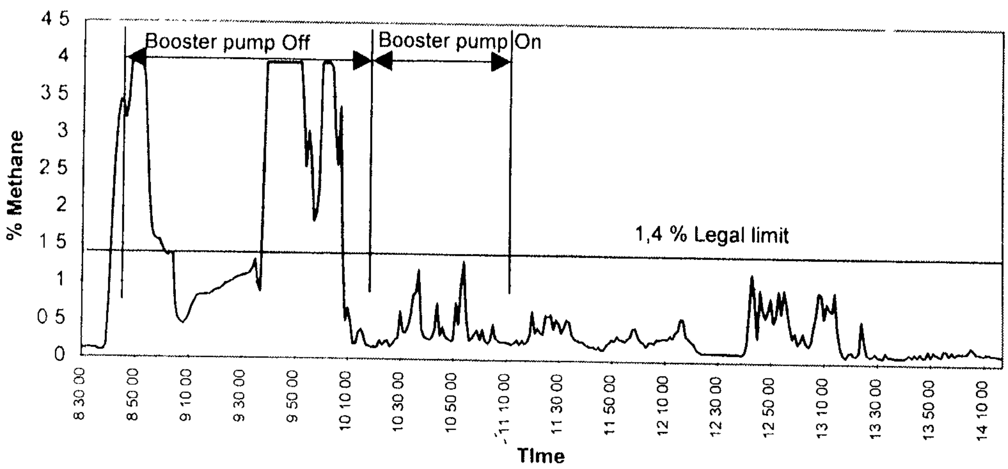

Figure 3.1.1: Influence of water spray system on methane concentration

In Figure 3.1.1 the influence on the methane levels by the operation of the booster pump, and as such the water spray system is shown. The correct installation of the pump resulted in a reduction in the methane levels measured, although normal production proceeded. Prior to this the methane sensor saturated at 4 % CH_4 per volume. The sweeping action of the directional spray system is severely hampered unless the design water pressure is adhere to.

3.1.2 Respirable dust concentration results

Table 3.1.2 shows the dust-concentration levels at the intake, operator and return for the sampling period. Five tests were attempted with the smaller scrubber connected to the integrated hood. The calculated average dust-concentration levels at the section intake (tests 1 to 5), operator and section return (tests 1, 3 and 4) were 1,587 mg/m^3, 6,082 mg/m^3 and 2,879 mg/m^3 respectively. Tests 2 and 5 were discarded as there was little cutting done during these tests. The average production during the use of the integrated hood system was 810 tons and the average sampling period for the three tests was 435 minutes. The SSAs for the integrated hood system at the intake, operator and return positions were 1,571 mg/m^3, 6,102 mg/m^3 and 2,874 mg/m^3 respectively.

Table 3.1.2

Average sample dust-concentration levels in mg/m^3 for the integrated hood system: smaller scrubber

Test #	**Sampler Position**			**CM Details**			
	Intake	**Operator**	**Return**	**Road No.**	**H or S**	**Cutting Box**	**Production (tons)**
1	1,195	5,741	3,349	2	H	3,4,10,9	815
2	1,313	1,194	1,117	3,4	H	-	13
3	0,993	7,189	2,255	3,4,1	H/S	1,2	900
4	2,650	5,317	3,033	6,3,4	S	3,4,5	715
5	1,786	2,958	1,855	3	H	13,14	90

Some of the identified shortcomings of the system were:

- Lower-than-required water flow rate
- Incorrect spray nozzles fitted
- Scrubber design volume flow too low for mining height.

The initial test results showed promise and a recommendation to increase the scrubber capacity (to increase the volume flow rate at the face) was made. To meet this objective, a scrubber with a bigger capacity was fitted.

3.2 Test results: larger scrubber

After the initial results and visual observations had confirmed that there was a problem with regard to the ability of the system to achieve 5 mg/m^3, a scrubber with larger capacity (30 inches) was fitted. The results obtained with this system with respect to respirable dust concentrations and methane concentration levels are discussed in the next section.

3.2.1 Methane concentration results

During test 11, the methane-logging system became dislodged from its position and the CM flattened the system, resulting in irrepairable damage and subsequent failure to log the last five tests (tests 11 to 15). Table 3.2.1 summarizes the methane levels during the underground tests with the larger scrubber (tests 6 to 10).

Table 3.2.1

Methane concentrations: larger scrubber tests

Test #	Peak Value	Av. Value	Variance	Comments
6	1,85	0,26	0,111	1,4 % exceeded twice for brief periods
7	0,80	-0,24	0,370	Data could not be used
8	1,32	0,81	0,229	Low peaks observed, just-steady increase in CH_4 over shift
9	0,96	0,70	0,034	Low peaks observed, just-steady increase in CH_4 over shift
10	0,84	0,39	0,035	Low peaks observed, just-steady increase in CH_4 over shift

3.2.2 Respirable dust concentration results

The respirable dust-concentration results for the individual tests with the larger scrubber are shown in Table 3.2.2.

Table 3.2.2

Average sample dust-concentration levels in mg/m^3 for the integrated hood system: larger scrubber

Test #	Sampler Position			CM Details			
	Intake	Operator	Return	Road #	H or S	Cutting Box	Production (tons)
6	1,430	7,51	2,972	5	H	3,4	640
7	-	6,475	3,537	3	H	9,8,7	815
8	1,334	17,79	3,187	4,5,6	H, S	3,4,6,5	1 015
9	0,960	7,151	1,784	6	H	3,4,9,10	620
10	5,201*	5,902	3,208	3,4,2	H, S	3,4,1,2,3	1 090
11	0,853	2,034	1,086	-	-	-	Nil
12	1,051	1,272	1,193	5,6	S	1	125
13	0,904	2,697	1,369	1,2	S	10,9	350
14	1,819	9,016	3,261	2	H	3,4,10,9	725
15	0,814	3,087	2,429	5	H	3,4	475

*Instrument at feeder breaker.

The SSAs for the tests were:

Intake: 1,054 mg/m^3

Operator: 7,845 mg/m^3

Return: 2,599 mg/m^3

During tests 6 and 7, the water sprays kept on blocking up resulting in a water flow rate that was lower than required. During test 8, a particularly poor water flow rate was recorded, resulting in poor dust conditions.

The intake SSA was calculated with tests 7 and 10 excluded. The operator and return averages were both calculated with tests 11 and 12 excluded.

If test 8 is discarded because of the exceptionally low water flow rate, the operator SSA concentration is 6,286 mg/m^3.

The increase of 1,116 mg/m^3 in the return-air dust concentration can be attributed to mining operations in the section. The average increase (intake to return) in tests 11 and 12 was 0,188 mg/m^3 whilst very little production occurred. The dust thus added to the return air amounts to 0,928 mg/m^3. This is an indication of the dust-capture efficiency of the system.

The sensitivity of the dust-suppression system to water flow rates and pressures was clearly demonstrated during this set of tests. This relationship is shown in Figure 3.2.2a. The concentration levels at the intake, operator and return positions for the tests on the integrated hood system are shown in Figure 3.2.2b. In the tests, water flow rates above approximately 100 ℓ/min resulted in dust concentrations below 5 mg/m^3. In test 8, very low water flow rates resulted in terribly dusty conditions (17,70 mg/m^3).

The relationship between the dust-concentration level and the production for the integrated hood system was plotted and is shown in Figure 3.2.2c. The plots for the intake and the return sampler position show no conclusive relationships. A steady increase in the dust concentration level at the operator's position is observed as production increased.

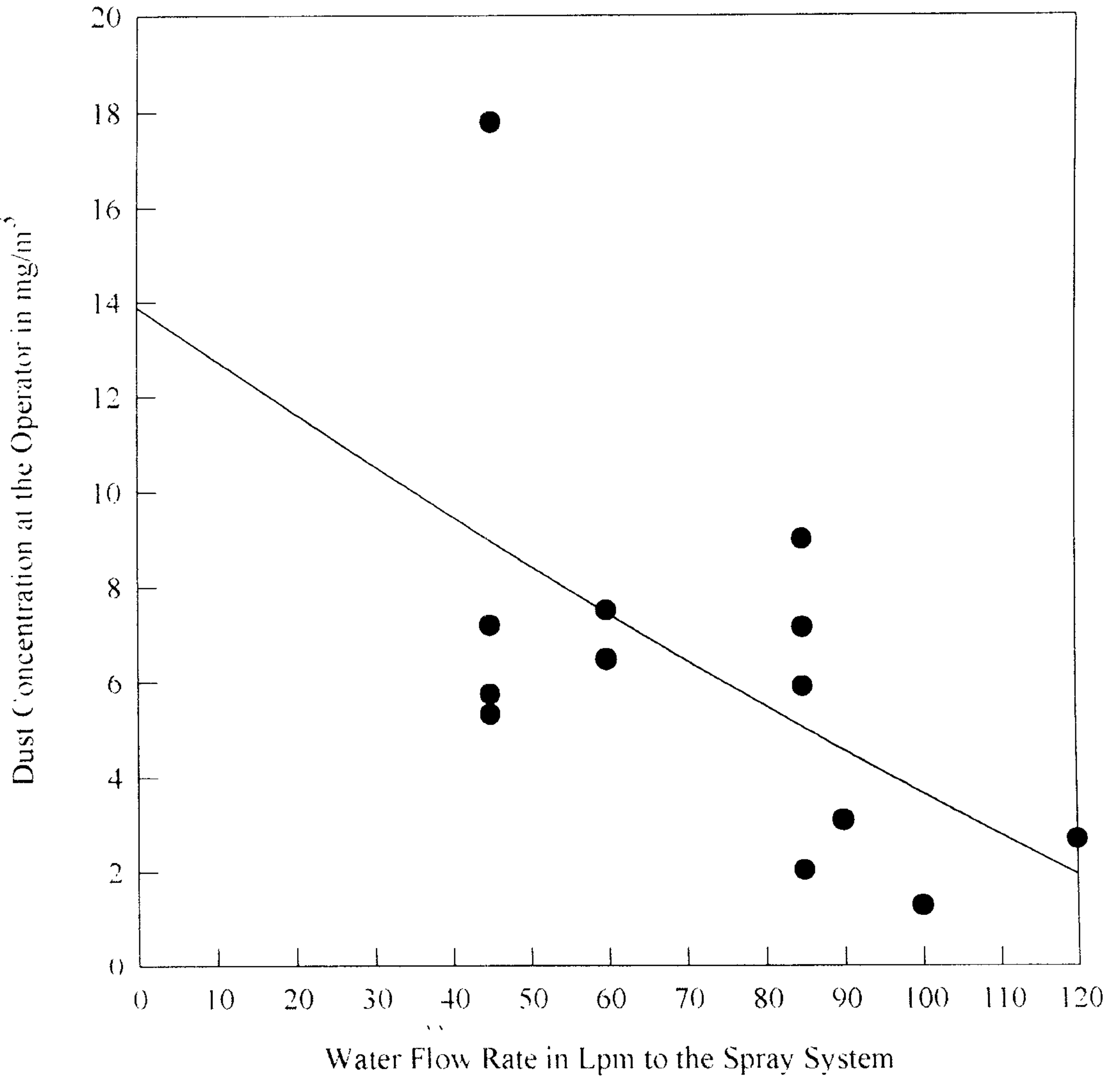

Figure 3.2.2a: Relationship between dust concentration and water flow rate

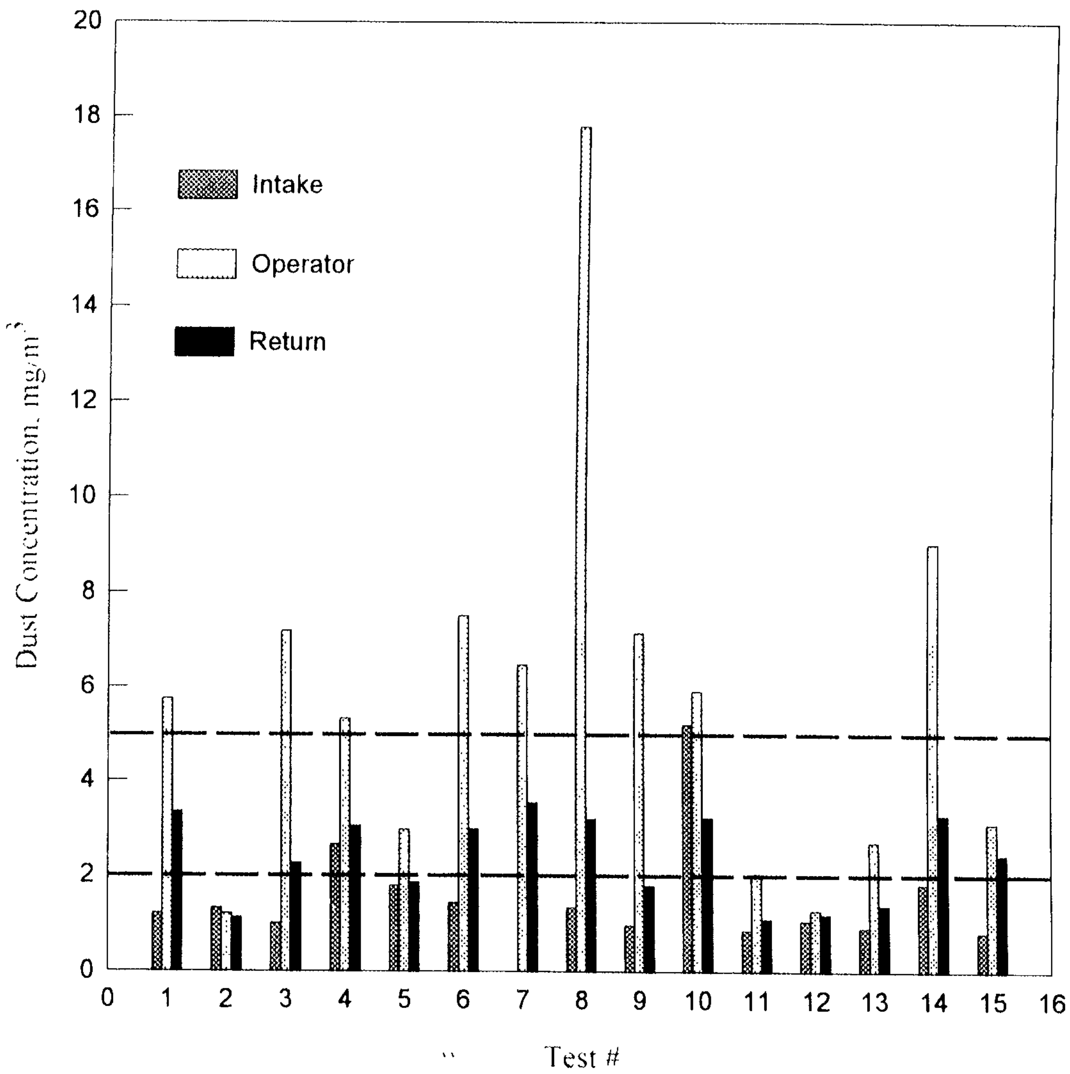

Figure 3.2.2b: Dust concentration levels for the integrated hood system

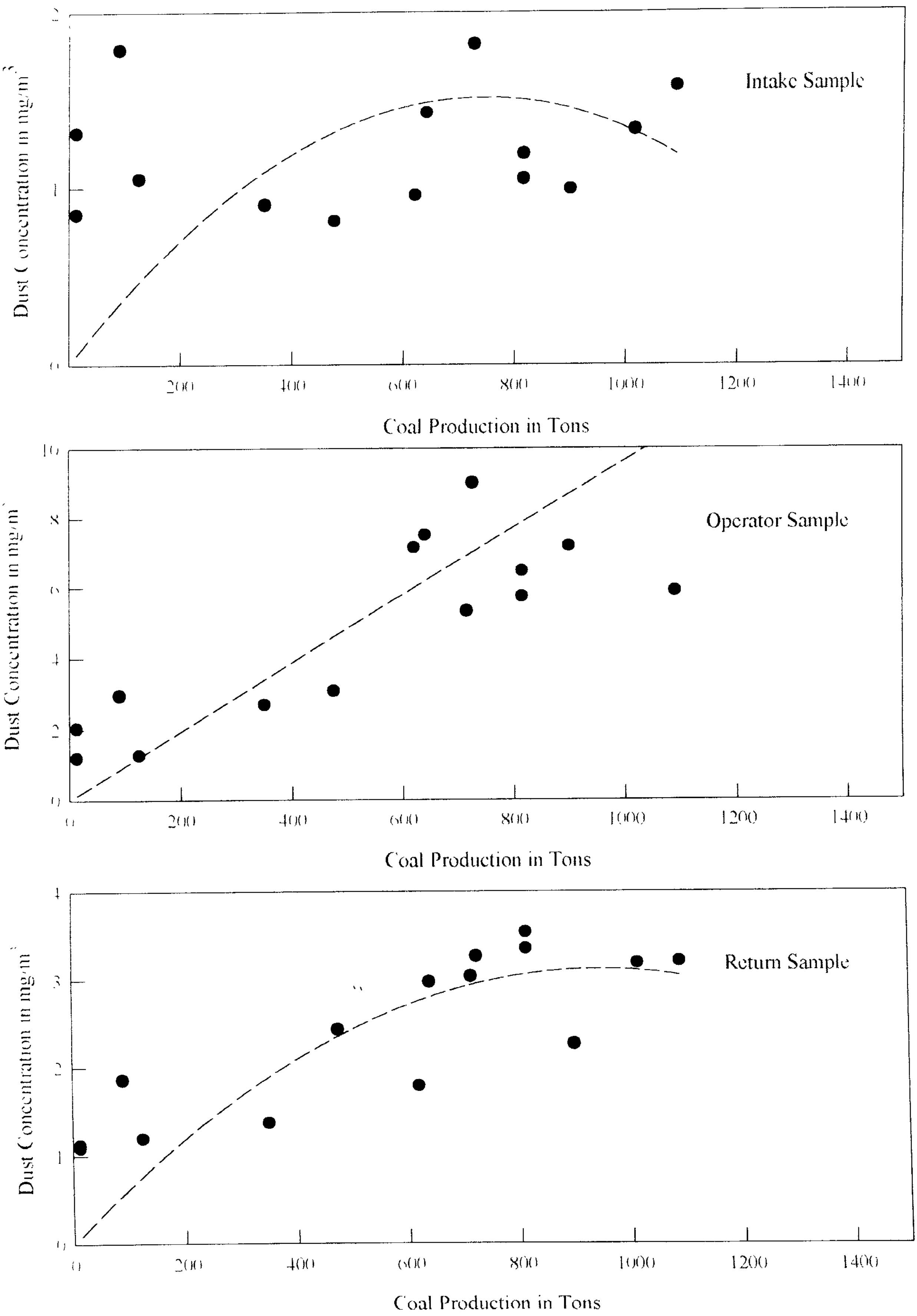

Figure 3.2.2c: Relationship between dust concentration levels and coal production

4 Conclusions

Both the integrated hood systems as evaluated failed to comply with the 5 mg/m^3 directive.

The smaller scrubber failed due to the following reasons:

- Lower-than-required airflow rate through the scrubber
- Problems encountered with water flow to the machine.

The larger scrubber failed primarily because of the water flow rates being low.

The tests showed the interdependence of all the components of the dust-suppression strategy, although all the individual systems, except the watersystem, complied with recommendations, i.e.

- cutting sequence was correct
- jet fan induction system worked correctly
- correctly designed water spray system and nozzles were used.

Another major problem was the maintenance of the hood system. The hood blocked up readily, resulting in poor airflow rates underneath the boom.

5 Recommendations

The following recommendations will assist in attaining the desired results:

- maintenance of machine-mounted systems
- adherence to the design and operational specifications of dust-suppression systems
- adherence to correct cutting sequences
- ensuring adequate section ventilation.

The important practices in the order of importance to achieve the regulatory requirements are:

a) Maintenance of machine systems and continuous supply of ventilation columns, water sprays, fan cables and pick sleeves.

b) System design and adherence to design specifications: water sprays with 1,6 mm inlet and 2,0 mm outlet. Water flow rate is 3,5 ℓ/min at a single nozzle outlet, at a pressure of 2 000 kPa. The water spray configuration developed during these tests, with critical emphasis on its three-dimensional position on the machine.

c) Flow rate (more than 100 ℓ/min) and pressure (between 1 500 and 2 000 kPa) measured at the dust-suppression system

d) Section ventilation requirement based on a LTR velocity of 1,0 m/s.

e) Auxiliary ventilation position, operation and control: column outlet should be positioned on the floor, not closer than 15 m from the face.

f) Use of the correct cutting sequence.

g) Awareness of section personnel through training.

6 References

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"Mine Health and Safety Act", 1996.

"South African Department of Minerals and Energy Directive," 1997.

APPENDIX

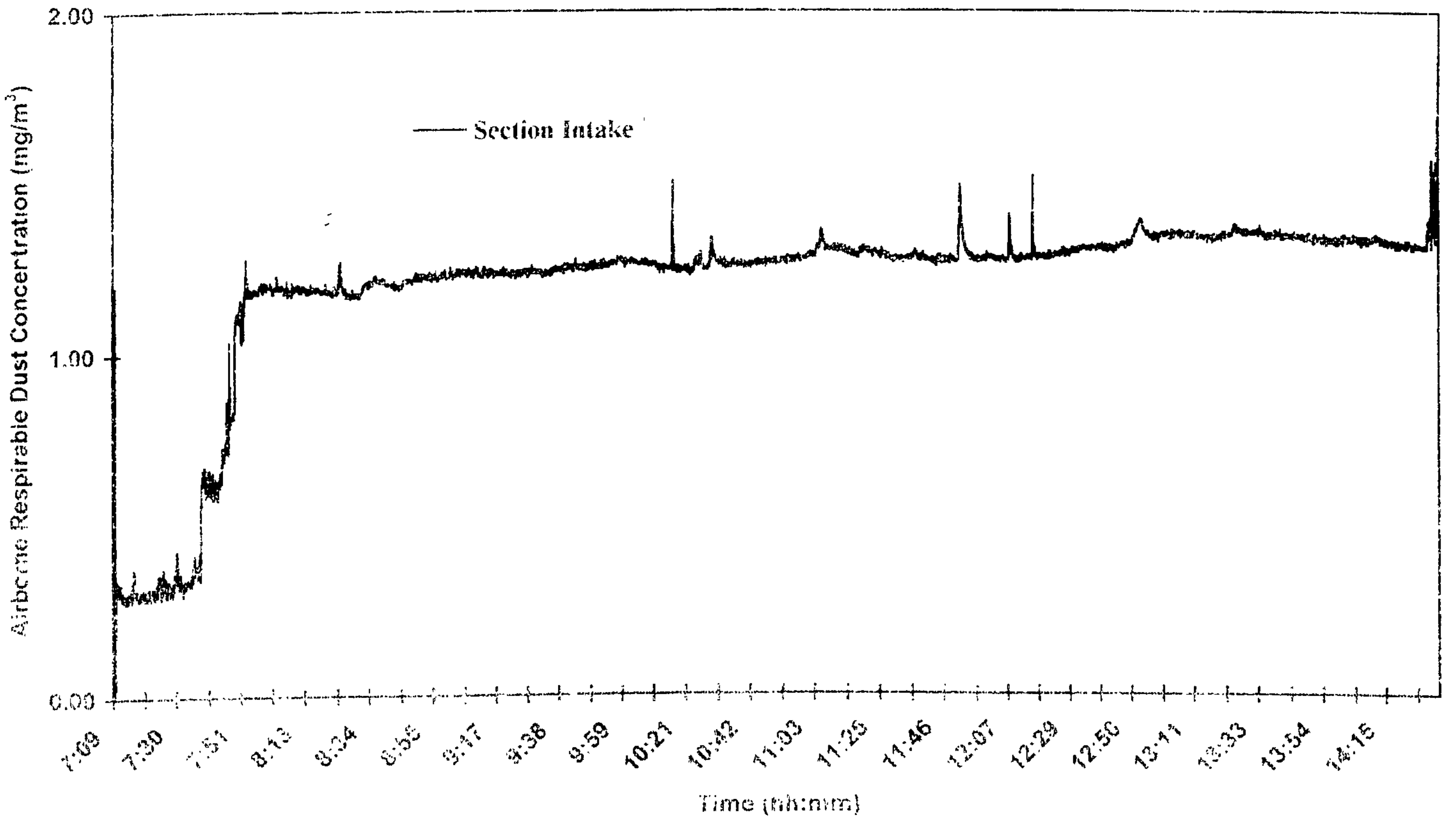

Figure 1.1: ARD concentration profile recorded by Hund at the Section Intake for Test 1

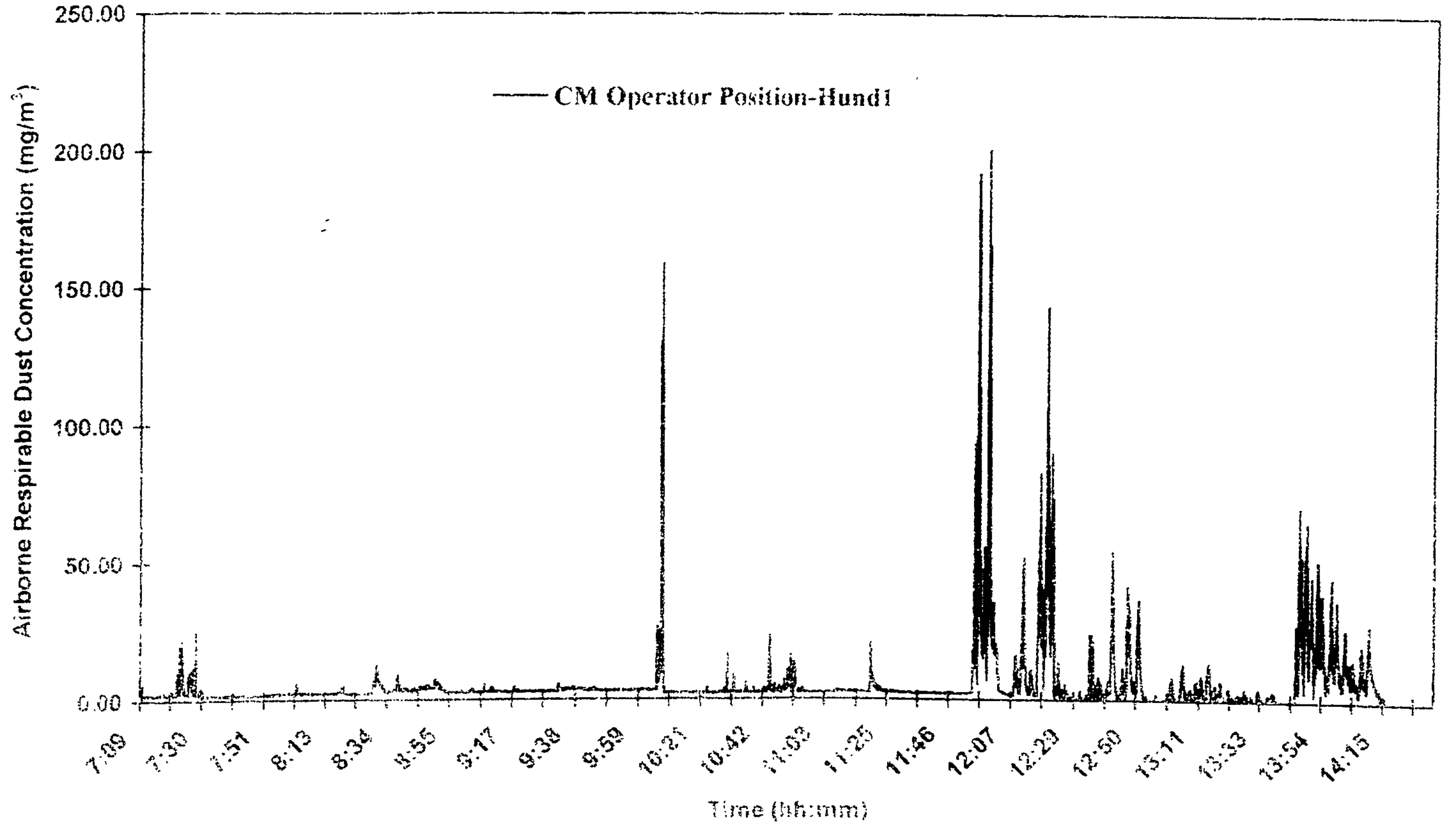

Figure 1.2: ARD concentration profile recorded by Hund-1 at the CM Operator Position for Test 1

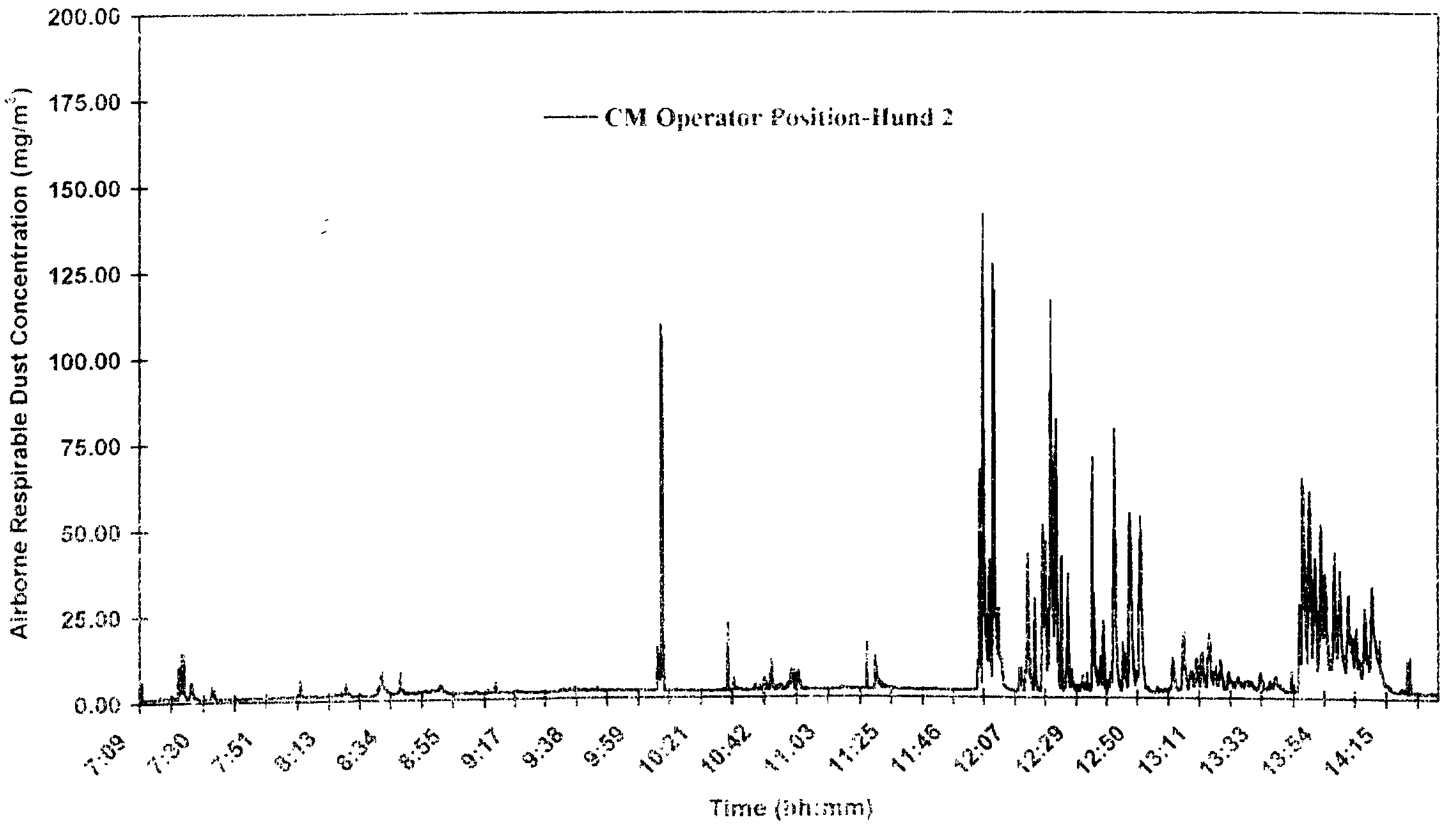

Figure 1.3: ARD concentration profile recorded by Hund-2 at the CM Operator Position for Test 1

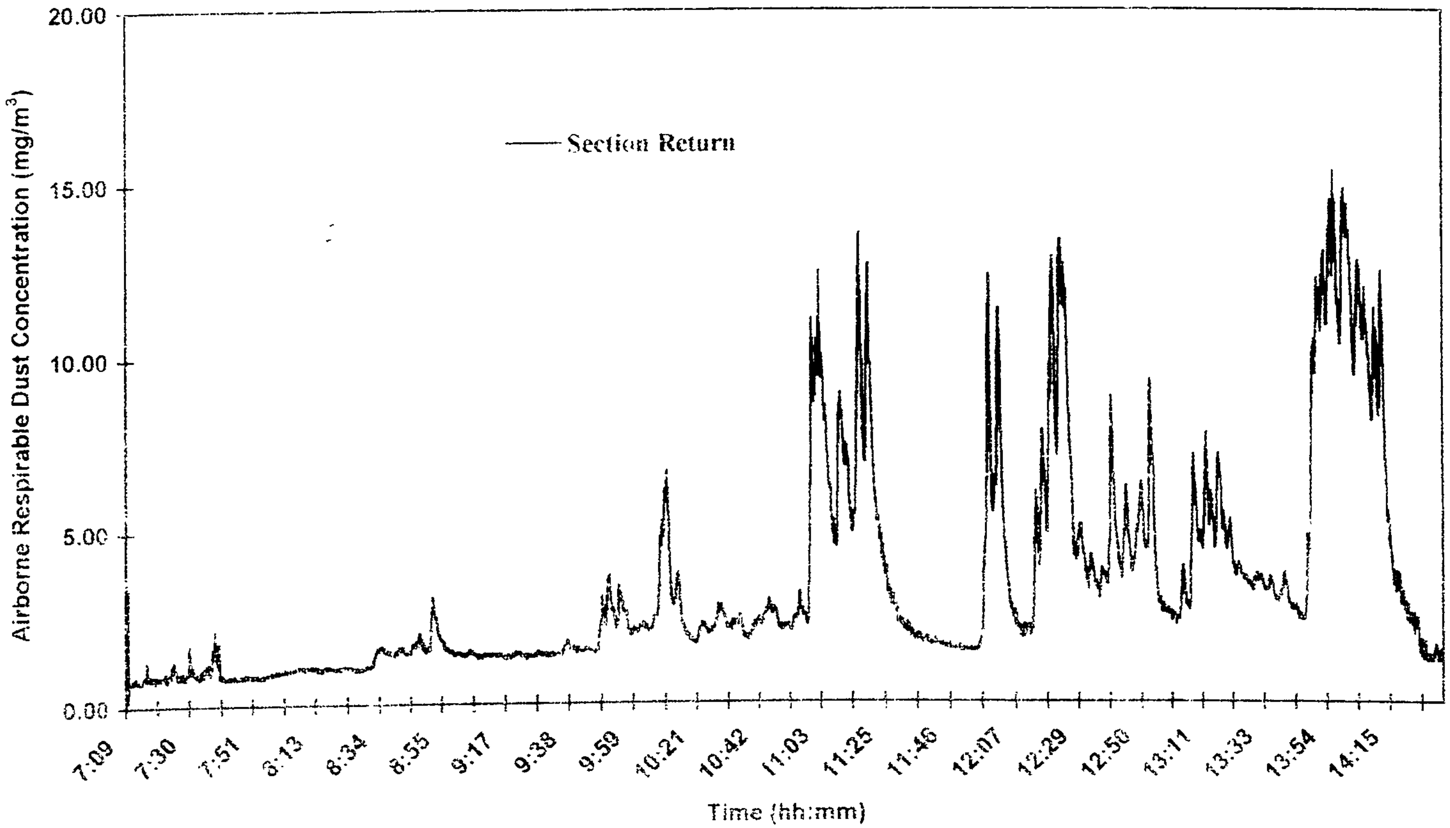

Figure 1.4: ARD concentration profile recorded by Hund at the section return for test 1

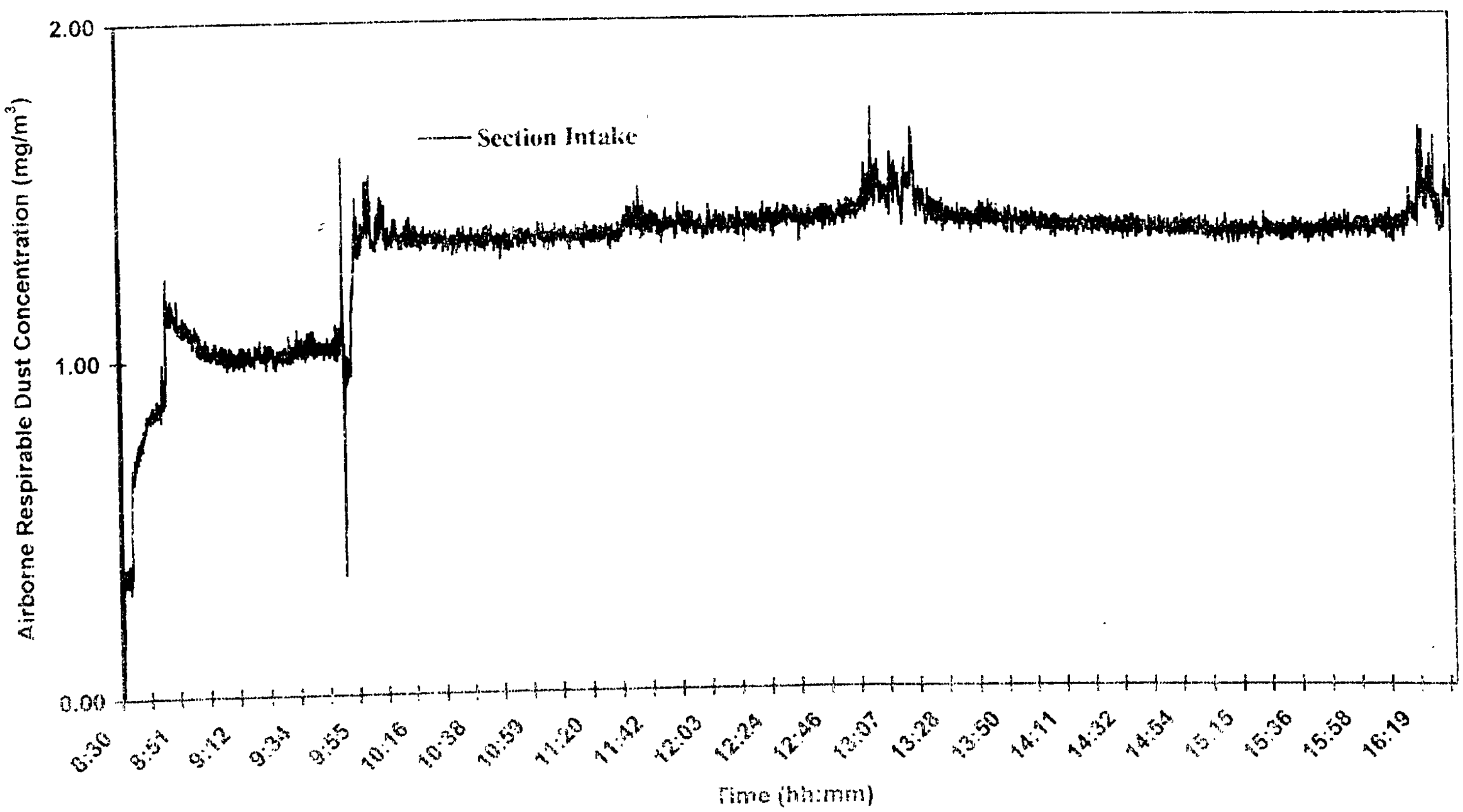

Figure 2.1: ARD concentration profile recorded by Hund at the section intake for test 2

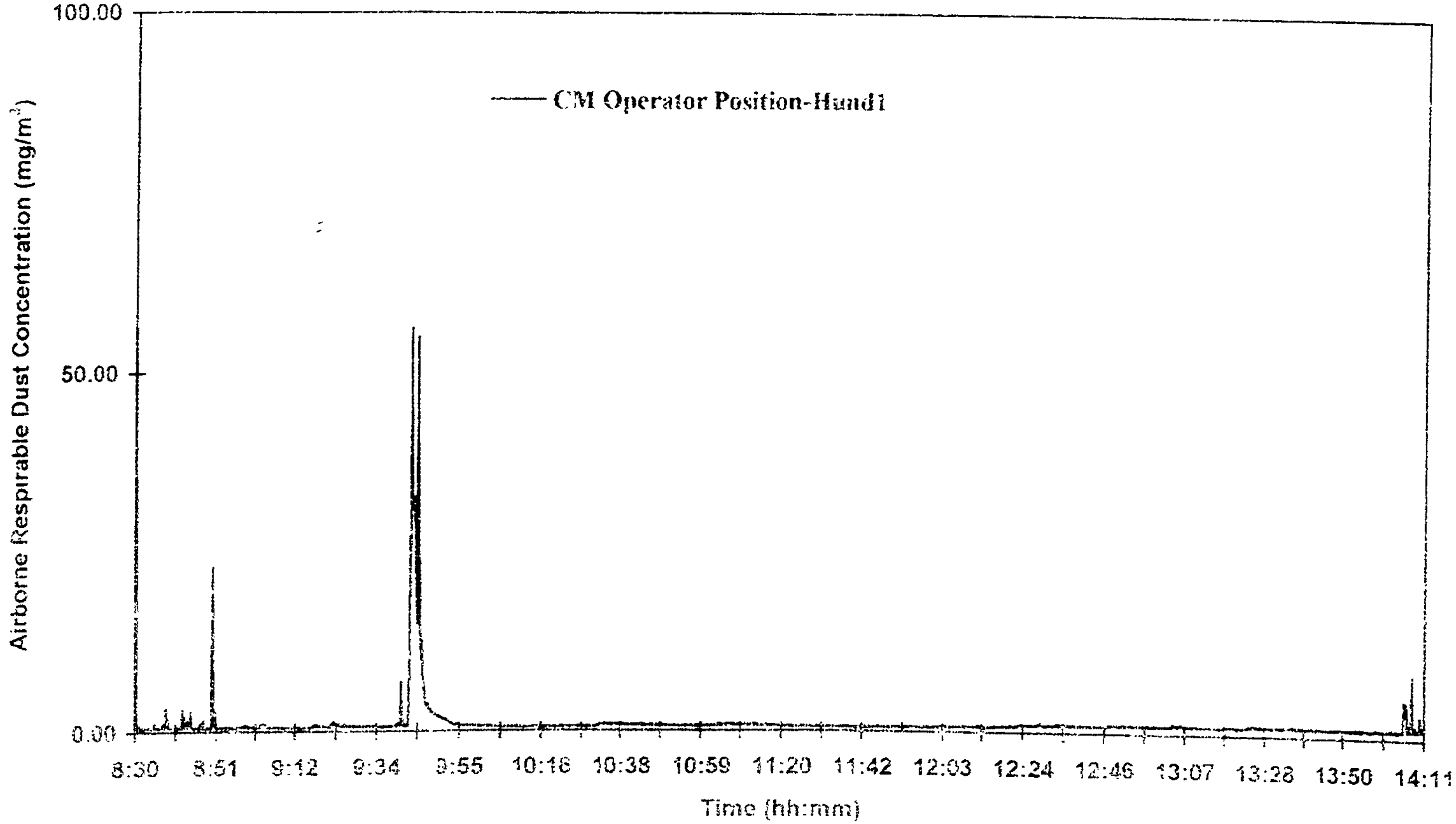

Figure 2.2: ARD concentration profile recorded by Hund-1 at the CM operator position for test 2

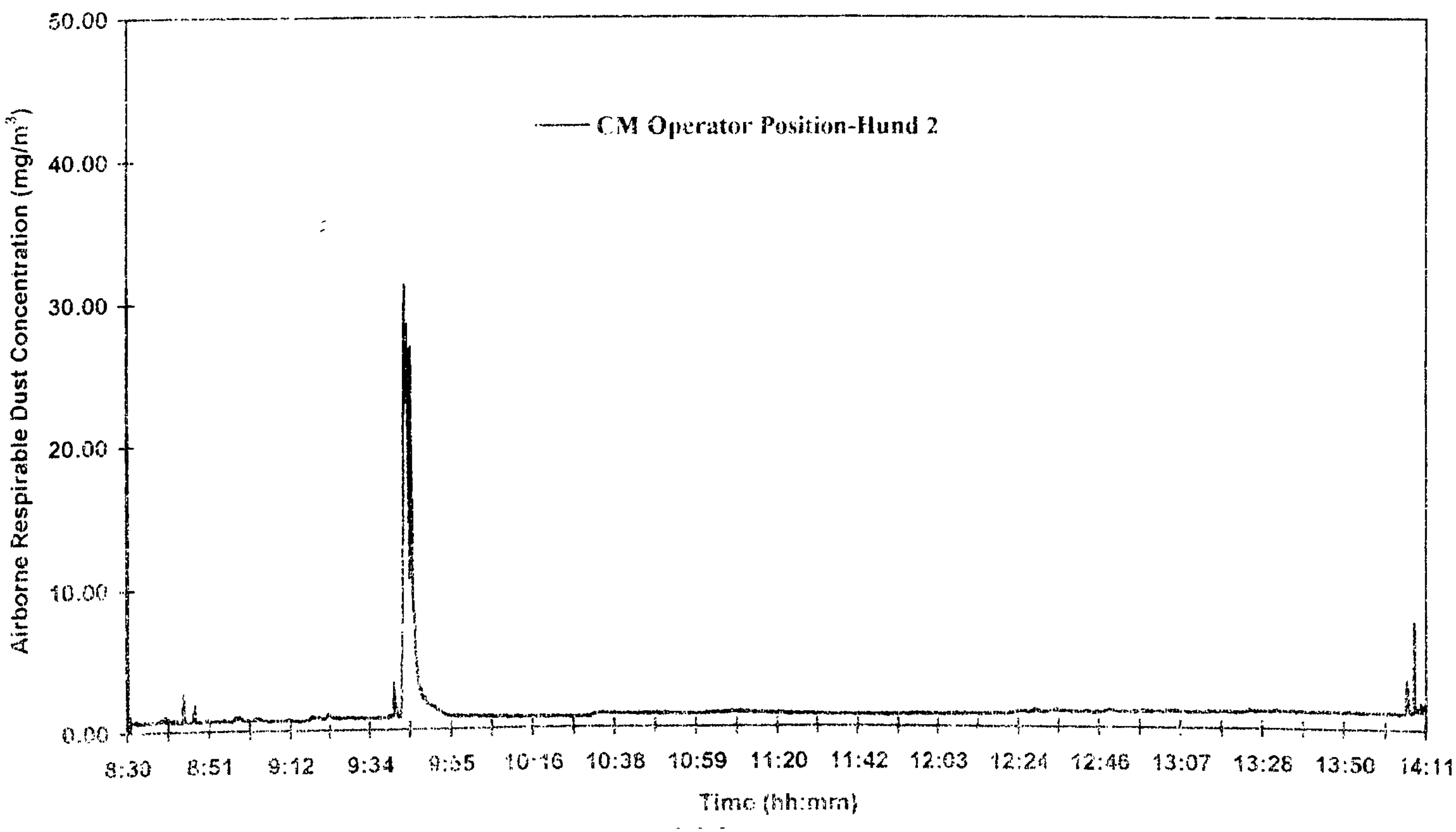

Figure 2.3: ARD concentration profile recorded by Hund-2 at the CM operator position for test 2

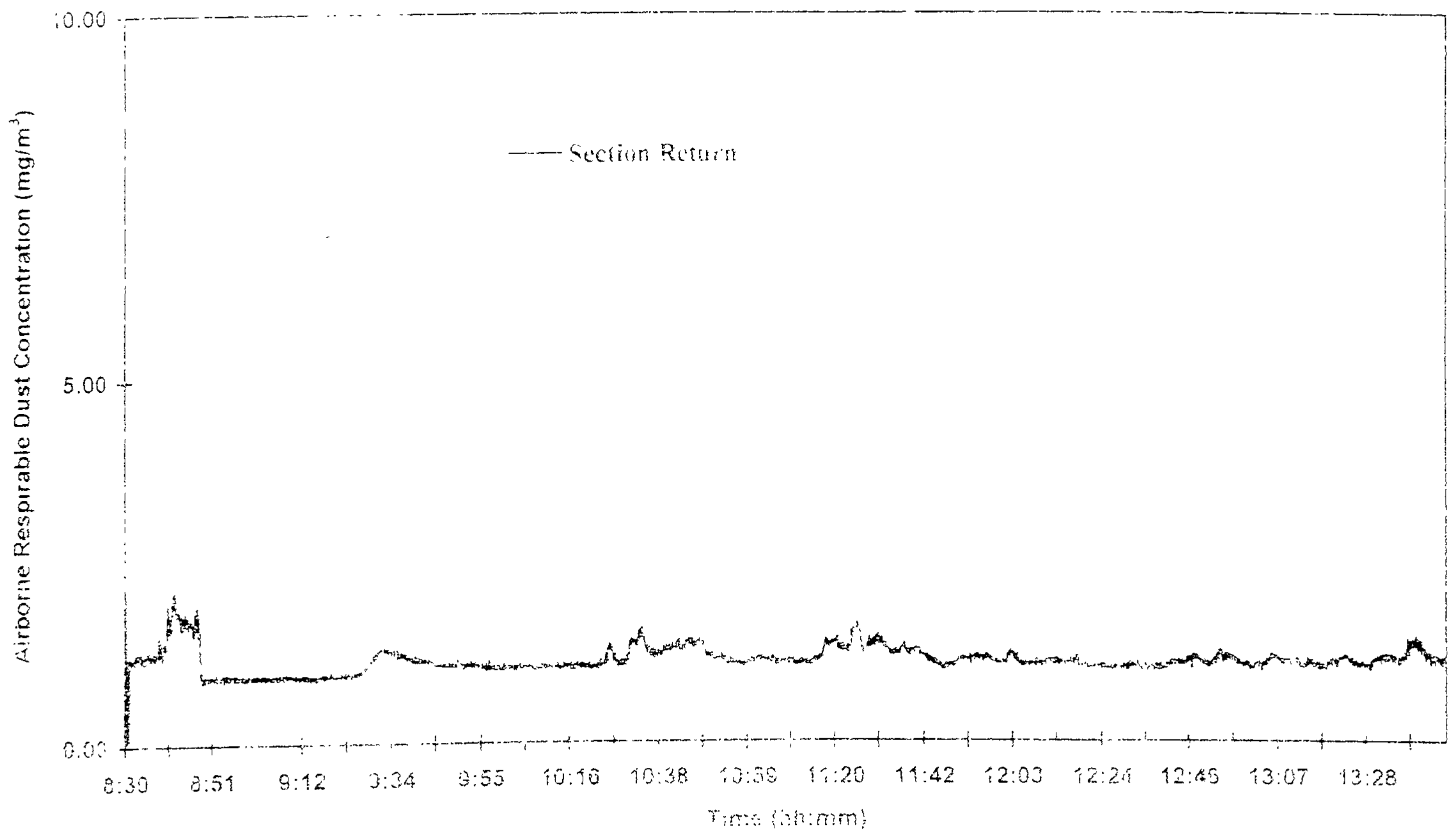

Figure 2.4: ARD concentration profile recorded by Hund at the section return for test 2

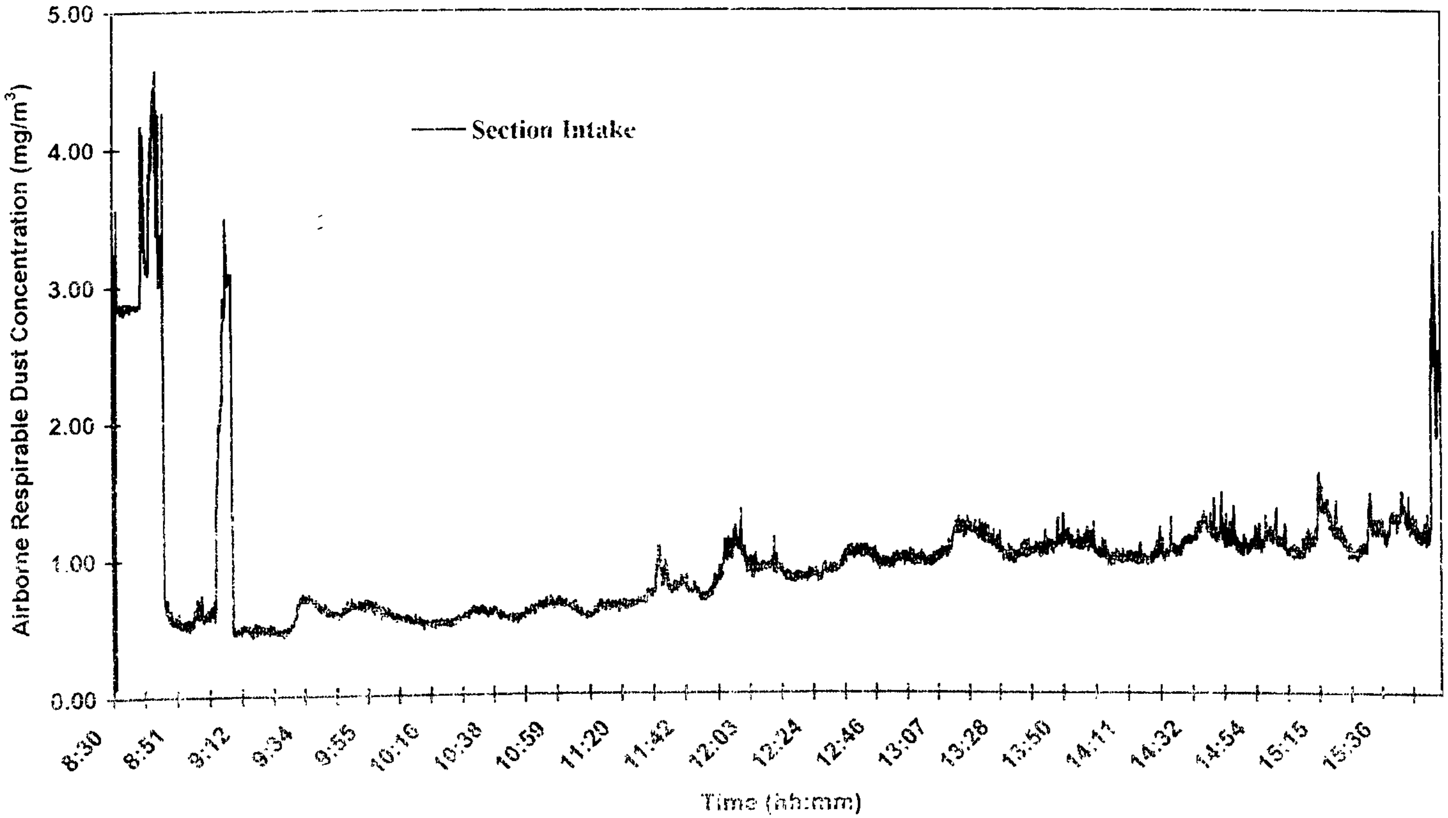

Figure 3.1. ARD concentration profile recorded by Hund at the section intake for test 3

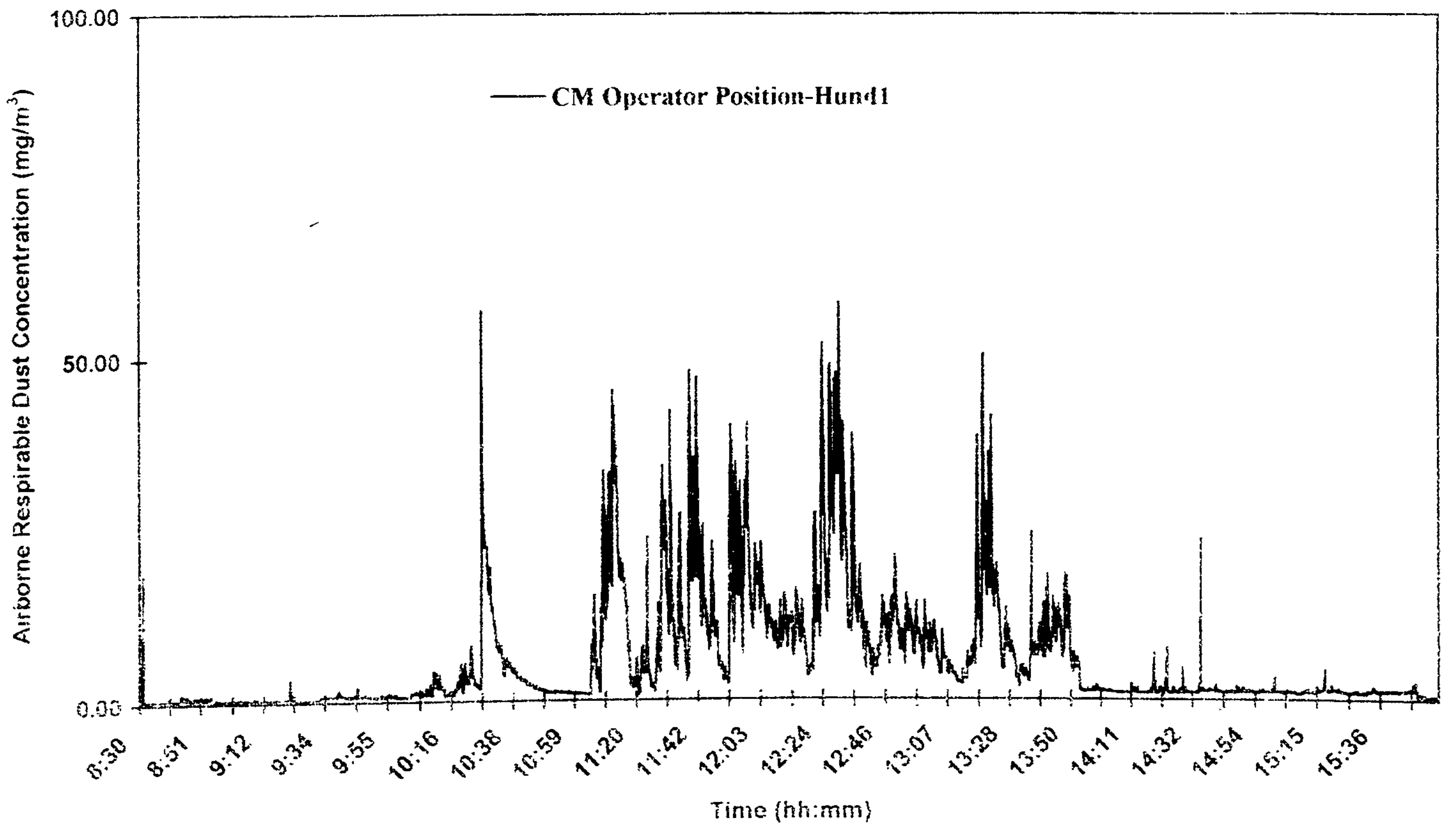

Figure 3.2: ARD concentration profile recorded by Hund-1 at the CM operator position for test 3

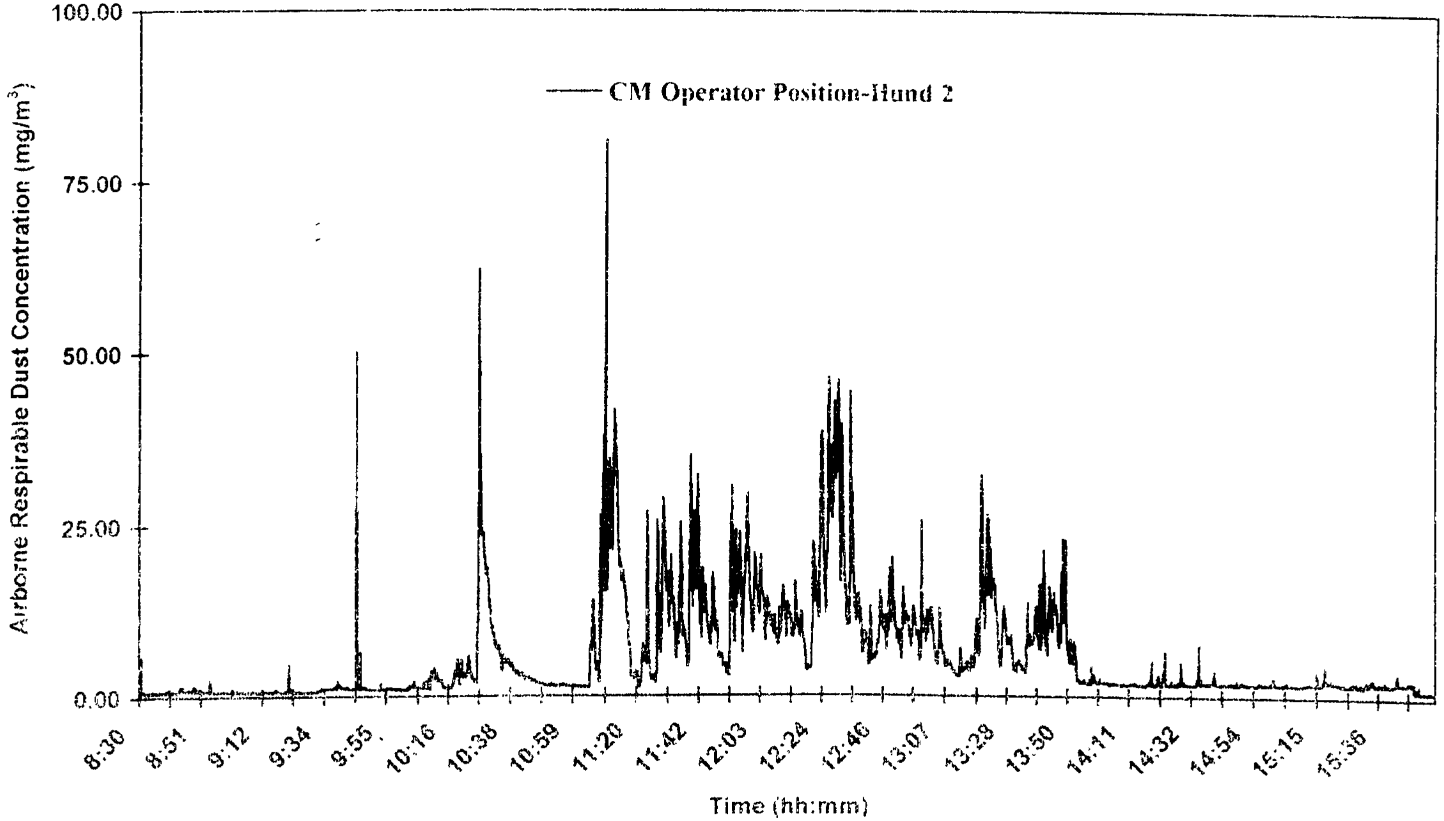

Figure 3.3: ARD concentration profile recorded by Hund-2 at the CM operator position for test 3

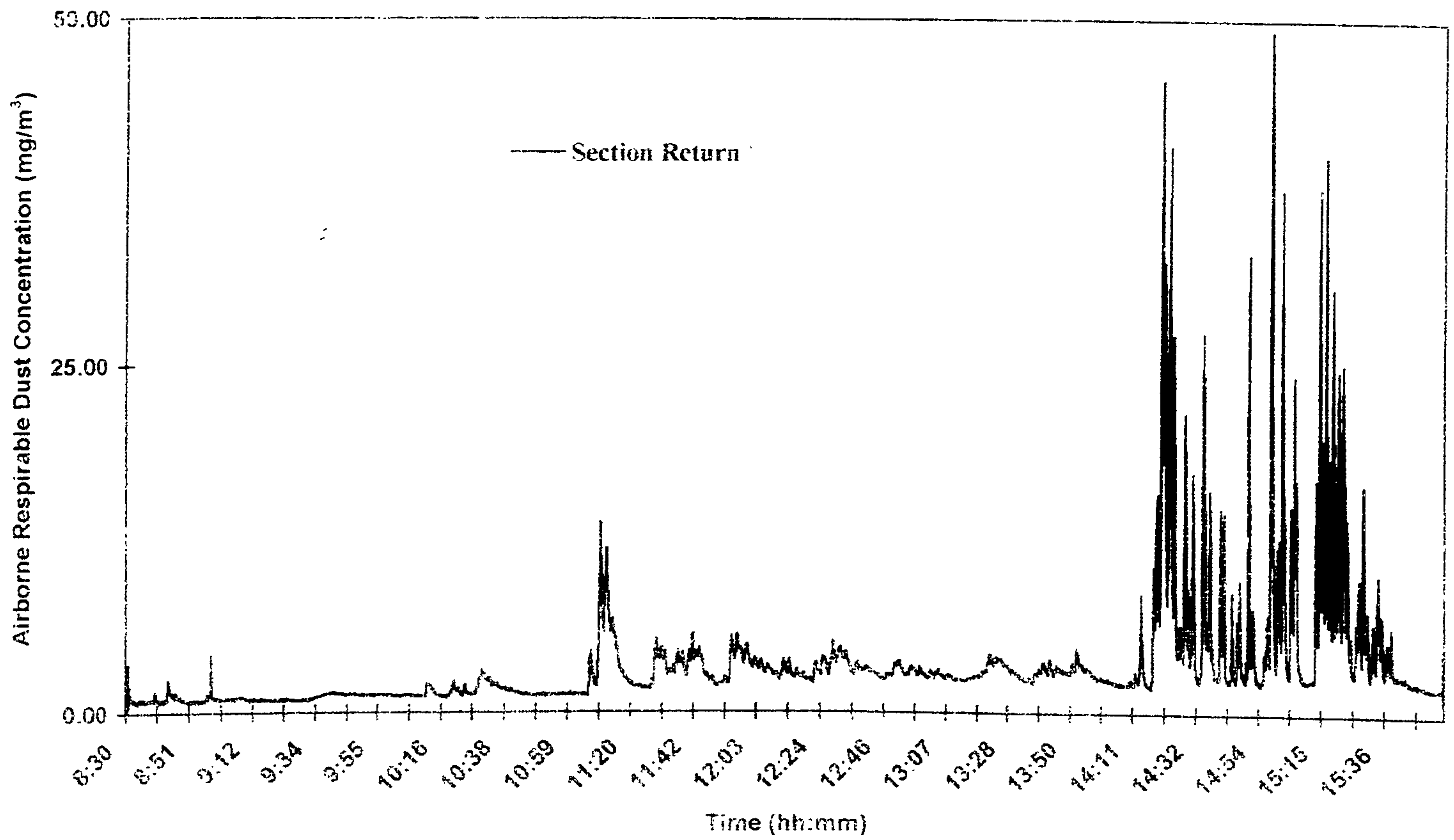

Figure 3.4: ARD concentration profile recorded by Hund at the section return for test 3

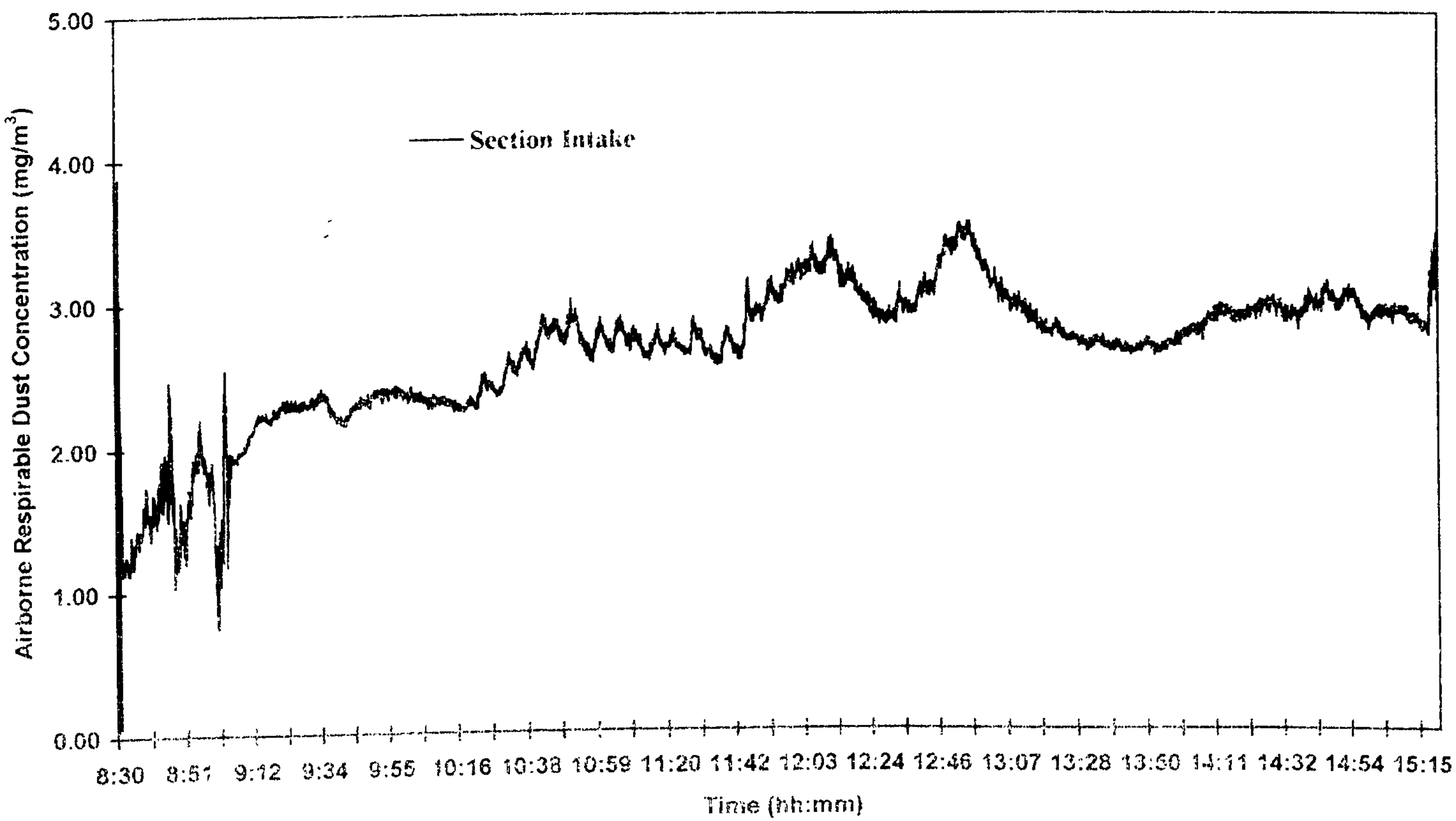

Figure 4.1: ARD concentration profile recorded by Hund at the section intake for test 4

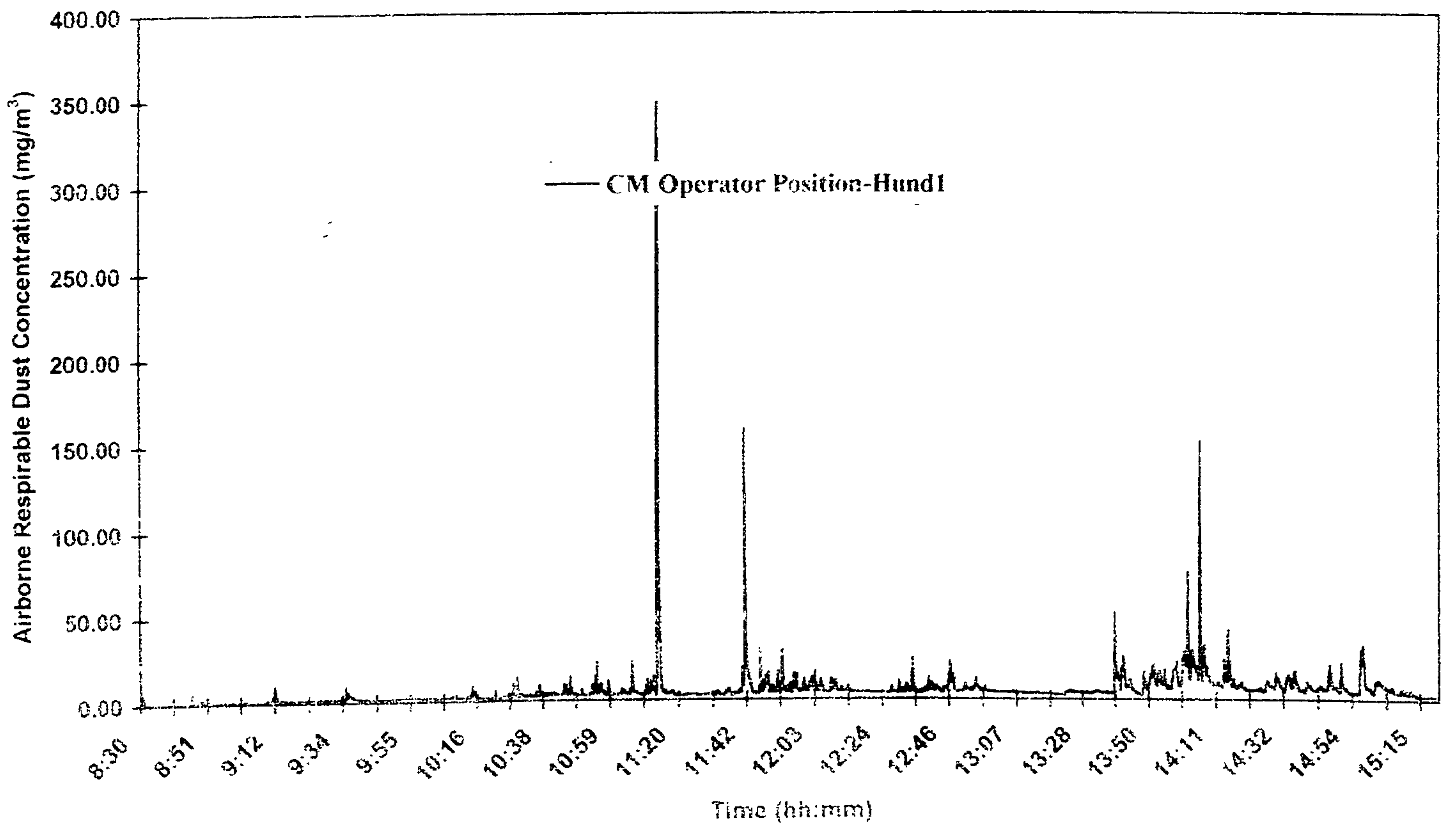

Figure 4.2: ARD concentration profile recorded by Hund-1 at the CM operator position for test 4

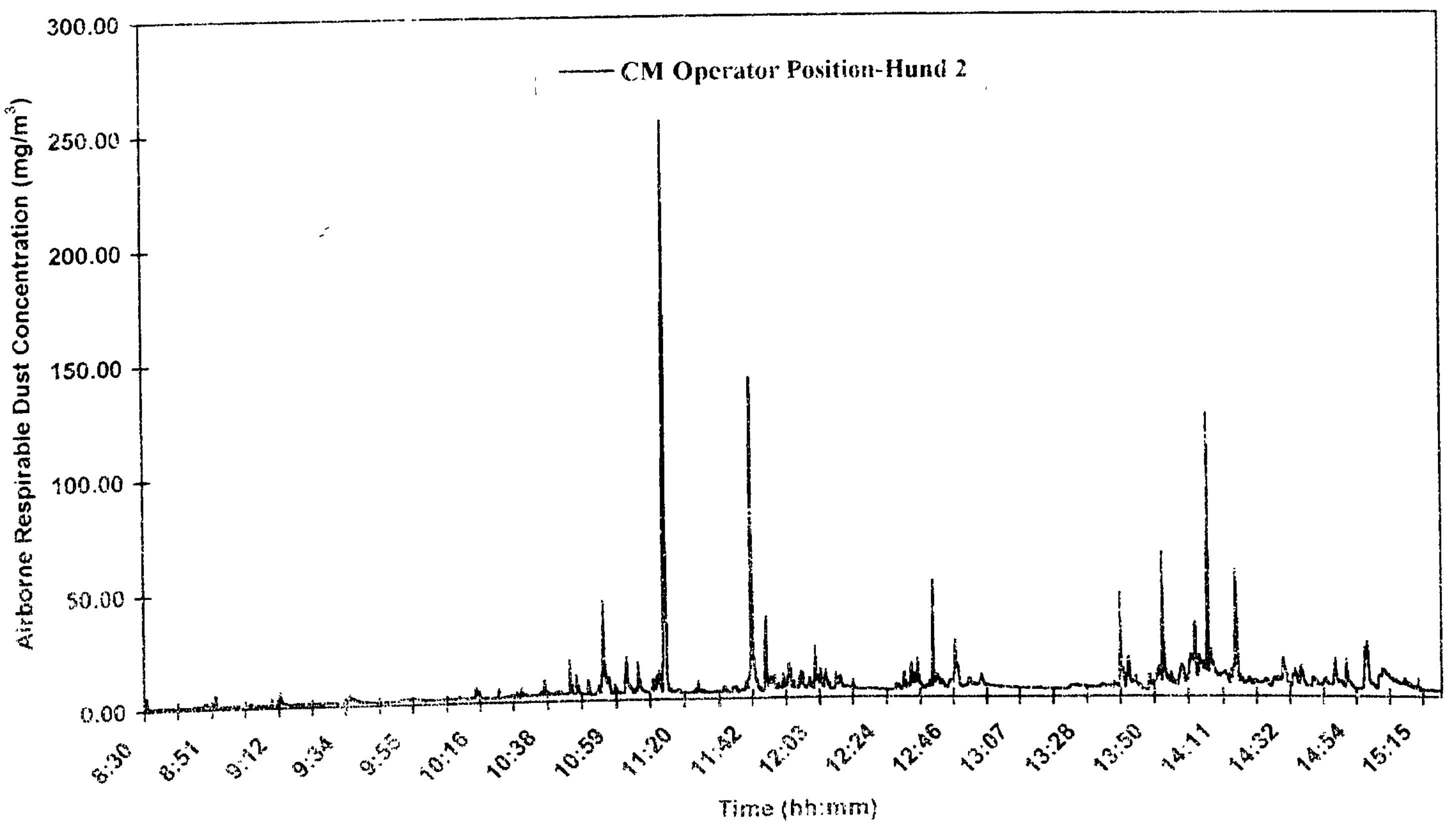

Figure 4.3: ARD concentration profile recorded by Hund-2 at the CM operator position for test 4

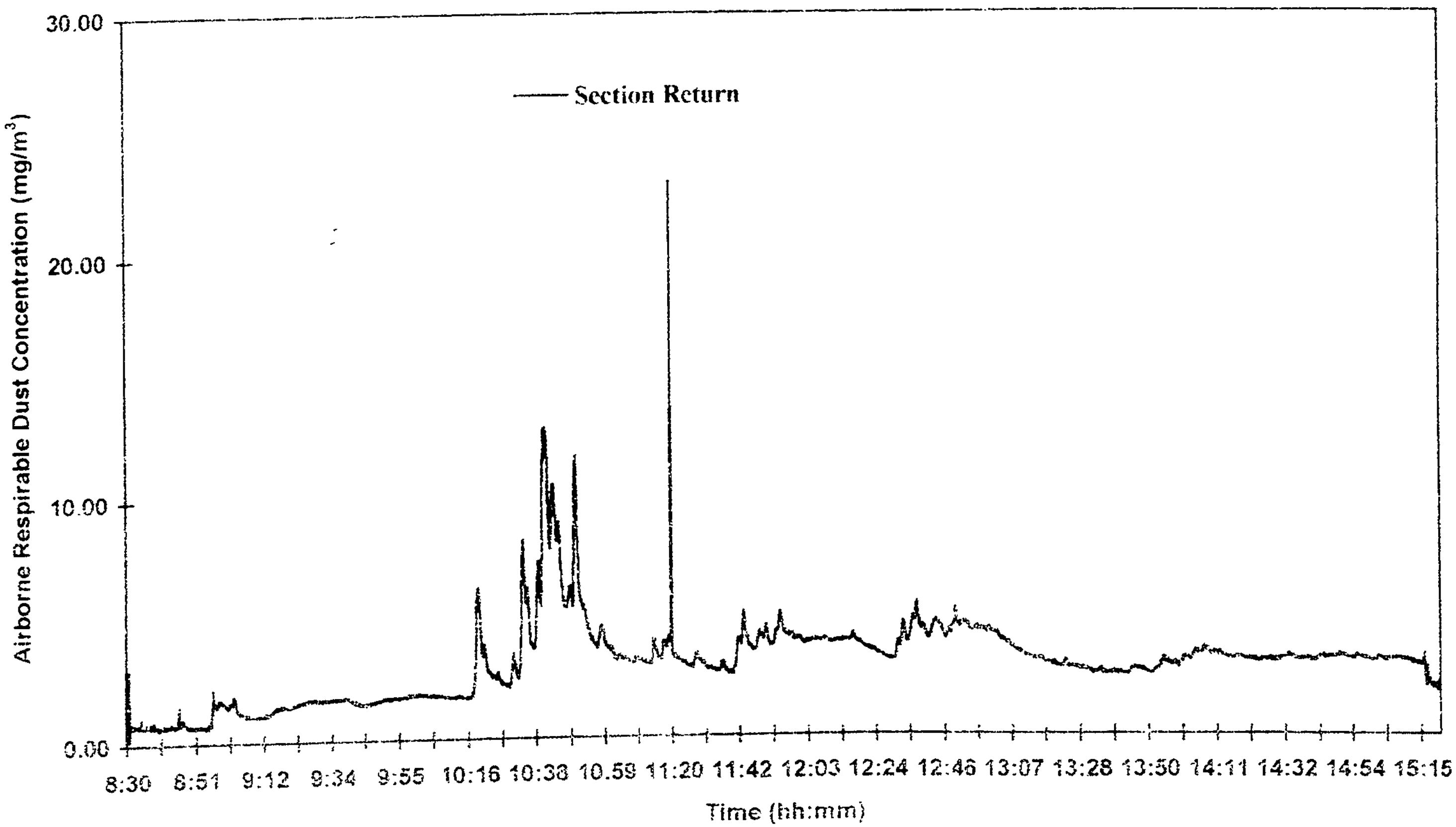

Figure 4.4: ARD concentration profile recorded by Hund at the section return for test 4

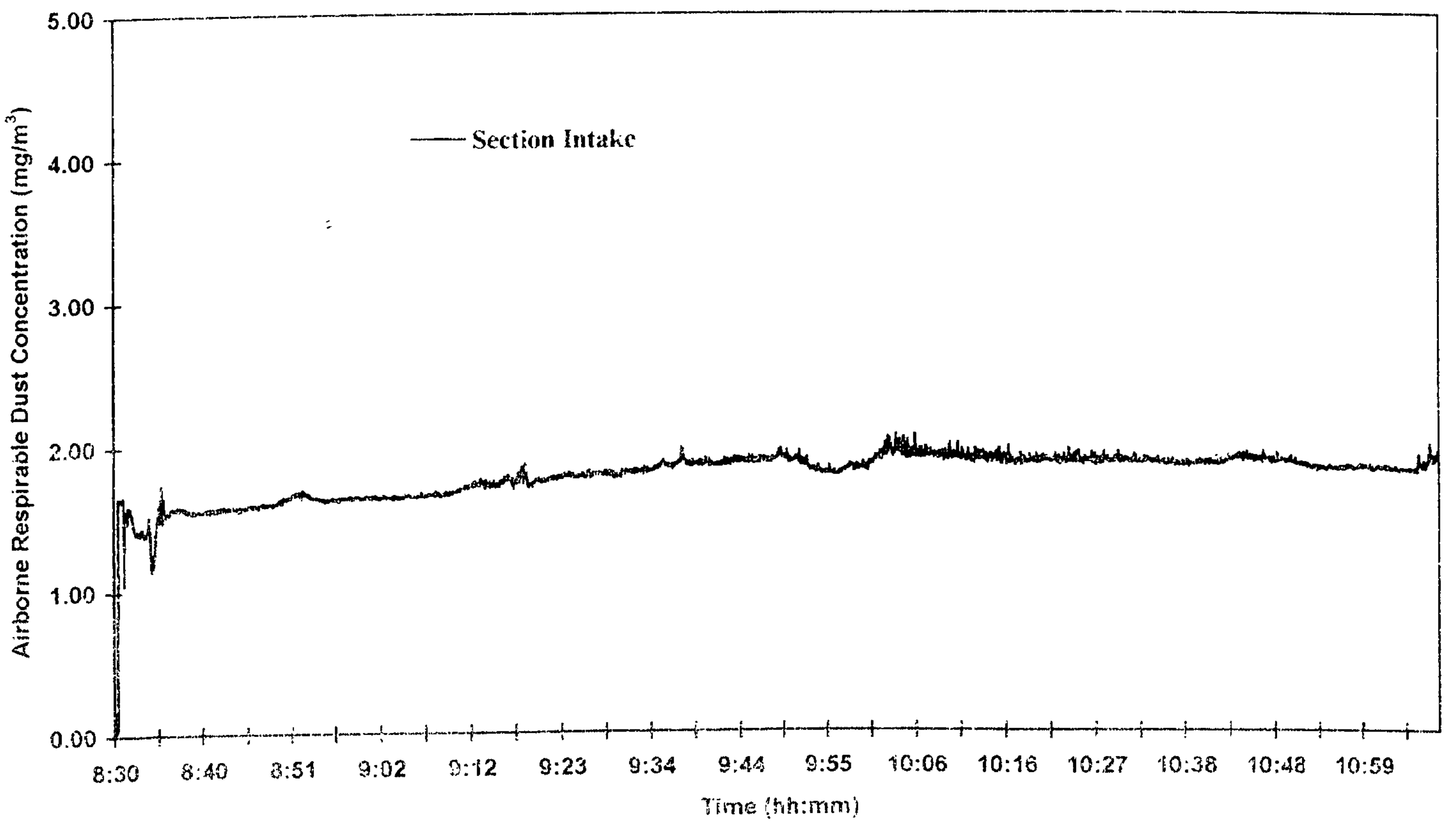

Figure 5.1: Typical ARD concentration profile recorded by Hund at the section intake for test 5

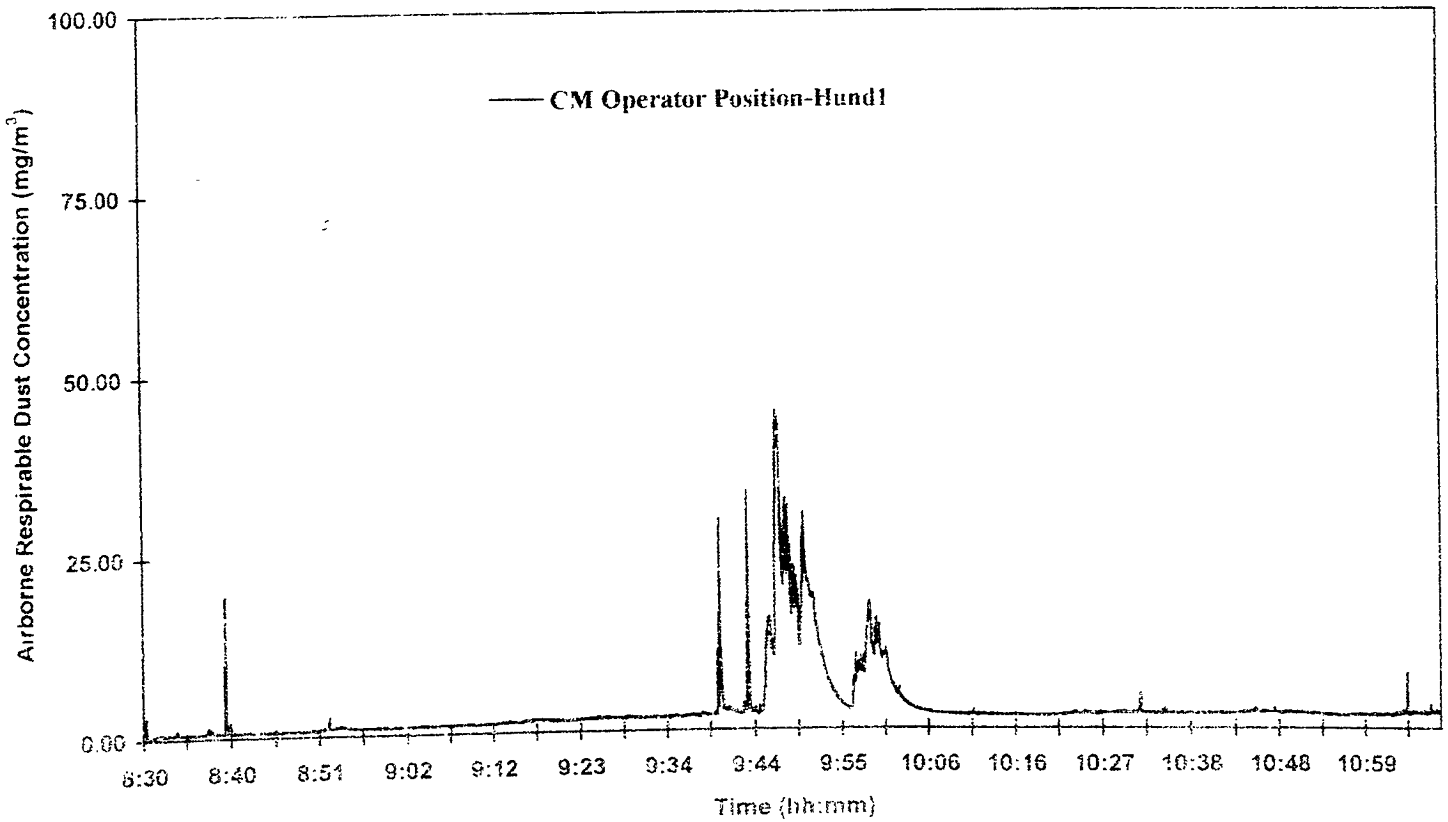

Figure 5.2: Typical ARD concentration profile recorded by Hund-1 at the CM operator position for test 5

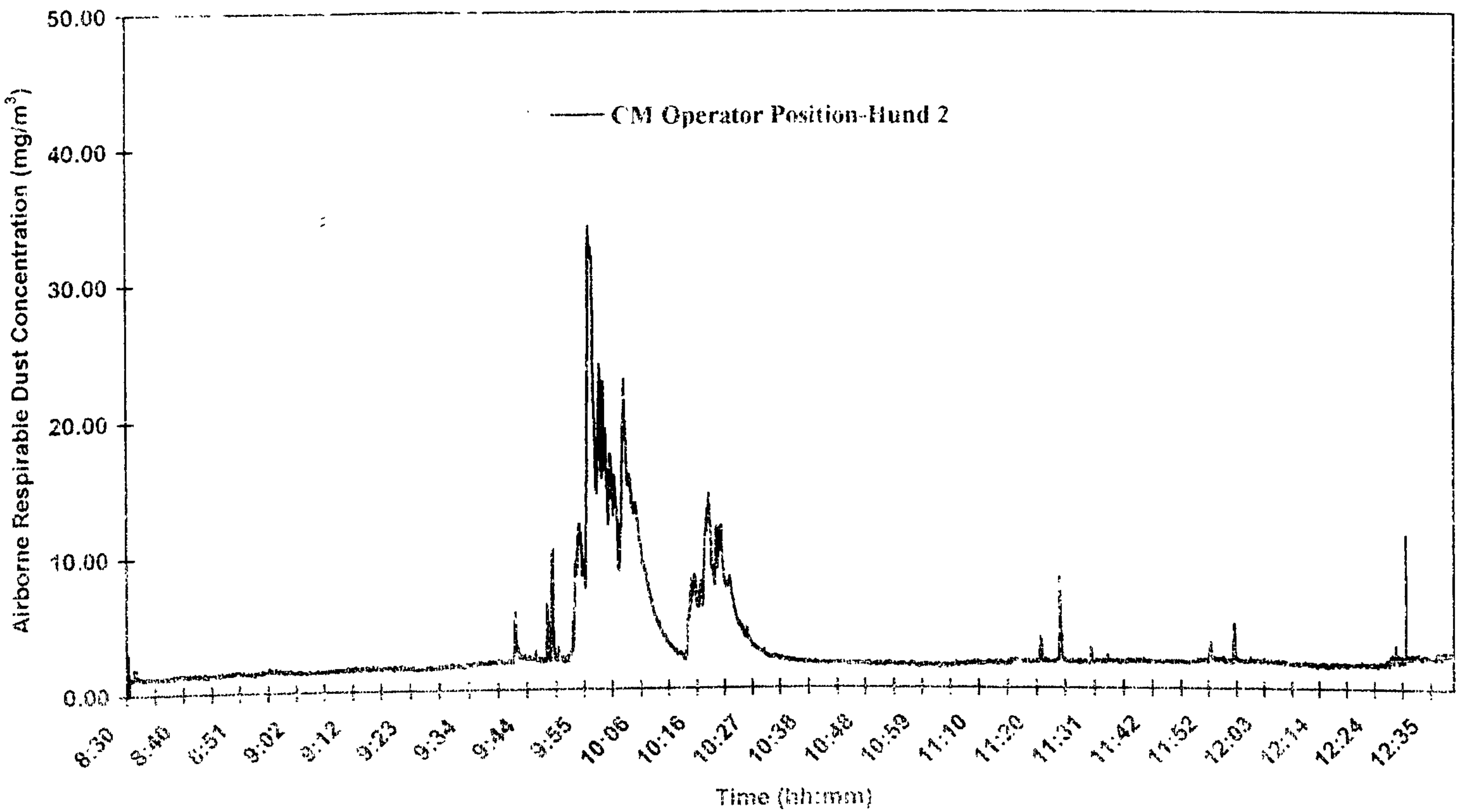

Figure 5.3: Typical ARD concentration profile recorded by Hund-2 at the CM operator position for test 5

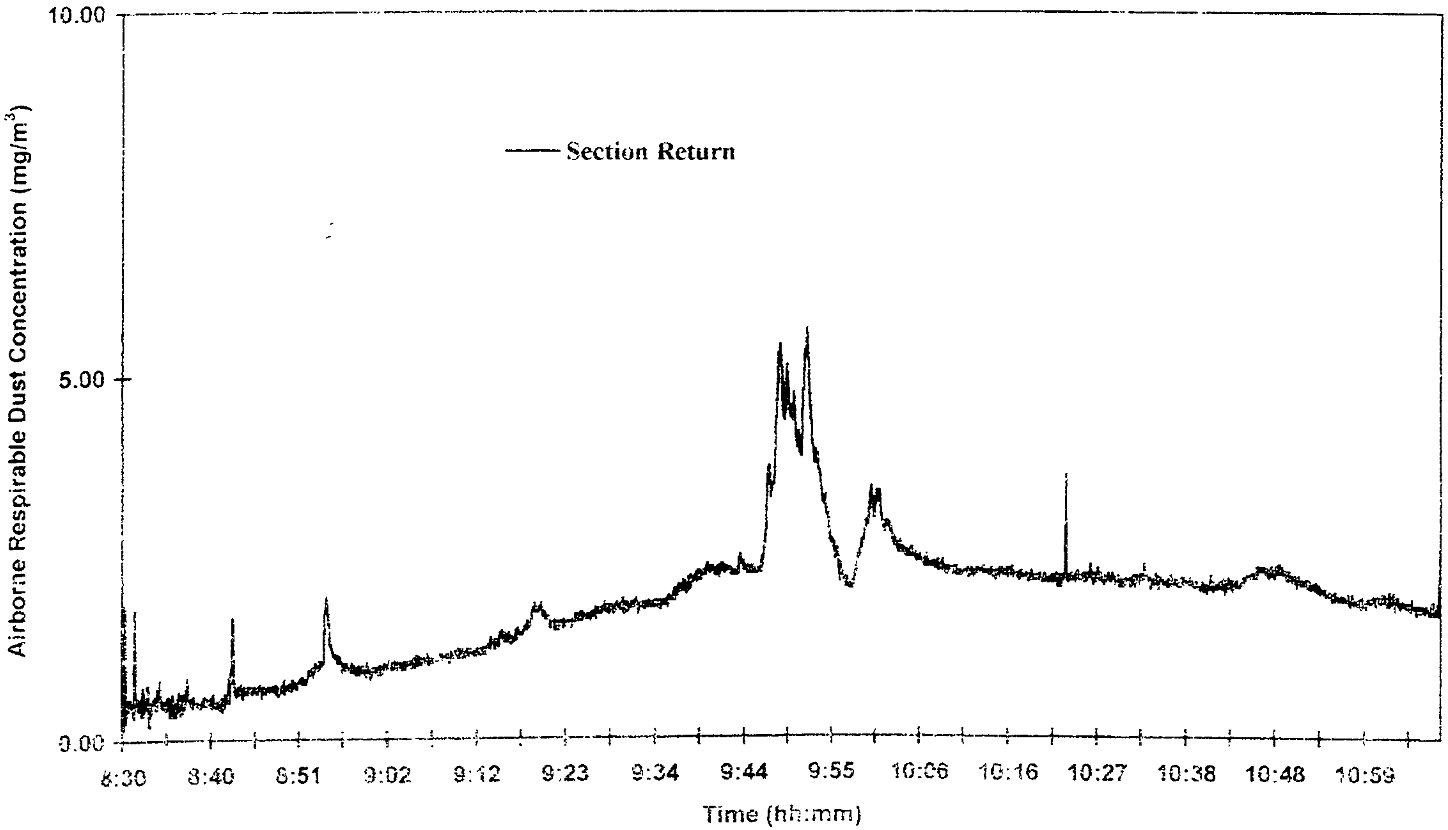

Figure 5.4: Typical ARD concentration profile recorded by Hund at the section return for test 5

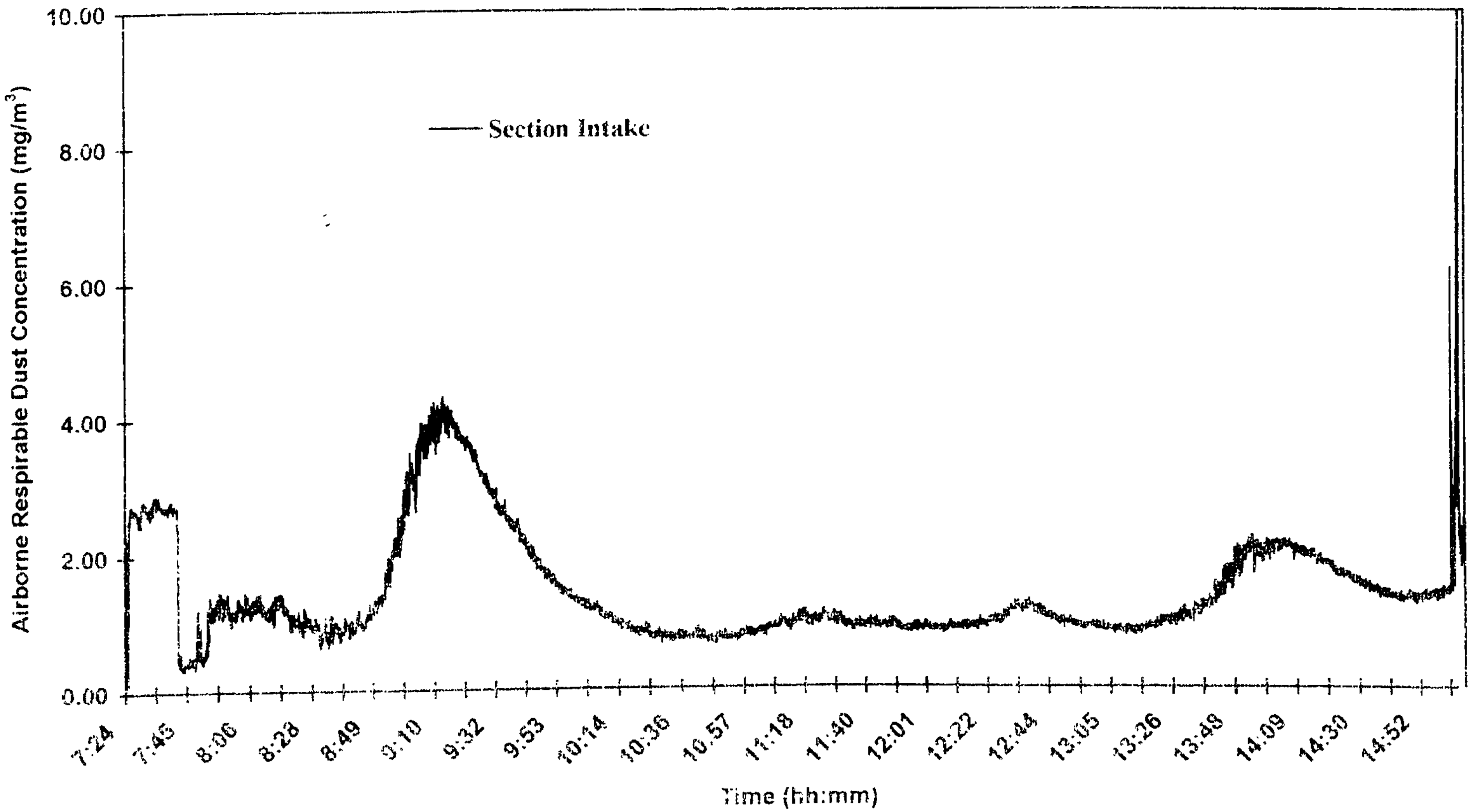

Figure 6.1: ARD concentration profile recorded by Hund at the section intake for test 6

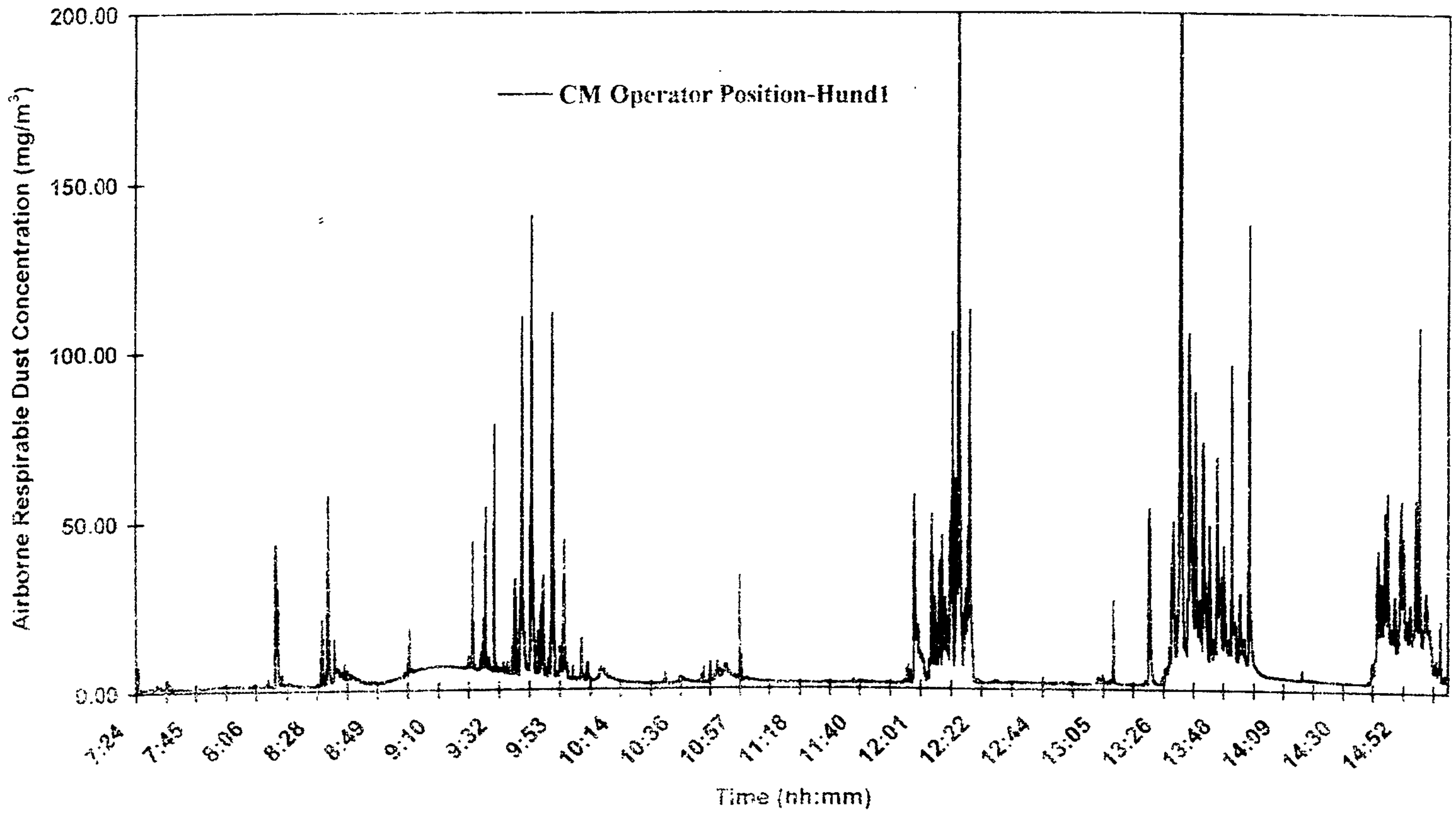

Figure 6.2: ARD concentration profile recorded by Hund-1 at the CM operator position for test 6

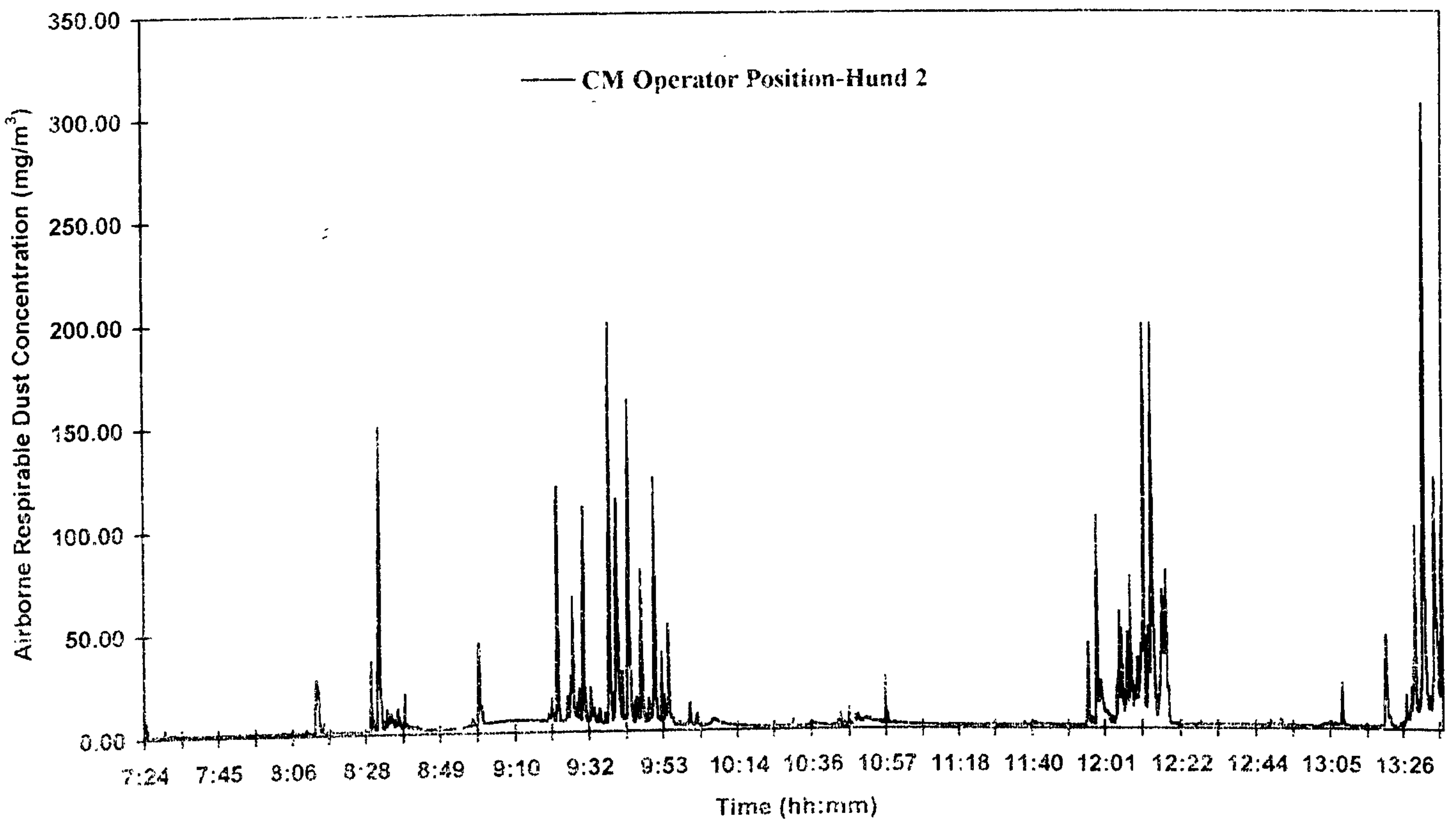

Figure 6.3: Typical ARD concentration profile recorded by Hund-2 at the CM operator position for test 6

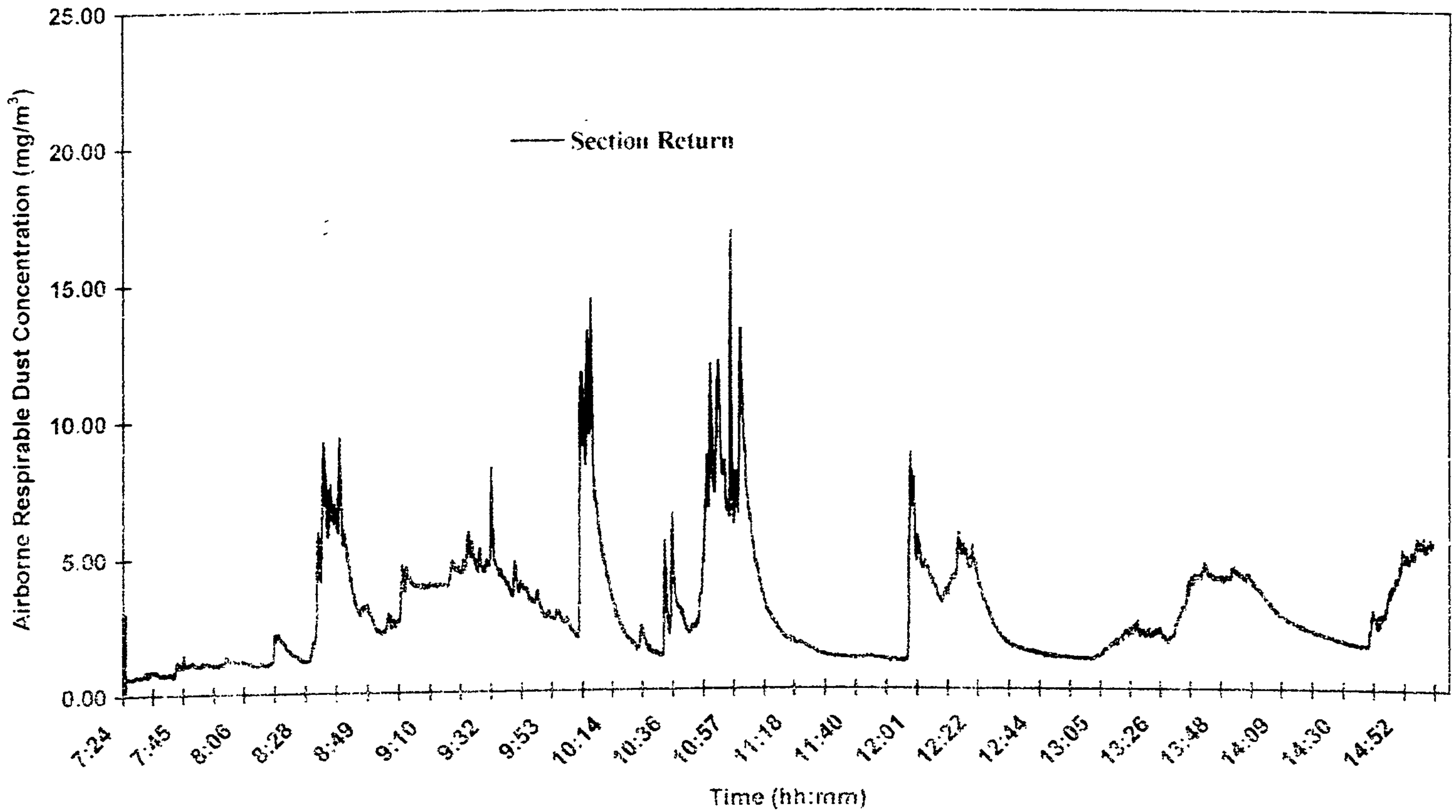

Figure 6.4: ARD concentration profile recorded by Hund at the section return for test 6

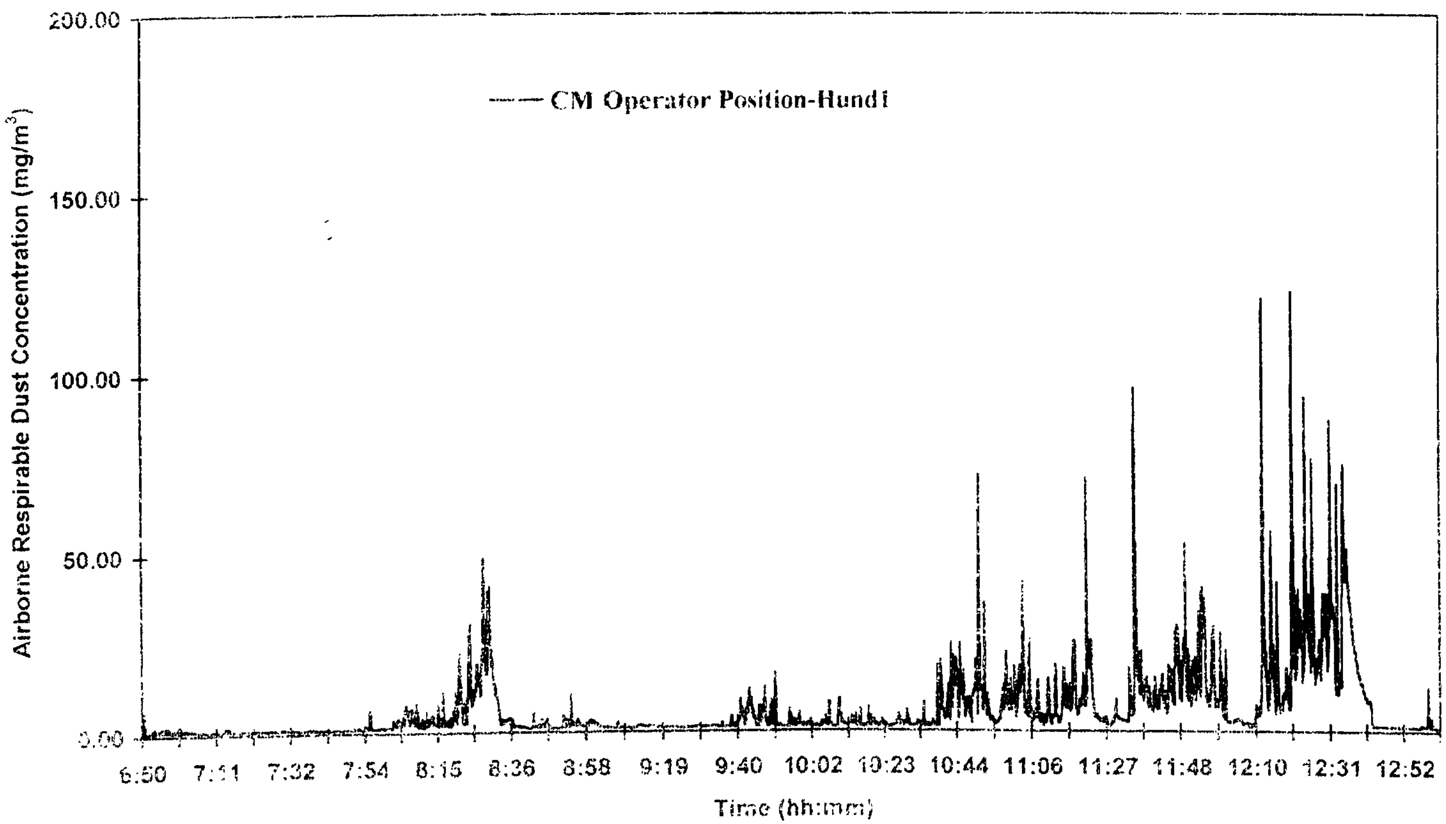

Figure 7.1: ARD concentration profile recorded by Hund-1 at the CM operator position for test 7

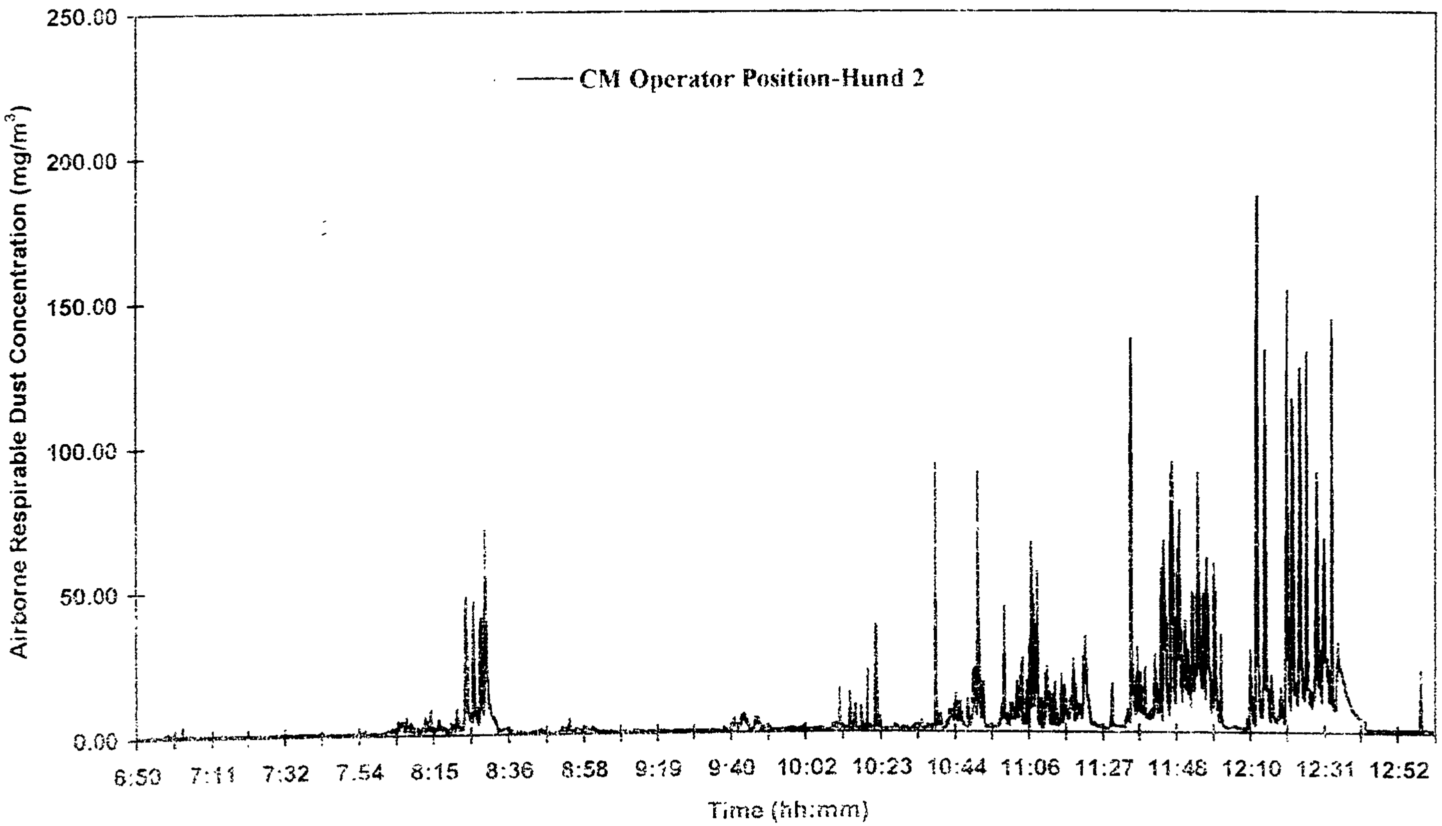

Figure 7.2: ARD concentration profile recorded by Hund-2 at the CM operator position for test 7

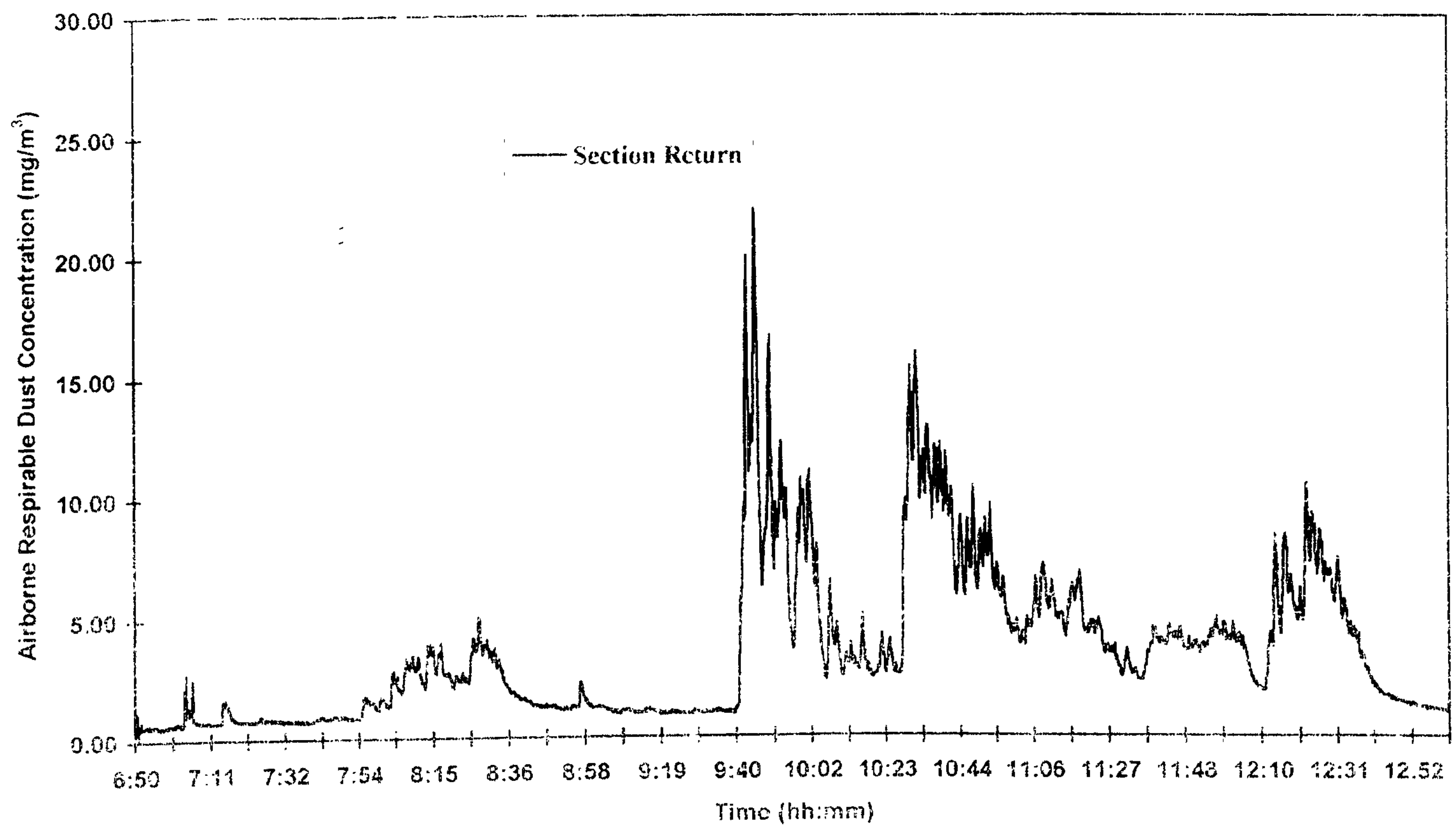

Figure 7.3: ARD concentration profile recorded by Hund at the section return for test 7

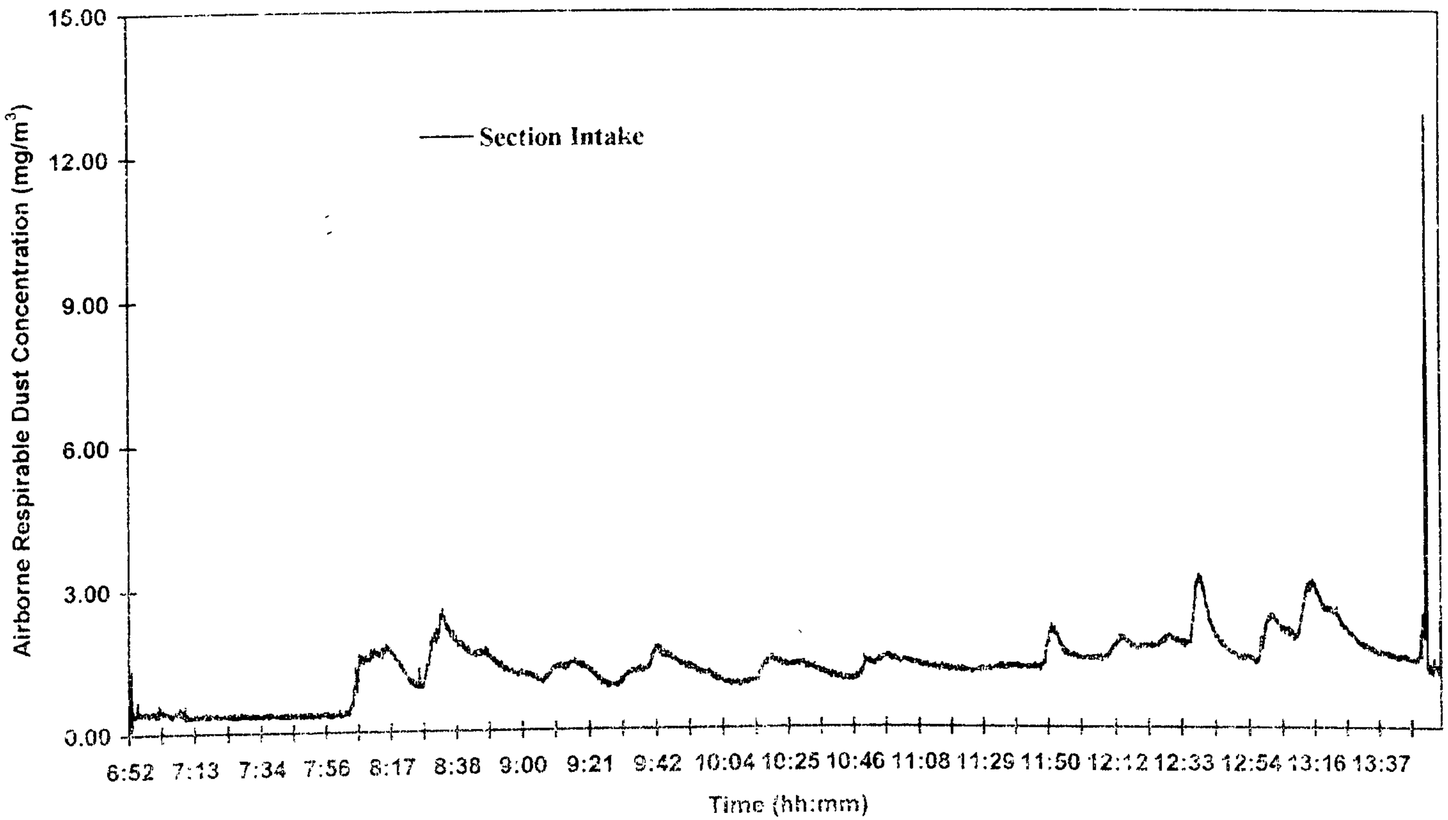

Figure 8.1: ARD concentration profile recorded by Hund at the section intake for test 8

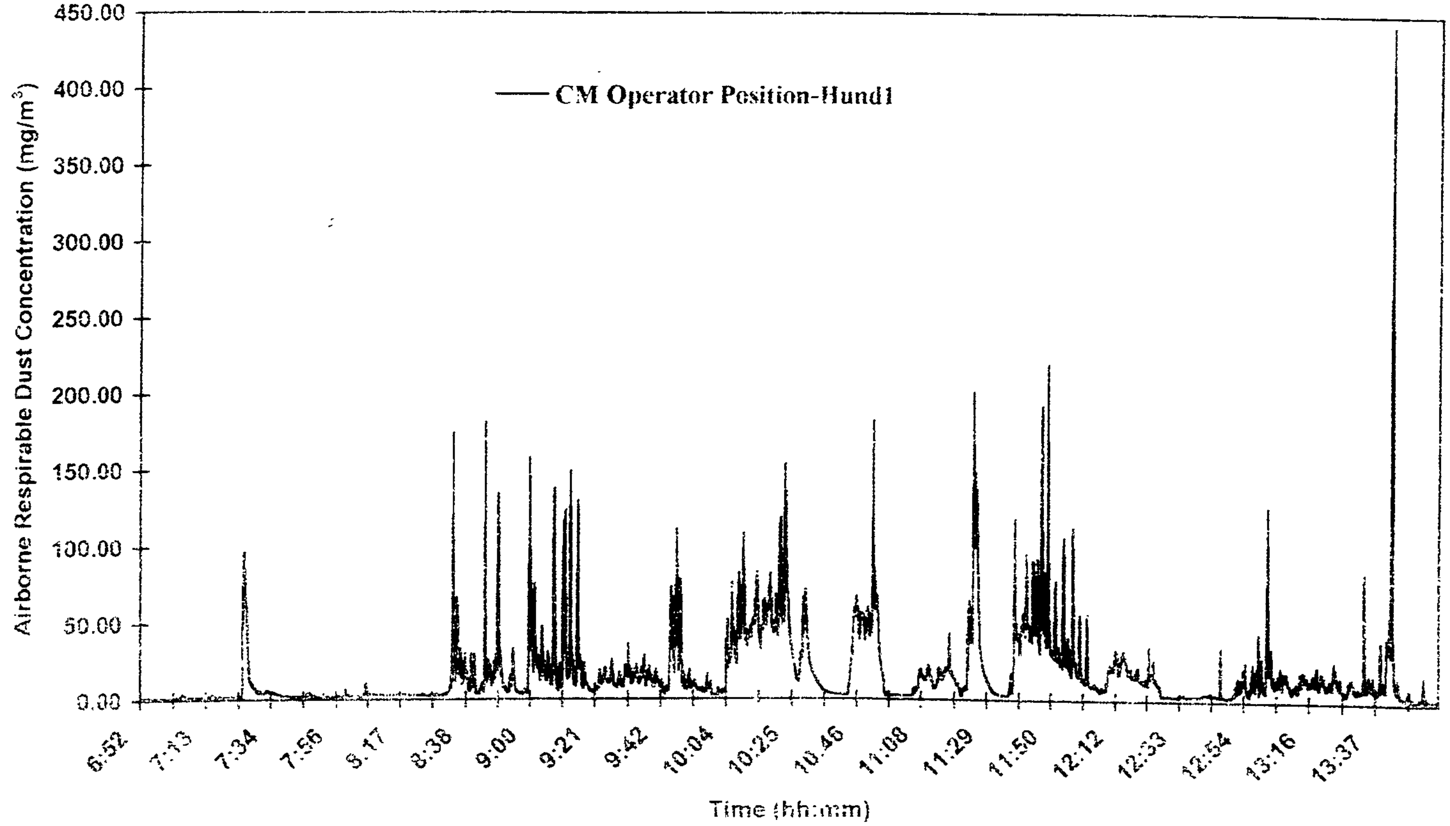

Figure 8.2: ARD concentration profile recorded by Hund-1 at the CM operator position for test 8

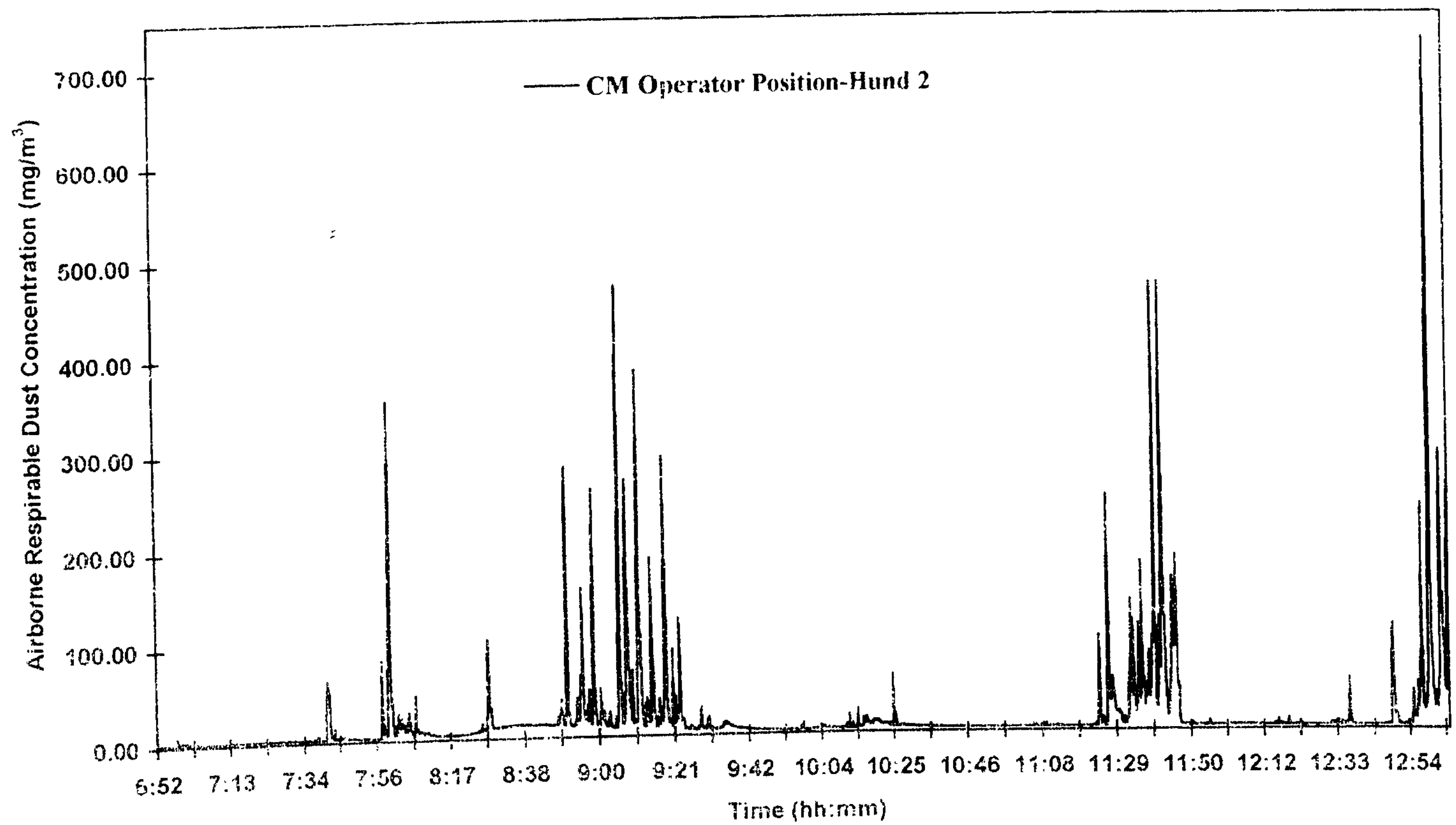

Figure 8.3: ARD concentration profile recorded by Hund-2 at the CM operator position for test 8

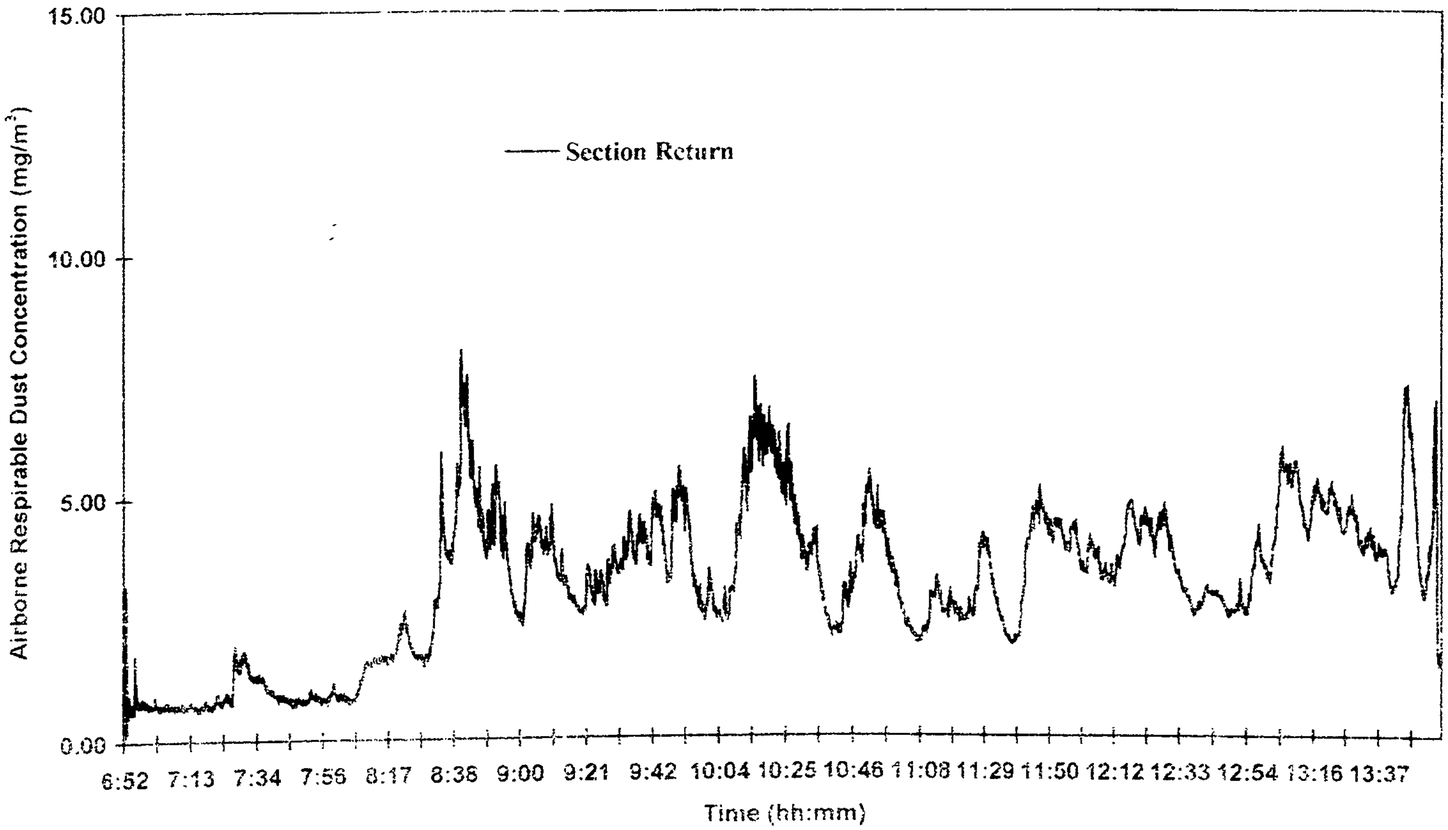

Figure 8.4: ARD concentration profile recorded by Hund at the section return for test 8

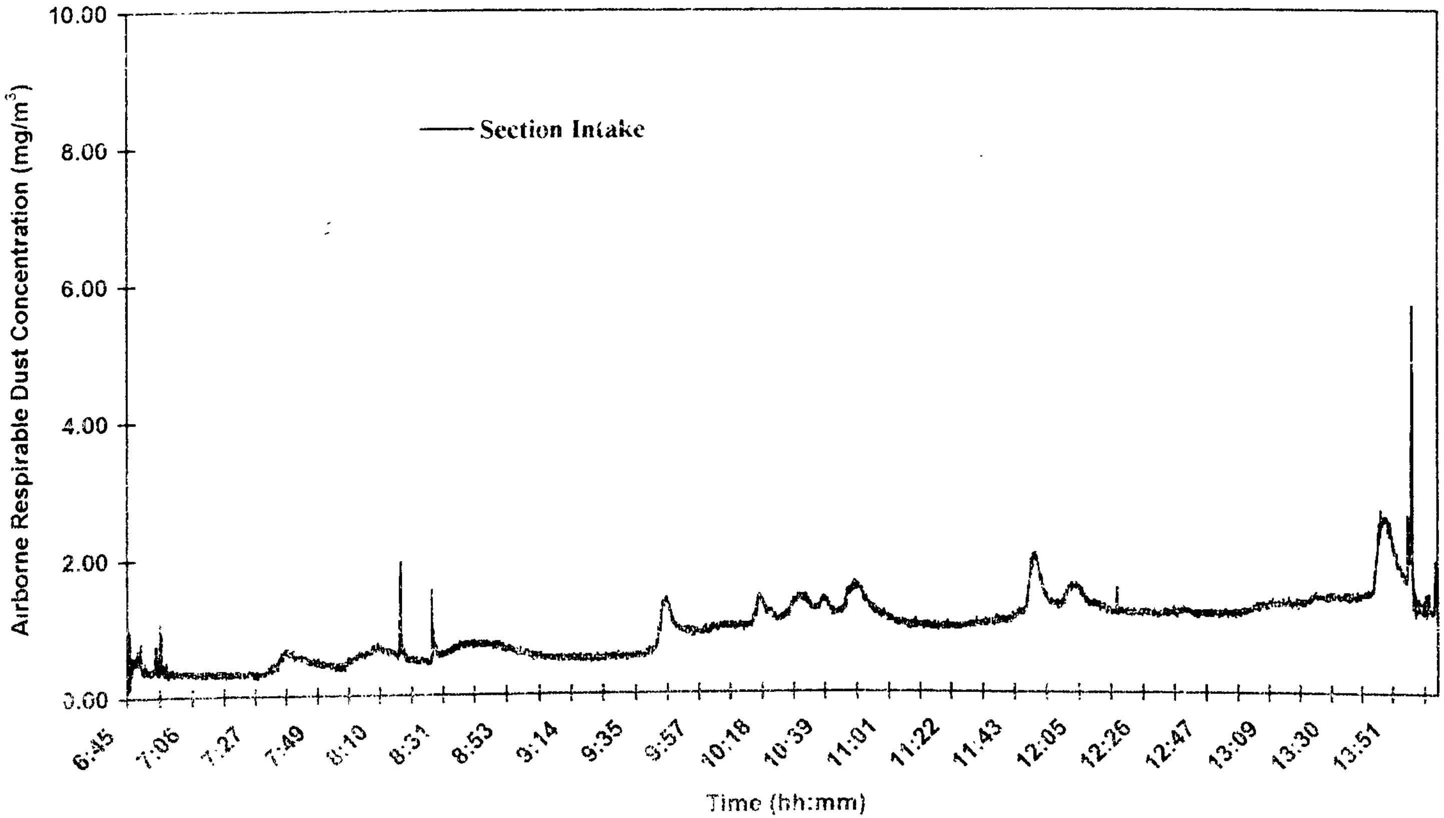

Figure 9.1: ARD concentration profile recorded by Hund at the section intake for test 9

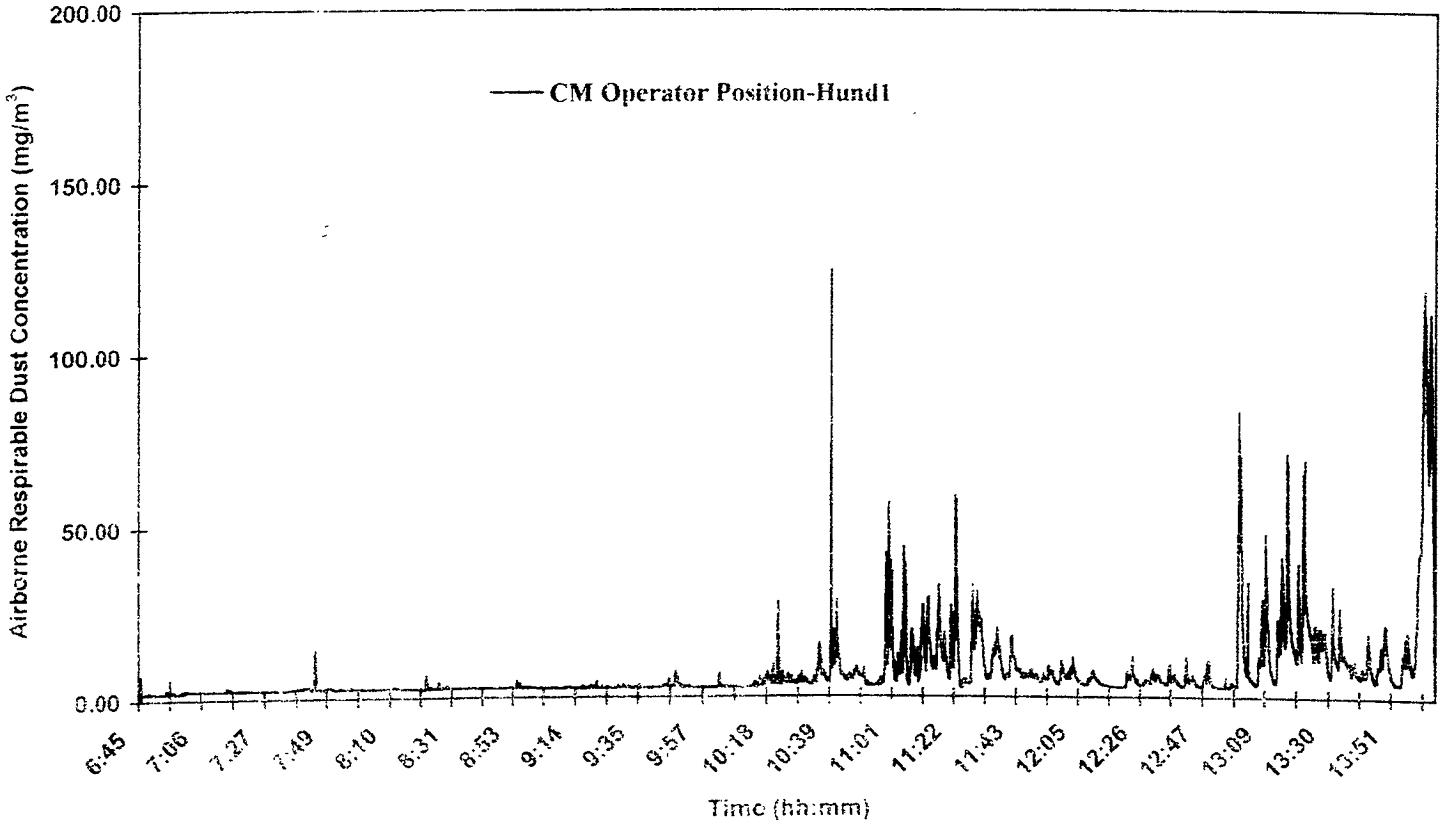

Figure 9.2: ARD concentration profile recorded by Hund-1 at the CM operator position for test 9

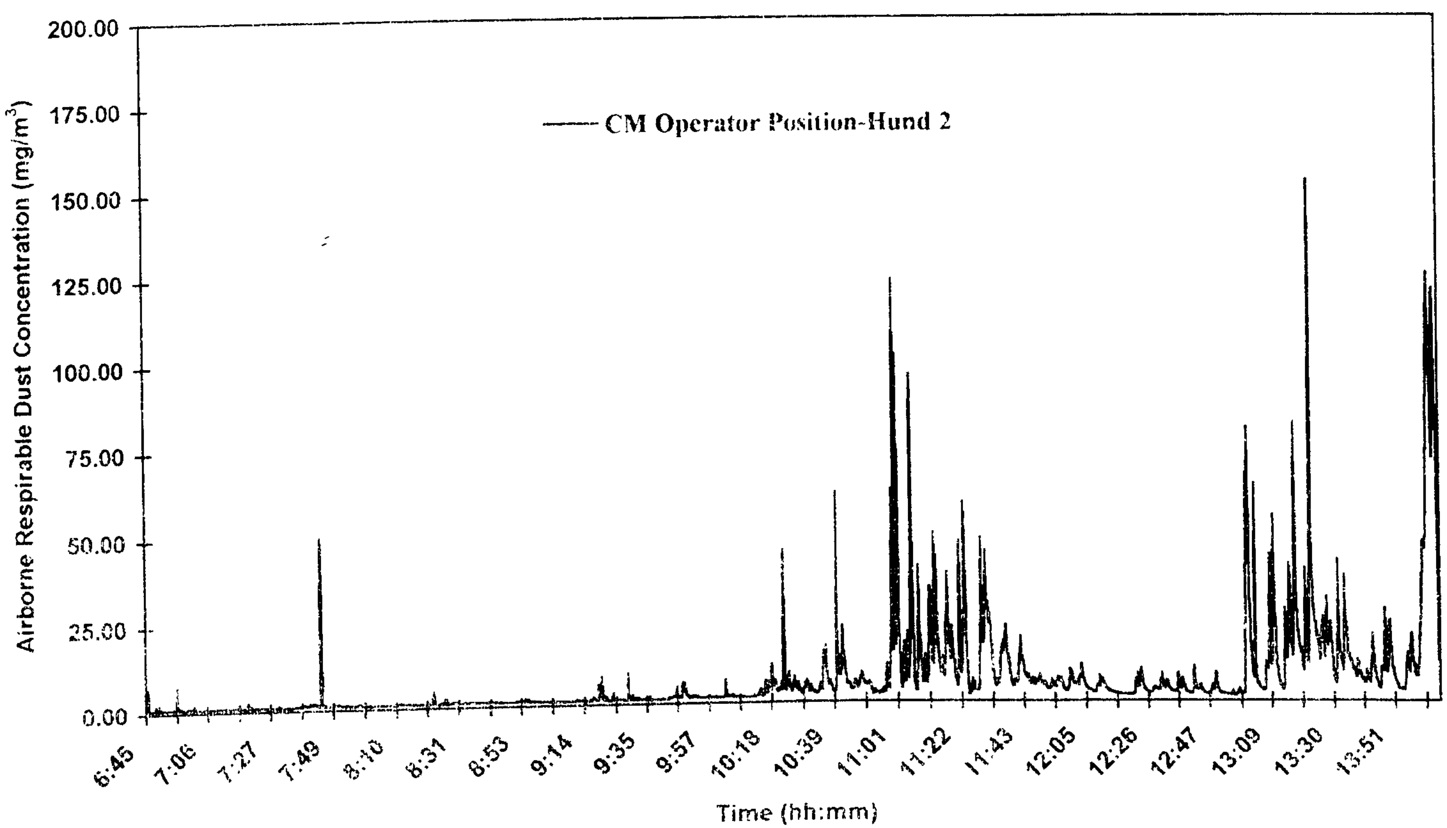

Figure 9.3: ARD concentration profile recorded by Hund-2 at the CM operator position for test 9

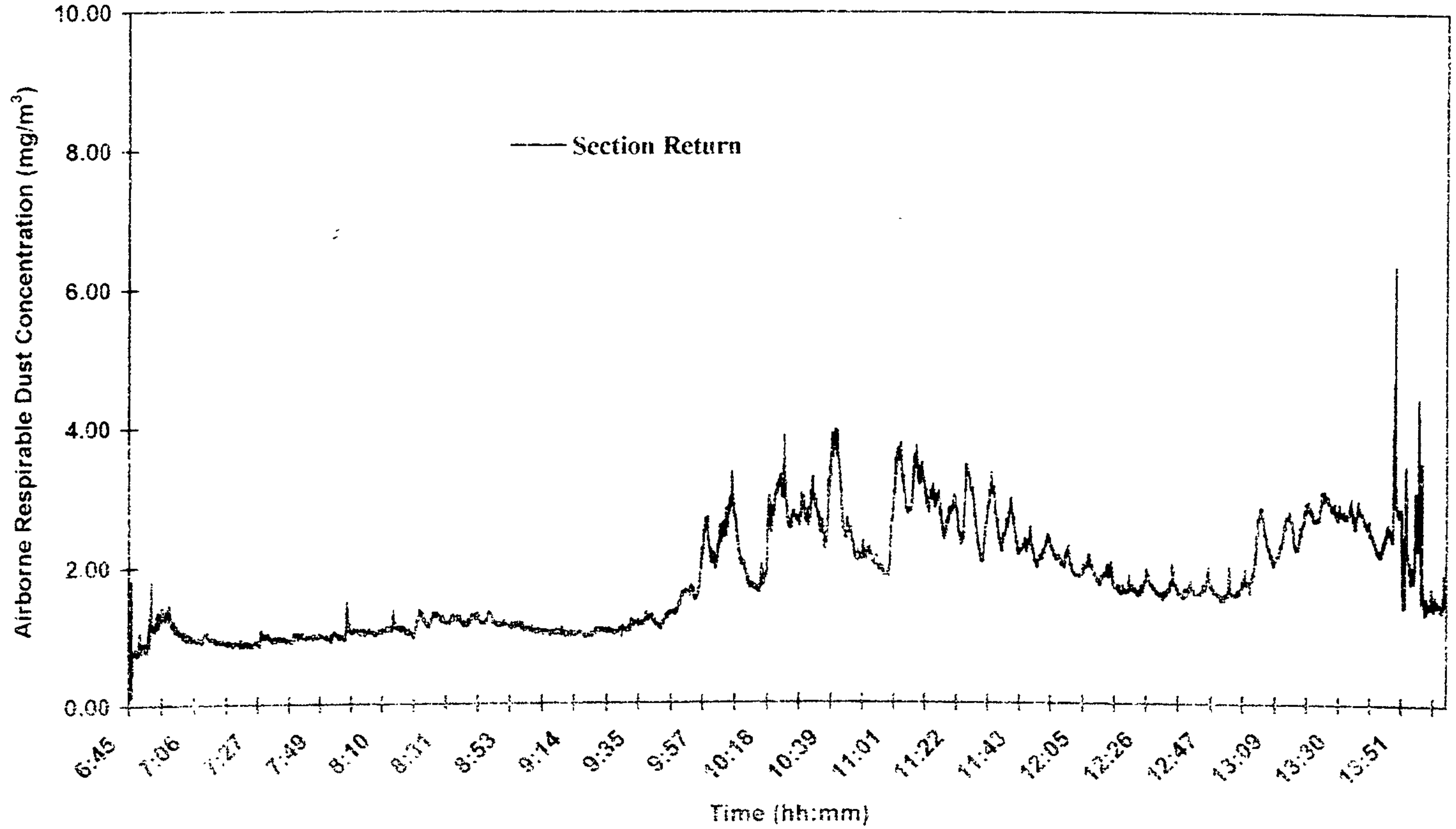

Figure 9.4: ARD concentration profile recorded by Hund at the section return for test 9

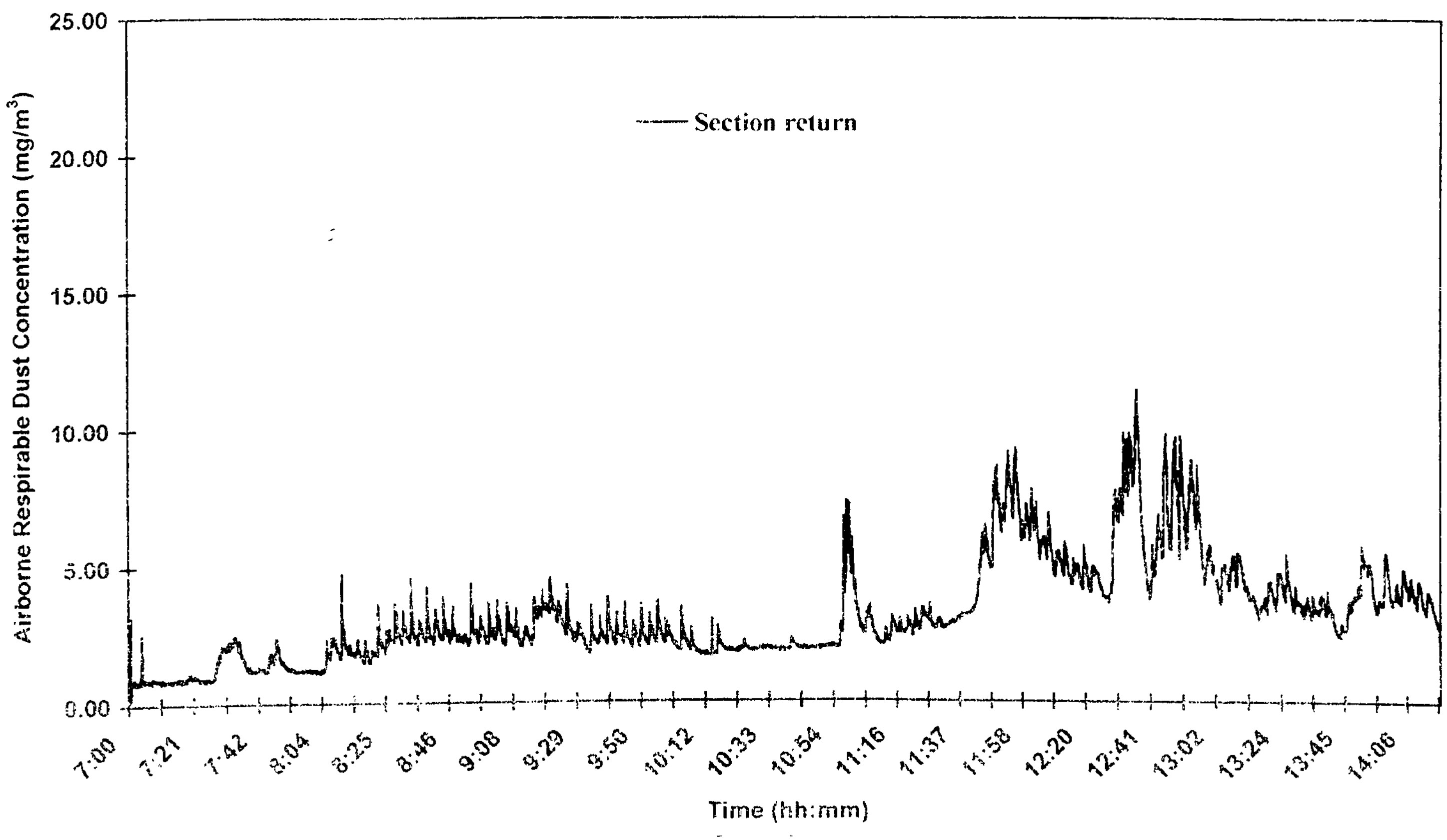

Figure 10.1: ARD concentration profile recorded by Hund at the section return for test 10

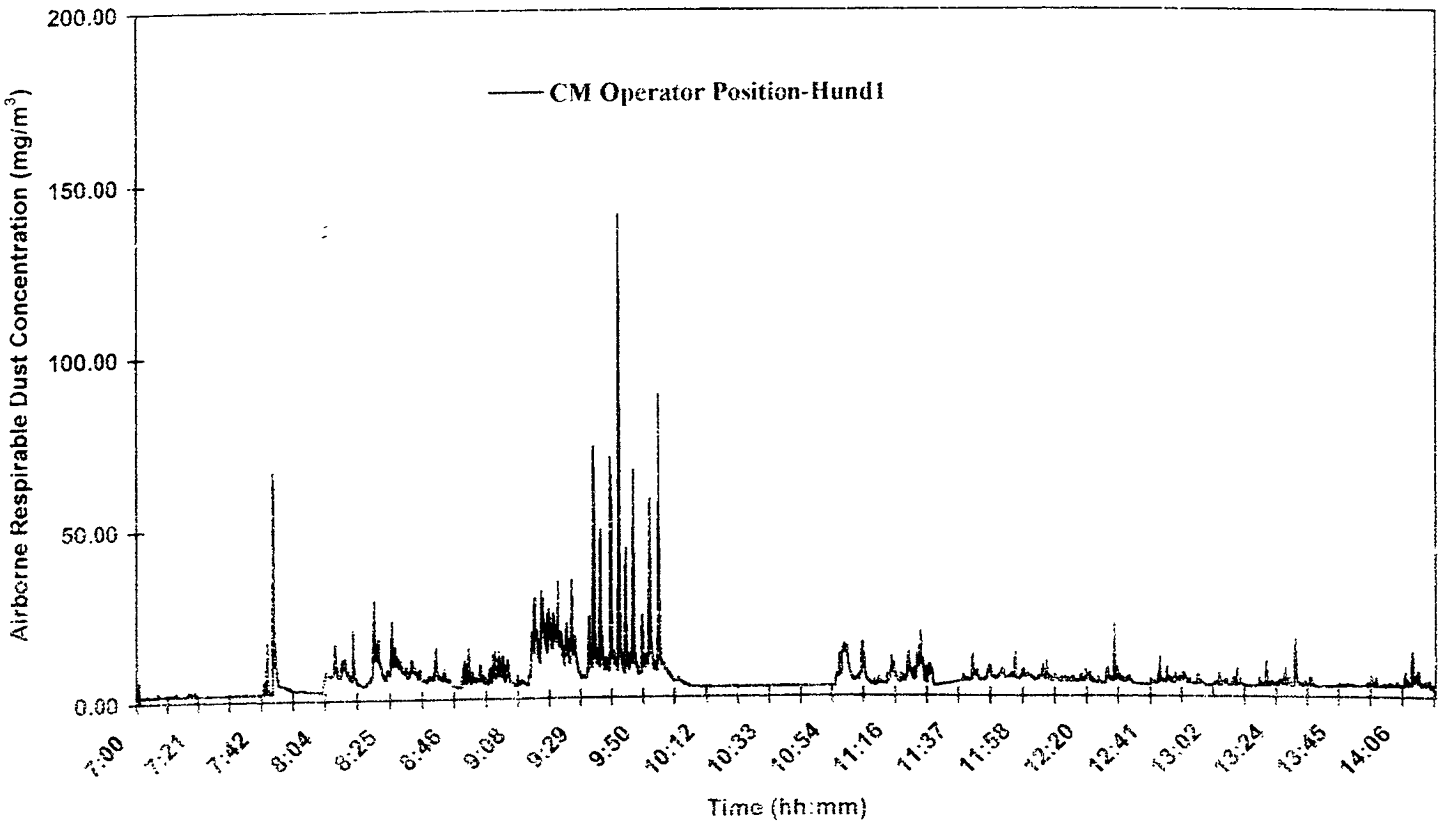

Figure 10.2: ARD concentration profile recorded by Hund-1 at the CM operator position for test 10

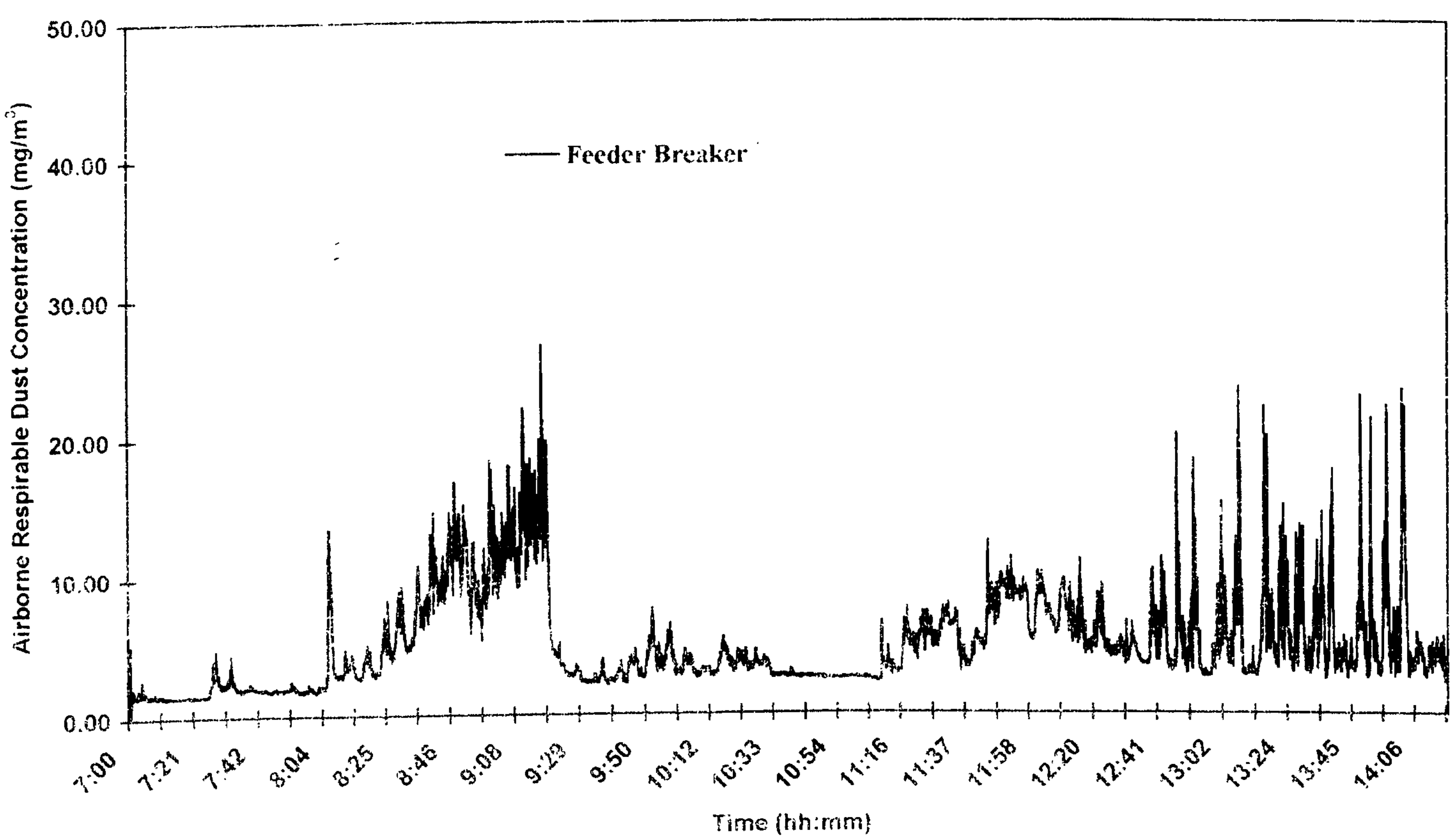

Figure 10.3: ARD concentration profile recorded by Hund at the feeder breaker for test 10

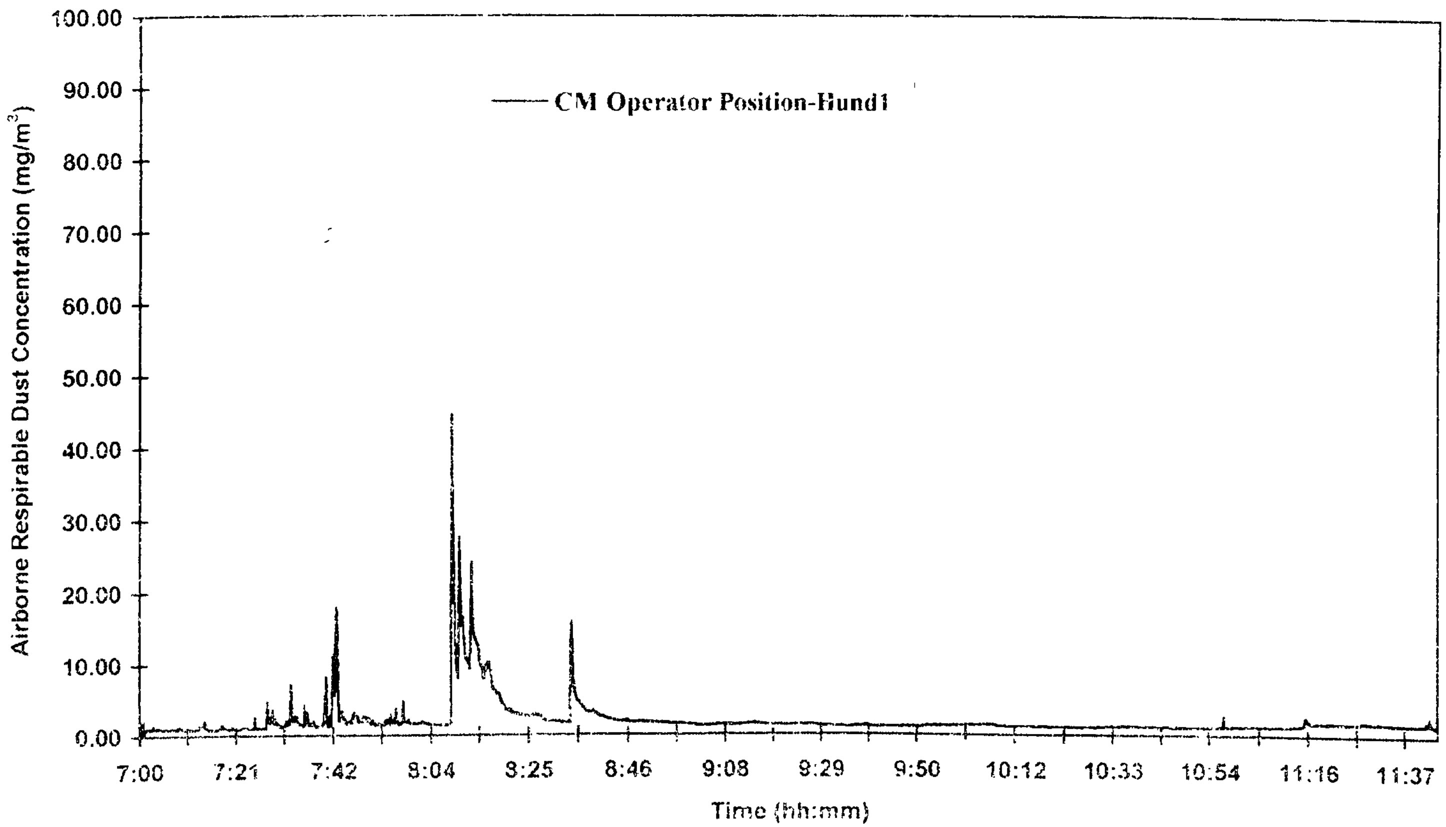

Figure 11.1: ARD concentration profile recorded by Hund-1 at the CM operator position for test 11

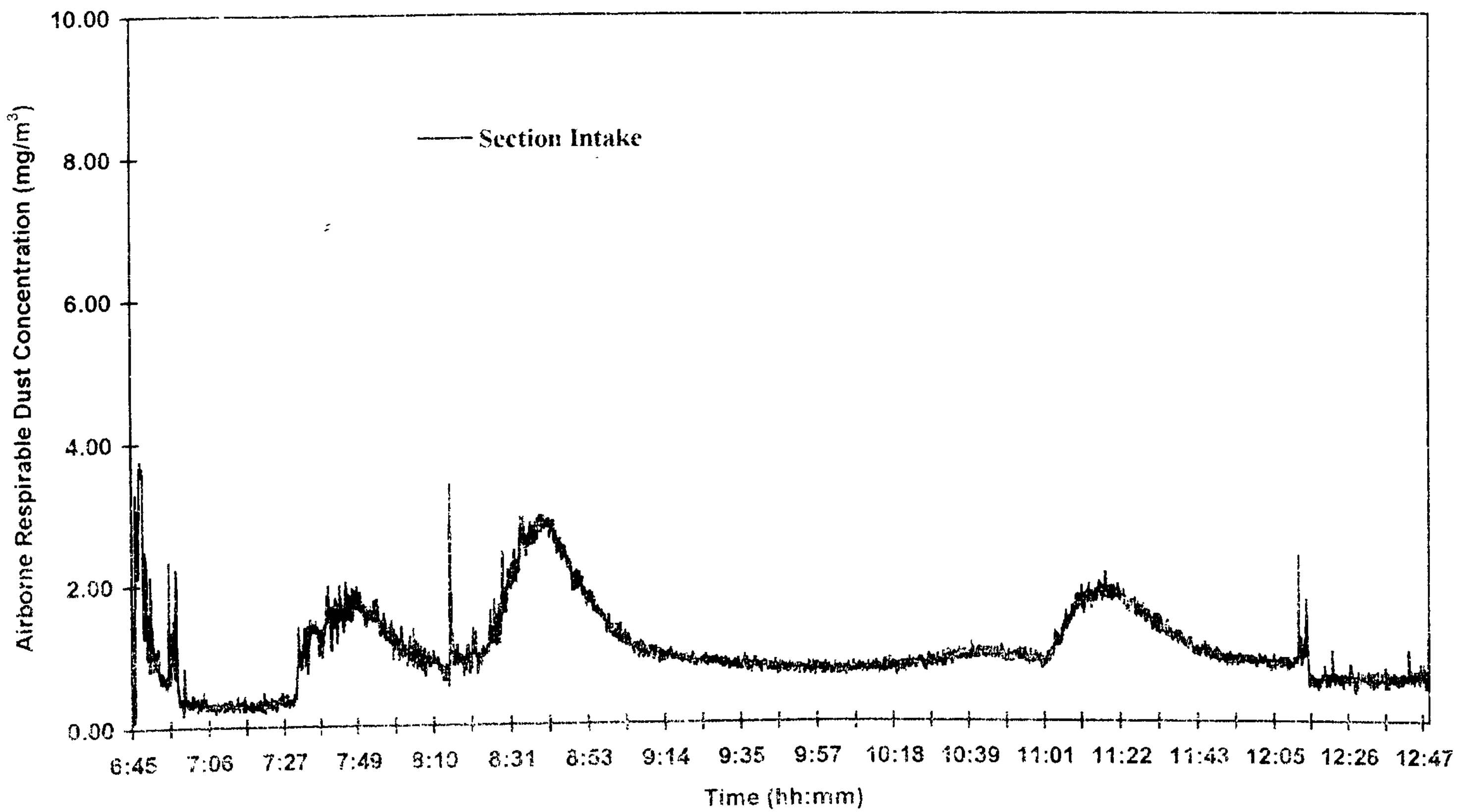

Figure 12.1: ARD concentration profile recorded by Hund at the section intake for test 12

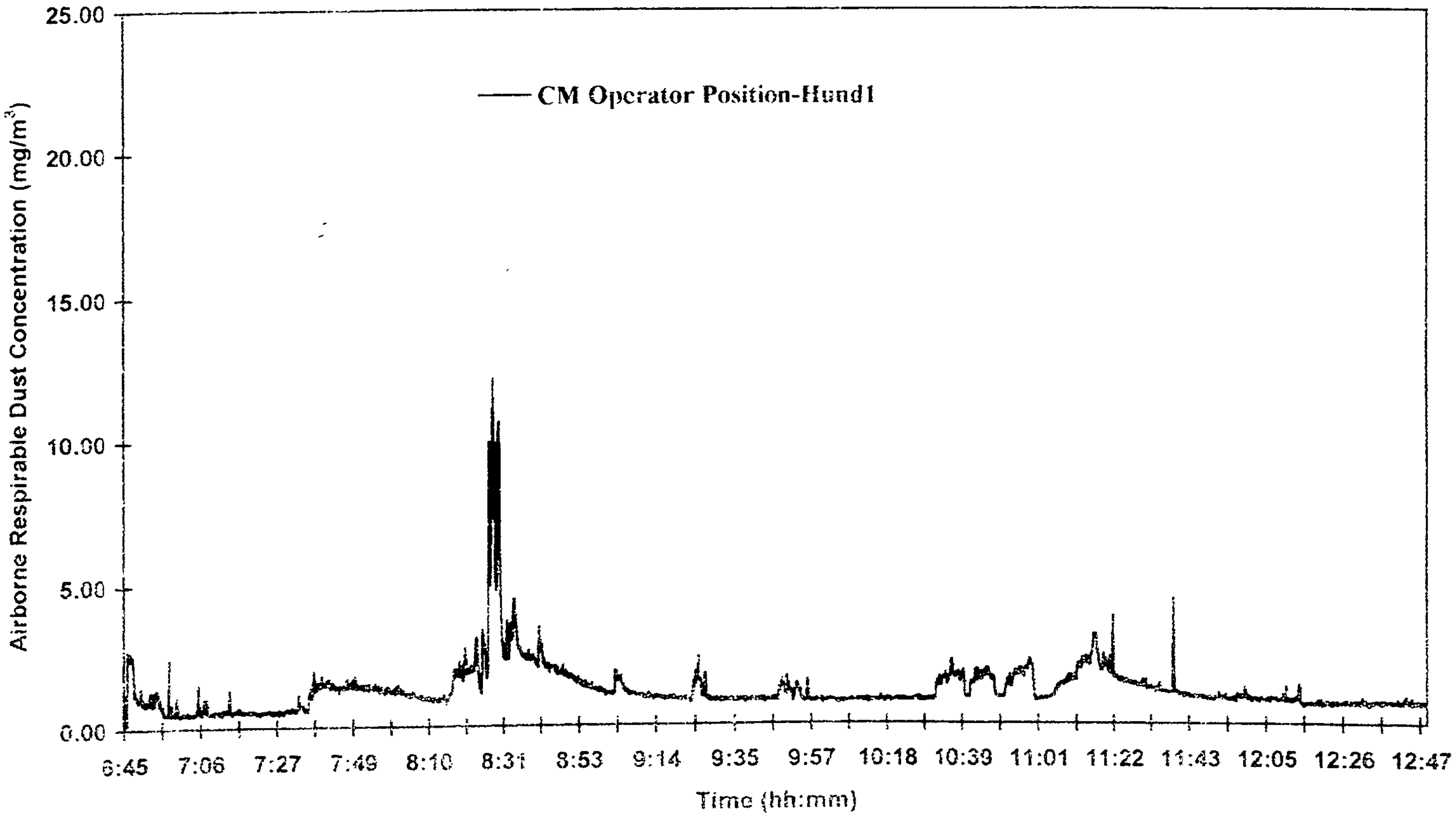

Figure 12.2: ARD concentration profile recorded by Hund-1 at the CM operator position for test 12

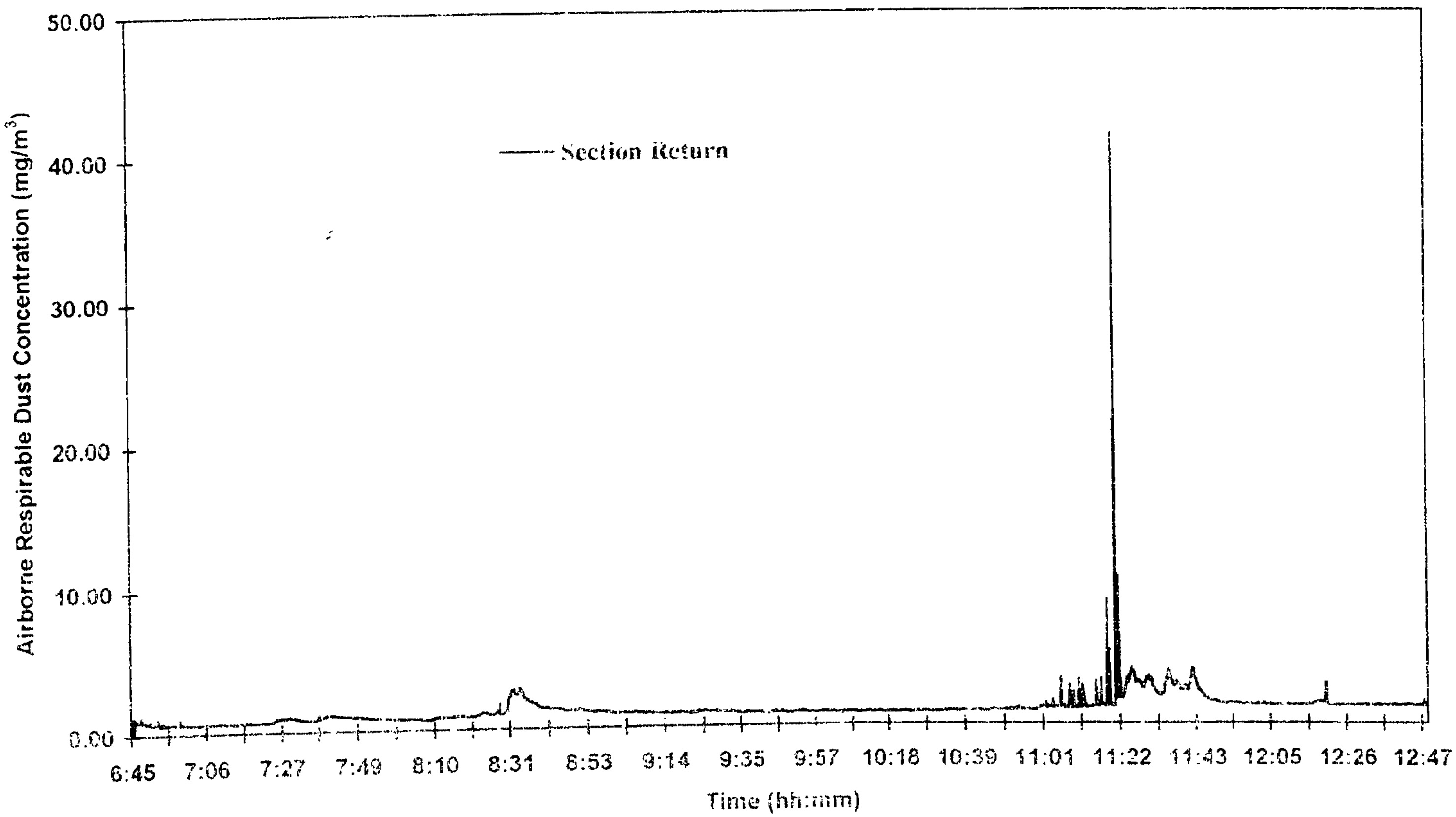

Figure 12.3: ARD concentration profile recorded by Hund at the section return for test 12

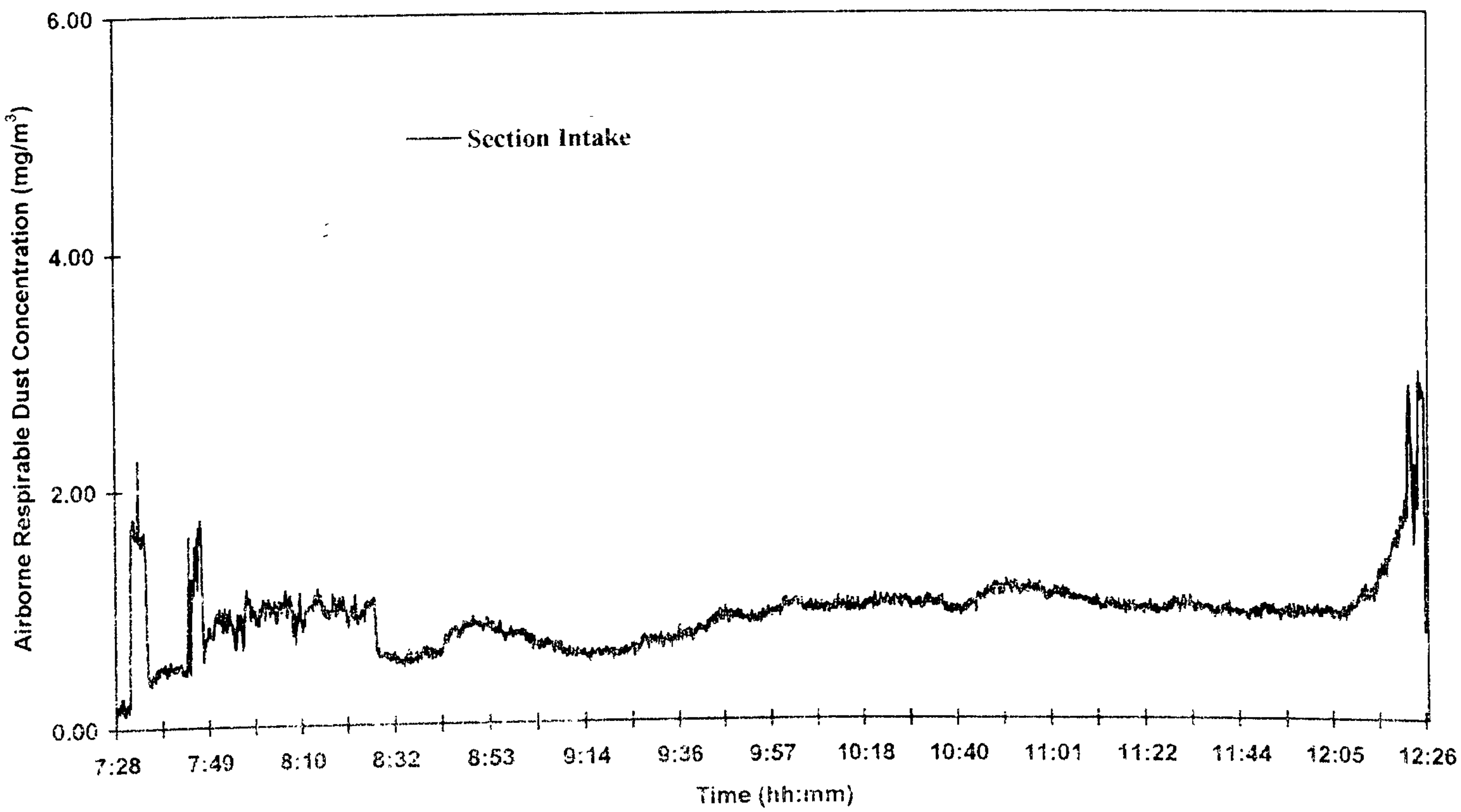

Figure 13.1: ARD concentration profile recorded by Hund at the section intake for test 13

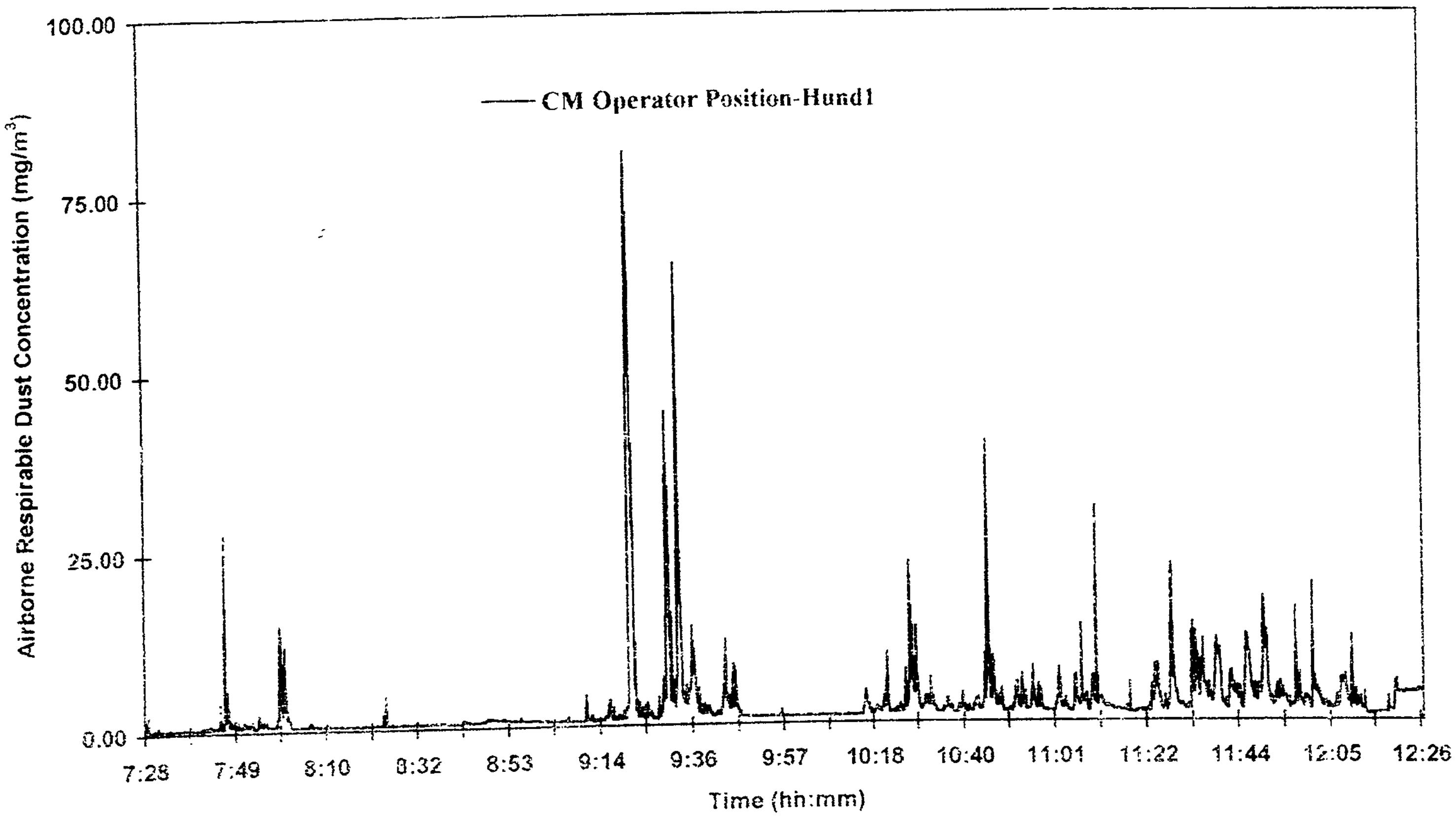

Figure 13.2: ARD concentration profile recorded by Hund-1 at the CM operator position for test 13

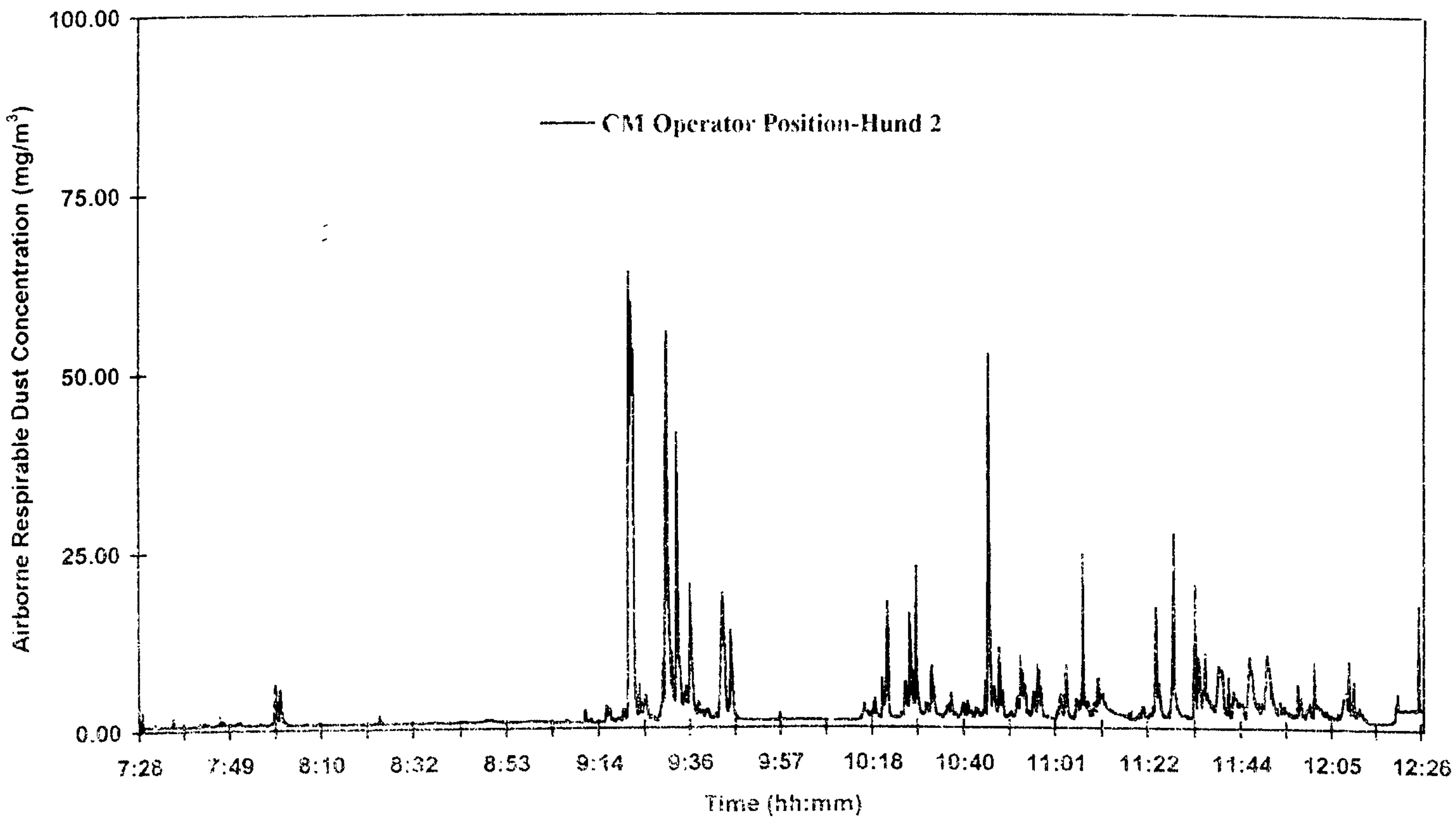

Figure 13.3: ARD concentration profile recorded by Hund-2 at the CM operator position for test 13

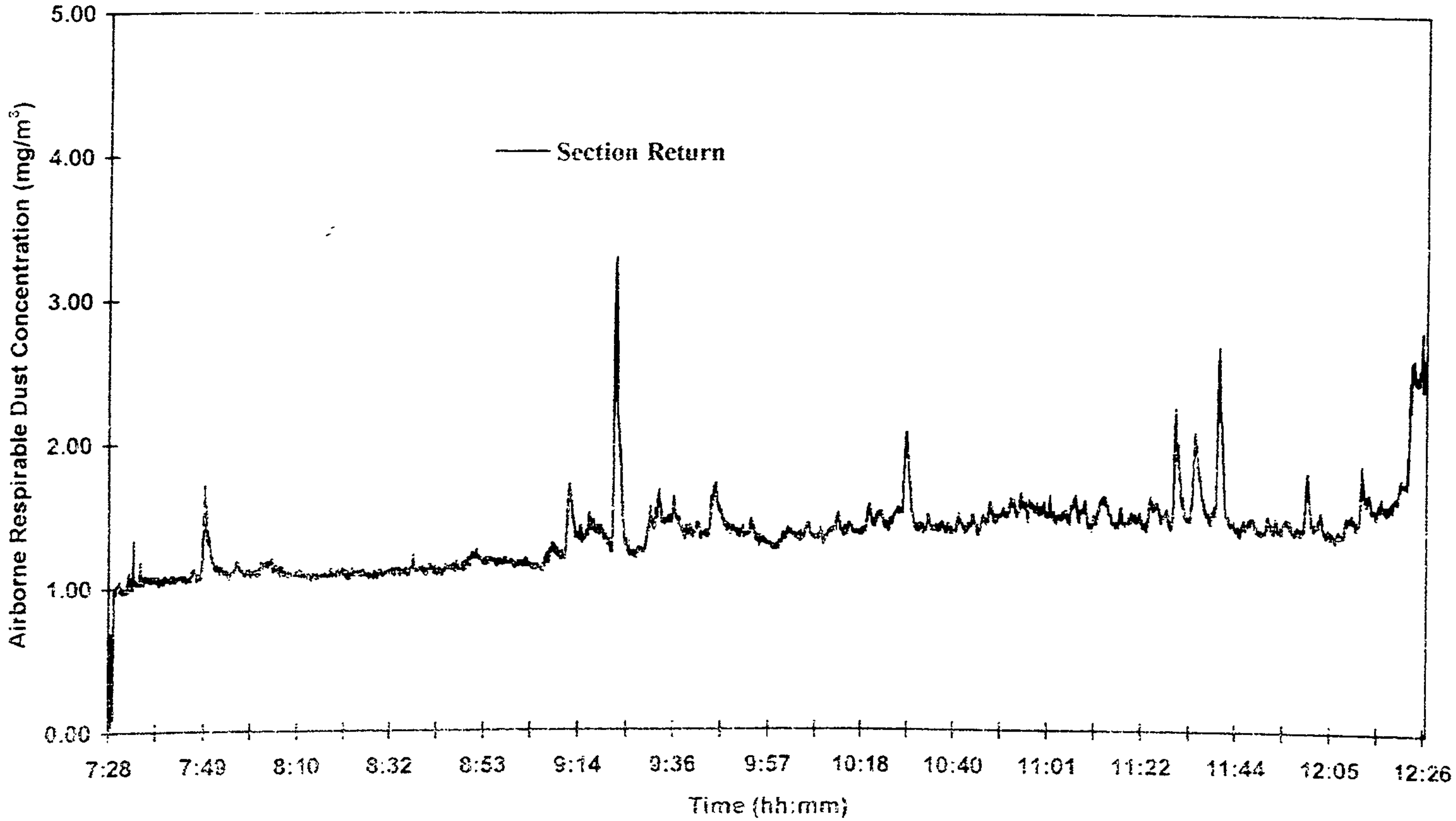

Figure 13.4: ARD concentration profile recorded by Hund at the section return for test 13

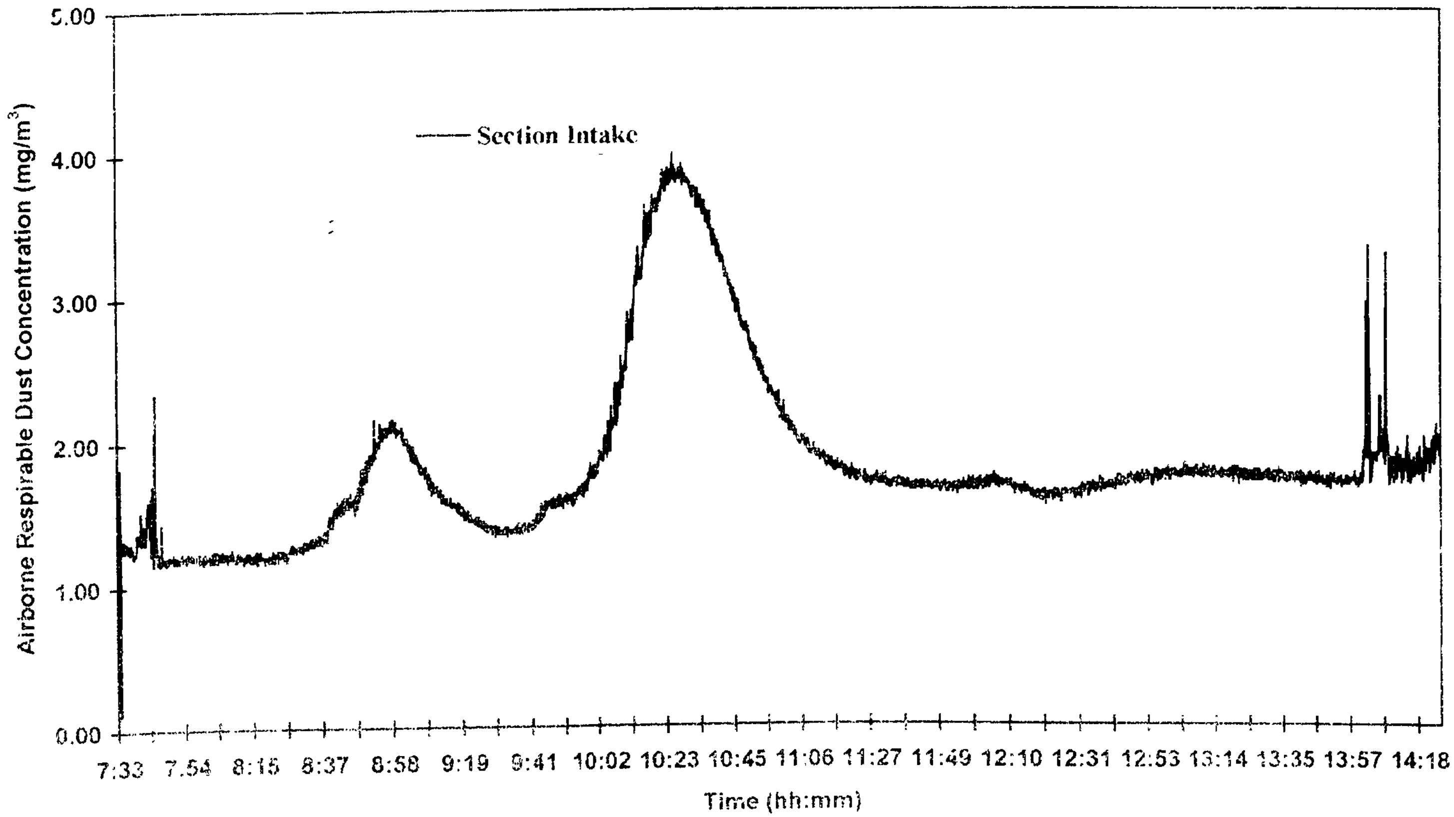

Figure 14.1: ARD concentration profile recorded by Hund at the section intake for test 14

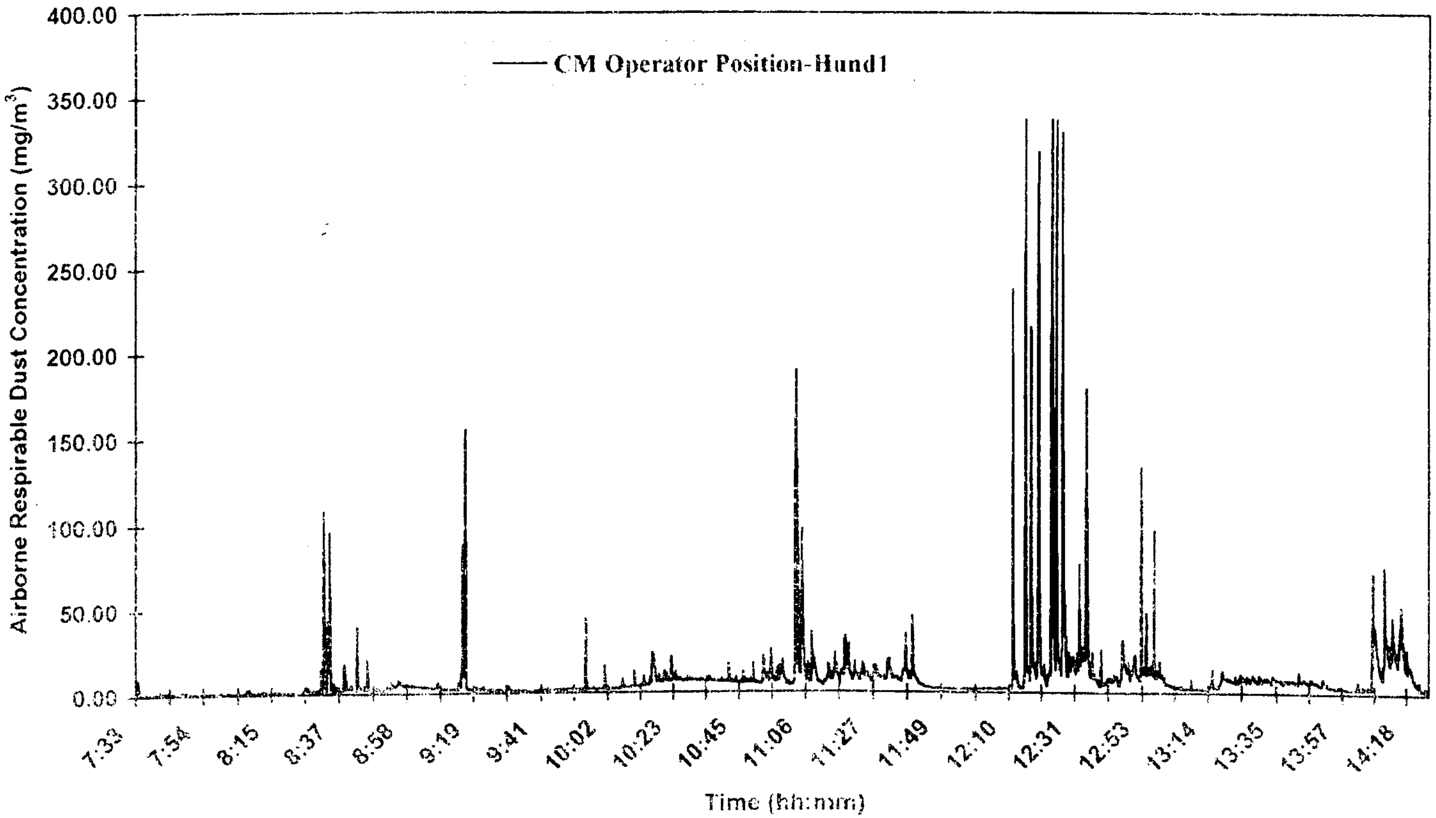

Figure 14.2: ARD concentration profile recorded by Hund-1 at the CM operator position for test 14

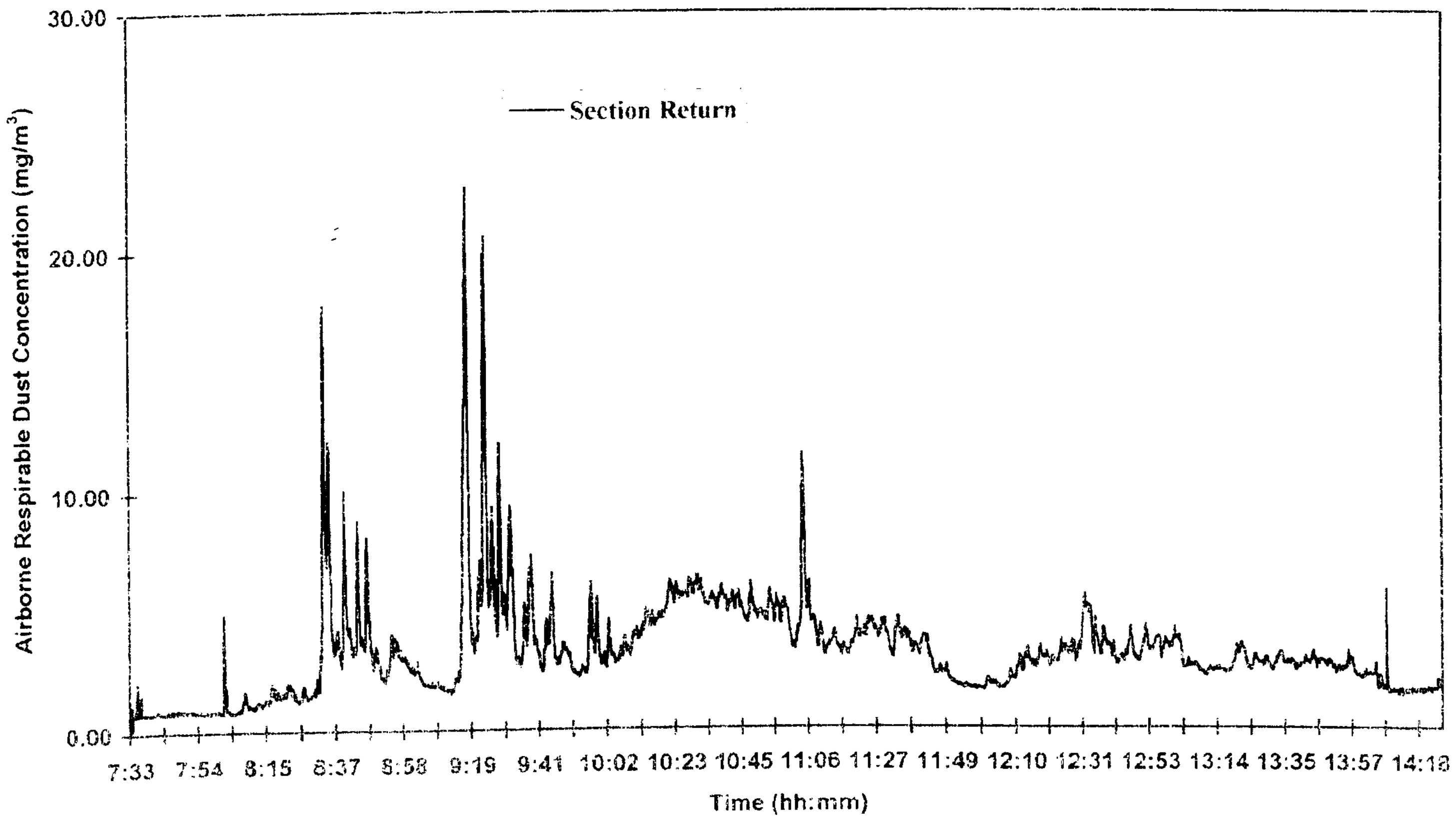

Figure 14.3: ARD concentration profile recorded by Hund at the section return for test 14

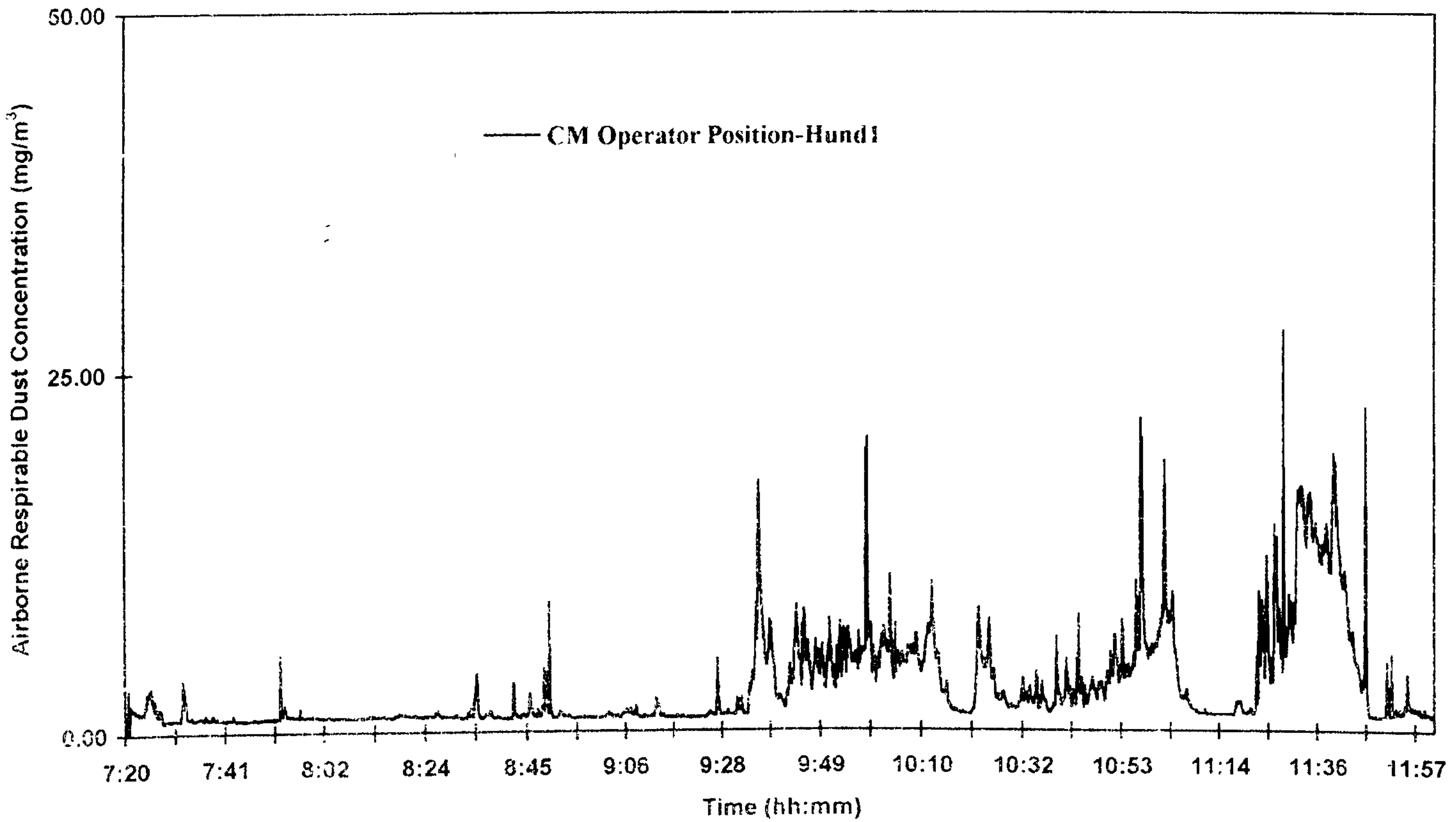

Figure 15.1: ARD concentration profile recorded by Hund-1 at the CM operator position for test 15

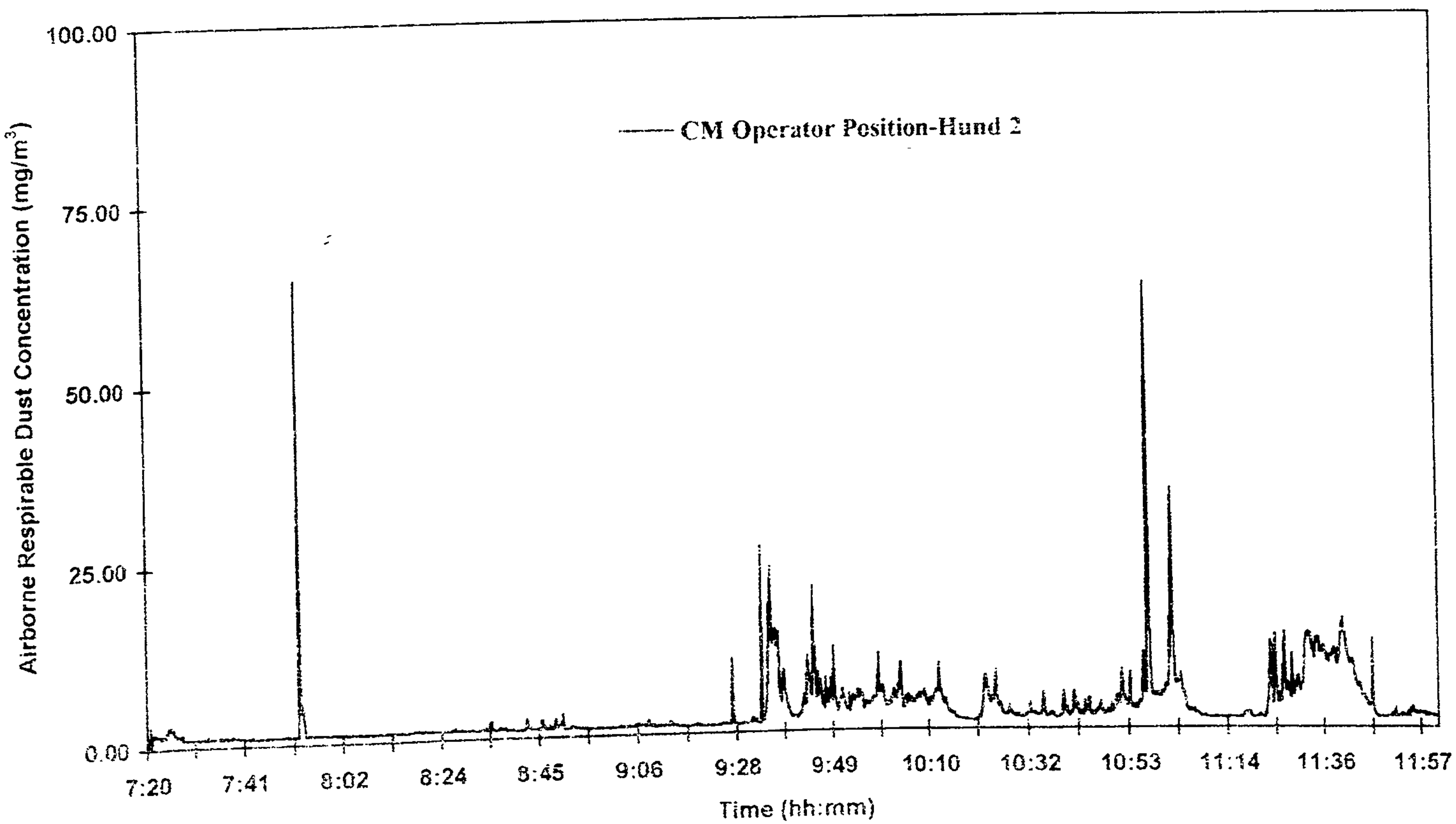

Figure 15.2: ARD concentration profile recorded by Hund -2 at the CM operator position for test 15

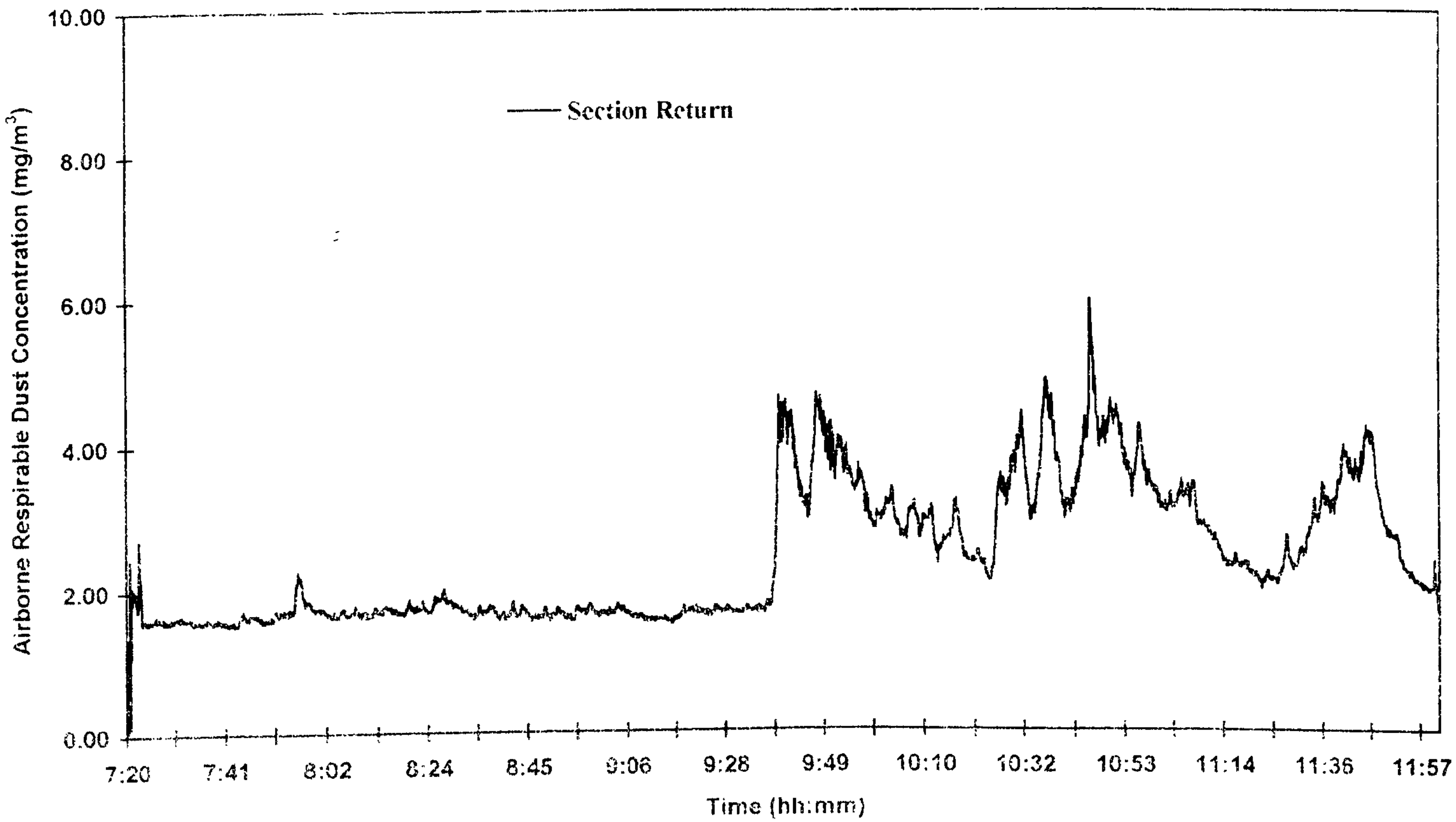

Figure 15.3: ARD concentration profile recorded by Hund at the section return for test 15