SIMRAC

DRAFT revised

Final Project Report

Title: DUST CAPTURE EFFECTIVENESS OF SCRUBBER SYSTEMS ON MECHANICAL MINERS OPERATING IN LARGER ROADWAYS

Author/s: B J HOLE AND F H VON GLEHN

Research Agency: BLUHM BURTON ENGINEERING / IMCL

Project No: COL 310

Date: March 1998

EXECUTIVE SUMMARY

The effectiveness of scrubber dust capture is dependent upon a number of factors relating to the entire mining operation. These factors include:

- the method of mining
- the mining sequence
- auxiliary ventilation arrangement
- the general layout of the scrubber and the inlet position/s
- the operating parameters of on-board ventilation and dust control systems.

The present project was directed towards bord and pillar working by mechanised miners operating in larger section roadways, where the problem of scrubber capture tends to be greatest owing to the limited size of the zone of influence around exhaust ventilation inlets. The study also concentrated on the use of jetfans for auxiliary ventilation, these representing the most common system in use in South African coal mining at the time of the study.

The project considered the influence of all the above factors using a variety of techniques including:

- literature reviews of previous work both in South Africa and other countries
- analysis of working methods from a number of underground visits and previous experience
- surface gallery trials studying the effect of the various components on scrubber capture, both individually and in combination.

The evaluation of each of the systems was carried out having regard to the primary function of any coal mine ventilation system - the effective ventilation of the working area to ensure the efficient removal of methane. An aspect of the working environment which was included in the work was a brief study into the problem of noise from scrubber systems.

Detailed guidelines on the optimum configuration of scrubber inlets and sprayfan configurations are given, together with a methodology for setting sprayfan parameters.

Mining Sequence

The mining sequence of a bord and pillar section can have a significant influence on both ventilation and scrubber dust capture. An analysis of the various options for the mining sequence has been carried out, deriving a mining sequence intended to maximise dust capture. This exact sequence may not be entirely practical from an operational viewpoint, but benefit to the environmental working conditions may be gained from adopting some of the principles recommended. Some general features relating to optimum scrubber operation and design were identified during this exercise including:

- maximising scrubber air flows, as far as possible within the general requirements of the DME ventilation guidelines
- the scrubber inlet should be sited as close to the face as possible
- the scrubber inlet should be kept close to the relevant sidewall of the heading at all times (particularly in 2-pass cutting systems using continuous miners)

On-Machine Forcing Systems/Sprayfans

On-machine forcing systems can have a great influence on both ventilation and scrubber dust capture. If operated at too low a level, they can be ineffective at ventilating the face, which is their primary function. However, if they have too great an effect, they can push dust past the scrubber inlet, resulting in poor control of dust. Such systems therefore need to be set to give the correct balance of both factors. Given the variation in conditions from site to site it is recommended that the optimum operational setting of these systems be established at each individual site. This is best carried out in a deep, straight cut with a flat face, using some means of visualising the airflow patterns such as a powder fire extinguisher or smoke, to identify the optimum operating range of settings for the system. Final setting-up of the system should be carried out with the addition of the normal auxiliary ventilation system. Such a procedure should only take a relatively short time to complete, but may achieve considerable improvements in environmental conditions while also identifying residual problem areas for ventilation or dust control which require attention at a specific site.

Auxiliary Ventilation Arrangement

The DME ventilation guidelines lay down a variety of different recommended secondary ventilation arrangements with rules governing their operation. Some of these arrangements incorporate 'ideal' systems, but which are currently difficult to engineer given operational requirements (for example, the use of trailing exhaust systems, where recirculation of dust by the scrubber can be eliminated). Given the ease of use of jetfan systems operationally, this represented the most popular system of auxiliary ventilation when the project was being undertaken. Such devices are a highly effective means of providing a high standard of ventilation of the face in circumstances where there is a direct route for the air jet to the face. However, for cutting the first split in particular, such direct influence on the face is not achieved and the flow of the air jet past the entrance to a split can cause extensive recirculation within the split itself, trapping both dust and methane.

However, the ventilation attributes of jetfans are not conducive to high scrubber dust capture efficiencies. By releasing air in the form of a small, high velocity jet in order to cause it to travel a considerable distance, the high energy of the jet is dissipated by extensive entrainment of additional air from the surroundings. Thus, a jetfan ultimately moves some 5 to 6 times the volume of air passed by the fan itself. Given the 50% restriction on recirculation by the scrubber, this means that the volume of forcing air passed to the face can exceed the maximum permissible capacity of the scrubber by a factor of 4. Jetfans inevitably cause dust from the face to be carried past the scrubber into the general air volume in the heading, being subsequently recirculated back to the face by entrainment into the jetfan air jet.

Reducing the energy of the air jet, by reducing its outlet velocity, reduces its entrainment. The alternative use of an auxiliary forcing fan and duct arrangement would enable far higher efficiencies of dust capture by the scrubber system. However, such a system is not able to 'throw' the air great distances, with the consequent drawback to operational considerations of requiring the duct to be advanced with the heading (present ventilation guidelines require such a duct outlet to be maintained within 10 m of the face).

Design of the Scrubber

Mounting the scrubber system on-board the machine inevitably restricts its length, introducing the possibility of interaction between the intake and outlet air flows. The release of air from the outlet will entrain additional airflow, with the danger that this additional air will be drawn from close to the inlet and hence be contaminated with dust. With the worst configuration of the scrubber discharge it was found that the scrubber could cause the flow of twice the airflow around the machine than that passed by the scrubber, resulting in a basic scrubber capture efficiency of only 50%. Such effects were minimised by use of upward directed deflectors located on the scrubber outlet, projecting the outlet air outbye along the roof. Additional benefit is achieved by advancing the inlet closer to the face. With no other ventilation systems operating, this results in the dust cloud being held closer to the face, further from both the machine operator and the scrubber discharge. Hence, general dust control can be improved with the added benefit of improved visibility for the machine operator.

The effect of both on-board and auxiliary forcing ventilation systems is to increase the disturbance of the dust cloud, their purpose being to ventilate the face. Provided that these systems are in balance with the scrubber volume and each system drives dusty air from the face towards the scrubber inlet or inlets, the end result will be a high scrubber capture efficiency combined with effective ventilation of the face. On continuous miners it was demonstrated that the optimum configuration for the scrubber inlet was with multiple inlets drawing air from beneath the machine jib such as systems commonly fitted to machines in the USA. An underground trial conducted with such inlet positions, indicated improvements in scrubber dust capture of 30 and 45% in two different cutting situations. Similarly on roadheaders, an inlet wrapped around the top of the jib, as close as possible to the cutting heads is suggested to represent the ideal position.

However, both the above systems involve flexible joints to allow jib movement, and the inlet ducts, being close to the point of cutting, may be considered to be too vulnerable to damage for practical use. Such problems may be minimised by proper design of the systems, but slightly less advantageous, more practical inlet positions are available as alternatives. Typically, both existing on-board ventilation systems and roof-mounted auxiliary ventilation systems, in combination with the effects of head rotation and falling material, tend to push air outbye close to floor level on one side of the machine. This flow of air from the face then carries up the loading shovel of the machine to where its smooth flow is disrupted by the rear spill plate. Location of a scrubber inlet just above and behind the spill plate, as close to the extreme side of the machine as possible, is therefore a good place to capture the majority of dust. Secondary inlets close to the point of emergence of coal through the jib of a continuous miner or the conveyor tunnel of a roadheader may also give significant benefit, these positions also representing areas where significant amounts of dust can be carried back from the face.

Significant improvements are possible through adoption of the above recommendations.

Contents

1. INTRODUCTION

Department of Minerals and Energy (DME) document 'Guidelines for a Code of Practice for Ventilating Mechanical Miner Sections in Coal Mines in terms of Section 34(1) of the Minerals Act, 1991' lays down the requirements for drivage ventilation in South African coal mines. The objective of these regulations is twofold :- firstly, to ensure the effective control of dust and secondly, to ensure the dilution of flammable gas to acceptable levels by providing sufficient fresh air.

Within the guidelines, distinction is made between 'Primary' and 'Secondary' ventilation systems. The main purpose of the primary (general section) system is "to ensure that ventilation systems are in place to ensure sufficient air reaches the last through road to prevent the possibility of secondary ventilation systems recirculating." The secondary ventilation system is defined as "the air moving mechanisms being utilised in a heading being cut by a mechanical miner." The objectives of the secondary ventilation system are :

- To supply a flow of air, of at least 0,4 m/s, past the operator's position to contain dust roll back
- To dilute the methane and the dust generated to acceptable levels
- To render this mixture harmless and to remove it in a controlled manner
- To capture the dust and transport it to a cleaning mechanism.

To achieve these objectives, the secondary ventilation system must incorporate both :-

- An on-board force system, and
- A scrubber system

In addition to these measures, once the heading has advanced a distance of 12m from the last through road, an auxiliary fan (either forcing or exhaust) must be installed in the last through road to ensure that fresh air is supplied to the face of the heading to prevent the on-board systems recirculating air.

The dual requirements for controlling both dust and methane in headings can conflict and therefore represent a major problem in coal mines world-wide. Dust is best controlled using some form of exhaust ventilation, drawing the dusty air from the vicinity of the face and passing it through a scrubber to remove the dust enabling the cleaned air to be returned into the main ventilation circuit of the mine. This is best achieved with little disturbance of the dust cloud formed around the cutting zone. However, a well-known characteristic of exhaust ventilation is that the air velocities it induces fall away rapidly with distance from the duct inlet itself, as described by Wesley [1] (References are located at the end of each section). This feature of exhaust ventilation is not good for the control of methane which can accumulate in the low velocity areas furthest from the exhaust inlet.

In contrast, the most effective method of ventilating the face of a heading to prevent methane accumulating is to use some form of forcing ventilation. The momentum of a force jet of air is such that it will carry for a considerable distance, its velocity decreasing only slowly, losing energy as it entrains additional air volume. Provided that a sufficient quantity of air is released close enough to the face of the heading, the forcing air will spread out in all directions, travelling to all corners of the roadway, preventing any possibility of methane accumulating. However, the effect of forcing ventilation with respect to dust control is to dilute the dust created during cutting, expelling it from the heading in the return air.

The general approach to this conflict in controlling both dust and methane is to combine elements of both types of ventilation. However, such an approach requires a strict balance of the various systems to achieve a reasonable level of control of both environmental problems. If the forcing element is not sufficiently effective, methane could still accumulate at the face while if its effect is too strong it can act to drive dust past the exhaust inlet resulting in poor dust capture efficiency of the scrubber, high dust levels around the machine and the uncontrolled release of dust into the return air.

The compliance testing required under the DME guidelines, together with statutory dust samples, have shown that such dust control problems are still prevalent in South African coal mines, particularly in larger headings. The present SIMRAC Research Project was therefore initiated to investigate and provide solutions to these problems. The primary objective of the work was to produce design guidelines and methodology for environmental control systems to optimise the dust capture efficiency of scrubber systems in these larger roadways.

The specific scope of work related to the following.

- Carry out a review of relevant environmental control systems and regulations in use world-wide together with evaluation of evidence from existing CFD modelling outputs for comparison with current South African practices and DME guidelines, for controlling dust in large section roadways.
- Survey 8 mine sites which are encountering dust problems, taking note of general dust behaviour and making recommendations for readily achievable improvements based on existing experience and implementation of previous research findings from work carried out by both SIMRAC and others.

- Carry out a survey of noise levels associated with the mining operations and evaluate the contribution of the dust scrubbers.
- Study specific site problems from two sites identified above, one involving a roadheader and the other a continuous miner, in a surface gallery to identify the causes of problems and examine the effect of making modifications to the system or the use of additional devices. The results of these findings to be implemented at a mine site and evaluated together with scrubber noise abatement measures.
- Formulate guidelines and methodology for the optimum design of scrubber and water spray systems on mechanical miners operating in medium and large roadways. These to be discussed with individual mine management and machine manufacturers to obtain the best practical design for particular machines.
- Produce guidelines for the use of any new, or modifications to existing, additional equipment identified above.
- Draw up guidelines and methodology for the optimum operation of all types of ventilation system for the effective control of both dust and methane in larger section roadways.
- Formulate recommendations for reducing noise levels from scrubbers for both retrofit and new equipment.

In the initial stages of the project, an extensive literature search was carried out in order to discover whether the various ventilation techniques used world-wide may have application under South African conditions. In addition, the results of recent computational fluid dynamics (CFD) modelling work and other work carried out under previous SIMRAC Research Projects were evaluated for further comparison with current South African practices and DME guidelines. This information was used to give some indication as to the best methods of maximising dust capture by scrubber systems while ensuring that subsequent investigations did not duplicate previous work. As an aid to identifying the nature of the dust control problems, a number of underground sites were also visited. This increased familiarisation with the practical application of the various ventilation systems together with operational techniques. From experience and the observations made during these underground visits an analysis of expected behaviour of dust and air flows during the various stages of a full cutting cycle has been drawn up. This compared the relative merits and drawbacks with regard to ventilation and dust for all the possible variants and options in the advance of bord and pillar sections. From this, an optimum pattern for the cutting cycle with regard to environmental control has been indicated.

Meetings were also held with various machine and equipment manufacturers in order to obtain specifications of the various types of equipment supplied to the mines and the recommended operating procedures for their equipment.

The main part of the investigations was carried out in a surface gallery in the UK, where typical ventilation layouts for both a continuous miner and a roadheader were simulated. The benefits of carrying out such work in surface galleries are substantial; the work can be carried out with no hindrance to production, consistent conditions can be reproduced and equipment which would not normally be allowed or is unsuitable for use underground can be used. Considerable experience of carrying out such simulations in surface galleries has been built up over a number of years, where the critical parameters for accurate simulations of underground conditions have been previously identified. The main objectives of the surface trials were :-

- To study the effect of each of the components of the on-board ventilation systems, both in isolation and in combination, in order to identify operating parameters and configurations which provided the best balance of ventilation and control of dust.
- To optimise the configuration of the scrubber system such that the best practical positioning for the inlet(s) to the scrubber could be identified to obtain the maximum dust capture efficiency and to minimise any effect of the discharge air from the scrubber on the air flows around the machine.
- To study the additional effect of any auxiliary ventilation fan on dust capture efficiencies, with particular attention being paid to the effect of jetfans.

By this means, it was hoped to identify the cause of dust control problems in larger roadways and examine practical means of preventing such problems through modification to existing equipment or the use of additional devices. In the original project proposal, one such device that was identified for study and development in the trials was air curtain systems. However, during the initial stages of the project it was discovered that development work on such devices had recently been carried out in South Africa and a number of systems were being installed. To avoid unnecessary duplication of this work and to reduce the overall cost of the project, this aspect of the project was not pursued. However, the effort originally envisaged in the project proposal relating to gallery testing and development of an air curtain system was replaced by more rigorous and extensive testing on other systems, together with additional aspects of the overall project.

In the surface trials, the use of multiple scrubber inlets sited on the jib of a continuous miner, similar in form to scrubber inlets used in the USA, were shown to be beneficial. A short underground trial was therefore carried out to try and validate the findings from the surface trials.

A final aspect of the project involved a survey of noise levels associated with mechanical miners and the relative contribution to these overall levels from the dust scrubber. A substantial amount of data was readily available from previous noise surveys carried out on similar UK mining machines. This has been compared with noise measurements taken around an Engart scrubber used in the surface trials to evaluate its contribution to the overall noise levels to be expected from mining machines. Recommendations for reducing noise levels from scrubber systems have been formulated from these measurements.

References

[1] R Wesley. Airflow at Heading Faces with Forcing Auxiliary Ventilation. Proceedings of the 3rd International Mine Ventilation Congress, IMM/IME, Harrogate, England, 1984, pp 73-82.

2. REVIEW OF VENTILATION AND DUST REGULATIONS AND PRACTICE, WORLD-WIDE

Literature searches have been carried out relating to dust and ventilation regulations and practice in the following countries, for comparison with the situation in South Africa :-

Germany

United States of America

United Kingdom

The following sections summarise the regulations, principles and usage of various types of equipment. Recent research carried out in South Africa on the ventilation of mechanised headings is also reviewed in Section 2.6.

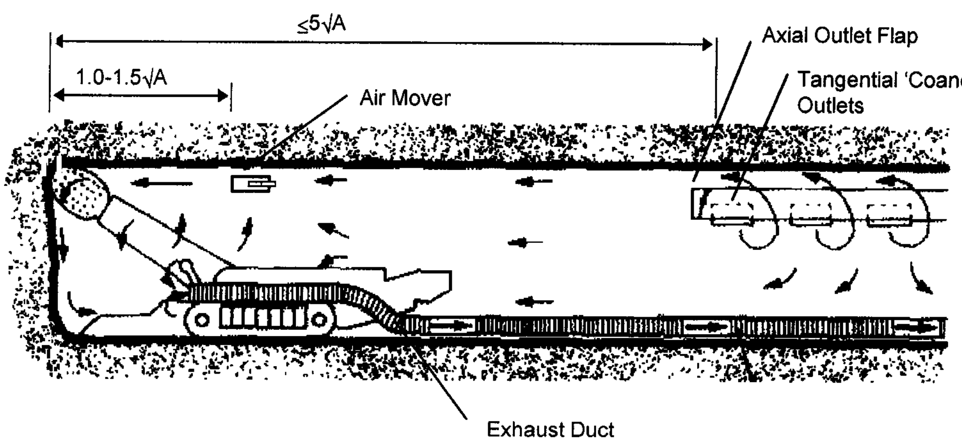
2.1 Ventilation and Dust Regulations

Germany

All drivages in German coal mines are single line developments for longwall faces. There are no bord and pillar type operations. Roadheading machines are used almost universally in drivages which in the recent past were all arch section, supported using steel RSJs. There has been a recent move towards rectangular section roadways supported using roofbolts.

Ventilation

The principles of drivage ventilation systems operated in Germany are described by Wesley (1984). A typical layout for an auxiliary ventilation system is shown below.



While not cutting, a simple forcing ventilation system is used with an axial discharge sited no more than 5√A from the face (where A is the cross-sectional area of the roadway). The use of an additional pneumatic airmover normally sited 1√A from the face ensures effective scouring of the face to remove methane. During cutting operations, the exhaust fan and deduster system are started, after which a flap valve at the discharge from the forcing duct is closed to prevent the air jet causing excessive disturbance of dust at the face, the forcing ventilation air then being released from special 'Coanda' duct sections sited near the end of the duct. These release the air tangentially into the roadway, helping to scour any methane layers from the roof in the poorly ventilated area of the roadway of the 'overlap zone' between the respective discharges of the forcing and exhaust systems. The regulations require that a ventilation air velocity of 0,5 m/s is maintained within the full cross-section of the roadway throughout its length, except for the 'overlap zone' provided the length of the overlap zone is no greater than 2√A. The forcing ventilation quantity must also be greater than the exhaust ventilation quantity to prevent recirculation of the discharged exhaust air back to the face.

The dry dust collectors used in Germany are very efficient, being capable of removing more than 99,9 % of respirable dust, but at the expense of very high pressure drops. To achieve the required air flows through the dust collectors it is common to use two or three auxiliary ventilation fans, of 90 kW or more, in series behind the dust collector. Typically, the dust collectors themselves are 7,5 m or more in length and with the addition of the fans, the equipment 'train' for the exhaust system behind the machine becomes very long. This can result in problems in maintaining the required position of the forcing discharge with respect to the face while keeping the overlap length to less than 2√A. In such circumstances, an additional short forcing ventilation duct system is used to ventilate just the overlap zone.

The exhaust system has either one or two inlets (with two inlets, they are located on either side of the machine) and the ducting is usually built into the body of the machine. The inlets are usually located in the lower third of the cross-section since, during cutting, the face is ventilated from roof to floor mainly due to the effect of the airmover sited in the roof. This air movement directs the dust made during cutting towards floor level from where it is drawn into the exhaust ducts.

For ignition prevention and dust suppression, all machines are fitted with wet heads, sprays being sited behind the cutter picks. These spray systems must be operating while the machine is cutting. To reduce water consumption, these systems are sometimes phased. In these systems water is released only on sectors of the cutting head which are in cut at any one time. Alternatively, the sprays may be 'pick activated', the cutting forces operating on the pick opening a valve to supply water to the spray behind that pick.

Dust

Germany operates a dosage-index standard based on the principle that a defined dosage relationship exists and that a worker should only be exposed to a toxic dust for a specified maximum time if no harmful effects are to be expected. A fixed point sampling method is used to determine respirable dust concentrations, from which the particular workplace is classified. In addition to this, each man is given a pneumoconiosis classification based upon compulsory X-rays taken every two years. These classifications are then used in combination to determine the number of shifts which an individual may work in particular dust conditions over a five year period.

The basis for the classifications is that, for a man who is judged to be 'clear' of any trace of pneumoconiosis over a 5 year period, his permissible average exposure to dust is subject to a limit of 4,0 mg/m³ provided that the quartz content of the dust is less than 5 %. For a quartz content of greater than 5 %, a limit value of 0,15 mg/m³ of quartz is applied. Men showing a 'trace' or greater classification of pneumoconiosis are subject to lower limits as shown in the following table :-

Workplace Classification		Respirable Quartz Conc. if Quartz content is >5 %	Overall Respirable Dust if Quartz <5 %
I	All may work.	< 0,2 mg/m³	< 5,0 mg/m³
II	All men classified as 'clear' of pneumoconiosis may work. Men with 'trace' of pneumoconiosis limited to 400 shifts in a 5 year period. Men with positive pneumoconiosis are not permitted to work.	0,2 - 0,4 mg/m³	5,0 - 10,0 mg/m³
III	Only men classified as 'clear' may work, limited to 400 shifts in a 5 year period.	0,4 - 0,6 mg/m³	10,0 - 16,0 mg/m³

It may be seen from the Table that although the workmen's *average* exposure is limited to 4,0 mg/m³, at Class I workplaces all men may work in zones where dust concentrations are less than 5,0 mg/m³. This apparent discrepancy takes into account the normal variations in dust conditions such that, provided the workplaces operate within a *limit* value of 5,0 mg/m³, a particular workman's dust exposure *averaged over a five year period* should not exceed

4,0 mg/m³. Similarly, by restricting men to working in high dust levels for a limited number of shifts in a five year period their *average* exposure may be limited to 4,0 mg/m³.

United States of America

A large proportion of coal production in the USA is from bord and pillar methods of extraction, typically in seam sections varying from 0,9 to 3,0 m. Most sections comprise three, four or five-entry roadway systems. Continuous miners and auger miners are commonly used for these operations.

Ventilation

Federal Regulations require a minimum of 4,25 m^3/s of air to be provided in the last open crosscut between any pair or set of rooms or at the intake end of a pillar line. A minimum of 1,42 m^3/s of air is required in each working face from which coal is being cut, mined or loaded with an additional requirement to maintain a minimum mean air velocity of 0,3 m/s (60 fpm). On belt conveyor entries the minimum velocity is that which provides methane dilution and sufficient oxygen. The air moving over the conveyor is to be a separate supply of air which is not used to ventilate the workings.

The most common method of ventilating entries is using line or "check" brattice curtains to course the ventilation air up to and around the faces of the section. Such systems are used for both forcing and exhaust forms of ventilation. Auxiliary fans with ducting are also used for exhaust ventilation. The brattice or duct outlet/inlet should normally be maintained to within 3 m (10 ft) of the face, although with the additional use of sprayfan or on-board scrubber systems in conjunction with remote control machine operation, brattice curtain or duct setbacks of up to 15 m are commonly used. A curtain setback of 15 m would normally allow a cutting depth of 12 m to be taken before the miner moves to the next cut.

The two most common types of ventilation systems for deep cut techniques are :-

1. On machine scrubber system in combination with forcing line brattice ventilation.
2. Sprayfan system in combination with exhaust ventilation.

Scrubber and sprayfan systems are described in detail later (see Sections 2.3 and 2.4 respectively). In summary, however, in the first type of ventilation system, scrubber systems in conjunction with water sprays on the machine are used to ensure ventilation of the face at greater depths of cut while also extracting and removing dust from the air. In the second type of ventilation system, effective ventilation of the face is achieved using a sprayfan system to push fresh air to the face and drive the dust and methane around the face towards the exhaust brattice curtain inlet.

The US Bureau of Mines recommends that the main ventilation and scrubber quantities should be within 0,47 m^3/s (1 000 fpm) of each other to prevent excessive recirculation and ensure maximum capture of dust. For the same reasons, the water pressure supplied to the sprayfan system is usually set up on site through experimentation, in order to obtain the correct balance of air flows between the main ventilation and the sprayfan systems.

Dust

In the USA, respirable dust is defined as dust below 5 µm in size. A system of personal sampling of the machine operator is used with a maximum exposure limit of 2,0 mg/m^3 where the quartz content is less than 5 %. Lower limits, specific to the quartz content of the sample, are applied where quartz content of the dust is greater than 5 %. Intake concentrations should be less than 1,0 mg/m^3.

United Kingdom

The majority of drivages in the UK are single line developments for longwall faces, although the driving of parallel, multiple gate roads using place-changing techniques are becoming increasingly common. A small number of bord and pillar sections are also operated. Both roadheader and continuous miner type machines are used.

Ventilation

Most drivages in the UK are ventilated by force-exhaust ‘overlap’ systems. Simple exhaust systems can be used for short drivage distances only. Simple forcing systems are rare, mainly due to dust control problems. All ventilation systems utilise auxiliary fans and ducts. Whichever type of system is used, for the final system ventilating the face, the duct inlet or outlet must be sited within 5 m of the face. Regulations require a minimum air velocity of 0,27 m/s to be achieved in the full cross-section of the roadway over its full length and 0,4 m/s in the section around the machine.

With overlap systems, the forcing ventilation is used to supply fresh air to the vicinity of the face while a short exhaust system (with the inlet closer to the face) pulls this air to the face while also extracting the dust. The discharge of the exhaust system and that of the forcing system must overlap by at least 5 m to minimise recirculation, although the overlap length is always kept as short as possible since the overlap section is ventilated only by the difference in quantity passed by each system. Normally, the forcing quantity must exceed that of the exhaust to prevent recirculation. However, in certain circumstances and with special provisions, 'controlled recirculation' ventilation systems may be used, although such sites are rare. At sites with high methane emissions, the forcing ventilation duct is normally sited close to the face (within 25 m is recommended) in order to increase air velocities at the face. It is recognised, however, that siting the duct closer than 15 m to the face will cause dust problems. In circumstances where the forcing duct outlet needs to be sited closer to the face, diffuser-type devices are normally fitted to the discharge to prevent too great a disturbance of the dust from cutting and to allow effective dust control.

A number of continuous miner machines operating in bord and pillar sections in the UK are fitted with USA type on-board scrubber systems which are operated in conjunction with main forcing auxiliary ventilation.

All machines operating in the UK are required to be fitted with some form of cutting zone ventilation system for the prevention of ignitions. On continuous miners, this is achieved using angled, hollow cone sprays mounted on the top of the jib of a similar form to those of a sprayfan system. On roadheading machines, water or compressed-air powered airmovers are sited on the machine jib, directing air to the top of the cut. All these systems are interlocked to the cutter motors of the machine to ensure correct operation at all times.

Dust

In UK drivages a fixed point sampling method is used, an MRE113A gravimetric sampler being suspended in the vicinity of the machine operator's breathing zone. The current limit in drivages is 5 mg/m^3 for a quartz content less than 0,45 mg/m^3, reduced to 3 mg/m^3 for higher quartz concentrations. The 5 mg/m^3 upper limit is based on a likely maximum dust exposure for an average drivage worker of 3,3 mg/m^3, the latter figure being the basis for health risk calculations. The difference between the two figures takes into account lower exposure during the part of the shift spent traveling and that a single worker is not likely to work in the worst dust conditions throughout his working life.

Summary of South African regulations

Ventilation

In mechanical miner sections the average air velocity in the last through road (LTR) must be 1 m/s with a minimum of 0,6 m/s at any point. Within the heading, the secondary ventilation system (an on-board force system, such as sprayfans, and a scrubber, which may be on- or off-board) must supply a flow of at 0,4 m/s past the operator. Once the heading has advanced more than 12 m from the LTR additional force or exhaust fans must be brought into operation. A maximum recirculation factor of 50 % is permitted for on-board scrubbers. A directive released after the completion of this project, the roof of a heading must be supported after advancing 12 m so that the discharge of auxiliary ventilation can be maintained close to the face.

Dust

Respirable dust is defined to have a diameter less than 7 µm. For a quartz content less than 5 %, spot measurements must have a respirable concentration less than 10 mg/m^3 and a respirable eight hour time weighted average (TWA) concentration of less than 5 mg/m^3. A daily gravimetric dust sample taken over the full shift is required each mechanical miner.

Comparison of German, UK and USA regulations with South African regulations

Ventilation

In South Africa and the USA, where bord and pillar methods of working are common, the minimum requirement for the primary ventilation of a section is specified in terms of the last through road (LTR). In the USA, a minimum quantity of 4,25 m^3/s is specified for the LTR ventilation while in South Africa the requirement is to achieve a minimum average air velocity of 1 m/s and no less than 0,6 m/s at any one point in the roadway. There are no comparable regulations in Germany or the UK where the regulations have been derived around single line drivages. In Germany and the UK minimum standards are laid down for the ventilation of a blind heading and the main airway must carry sufficient extra air to prevent recirculation by the auxiliary ventilation system while maintaining adequate ventilation at all points of the main airway.

To ensure good ventilation of a heading and the prevention of methane layering, most countries specify a minimum air velocity to be maintained by the auxiliary ventilation system within the heading. The highest requirement is in Germany at 0,5 m/s followed by the USA at 0,3 m/s and the UK at 0,27 m/s. In South Africa, such a figure is only stipulated for sites where main force column systems or jetfans are used, where a minimum discharge volume of 0,2 m^3/s per m^2 of face area (or a velocity of 0,2 m/s) is required, and for overlap systems where a minimum velocity of 0,4 m/s must be maintained in the overlap.

A further ventilation air velocity requirement is stipulated in the UK and South Africa, which is that of air velocity over the machine operator position. This parameter relates to the prevention of dust roll-back where scrubber or exhaust column systems are used as well as further reducing the possibility of methane layering close to the face. Both countries stipulate a minimum velocity of 0,4 m/s. Although this parameter is not specifically stipulated in German or USA regulations, the requirements for the general roadway ventilation will have a bearing on actual velocities around the machine. In Germany, the requirement to maintain 0,5 m/s in the full roadway section will result in much higher velocities around the machine. In the USA, the velocity will similarly be greater than 0,3 m/s. Work carried out in both the USA and the UK has shown that provided a ventilation system is well managed and that there is no excessive disturbance to the dust cloud, a forward velocity of 0,5 m/s around the machine operator should be adequate to prevent the dust cloud reaching his position.

In South Africa, 50 % recirculation by on-board scrubber systems is permitted to allow higher air velocities past the machine operator to be achieved. Such recirculation systems can also be used in the UK, provided that the system is fully monitored and specifically approved by the Mines Inspectorate. Such systems are very rarely used in the UK.

In all four countries it is recognised that forcing ventilation is best for the control of methane while exhaust ventilation is best for dust control. For many years it was believed that the best method of dealing with dust was by providing minimal disturbance to the dust cloud from cutting, thus allowing it to be extracted by a scrubber or exhaust ventilation system whose inlet was sited close to the face. However, under these conditions, the low velocities at the face can allow dangerous accumulations of methane to develop, substantially increasing the risk of frictional ignition. The common approach to overcome this problem is to use some form of force ventilation system in the form of sprayfans, airmovers, air curtain systems or even main force ventilation systems to effectively ventilate the face and drive the dust and methane towards the extraction system. Such an arrangement must be balanced such that the forcing system is effective at ventilating the face whilst not being too powerful such that it pushes dust past the inlet to the extraction system. These systems are reviewed in later sections.

Dust

In South Africa, in addition to statutory risk assessment sampling, the relevant DME guidelines include a compliance test for judging the effectiveness of the secondary ventilation system in terms of dust conditions. This compliance test requires one gravimetric dust sample to be taken per day from each mechanical miner. The sample must be taken at a stationary position inside the driver's cab and the sampling conducted on a production shift. The acceptable respirable dust level for less than 5 % quartz content is less than 10 mg/m^3 for spot measurements taken over a period of one minute, or less than 5 mg/m^3 for an eight hour TWA.

Only the 5 mg/m^3 value for the eight hour TWA is comparable to the standards used in the other countries, which is similar to that set in both the UK and Germany but less stringent than the 2,0 mg/m^3 in the USA.

2.2 Jetfans

Jetfans are standard axial-blade fans fitted with reduction nozzles on the outlet side to increase the discharge velocity of the air from the fan and hence the penetration of the jet. Such fans are capable of effectively ventilating deep, blind headings without the necessity for ducts. Thus, the requirement for manually advancing duct systems is eliminated, together with the need to provide roof support to protect workers while they advance the duct system. The use of such fans therefore has large benefits for production not only by reducing lost production time due to installing and advancing duct systems but also by allowing greater depths of cut to be taken before place changing.

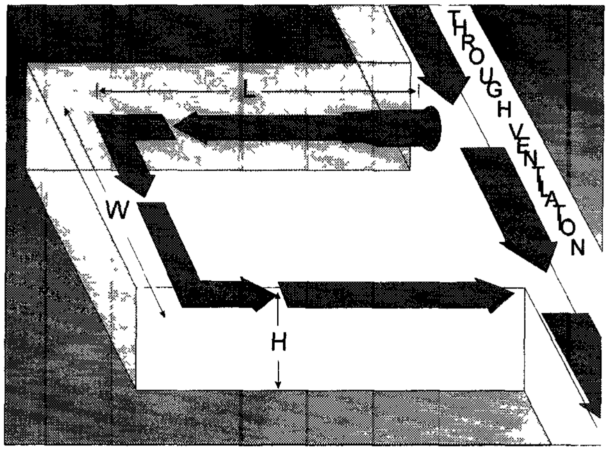
Jetfans have traditionally been used for a variety of purposes including tunnel ventilation and as booster fans together with ventilating large faces in metal mining. Their use in heading development in coal mines is relatively new. Although the use of jetfans for this purpose has been investigated in the USA as a method of providing ventilation in deep cuts [1,2], their use is restricted at present to South Africa where most research in this context has been carried out. (This work is reviewed in Section 2.6). The benefits from the use of jetfans are so great that they are now the most common method of providing auxiliary force ventilation in South African coal mines.

The theory behind the jetfan is that by producing a high outlet air velocity, the jet of air will travel further. On discharge from the fan the jet expands, entraining further air from its surroundings into the air stream, resulting in the jet slowing down but increasing in volume as distance from the fan increases. In a blind heading, the penetration of the jet is ultimately determined by the roadway shape and dimensions such that the jet expansion is limited by the walls of the roadway while still leaving sufficient area outside of the inflowing jet for the air to return from the heading. This penetration distance can be increased by siting the jetfan close to a corner of a rectangular section roadway so that the jet 'attaches' itself to the walls restricting the expansion of the jet on two sides. The effectiveness of this technique is, however, dependent upon the 'roughness' of the wall which can result in frictional losses or, in the worst case, detachment or deflection of the jet away from the wall [3, 4].

Information on the performance of jetfans in development end ventilation has been obtained from one manufacturer, Howden Safanco, which is reproduced below.

Fan Type	Airway Ratio (see below)	Thrust (Newtons)	Effective Depth Dead End Ventilation L (m)	Air Moving Capacity (m^3/s)	Velocity at Nozzle (m/s)	Fan Volume (m^3/s)	Absorbed Power (kW)
305/0,75 JF	C	17	17	3,5	22	0,65	072
406/4 JF	B	96	32	8,5	42	1,9	3,2
406-2/8 JF	B	131	43	9,5	57	1,9	6
572/8 JF	A	181	32	24	43	3,5	5,8
572/11 JF	A	211	29	26	39	4,5	9
572/18,5 JF	A	409	46	34	39	5,5	15,3
572-2/30 JF	A	482	61	35	82	4,9	33

Most Effective Airway Ratios						
	Airway Ratio			Typical Size		
	L	W	H	L	W	H
A	12	1,5	1	60	8	5
B	15	3	1	30	6	2
C	15	4	1	22,5	6	1,5



From this data it may be seen that jetfans can be effective at ventilating faces a considerable distance from the fan. In addition, comparison of the data for fan volume and air moving capacity shows that the fans can entrain between 4,5 and 7 times the volume of air passed through the fan itself. This aspect of the use of jetfans makes them highly effective at maintaining high velocities within the heading, helping to scour the roof and face of methane and ensuring that it is rapidly mixed and diluted into the general body air. However, a high proportion of this additional air flow moved by the jet is drawn from the general body of the air **within** the heading, and hence recirculating contaminated, outflowing air back to the face. The remainder of the entrained air is drawn from the LTR where care must be taken in siting the jetfan to ensure that the fan itself passes only fresh, intake air and does not recirculate contaminated air flowing out from the heading. Such recirculation around the fan inlet is prohibited in the ventilation guidelines. It is the fresh air volume introduced into the heading by the jetfan which determines the dilution of any gas produced within the heading. Recirculation of air within the heading itself should not, therefore, lead to any overall increase in general body gas concentrations. However, this recirculation can lead to dust problems unless the dust can be effectively captured and removed from the air by a high efficiency scrubber system.

References

[1] G V R Goodman, C D Taylor and E F Divers. Ventilation schemes permit deep advance [USBM, Pittsburgh Research Centre] Coal, October 1990, pp 50-53

[2] G V R Goodman, C D Taylor and E D Thimons. Jet fan ventilation in very deep cuts - a preliminary analysis [USBM, Pittsburgh Research Centre] USBM Report of Investigations RI9399, 1992

[3] L W Jenner. Jet fan - an old principle put into practice. Proceedings - The effects of mechanised mining 21-24 May, 1989, Mine Ventilation Society of South Africa.

[4] M Dumka, A P J Meets and C B J Reynolds. Practical airjet fan applications in mechanised mines. Proceedings - The effects of mechanised mining 21-24 May, 1989, Mine Ventilation Society of South Africa.

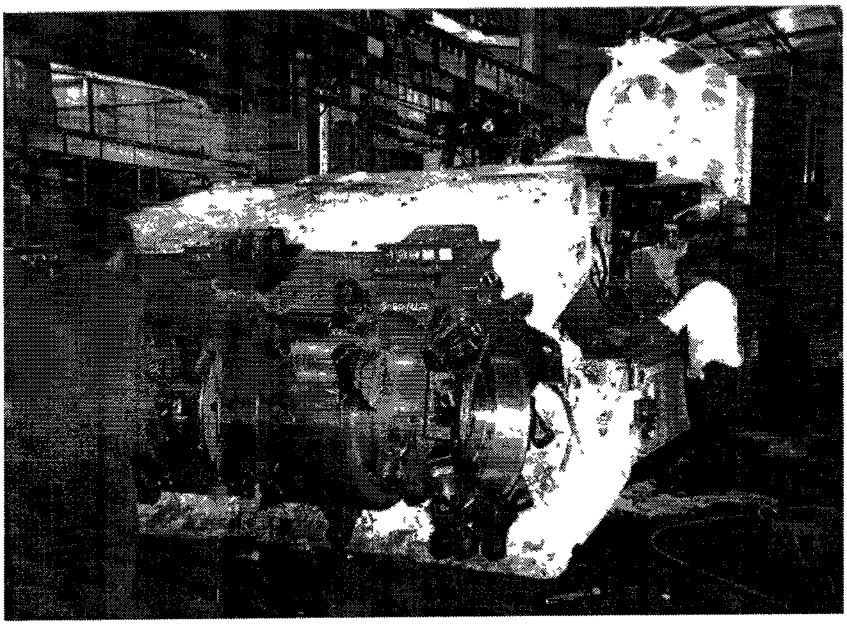
2.3 Scrubber Systems

Dust may be removed from air in several different ways using the cyclone principle, dry filter materials or by passing dusty air through water. Cyclone systems have only a limited application in mining since they are not very efficient at removing small, respirable particles. Dry filter systems are capable of very high efficiencies for respirable dust. However, such systems are in universal use in Germany, giving filtration efficiencies of better than 99,9 % on respirable dust, requiring very high pressure drops and the use of powerful fans. The most common form of scrubber used in coal mining world-wide is the wet scrubber. This comes in many different forms but the most efficient types involve passing dust laden air through a screen which is kept constantly wet by water sprays sited immediately in front of it. The filter screen acts to hold the water in the air flow encouraging intimate mixing between the water and dust so that the dust is wetted and carried away in the water which drains from the screen. Behind the screen, mist eliminators are used to remove any water blown through the screen by the air flow, allowing clean, dry air to be discharged from the scrubber. Respirable dust collection efficiencies in excess of 90 % on coal dust are achieved with such scrubber systems. Greater scrubber efficiencies may be obtained by passing additional water through the impellor of a fan sited upwind of the filter screen. Water sprayed onto the fast-moving impellor blades of a fan is finely atomised and again effectively mixed with the dusty air, capturing some of the dust before it is passed to the filter screen where it is removed. This combined form of wet scrubber was originally developed in the UK where it is known as the MRDE Dust Collector [1,2]. The combined filtration processes allow the scrubber to give a reasonably constant dust removal efficiency over a range of air flows which can be in excess of 95 % for respirable coal dust.

All scrubber systems remove larger size fractions of dust more efficiently. The size fraction of dust in the discharged, clean air being appreciably smaller than that drawn into the inlet. If respirable dust is recirculated around a scrubber it may therefore, for example, have an efficiency of 95 % on the first pass, but only 60 % on the second pass, 40 % on the third, diminishing further with each subsequent pass. (The actual efficiency figures are dependant on the specific size distribution of the dust and the particular scrubber performance.)

The scrubber systems normally used in South African coal mines are of the wet type, manufactured by Howden Safanco and Colliery Dust Control Services. Howden Safanco produce the Engart range of dust extractors, which are in fact MRDE Dust Collectors produced under license to British Coal Corporation. Colliery Dust Control Services originally manufactured wet screen scrubbers with a dry fan located on the outlet side but have recently introduced a new version, incorporating a wet fan, with claimed efficiencies similar to those of the Engart range. Since these scrubber units have a proven high dust filtration efficiency, it was not an objective of the present project to try to gain further improvement in efficiency. However, the layout of the scrubber unit and the positioning and configuration of the inlet and outlet do have a bearing on the main objective of the project, which was to improve the overall efficiency of capture of dust produced from cutting.

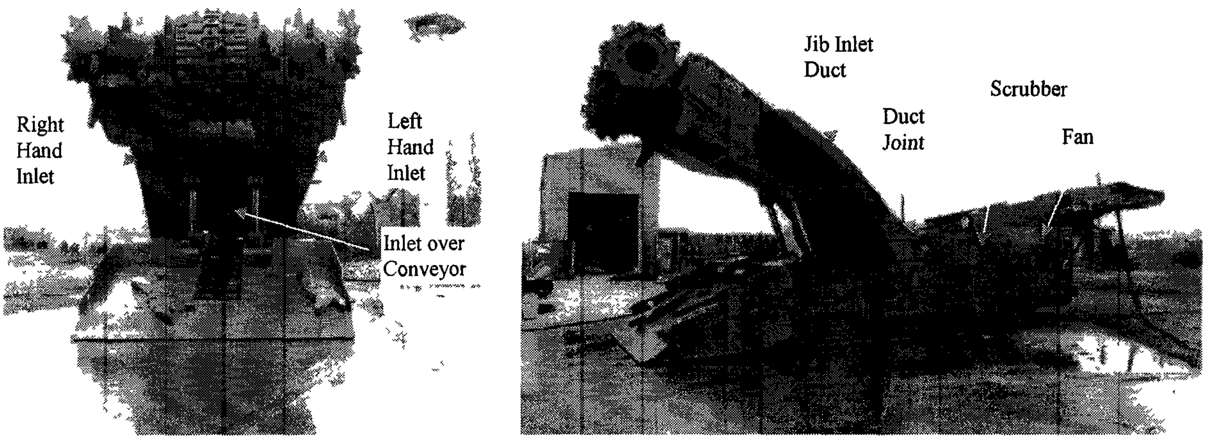
The scrubber units are normally fitted to mechanical miners as 'add-on extras', sited on top and to the rear of the miners on the opposite side of the machine to the operator's position as shown in the photograph below.



Joy 12HM21 continuous miner fitted with 10,5 m^3/s Engart scrubber Unit

The scrubber inlet is normally located above the body of the machine some 5 to 6m back from the front of the cutting head. On continuous miners, extension ducts are sometimes fitted to the scrubber inlet, transforming the inlet to a rectangular section, which is narrower but deeper than the fan inlet. Such ducts normally take the inlet some 1 to 1,5 m closer to the face, level with the front of the tracks, often extending the inlet closer to the floor. In practice, however, such extension ducts tend to be vulnerable to damage, although mine staff who have tried such devices have reported benefits in the form of improved dust capture. Similarly, on roadheader type machines, Voest Alpine produce a 2 m inlet extension duct made of rubber. This extension permits full movement of the machine jib by allowing the jib to deform the inlet duct when cutting the extreme side of the profile closest to the inlet. This device was tried on an AM80 roadheader in a local colliery with some success. However, when a visit was made to the colliery to view the system in use, it had been removed from the machine. The colliery intended to refit the extension since it was believed to give benefits for improved dust capture.

In the USA and the UK, on-board scrubber systems fitted to continuous miner machines are also common. Unlike South Africa, however, complete scrubber systems tend to be designed and manufactured by the machine suppliers themselves and therefore purpose-built into the machine. Designing the scrubber system into the machine in this way tends to make the components much less vulnerable to damage. The requirement to ventilate within 3 m of the face in the USA means that the scrubber inlets are normally ducted onto the jib of the machine, a flexible joint in the ductwork allowing vertical movement of the jib. The scrubber systems normally have two inlets sited on the jib, drawing air from underneath the jib on either side, sometimes with an additional, third inlet sited at the back of the jib above the conveyor. During the development of this type of scrubber, Campbell [3, 4] showed that the zone of air capture by the inlets did not reach the face of the heading. The additional use of a symmetrical arrangement of water sprays on top of the jib being required to drive gas and dust down and back from the face towards the inlets. Photographs of such a scrubber system on a Joy 12CM18 machine are shown below.



Front and side views of a USA type scrubber system fitted to a Joy 12CM18 Continuous Miner

The actual scrubber units incorporate a wet screen but the fan, sited at the back of the machine, is operated dry. The system typically gives filtration efficiencies of the order of 90 % for respirable coal dust. The largest known size of scrubber unit is rated at 4,5 m³/s, which is relatively small by South African standards. Much research work into the effectiveness of these types of system for effective face ventilation and dust control has been carried out [5-10].

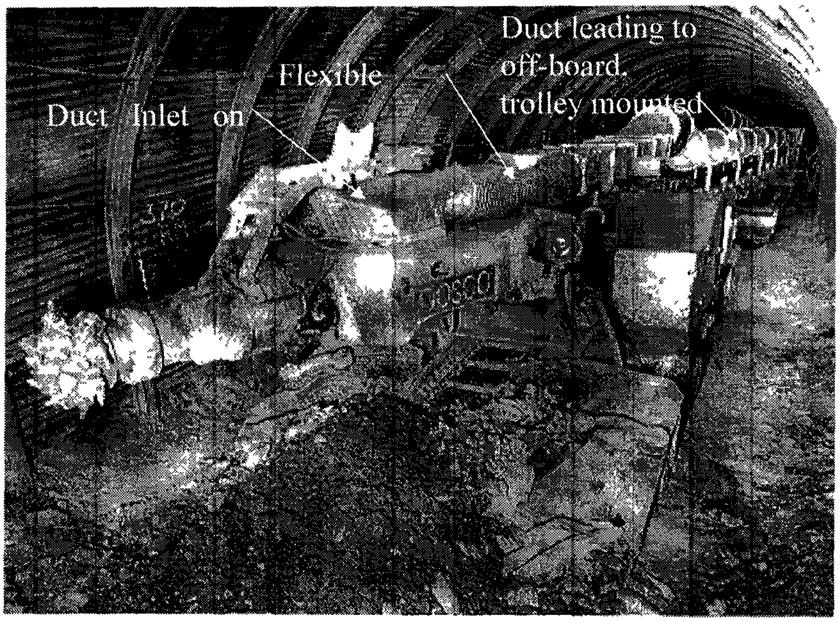
In smaller seam sections in the USA, where it is more difficult to fit ducts onto the jib, alternative configurations of scrubber have been tried, including dust scrubbers fitted over the conveyor throat of the jib [11, 12] and systems with a single inlet sited just behind the jib on one side of the machine, used in conjunction with directional sprayfan sprays. The latter type of system has been the subject of recent research [13, 14].

In the USA, scrubber systems are normally operated in conjunction with a forcing auxiliary ventilation system, although there is an increasing trend towards use with exhaust systems. The US Bureau of Mines recommends that the auxiliary ventilation volume be matched to the scrubber volume with the auxiliary ventilation volume being some 10 to 20 % higher than the scrubber quantity to avoid recirculation while giving optimum capture of dust.

On-board scrubbers are rarely fitted to roadheading machines worldwide since these types of machine are usually employed in single-line drivages where required machine mobility is much less than in bord and pillar sections. However, in Germany and the UK, there has been extensive experience with off-board scrubbers used in overlap ventilation systems where the scrubber inlet has been ducted onto the machine.

In Germany, scrubber inlets are ducted to the front of the machine body on one or both sides of the machine. These are normally located in the lower third of the roadway cross-section to give optimum dust capture of dust driven down the face towards the floor by an airmover sited in the roof (see section 2.1 for further details) [15,16]. Only a very limited amount of machine movement is enabled in these systems by the expansion and collapse of flexible ducting.

In the UK, much work was carried out on improving dust capture by scrubber systems on roadheading machines operating in single-line drivages in the late 1970's and early 1980's. In this work, it was found that ducting the scrubber inlet onto the boom of the roadheader brought considerable benefits, such that the inlet was sited as close as possible to the machine cutting head at all times. A number of systems were engineered and used on various machines, mostly heavy duty roadheaders cutting hard rock in large arch-section roadways. Such machines produce very large amounts of dust which was difficult to control in the large cross-section using a conventional roof-mounted exhaust duct system. In such systems, the jib inlet was connected via a flexible joint to ducting on the machine, then via another flexible joint to ducting on the bridge conveyor leading to an off-board, trolley-mounted scrubber on the end section of the main conveyor, as shown in the photograph below.



Jib mounted scrubber duct system fitted to a Dosco Mk2B Roadheader in the UK

This arrangement gave the machine a reasonable amount of movement while retaining an overlap between the main forcing ventilation system and the exhaust system [17, 18, 19]. Few systems are still in use, however, mainly due to a change in mining techniques in the UK where smaller, rectangular section roadways are now driven largely in-seam, without the need to cut hard strata.

References

[1] Dust control by exhaust ventilation and filtration. Final Report on ECSC Research Project 6253-11/8/022 [National Coal Board, MRDE], 1975

[2] Dust control by exhaust ventilation and filtration. Final Report on ECSC Research Project 6253-11/8/065 [National Coal Board, MRDE], 1978

[3] J A L Campbell and W S Smith. Peabody's scrubber system improves both health and safety. 69th Annual Convention, Mine Inspectors' Institute of America, Columbus, Ohio, June 1979.

[4] J A L Campbell. The recirculation hoax. Proceedings of the 3rd US Mine Ventilation Symposium, University Park, PA, Oct 1987, pp 24-29

[5] Scrubber in blowing section offers good ventilation taking 50 foot cuts. Technology News No.209 [USBM], September 1984

[6] J C Volkwein, G Halfinger, Jr and E D Thimons. Machine-mounted scrubber helps ventilate face. World Mining Equipment, Vol 9, No. 2, Feb 1985, pp15-16

[7] N I Jayaraman, J C Volkwein et al. Enhancing continuous miner production with scrubbers and exhaust ventilation. Proceedings of 3rd International Conference on Innovative Mining Systems, Univ. MO, Rolla, MO, 1988

[8] E F Divers and J C Volkwein. Scrubbers versus sprayfans for face ventilation - a comparison. Publication unknown.

[9] G V R Goodman and C D Taylor. A technique for evaluating scrubber recirculation during deep cut mining. Proceedings of the 6th US Mine Ventilation Symposium, SME,1993, pp 19-24

[10] A Samanta, R Bhaskar and R Gong. Studies on the use of scrubbers in continuous miner faces. Proceedings of the 6th US Mine Ventilation Symposium, SME,1993, pp 51-56

[11] N I Jayaraman, J C Volkwein and F N Kissel. Update on continuous miner dust scrubber applications. Mining Engineering, Vol 42, No 3, March 1990

[12] N I Jayaraman, J F Colinet and R A Jankowski. Recent basic research on dust removal for coal mine applications. 5th International Mine Ventilation Congress, Johannesburg, 1992, pp395-405

[13] J C Volkwein and T S Wellman. Impact of water sprays on scrubber ventilation effectiveness. USBM Report of Investigations RI9259, 1989.

[14] C D Campbell and W Allen Dupree, Jr. Evaluation of methane dilution capacity of a blowing face ventilation system using a water sprayfan and dust scrubber. Proceedings of 5th US Mine Ventilation Symposium, SME 1991, pp109-118

[15] G Dupre and K Graumann. Ventilation around heading machines fitted with dust exhausters (Part 1). Bergbau 5, 1978, pp 188-196

[16] G Dupre and K Graumann. Ventilation around heading machines fitted with dust exhausters (Part 2). Bergbau 6, 1978, pp 226-272

[17] Dust control at the ends of longwall faces. Final Report on ECSC Research Project 6253-11/8/046, National Coal Board, MRDE, 1976

[18] Further work on the control of dust at the ends of longwall faces. Final Report on ECSC Research Project 7251-11/8/084, National Coal Board, MRDE, 1979

[19] Dust control in drivages and roadways. Final Report on ECSC Research Project 7256-12/030/08, National Coal Board, MRDE, 1981

2.4 Sprayfan Systems

Sprayfan systems are based on the ability of water sprays to move air and therefore to act as ventilation devices. Systems were originally developed in the USA in the mid-1970's for use on continuous miners to aid the movement of fresh air to ventilate the face of a heading with exhaust ventilation. The system normally comprises between 15 and 30 water spray nozzles located on top of the machine jib, just behind the cutter drums, and on one side of the machine body. With the correct layout and angling of the sprays the system moves and directs air forwards along one side of the machine, across the face and outbye on the opposite side of the machine towards the exhaust ventilation inlet. The improvement in face ventilation achieved by the system was such that the Mine Safety and Health Administration (MSHA) began permitting extended cuts to be taken whereby the exhaust ventilation inlet was allowed to be sited further than the normal 3 m from the face. Improvements were made to the system in the mid-1980s and demonstrated to give good control of both methane and dust in headings with the exhaust inlet as far back as 12 m from the face, provided that the sprays were operated at pressures lower than approximately 10bar [1, 2, 3, 4]. At higher pressures, it was found that although ventilation of the face was improved, the spray system had the potential to overwhelm the primary ventilation system causing excessive turbulence and consequent dust roll-back [5, 6, 7]. In view of the dust roll-back problem it is currently recommended that the sprayfan system be set up at each site, setting the spray pressure in balance with the main entry ventilation in the section. This is carried out using a powder-type fire extinguisher to visualize the air flow patterns.

The sprayfan systems used on continuous miners in South Africa are very similar to those described above and are suitable for use as on-board forcing systems within the terms of the ventilation guidelines.

A similar system of sprays is required on all continuous miners in the UK for providing ventilation of the cutting zone to prevent ignitions of methane. However, the system has been extensively modified to minimize water consumption to avoid the frequently encountered problem with soft floor conditions. The system therefore comprises 8 to 10 1,4 mm orifice, hollow cone sprays located across the top of the jib and angled to one side of the machine (the number used varying with cutting head widths from 3,0 to 4,9 m). An additional bank of 3 sprays is normally sited in one corner of the loading shovel. To avoid problems with dust roll-back, water pressure at the sprays is limited to between 11 and 17bar [8, 9]. Where US type multi-inlet dust scrubbers are used in the UK, it is normally recommended that the sprays are not angled to one side of the machine such that the methane and dust is directed around the cutter drums, down the face towards the inlets beneath the jib.

In view of continuing problems with dust roll-back from water spray systems in the USA, recent research has led to the development of a new 'Tuned Spray System', in which fewer, large orifice, flat fan sprays are sited beneath the jib of the machine, together with forward directed, single sprays on either side of the machine body [10]. Flat fan sprays still move air, but to a lesser extent than hollow cone sprays, while the use of large orifices allow water quantities to be maintained. Laboratory tests on this system suggested a much lesser tendency for the system to induce dust roll-back while giving improved ventilation of the face when compared with a conventional system with sprays above the jib.

On roadheading machines in South Africa, a different type of sprayfan system is used to ensure good ventilation of the face, utilizing water-powered airmovers. In these devices a hollow cone water spray is located within a short, steel tube or box. Such a confinement of the water spray reduces its total air moving capacity but concentrates the air moved into a jet with higher velocity and consequently greater 'throw' [11, 12]. Such devices, when used at very high pressures, can be used as high efficiency dust scrubbers in their own right, but for ventilation purposes they are normally used at lower pressures as a means to direct air to localized areas. On most roadheaders, the latter virtue is utilized, where a collection of airmovers, mounted in a vertical box frame located on one side of loading shovel, is used to direct ventilation air into one corner of the face, sweeping methane and dust towards the scrubber inlet on the opposite side of the machine. In principle, this is very similar to the use of roof-mounted compressed air movers in Germany except that the sweep of air movement on the face of German headings is from roof to floor.

In the UK, water powered airmovers are used slightly differently on roadheading machines, being mounted on the top of the jib of the machine, directing the air moved into the immediate cutting zone for ignition prevention purposes [8, 9]. To prevent excessive turbulence and avoid dust roll-back, the water pressure applied is limited to a range of 17 to 34bar.

References

[1] S K Ruggieri, D M Doyle and J C Volkwein. Improved sprayfans provide ventilation solutions. Coal Mining, Vol 21, No 4, April 1984, pp 94-98

[2] J C Volkwein, S K Ruggieri, C McGlothlin and F N Kissel. Exhaust ventilation of deep cuts using a continuous-mining machine. USBM Report of Investigations 8992, 1985

[3] S K Ruggieri, J C Volkwein, F N Kissel and C McGlothlin. Extended advance face ventilation systems. Proceedings of the 2nd US Mine Ventilation Symposium, Reno, NV, Sept. 1985

[4] E F Divers and J C Volkwein. Scrubbers versus sprayfans for face ventilation - a comparison. Publication unknown.

[5] R A Jankowski, F N Kissel and R E Nesbit. An update on the reduced standards problem and overview of improved control technology for respirable coal mine dust. Proceedings of the 2nd US Mine Ventilation Symposium, Reno, NV, September 1985, pp 151-167

[6] R A Jankowski, N I Jayaraman and C A Babbitt. Proceedings of the 3rd US Mine Ventilation Symposium, SME 1987, pp605-611

[7] J F Colinet, J J McClelland and R A Jankowski. Interactions and limitations of primary dust controls on continuous miners for reducing quartz and coal dust concentrations.

[8] Notes for Guidance on the Control of Frictional Ignitions and Dust on Heading Machines. British Coal Corporation, Revised January 1990.

[9] E J Browning and J S Warwick. Ignition prevention. Mining Engineering, Vol 152, No. 376, Jan 1993, pp204-212

[10] S J Page, T Mal and J C Volkwein. Unique water spray system improves exhaust face ventilation and reduces exposure to respirable dust on continuous miners in laboratory tests. Journal of the Mine Ventilation Society of S. Africa, October 1994, pp196-205

[11] R C Miles. Venturis ventilate and control dust. Coal Age, March 1979, pp84-86

[12] A D Jones and G C James. Air movement and cleaning by water sprays. Annals of Occupational Hygiene, Vol 31, No. 2, 1987, pp161-179

2.5 Air Curtain Systems

Air curtain systems for use on mechanical miners were first developed in the UK for containing the dust cloud close to the face of a heading by reducing dust roll-back with exhaust ventilation [1-5]. In principle, the system uses an hydraulically-powered, high pressure, low volume fan to power air mover devices in the form of straight 'Coanda' tubes located around the periphery of the machine body. These airmovers use the same principle as a normal compressed-air powered airmover where a high velocity jet of air is directed tangentially onto a curved surface causing it to entrain air from a specific area in a controlled manner. The resultant sheet of air can then be directed forwards and outwards from the machine to help contain the dust cloud and push it around the face towards an exhaust inlet. By entraining air in this way the system modifies the normal ventilation air flow patterns around the machine, ensuring that the majority is passed to the face rather than short circuiting directly to the exhaust or scrubber inlet. By pushing air into the roof and towards the face, the system is also highly effective in dispersing methane roof layers and improving general face ventilation. Provided that the system is in balance with the ventilation system (so that it does not move excessive amounts of air to the face, causing recirculation) it is capable of aiding the control of both dust and methane at the face.

At the outset of the present research project, it was intended to investigate the possible application of this technique to South African mining systems and conditions. However, it was discovered at an early stage of the project that systems had recently been developed for use in South Africa and were being marketed by Locked Torque-Africa, with some success. To avoid duplication of effort, therefore, this relatively small part of the overall project was not pursued.

The use of air curtain systems in South Africa is similar to that in the UK, with air mover tubes located forward of the operator's position on the driver's side of the machine and over the top of the machine body. A lower pressure, higher volume hydraulic fan is used to power the system, with wider outlet slots being used on the tubes themselves. This is considered to increase the 'throw' of the air curtain such that it reaches the walls of the roadway which are more remote than usually found in the UK, especially in larger section headings. Air curtain systems have been approved for use as on-board force ventilation systems within the terms of the ventilation guidelines.

References

[1] Studies of air curtain technology with particular application to the provision of clean air for underground workers. Final Report on ECSC Research Project 7251-17/8/085, National Coal Board, MRDE, 1981.

[2] Application of air curtains and other methods for controlling ventilation and providing clean air at the workplace. Final Report on ECSC Research Project 7256-13/039/08, National Coal Board, MRDE, 1983.

[3] V H W Ford and B J Hole. Air Curtains for reducing exposure of heading machine operators to dust in coal-mines. Annals of Occupational Hygiene, Vol 28, No. 1, 1984, pp93-105

[4] Further work on Dust Control in Drivages. Final Report on ECSC Research Project 7260-02/004/08, National Coal Board, MRDE, 1986

[5] Control of Airborne Dust in Drivages. Final Report on ECSC Research Project 7260-02/033/08, British Coal Corporation, Technical Department, 1989

2.6 Recent Research in South Africa on the Ventilation of Mechanised Headings

Jetfans were introduced to overcome the problems associated with channeling air to the face using ducts in mechanised miner sections [1, 2]. The initial requirements were that air should be transported over distances of at least 20 m and that there should be no recirculation introduced. One of the advantages seen in jetfans was that, if needed, the jetfan could be placed at any position in the heading to rectify any immediate danger areas, such as a methane pockets, because of the robustness of the fan.

Early tests in coal mines [1] indicated that recirculation occurred unless line brattices were installed at the fans. However, these line brattices reduced the performance of the jetfans. The tests also indicated that better entrainment was achieved at lower LTR velocities (as low as 0,5 m/s). The maximum distance of throw was found to be 28 m.

Secunda Mines carried out two dimensional CFD tests in 1993 [3]. The following results were obtained (the effect of machinery in the face, a wet scrubber system and the effect of height of seam were taken into account).

- A heading 40 m from the LTR with a seam height greater than 3,5 m could be adequately ventilated with a single jetfan (this allowed for the largest pillar size of 36 m x 36 m).
- A 30 m split off a heading 40 m from the LTR could be ventilated with a second jetfan in semi-series.
- A minimum velocity of 0,3 m/s was achieved at the face.

No experimental measurements were undertaken to verify these CFD results.

Meyer [4, 5] undertook underground experiments with different configurations of hydraulic vortex fans and electric jetfans. These tests showed significant advantages of jetfans over vortex fans. The results showed that the air volume drawn through a scrubber system must match the total flow entrained by a jetfan. Nevertheless, a significant amount of recirculation still took place and Meyer recommended that jetfans should be used together with an exhaust system. The tests showed that an acceptable throw of up to 30 m was achieved.

Following the above trials, a major SIMRAC project was initiated to investigate the ventilation of mechanised headings using three dimensional CFD techniques. Five different secondary ventilation systems were initially investigated:

1. A jetfan situated at the entrance of the heading on the floor. The continuous miner (CM) was fitted with a sprayfan system and an on-board wet scrubber.
2. A force ventilation duct blowing air directly onto the face. The CM was fitted with a sprayfan system and an on-board wet scrubber.
3. The use of only the scrubber and sprayfan system in the heading.
4. A trailing exhaust duct connected to the outlet of the scrubber. The system also included a jetfan and an on-board sprayfan system.
5. A conventional force/exhaust overlap system. The scrubber fan was switched off but the sprayfan system was operational.

A number of different mining scenarios were also investigated. These were:

- Partial and full cuts in a heading at different distances from the LTR.
- Partial and full cuts in a split to the right of a heading.
- Partial and full cuts in a split to the left of a heading.

The work was carried out in a number of phases [6,7,8,9] and the reported findings are briefly discussed for each of the phases. Some of the findings, although discussed within a particular phase or for a particular configuration, are relevant to all scenarios.

Phase 1 - Full Heading Development

<u>System 1 [jetfan on the floor]</u>

The results showed that more fresh air from the LTR than contaminated air from within the heading is entrained and circulated by the jetfan because of its position. The velocity in the LTR had little influence on the air flow pattern in the heading but it was confirmed that the jetfan should always be placed on the upstream side of the heading, relative to the flow in the LTR. The jetfan should not be placed on the same side of the heading as the scrubber outlet.

The on-board sprayfan system was shown to have definite advantages. This flow, together with the air delivered by the jetfan and the recirculation caused by the scrubber fan, creates a positive flow of air over the CM operator and, although the air is contaminated with dust, good mixing takes place in the face area at fairly high velocities. The recirculation has disadvantages from the dust content point of view, but the possibilities for methane build-up and/or layering are limited.

To reduce recirculation, the flow delivered by the jetfan should be balanced with the scrubber quantity, or alternatively, the outlet of the scrubber could be extended closer to the LTR. A ventilation curtain on the left hand side of the heading would also prevent air circulating back to the scrubber intake.

The importance of creating a large capture area for the scrubber close to the face was emphasized. The importance of the sprayfan system in directing the dust towards the scrubber was also shown.

System 2 [forcing duct]

This system had been in use for many years before the introduction of jetfans and the simulations showed that fresh air is delivered onto the face at a constant rate. This makes a positive impact on the rate of dilution of any methane gas when assisted by the sprayfan. However, the velocity of air delivered to the face must be kept low to prevent a negative influence on the sprayfan system. This could bring the volume flow below the legal requirements. Recirculation of air around the machine was again shown to be caused by the scrubber.

System 3 [scrubber and sprayfan system only]

Total recirculation is occurring inside the face area, causing major roll-back and layering. The effect of the sprayfan is diminished and dust concentrations increase towards the operator. Very little fresh air was introduced into the heading, because of the amount of dust and air that is contained in the face area.

It was shown that the sprayfan cannot be used only with a scrubber system, unless the air from the scrubber is ducted to the outside of the heading. Additional ventilation is necessary to create better air flow patterns inside the heading. The LTR air flow conditions play a major role in determining the conditions inside the heading.

System 4 [jetfan plus trailing exhaust connected to scrubber]

In this scenario there was always a positive flow of fresh air over the operator and the air recirculation patterns that were caused by the scrubber without the trailing exhaust were eliminated. The sprayfan system is effective in the face zone, assisted by the jetfan. The jetfan entrains a large volume of air into the heading without recirculating it. The velocity of the air in the LTR has an influence on the dust accumulation against the roof. The length of the trailing exhaust is critical in ensuring that dusty air is not re-entrained out of the LTR and back into the heading. The efficiency of the scrubber also has a significant influence on the dust concentration in the air released into the LTR. With this system the scrubber could be located off the scrubber in the LTR, although this leads to practical problems.

System 5 [force/exhaust overlap system]

Air recirculation is low with this system and the operator is exposed to lower dust levels. The dust is concentrated against the roof and in the face. The importance of balancing the force and exhaust flows was shown to ensure minimum air velocities in the overlap section. Correct force/exhaust balancing is also important to ensure effective sprayfan operation. Fresh air is always delivered onto the face, ensuring good dilution and mixing. As with the previous scenario, the scrubber could be located off the CM.

Summary of Results for Phase 1

The on-board sprayfan system was shown to be an efficient way to ventilate the face. The directional sprays create a flow of air around the cutting drum and the water from the sprays ensure that dust is suppressed. For this system to function effectively it must be assisted by a force ventilation system, but avoiding an excessive direct flow of air onto the water sprays that could influence the normal flow created by the sprays.

Except for the jetfan simulation, it was shown that the air flow conditions in the LTR play a major role in the air flow patterns inside the heading. The simulations indicated that in most cases better air flow patterns and conditions were achieved inside the heading with a higher LTR velocity (1,5 m/s).

A jetfan was shown to cause some recirculation in a small part of the heading, mainly because of the air entrainment action of the fan. However, the scrubber was shown to be the cause of most of the air recirculation inside the heading and in the face area, except when the exhaust duct was used.

The position and inlet dimensions of the scrubber were shown to be very important in determining the capture efficiency of a system.

The simulations showed that the outlet of any exhaust column should be away from the intake to the heading in the LTR and should, if possible, be located in the return airway.

Phase 2 - Full Split Development to Right of Heading

System 1 [jetfan on the floor]

The use of the jetfan in this scenario is not of real benefit to the conditions inside the split, nor do LTR velocities have any great effect. The amount of air that is pushed past the split by the jetfan creates an air curtain which assists in causing air recirculation inside the split, resulting in high dust concentrations. However, because of the jetfan, good air velocities are present at the face of the heading at 30 m from the LTR.

Although some recirculation occurs at the entrance of the heading, a jetfan ensures that the dust concentration inside the heading is kept very low. The sprayfan system removes the dust from the operator position to the left of the CM, although this is not as effective as for the straight heading scenario.

System 2 [forcing duct]

Fresh air is delivered onto the face by the force system ensuring good mixing and dilution of methane and dust. By balancing the ventilation systems and perhaps introducing some type of exhaust system, good conditions could be ensured inside the face area. Velocities in the LTR have no effect on the flow pattern in the split.

Dust is pushed out into the heading and the LTR, indicating that the overall dust concentration inside the split is less than for system 1. The scrubber dominates the air flow patterns inside the split, causing high levels of air recirculation, which in turn causes high dust levels. The force volume directed onto the face influences the directional sprays on top of the boom and underneath the boom, resulting in dust roll-back towards the CM operator.

System 3 [scrubber and sprayfan system only]

Very little fresh air reaches the split. The scrubber dominates the air flow patterns in the face area, adversely influences the effect of the sprayfan system on the face. However, with the large amount of air recirculation in the face area, methane layering and/or build-up is eliminated because of good mixing. Although overall dust concentrations are high, no dust accumulation occurs. The majority of the dust produced at the face is concentrated in the left hand side of the face away from the operator.

Additional force ventilation is needed to assist the sprayfan system in effectively ventilating the face and to replace the air inside the split as often as possible.

System 4 [jetfan plus trailing exhaust connected to scrubber]

The results showed that the operators of the shuttle car (SC) and CM are constantly exposed to air with a very low dust concentration. It appears that this system is the best to use for dust control purposes. The jetfan positively ventilates the heading, keeping the possibility of a methane build-up to a minimum. Air recirculation in the split is kept to a minimum, resulting in relatively low dust concentrations.

The dust in the LTR could contaminate the air flowing into the headings further downstream. This could be avoided by installing the outlet of the exhaust duct in the return airway. The directional sprays do not work effectively because of the influence of the scrubber inlet. Air velocities and air flow patterns inside the split are not very favourable for methane mixing and dilution. The results indicate that the air flow patterns produce little turbulence, which could increase the possibility of methane layering and/or accumulation.

Although the sprayfan system operates satisfactorily, the simulations indicate that some form of force ventilation is required to assist in ventilating the face area. The jetfan is not very useful in ventilating the split area, but is effective in keeping the straight heading well ventilated. The LTR air flow velocity does not have a significant influence on the air flow patterns inside the heading or split, but the direction is very important, in order to keep the dust in the LTR from re-entering the heading.

System 5 [force/exhaust overlap system]

There is a continuous supply of fresh air into the heading and onto the face of the split and highly turbulent flows in the face area indicate good mixing. The sprayfan system effectively moves the dust from one side of the face to the other, assisted by the force ventilation. There is no recirculation of air in the face area. Positioning of the columns and the force/exhaust volumes is crucial for good air flow patterns and effective dust control. The force duct pushes the dust away from the exhaust inlet, causing most of the dust to accumulate inside the split. Dust in the LTR contaminates air flowing in the LTR as well as the air flowing into the heading and split.

Apart from the practical implications of using this system, it could be used effectively if a balance between the force, exhaust and sprayfan system could be achieved. The problem of dust in the LTR must be addressed by either removing the fan from the LTR or installing a scrubbing system at the rear of the fan. This will ensure that the air in the LTR remains uncontaminated.

Summary of results for Phase 2

The results from Phase 2 investigations indicate that even the use of conventional ducted ventilation does not address the dust and methane problems inside a split effectively. The fact that the scrubber is not working 100 % efficiently in the simulations and is dominating the air flow patterns inside the split and therefore influencing the sprayfan system, shows that the systems used inside a split must work together in addressing methane and dust. The sprayfan system must be assisted by force ventilation to create the necessary turbulence for methane dilution and the scrubber inlet or exhaust inlet must be positioned in such a manner that the significant quantity of dust being made at the face is captured efficiently.

Phase 3 - Different Development Stages of Heading and Splits

System 1 [jetfan on the floor]

In a situation where a CM is taking a partial cut, because the CM is 'boxed-in' and the scrubber is confined on the right hand side, the scrubber is relatively effective. There is a certain amount of recirculation and the scrubber effectively controls the air in the face region. When the CM is cutting the full heading, (when the scrubber is not confined on the right hand side), the open volume into which the dust from the face can flow means that a significant amount of dust flows past the CM into the heading.

Similar situations arise for the cutting of partial and full splits to the right and a full split to the left. The jetfan re-entrains a significant amount of the air recirculated in the heading but does not otherwise affect the flow pattern inside the split. The split to the left appears to be the worst situation.

System 2 [forcing duct]

The containment effect of the right hand side at the scrubber is again shown by the simulations. There is a large amount of recirculation and some re-entrainment of recirculated air by the force duct. This recirculation/re-entrainment means that most of the dust is kept within the heading.

When mining splits, large concentrations of dust flow past the scrubber and out of the split into the heading, towards the LTR. In the situation where the split is to the left, the force duct blows air over the driver at roof level towards the face, but some of the dust-laden air flows back over the driver.

System 3 [scrubber and sprayfan system only]

This scenario indicates that the use of a scrubber and sprayfan only is not sufficient to create adequate conditions at the face. The scrubber is in control of the flow patterns at the face and a large amount of recirculation takes place.

In scenarios with splits, fresh air from the LTR only penetrates 10 m into the heading and then returns to the LTR. The scrubber creates sufficient air velocities in the split. Some dust leaves the split to enter the heading and is diluted by the small amount of fresh air entering from the LTR.

System 4 [jetfan plus trailing exhaust connected to scrubber]

This represents the most favourable of all the scenarios simulated in terms of a dust free environment in the heading. The importance of balancing the jetfan flow and the exhaust flow is shown by dust being pushed past the exhaust inlet and thus contaminating the heading/split.

In the split situation, even when the jetfan flow is greater than the exhaust quantity, the dust which flows past the exhaust inlet is re-entrained and no dust enters the heading.

System 5 [force/exhaust overlap system]

Some dust-laden air discharged from the exhaust duct into the LTR re-enters the heading and is drawn into the exhaust duct again. Some of the fresh air in the force dust bypasses the exhaust inlet and flows directly back to the LTR. High dust concentrations are experienced in the whole of the heading. For the split situation, dust-laden air is pushed past the exhaust inlet contaminating the whole split. Dust-laden air is re-entrained from the exhaust outlet in the LTR back into the heading.

Phase 4a - Partial Heading Development Stages [10 m, 15 m, 20 m]

In previous phases the boom was positioned against the roof. In Phase 4a an additional boom position at floor level was simulated. Different ventilation systems were also simulated in this phase.

System 1 [jetfan on floor across the LTR]

In this scenario, when the shuttle car extends into the LTR, it acts as a channel for the fresh air to the face as well as for the return air from the scrubber. More recirculation is observed when the boom is in the floor position and more air reaches the face. Because of the limited space around the cutting head and the limited number of sprays underneath the boom, only a small amount of air reaches the face underneath the boom and thus the sprayfan system does not work effectively. With the boom in the roof position, less dust roll-back is evident than when the boom is down. As the heading is extended the dust concentrations at the driver position worsens.

System 2 [jetfan in heading against roof]

For a heading at 10 m the jetfan is too close to the face and the air bounces off the face and past the scrubber inlet to be recirculated and re-entrained by the jetfan. This spreads the dust throughout the heading. This improves for the 15 m and 20 m scenarios but the amount of dust that is forced out of the heading by the jetfan is still extensive. Very high velocities are experienced at the driver position.

System 3 [jetfan in heading on floor]

The jetfan recirculates some air and the dust concentrations at the face are dictated by the boom position. With the boom in the roof position, dust is trapped underneath the boom, while the scrubber captures dust more effectively when the boom is in the floor position. Generally the dust flows past the scrubber inlet towards the driver position, but most of the dust is concentrated against the roof and flows towards the LTR.

A jetfan only influences the air flow patterns up to the CM position. Beyond this the patterns are dictated by the scrubber, sprayfans and boom position.

System 4 [force duct and scrubber]

With the boom in the roof position, the air from the duct is blown directly against the boom and then forced down onto the CM by the returning air from the face. A limited amount of air reaches the face. With the boom in the floor position, more air reaches the face. Dust roll-back is extensive and the sprayfan system does not function effectively because the air is blown directly onto the sprays.

System 5 [trailing exhaust and scrubber]

The scrubber effectively draws fresh air into the heading but a significant amount of roll-back is present against the face and above the CM. With the boom in the floor position, the dust cloud reaches the driver. With the boom in the roof position most of the dust seems to be trapped underneath the boom against the face, with fresh air flowing over the driver.

System 6 [on-board scrubber only]

Reasonable air velocities are experienced at the driver position. The outlet air from the scrubber appears to bounce off the sidewall and roof and is recirculated back to the face area. Again more fresh air reaches the face when the boom is in the floor position.

System 7 [4 kW or 11 kW jetfan in heading against roof]

With the small motor, more fresh air appears to reach the face than with the large motor. This is possibly because of the lower air velocity delivered by the jetfan nozzle, which tends to reduce the angle of the air flow leaving the nozzle and causes more penetration of the air towards the face. For both motors, very little air actually reaches the face because of the position of the boom and the CM.

Phase 4b Split Development with Force Duct and Jetfan in Series

In Phase 4b attempts were made to determine how much fresh air was being delivered to the face. The force duct blows air into the heading and the jetfan is positioned opposite the split on the floor. The results showed that the amount of fresh air delivered into the split is limited, particularly when the jetfan and scrubber outlet are located directly opposite each other. However, there is sufficient air turbulence inside the split to prevent any accumulation of gas.

Overall Conclusions from the Four Phases of CFD work

Force ventilation systems should deliver fresh air directly over the driver and not directly opposite the outlet of on-board scrubber systems. Air moving systems near the cutting drum, such as a sprayfan system, are important in creating sufficient air movement on the face. Additional sprays should be located underneath the boom. The air leaving the scrubber should be forced directly towards the LTR to limit the amount of recirculation.

The scrubber/exhaust inlet position at the face is critical. The closer this is to the point of cutting, in conjunction with the air moving system on the cutting drum, the more dust will be captured, increasing the efficiency of the entire system.

The delivery of force systems should not be nearer to the face than 10 m to prevent fresh air being blown out of the face and past the capture zone of the scrubber.

A trailing exhaust system creates the best situation from a dust capture point of view, but must be used in conjunction with a force duct or jetfan to create favourable turbulence conditions for methane dilution.

Jetfans installed against the roof create better conditions than fans installed on the floor. The inlet of jetfans should always extend at least 1 m into the LTR to avoid air recirculation. Jetfans should be placed in the upstream position of the heading relative to the flow in the LTR.

Additional Research into Suitability of Jetfans

A special investigation was undertaken to determine whether the ventilation conditions as specified in the DME guidelines can be met when a jetfan is used as the main forcing system in a heading [10].

A number of underground evaluations were carried out in headings with different seam heights to determine the air flow patterns both at the face itself and at a distance of 5 m from the face. The tests showed that jetfans could meet the specifications of the guidelines and the recommendation was made that the use of jetfans should be permitted. The tests showed that better flow patterns in the face zone were obtained when the scrubber and jetfan flows are closely matched rather than when the jetfan flow exceeded the scrubber flow. The tests also showed that adequate conditions were obtained irrespective of whether the jetfan was located on the floor or against the roof.

References

[1] M Dumka, APJ Meets, CBJ Reynolds Practical air jetfan applications. Proceedings - The effects of mechanised mining 21-24 May 1989, Mine Ventilation Society of South Africa.

[2] LW Jenner Jetfans an old principal put into practice. Proceedings - The effects of mechanised mining 21-24 May 1989, Mine Ventilation Society of South Africa.

[3] J van Dyk, Bossiespruit Steenkoolmyn, Twistdraaiskag Stofbekamping.

[4] CF Meyer. Review of research done in the area of coal mine ventilation for the period 1989 to 1992 SIMRAC Project COL 029A/93

[5] E J Meets, C F Meyer. Some applications of ductless fans in bord and pillar headings in South African Coal Mines. Proceedings 6th US Mine Ventilation Conference.

[6] CF Meyer Report on CFD Simulations using different ventilation systems to assess heading ventilation, methane and dust Part 1: Full heading development , SIMRAC COL 027 March 1994

[7] CF Meyer Report on CFD Simulations using different ventilation systems to assess heading ventilation, methane and dust Part 2: Full split development to the right of the heading SIMRAC COL 027 May 1994

[8] CF Meyer Report on CFD Simulations using different ventilation systems to assess heading ventilation, methane and dust Part 3: Different development stages of the reading and splits SIMRAC COL 0127/030 October 1994

[9] CF Meyer Report on CFD Simulations using different ventilation systems to assess heading ventilation, methane and dust Draft Part 4: Four partial heading development stages as well as split ventilation COL 027/COL 205 July 1995

[10] CF Meyer, BA Doyle, HR Phillips Evaluation of the stability of using jetfans to ventilate continuous miner headings in collieries. SIMRAC September 1994.

2.7 OVERALL CONCLUSIONS DRAWN FROM LITERATURE SURVEY

The key points which can be drawn from the extensive literature survey are as follows :

- For adequate control of methane at the face some form of forcing ventilation system must be used which has a significant influence on air flows at the face. However, the additional requirement to control and remove dust from the general body air is best accomplished with an exhaust ventilation system or scrubber. These joint requirements are often in conflict and, to achieve effective control of both contaminants, each system must operate in conjunction with the other and the relative air flows matched. In addition, the face velocities created by the force ventilation system should not be so high as to carry dust past the capture zone of the scrubber. Such attributes are required of all systems including, for example, an on-board force system on its own as well as when it is used in combination with a jetfan.

- Optimal positioning of the scrubber inlet is an important factor in maximizing the dust capture efficiency of any scrubber system. Where the forcing system ventilates the face from left to right, for example, optimum dust capture will be achieved by siting the scrubber inlet close to the right hand sidewall, 'boxing in' the inlet and minimizing the opportunity for the force system to blow dust past the effective capture zone of the scrubber. Siting the scrubber inlet as close to the point of cutting as possible also maximizes dust capture, minimizing the chance of the dust being more widely dispersed into the general body air away from the limited capture zone of the scrubber inlet.

- Once any jet of air is released from a duct or fan outlet general body air will be entrained into it, raising the issue of recirculation. This applies to both the release of a force jet of air and the discharge from a scrubber system. Conventionally, when auxiliary force and exhaust systems are combined, an overlap between the two air release positions is used to prevent intermixing or recirculation between the two air flows and their contaminants. Where no such overlap exists, as is the case where jetfans are used, the effects of recirculation must be considered. For methane, provided that an adequate quantity of fresh air is delivered to the face of the heading to dilute the methane released, there should be no significant increase in general body methane levels as a result of recirculation. With dust, however, unless it is both efficiently captured and removed from the air by the scrubber, recirculation will carry dust back to the face increasing both its residence time in the heading and the overall dust concentration to which the machine operator is exposed.

- The physical bulk of the jib of a continuous miner can influence air flow patterns at the face, with the extent of its effect being dependent upon its position. Consequently, it will also have a variable effect on both face ventilation and the behavior of dust. An additional influence of boom position is the variation in effect of sprays mounted on the jib. This latter aspect is also relevant to roadheading machines.
- The available evidence indicates that jetfans are capable of providing adequate ventilation for straight development headings of up to 35 m deep although it appears that they are not so effective during the cutting of splits.

3. ASSESSMENT OF UNDERGROUND SITES

In order to gain a greater understanding of the nature of the dust capture problem in mechanised drivages in larger roadways, six mines were visited during the early stages of the project. Each of these sites are discussed individually in the following sections 3.1 to 3.6. The observations made during these visits were also helpful in ensuring that the later surface gallery simulations represented an accurate reflection of actual conditions underground.

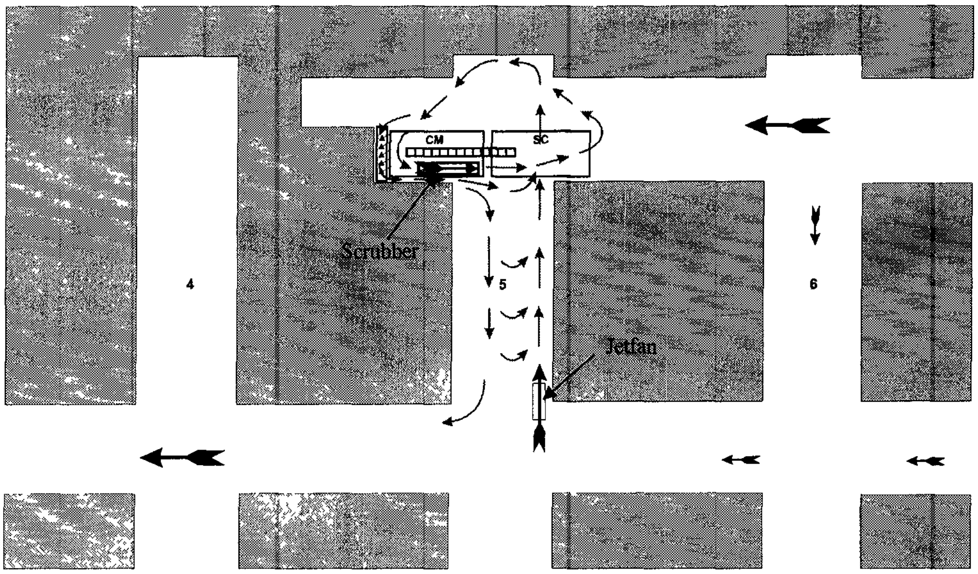
Most of the sites visited were being mined by continuous miners, except for two sites where roadheaders were used. At a small number of sites, dust concentrations were monitored using Simslin continuous dust sampling instruments. These instruments use a laser beam diffraction technique to measure instantaneous respirable dust levels, the results being logged at 15 second intervals enabling dust concentration throughout the shift to be determined. A pump in the instrument draws air through a single channel elutriator to give a respirable size selection of the dust in the sampled air. After passing through the optical chamber, the dust-laden air is passed through a standard glass-fibre filter which may be weighed before and after use to enable optical response of the instrument to be calibrated to a gravimetric dust weight.

3.1 Site No. 1

The details of the site visited are shown below :-

Section	Bord and Pillar
Machine	Joy 12CM21
Roadway Size	6,5m (W) x 3,5-4,0m (H)
Section Layout	7 road, 23-25m centres (16,5x16,5m pillars).
LTR Vent	R - L, min 1m/s. Section Ventilation 70m³/s
Scrubber	Engart 75kW Type 30HC, 10,5m³/s, LHS, let into machine body and fitted with flared extension duct inlet located approximately 4,0-4,5m from face, level with front of tracks.
Auxiliary Ventilation System	5,5kW jetfan, to be used at min. 10m, max. 35m from LTR for cutting straights. Fan to be positioned on upstream (RH) side, in roof, inlet >2m into LTR. Auxiliary fan and duct nominally used for cutting the first split.
Sprayfan System	Standard Joy system - 29 sprays, (approximately 50% blocked at time of visit), nominal flow 135 l/min, pressure unknown (suspect ~10bar)

The colliery was in the process of replacing the 5,5 kW jetfans with 11 kW versions. At the time of the visit, the machine was cutting the split from Road 5 (counting from the left) to Road 4, as shown in the figure below. A roof-mounted jetfan was in operation at the entrance to Road 5, although it is believed that this had been mistakenly left running since it opposed the natural route of ventilation air.



Site No. 1-Site Layout and Air flow Patterns at the Time of the Visit

As a direct result of the use of the jetfan in this situation, dust conditions were very poor with a great deal of recirculation taking place around the machine. The high velocity jet from the jetfan swept dust from coal being discharged from the machine into the shuttle car which was then carried around the blind end of Road 5 back to the front of the machine. The high ventilation velocities and quantities acting on the face also swept a considerable amount of dust past the scrubber inlet on the 'tight' side of the machine which was carried outbye in Road 5. Here, a significant proportion of this dusty air was re-entrained into the air jet from the fan, recirculating it back to the machine. Conditions would have been much improved, with much less recirculation, without the jetfan operating.

3.2 Site No. 2

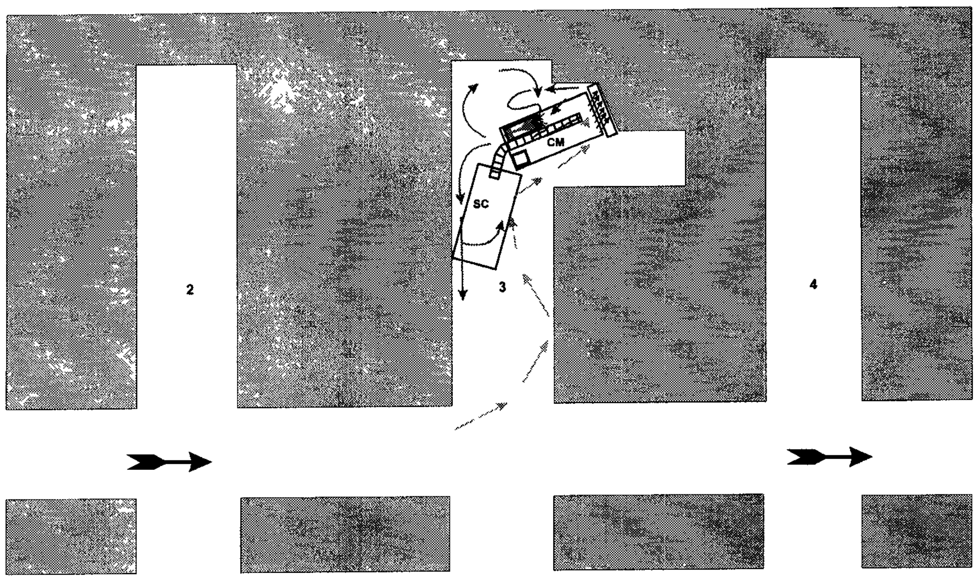
The details of the site visited are shown below :-

Section	Bord and Pillar
Machine	Joy 12HM9
Roadway Size	6,0m (W) x 4,0-4,5m (H)
Section Layout	7 road, 20m centres (14x14m pillars).
LTR Vent	L - R, min 1m/s. (R - L is more normal) Section Ventilation 32m³/s
Scrubber	Engart 75kW Type 30HC, 10.5m³/s, LHS, standard inlet 6m from face.
Auxiliary Ventilation System	None.
Sprayfan System	Directional spray system - 26-off 1.5mm orifice sprays, nominal flow of 130 l/min supplied from on-board booster pump set to a delivery pressure of 40 bar. 7 sprays fitted on right side of machine body, 15 angled sprays behind cutter drums, 2 loading shovel sprays and 2 under-jib sprays - all operational at time of visit.

Investigations into the layout of the sprayfan system have previously been done by mine personnel in a surface simulation. The sprayfan system fitted to machines at this colliery conform to the layout of the USA-type 'improved sprayfan system'. When fitted with 1,5 mm nozzles, the system was found to move a total of 7 m³/s of air around the machine, the same as the that moved by the more usual, larger orifice Spraying System BM30 nozzles, but using a lesser water quantity and higher pressure from the fixed displacement booster pump. A further reduction in spray orifce to 1,0 mm resulted in more air being moved by the system (approximately 11 m³/s). However, 1,0 mm nozzles have not been used underground since it was felt that there may have been a problem with blockages resulting from the use of a small orifice size.

No form of auxiliary ventilation was in use at the colliery at the time of the visit; staff were reluctant to introduce jetfans on the basis that the high velocities produced were liable to cause dust control problems.

At the time of the visit, the machine was in the process of cutting the first split to the right from Road 3 (counting from the left), as shown in the figure below.



Site No. 2 - Site Layout and Air flow Patterns at the Time of the Visit

In terms of the general site layout, it was noted that the direction of ventilation in the LTR was incorrect for the scrubber layout on the machine - the scrubber exhaust is on the upwind side of the heading, having to cross the normal inflow of LTR ventilation into the heading to reach the return side. This layout encourages recirculation of return air from the scrubber back into the heading. The colliery personnel recognised that this arrangement was not satisfactory.

A further general cutting practice at the colliery, although not carried out at the time of the visit, leads to unsatisfactory dust control: that of taking first, partial cuts to the left hand side of the face on machines fitted with left hand scrubbers. Such a system means that during the second pass, full cut phase, the area to left of the machine is always open with no confinement or 'boxing-in' of the scrubber. This will result in poor dust capture efficiency by the scrubber since the sprayfan system will act to drive dust into the open space to the left of the machine, away from the immediate capture zone of the scrubber. There was a positive reason for this cutting method, however, in that this practice maintained the driver close to the sidewall for most of the cutting cycle. The colliery suffers from extensive spalling of coal from the rib side which can endanger the machine operator. Maintaining the operator close to the sidewall affords him better overall protection from falling coal and will therefore not change this operating practice.

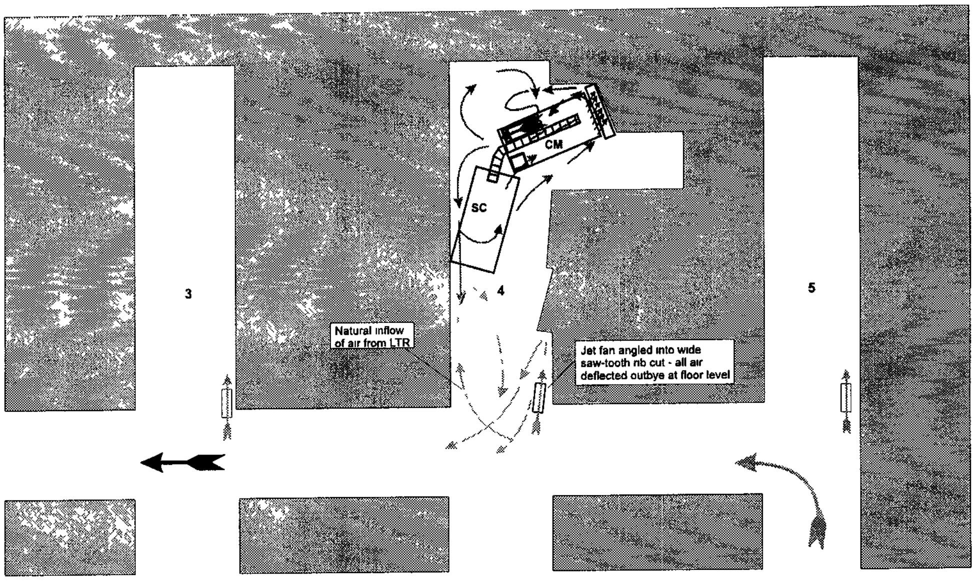
During the site visit, the observed dust conditions appeared very good in the situation shown above and the air patterns around the machine could be easily observed from the fine water spray produced from releasing water through the fine orifice sprays at high pressure. The sprayfan system and scrubber appeared to have a good balance of air flows with little tendency for air or dust to roll back from the face. There was a tendency for some dust to evade immediate capture by the scrubber on the left hand side of the machine, at floor level, but this appeared to rise to a higher level alongside the machine body to be drawn back into the scrubber inlet. Of greater concern was the amount of air passed back through the conveyor throat of the jib, particularly when the conveyor was operating. This did not appear to reach as far as the machine operator's position, but rose out of the conveyor to be drawn back forwards to the scrubber inlet. In different circumstances, however, this may have proved to be a problem area with respect to dust reaching the operator.

3.3 Site No. 3

The details of the site visited are shown below :-

Section	Bord and Pillar
Machine	Joy 12HM17
Roadway Size	6,6m (W) x 4,5-5,0m (H)
Section Layout	5 road, 31m centres (25,4x25,4m pillars).
LTR Vent	R-L, min 1m/s.
Scrubber	Engart 75kW Type 30HC, 10,5m³/s, LHS, standard inlet 6m from face.
Auxiliary Ventilation System	4kW jetfans.
Sprayfan System	Directional spray system - 29-off 1.6mm orifice sprays, nominal flow of 130 l/min supplied from on-board booster pump regulated down from 45-50bar capability to unknown delivery pressure. 5 sprays fitted on right side of machine body, 18 angled sprays behind cutter drums, 3 at jib conveyor throat, 3 loading shovel sprays (blocked) and 2 under-jib sprays (disconnected).

At the time of the visit, the machine was in the process of cutting the first split to the right from Road 4 (counting from the left), as shown in the figure below.



Site No. 3 - Site Layout and Air flow Patterns at the Time of the Visit

The jetfan installed in Road 4 was directed towards a large saw-tooth cut in the sidewall some 10m into the heading. As a result, the majority of the air jet from the fan was turned towards the floor, returning air directly back into the LTR. Very little of the air from the fan therefore reached the face and most of the air within the heading itself was 'trapped', being mostly recirculated around the machine by the sprayfan and scrubber system. Despite this, visible dust conditions around the machine appeared reasonable, indicating that the scrubber was operating efficiently. Whenever a full shuttle car left the heading it appeared to draw dust from around the machine out of the heading into the LTR, confirming the apparent recirculation near the face.

Near the machine itself, there appeared to be a tendency for dust from cutting to roll back on the left of the machine near the floor but, as in the similar situation at Site No. 2, most of this tended to rise from the floor into a forward moving airstream back to the scrubber inlet before reaching the rear of the machine. The problem of cutting dust being drawn back from the face by the machine conveyor appeared to be much less of a problem than at Site No. 2. This was possibly due to additional use of water sprays acting near the jib throat on this machine, which is their intended function.

3.4 Sites 4, 5, 6

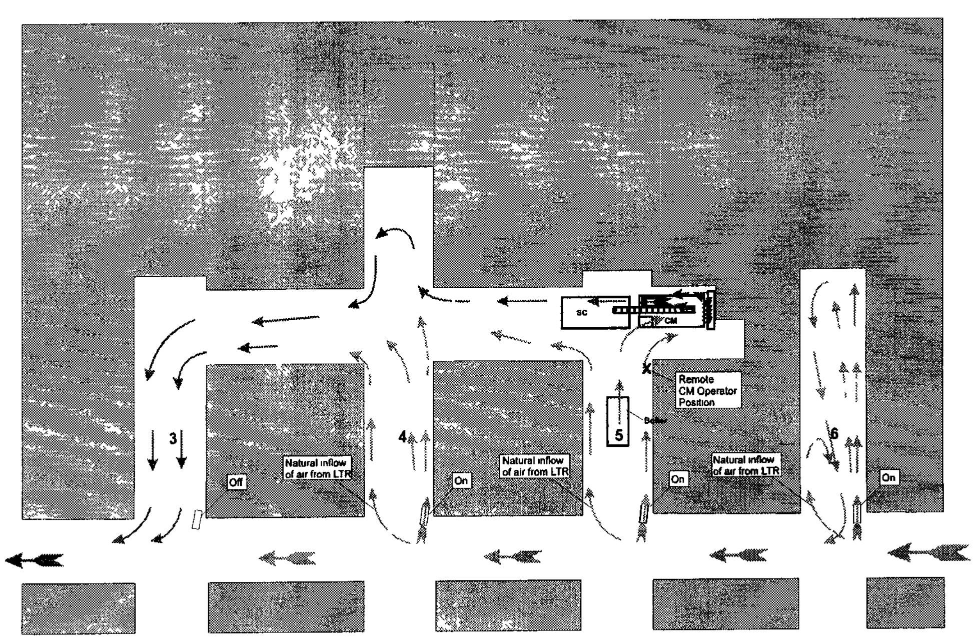
A total of 3 sections were visited at the fourth colliery, Sites No. 4 and 5 operated by continuous miners and Site 6, where a roadheading machine was used. Dust sampling was carried out at Sites 5 and 6.

Site No. 4

The details of the site are shown below :-

Section	Bord and Pillar
Machine	Joy 12HM31 - Remote Controlled
Roadway Size	7,0m (W) x 3,5m (H)
Section Layout	9 road, 20/24m centres (13 (L) x 17m (W) pillars).
LTR Vent	R-L, min 1m/s.
Scrubber	Engart 55kW Type 27, 10.5m³/s, LHS, standard inlet 6m from face.
Auxiliary Ventilation System	7,5kW jetfans.
Sprayfan System	Directional spray system - 29-off 1.2mm orifice, CDCS sprays, nominal flow of 85-90 l/min at 12bar pressure supplied by low pressure, on-board piston pump. 6 sprays fitted on right side of machine body, 9 angled sprays behind cutter drums, 6 sprays on drum end-rings, 3 at jib conveyor throat + 3 below jib in centre, directed forward, 2 loading shovel sprays (block had been knocked off from mounting position).

The layout and cutting circumstances observed during the visit is shown in the Figure below.



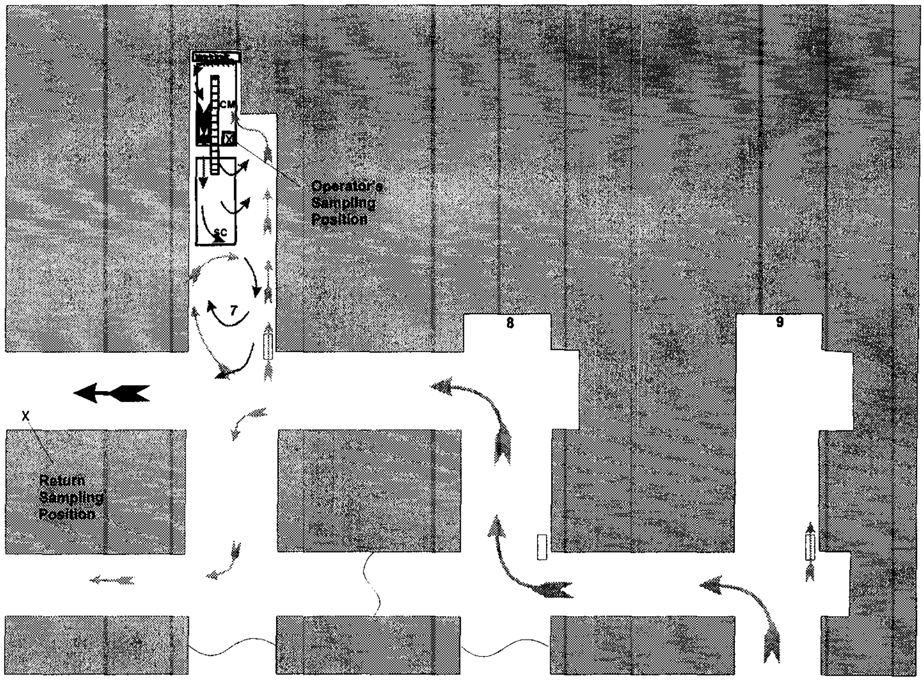
Site No. 4 - Site Layout and Air flow Patterns at the Time of the Visit

The observed dust conditions in this situation appeared to be very good, the bulk of the machine and/or the shuttle car helping to deflect air from the jetfan in Road 5 into the split to be carried to the face by the sprayfan system. However, when the machine was deep into the partial cut to the right of the split with no shuttle car in place to deflect the jetfan air into the face, some dust roll back was observed at floor level to the right of the machine. After breaking through into Road 6 on the partial cut, resulting in through ventilation in the split, dust conditions remained reasonable during the second pass, full cut. Dust from cutting was pushed across the face to the left hand sidewall by the sprayfan system and then passed to the scrubber inlet. Only a relatively small amount of dust was swept from the cut by the through-air flow to the right of the machine. No problems were observed with dust being carried up the conveyor. Overall dust conditions at the site were hampered by high levels of intake contamination due to an additional section operating close to Site 4, but downstream in the ventilation circuit. The machine in this section was operating with a damaged scrubber resulting in the release of substantial amounts of dust.

Personnel at the site was very familiar with the dust control systems used on machines, having recently carried out a project to optimising the various systems. Optimum dust control was achieved in the tests using a sprayfan system comprising 1,6mm orifice sprays, operated at a pressure of 40bar. This system could not be used at this particular site due to insufficient water supplies for the required high pressure pumps.

Site No. 5

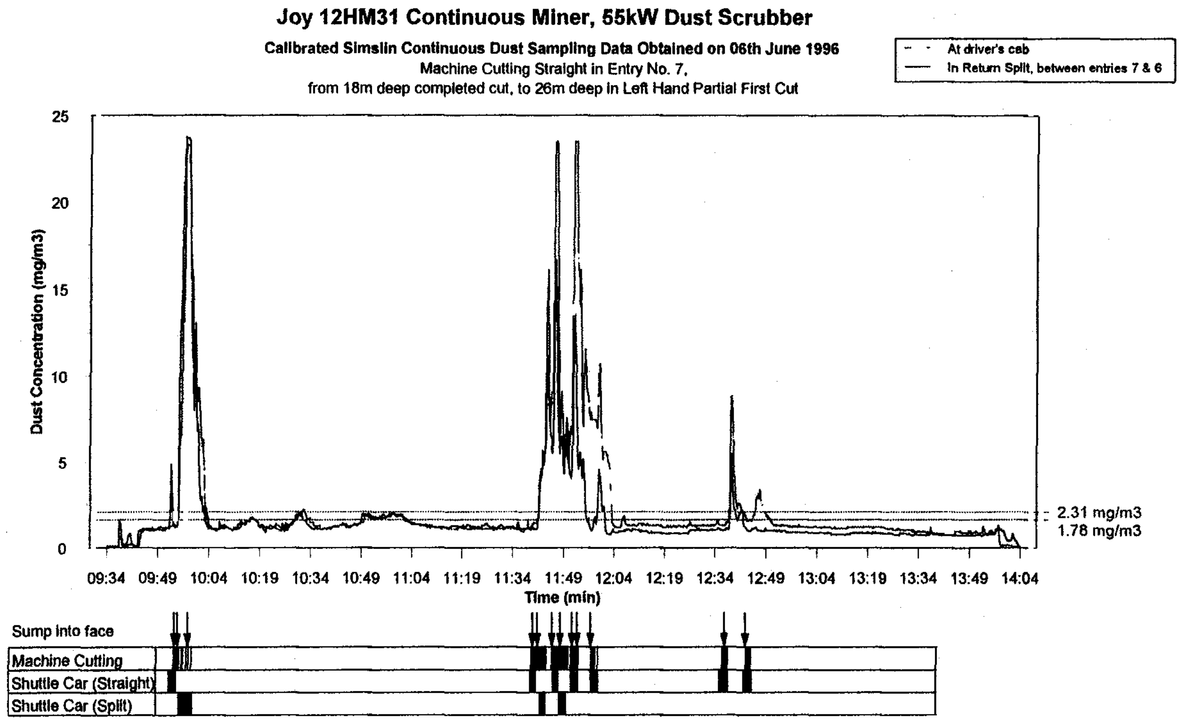
The details of the site were similar to those at Site No. 4 except that the sprayfan system on the machine used larger spray nozzles, most of which had apparently been further enlarged using a punch-type tool. The orifice size of the sprays therefore varied between approximately 3 to 5mm with very poor spray formation. During the visit the machine was cutting the straight heading in Road 7, taking the first, partial cut from 18 to 26m depth, .as shown below. During the shift, the machine suffered lengthy breakdowns and hence the amount of cutting was limited. Dust sampling was carried out during the course of the visit at the locations shown on the diagram.



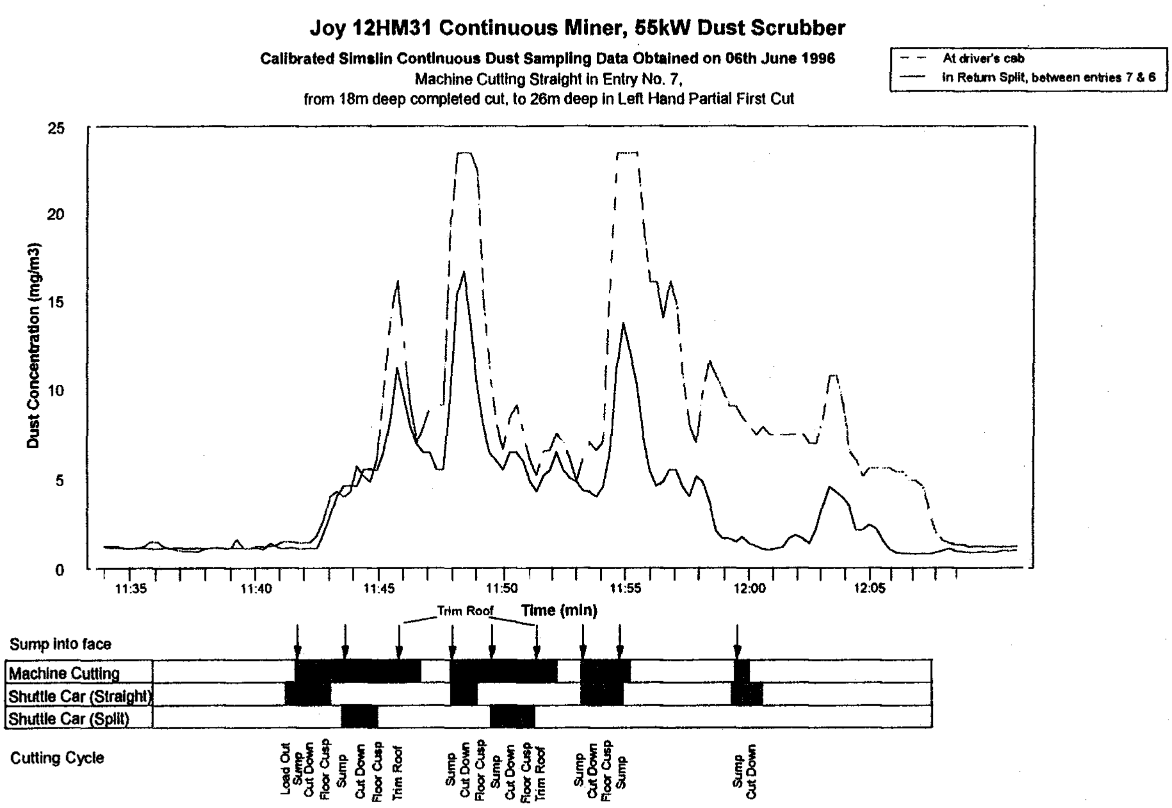
Site No. 5 - Site Layout and Air flow Patterns at the Time of the Visit

In the cutting situation observed, there appeared to be a substantial amount of recirculation occurring within the heading, both around the machine and at the entrance. The door to the filter panel of the scrubber was missing resulting in some of the dust drawn into the scrubber fan by-passing the filter panel resulting in a reduced dust filtration efficiency. Consequently, dust conditions both behind the machine and in the return were quite bad while cutting and the dust was slow to clear from the heading due to the recirculation.

The results from the sampling exercise are shown in the Figures below, the upper graph showing dust levels over the shift and the lower graph, the detail of the main cutting period.



Calibrated shift dust concentrations measured at Site No.5



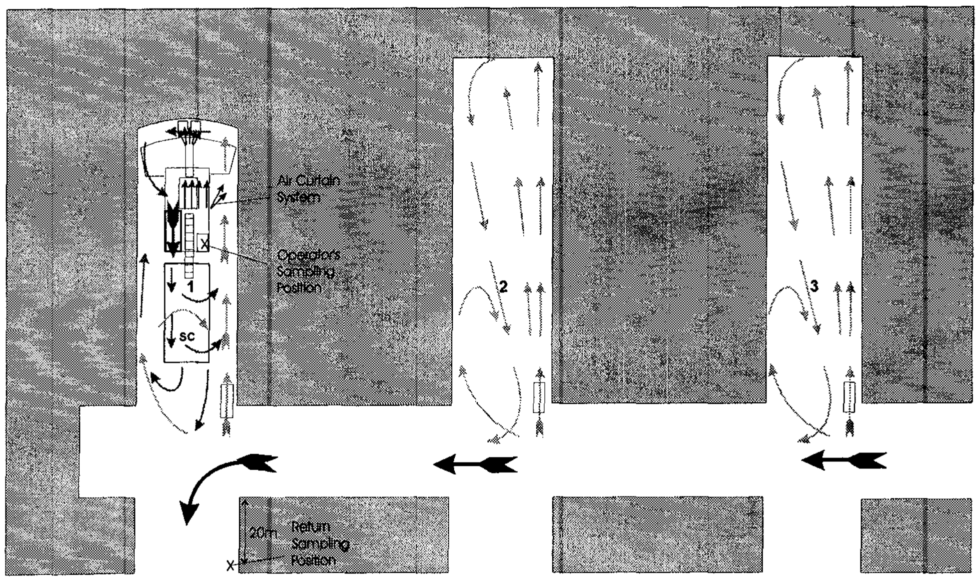
The average shift gravimetric dust concentrations measured by each of the instruments are shown in the top graph. General intake dust levels at the site were of the order of 1,0 to 1,5mg/m³ during the long periods where no cutting took place, with substantial increases at both positions during periods of cutting. From the lower graph, it may be seen that the highest peaks in dust concentration appeared to be produced while the machine was sumping and cutting down the face, although such peaks were not produced during these operations at 11:50 and 11:58. The main feature shown in the lower graph is that during the early stages of the cut, dust concentrations in the heading and in the return were similar while at a later stage the concentration measured in the return was significantly less. This may be due to changes in the dust capture efficiency of the scrubber. During the early stages of the cut, the air from the jetfan passed from the blind end of the right hand side of the face into the cut on the left, sweeping dust past the scrubber inlet resulting in inefficient capture. However, during the later stages, when the machine was deeper into cut, the jetfan air was deflected across the rear of the machine, preventing it from reaching into the cut and tending to trap the dust within the partial cut from where the scrubber could capture it more effectively.

Site No. 6

The details of the site are shown below :-

Section	Bord and Pillar
Machine	Voest Alpine AM 85
Roadway Size	7.2m (W) x 3,5-4,0m (H)
Section Layout	9 road, 20/24m centres (13 (L) x 17m (W) pillars).
LTR Vent	R-L, min 1m/s.
Scrubber	Engart 55kW Type 27, 10,5m³/s, LHS, standard inlet 6m from face.
Auxiliary Ventilation System	7,5kW jetfans.
Sprayfan System	Directional spray system - 29-off 1.2mm orifice, CDCS sprays, nominal flow of 85-90 l/min at 12bar pressure supplied by low pressure, on-board piston pump. 6 sprays fitted on right side of machine body, 9 angled sprays behind cutter drums, 6 sprays on drum end-rings, 3 at jib conveyor throat + 3 below jib in centre, directed forward, 2 loading shovel sprays (block had been knocked off from mounting position).

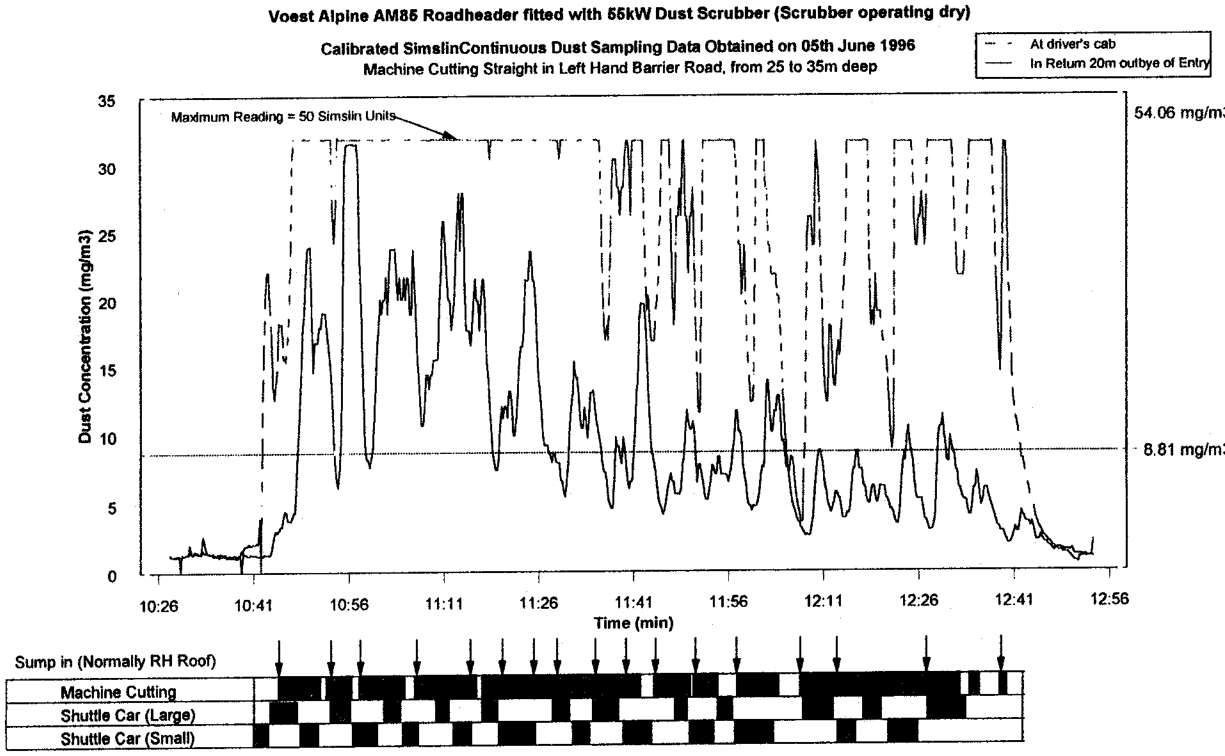
On inspecting the machine at the end of the shift it was discovered that the dust scrubber on the machine was operating dry, and hence had a very low filtration efficiency. The layout and cutting circumstances observed during the visit is shown in the Figure below, as are the dust sampling positions.



Site No. 6 - Site Layout, Air flow Patterns and Sampling Positions

During the course of the shift, the machine advanced the heading from 25 to 35m from the LTR. General dust conditions were poor due to the scrubber operating dry. A considerable amount of recirculation of dust occurred both around the machine and at the entrance to the heading. The dust tended to be removed from the heading into the LTR both below the roof-mounted jetfan on the right and close to the roof to the left of the heading entrance. The natural flow of LTR air into the heading tended to be at a low level on the left.

The dust measurements obtained during the visit are shown in the Figure below.



Calibrated shift dust concentrations measured at Site No.6

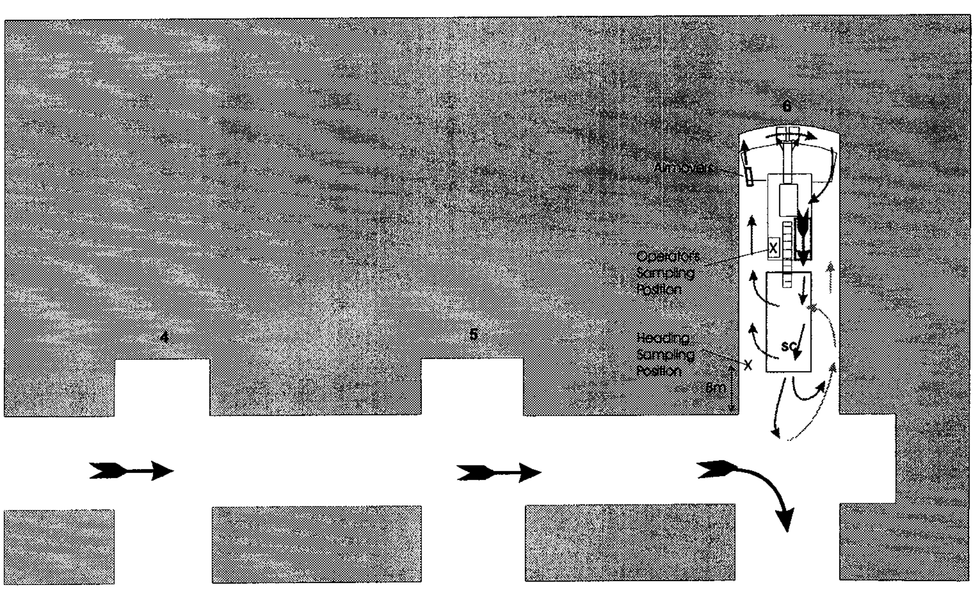
The measured dust concentrations at the operator's position was very high, averaging a gravimetric result of 54mg/m³ over the sampling shift. This instrument was at its maximum limit reading of 50 Simslin units (later calibrated to represent 32mg/m³) for most of the shift. True peak concentrations during the early part of the shift must, therefore have been well in excess of 100mg/m³. The concentration released into the return was much lower, averaging 8.81mg/m³, which will include the effect of dilution of the dust from the heading by the main LTR air volume. The most obvious trend shown in the results is the general decrease in dust levels at both positions as the cut deepened. In view of the poor filtration efficiency of the scrubber and assuming that dust make by the machine remained constant, this effect can only be attributed to lesser recirculation occurring in the heading as the cut deepened.

3.5 Site No. 7

The site visited was driven by a roadheader fitted with a new, large capacity Engart scrubber with a nominal flow of 17m³/s. The details of the site are given in the Table below.

Section	Bord and Pillar
Machine	Voest Alpine AM 80
Roadway Size	6,5m (W) x 5,0m (H)
Section Layout	6 road, 26,5m centres (20 x 20m pillars).
LTR Vent	L-R, min 1m/s.
Scrubber	Engart 90kW Type 36, 17m³/s, RHS, standard inlet 5m from face.
Auxiliary Ventilation System	None for cutting straight headings. Jetfan used for cutting first split.
Sprayfan System	4-tube Airmover sited at left hand rear corner of loading shovel. Bank of 3 sprays sited either side of jib just behind cutting head fitted with 2mm orifice sprays. 2 flat-fan sprays sited at conveyor throat to overcome problems with carry back of dust by the conveyor (1-off blocked at time of visit) Spray system supplied by on-board booster pump set to a delivery pressure of 60bar, but only operated while cutting high in the section.

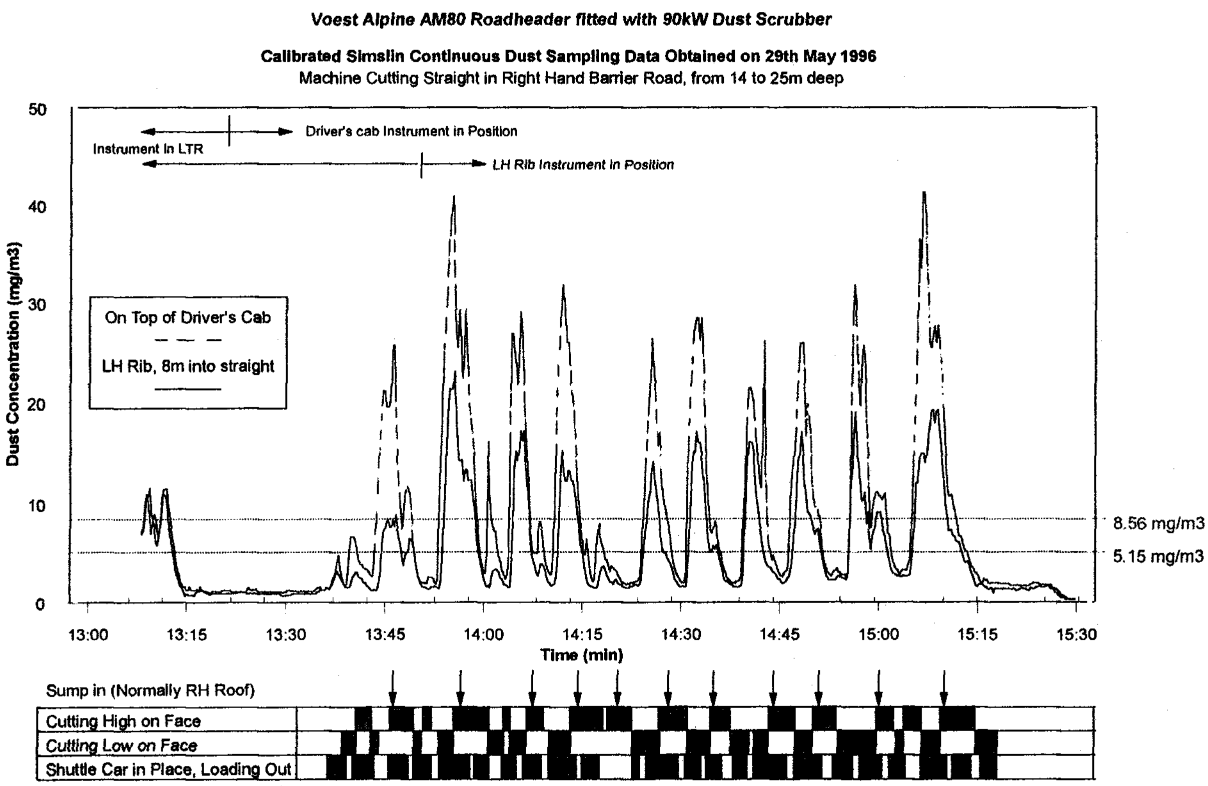
During the visit, cutting was observed in the boundary heading at the right hand end of the section. The layout and cutting circumstances observed during the visit is shown in the Figure below, as are the dust sampling positions.



Site No.7 - Site Layout, Air flow Patterns and Dust Sampling Positions

During the course of the shift, the machine advanced the heading from 14 to 25m from the LTR. There was a considerable amount of recirculation both around the machine and at the entrance to the heading. However, the system effectively controlled the dust cloud which was normally held close to the face, in front of the scrubber inlet with no visible dust roll back.

However, at times during the cutting cycle, normally while cutting high in the roof, entire heading became filled with dispersed dust which was slow to clear, owing to the recirculation taking place. this effect may be seen in the sampling results, shown in the Figure below.



Calibrated shift dust concentrations measured at Mine No.5

From the sampling results, it was seen that the high dust peaks within the heading coincided with cutting high on the face while conveying coal to the shuttle car. The main reason for the link to the operation of the conveyor is shown by the much lower dust concentrations between 14:16 and 14:19 when the machine was cutting high on the face without a shuttle car in place. While cutting low on the face, dust levels were much lower even with the conveyor operating. The cause of the dust problem was therefore surmised to be due to the conveyor carrying dust back from the face to be released into the general air at the conveyor throat alongside the scrubber. From here it was drawn into the discharge air jet from the scrubber which acted to rapidly disperse the dust into the general body recirculating air of the heading. The connection with cutting high on the face is probably due to the increased disturbance to the dust cloud caused by falling material and the water sprays resulting in the dust being pushed further back on the loading shovel from where it is drawn into the conveyor tunnel.

The recommended solution to this problem was to replace the existing flat fan sprays located at the throat of the conveyor with hollow cone sprays, with greater air-moving capacity, directed into the conveyor tunnel at a downward angle of 30° to the conveyor floor. A pair of sprays of this form should create sufficient air flow through the conveyor tunnel to prevent the passage of dusty air from the face.

3.5 Site No. 8

A number of sites without any cutting taking place were briefly visited. This proved extremely useful in terms of comparing different cutting situations.

3.6 Effect of Mining Sequence on Dust Control

During the visits to the various collieries it was observed that the mining sequence had a great influence on the effectiveness of the scrubber and the general control of dust. Discussions with environmental staff at many of the collieries visited also revealed that many were considering alternative options for the mining sequence to try and improve dust conditions. A paper exercise has therefore been carried out, analysing the various options for the mining sequence with a continuous miner with the objective of deriving an optimum sequence for the control of dust. This analysis was carried out using a combination of observations made at the various sites, evidence from CFD predictions together with experience of the general behaviour of ventilation air flows. This analysis is attached to the main report as Appendix 1.

4. SURFACE GALLERY TRIALS

The major element of work on the project was to investigate the fundamental aspects relating to the efficiency of dust capture by a scrubber located on a mechanical miner. This work was carried out in a 35 m long straight-line gallery operated in the UK by IMCL. The gallery was set up with basic roadway dimensions of 6 m wide by 5 m high representing a medium to large cross-section in South African mining terms. The main elements of the investigations were carried out with a model of a typical continuous miner constructed around a smaller mining machine to allow the model to be moved and the jib to be raised and lowered. These trials are reported in Section 4.1. A limited number of underground tests in a production heading was undertaken to confirm some of the results obtained in the surface gallery trials. These are discussed in Section 4.1.4. Further investigations were carried out with a simulated roadheader, again based around an actual machine to enable various jib positions to be evaluated. These are described in Section 4.2.

The main objectives of the gallery work were to evaluate the overall behaviour and balance of the various ventilation systems commonly used on South African machines. This was achievable within the straight-line gallery by considering the cutting of straight headings. However, the effect of LTR ventilation flows could not be simulated.

4.1 Continuous Miner Investigations

4.1.1 Layout of Gallery and Ventilation System Components

The gallery used for the trials was constructed inside a larger building using telescopic steel frames covered by tarpaulins to form the walls. The tarpaulins were of a special construction allowing them to be joined together along the full 35 m length of the gallery to give an airtight seal. In order to achieve the required section for the present purpose, special extensions for the steel frames were manufactured. The confines of the outer building placed a constraint on the cross-section formed in that the left hand upper corner had to be in the form of a diagonal rather than a right angle. Although the nominal roadway cross-section was 6 m x 5 m, the actual cross-sectional area was 28 m^2.

The face of the heading was constructed from standard building blocks which had previously been cut by an actual continuous miner to give the correct cut profile of the face to a height of 3,3 m. The extra height of the face to raise it to the required 5 m was achieved using plywood sheets angled to give approximately the correct form. Care was taken with this issue, since previous experience with simulating underground ventilation situations shows that the shape of the face has a significant effect on air flow behaviour. Basic aerodynamic theory demonstrates that air flows carry around smooth corners far more readily than sharp right angles, with far less energy being lost through turbulence. The effect of a localised air jet acting on a curved profile face can therefore be far greater than on a flat face with sharp corners. The cutting profile of a continuous miner is a curve in the face from roof to floor but with sharp corners at each side.

For secondary auxiliary ventilation within the roadway, the trials concentrated on the use of jetfans, this being the most common form in use underground and that which reportedly gave the majority of dust control problems. A jetfan was simulated using a 760 mm diameter, 37 kW auxiliary fan fitted with an outlet cone reducer nozzle to produce an air jet from an 0,32 m diameter orifice. With the 'jetfan' outlet nozzle fitted, this fan passed 5,6 m^3/s, sufficient to achieve the minimum required ventilation flow in the roadway cross-section of 0,2 m/s per m^2. The output was equivalent to a 0,57 m diameter, 11kW jetfan which nominally passes 4,5 m^3/s through a 0,32 m diameter outlet nozzle. In relation to the auxiliary ventilation, the trials considered four different ventilation situations for cutting a straight heading :-

1. up to a distance of 12 m without a jetfan
2. jetfan outlet located 12 m from the face
3. jetfan outlet located 20 m from the face, and
4. jetfan outlet located 30 m from the face.

In addition, three different cutting scenarios were studied :-

1. at the start of the cutting cycle, the machine being placed at the right hand side of an uncut, flat face,
2. with the machine 4 m deep into the first, partial cut on the right (this was simulated by constructing a covered frame to the left of the machine to represent the uncut part of the heading) and, where a jetfan was being used, siting this an additional 4 m from the partial face,
3. during the second pass, final cutting stage, with the machine on the left of the heading, in front of the covered framework and using the same jetfan position as for 2, above.

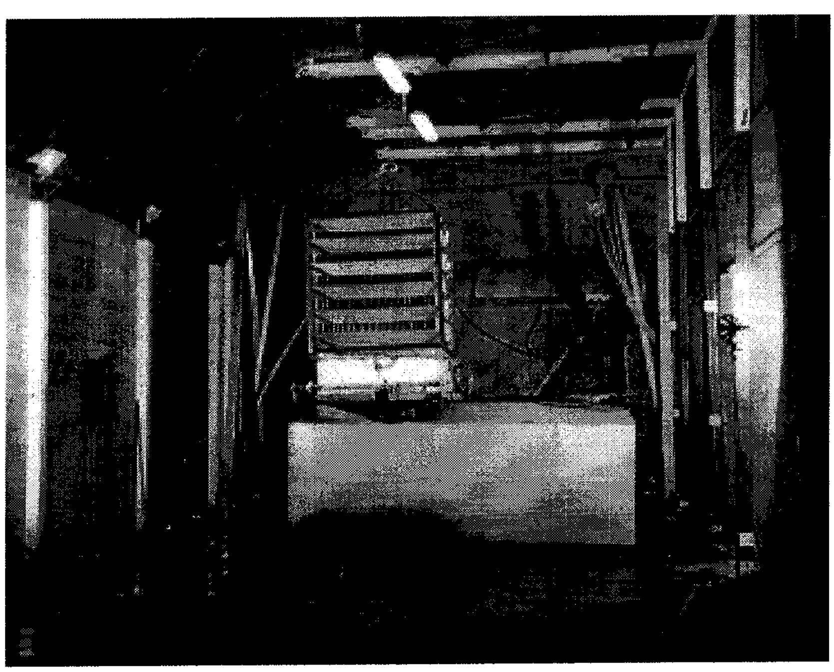
The machine simulation was taken to represent a relatively small continuous miner since it is known that the worst situation for controlling dust is for a small machine operating in a large roadway. The overall dimensions of the simulated machine body were therefore set at 1,5 m high by 3,1 m wide (a cross-section of 4,7 m²). These dimensions compare with those of actual machines as follows :-

12HM9	- basic chassis height - 1,42 m, width - 3,16 m
12HM31 Model B	- basic chassis height - 1,78 m, width - 3,30 m
12HM21, 5 m model	- basic chassis height - 2,15 m, width - 3,16 m

The simulation did not take into account the drivers cab, which is mainly open on actual machines and therefore not a resistance to air flow, nor the machine conveyor. But the effective cross-section of the conveyor at its normal angle for loading is negligible when considered with respect to its effect on air flow around the machine. Simulating the machine conveyor would also have inhibited the view of the face during video recording of the tests.

An Engart scrubber unit was suspended from an 'A'-frame over the left hand side of the machine in a typical position, with the inlet located 5,5 m from the face. The scrubber was identical to a 30" EDE model with a 37kW fan motor, but fitted with a slurry tank and recirculating pump which allowed overall water consumption to be minimised while raising the level of the inlet to a height comparable to that on actual machines.

A photograph and diagram of the overall arrangement of the gallery and machine are shown below.



General arrangement of test gallery with simulated continuous miner

The scrubber unit was measured as passing an air quantity of 8,25 m³/s. The scrubber had a cross-sectional area of 2,3 m² which, when added to the machine body area, resulted in a total cross-sectional area of 7,0 m² for the overall machine. The open roadway area around the machine was therefore 21 m² and hence this scrubber flow was sufficient to produce a mean air flow around the drivers position of 0,39 m/s per m². Compared with the jetfan air flow of 5,6 m³/s, this scrubber volume represented a recirculation factor of 50 %. The overall ventilation arrangement therefore complied with the requirements laid down in the DME Ventilation Guidelines.

In addition to the auxiliary ventilation system, a typical sprayfan system was fitted to the machine. This comprised 21 sprays (1,2 mm orifice) located as follows:-

- 12 sprays located on top of the machine jib, behind the cutter drums, the right hand end spray directed forward, the remaining 11 sprays angled 30° to the left. (Systems seen underground varied from 9 to 15 sprays located in this position.)

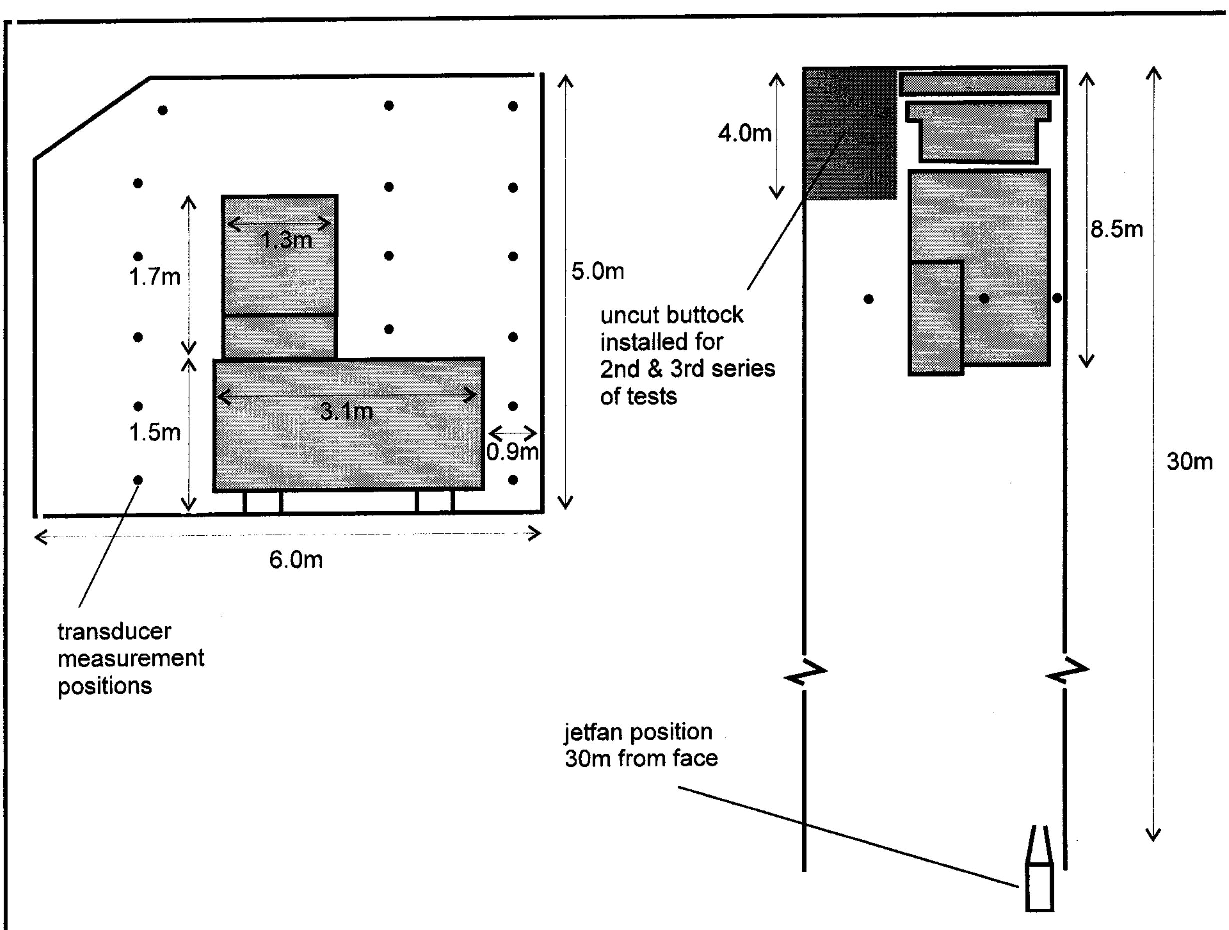


Diagram of the Layout of the Gallery

- 2 sprays sited horizontally on the right hand top of the main machine body, 4,5 m back from the face, directed forwards.
- 4 sprays sited vertically on the right hand side of the main machine body, 4,5 m back from the face, directed forwards.
- 3 sprays sited in a position corresponding to the right hand rear corner of the loading shovel, directed towards the face but angled to the left.

For the main test programme, operating pressures of 6, 12 and 30 bar, measured at the sprays, were selected for study. These appear to be the typical minimum and maximum pressures used on machines underground. Previous experience suggests that smaller orifice sprays operated at higher pressures are capable of moving more air than larger orifice sprays at lower pressures. Small orifice nozzles were therefore selected for use in the trials since the greater air movement may lead to more significant problems with scrubber dust capture, despite providing better ventilation of the face.

The final aspect of accurately simulating underground conditions involves the effects of cutting head rotation and falling material, both of which can have a substantial influence on air flows, and hence dust behaviour, at the face and around the machine. These factors, together with the effect of water sprays, are normally responsible for any dust roll-back around machines which normally occurs close to floor level. IMCL staff have a great deal of experience on surface gallery testing of environmental control systems fitted to many different types of mechanical miners and have previously compared conditions during actual cutting with static test situations.

On continuous miners, the order of significance of the various factors which work in combination to create a downward air flow at the face, and hence dust roll-back at floor level, is as follows:-

1. Sprays sited along the top of the jib,
2. Cut material falling to the floor, and
3. Rotation of the cutting head from roof to floor.

The spray system has by far the largest effect, the system being purposely designed to move air. Falling material can also have a substantial effect, particularly when cutting in the roof of high roadways. Rotation of the cutting head has the least effect; with no ventilation around the cutter drums, rotation tends to recirculate air around the drums dispersing gas and dust to a distance of approximately 1,5 m from the periphery of the drum. While shearing down the face, the buttock beneath the cutter drums tends to restrict the effect of both the spray system and the drum rotation, also causing any air movement to be directed back underneath the jib, away from the face, rather than towards the floor. In the gallery simulation, there was no cutting buttock within the form of the face to restrict or deflect the air flow from the sprays which acted directly down the face, nor was the simulated machine equipped with rotating cutter drums. The additional effect of the sprays therefore compensated for the effect on disturbance of the dust cloud due to the lack of falling material and drum rotation. Because of the differences in effect with respect to cutting height, the main series of tests considered both the situation of cutting at a high level on the face, with the jib raised, and also with the jib lowered to approximately 1 m from the floor.

Two techniques were used in the investigations, firstly, a visual assessment using smoke to determine the air flow patterns and distribution of dust around the machine and, secondly, by measuring the air velocities around the machine to determine the actual air flows. In the visual assessment, a generator was used to produce smoke which was normally released at the cutter drums and its behaviour recorded on video for later analysis in conjunction with the air flow measurements. Smoke behaves similarly to respirable dust, being of the same order of magnitude in particulate size, but less dense. The particulate diameter in the smoke is of the order of 1 µm diameter, while respirable dust has a particulate size range of between 1 and 7 µm diameter. The smoke particles, being both smaller and less dense than respirable coal dust, will therefore tend to remain suspended in air for longer periods. However, in typical eading conditions, the fallout of respirable dust would not normally be measurable until it had travelled several hundreds of metres, a far greater distance than is relevant in bord and pillar headings. The use of smoke is therefore a reliable indicator to the behaviour of respirable dust. As well as studying the specific behaviour of dust in a static situation, which related to the velocity measurements, a video record was also made of the smoke behaviour during a simulated cutting situation while the machine jib was being raised and lowered.

Most velocity measurements were taken around the machine body at a position 6,5 m from the front of the cutter drums. This position was alongside the scrubber, 1 m behind its inlet, and therefore allowed measurement of any net air flow around the machine. If all the air movement at this position is in a forward direction, all the dust from cutting would normally be held in front of the scrubber inlet and the scrubber capture efficiency would be 100 %. However, any localised passage of air back from the face at this position represents dust-laden air which is by-passing the scrubber inlet. Determination of the quantity of air by-passing the scrubber in relation to the air flow through the scrubber itself gives a measure of dust capture efficiency of the scrubber system. Of course, this measure depends upon the assumption that the dust is evenly distributed within the outflowing air around the machine. In general, this is a valid assumption if the face ventilation is turbulent which is normally the case with an effective forcing auxiliary ventilation system. However, with a less effective face ventilation system where dust roll-back is a predominant factor, the dust would tend to stream back from the face relatively slowly, without turbulent mixing to evenly distribute the dust. In this latter circumstance, evaluation of dust scrubber capture by means of air flow measurement is less valid, although still providing a useful guide to the relative extent of the dust roll-back problem.

The velocity measurements were taken using TSI Model 8470 omni-directional air velocity transducers with a range of 0-5,0 m/s. Six transducers were mounted in a vertical array to measure the velocities around the machine, the array being moved between three positions in the roadway to measure the air velocities all around the machine. These measurement positions are shown in the above diagram (layout of gallery). The output from each of the transducers were logged on a computer at 1 second intervals over a period of 4 minutes. Subsequent analysis of this data yielded mean values for the air velocity at each point. In some circumstances, air velocities were beyond the range of the transducers, particularly when they were directly within the air jet from the jetfan. Additional problems were encountered on occasion with excessive water from the sprayfan system being carried back to the transducers causing them to read incorrectly. In both these circumstances, a hand-held anemometer was used to give a more accurate indication of air velocity.

The transducers were omni-directional, that is, they gave only an indication of air speed irrespective of its direction. Analysis of the video record, together with specific smoke tests were therefore used to identify the air flow directions which, in the results, are shown only as towards (positive) or away (negative) from the face. By apportioning a cross-sectional area to each of the velocity measurements, the approximate air flows around the machine were calculated. The accuracy of these calculated air flows is questionable, particularly where there were very localised flows. For example, within the air jet from the jetfan where the spacing of the transducers is very wide with respect to the velocity gradient within the jet, or where the air flow was not strictly along the axis of the heading. Nevertheless, they still provide a useful guide to conditions within the heading.

4.1.2 Evaluation of the Basic Components of the Ventilation System

In the initial stages of the trials it was intended to assess the effect of the individual components of the secondary ventilation system in their normal configuration. The first tests were carried out with only the scrubber operating, after which the additional effect of the sprayfan system was evaluated at various pressure settings. Finally, the jetfan was added to the overall system at different distances from the face. Having identified the individual effect of the various components, means of improving the dust capture efficiency of the scrubber by siting the inlet in alternative positions were investigated. Each stage of the investigations is described in the following Sections.

Effect of a Standard Scrubber

For the initial test with only the scrubber operating, velocity transducer measurements were taken at two positions, 6,5 and 2,5 m from the face, the results being shown in Figures 4,1 and 4.2 respectively. In the figures a positive velocity indicates flow *towards* the face, while a negative velocity indicates flow *away* from the face. The air flow patterns around the machine are shown in Figure 4.3, together with the calculated air flows around the machine. The results show that the scrubber was drawing air towards the face to the right of the scrubber while there was a general outflow of air past the scrubber on the left. At the 6,5 m position, the calculated total flows towards and away from the face were in reasonable agreement, showing that the scrubber was actually moving approximately twice the volume of air that actually passed through it. Taking the lower, outbye calculated air flow of 15,8 m^3/s (including the scrubber air flow of 8,3 m^3/s) to be more reliable, because the air flow tends to be straighter with respect to the roadway axis, this indicates that only 53 % of the air passing back from the face was captured by the scrubber.

At the 2,5 m position, the measured air flows were much smaller, less than half those further back. There was also a greater discrepancy between the calculated flows which was probably due to the sideways vector of the air flow towards the right of the machine as it turned back towards the scrubber inlet. The value for the outbye air flow, 5,9 m^3/s, is therefore probably more valid. Around the face itself, the air was quite still, only secondary entrained flows being observed. The effective capture zone of the scrubber did not, therefore, reach the face.

Analysis of the situation with smoke revealed that the discharge jet of the scrubber was largely responsible for the additional air flow around the machine and consequent low scrubber capture efficiency. The scrubber outlet contained a series of vertical parallel plates intended to straighten the discharge air jet. However, these were not completely effective, the discharge air tending to be angled by about 5° towards the left hand side of the roadway, expanding quickly to both floor and roof, as shown in Figure 4.3. The overall effect of this was to entrain air from close to the face drawing it outbye along the left hand side of the machine. The form of the scrubber discharge was therefore having a significant effect on scrubber dust capture.

Since it was the jet of air issuing from the rear of the machine that was causing the entrainment of extra air, the first approach which was tried to reduce its effect was to fit a diffuser device. This diffuser took the form of a 2,5 m length of duct with 75 mm holes in its periphery and in the blank end, so that the air was discharged in small jets in all directions. Although this device significantly reduced the entrainment effect, smoke trials showed that the air flow patterns became very disturbed around the rear of the machine, the scrubber air totally recirculating within a distance of 12 m from the face. Such a high degree of recirculation within such a short distance was considered to be undesirable from a methane control aspect. Ventilation measurements were therefore not carried out.

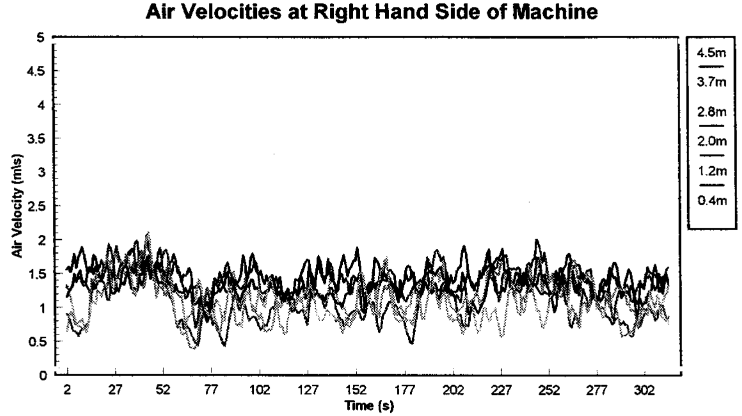
A second approach was to deflect the scrubber discharge air towards the nearest wall of the roadway. By minimising the distance the air jet travels through the general body air and attaching the jet to a wall, the opportunity for entrainment of additional air is limited, while the jet will still maintain its momentum away from the machine, helping to throw it towards the LTR and hence minimise recirculation. The nearest practical wall of the roadway to which the air jet could be deflected was the roof. Such angled deflectors are already fitted to some scrubbers underground, but for the purpose of deflecting the scrubber discharge jet away from shuttle car drivers. A series of parallel deflector plates to direct the scrubber discharge upwards at an angle of 30° were fitted to the rear of the scrubber, as shown in the photograph in Section 4.1.1.

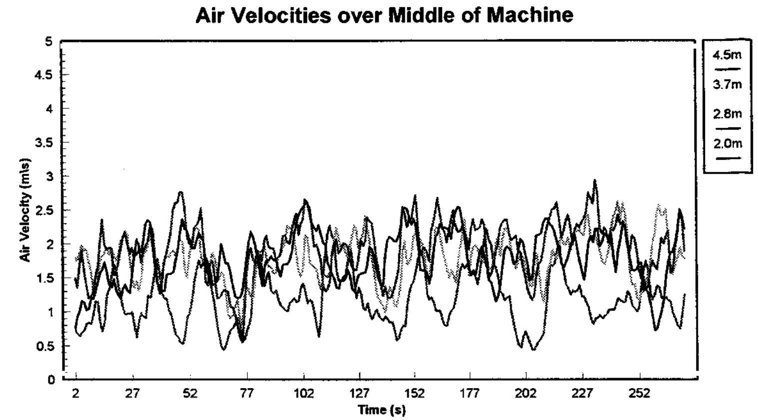
With deflectors fitted, smoke tests indicated that the air flow to the left of the machine was reversed, now moving towards the face. In addition, the discharge jet tended to travel at least 10 m away from the rear of the machine, at roof level, before losing its momentum and mixing back into the inward flowing general body air of the gallery. The air flow measurement results and air flow patterns are shown in Figures 4.4 and 4,5 respectively. These show that the majority of air around the machine now flowed towards the face, except for a small zone close to the roof on the left. This small area was influenced by the cooling air from the fan motor of the scrubber which was directed away from the face. The total air flow travelling away from the face was calculated to be 9,5 m^3/s, representing a scrubber capture efficiency of 87 %. As a result of the reduced air flow around the machine, the air velocities were correspondingly much lower than without the deflectors fitted and reasonably well distributed. However, the decreased momentum of the forward moving air meant that the air was pulled towards the scrubber inlet more quickly, resulting in the poorly ventilated zone near the face deepening.

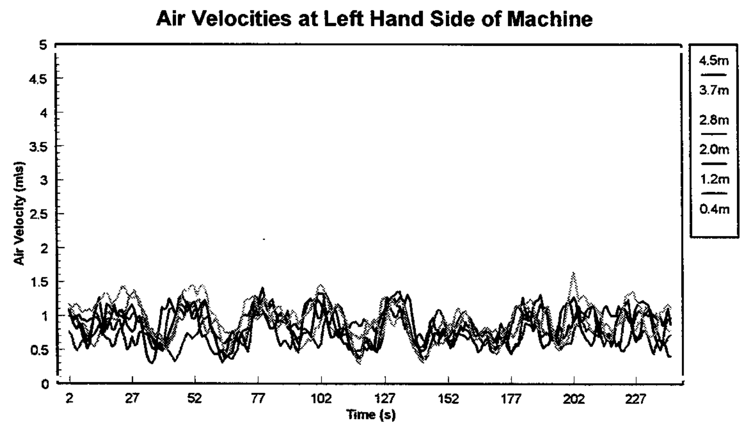
The deflectors made a significant improvement in scrubber dust capture. In addition, when a machine is cutting up to a distance of 12 m from the LTR without additional auxiliary ventilation, the 'throw' of the scrubber discharge should be sufficient to ensure that most of this air is pushed out into the LTR, minimising recirculation. This outlet configuration for the scrubber was retained for all further tests. However, the consequently larger, poorly ventilated zone close to the face does have implications for the control of methane. This demonstrates that the present scrubber inlet position, 5,5 m from the face, is too remote to provide effective face ventilation. The use of an effective sprayfan system is therefore imperative.

Test Conditions -

Start of 1st Pass Cut on Right Scrubber only operating -
Standard inlet,
Standard discharge







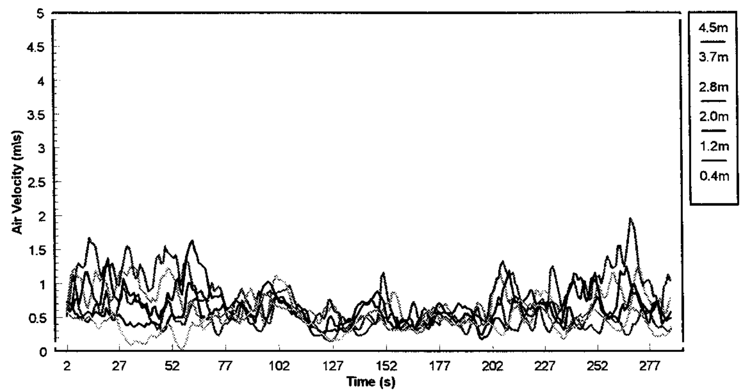
Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	1.11 +/- 0.37 m/s
	- 3.7m	1.14 +/- 0.29 m/s
	- 2.8m	1.39 +/- 0.22 m/s
	- 2.0m	1.44 +/- 0.19 m/s
	- 1.2m	1.31 +/- 0.17 m/s
	- 0.4m	1.10 +/- 0.29 m/s
Over Middle of Machine	- 4.5m	1.17 +/- 0.39 m/s
	- 3.7m	1.79 +/- 0.35 m/s
	- 2.8m	1.95 +/- 0.42m/s
	- 2.0m	1.79 +/- 0.39 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	- 0.76 +/- 0.19 m/s
	- 3.7m	- 0.86 +/- 0.17 m/s
	- 2.8m	- 0.83 +/- 0.24 m/s
	- 2.0m	- 0.91 +/- 0.24 m/s
	- 1.2m	- 0.81 +/- 0.23 m/s
	- 0.4m	- 0.97 +/- 0.28 m/s

Figure 4.1 Air velocities at 6,5 m from the Face, Standard Scrubber Only Operating

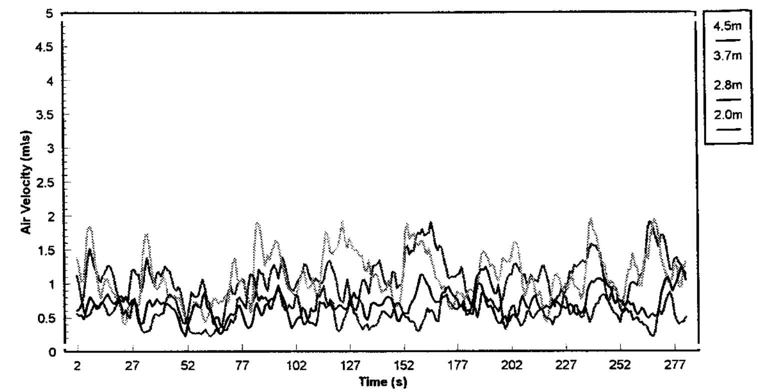
Test Conditions -

Start of 1st Pass Cut on Right,
Scrubber only operating -
Standard inlet,
Standard discharge

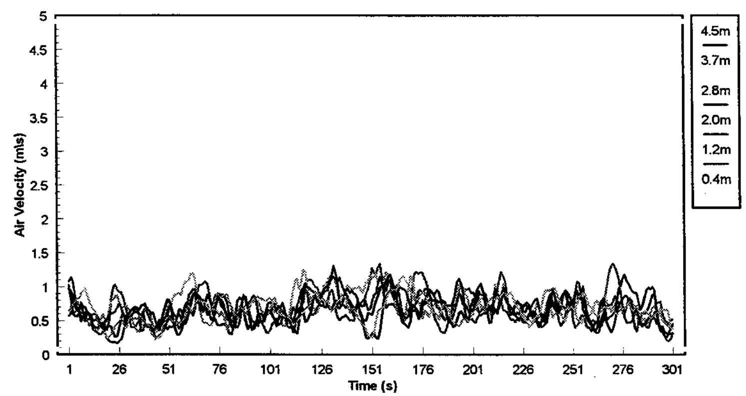
Air Velocities at Right Hand Side of Machine



Air Velocities over Middle of Machine



Air Velocities at Left Hand Side of Machine



Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	0.54 +/- 0.20 m/s
	- 3.7m	0.71 +/- 0.25 m/s
	- 2.8m	0.80 +/- 0.39 m/s
	- 2.0m	0.71 +/- 0.26 m/s
	- 1.2m	0.54 +/- 0.17 m/s
	- 0.4m	0.43 +/- 0.16 m/s
Over Middle of Machine	- 4.5m	1.05 +/- 0.34 m/s
	- 3.7m	1.12 +/- 0.36 m/s
	- 2.8m	0.62 +/- 0.20 m/s
	- 2.0m	0.68 +/- 0.18 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	- 0.66 +/- 0.24 m/s
	- 3.7m	- 0.72 +/- 0.21 m/s
	- 2.8m	- 0.69 +/- 0.20 m/s
	- 2.0m	- 0.71 +/- 0.21 m/s
	- 1.2m	- 0.60 +/- 0.16 m/s
	- 0.4m	- 0.67 +/- 0.18 m/s

Figure 4.2 Air velocities at 2,5 m from the Face, Standard Scrubber Only Operating

Test Conditions -

Start of 1st Pass cut on Right,
Scrubber only operating -
Standard inlet,
Standard discharge

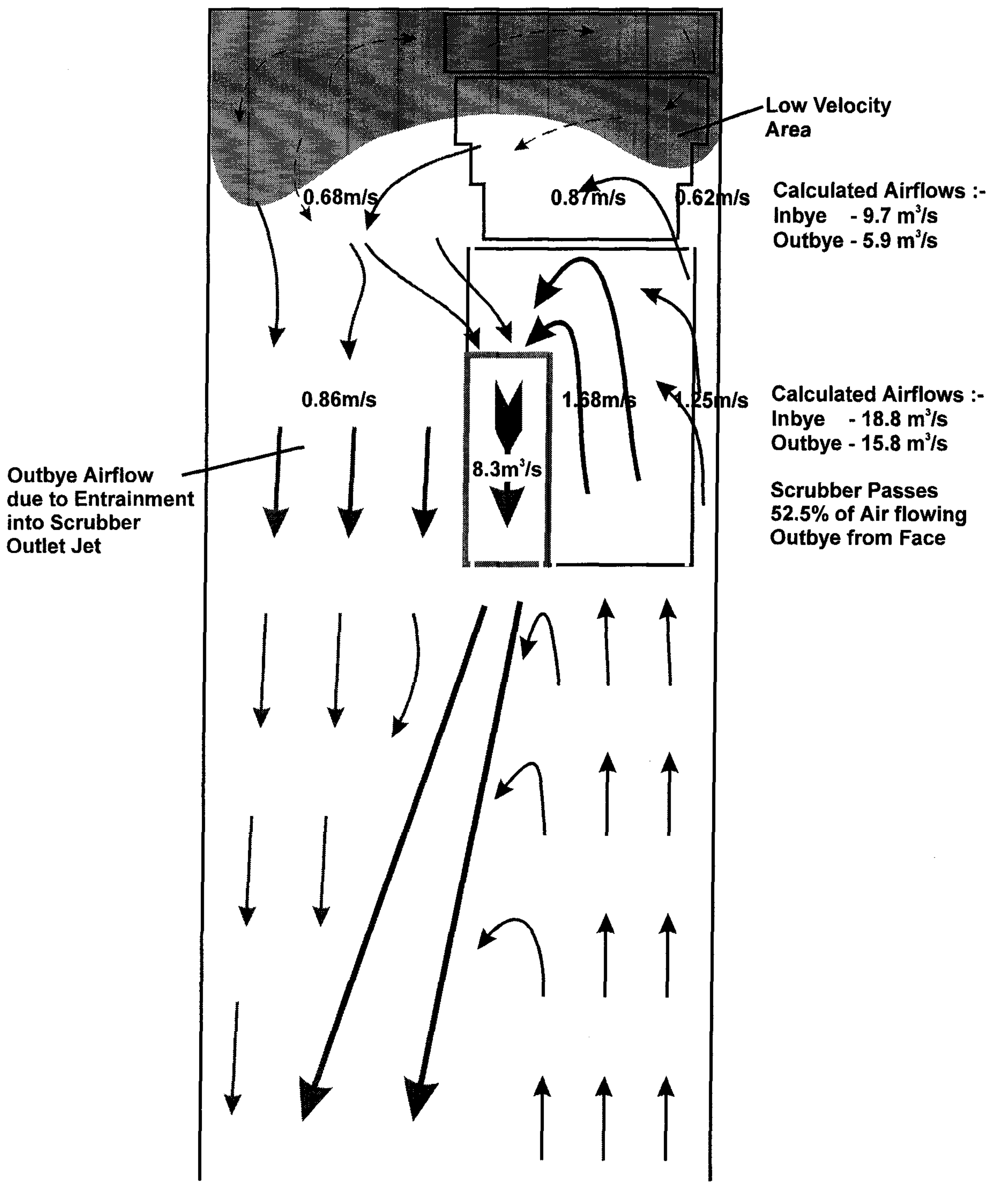
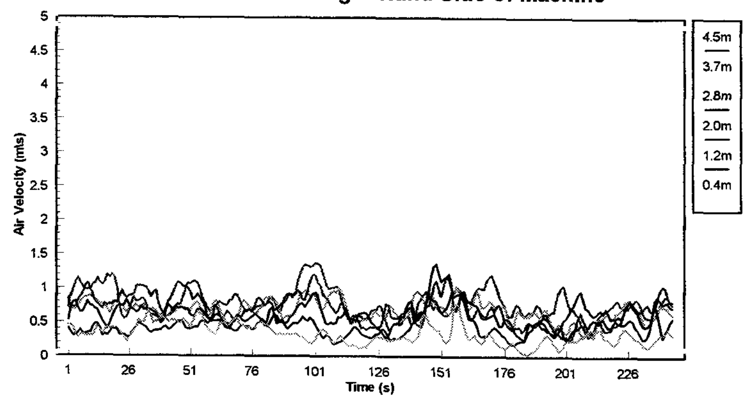
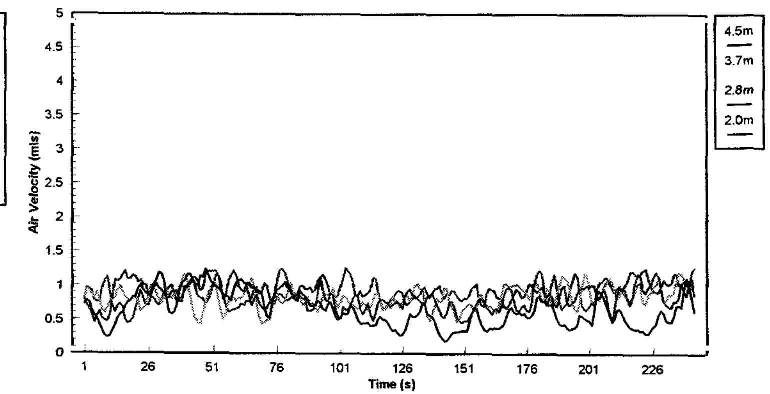


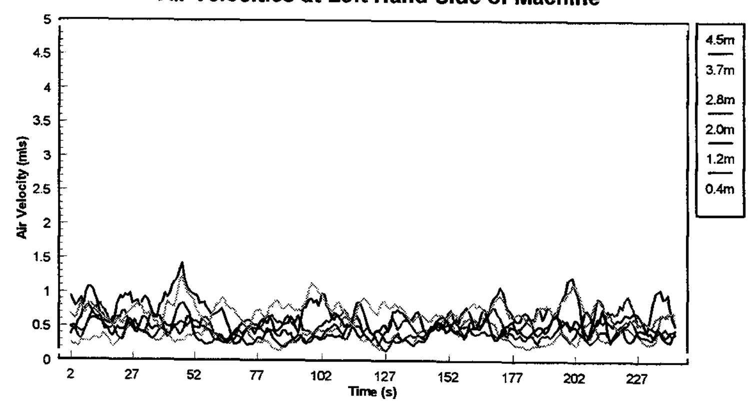
Figure 4.3 General Airflow Patterns around the Machine, Standard Scrubber Only Operating

Test Conditions -

Start of 1st Pass Cut on Right
Scrubber only operating -
Standard inlet,
Outlet deflected upwards







Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	0.78 +/- 0.22 m/s
	- 3.7m	0.68 +/- 0.14 m/s
	- 2.8m	0.72 +/- 0.21 m/s
	- 2.0m	0.64 +/- 0.18 m/s
	- 1.2m	0.44 +/- 0.15 m/s
	- 0.4m	0.33 +/- 0.14 m/s
Over Middle of Machine	- 4.5m	0.89 +/- 0.16 m/s
	- 3.7m	0.83 +/- 0.16 m/s
	- 2.8m	0.86 +/- 0.19 m/s
	- 2.0m	0.65 +/- 0.25 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	0.53 +/- 0.13 m/s
	- 3.7m	- 0.38 +/- 0.13 m/s
	- 2.8m	- 0.42 +/- 0.09 m/s
	- 2.0m	0.45 +/- 0.15 m/s
	- 1.2m	0.70 +/- 0.22 m/s
	- 0.4m	0.73 +/- 0.14 m/s

Figure 4.4 Air velocities at 6,5 m from the Face, Standard Scrubber Only Operating, Fitted with Outlet Deflectors

Test Conditions -

Start of 1st Pass cut on Right,
Scrubber only operating -
Standard inlet,
Outlet deflected upwards

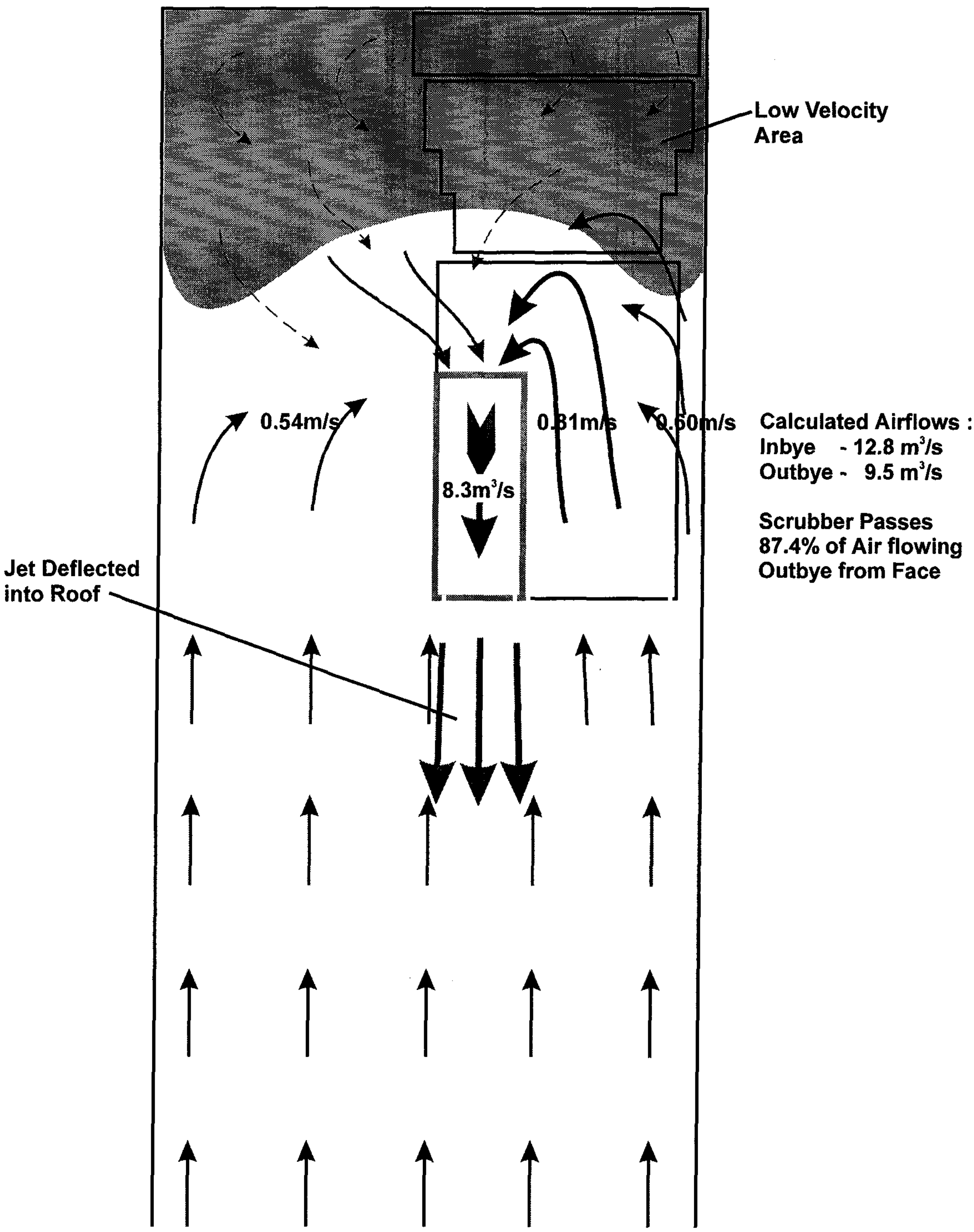


Figure 4.5 General Airflow Patterns around the Machine, Standard Scrubber Only Operating, Fitted with Outlet Deflectors

Effect of Sprayfan System

The effect of the sprayfan system was initially assessed at three operating pressures of 6, 12 and 30 bar in the situation at the start of the first pass cut on the right. All spray pressures were measured at the spray nozzles. Tests were carried out with the jib raised and with the jib lowered, but the effect of the sprayfan system on scrubber capture was greatest with the jib raised, as shown in the summary table of calculated air flows below. As before, the calculated air flow away from the face was considered to be more reliable and has been used for calculating the nominal scrubber capture efficiency.

Spray Pressure (bar)	Jib Position	Calculated Flow Outbye (m^3/s)	Scrubber Vol / Outbye Vol (%)
--	Raised	9,5	87
6	Raised	10,6	78
12	Raised	11,7	71
30	Raised	14,8	56
6	Lowered	10,6	81
12	Lowered	10,7	78
30	Lowered	11,7	71

The individual air flow measurements at the three different spray pressures with the jib raised are shown in Figures 4.6 to 4.8. At all pressures, the sprayfan system was effective in ventilating the face, eliminating the 'dead' zone that was present with only the scrubber operating. However, with the jib raised, the angled sprays located along the top of the jib tended to push air down and to the left of the face, the left hand sidewall and the floor tending to deflect this air flow into the lower left corner of the face. From here, the air flowed away from the face close to the floor. The extent of this outflow of air past the scrubber increased with spray pressure.

The same general air flow patterns occurred at the face with the jib lowered, but the proximity of the floor reduced the collection of air in the left hand corner, resulting in a lower overall effect of the spray system on air flows on the left of the machine. In addition, it may be seen from the calculated air flows around the machine that much less air was moved by the sprayfan system with the jib lowered. This may be partly due to the overall configuration of the sprays. With the jib lowered, the sprays located on the body of the machine push air towards the sprays located on the machine jib which then entrain and move this same air volume. However, when the jib is raised, the sprays on the side of the machine body push air towards the face underneath the jib, while the sprays on the jib entrain air from a much higher level. In effect, each set of sprays affects a different air volume and therefore the system moves a greater total volume of air.

As expected, the extent of the effect of the sprayfan system on scrubber capture efficiency varied with spray pressure. At 6 bar with the jib lowered, the outward flowing air on the left hand side at floor level did not reach the rear of the machine, but turned and rose into the inflowing air above, which carried it back towards the scrubber inlet. With the jib raised, the outward flowing air was observed to reach the rear of the machine at floor level, with only a small amount escaping into the area behind the machine from where it recirculated back over the driver's position towards the face. Increasing the pressure to 12 bar increased this effect: with the jib lowered, the air flow just reached the rear of the machine but with the jib raised a significant amount of air was pushed behind the machine, then returning towards the scrubber inlet by flowing over the top of the machine. At 30 bar, this latter effect occurred with both the jib raised and lowered, resulting in a significant reduction in scrubber dust capture efficiency.

The results from this cutting situation suggested that a spray pressure of 30 bar was excessive, substantially reducing the dust capture ability of the scrubber. The results also suggested that 12 bar pressure may also be too high, with 6 bar representing the optimum pressure for dust control. However, reducing the operating pressure of the sprayfan system also reduces the its ventilation effect at the face. Before making final judgement as to the optimum operating pressure for the system the effects in the other cutting situations were assessed, using smoke and video.

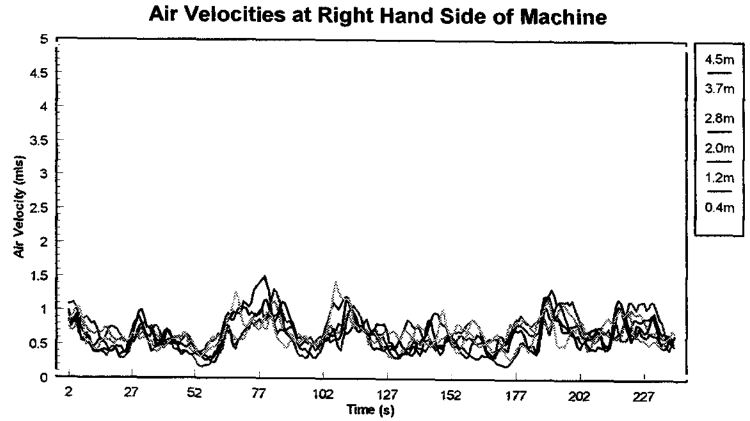
In the second cutting situation, 4 m into the partial cut on the right, operation of the sprayfan system in conjunction with the scrubber gave improved conditions, the partial wall to the left of the machine confining and turning the air moved by the sprays back towards the scrubber inlet. The body of the machine also tended to block the movement of air back from the face at floor level on the left hand side. However, this restriction at a low level resulted in the outflow of air to occur closer to the roof, above the scrubber. This outflow subsequently becomes entrained in the discharge air from the scrubber which then blows it back behind the machine. This effect appeared to be worst with the jib lowered and slightly worse at a sprayfan pressure of 30 bar than at 12 bar. Reducing the spray pressure to 6 bar had little additional beneficial effect. Very similar effects were observed in the final cutting situation of the second pass cut.

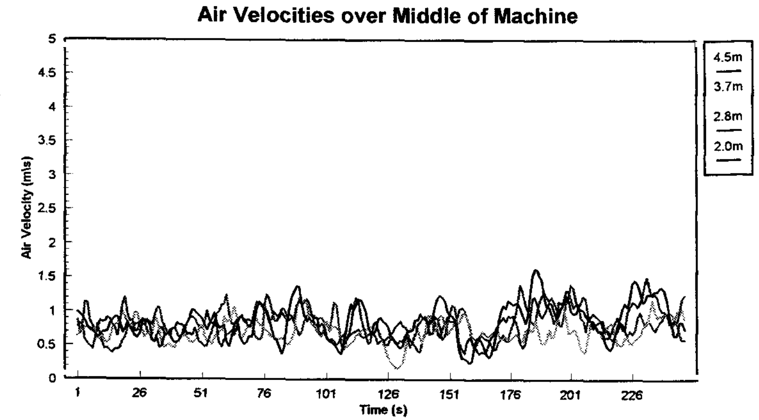
On balance, therefore, and taking into account the progression through stages of the cutting cycle, it is recommended that the sprayfan system should be operated at a pressure of between 6 and 12 bar to obtain good face ventilation and a high scrubber dust capture efficiency.

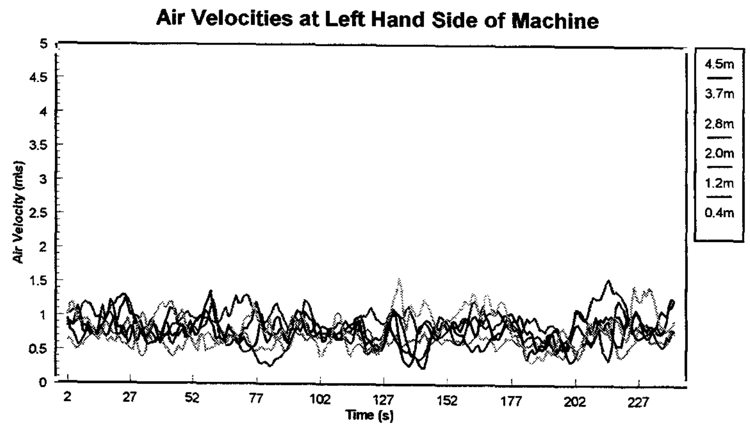
A single pressure setting of 12 bar was used for comparison of effects during further testing.

Test Conditions -

Start of 1st Pass Cut on Right
Jib Raised
Scrubber operating -
Standard inlet,
Outlet deflected upwards
Sprayfan System at 6 bar





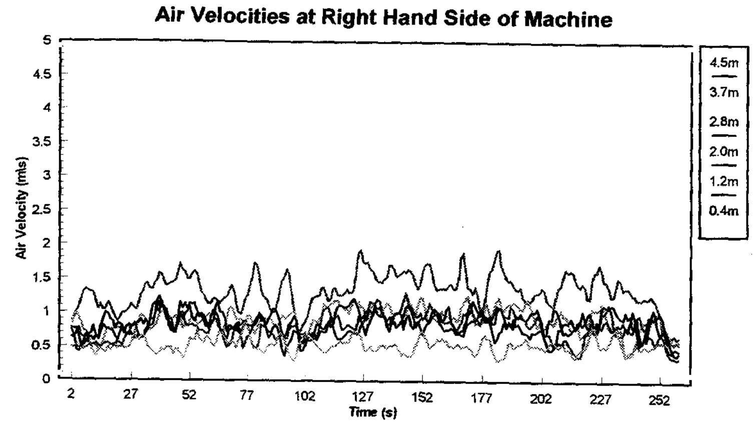


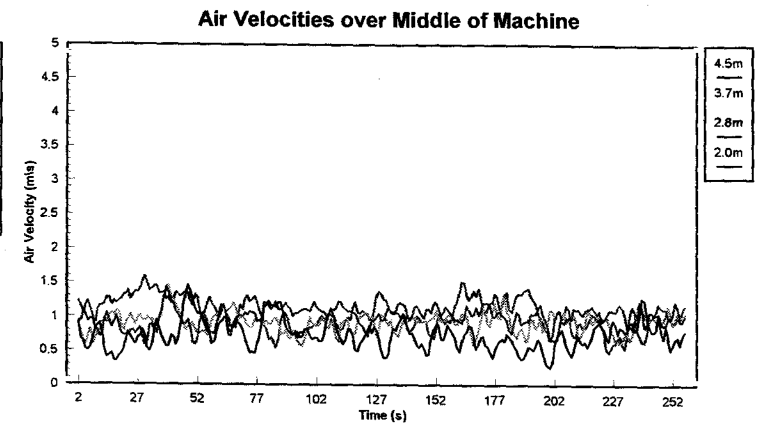
Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	0.73 +/- 0.20 m/s
	- 3.7m	0.68 +/- 0.17 m/s
	- 2.8m	0.60 +/- 0.19 m/s
	- 2.0m	0.67 +/- 0.27 m/s
	- 1.2m	0.64 +/- 0.24 m/s
	- 0.4m	0.67 +/- 0.21 m/s
Over Middle of Machine	- 4.5m	0.81 +/- 0.21 m/s
	- 3.7m	0.72 +/- 0.18 m/s
	- 2.8m	0.83 +/- 0.22 m/s
	- 2.0m	0.85 +/- 0.27 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	0.96 +/- 0.17 m/s
	- 3.7m	0.65 +/- 0.11 m/s
	- 2.8m	0.75 +/- 0.21 m/s
	- 2.0m	0.80 +/- 0.19 m/s
	- 1.2m	- 0.77 +/- 0.18 m/s
	- 0.4m	- 0.84 +/- 0.26 m/s

Figure 4.6 Air velocities at 6,5 m from the Face, Scrubber plus Sprayfan System at 6 bar

Test Conditions -

Start of 1st Pass Cut on Right
Jib Raised
Scrubber operating -
Standard inlet,
Outlet deflected upwards
Spraryfan System at 12 bar



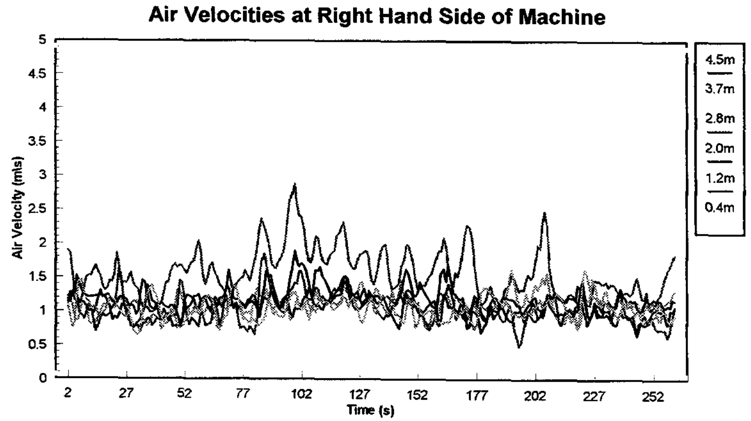


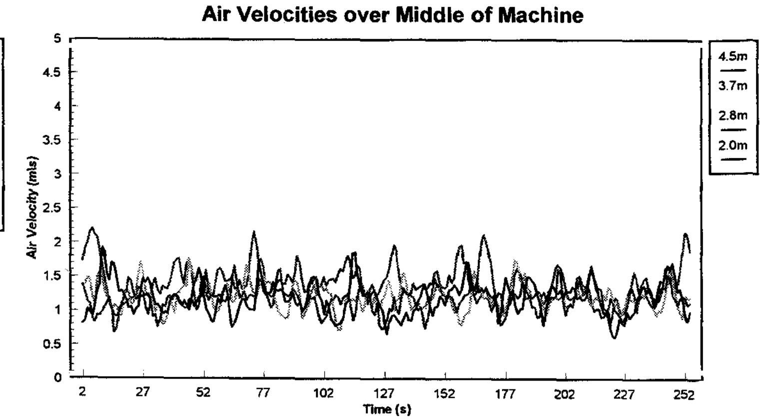
Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	1.33 +/- 0.26 m/s
	- 3.7m	0.91 +/- 0.18 m/s
	- 2.8m	0.79 +/- 0.20 m/s
	- 2.0m	0.80 +/- 0.16 m/s
	- 1.2m	0.87 +/- 0.16 m/s
	- 0.4m	0.53 +/- 0.10 m/s
Over Middle of Machine	- 4.5m	1.05 +/- 0.23 m/s
	- 3.7m	0.92 +/- 0.15 m/s
	- 2.8m	1.01 +/- 0.15 m/s
	- 2.0m	0.74 +/- 0.21 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine (Anemometer Measurement)	- 4.5m	0.75 m/s
	- 3.7m	0.40 m/s
	- 2.8m	- 0.30 m/s
	- 2.0m	- 0.50 m/s
	- 1.2m	- 0.75 m/s
	- 0.4m	- 0.80 m/s

Figure 4.7 Air velocities at 6,5 m from the Face, Scrubber plus Sprayfan System at 12 bar

Test Conditions -

Start of 1st Pass Cut on Right
Jib Raised
Scrubber operating -
Standard inlet,
Outlet deflected upwards
Sprayfan System at 30 bar





Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	1.57 +/- 0.35 m/s
	- 3.7m	1.10 +/- 0.16 m/s
	- 2.8m	1.03 +/- 0.22 m/s
	- 2.0m	1.06 +/- 0.15 m/s
	- 1.2m	1.21 +/- 0.18 m/s
	- 0.4m	1.05 +/- 0.16 m/s
Over Middle of Machine	- 4.5m	1.39 +/- 0.27 m/s
	- 3.7m	1.21 +/- 0.19 m/s
	- 2.8m	1.20 +/- 0.21 m/s
	- 2.0m	1.19 +/- 0.24 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine (Anemometer Measurement)	- 4.5m	0.50 m/s
	- 3.7m	- 0.65 m/s
	- 2.8m	- 0.60 m/s
	- 2.0m	- 0.90 m/s
	- 1.2m	- 1.10 m/s
	- 0.4m	- 1.20 m/s

Figure 4.8 Air velocities at 6,5 m from the Face, Scrubber plus Sprayfan System at 30 bar

Effect of Jetfan

The effect of a jetfan was initially assessed in the first cutting position, at the start of the first pass cut at the right of the face. Measurements were taken for each of the selected jetfan positions both with and without the scrubber operating. At the 20 m position, an additional test was carried out with both the scrubber and sprayfan system operating at a pressure of 12 bar. A final test was also conducted with the full ventilation system operating, but to compare the effect of siting the jetfan at floor level rather than in the roof. The results obtained with the machine jib in the raised position are summarised in the table below.

Jetfan Position (m)	Jib Position	Scrubber Quantity (m^3/s)	Sprayfan Pressure (bar)	Calculated Flow Outbye (m^3/s)	Scrubber Vol / Outbye Vol (%)
Roof, 30 m	Raised	--	--	11,7	--
Roof, 20 m	Raised	--	--	26,1	--
Roof, 12 m	Raised	--	--	29,8	--
			--		
--	Raised	8,3	--	9,5	87
Roof, 30 m	Raised	8,3	--	15,7	53
Roof, 20 m	Raised	8,3	--	32,3	26
Roof, 12 m	Raised	8,3	--	35,9	23
--	Raised	8,3	12	11,7	71
Roof, 20 m	Raised	8,3	12	31,4	26
Floor, 20 m	Raised	8,3	12	27,8	30

It can be seen that the jetfan had a considerable effect on the ventilation flows around the machine. As mentioned above, there was considerable discrepancy between the calculated flows towards the face and the flows away from the face. This can be attributed to the coarseness of the grid measurement positions with respect to the relatively narrow air jet from the jetfan. The more uniform outbye flows are more accurate and these have been used in the calculation of scrubber capture efficiency.

The data showed that the jetfan on its own was capable of moving much larger quantities of air around the machine than was actually passed through the fan. This air quantity varied with distance from the face, the greatest volume flow of nearly 30 m^3/s being measured with the jetfan 12 m from the face. This flow reduced only marginally with the jetfan sited at a distance of 20 m, but fell to less than 12 m^3/s at a distance of 30 m. The reduced air flow at the 30 m distance was shown during the smoke trials to be mostly due to the extensive expansion of the air jet so that the bulk of the machine deflected some air away from the face.

As already stated, the simulated jetfan used in the gallery was based around the configuration and performance of an 11kW jetfan. Manufacturer's data for an 11kW jetfan, as shown in Section 2.2, indicates an air moving capacity of 26 m^3/s and an effective jet penetration depth of 29 m. The measurements obtained were in good agreement with the manufacturer's data.

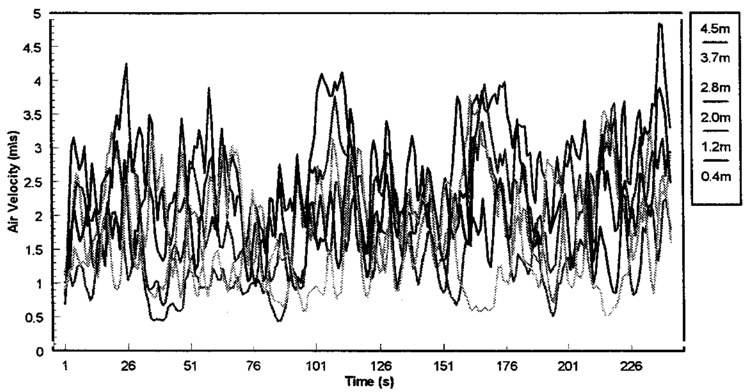
With the jetfan sited 30 m from the face, precise alignment of the fan was crucial to its ability to ventilate the face. When the jetfan was directed towards the centre of the face (angled at approximately 5° away from the right hand sidewall) very little air from the jetfan reached the face. However, when the jetfan was angled slightly towards the roof or into the right hand sidewall, some air still reached the face, the jet being confined in the upper right corner of the heading. For the purpose of the tests, the jetfan was accurately aligned, aimed into the top right hand corner of the face using a laser attached to the fan, in order to achieve its maximum effect. With this arrangement, the air travelled towards the face above the body of the machine on the right of the roadway at velocities varying between 0,7 and 2,7 m/s. On striking the face, the air jet dispersed across the face both from right to left and from floor to roof. As a consequence, air flowed back from the face at low level on the right of the machine, at an average velocity of 0,8 m/s, and over the full height of the roadway to the left of the machine at velocities of between 1,1 to 1,4 m/s.

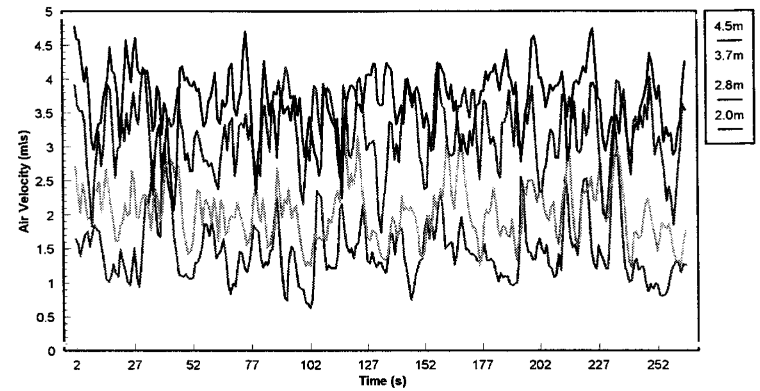
With the jetfan sited closer to the face, the air flow patterns were similar but the velocities much higher. At 20 m distance, a maximum air velocity of 8,2 m/s was measured in the inflowing air jet above the machine, increasing to 14 m/s with the jetfan at 12 m. The outflowing air on both sides of the machine also increased in velocity. On the left of the machine, however, a gradient in the air velocity from roof to floor became apparent with the highest velocities being measured close to the floor. With the jetfan 20 m from the face the air velocities from roof to floor on the left of the machine varied from 1,9 to 3,8 m/s while at 12 m this range was 1,4 to 4,7 m/s. The highest outflowing air velocities were thus in the diagonally opposite position in the roadway section to those flowing towards the face from the jetfan.

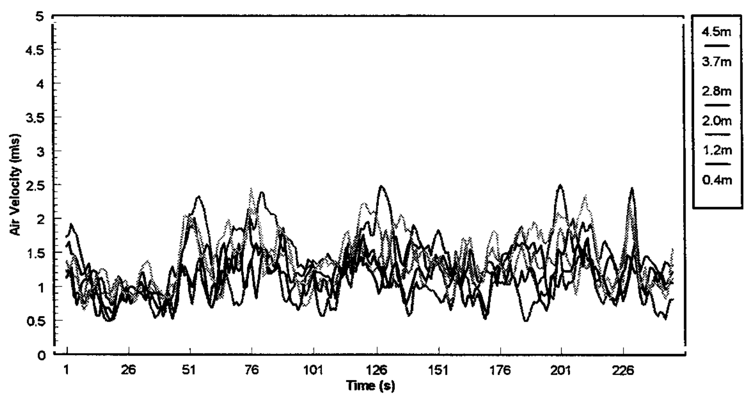
Operation of the scrubber resulted in a small increase in the overall air flow around the machine, but had little effect on the air flow patterns. With the jetfan 30 m from the face, operation of the scrubber increased the total outflowing air volume by approximately 4 m^3/s, while at the 12 and 20 m positions the volume increased by approximately 6 m^3/s. Such an increase was not expected since it would be logical to assume that the scrubber would merely modify the flow patterns of the air already moving around the machine under the influence of the jetfan. The results of the air flow measurements for this situation, with jetfan positions of 30, 20 and 12 m are shown in Figures 4.9 to 4.11 respectively. The corresponding air flow pattern for the 20 m jetfan position is shown in Figure 4.12.

Test Conditions -

Start of 1st Pass Cut on Right
Jib Raised
Scrubber operating -
Standard inlet,
Outlet deflected upwards
Jetfan operating -
30 m from face in roof





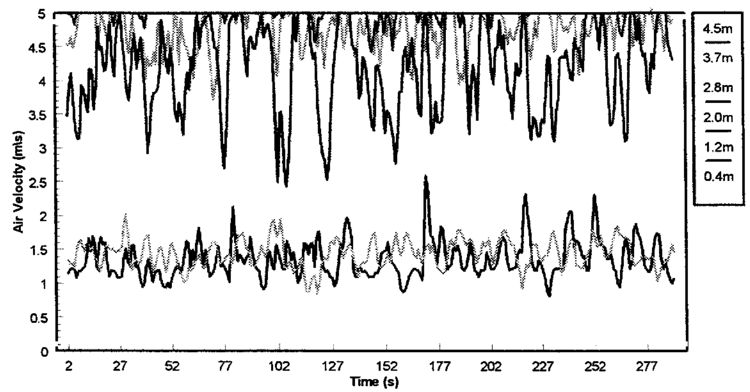


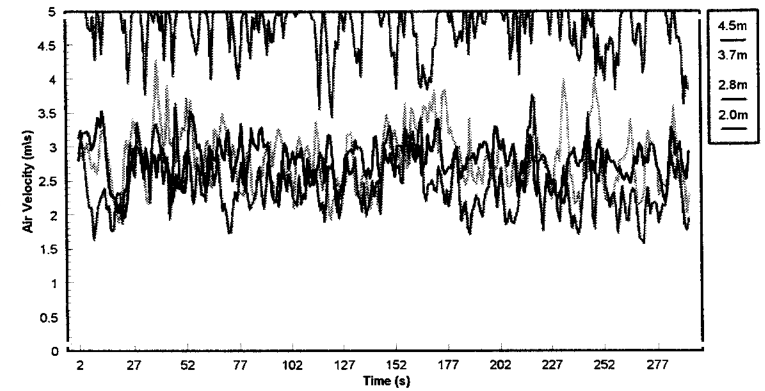
Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	1.49 +/- 0.69 m/s
	- 3.7m	1.89 +/- 0.71 m/s
	- 2.8m	2.15 +/- 0.71 m/s
	- 2.0m	2.71 +/- 0.75 m/s
	- 1.2m	1.98 +/- 0.60 m/s
	- 0.4m	- 1.57 +/- 0.67 m/s
Over Middle of Machine	- 4.5m	1.48 +/- 0.46 m/s
	- 3.7m	2.05 +/- 0.42 m/s
	- 2.8m	3.20 +/- 0.51 m/s
	- 2.0m	3.66 +/- 0.49 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	1.49 +/- 0.45 m/s
	- 3.7m	1.26 +/- 0.30 m/s
	- 2.8m	- 1.00 +/- 0.26 m/s
	- 2.0m	- 1.17 +/- 0.27 m/s
	- 1.2m	- 1.21 +/- 0.29 m/s
	- 0.4m	- 1.47 +/- 0.40 m/s

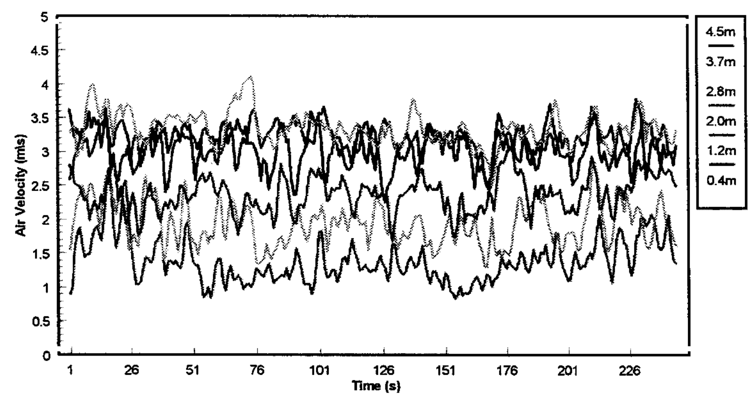
Figure 4.9 Air velocities at 6,5 m from the Face, Scrubber plus Jetfan at 30 m

Test Conditions -

Start of 1st Pass Cut on Right
Jib Raised
Scrubber operating -
Standard inlet,
Outlet deflected upwards
Jetfan operating -
20 m from face in roof





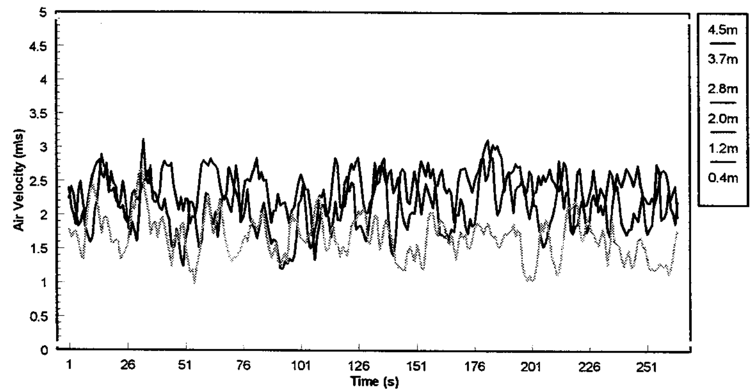


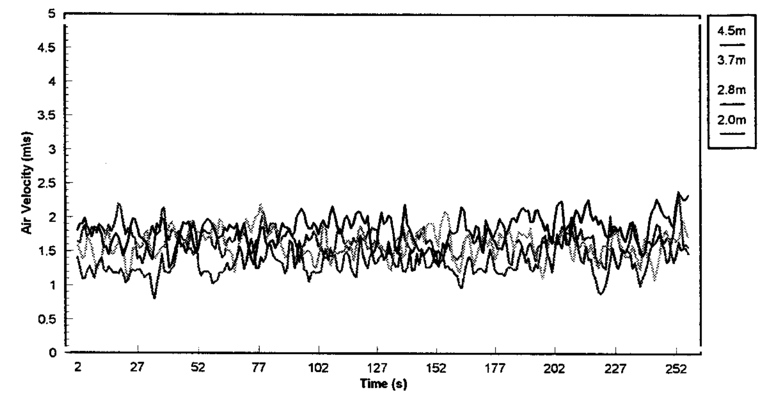
Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	8.3 m/s
	- 3.7m	6.9 m/s
	- 2.8m	5.4 m/s
	- 2.0m	4.22 +/- 0.69 m/s
	- 1.2m	- 1.36 +/- 0.28 m/s
	- 0.4m	- 1.44 +/- 0.20 m/s
Over Middle of Machine	- 4.5m	6.3 m/s
	- 3.7m	2.85 +/- 0.45 m/s
	- 2.8m	2.43 +/- 0.42 m/s
	- 2.0m	2.79 +/- 0.30 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	- 1.39 +/- 0.33 m/s
	- 3.7m	- 1.94 +/- 0.32 m/s
	- 2.8m	- 2.37 +/- 0.27 m/s
	- 2.0m	- 3.10 +/- 0.27 m/s
	- 1.2m	- 3.13 +/- 0.26 m/s
	- 0.4m	- 3.34 +/- 0.25 m/s

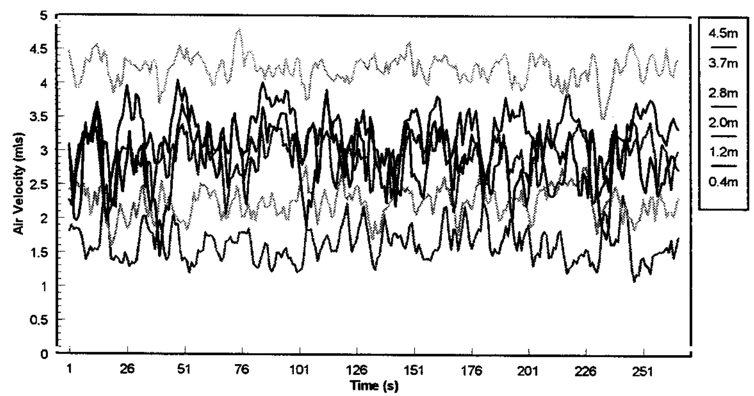
Figure 4.10 Air velocities at 6,5 m from the Face, Scrubber plus Jetfan at 20 m

Test Conditions -

Start of 1st Pass Cut on Right
Jib Raised
Scrubber operating -
Standard inlet,
Outlet deflected upwards
Jetfan operating -
20 m from face in roof







Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	15.0 m/s
	- 3.7m	14.8 m/s
	- 2.8m	5.5 m/s
	- 2.0m	2.11 +/- 0.39 m/s
	- 1.2m	2.39 +/- 0.28 m/s
	- 0.4m	1.67 +/- 0.31 m/s
Over Middle of Machine	- 4.5m	1.67 +/- 0.17 m/s
	- 3.7m	1.61 +/- 0.20 m/s
	- 2.8m	1.36 +/- 0.23 m/s
	- 2.0m	1.82 +/- 0.22 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	1.63 +/- 0.25 m/s
	- 3.7m	2.25 +/- 0.22 m/s
	- 2.8m	2.93 +/- 0.31 m/s
	- 2.0m	3.28 +/- 0.38 m/s
	- 1.2m	2.84 +/- 0.44 m/s
	- 0.4m	4.22 +/- 0.22 m/s

Figure 4.11 Air velocities at 6,5 m from the Face, Scrubber plus Jetfan at 12 m

Test Conditions -

Start of 1st Pass Cut on Right
Jib Raised
Scrubber operating -
Standard inlet,
Outlet deflected upwards

Jetfan operating -
20 m from face in roof

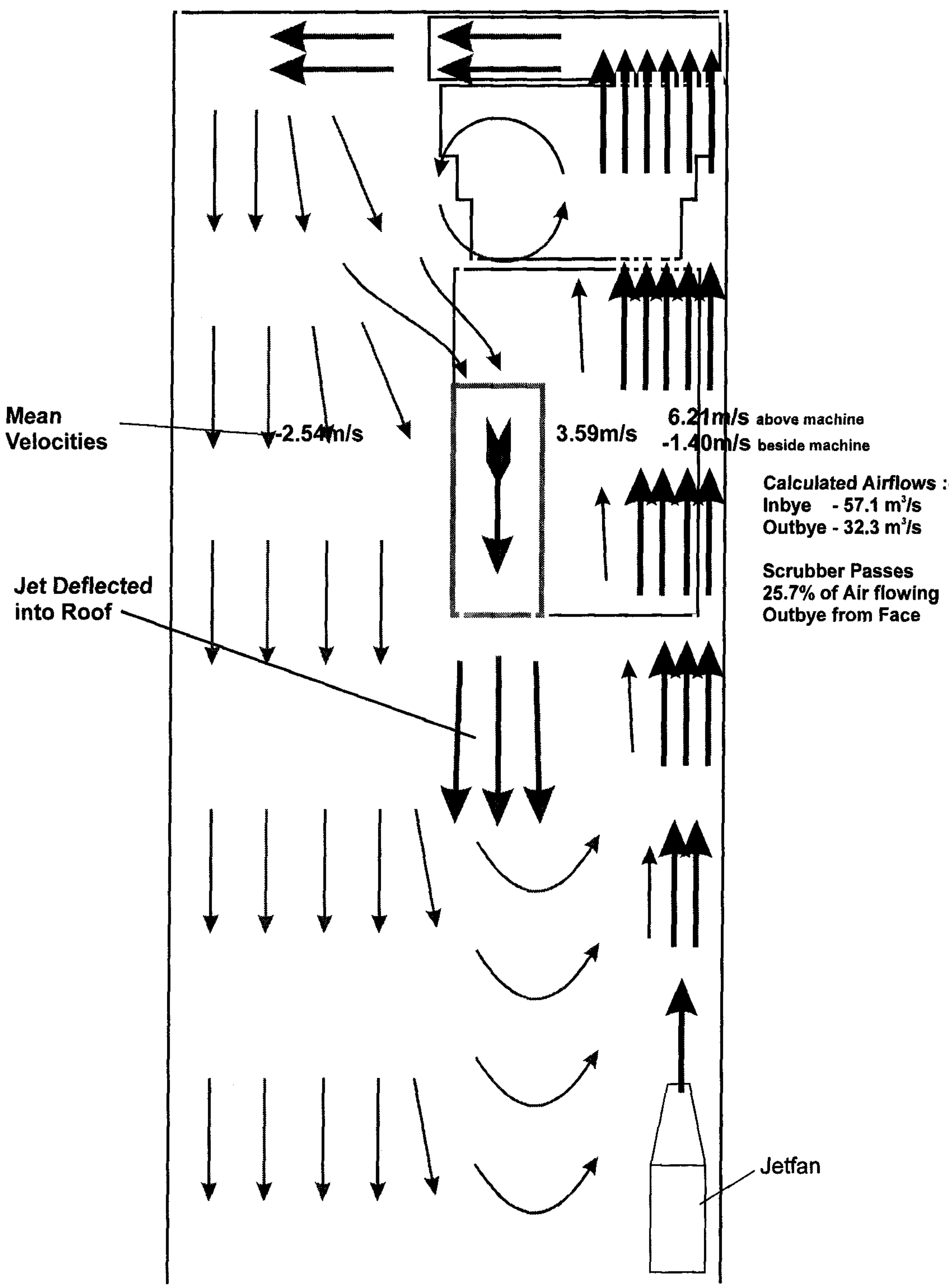


Figure 4.12 General Airflow Patterns around the Machine, Scrubber plus Jetfan at 20 m

At the 30 m position, the scrubber reversed the direction of air flow near the roof on the left of the machine, but towards floor level the outflowing air velocities remained very similar to those without the scrubber operating. On the right of the machine, the outflow of air was kept closer to floor level by the scrubber but the velocity at this position doubled. The measured volume of air flowing towards the face almost doubled upon operation of the scrubber. This was due to significantly higher velocities flowing towards the face over the middle and on the right of the machine. This indicates that the scrubber was drawing additional air towards the face.

With the jetfan at 20 m and 12 m, operation of the scrubber had a limited effect on the outflowing air velocities on the left of the machine, reducing the mean velocity from 2,8 to 2,5 m/s for the 20 m position, and from 3,1 to 2,9 m/s at the 12 m position. On the right of the machine the scrubber marginally reduced the velocity of outflowing air at the 20 m position, but at the 12 m position these velocities actually increased.

The above data, and air flow patterns indicate that the increase in air flow around the machine resulting from operation of the scrubber (in addition to the jetfan) was due to the high velocities caused by the jetfan. These high velocities tend to push air from the face past the scrubber inlet and past the rear of the machine where, having lost momentum over this distance of travel, the additional air is then drawn back towards the scrubber above the machine. The lower velocities associated with a jetfan at 30 m reduces this effect which, together with the deflection of some air by the machine body, results in a higher scrubber capture efficiency. At all locations of the jetfan, the volume of air moved by the jetfan was much greater than the capacity of the scrubber, resulting in a large proportion of the air travelling away from the face and by-passing the scrubber. As a result, operation of the jetfan at 12 and 20 m caused a substantial reduction in scrubber capture from about 87 % to 25 %. At 30 m the scrubber capture was reduced to 53 %.

A test was conducted with the jetfan 20 m from the face with the full ventilation system (with the scrubber and the sprayfan system operated at 12 bar). The results of the tests are shown in Figure 4.13. The sprayfan system had only a marginal effect on ventilation flows around the machine. The sprays on the machine body reduced the outflow of air near the floor to the right of the machine and additional air was pulled forward over the middle of the machine. On the left, the sprayfan system modified the gradient in air velocities from roof to floor, tending to reduce those nearer to the roof while increasing those nearer to the floor.

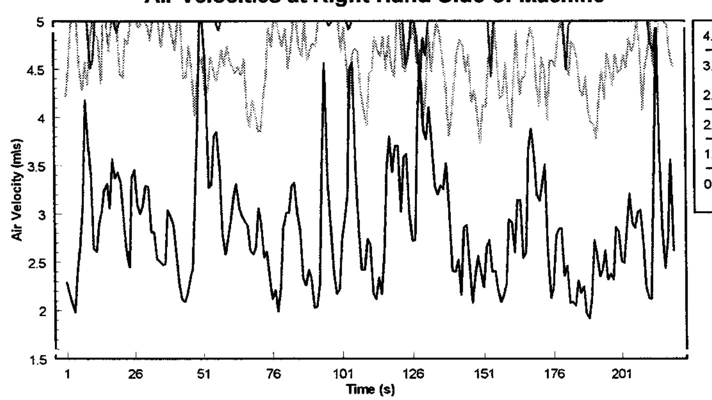
This is in accordance with the general effect of the sprayfan system without the jetfan operating.

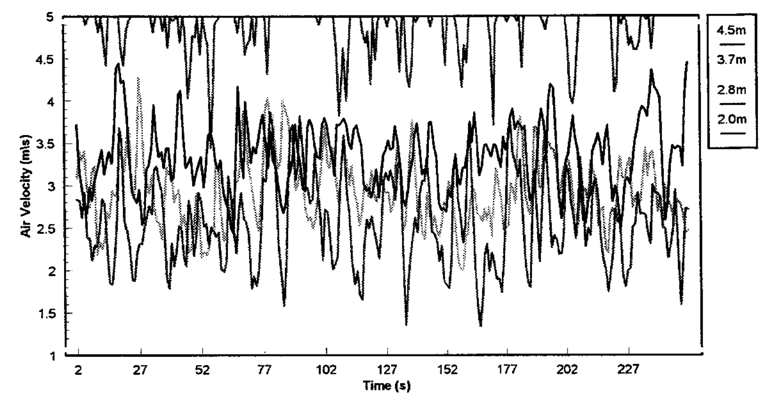
A test was conducted with the jetfan sited on the floor rather than in the roof at a distance of 20 m from the face (this is normal practice at some mines). The results are shown in Figure 4.14.

The test showed a greater interference on the jet due to the bulk of the machine, resulting in a reduction in the measured air flow away from the face of about 11 %. On the right of the machine the jetfan at floor level resulted in an outflow of air at roof level. On the left of the machine, high air velocities occurred at the roof and floor and low air velocities occurred in the centre. The results indicate that instead, of the jetfan and sprayfan system both pushing air outbye at floor level, the jetfan was now responsible for the outflow at roof level while the sprayfan caused the outflow towards the floor. The overall difference in scrubber capture from by siting the jetfan at floor level was an increase of only about 3,5 %.

Test Conditions -

Start of 1st Pass Cut on Right
Jib Raised
Scrubber operating -
Standard inlet,
Outlet deflected upwards
Jetfan operating -
20 m from face in roof
Sprayfan system at 12 bar



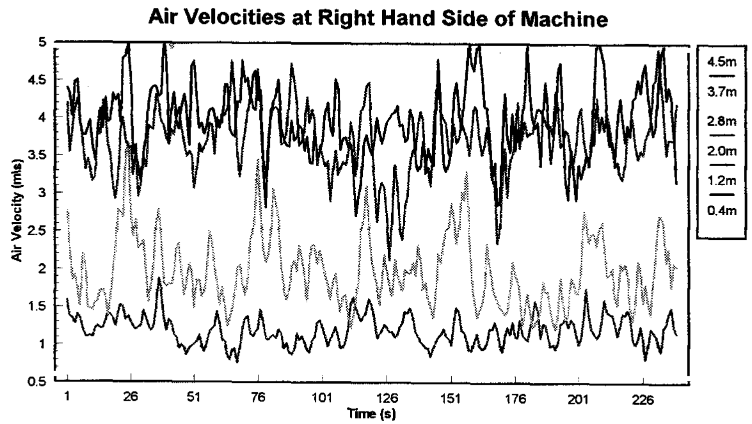


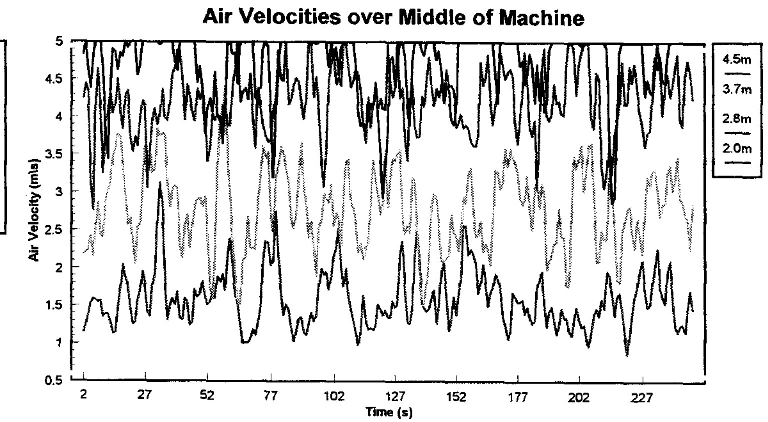
Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	8.5 m/s
	- 3.7m	6.2 m/s
	- 2.8m	5.5 m/s
	- 2.0m	2.88 +/- 0.63 m/s
	- 1.2m	-1.0 m/s
	- 0.4m	-1.0 m/s
Over Middle of Machine	- 4.5m	7.0 m/s
	- 3.7m	2.94 +/- 0.42 m/s
	- 2.8m	2.55 +/- 0.51 m/s
	- 2.0m	3.35 +/- 0.41 m/s
	- 1.2m	------
	- 0.4m	------
Left Hand Side of Machine	- 4.5m	-1.5 m/s
	- 3.7m	-1.6 m/s
	- 2.8m	-1.9 m/s
	- 2.0m	-3.2 m/s
	- 1.2m	-3.2 m/s
	- 0.4m	-3.6 m/s

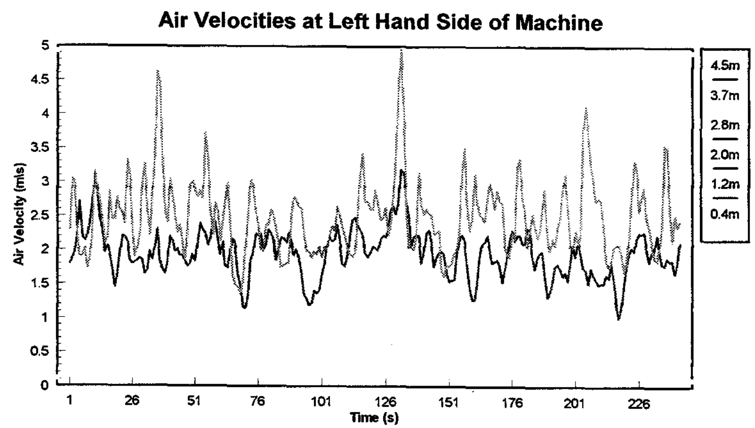
Figure 4.13 Air velocities at 6,5 m from the Face, Scrubber plus Jetfan at 20 m plus Sprayfan at 12 bar

Test Conditions -

Start of 1st Pass Cut on Right
Jib Raised
Scrubber operating -
Standard inlet,
Outlet deflected upwards
Jetfan operating -
20 m from face on floor
Sprayfan system at 12 bar







Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	-1.20 +/- 0.19 m/s
	- 3.7m	1.98 +/- 0.47 m/s
	- 2.8m	3.71 +/- 0.44 m/s
	- 2.0m	3.98 +/- 0.49 m/s
	- 1.2m	8.8 m/s
	- 0.4m	9.3 m/s
Over Middle of Machine	- 4.5m	-1.59 +/- 0.38 m/s
	- 3.7m	2.80 +/- 0.54 m/s
	- 2.8m	4.22 +/- 0.45 m/s
	- 2.0m	4.83 +/- 0.52 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	-1.96 +/- 0.35 m/s
	- 3.7m	-2.50 +/- 0.56 m/s
	- 2.8m	-1.1 m/s
	- 2.0m	-0.7 m/s
	- 1.2m	-2.3 m/s
	- 0.4m	-2.1 m/s

Figure 4.14 Air velocities at 6,5 m from the Face, Scrubber plus Jetfan on Floor at 20 m plus Sprayfan at 12 bar

Further tests were carried out for other cutting positions. The results of these tests are shown in the table below.

Cut Position	Jetfan Position (m)	Calculated Flow Outbye (m^3/s)	Scrubber Vol / Outbye Vol (%)
Start of 1st Pass Cut (first cutting situation)	Roof, 20 m	31,4	26
4 m into 1st Pass Cut (partial cut situation)	Roof, 24 m	25,6	32
2nd Pass Cut, 4 m from end of cut (final cutting situation)	Roof, 24 m	30,5	27

The measurements for the machine 4 m into the first pass cut are shown in Figure 4.15 and those for the second pass cut in Figure 4.16. These can be compared with Figure 4.13 for comparison with the start of the first pass cut.

In the position simulating the machine 4 m into the partial cut on the right hand side of the face, conditions were considerably improved by confinement of the machine and scrubber inlet by the uncut portion of the face to the left of the machine. The 4 m increase in distance of the jetfan, possibly in conjunction with the changed face configuration, results in a significant reduction in both the inflow and outflow of air around the machine. The proximity of the machine body to the left hand sidewall substantially reduced the amount of air escaping past the scrubber to the left of the machine towards the floor. Above the machine, the outflowing air velocities were marginally reduced adjacent to the scrubber. This reduction in the outflow of air on the left was balanced by slightly more air flowing from the face at floor level on the right hand side. The overall capture efficiency of the scrubber was 32 % in this situation (an improvement of 6 % on the first cutting situation). Smoke tests indicated a higher improvement, but this may have been due to higher turbulence around the face area due to the presence of the short uncut part of the face to the left of the machine. This extra turbulence may have increased the mixing and dilution of smoke into the general body air rather than allowing it to stream past the scrubber inlet at floor level to the left of the machine in a more concentrated form as in the first cutting situation.

Smoke observations made in the partial cut situation showed that the sprayfan system at 12 bar considerably reduced the outflow of air at floor level to the right of the machine. This was due entirely to the effect of the sprays sited on the side of the machine body.

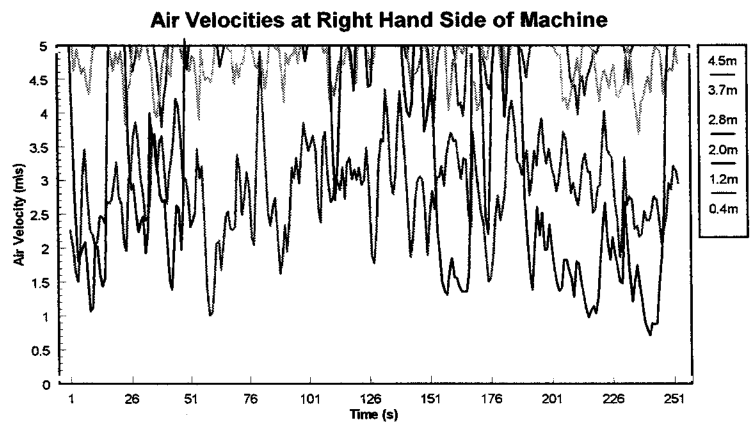
Increasing the operating pressure of the system to 30 bar made a further significant reduction in the air flow from the face area at this position. A similar improvement was also obtained at 12 bar by the addition of two further sprays at the bottom of the existing vertical spray arrangement, these directed downwards at an angle of 10 and 20° towards the floor.

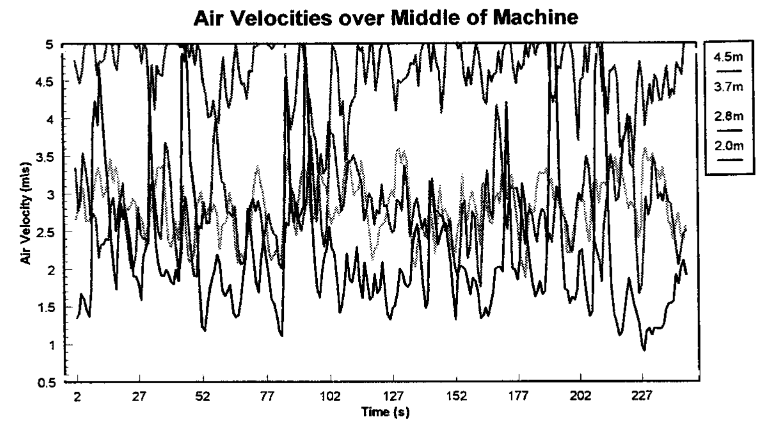
In the final cutting situation (second pass cut on the left) there was a considerable change in the air flow patterns, as may be seen in Figure 4.16. This change was reflected in the air flows around the machine where the inbye and outbye flows were more closely matched than in the previous situations. This was due to the lack of interference by the machine on the flow of air from the jetfan, which now passed unobstructed to the face of the partial cut. The highest air velocities were measured near the floor to the left of the partial cut, a position diametrically opposite to the inflowing air. Some of the return air was trapped by the projecting form of the machine jib and body which deflected this air across the machine, beneath the jib, toward the left hand side. Additional air travelled outbye over the centre of the machine body and at floor level to the right of the machine. The combined effect of the jetfan system and the machine profile in moving air to the left hand sidewall resulted in more air passing outbye to the left of the machine than was passed by the scrubber. Air flow at the measurement position to the left of the machine, adjacent to the scrubber, was therefore also outbye. As a consequence of all these effects, the calculated scrubber capture efficiency was only 27 %.

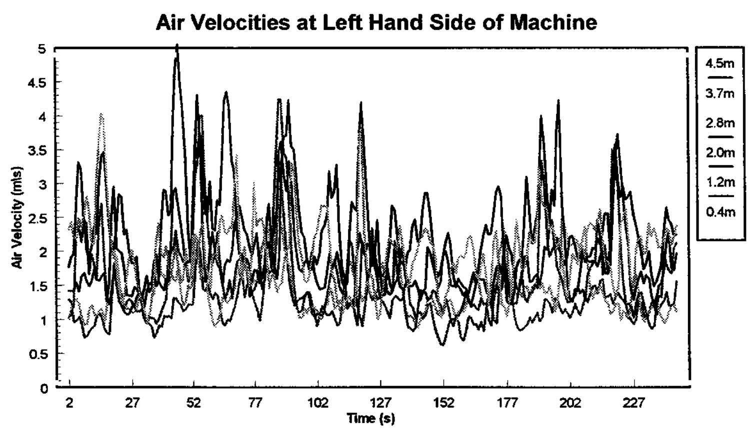
Smoke observations carried out with the jib lowered which showed a further deterioration in scrubber capture since the jib no longer trapped a proportion of the air returning from the partial face. Most of the air now swept over the top of the machine body at a high velocity, drawing smoke back from the face and past the scrubber inlet to the rear of the machine. A large proportion of this air was entrained in the air jet from the jetfan and recirculated back to the front of the heading.

Test Conditions -

4m into 1st Pass Cut on Right
Jib Raised
Scrubber operating -
Standard inlet,
Outlet deflected upwards
Jetfan operating -
24 m from face in roof
Sprayfan system at 12 bar





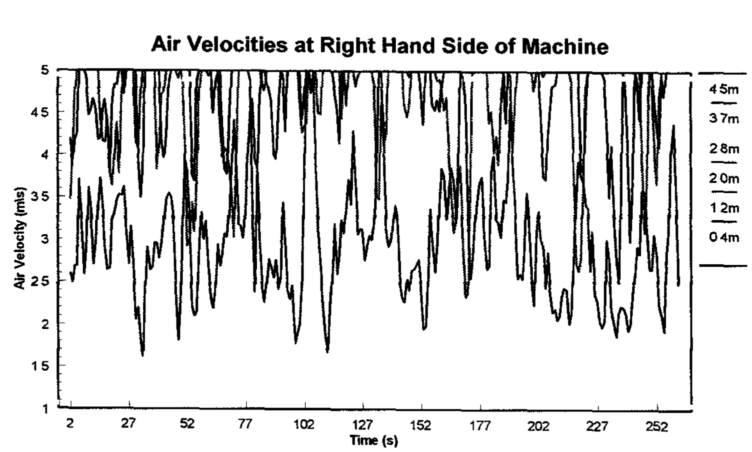


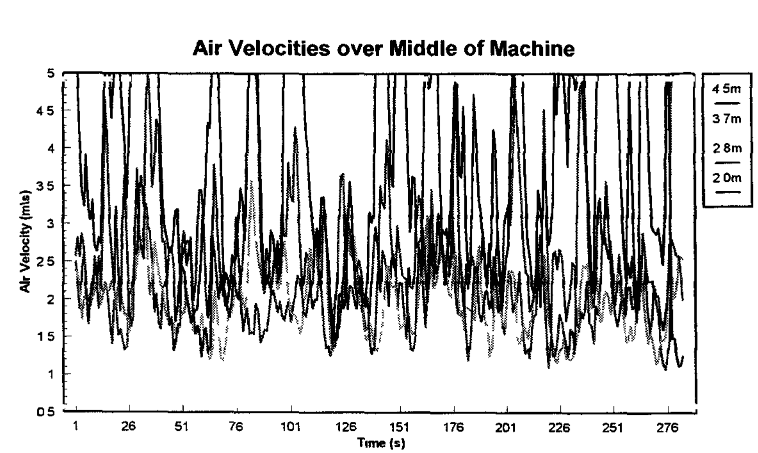
Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	6.4 m/s
	- 3.7m	4.9
	- 2.8m	2.89 +/- 0.63 m/s
	- 2.0m	3.63 +/- 1.65 m/s
	- 1.2m	-1.5 m/s
	- 0.4m	-1.5 m/s
Over Middle of Machine	- 4.5m	5.2 m/s
	- 3.7m	2.83 +/- 0.39 m/s
	- 2.8m	2.79 +/- 0.49 m/s
	- 2.0m	2.18 +/- 0.93 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	-1.24 +/- 0.36 m/s
	- 3.7m	-1.44 +/- 0.37 m/s
	- 2.8m	-1.62 +/- 0.63 m/s
	- 2.0m	-1.91 +/- 0.56 m/s
	- 1.2m	-2.32 +/- 0.74 m/s
	- 0.4m	-1.99 +/- 0.53 m/s

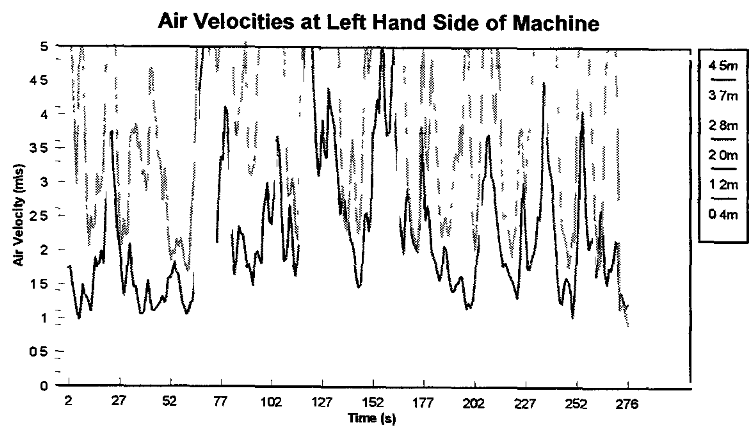
Figure 4.15 Air velocities at 6,5 m from the Face, 4 m into First Pass Cut, Full Ventilation System Operating

Test Conditions -

2nd Pass Cut on Left, 4m from end
Jib Raised
Scrubber operating -
Standard inlet,
Outlet deflected upwards
Jetfan operating -
24 m from face in roof
Sprayfan system at 12 bar







Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	7.9 m/s
	- 3.7m	6.7 m/s
	- 2.8m	4.84 +/- 0.70 m/s
	- 2.0m	3.01 +/- 0.73 m/s
	- 1.2m	-1.9 m/s
	- 0.4m	-2.7 m/s
Over Middle of Machine	- 4.5m	2.25 +/- 0.66 m/s
	- 3.7m	2.00 +/- 0.45 m/s
	- 2.8m	-2.53 +/- 0.88 m/s
	- 2.0m	-0.8 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	-2.37 +/- 1.07 m/s
	- 3.7m	-3.92 +/- 1.29 m/s
	- 2.8m	-------
	- 2.0m	-------
	- 1.2m	-1.9 m/s
	- 0.4m	-2.3 m/s

Figure 4.16 Air velocities at 6,5 m from the Face, 4 m from End of Second Pass Cut, Full Ventilation System Operating

Effect of Varying the Scrubber Inlet Position

As discussed in Section 2, experience with the siting of scrubber inlets is that they should be positioned close to the highest outflow of air from the face and sited as close to the face as possible. The easiest modification to make to the scrubber inlet is to fit an extension duct to move the inlet closer to the face. A 1,5 m long, circular duct was fitted to the scrubber giving an inlet position 4 m from the face. Smoke observations indicated an improvement in scrubber capture with most improvement occurring when the machine was 4 m into the partial cut. In this situation, the extended inlet was level with the corner of the uncut part of the face which significantly reduced the escape of smoke to the open area to the left of the machine (which had occurred with the standard inlet). The extension also improved scrubber capture when the jetfan was operated with this layout. However, previous tests showed that a roof-mounted jetfan and the sprayfan system both pushed most air back from the face near to the floor on the left of the machine. To verify this effect, an assessment was carried out with a length of flexible duct as the inlet of the scrubber. The inlet of the duct was sited approximately 0,3 m above the floor, 3 m from the face. Having proved the effectiveness of this preliminary arrangement, a more practical arrangement with the inlet on the machine jib, further away from the floor was evaluated (as on scrubber systems used in the USA), together with the use of a second inlet located on the right of the machine jib. This was achieved by fitting a box section across the top of the cutter jib with inlets located underneath, on either side of the jib frame. The intention of the additional inlet on the right was to help in the collection of air flowing away from the face at floor level when the jetfan is in operation. The box section was connected to the scrubber using flexible ducting to allow the jib to be raised and lowered. This arrangement reduced the air flow through the scrubber. The results obtained in the first cutting situation with the jib both raised and lowered and with and without the jetfan operating are summarised in the table below.

Scrubber Inlet Configuration	Jib Position	Scrubber Quantity (m^3/s)	Spray Pressure (bar)	Jetfan Position (m)	Calculated Flow Outbye (m^3/s)	Scrubber Vol / Outbye Vol (%)
Standard, 5,5 m	Raised	8,3	12	--	11,7	71
Duct LHS Floor, 3 m	Raised	7,9	12	--	10,4	76
LHS Jib Only, 3 m	Raised	6,1	12	--	9,9	62
LHS+RHS Jib, 3 m	Raised	7,3	12	--	9,3	79
Standard, 5,5 m	Lowered	8,3	12	--	10,7	78
Duct LHS Floor, 3 m	Lowered	7,9	12	--	10,4	76
Standard, 5,5 m	Raised	8,3	12	Roof, 20 m	31,4	26
Duct LHS Floor, 3 m	Raised	7,9	12	Roof, 20 m	24,6	32
LHS Jib Only, 3 m	Raised	6,1	12	Roof, 20 m	23,3	26
LHS+RHS Jib, 3 m	Raised	7,3	12	Roof, 20 m	23,6	31
Duct LHS Floor, 3 m	Lowered	7,9	12	Roof, 20 m	24,2	33
Standard, 5,5 m	Raised	8,3	12	Floor, 20 m	27,8	30
LHS+RHS Jib, 3 m	Raised	7,3	12	Floor, 20 m	26,5	28

Without the jetfan operating, the air velocities with the inlet ducted close to the floor on the left and the jib raised are shown in Figure 4.17. These may be compared with Figure 4.7 for the equivalent measurements with the standard scrubber inlet. The comparison shows that the outflow of air to the left of the machine with the standard scrubber inlet is reversed by locating the inlet near to the face and close to the floor where most of the air is pushed by the sprayfan system. Air from the face only evaded capture by the scrubber in this situation close to the roof in the centre and to the left of the machine. Lowering the jib made very little difference to the air flow patterns or velocities. Although the scrubber capture efficiencies only showed a slight improvement with the jib raised, the smoke tests indicated a more dramatic improvement in scrubber capture with 100 % being collected by the scrubber (no smoke was observed in the air flowing outbye at roof level). Complete capture of smoke was also observed for both scrubber inlet positions with the jib lowered, but conditions were significantly better with the inlet ducted close to the floor. With the standard inlet, smoke travelled back alongside the machine body almost to the rear of the machine before rising and travelling back to the scrubber inlet at a higher level. However, with the inlet ducted to the floor at the front of the machine body, the smoke was immediately drawn into the duct as it passed back from the face.

Raising the inlet onto the jib and using only the left hand inlet of the box section caused a slight deterioration in conditions, some air from the face flowing past the scrubber inlet at floor level. Although this resulted in a dramatic reduction in the scrubber capture efficiency, this was with a 25 % reduction in scrubber quantity brought about by the increased resistance of the inlet ductwork. Smoke observations indicated a much lower reduction in scrubber efficiency. Nevertheless, they still indicated a considerable improvement over conditions with the standard inlet.

Use of dual inlets on both sides of the jib showed a marginal improvement in dust capture conditions compared with the single jib inlet on the left. However, the air velocity measurements, shown in Figure 4.18 indicated a much larger improvement. This was mainly due to the reversal of outflowing air at roof level to the left of the machine together with a considerable reduction in the outflow velocity near the floor on the left.

Operating the jetfan, with ducting the scrubber inlet close to the floor resulted in a slight improvement in scrubber capture from 26 to 32 %. The air velocities are shown in Figure 4.19 and can be compared with Figure 4.13 (standard scrubber inlet). The major effect was a reduction in the outflowing air velocities to the left of the machine from an average of 2,5 to 1,8 m/s. Use of the left hand jib inlet had a similar effect, allowing for the reduction in air flow passed by the scrubber. This was assist by the profile of the front of the machine, which deflected some of the high velocity air flowing back from the face upwards towards the jib inlet. The results for the additional second inlet on the right of the jib are shown in Figure 4.20. These show a slight increase in outbye air velocities at floor level to the left of the machine, due to the lower scrubber flow on this side. However, the outflow near the floor on the right of the machine was substantially reduced when using the right hand scrubber inlet so that smoke no longer escaped on this side of the machine. As on the left, the front of the machine body helped to deflect the outflowing air upwards into the scrubber inlet.

With the jetfan located at floor level, the results obtained with the standard inlet and the dual jib inlets were similar, with only a slight redistribution of air velocities to the left of the machine.

In the other two cutting positions, the use of dual jib inlets was evaluated, with the jib raised and the sprayfan system operated at 12 bar. The results obtained are compared with those for the standard inlet in the table below.

Cut Position	Jetfan Position	Scrubber Inlet Configuration	Calculated Flow Outbye (m^3/s)	Scrubber Vol / Outbye Vol (%)
Start of 1st Pass	Roof, 20 m	Standard, 5,5 m	31,4	26
		Dual Jib, 3 m	23,6	31
4 m into 1st Pas Cut	Roof, 24 m	Standard, 5,5 m	25,6	32
		Dual Jib, 3 m	25,9	28
2nd Pass Cut, 4 m from end of cut	Roof, 24 m	Standard, 5,5 m	30,5	27
		Dual Jib, 3 m	27,3	27

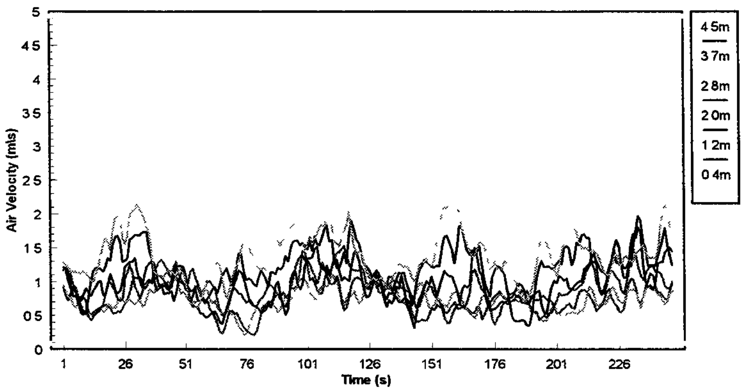
The air velocities obtained with the machine part way (4 m) into the first pass cut are shown in Figure 4.21. These can be compared with Figure 4.15 (standard scrubber inlet). The data indicates a slight deterioration in scrubber capture. However, smoke observations indicated that a system using the dual jib inlets was a considerable improvement. With the standard inlet, smoke passed outbye near floor level on both sides of the machine. However, use of the dual jib inlets prevented almost all escape of smoke to the left of the machine while that on the right was considerably reduced. Capture of smoke by the inlets under the jib was considerably aided by the bulk of the machine under the jib, the air flowing back from the face striking the front face of the machine body, which was enclosed by the cut on both sides, deflecting this air flow upwards into the scrubber inlets. Increasing the sprayfan pressure to 30 bar in this situation further reduced the outflow of smoke on the right of the machine. The increased effect of the vertical sprays on the machine body almost overcoming the outflow of air. Use of the two additional sprays at the bottom, and an operating pressure of 12 bar had a similar effect in preventing roll-back of smoke.

Air velocities for the second pass cutting situation are shown in Figure 4.22. These can be compared with Figure 4.16 (standard scrubber inlet). Essentially, the data was similar when comparing the different inlet positions, except near the roof on the left of the machine where the outflow velocities were less with dual jib inlets. Smoke observations indicated that flow of smoke on the left of the machine was reduced with the dual jib inlets.

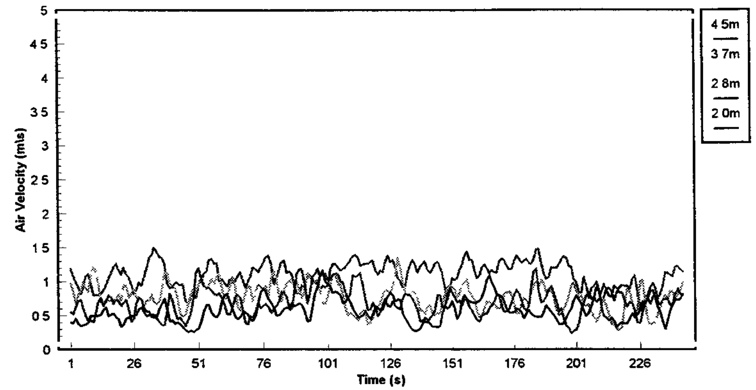
Test Conditions -

Start of 1st Pass Cut on Right
Jib Raised
Scrubber operating -
Inlet ducted to left hand floor, 3 m, 7.9 m³/s
Outlet deflected upwards
Sprayfan system at 12 bar

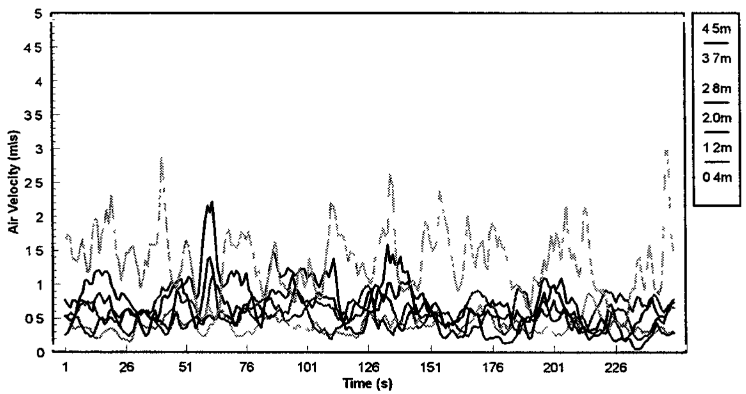
Air Velocities at Right Hand Side of Machine



Air Velocities over Middle of Machine



Air Velocities at Left Hand Side of Machine

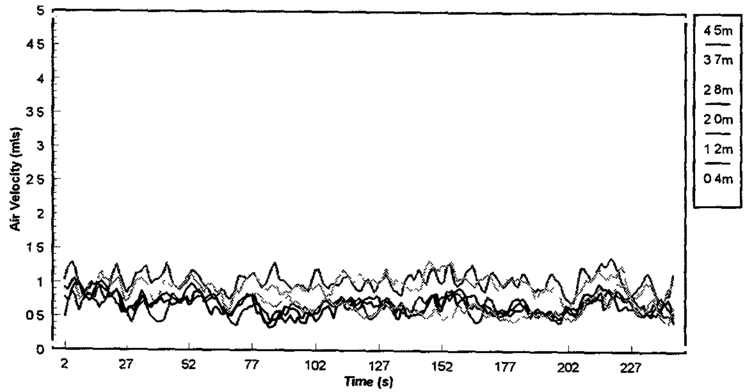


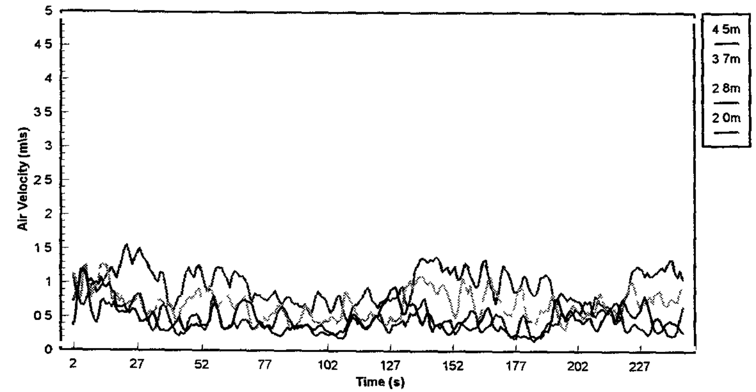
Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	0.85 +/- 0.22 m/s
	- 3 7m	0 73 +/- 0.16 m/s
	- 2.8m	0.83 +/- 0.27 m/s
	- 2.0m	0.97 +/- 0 28 m/s
	- 1.2m	1.22 +/- 0.33 m/s
	- 0 4m	1.39 +/- 0.35 m/s
Over Middle of Machine	- 4.5m	-1.10 +/- 0.19 m/s
	- 3.7m	0.78 +/- 0.20 m/s
	- 2.8m	0.70 +/- 0.20 m/s
	- 2.0m	0.58 +/- 0.17 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	-0.63 +/- 0.15 m/s
	- 3.7m	0.39 +/- 0.12 m/s
	- 2.8m	0.49 +/- 0.17 m/s
	- 2.0m	0.68 +/- 0.22 m/s
	- 1.2m	0.70 +/- 0.43 m/s
	- 0.4m	1.34 +/- 0.47 m/s

Figure 4.17 Air velocities at 6,5 m from the Face, Scrubber with Ducted Inlet plus Sprayfan at 12 bar

Test Conditions -

Start of 1st Pass Cut on Right
Jib Raised
Scrubber operating -
Dual Jib Inlets, 3 m, 7.3 m^3/s,
Outlet deflected upwards
Sprayfan system at 12 bar



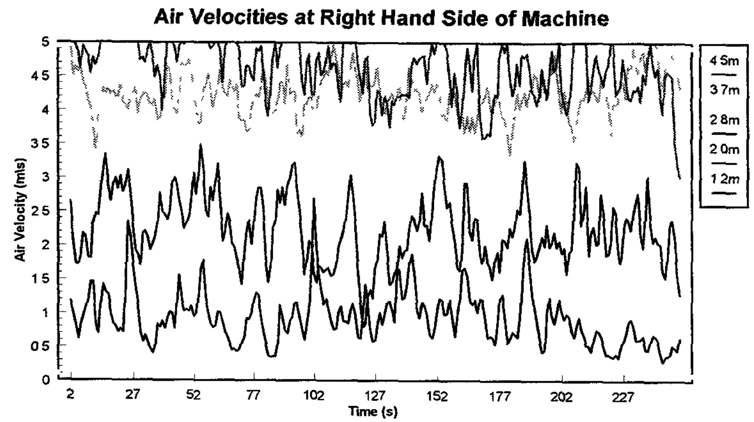


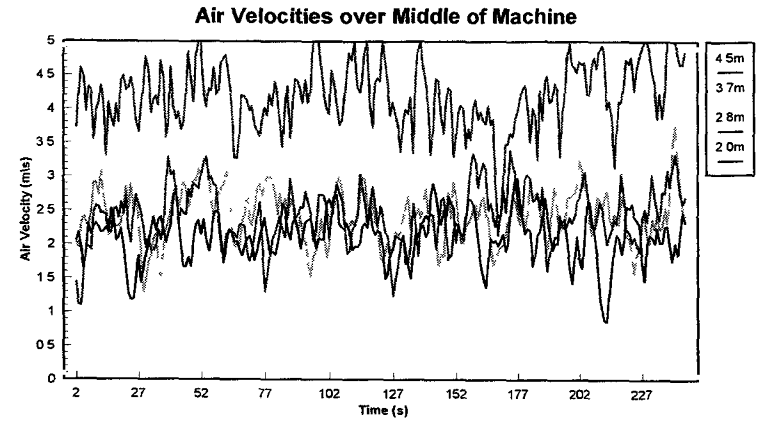
Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4 5m	1 02 +/- 0.15 m/s
	- 3.7m	0.98 +/- 0.14 m/s
	- 2.8m	0.65 +/- 0.12 m/s
	- 2.0m	0.69 +/- 0.14 m/s
	- 1.2m	0.69 +/- 0.13 m/s
	- 0.4m	0.63 +/- 0.13 m/s
Over Middle of Machine	- 4.5m	-0.96 +/- 0.25 m/s
	- 3.7m	0.70 +/- 0.21 m/s
	- 2.8m	0.46 +/- 0.18 m/s
	- 2.0m	0.48 +/- 0.21 m/s
	- 1.2m	------
	- 0.4m	-------
Left Hand Side of Machine (Anemometer Readings)	- 4.5m	0.5 m/s
	- 3.7m	0.3 m/s
	- 2.8m	0.1 m/s
	- 2.0m	0 m/s
	- 1.2m	-0.2 m/s
	- 0.4m	-0.2 m/s

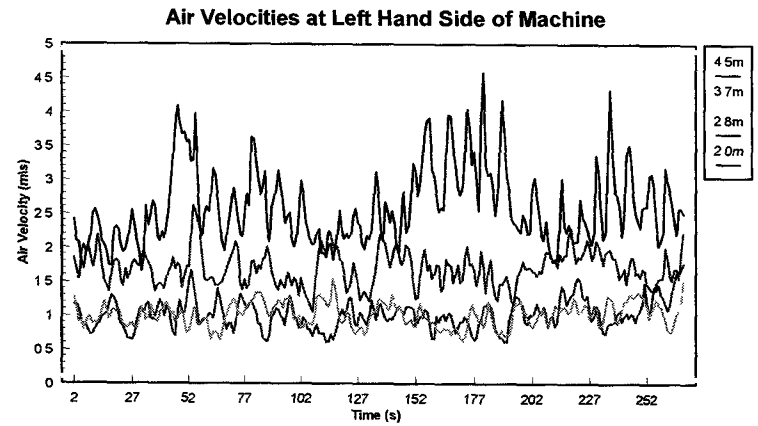
Figure 4.18 Air velocities at 6,5 m from the Face, Scrubber with Dual Jib Inlets plus Sprayfan at 12 bar

Test Conditions -

Start of 1st Pass Cut on Right
Jib Raised
Scrubber operating -
Inlet ducted to left hand floor, 3 m, 7.9 m^3/s
Outlet deflected upwards
Sprayfan system at 12 bar
Jetfan operating -
20 m from face in roof





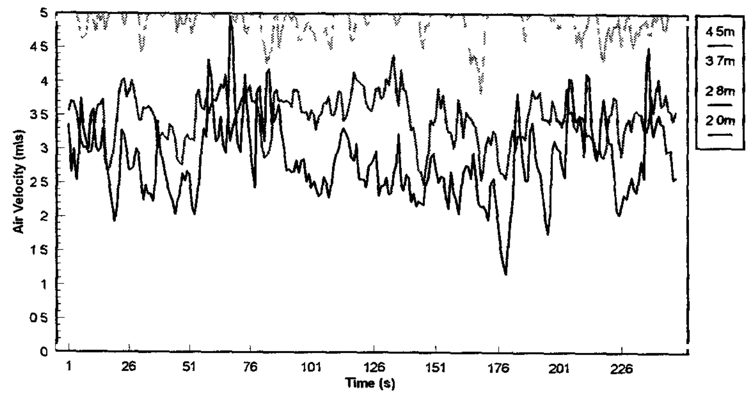


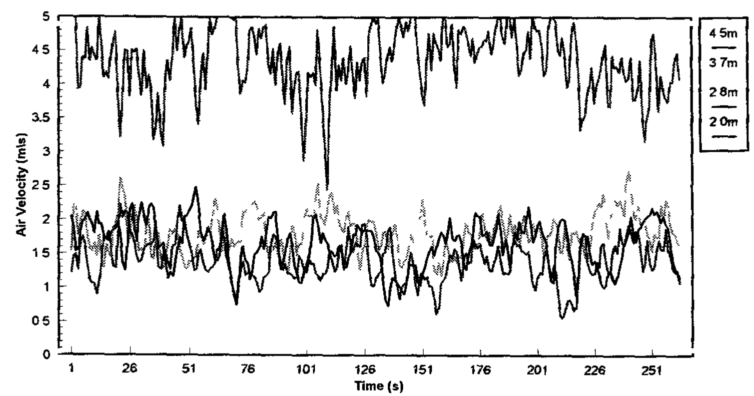
Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	7.7 m/s
	- 3.7m	4.25 +/- 0.32 m/s
	- 2.8m	4.67 +/- 0.46 m/s
	- 2.0m	2.25 +/- 0 50 m/s
	- 1.2m	-0.93 +/- 0.39 m/s
	- 0.4m	-1.2 m/s
Over Middle of Machine	- 4.5m	4.19 +/- 0.51 m/s
	- 3.7m	2.43 +/- 0.39 m/s
	- 2.8m	2.42 +/- 0.42 m/s
	- 2.0m	2.12 +/- 0.35 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	-1.02 +/- 0.22 m/s
	- 3.7m	-1.02 +/- 0.18 m/s
	- 2.8m	-1.70 +/- 0.26 m/s
	- 2.0m	-2.61 +/- 0.56 m/s
	- 1.2m	-2.6 m/s
	- 0.4m	-1.6 m/s

Figure 4.19 Air velocities at 6,5 m from the Face, Scrubber with Ducted Inlet plus Jetfan at 20 m and Sprayfan at 12 bar

Test Conditions -

Start of 1st Pass Cut on Right Jib Raised
Scrubber operating -
Dual Jib Inlets, 3 m, 7.3 m³/s, Outlet deflected upwards
Sprayfan system at 12 bar
Jetfan operating -
20 m from face in roof



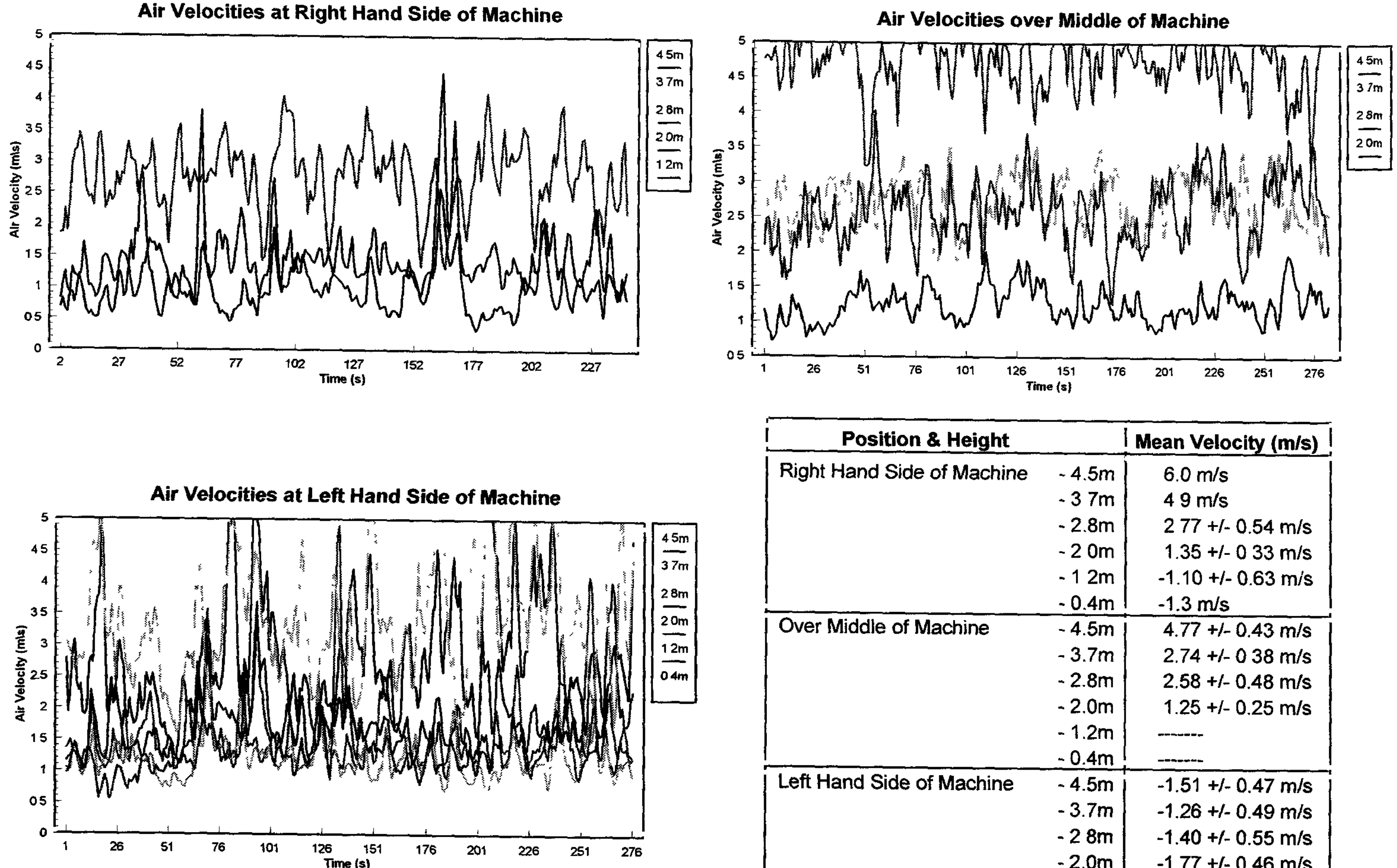


Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	7.5 m/s
	- 3.7m	4 97 +/- 0.28?m/s
	- 2.8m	3.46 +/- 0.36 m/s
	- 2.0m	2.82 +/- 0 58 m/s
	- 1.2m	1.0 m/s
	- 0 4m	-0.5 m/s
Over Middle of Machine	- 4.5m	4.37 +/- 0.51 m/s
	- 3.7m	1.82 +/- 0.30 m/s
	- 2.8m	1.39 +/- 0.30 m/s
	- 2.0m	1.64 +/- 0.35 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine (Anemometer Readings)	- 4.5m	-0.8 m/s
	- 3.7m	-0.8 m/s
	- 2.8m	-1.0 m/s
	- 2.0m	-2.9 m/s
	- 1.2m	-3.2 m/s
	- 0.4m	-2.3 m/s

Figure 4.20 Air velocities at 6,5 m from the Face, Scrubber with Dual Jib Inlets plus Jetfan at 20 m and Sprayfan at 12 bar

Test Conditions -

4m into 1st Pass Cut on Right Jib Raised
Scrubber operating -
Dual Jib Inlets, 3 m, 7.3 m³/s, Outlet deflected upwards
Sprayfan system at 12 bar
Jetfan operating -
20 m from face in roof

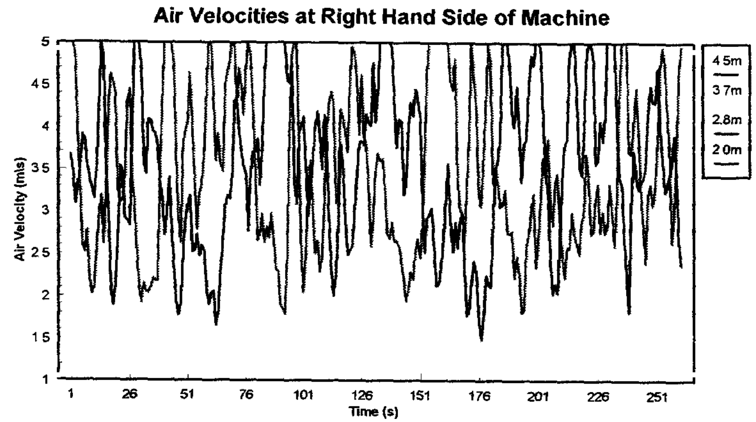


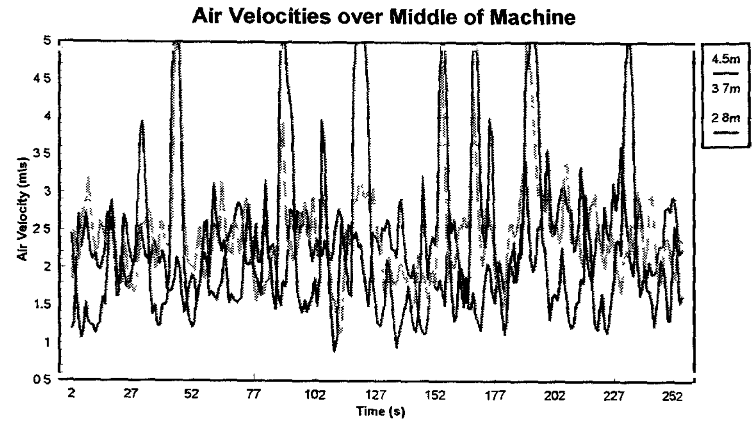
Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	6.0 m/s
	- 3 7m	4 9 m/s
	- 2.8m	2 77 +/- 0.54 m/s
	- 2 0m	1.35 +/- 0 33 m/s
	- 1 2m	-1.10 +/- 0.63 m/s
	- 0.4m	-1.3 m/s
Over Middle of Machine	- 4.5m	4.77 +/- 0.43 m/s
	- 3.7m	2.74 +/- 0 38 m/s
	- 2.8m	2.58 +/- 0.48 m/s
	- 2.0m	1.25 +/- 0.25 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	-1.51 +/- 0.47 m/s
	- 3.7m	-1.26 +/- 0.49 m/s
	- 2 8m	-1.40 +/- 0.55 m/s
	- 2.0m	-1.77 +/- 0.46 m/s
	- 1.2m	-2.84 +/- 0.96 m/s
	- 0.4m	-3.41 +/- 0.93 m/s

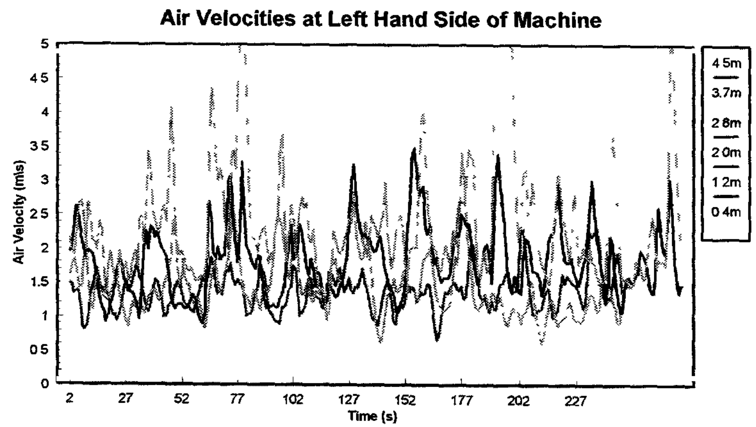
Figure 4.21 Air velocities at 6,5 m from the Face, 4 m into First Pass Cut, Full Ventilation System, Scrubber with Dual Jib Inlets

Test Conditions -

2nd Pass Cut on Left, 4 m from end
Jib Raised
Scrubber operating -
Dual Jib Inlets, 3 m, 7.3 m^3/s, Outlet deflected upwards
Sprayfan system at 12 bar
Jetfan operating -
20 m from face in roof







Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	7.5 m/s
	- 3.7m	6.4 m/s
	- 2.8m	3.49 +/- 0.98 m/s
	- 2.0m	3.56 +/- 0.98 m/s
	- 1.2m	-2.8 m/s
	- 0.4m	-2.4 m/s
Over Middle of Machine	- 4.5m	2.21 +/- 0.46 m/s
	- 3.7m	2.44 +/- 0.65 m/s
	- 2 8m	-2.33 +/- 1.18 m/s
	- 2.0m	-0.8 m/s
	- 1.2m	------
	- 0.4m	------
Left Hand Side of Machine	- 4.5m	-1.37 +/- 0.29 m/s
	- 3.7m	-1.51 +/- 0.57 m/s
	- 2.8m	------
	- 2.0m	------
	- 1.2m	-1.84 +/- 0.53 m/s
	- 0.4m	-2.36 +/- 0.91 m/s

Figure 4.22 Air velocities at 6,5 m from the Face, 4 m from End of Second Pass Cut, Full Ventilation System, Scrubber with Dual Jib Inlets

4.1.3 Conclusions from the Gallery Trials with a Continuous Miner Machine

The following conclusions can be drawn from the gallery trials.

Sprayfan System

A sprayfan system is an essential component for effective ventilation of the face, particularly when cutting the first 12 m of a heading when only the scrubber is used for auxiliary ventilation. Considering all the possible cutting situations, it is concluded that the optimum operating pressure should be approximately 12 bar. This may be excessive for good dust control at the start of a cut with a flat face, but it is appropriate at later stages of the cutting cycle which represent a much greater proportion of the cutting cycle. Operation of the system at a pressure of 6 bar gives less effective ventilation at the face. At 30 bar, excessive dust roll-back occurred on the left of the machine in some circumstances, while in conjunction with the jetfan it was able to prevent dust roll-back to the right of the machine. Nevertheless, a similar effect could be obtained at 12 bar through use of additional sprays directed towards the floor from the bottom of the vertical spray array on the right hand side of the machine.

The optimum operating pressure cannot be defined precisely since the number, nozzle size and layout of sprays on machines vary considerably, as do roadway size and ventilation (according to mine preference). It is therefore recommended that the sprayfan system should be balanced with the scrubber arrangement individually at each site, possibly using a powder type fire extinguisher to visualise the air flow patterns, in order to optimise scrubber dust capture.

Jetfan System

The tests have confirmed jetfans to be an efficient means of moving large volumes of air. In the test gallery arrangement, a jetfan was shown to be capable of effectively ventilating a heading at least 30 m long. However, the high velocity of the outlet jet, required to achieve the long 'throw' of the jet, results in considerable entrainment of air from within the heading itself, resulting in recirculation of contaminated air. Despite the allowed 50 % recirculation of the scrubber over and above the nominal 'fresh' air quantity moved by the jetfan, it was shown that in the worst case, the scrubber only passed some 23 % of the total air volume moved to the face by the jetfan (the case was with the jetfan sited in the roof, 12 m from the face, at the start of the first cut). This imbalance in air flows inevitably results in poor scrubber dust capture. The excess jetfan air flow reaching the face reduces with distance, partly due to further expansion of the jet so that some air is deflected away from the face by the bulk of the machine. However, even with the jetfan located 30 m from the face, the scrubber volume still only represented 53 % of the air passed to the face by the jetfan. A high dust capture efficiency by the scrubber system in such circumstances is therefore very difficult to achieve unless the scrubber system can capture the dust very close to its source, before it is dispersed more widely into the general body of air at the face.

Higher dust capture efficiencies would be more readily achievable using a force column ventilation system where the air is released at a lower velocity and hence will not entrain such high volumes of air to the face. The use of a slower-moving body of air to ventilate the face would also reduce air velocities near the scrubber inlet such that less dust is carried away from the immediate capture zone of the scrubber.

Scrubber System

The configuration of the air discharge from the scrubber can have a substantial effect on dust capture. In a standard arrangement, where the distance between the inlet and discharge is only of the order of 2,5 m, any entrainment effect of the outlet air jet will draw dust laden air away from the scrubber inlet and pass it untreated into the general body air behind the machine. It is therefore important that any entrainment effect should be minimised. An air discharge directed straight out from the scrubber was shown to have the greatest air entrainment effect, while deflecting the discharge upwards, towards the roof, reduced this effect considerably. An upward deflection angle of 30° was successful, with entrainment from in front of the scrubber inlet being minimised while the outlet jet was still thrown a considerable distance away from the machine at roof level. This effect is important since this would maximise the removal of the still contaminated, scrubbed air into the LTR, while minimising recirculation back to the face.

Use of a trailing exhaust system would eliminate any possibility of entrainment by the scrubber discharge and completely prevent recirculation of the discharge air back to the face. This represents the optimum layout for the scrubber system. However, the practical design of such a system, while still allowing freedom of movement for the machine both forwards and backwards during the cutting cycle, is extremely difficult. If the engineering difficulties could be overcome this would represent the optimum arrangement for scrubber dust capture.

The tests demonstrated that dust capture is improved by extending the inlet of the scrubber close to the face. Further improvement may be gained by siting it at a relatively low level at the face since this is where both the sprayfan system and roof-mounted jetfan tend to direct most of the outflow of dusty air from the face. Ideally, the inlet should be sited just above the rear of the loading shovel so that the air travelling away from the face moves up the angled form of the shovel to the rear spill plate which will deflect the air upwards into the scrubber inlet. The best means of achieving such an inlet position is by locating it underneath and to the side of the jib frame. This has the disadvantage of requiring a hinged joint in the ductwork to allow the jib to be raised and lowered. Alternatively, an inlet position could be placed on the front of the main frame of some machines facing forwards, which would be as effective.

The use of multiple scrubber inlets was shown to be of benefit in some cutting situations, particularly during the first pass cut where a jetfan is used when the confinement of the machine results in some contaminated air travelling back from the face to the right of the machine. This dust escape can be only be prevented by using a combination of an additional scrubber inlet on the right of the machine together with the effective use of sprayfan sprays on the right hand side of the machine.

An additional position which should be considered for a scrubber inlet is near to the throat in the jib for the machine conveyor. The simulated machine used in the present tests did not allow investigation of this aspect. However, this is a position on the machine where air may travel back from the face, encouraged by the action of the conveyor. Dust control problems in this area were observed during underground visits.

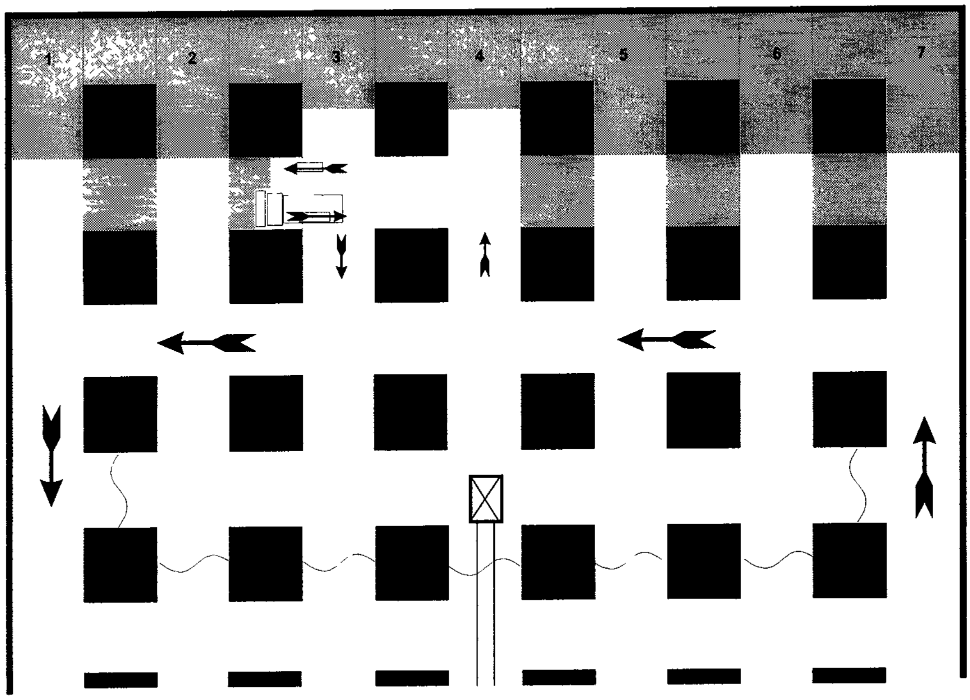
Overall, therefore, it is concluded that the optimum layout for scrubber systems in South African conditions should be of a similar form to those commonly fitted to machines in the USA. These involve ducts on the machine jib with two inlets located underneath on both sides of the jib with a third inlet located above the conveyor. The potential problem with such a system is from damage to the ducts on the jib, in addition to the ongoing problem of damage to dust scrubbers. To minimise these problems, the duct/scrubber system needs to be built into the machine during its design and manufacture (as in the USA). Modifications made on South African continuous miners to enable them to operate in high seam roadways mean that inclusion of such a duct system will have practical implications. Such a solution to improving scrubber capture must therefore be considered as a relatively long-term objective.

4.1.4 Evaluation of Dual Inlet Scrubber in a Production Section

Underground tests were carried out to confirm the findings of the gallery tests in relation to scrubber inlet position. In a short evaluation trial, it was not thought practical to construct a permanent duct inlet system for mounting on the jib. Hence a flexible duct arrangement was constructed to carry the inlet onto the jib from where a T-piece was used to allow use of two inlets; one to be sited to one side of the jib frame the other above the conveyor throat of the jib. Measurements were made using a Simslin dust sampling instrument located at the machine operator's position to obtain a comparison between the standard scrubber inlet arrangement and the ducted, dual inlet system.

The initial site selected was a 7-road section, with a roadway section of 6 m wide by 2,7 m high and pillar centres of 28 m. The machine was a Joy 12HM9 fitted with a 3,5 m^3/s CDCS scrubber unit. The scrubber had recently been dislocated, resulting in the normal inlet position being some 0,7 m further forward than normal. Fitting of the dual inlet trial duct arrangement resulted in the inlets being moved an additional 1 m further forward on the machine. Because of the low seam height, the inlets were angled downwards at 30-40° from the vertical. Any greater angle would have resulted in the ducts being crushed and scraped on the roof of the heading. This arrangement permitted the duct to flex in accordance with raising and lowering the jib. Through the use of large, 0,76 m diameter duct, any restriction caused by the flexing of the ducting did not affect the scrubber air flow. Auxiliary ventilation in the section was provided by a 5,5kW jetfan.

Simslin dust recordings were taken over two shifts during which the machine was in exactly the same stage of advancement. The site layout is shown in the diagram below :



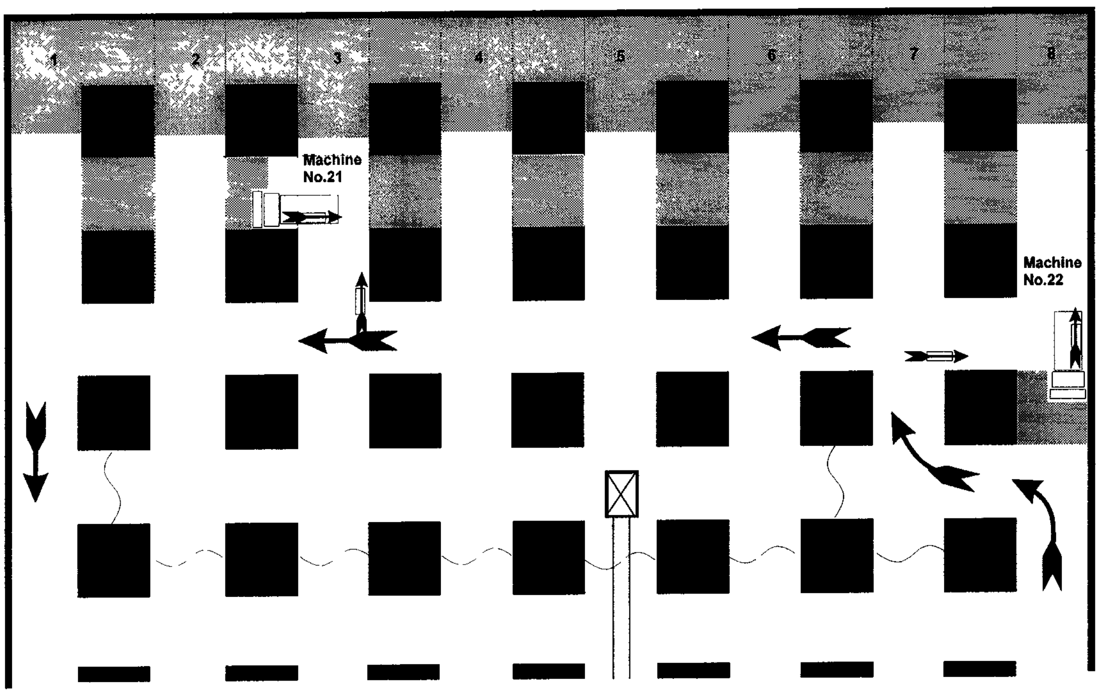
Layout of Initial Underground Trial Site

As shown, the machine was cutting the split from Road 3 to Road 2 with a jetfan located on the right of the split, the machine taking the first pass cut to the left of the split.

The calibrated Simslin dust recordings for the equivalent cutting of the partial cut of the split on the left from the two visits are shown in Figure 4.23. The data was analysed within a spreadsheet to determine the mean dust concentration over the periods of actual cutting. With the standard scrubber inlet, an average of 7,90 mg/m³ was measured at the driver's position, while with the dual duct inlet fitted, between 10:59 and 11:16 (before the jetfan was moved) the mean dust concentration was 5,57 mg/m³, a reduction of nearly 30 %. For the short duration of cutting after the jetfan had been redirected, dust levels were slightly higher but, since this was for a different alignment of the jetfan, this data is not valid for comparison.

Having only obtained comparison of the two scrubber inlet configurations over a very short period of cutting in one situation, a further visit was made to the colliery to try and obtain further data. This visit was to a different section, which was operated by two machines. The trial was carried out on Machine No 22, which was again a Joy 12HM9, fitted with a 45kW CDCS scrubber with a standard inlet 5,0 m from the face. Fitting of the dual inlet duct system, as previously, moved the scrubber inlet to 3,7 m from the face. A 5,5kW jetfan was again used at the site.

The site layout at the time of the visit is shown in the diagram below.



Layout of Second Underground Trial Site at Time of Visit

The calibrated trace of dust concentrations over the shift from the Simslin instrument at the operator's position is shown in Figure 4.24. It may be seen from this that dust conditions were poor, the measured concentration being above the upper limit of the instrument during all cutting periods, mainly due to the effect of the jetfan which tended to recirculate dust within the heading. However, the instrument is equipped with an averaging device which is able to deal with data four times higher than that recorded to the solid state memory of the instrument. Whenever feasible, therefore, readings of the updated average were noted from the instrument from which the average dust levels during specific cutting periods could be calculated. These are shown on the graph. The dual inlet scrubber duct was fitted at the start of the shift and removed for the final cutting period. Between 09:45 and 10:16, the machine took the first, partial cut to the left of the heading, the second pass to the right being cut from 10:18 to 11:12. During these periods the calculated mean dust concentrations were 24,2 and 27,1 mg/m³ respectively. Cutting to the left was resumed at 11:37, the machine moving to the right of the heading at 12:33, cutting continuing until 12:47. Over this period the calculated mean dust concentration was 32,2 mg/m³. During the subsequent break in cutting, while the picks were being changed, the scrubber inlet ducting was removed. Continued cutting on the right of the heading gave a mean dust concentration of 57,7 mg/m³ with the standard scrubber inlet.

Generally, there appeared to be a gradual increase in dust levels as the heading was being cut. However, removal of the dual duct inlet from the scrubber still appeared to result in a significant increase in dust levels. Comparing the figure of 57,7 mg/m³ with the ducting removed with the concentration of 32,2 mg/m³ for the previous cutting period with the ducting fitted, indicated an overall improvement of 44 % in dust levels through use of the dual inlet system.

On the day of the third underground test (29 April 1997), continuous recording methane monitors were fitted to several locations on the continuous miner by mine head office staff. The objective was to determine whether the modified scrubber inlet configuration caused changes in overall methane patterns.

The results showed that the general methane concentrations were normal for coal in that region, and dilution rates from the face to the back of the continuous miner were unaffected. However, higher than normal methane concentrations were recorded at the front right and under-boom positions (that is, on the side opposite to the scrubber inlet). The distribution of methane was more even over all of the forward position sensors than usual and the methane was being distributed more widely around the area between the face and the scrubber. Without the scrubber modification, higher concentrations usually occur on the left (scrubber intake) side of the continuous miner. However, the highest peaks of methane concentration were still recorded at the mid-left boom position indicating that some air still bypassed the advanced scrubber intake.

Overall these measurements indicate an airflow pattern caused by the modified scrubber inlet which is more favourable for improved dust capture efficiency than the standard scrubber inlet.

The limited evidence from the underground trials in two different cutting situations appears to confirm the findings from the surface trials that the use of multiple, jib mounted scrubber inlets improves scrubber dust capture efficiency. However, given the wide variety of cutting situations in bord and pillar operations, the limited underground verification cannot not be taken as conclusive. Such evidence would need to be obtained over a much longer trial period with a properly designed inlet duct system and controlled test conditions.

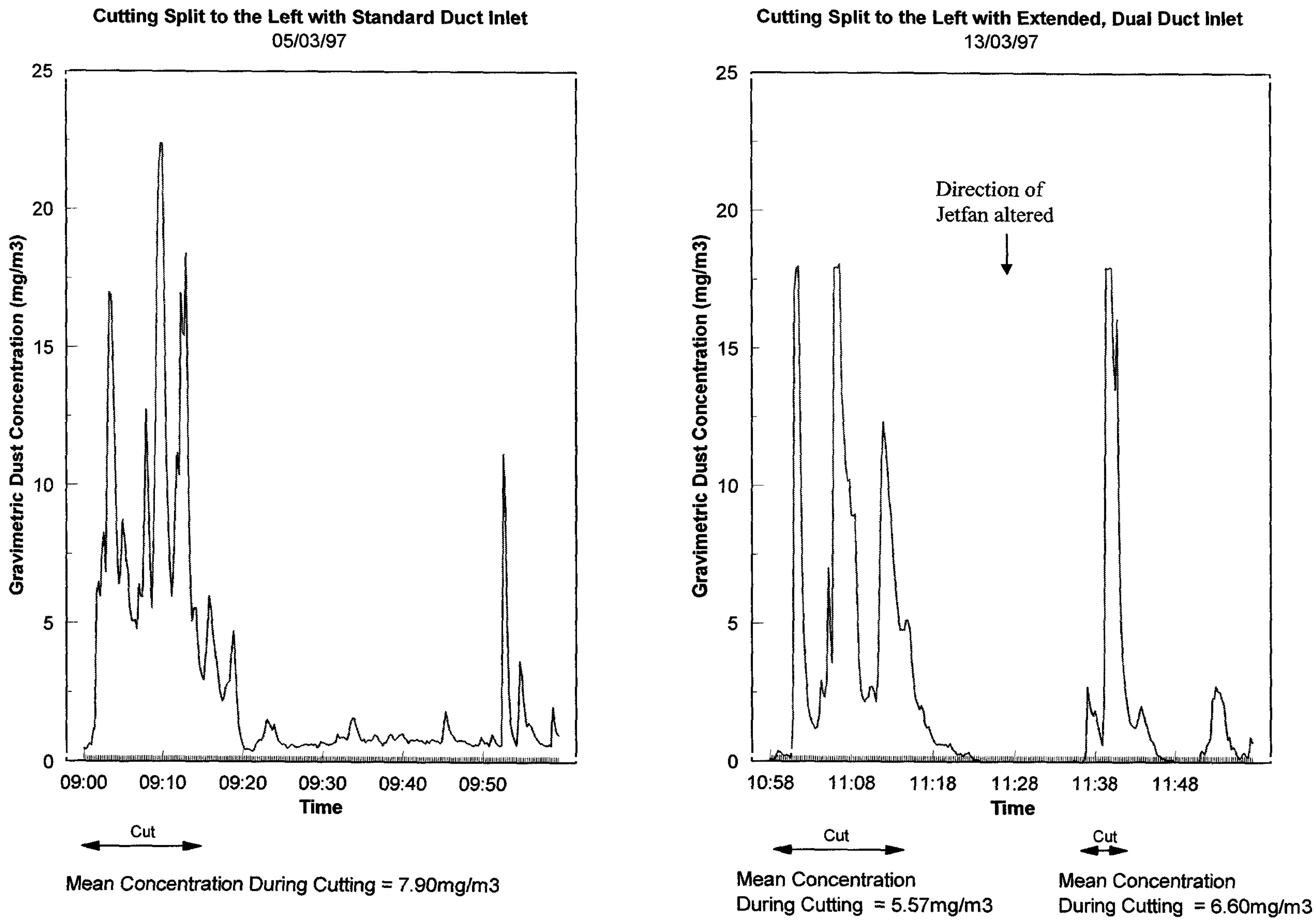


Figure 4.23 Initial Underground Evaluation of the use of Dual Scrubber Inlets Sited on the Jib of a Continuous Miner

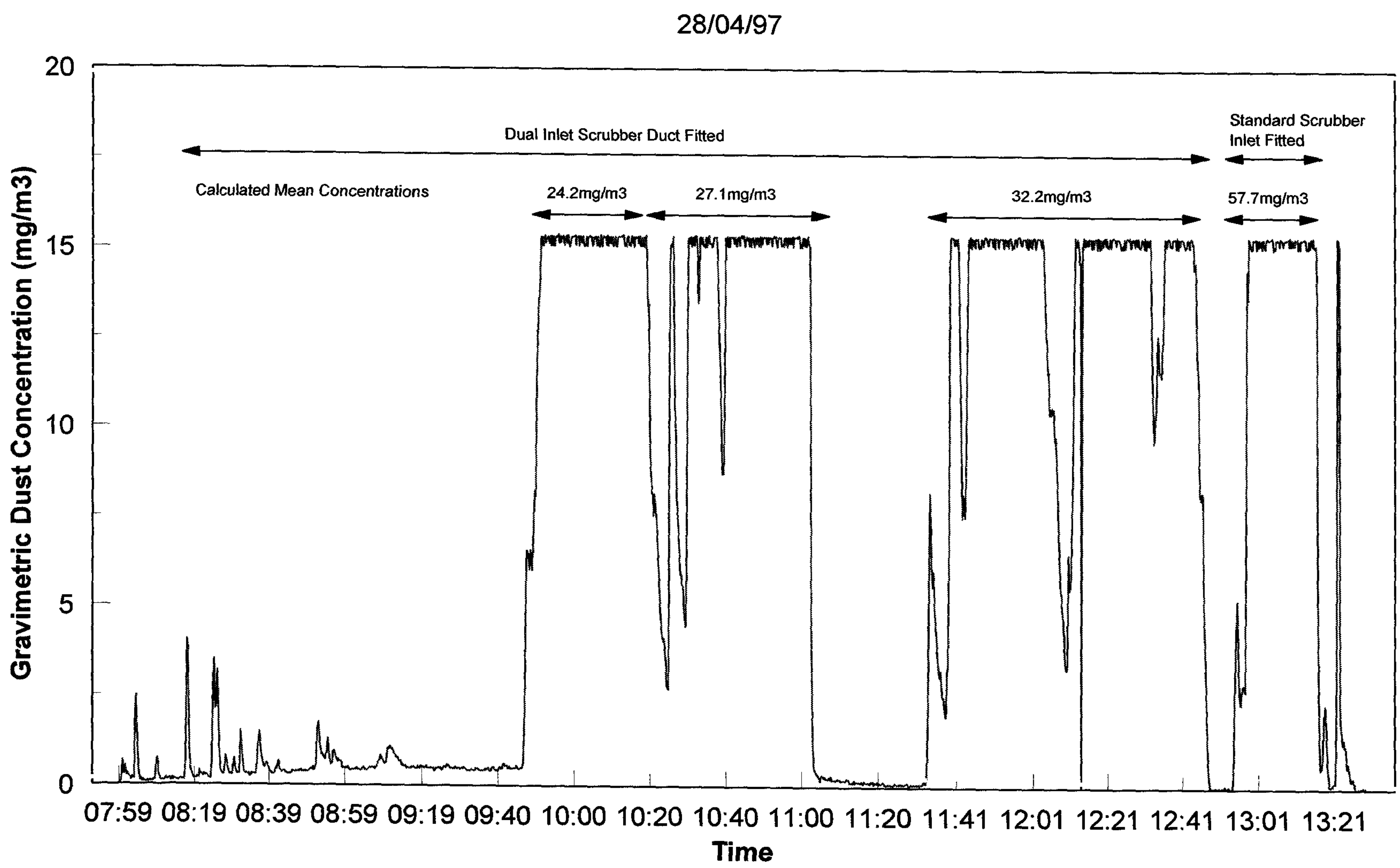


Figure 4.24 Second Underground Evaluation of the use of Dual Scrubber Inlets Sited on the Jib of a Continuous Miner

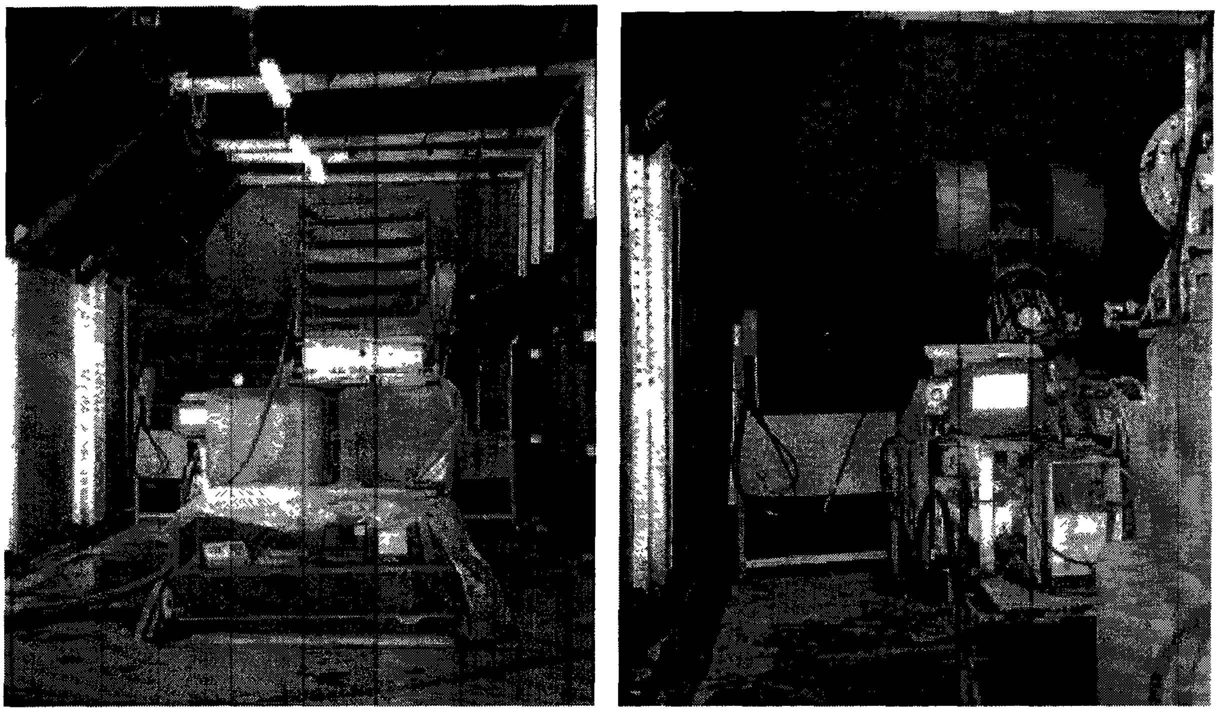
4.2 Roadheader Investigations

4.2.1 Layout of Gallery and Ventilation System Components

The gallery layout for the roadheader trials was identical to that used for the continuous miner trials, and the same jetfan and scrubber units were used. Throughout the roadheader tests the deflectors on the discharge of the scrubber were left in place. However, the scrubber was located on the right hand side of the machine and the jetfan on the left of the heading, the opposite arrangement to that for the continuous miner trials.

Roadheading machines, being able to cut the full roadway section from a single, central position, represent a much simpler situation to assess than that of a continuous miner cutting the section in two passes. Only two jetfan positions were considered in the trials, sited 12 and 20 m from the face. However, more extensive comparison between siting the jetfan in the roof and on the floor was made.

The machine simulation was based upon the approximate dimensions of a Voest Alpine AM75 machine. This was actually constructed around an axial-type cutter head Dosco Mk2A roadheader, the body of this machine being extended to the correct length and wooden, transverse-type cutting heads being fitted to the machine jib. The use of this machine in the simulation allowed the jib to be moved to different positions on the face. The loading shovel of the Dosco machine was also extended to the full roadway width, as on an actual machine. Photographs of the machine simulation in the gallery are shown below.



Photographs of the Roadheading Machine Simulation in the Surface Gallery

The water spray system fitted to the machine was representative of the minimum system fitted to machines underground. The system comprised :-

- A bank of three, 2 mm orifice hollow-cone sprays fitted to each side of the cutter jib, directed outwards towards the cutting heads. The upper and lower sprays were angled to cover the area above and below the cutting head.
- A vertical bank of 4 water-powered airmovers located near the left hand rear of the loading shovel. These were directed towards the left hand corner of the face and the individual airmover tubes progressively angled to cover the full height of the face.

In the roadheader trials, comparisons were made for nozzle water pressures of 17 and 29 bar.

Roadheaders can be used to cut a face in any direction. Part of the cutting cycle may involve an upwards direction of cutting where there is no coal buttock beneath the heads to reduce any influence on dust disturbance of cutting head rotation or falling material. In this situation, such effects were simulated using an array of four coarse-droplet sprays, suspended vertically just beneath the jib. Previous work has shown that such an arrangement can simulate the effect of falling material, which has the greatest effect on the dust cloud, since the sprays move a larger quantity of air when the jib is raised. This quantity reduces as the jib is lowered, when the distance of spray travel is limited. These sprays were operated at a constant pressure during the trials (irrespective of the pressure of the sprayfan system).

Assessments of the ventilation flows around the machine were carried out using the same techniques as for the continuous miner trials.

4.2.2 Evaluation of the Basic Components of the Ventilation System

Initial tests were carried out to evaluate the ability of a standard arrangement of scrubber and sprayfan system to control dust produced at the face. The additional effects of a jetfan were then assessed. Finally, alternative scrubber inlet positions were evaluated to obtain further improvement in scrubber capture.

Effect of the Sprayfan System

An assessment of the combined effect of the scrubber and sprayfan was carried out using smoke visualisation. This demonstrated that dust capture was reduced with the jib raised than with it lowered, largely due to the simulated effect of falling material. The tests also revealed a difference in conditions between the jib located on the left and on the right of the face. On the basis of these tests, the ventilation measurements were carried out on two cutting positions high on the face, to the left and to the right. The results obtained are shown in the table below (at two sprayfan operating pressures). As previously mentioned, the calculated outbye flow was used in the analysis.

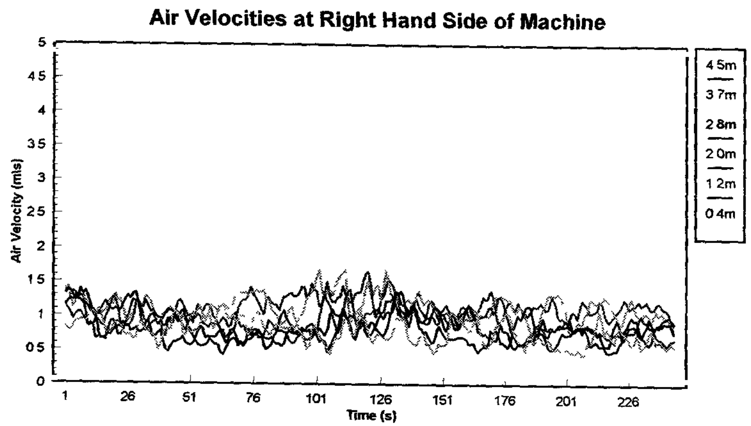
Jib Position	Scrubber Quantity (m^3/s)	Spray Pressure (bar)	Jetfan Position (m)	Calculated Flow Outbye (m^3/s)	Scrubber Vol / Outbye Vol (%)
Left	8,3	17	--	10,0	83
Left	8,3	29	--	11,5	72
Right	8,3	17	--	10,1	82
Right	8,3	29	--	12,2	68

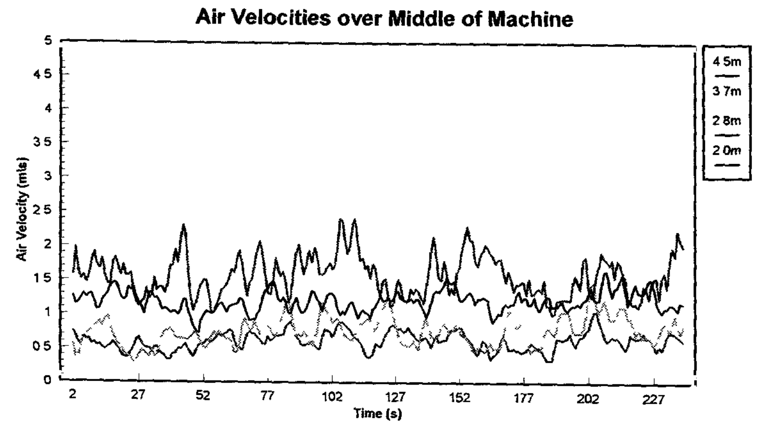
This data confirmed the visual indications that scrubber capture was reduced when the jib was located to the right of the face and also at the higher sprayfan water pressure. The air velocity measurements obtained for the jib sited to the right and sprayfan operating pressures of 17 and 29 bar are shown in Figures 4.25 and 4.26 respectively. It can be seen that for the 29 bar sprayfan pressure, the main area of dust roll-back was near floor level on the right of the machine. This roll-back also occurred to a limited extent at 17 bar, but did not reach as far as the measurement position, the outflowing air rising towards the scrubber inlet a short distance behind the inlet position. The roll-back was caused by the downward flow at the face from the jib sprays and simulation of falling material pushing air outbye from the face at a low level on the right of the machine. Since the scrubber inlet was closer to the roof than the floor, the smoke was pushed to the furthest point from the scrubber inlet in this area and hence the weakest area of capture. At a higher level, the air moved across the face by the airmover array was all captured by the scrubber. Dust roll-back occurred in this same position even when the jib was to the left of the face, but to a lesser extent, the airmovers on left of the machine being effective at preventing the effect on the left hand side.

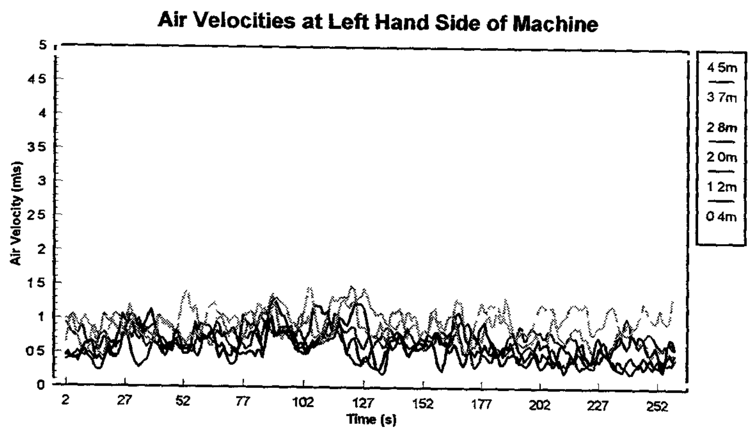
It was concluded that an operating pressure of 29 bar was too high with the standard scrubber inlet configuration. Essentially dust roll-back occurred which resulted in dust being recirculated to the operator's position around the rear of the machine. Conversely at 17 bar, the face was still effectively ventilated by the airmover array while all the smoke was captured by the scrubber. The calculated scrubber efficiency for this situation was of the order of 83 % for both jib positions. This reduced figure resulted from a slight outflow of air over the centre of the machine caused by entrainment into the outlet jet of the scrubber. No smoke from the face was observed to be entrained into this air flow, indicating that the scrubber capture efficiency was close to 100 %.

Roadheader Test Conditions -

Jib Raised on Right
Scrubber operating -
Standard inlet, 5.5 m
Outlet deflected upwards
Sprayfan system at 17 bar







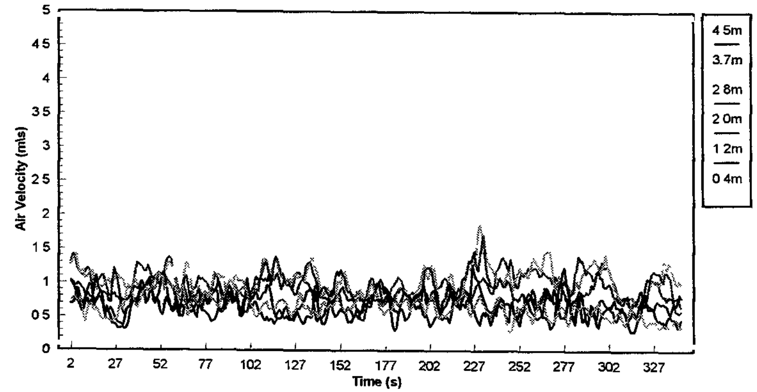
Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4 5m	1.11 +/- 0.20 m/s
	- 3.7m	1.14 +/- 0.18 m/s
	- 2.8m	0.92 +/- 0.17 m/s
	- 2 0m	0.85 +/- 0.23 m/s
	- 1.2m	0.82 +/- 0.18 m/s
	- 0.4m	0.77 +/- 0.17 m/s
Over Middle of Machine	- 4.5m	-0.61 +/- 0.13 m/s
	- 3.7m	0.76 +/- 0.21 m/s
	- 2.8m	1.58 +/- 0.30 m/s
	- 2.0m	1.20 +/- 0.15 m/s
	- 1.2m	------
	- 0.4m	------
Left Hand Side of Machine	- 4.5m	0.71 +/- 0.15 m/s
	- 3.7m	0.87 +/- 0.22 m/s
	- 2.8m	0.62 +/- 0.19 m/s
	- 2.0m	0.53 +/- 0.17 m/s
	- 1.2m	0.68 +/- 0.23 m/s
	- 0.4m	0.98 +/- 0.19 m/s

Figure 4.25 Roadheader Simulation - Air velocities at 6,5 m from the Face, Standard Scrubber plus Sprayfan at 17 bar

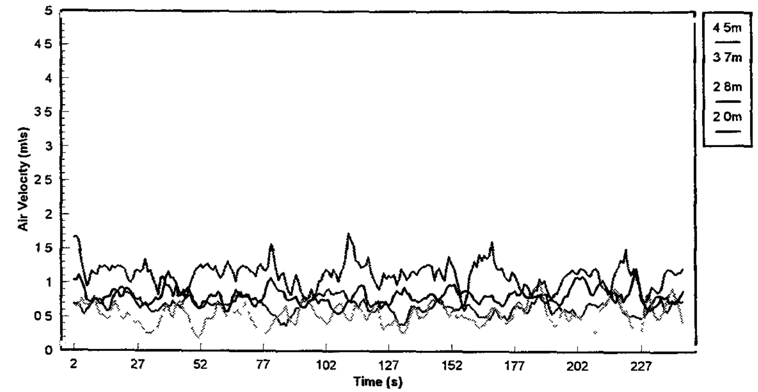
Roadheader Test Conditions -

Jib Raised on Right
Scrubber operating -
Standard inlet, 5.5 m
Outlet deflected upwards
Sprayfan system at 29 bar

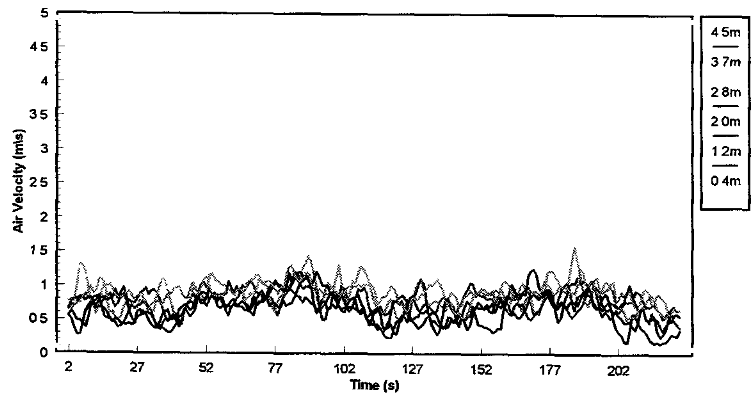
Air Velocities at Right Hand Side of Machine



Air Velocities over Middle of Machine



Air Velocities at Left Hand Side of Machine



Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	0.96 +/- 0.17 m/s
	- 3.7m	1.02 +/- 0.21 m/s
	- 2.8m	0.91 +/- 0.20 m/s
	- 2.0m	0 70 +/- 0 17 m/s
	- 1.2m	-0.62 +/- 0.16 m/s
	- 0.4m	-0.67 +/- 0.16 m/s
Over Middle of Machine	- 4.5m	-0.67 +/- 0 11 m/s
	- 3.7m	0.55 +/- 0 16 m/s
	- 2.8m	1.12 +/- 0.19 m/s
	- 2.0m	0 81 +/- 0.12 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	0.76 +/- 0.13 m/s
	- 3.7m	0.88 +/- 0.21 m/s
	- 2.8m	0.70 +/- 0.19 m/s
	- 2.0m	0.60 +/- 0.20 m/s
	- 1.2m	0.72 +/- 0.22 m/s
	- 0.4m	0.89 +/- 0.15 m/s

Figure 4.26 Roadheader Simulation - Air velocities at 6,5 m from the Face, Standard Scrubber plus Sprayfan at 29 bar

Effect of a Jetfan

Assessments of the effect of the jetfan were carried out with the jetfan sited both in the roof and at floor level, at 12 and 20 m from the face and at 17 and 29 bar sprayfan pressures. At the 12 m jetfan position, the effect of jib position to the right and left of the face was also compared. The air flow results are compared in the table below.

Jib Positio n	Spray Pressure (bar)	Jetfan Position (m)	Calculated Flow Outbye (m^3/s)	Scrubber Vol / Outbye Vol (%)
Right	17	--	10,1	82
Right	17	20 m, Roof	37,4	22
Right	17	20 m, Floor	43,7	19
Right	17	12 m, Roof	40,1	21
Right	17	12 m, Floor	42,4	20
Right	29	--	12,2	68
Right	29	12 m, Roof	--	--
Right	29	12 m, Floor	37,5	22
Left	17	--	10,0	83
Left	17	12 m, Roof	42,6	20
Left	17	12 m,Floor	44,5	19
Left	29	--	11,5	72
Left	29	12 m, Roof	--	--
Left	29	12 m, Floor	40,7	20

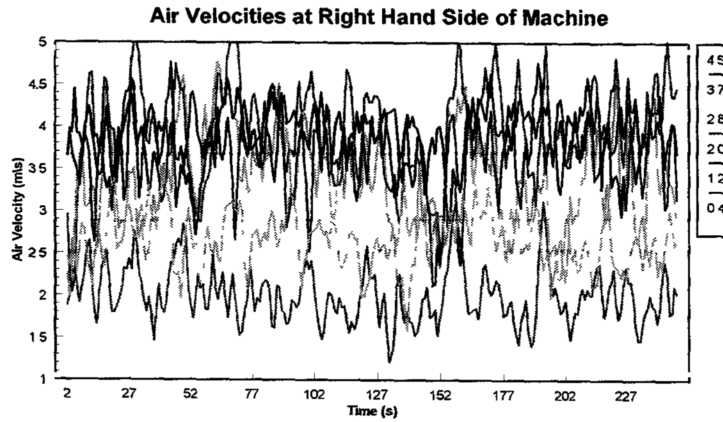
The effect of the jetfan on scrubber capture was significant, with the volume of air moved to the face completely overwhelming that passed by the scrubber and reducing the scrubber capture efficiency to about 20 %. At the high sprayfan pressure of 29 bar and with the jetfan in the roof, so much water spray was carried back from the face and recirculated around the machine that air flow measurements on the right of the machine were impossible to obtain. With the jetfan in operation, conditions were worse with the jib located on the left of the face. This was due to the bulk of the raised cutter heads deflecting more of the jetfan air towards the lower part of the face, increasing the outflow to the rear of the machine at floor level on the right, away from the capture zone of the scrubber inlet.

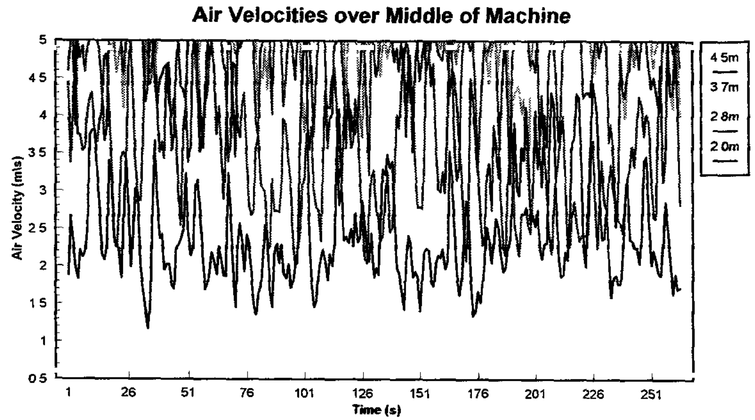
The air velocity measurements for the 20 m jetfan position, sited in the roof and at floor level and with a 17 bar sprayfan pressure are shown in Figures 4.27 and 4.28. The figures show that, with the with the jetfan located in the roof, air flow around the machine tends to be more turbulent, showing greater variation than with the jetfan at floor level (note this did not appear to be the case at 12 m). Siting the jetfan at floor level also tended to result in a lower scrubber capture efficiency. This latter effect can be attributed to the reduced influence of the machine on the floor-mounted jetfan air flow. The body of the machine is central in the roadway, and hence the machine body helps to confine and guide the air jet travelling to the face at a low level. Close to the face, however, the air jet strikes the low profile of the rear of the loading shovel, causing considerable disturbance to the air jet travelling towards the face.

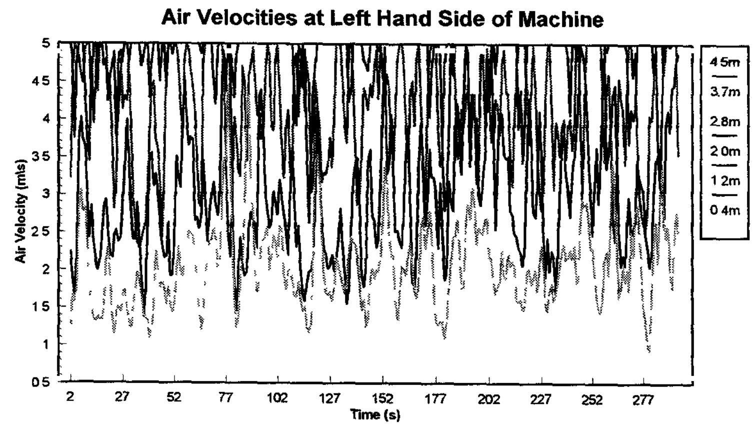
The position of highest outflow of air to the right of the face with the jetfan was also influenced by the profile of the loading shovel which lifted the outflowing air from the floor along its face. This air was subsequently deflected upwards by the rear spill plate. Most outflow of air from the face was therefore towards the centre or high in the roadway for both a roof and a floor mounted jetfan. The upward deflection of the outflowing air depended on its velocity. There was a greater tendency for the highest outflow to be higher in the roof with the jetfan 12 m from the face than at 20 m. Superimposed upon this was the effect of the sprayfan system which, at the higher operating sprayfan pressure, tended to push the outflowing air to a lower point in the roadway.

Roadheader Test Conditions -

Jib Raised on Right
Scrubber operating -
    Standard inlet, 5.5 m
    Outlet deflected upwards
Sprayfan system at 17 bar
Jetfan operating -
    20 m from face in roof





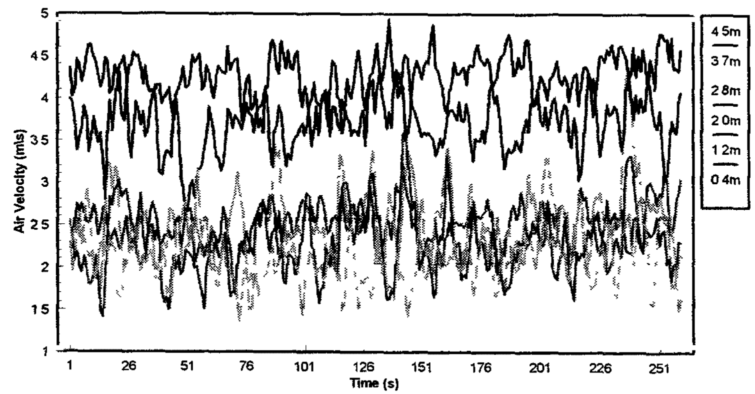


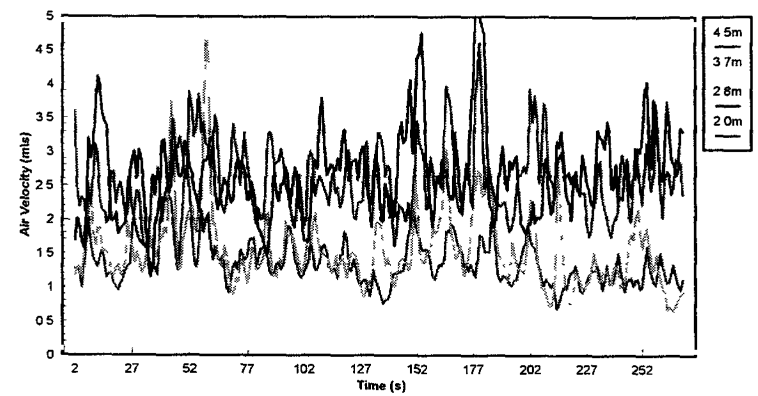
Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	-2.01 +/- 0.33 m/s
	- 3.7m	-3.37 +/- 0.62 m/s
	- 2.8m	-3 98 +/- 0.57 m/s
	- 2.0m	-3.82 +/- 0.42 m/s
	- 1.2m	-3.76 +/- 0.42 m/s
	- 0.4m	-2.70 +/- 0.30 m/s
Over Middle of Machine	- 4.5m	3.68 +/- 0.93 m/s
	- 3.7m	4.3 m/s
	- 2.8m	4.53 +/- 0.75 m/s
	- 2.0m	2.42 +/- 0.69 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	4.25 +/- 0.81 m/s
	- 3.7m	7.0 m/s
	- 2.8m	8.0 m/s
	- 2.0m	5.00 +/- 0.49 m/s
	- 1.2m	3.01 +/- 0.84 m/s
	- 0.4m	2.07 +/- 0.58 m/s

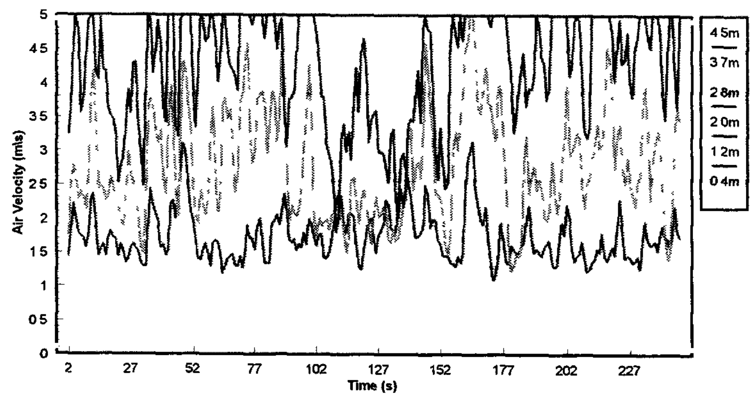
Figure 4.27 Roadheader Simulation - Air velocities at 6,5 m from the Face, Standard Scrubber, Jetfan at 20 m in the Roof, Sprayfan at 17 bar

Roadheader Test Conditions -

Jib Raised on Right
Scrubber operating -
Standard inlet, 5.5 m
Outlet deflected upwards
Sprayfan system at 17 bar
Jetfan operating -
20 m from face on floor







Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	-2.51 +/- 0 24 m/s
	- 3.7m	-2.50 +/- 0.45 m/s
	- 2.8m	-2.29 +/- 0.40 m/s
	- 2.0m	-3.71 +/- 0.33 m/s
	- 1.2m	-4.27 +/- 0.27 m/s
	- 0.4m	-2.14 +/- 0.32 m/s
Over Middle of Machine	- 4.5m	-1.39 +/- 0.36 m/s
	- 3.7m	-1.56 +/- 0.56 m/s
	- 2.8m	2.60 +/- 0.52 m/s
	- 2.0m	2.70 +/- 0 66 m/s
	- 1.2m	------
	- 0.4m	------
Left Hand Side of Machine	- 4.5m	-1.75 +/- 0.38 m/s
	- 3.7m	2.79 +/- 0.81 m/s
	- 2.8m	4.31 +/- 0.91 m/s
	- 2.0m	5.0 m/s
	- 1.2m	6.5 m/s
	- 0.4m	8.2 m/s

Figure 4.28 Roadheader Simulation - Air velocities 6,5 m from the Face, Standard Scrubber, Jetfan at 20 m on the Floor plus Sprayfan at 17 bar

Effect of Varying the Scrubber Inlet Position

In addition to the standard scrubber inlet, two extensions on the scrubber inlet were assessed. First, the effect of a simple 1,5 m extension of the scrubber inlet was assessed, advancing it to 4 m from the face. Second, the effect of ducting the inlet onto the jib itself to a point close behind the cutter heads, 3 m from the face, was assessed. To achieve this, a length of 0,76 m diameter flexible ducting was attached to the scrubber inlet. The duct was routed along the top of the jib allowing the inlet to remain in a fixed position in relation to the cutter drums as the jib was moved around the face.

Assessments were carried out at the two sprayfan pressures, with the jib to the left and right, and with a jetfan located 20 m from the face in the roof and floor. The air flows obtained with these alternative inlet positions are tabulated below.

Jib Position	Scrubber Inlet onfiguration	Scrubber Quantity (m^3/s)	Spray Pressure (bar)	Jetfan Position (m)	Calculated Flow Outbye (m^3/s)	Scrubber Vol / Outbye Vol (%)
Right	Std, 5,5 m	8,3	17	--	10,1	82
Right	Ext, 4,0 m	8,2	17	--	10,5	78
Right	Jib Duct	8,0	17	--	9,7	83
Right	Std, 5,5 m	8,3	29	--	12,2	68
Right	Jib Duct	8,0	29	--	10,6	76
Left	Std, 5,5 m	8,3	17	--	10,0	83
Left	Jib Duct	8,0	17	--	9,8	82
Left	Std, 5,5 m	8,3	29	--	11,5	72
Left	Jib Duct	8,0	29	--	10,7	75
Right	Std, 5,5 m	8,3	17	20 m, Roof	37,4	22
Right	Ext, 4,0 m	8,2	17	20 m, Roof	40,2	20
Right	Jib Duct	8,0	17	20 m, Roof	--	--
Right	Std, 5,5 m	8,3	17	20 m, Floor	43,7	19
Right	Ext, 4,0 m	8,2	17	20 m, Floor	44,8	18

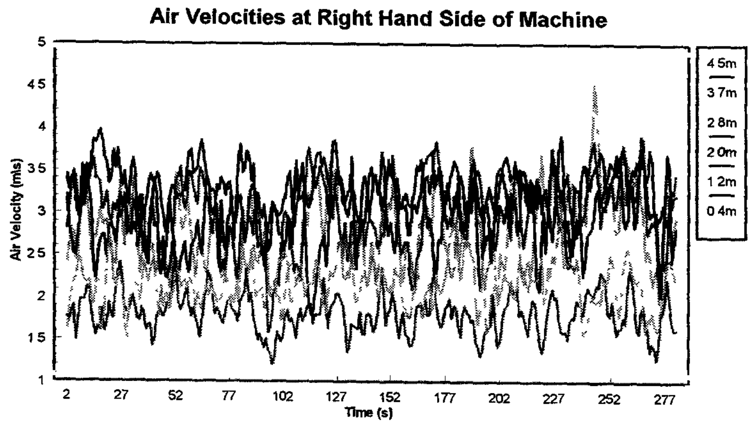
With no jetfan in operation, the scrubber efficiencies calculated from air flows do not accurately reflect the true capture ability of the scrubber, particularly at the sprayfan pressure of 17 bar. This is because the only outflow of air was over the middle of the machine at roof level. This outflow is caused by entrainment of air into the scrubber discharge which would not necessarily be contaminated by dust from the face. Visually, the effect of changing the duct inlet position was seen to be greater. Advancing the scrubber inlet closer to the face tended to contain the smoke closer to the face, indicating a reduction in the extent of dust roll-back and the possibility of dust roll-back reaching into the outflow at roof level above the centre of the machine. There was one exception to this trend, however, which occurred with the short extension duct fitted to the scrubber and the jib located to the right of the face. With this particular configuration the general smoke cloud was held closer to the face, but smoke was pushed away from the face around the outside of the loading shovel by the downward flows created by the sprays on the machine. This area was shielded from the direct influence of the scrubber inlet by the sideplate of the loading shovel, emerging into the general body air to the right of the machine behind the scrubber inlet. From here, the smoke rolled back further along the length of the machine body than was the case with the standard inlet position, although this did not escape as far as the rear of the machine.

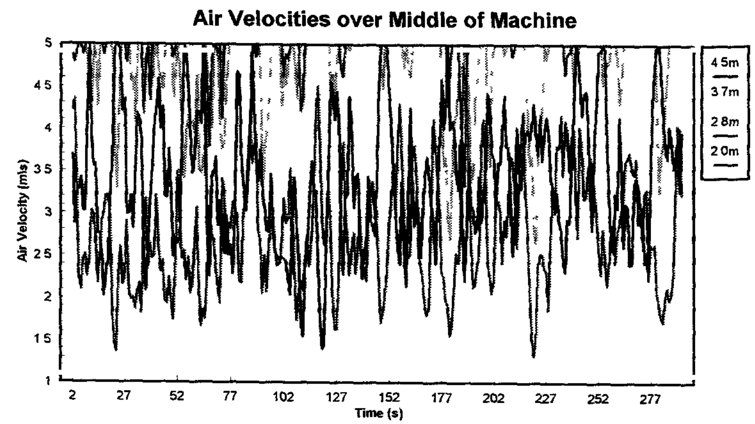
Advancing the duct onto the jib itself resulted in a dramatic improvement in conditions, especially with a spray pressure of 17 bar. With this layout, all the smoke released at the cutting head was drawn directly into the duct inlet, little smoke being visible at all around the face or cutting head. In particular this would give the additional benefit of improved visibility for the machine operator. Similar conditions were obtained irrespective of machine jib position on the face. At 29 bar, the effect of the airmover and jib sprays was greater, drawing some smoke away from the cutting zone and pushing it towards the floor. Visibility was therefore slightly less than at the lower pressure, a relatively thin cloud of smoke forming beneath the jib. However, at no position of the jib was the smoke pushed further back than the rear of the loading shovel.

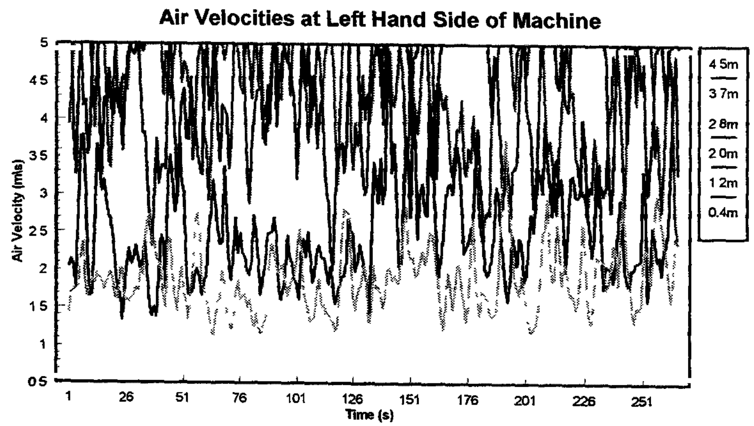
The addition of the jetfan to the ventilation system resulted in a deterioration in conditions. The air flow at the face being too great and too high a velocity for the scrubber system to capture a significant proportion of any smoke released. The air velocity measurements for the extended inlet and the jib duct with the jetfan located in the roof, 20 m from the face and a spray pressure of 17 bar, are shown in Figures 4.29 and 4.30. These should be compared with Figure 4.27 for the equivalent situation with the standard duct inlet. It was not possible to obtain air velocity measurements to the right of the machine for the use of the ducted inlet on the machine jib. This was due to excessive water from the sprays sited beneath the cutter heads, to simulate falling material, being carried around the machine in the high velocity air from the jetfan. Overall, operation of the jetfan resulted in a reduction in calculated scrubber capture from about 80 to 20 %, with little variation on this figure being shown by moving the scrubber inlet to alternative positions. This capture efficiency of about 20 % is marginally lower than that obtained for the continuous miner which is due to the more ‘open’ area around a roadheader machine, which allows better access to the face for the air jet from the jetfan.

Roadheader Test Conditions -

Jib Raised on Right
Scrubber operating -
Extended inlet, 4.0 m
Outlet deflected upwards
Sprayfan system at 17 bar
Jetfan operating -
20 m from face in roof







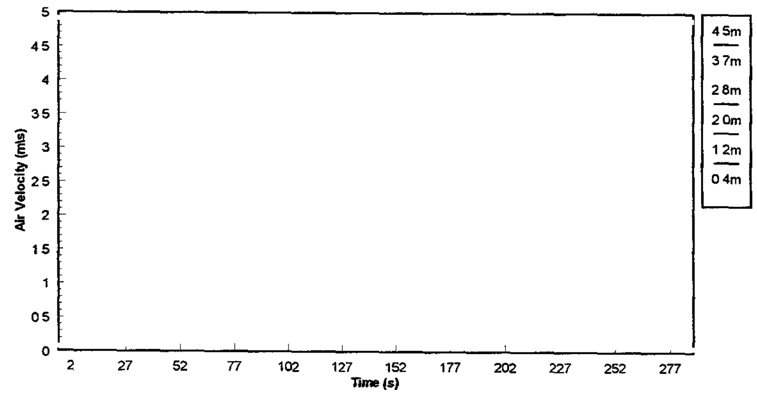
Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	-1.80 +/- 0.23 m/s
	- 3.7m	-2.79 +/- 0.45 m/s
	- 2.8m	-3.00 +/- 0.41 m/s
	- 2.0m	-3.27 +/- 0.28 m/s
	- 1.2m	-2.97 +/- 0.43 m/s
	- 0.4m	-2.16 +/- 0.26 m/s
Over Middle of Machine	- 4.5m	-2.78 +/- 0.71 m/s
	- 3.7m	4.85 +/- 0.59 m/s
	- 2.8m	5.16 +/- 0.29 m/s
	- 2.0m	3.46 +/- 0.82 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	4.45 +/- 0.79 m/s
	- 3.7m	7.6 m/s
	- 2.8m	7.4 m/s
	- 2.0m	4.44 +/- 0.80 m/s
	- 1.2m	2.51 +/- 0.67 m/s
	- 0.4m	1.89 +/- 0.44 m/s

Figure 4.29 Roadheader Simulation - Air velocities at 6,5 m from the Face, Scrubber with Extended Inlet, Jetfan at 20 m in the Roof plus Sprayfan at 17 bar

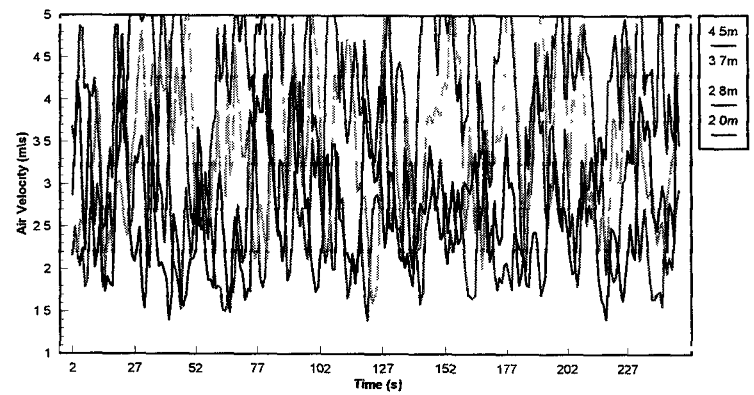
Roadheader Test Conditions -

Jib Raised on Right
Scrubber operating -
  Jib Duct inlet, 3.0 m
  Outlet deflected upwards
Sprayfan system at 17 bar
Jetfan operating -
  20 m from face in roof

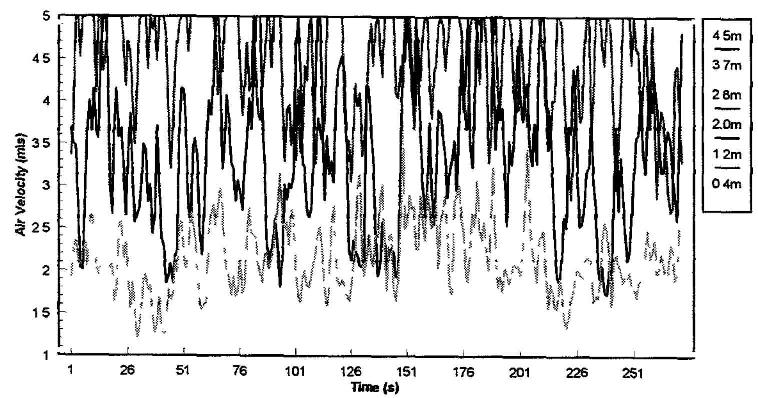
Air Velocities at Right Hand Side of Machine



Air Velocities over Middle of Machine



Air Velocities at Left Hand Side of Machine



Position & Height		Mean Velocity (m/s)
Right Hand Side of Machine	- 4.5m	- m/s
	- 3.7m	- m/s
	- 2.8m	- m/s
	- 2.0m	- m/s
	- 1.2m	- m/s
	- 0.4m	- m/s
Over Middle of Machine	- 4.5m	2.64 +/- 0.74 m/s
	- 3.7m	3.50 +/- 0.90 m/s
	- 2.8m	4.15 +/- 0.86 m/s
	- 2.0m	2.67 +/- 0.75 m/s
	- 1.2m	-------
	- 0.4m	-------
Left Hand Side of Machine	- 4.5m	4.55 +/- 0.70 m/s
	- 3.7m	7.6 m/s
	- 2.8m	7.4 m/s
	- 2.0m	5 21 +/- 0.22 m/s
	- 1.2m	3.37 +/- 0.91 m/s
	- 0.4m	2.16 +/- 0.42 m/s

Figure 4.30 Roadheader Simulation - Air velocities at 6,5 m from the Face, Scrubber with Inlet Ducted onto the Jib, Jetfan at 20 m on the Floor plus Sprayfan at 17 bar

4.2.3 Conclusions from the Gallery Trials with a Roadheading Machine

Taking into account the range of ventilation conditions which are encountered as a heading is developed by a roadheader, the following conclusions can be drawn from the surface gallery investigations.

Sprayfan System

The airmover array sited to one side of the loading shovel is an effective means of providing ventilation of the full face during the early stages of cutting a heading when there is no additional auxiliary ventilation (apart from the scrubber). In combination with the spray arrangement sited on the jib, it was seen that an operating pressure of 17 bar provided adequate ventilation while allowing a high scrubber capture efficiency. Raising the operating pressure to 29 bar tended to provide too great a ventilating effect, disturbing smoke released at the face so that it tended to roll back past the scrubber inlet near floor level.

The optimum operating pressure cannot be stipulated precisely since there are many factors which will influence this. It is therefore recommended that the optimum setting should be determined by trial and error investigation at each site.

Jetfan System

Operation of the jetfan significantly reduced the capture efficiency of the scrubber system in all circumstances, the volume and high velocity of the resultant air flow at the face overwhelming the scrubber system. The layout and positioning of a roadheading machine in a heading is such that the jetfan is able to pass more air to the face than with a continuous miner type machine, irrespective of the jetfan being sited at roof or floor level. As a result the majority of dust is driven past the scrubber to the rear of the machine and the high entrainment of the air jet from the jetfan then recirculates much of this dust back to the face, past the machine operator's position.

Effect of Varying Scrubber Inlet Position

The use of alternative scrubber inlet positions can significantly improve the scrubber capture efficiency in situations where jetfans are not used. Optimum scrubber capture was obtained by locating the scrubber inlet on the jib of the machine, just behind the cutter heads. In this position, the scrubber inlet is in a fixed position in relation to the cutter heads and consequently the dust source. Provided that the sprays on the jib are configured and operated so that they do not cause too great a dispersion of the dust produced, a scrubber inlet located at this position will immediately capture all the dust and improve visibility. However, such a system is vulnerable to damage and should be purpose-built for individual machines, incorporating a substantial steel inlet duct which is wrapped around the top and sides of the jib and connected to the scrubber unit via a flexible joint or duct to allow for movement.

If the above design is considered vulnerable to damage, alternative inlet positions could still give some improvement in scrubber capture. First, extending the inlet further forward on the machine will tend to contain the dust cloud closer to the face, preventing the cloud reaching back to the machine operator's position. However, some dust roll-back may still occur to the side of the scrubber close to the floor. Such roll-back could be prevented using forward-directed sprays, acting towards the floor, mounted part-way along the machine body. A second alternative would be to duct the inlet to the side of the machine just above the rear spill plate of the loading shovel, which is where the air naturally returns from the face. This position is shown in the diagram below.

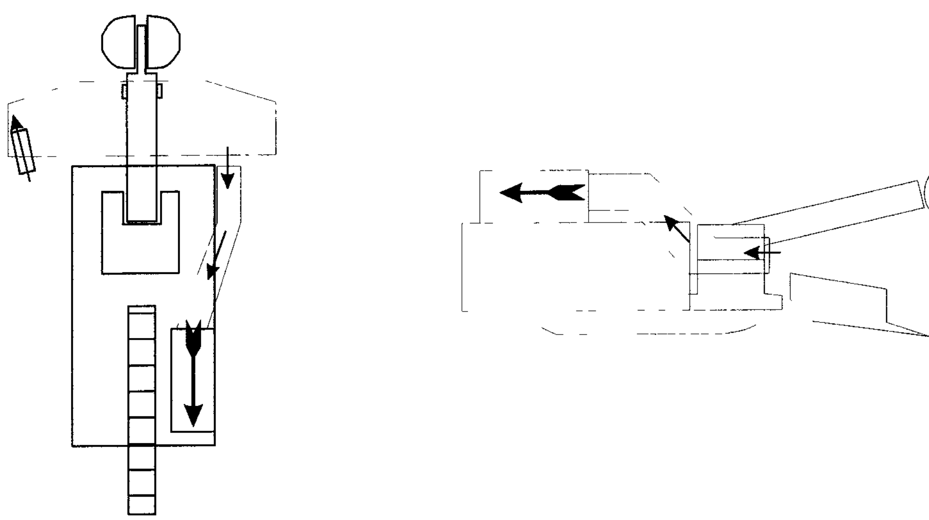


Diagram Showing Improved Location Position for Scrubber Inlet

5. ASSESSMENT OF NOISE EMISSIONS FROM SCRUBBER SYSTEMS

An aspect of the project was to carry out a noise impact assessment on scrubber systems and to formulate basic recommendations on noise reduction. It had originally been intended to carry out the assessment at an underground site. However, the measurement equipment available was certified for use only in UK Coal Mines. The assessment of noise levels from scrubbers was therefore carried out in the surface gallery. The data obtained was compared with existing information on noise levels from similar types of machine used in the UK.

5.1 Description of the Gallery Layouts for Noise Tests

The noise tests were conducted using the same layouts used for the scrubber dust capture trials. A Type 30 Engart Dust Scrubber with an inlet diameter of 760mm and fitted with a Brush 37.3 kW NCB type 542, flameproof motor was used for the assessment. The overall design of this unit is identical to the 30" EDE Engart scrubber units used in South Africa, but fitted with a smaller fan motor.

Noise tests were carried out on the simulated continuous miner and the roadheading machine. For the continuous miner tests the scrubber unit was suspended from an A-frame above the continuous miner, as previously described in Section 4. For the roadheader tests the scrubber unit was mounted on the top right side of the machine. Measurements were taken with only the scrubber operating (the mining machines were not operated). In this manner the results were not influenced by any contribution from operational or cutting noise.

5.2 Noise Measurements

Figure 5.1 shows the layout of the noise measurement positions in the gallery. The results are shown in Tables 5.1 and 5.2. The measurement positions were chosen to represent first, the location of the machine operator and second, the location of a shuttle car driver, approximately 7.5 metres behind the scrubber unit. The continuous miner driver position was at the rear right corner of the continuous miner while that on the roadheader was on the opposite side of the machine. For the roadheading machine, the possibility of a remote control machine was also considered, with the operator position assumed to be some 3 m behind the machine, close to the left hand sidewall.

For the continuous miner, the highest noise levels at both measuring positions were produced with the combination of scrubber inlet ducted onto the machine jib and the scrubber discharge deflected upwards towards the roof, which gave 104 dB(A) at the operator (position 1) and 107 dB(A) at the shuttle car position (position 2). With the inlet ducting and outlet deflector removed, the scrubber gave noise levels of 102 dB(A) at the operator position and 105 dB(A) at the shuttle car position.

A standard silencer unit, 0,76 m in diameter, 1, 2 m long and lined with absorbent rockwool material was fitted to the scrubber inlet. The noise level at the driver's position was reduced by 2 dB(A) to 100 dB(A). A reduction of 2 dB(A) was also measured at the shuttle car driver's position. With the deflector plates refitted to the scrubber outlet the noise level at the driver's position increased to 103 dB(A), negating the benefit of the scrubber inlet silencer.

For the roadheader tests similar reductions were measured at positions 1 and 2 with the inlet silencer fitted to the scrubber. Further tests were carried out with a special silencer fitted to the outlet of the scrubber. This silencer had a square section, 0.9m long and lined with absorbent rockwool material. With silencers fitted to both the inlet and outlet of the scrubber, their combined effect was to reduce the level at the machine operator's position, by 8 dB(A) to 96 dB(A). The reduction at the typical position for a shuttle car driver position, was 5 dB(A), to 100 dB(A).

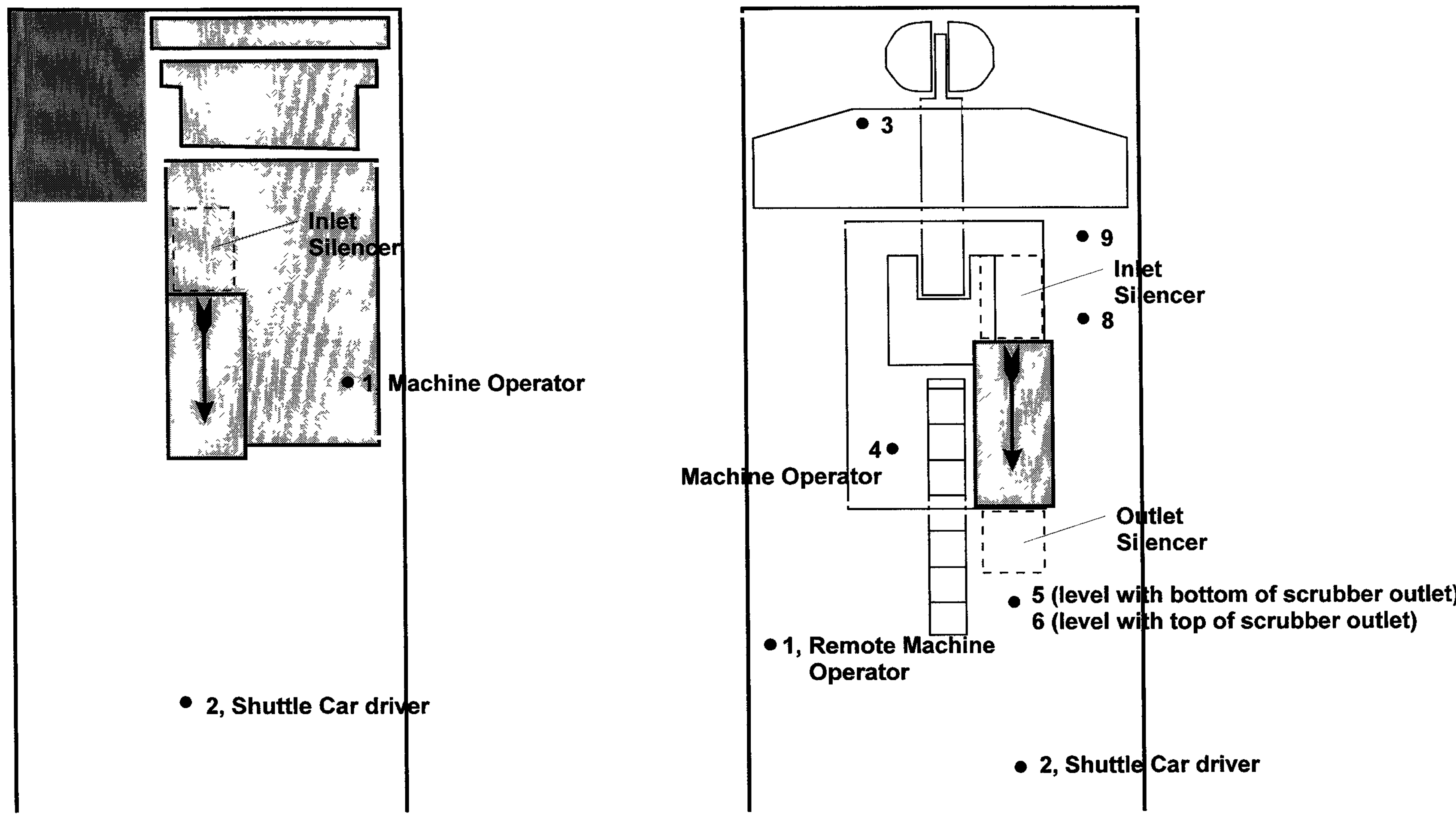


Figure 5.1 Noise Measurement Positions within the Surface Gallery

Position	Standard Scrubber	Scrubber with Inlet Silencer	Scrubber with Inlet Silencer and Outlet Deflector Fitted	Scrubber with Outlet Deflector Fitted	Scrubber with Inlet Ducting and Outlet Deflector Fitted
1	102	100	103	103	104
2	105	103	103	105	107

Position 1 is typical of Machine Operator Position
Position 2 is typical of Shuttle Car Driver Positiuon

Table 5.1 Noise Measurements Obtained around the Simulated Continuous Miner

Position	Standard Scrubber	Scrubber with Inlet Silencer	Scrubber with Inlet and Outlet Silencers	Scrubber with Outlet deflector Fitted	Scrubber with Inlet Ducting and Outlet Deflector Fitted
1	104	103	96	106	105
2	105	103	100	105	105
3	107	101	97	107	106
4	103	101	97	104	106
5	109	108	107	111	110
6	108	107	105	108	108
7	103	99	96	103	103
8	108	99	97	109	103
9	108	98	96	108	102

Position 1 is typical of Remote Machine Operator Position
Position 2 is typical of Shuttle Car Driver Positiuon
Position 4 is typical of Machine Operator Position on the Machine

Table 5.2 Noise Measurements Obtained around the Simulated Roadheading Machine

5.3 Comparison of the Scrubber Noise Levels with those from Typical Machines and Mining Operations

In relation to the noise levels from typical operations of mechanical miners, the measured levels from the scrubber rank amongst the highest. A survey of noise levels from various machine operations, measured on typical roadheaders and continuous miners in UK coal mines, in terms of the noise levels measured at the operator's position, are shown below :

Scraper conveyor running empty	up to 111 dB(A)
Cutting and loading	99 to 104 dB(A)
Cutting	98 dB(A)
Cutting head rotating	83 to 93 dB(A)
Tramming	80 to 90 dB(A)
Dust scrubber (present gallery measurements)	102 to 104 dB(A)

5.4 Discussion and Recommendations

There are clearly two aspects of reducing the noise from dust scrubbers. First, the reduction by retrofit treatment and/or design modifications of existing scrubber units and second, the design and manufacture of new equipment.

In terms of retro-fitting equipment to existing scrubber units, the most effective means of reducing workmen's noise exposure is to fit silencers to the scrubber. Typically, use of a single 1.5x diameter silencer would be expected to produce a noise reduction of the order of 5-10 dB(A). However, noise is emitted from both the scrubber inlet and outlet and therefore, the fitting of a silencer to one end only, allows emission from the untreated end to predominate. Hence, with only one silencer fitted, the overall measured reduction in noise level was only 2 dB(A) at the operator's position. The effect of using silencers on both the inlet and outlet was much more substantial resulting in a more typical measured reduction of the order of 8 dB(A). To obtain significant noise reduction silencers should therefore be fitted to both the inlet and outlet of the scrubber.

The operational practicality of incorporating an outlet silencer may not be straightforward due to the additional length and bulk at the rear of the machine. The additional requirement of deflecting the scrubber discharge air away from the shuttle car driver must also be considered. The measurements indicate that the deflectors result in a general increase in noise levels. However, these were not aerodynamically designed nor fitted in a manner which would minimise turbulence and hence noise. Any design of deflectors should therefore take into account acoustic principles and should constructed as an integral part of a silencer unit. At the scrubber inlet, a silencer should be built into any ductwork extension used to move the inlet to a position closer to the face.

Assessment of the potential for vibration damping by stiffening of the scrubber sheet metal casing should also be conducted to evaluate this for retrofit treatment and the re-design of new scrubbers. However, the potential for reducing noise emissions by this means is an order of magnitude below the effect of silencers, casing breakout noise being typically of the order of 94 to 95 dB(A). Such a measure is therefore liable to have any effect only if silencers are already fitted to both the inlet and outlet of the scrubber.

The main source of scrubber noise derives from the fan. Fan noise has received much investigation over the years with varying success. Attention should be paid to reducing the noise at source, by re-design of the impellor and consideration of tip speed and tip clearance. Any re-design should be considered for both new equipment and for retrofitting to existing scrubbers.

6. DISCUSSION

The efficiency of dust capture by scrubber systems is dependent upon many different factors ranging from the sequence of mining a bord and pillar section, the ventilation system layout, operational parameters of spray systems to the layout and operation of the scrubber system itself. Given the wide variation in roadway size, machine types, equipment specification and individual colliery preferences and considerations, it is not possible to stipulate precise means of obtaining optimum scrubber capture.

The work carried out during this project has therefore been directed towards identifying the general influence of each aspect, with the aim of deriving guidelines by which scrubber capture efficiency may be optimised at all levels from machine and equipment manufacture to specific setting-up of machines. Although the studies carried out have focused on larger roadway sections, where the problems of dust control are greatest, similar principles apply to all roadway sizes.

In the following discussions, consideration of the ventilation requirements with respect to the control of methane has also been taken into account.

6.1 Mining Sequence

The mining sequence of a bord and pillar section has a great influence on both ventilation and dust control around the working face. Although this issue was not within the scope of work of this project, observation at underground sites and discussions with colliery staff indicate that this is a significant area of concern. From observation of a wide range of cutting situations during underground visits, together with previous experience, an analysis of the various options within the more complex situation of a continuous miner has been carried out. This is included in this report as Appendix 1. This includes recommendations for a mining sequence which is believed to represent the optimum for dust control.

Purely from this analysis, the following conclusions were drawn relating to the optimum dust capture by the scrubber system :-

1. The air flow capacity of the scrubber must be maximised with respect to the force ventilation quantities while having regard to the limitations for recirculation within the DME Ventilation Guidelines.

2. The scrubber inlet should be sited as near to the face as practically possible.
3. The cutting sequence for partial and full cuts should be such as to maintain the scrubber close to the sidewall for both cuts.

6.2 On-Machine Forcing Systems/Sprayfans

The use of effective on-board force ventilation systems, as required under the DME Ventilation Guidelines, is vital to ensure a good standard of face ventilation during the first 12 m of cutting (when no force auxiliary ventilation is required). Even when some form of force auxiliary ventilation is operating, such systems still fulfil an important ventilation function. Correct operation and maintenance of on-board force systems is therefore important for good control of methane emissions.

The use of excessive pressures on water spray systems or excessive air quantity on air curtain systems can cause dust roll-back, with consequent reductions in scrubber dust capture efficiency. It was found that for a continuous miner, the optimum operating pressure was of the order of 12 bar, measured at the spray nozzles. This gives good ventilation of the face while avoiding excessive dust roll-back. For a roadheader, it was found that the optimum operating pressure was of the order of 17 bar, measured at a the nozzles. It is not suggested that these values are applicable in all circumstances given the normal variation in roadway size, machine type, spray layout etc. It is therefore recommended that at specific sites, the optimum pressure should be obtained through tests in a deep straight cut, with a flat, fully cut face. Use of a deep cut is indicated since this will minimise any effect from the influence of air flow into the heading from the LTR. In addition, the machine should be sited to one side of the roadway with the operator's position closest to the sidewall and the scrubber near the centre of the heading. Such a combination of machine position and flat face will produce the maximum tendency for dust to roll-back past the scrubber inlet. Initial tests should be carried out with only the on-board force and scrubber system operating, with the jib of the machine raised and, in the case of a roadheading machine, with the jib on both sides of the face. Using some means of visualising the air flows near the face, such as the release of a powder-type fire extinguisher, the minimum setting for good face ventilation by the on-board force system, along with the maximum setting for minimal dust roll-back, may be determined by trial and error. In observing any tendency for dust to roll-back, particular regard should be given to the areas close to floor level on both sides of the machine. After determining the acceptable operating range for the system, the auxiliary force ventilation system should be switched on and the overall system reassessed to obtain the optimum operational setting for the on-board system both with and without auxiliary ventilation. Such a set-up procedure should only take two or three hours to complete, but the benefits to scrubber dust capture could be substantial in addition to ensuring effective ventilation of the face.

Where dust rollback occur at floor level on the operator side of the machine, the use of additional sprays at the bottom of the vertical array on the body of the machine, directed forwards but towards the floor, should be considered. Such sprays should be effective in preventing dust roll-back at this position. A further area which can be a problem for dust control is at the mouth of the conveyor tunnel on a roadheading machine or at the conveyor throat on the jib of a continuous miner. On roadheader conveyor tunnels, a spray bar with a pair of hollow cone sprays directed towards the floor of the conveyor at an angle of 30° should be effective in creating sufficient forward movement of air through the tunnel to prevent the emission of dust. On continuous miners, the problem is more difficult to overcome due to the movement of the jib. A solution is to construct a short tunnel section over the conveyor, just behind the jib throat, with a similar spray bar mounted at its rear and sealed to the top of the jib using a conveyor belting flap seal. An alternative is to direct a water-powered airmover into the jib throat, angled from a suitable position on the machine body in front of the machine operator, to create a positive, forward air movement over the conveyor.

A procedure for setting optimum spray pressure is given in Section 7.

Auxiliary Ventilation Arrangement

The DME Ventilation Guidelines lay down a number of recommendations for the auxiliary ventilation system. These include :-

1. Ducted exhaust
2. Ducted force system with on-board scrubber
3. Ducted force system with ducted exhaust
4. Jetfan with on-board scrubber

The optimal arrangement for the scrubber system is for the treated discharge air to be ducted out of the heading, the scrubber unit either being mounted on-board the machine or off-board, in the LTR. Such an arrangement means that any dust remaining in the scrubber discharge air is released outside the heading and cannot be recirculated back to the face, raising the dust exposure of the machine driver. Of the two alternative layouts, an on-board scrubber with ducting on the discharge is preferable to an off-board unit with ducting on the inlet, when the effect of leaks in the ductwork is considered. Leaks into ductwork (with an off-board scrubber) would result in lower air flows at the face, with consequently poorer capture of high concentration dust near the face. However, leaks out of ducting (with an on-board scrubber) would release filtered air, with a relatively low dust concentration, into the air flow travelling towards the face. A further negative aspect of using ductwork on either side of the scrubber is that damaged duct sections can restrict air flow.

In any event, a practical system for engineering a trailing exhaust duct system, which allows the required freedom of movement for the machine in bord and pillar type work, has yet to be designed. Operation of on-board scrubber systems without ducting is therefore the most practical alternative. However, given the associated recirculation by the scrubber unit, this inevitably results in at least some, still contaminated, discharge air being recirculated back to the machine operator. Recirculation by the scrubber is not necessarily a bad feature, particularly in larger roadway sections, where the benefits to improved capture of concentrated dust from cutting through use of high scrubber volumes outweighs the disadvantage of lower concentration dust being recirculated. The degree of recirculation of the scrubber discharge air can be minimised by ensuring that the discharge jet is projected as far away from the scrubber unit as possible, provided that this does not result in excessive entrainment of high concentration dust from the face. (See later for recommendations for the overall design of scrubbers.) The dust aspect of recirculation is minimised through the use of highly efficient scrubber units, efficient both in terms of dust removal and dust capture.

Force ventilation systems may take two forms, a jetfan located at the entry to the heading or air being ducted to within 10m of the face from an auxiliary fan. From a practical viewpoint, the use of a jetfan has many benefits, mainly from being simple to locate and there being no necessity for additional ductwork to be installed and advanced. For these reasons, use of jetfans has become popular. The release of any jet of air into a heading will involve some degree of entrainment of the general body air into the jet. However, the high energy content of the air jet from a jetfan, means that it entrains far more air from its surroundings. Near to the face, the volume of air induced by a jetfan can therefore be several times the magnitude of the scrubber capacity and can still be travelling at high velocity. Both these factors act against the requirement for a high efficiency of dust capture by the scrubber. Any excess volume will inevitably carry dust from the face past the scrubber while the velocity effect can drive dust past the scrubber inlet to a point where the energy reduces to such a level that it is either pulled back to the scrubber inlet or re-entrained into the air jet from the jetfan. Both effects result in dust being passed across the machine operator's position. However, the high velocity effect of the jetfan also makes it ideal for rapidly dispersing and diluting methane from the face.

During the surface gallery trials, it was found that at distances of 12 and 20m from the face, the jetfan ventilated the face with volumes of air typically 5 to 6 times that passed through the fan. Even with a 50% recirculation factor, the scrubber was only able to pass approximately 20% of the dust laden air returning from the face in the simulated straight cutting situation. With the jet fan sited at roof level, the air jet reached the face unobstructed. When the jetfan was mounted at floor level, the bulk of the machine had a slight influence on the quantity and air flow patterns of the air jet. This influence was greatest for a continuous miner cutting on the same side of the heading as the jetfan. When the jetfan was moved back to 30m from the face, the influence of the machine body in blocking the air flow from the jetfan before it reached the face became much more significant. The lower forward velocity of the jet at this jetfan distance meant that, instead of the air tending to flow around the machine body, retaining sufficient forward momentum to reach the face, blockage by the machine now turned the air flow, deflecting it across the back of the machine. Less air actually reached the face in this situation. The ability of the jetfan to effectively ventilate the face at this distance also depended on the exact alignment of the fan such that the 'wall effect' of the roof and sidewall helped carry the jet to the face. Directing the jetfan towards the centre of the face at this distance dramatically reduced the penetration of the jet which only tended to reach as far as the rear of the machine. A further problem with the use of jetfans was identified at an underground site where it was observed that a saw-tooth cut in the sidewall, close to the jetfan, had an almost perfect shape to trap the air jet at roof level, turning it to travel in the opposite direction at floor level. As a result, very little or no air from the jetfan actually reached the face of the heading.

In contrast, release of air from an auxiliary fan and duct is a much more controlled method of ventilating the face. The air jet is released from the duct with much lower energy than from a jetfan, therefore entraining much less air volume from its surroundings and creating lower velocities at the face. Such a forcing auxiliary ventilation system is therefore much more conducive to a high dust capture efficiency by the scrubber. While cutting the first split, a ducted system will produce both better ventilation of the face and better dust control, the duct being able to be turned into the split and directed towards the face, maintaining acceptable air flow patterns around the machine. In the equivalent situation with a jetfan, located at the entry to the straight heading, there is no direct ventilation effect at the face and the air jet travelling past the mouth of the split acts to trap dusty air within the split.

Design Guidelines for Scrubber Systems

An important factor with regard to the design of on-board scrubber systems is the configuration of the discharge jet. The short distance between the inlet and outlet of the scrubber means that any entrainment effect of the discharge jet will draw air from close to the inlet where dust concentrations are high. This entrainment results in dust by-passing the scrubber, possibly to be recirculated around the rear of the machine, back to the machine operator.

This problem was found to occur with a normal scrubber outlet whereby the discharge jet was directed out of the scrubber angled slightly outwards towards the sidewall. Such an arrangement, with no other ventilation system operating, resulted in the scrubber moving approximately twice the air flow around the machine as was passed through the scrubber itself, with a consequent dust capture efficiency of the order of only 50%. By fitting deflectors to the outlet of the scrubber, angled upwards at 30° to horizontal, the discharge jet was directed into the roof, dramatically reducing the entrainment of air from the face along the side of the machine. This had a dramatic effect on scrubber capture, increasing the efficiency to more than 85%, while the discharge jet was still projected a long distance behind the machine, minimising the possibility of recirculation back to the face. It is therefore concluded that all scrubber units should be fitted with deflectors. These should be aerodynamically designed so as to minimise resistance to air flow and consequent effect on scrubber quantity and noise levels. Consideration should also be given to incorporating a deflector plate arrangement into any silencer for fitting to the outlet of scrubber units.

Relocating the scrubber inlet will give improvements to dust capture efficiency. Benefits can be gained by siting the inlet as near to the face as practical. There are three benefits to be obtained. First, by increasing the distance between the inlet and discharge, the bypass of dust near the inlet into the discharge jet is reduced. Second, by retaining the dust cloud closer to the face and further from the machine operator, it reduces the extent of dust roll-back and improves visibility at the face. Third, by siting the scrubber inlet close to the face, it has an improved influence on face ventilation for the control of methane.

On continuous miners, an inlet sited close to the face also gives improvement to dust capture efficiency during the early stages of a partial cut, the coal buttock 'boxing-in' the scrubber inlet, reducing the escape of dust into the large open area to the side of the machine at an earlier stage of the cut.

By siting the inlet on the jib of the machine the greatest benefit can be obtained, since the scrubber can capture the dust close to the source of its production, before it is dispersed into the air around the face. On a roadheading machine, such an inlet is best engineered such as to wrap around the top and sides of the machine jib. The advantage of such an inlet position was difficult to quantify in the surface gallery by air flow measurement, since with the sprayfan system operating at a pressure of 17 bar and the jib to the right of the face, roll-back occurred at floor level with the standard scrubber inlet, but did not quite reach the rear of the machine. With the jib mounted inlet this roll-back was completely eliminated. At the higher sprayfan pressure of 29 bar, an improvement in scrubber capture from 68 to 76% was inferred by the measurements but visually, the indicated improvement was much more significant.

The optimum arrangement for a continuous miner is considered to be a US-style scrubber arrangement with a duct sited across the width of the machine jib giving three inlets beneath the jib: one on each side of the jib and one above the throat of the machine conveyor. In the surface gallery, use of just two inlets on either side of the jib and a sprayfan pressure of 12 bar gave a measured improvement from 71% to 79% in scrubber capture compared with the standard inlet. These figures were obtained at the worst position for scrubber capture at the very start of cutting a flat face. At first sight, this improvement may appear small, but in fact, the amount of dusty air evading capture by the scrubber was reduced from 29 to 21%, a factor of nearly one third. The underground trials carried out to assess this arrangement used only two inlets: one on one side of the jib and one over the conveyor throat, but with an angled sprayfan arrangement. In the two cutting situations evaluated, significant improvements were obtained when compared with a single inlet further back on the machine body. With such a scrubber inlet arrangement, other work has shown that the optimum layout for the sprayfan sprays is with the sprays directed straight forward rather than angled to one side of the machine, so that the dust is directed down the face to travel back up the loading shovel towards the duct inlets. Similarly, sets of sprays should be sited on both rear corners of the loading shovel to help contain the dust beneath the jib, further promoting dust capture.

Siting the inlets on the jib makes them more vulnerable to damage and also requires flexible joints to permit movement of the jib. The design of the system is best carried out by machine manufacturers so that the various components can be an integral part of the machine structure. This would also ensure that the system is designed specifically for a particular machine, rather than representing 'add-on' components which are susceptible to damage.

Inlet positions on the machine body would also give some improvement to scrubber capture efficiency. Generally, sprayfan and jetfan systems tend to direct the outflow of dust laden air from the face near floor level on the scrubber side of the machine. This outflow is directed up the loading shovel to the rear spill plate which deflects it slightly upwards. A scrubber inlet located just above and behind this spill plate, close to the sidewall, represents the optimum position for a scrubber inlet. However, there is greater opportunity for dust from cutting to be dispersed into the general body air, some of which flows away from the face at a higher level, away from the capture influence of the scrubber inlet. Such an inlet position should give improved scrubber capture compared with that normally used at present which is sited too high and too far back on the machine. The use of a secondary scrubber inlet close to the conveyor throat in the jib of a continuous miner (or the tunnel outlet of a roadheader) will also help capture of any dust carried back from the face by the conveyor chain.

Consideration should be given to incorporating a silencer into any inlet ductwork. However, the fitment of a silencer to only one end of scrubber will give limited reductions, of the order of 2dB(A), to overall noise levels since emissions from the non-silenced end become predominant. For full effect, silencers need to be fitted to both the inlet and outlet of the scrubber, which should result in more significant reductions of the order of 5-10dB(A).

Furthermore, an effective method of reducing noise emissions from the scrubber would be through redesign of the fan. Reduction of both tip speed and impellor clearance are important factors in any such redesign. The remaining option is to use thicker materials on the scrubber shell or stiffening its casing by other means. However, this option should only be considered as a secondary measure, since emissions from this source are an order of magnitude less than those from the inlet and outlet of the fan.

Comparison of Findings with Previous CFD Studies

The major effects of the various ventilation systems observed both in the surface gallery and underground were in agreement with previous CFD simulations. Hence, it is considered that CFD simulations are a valuable tool in modelling the effect of face ventilation. However, more localised air flow patterns such as those which cause dust roll-back and are influenced by machine shape and the precise configuration of sprayfan sprays are difficult to predict using CFD techniques, being much more dependant upon the accuracy of the model. Another feature of CFD modelling is that it only represents an instant in time rather than the dynamic situation which actually exists. For example, the lowering of the jib of a continuous miner tends to squeeze a substantial volume of air out from beneath the jib. This affects the air flow pattern around the machine and hence the behaviour of dust. Such an effect cannot be shown with CFD modelling. Nevertheless, CFD and gallery simulation techniques are valuable tools for assessing specific situations and aspects of ventilation, provided that the models are checked against practical situations.

7 SPECIFIC DESIGN GUIDELINES FOR OPTIMISING THE DUST CAPTURE OF SCRUBBER SYSTEMS ON MECHANICAL MINERS OPERATING IN LARGER ROADWAYS

7.1 Introduction

The effective capture zone around the inlet to an exhaust ventilation or scrubber system is extremely limited, as shown in the diagram below.

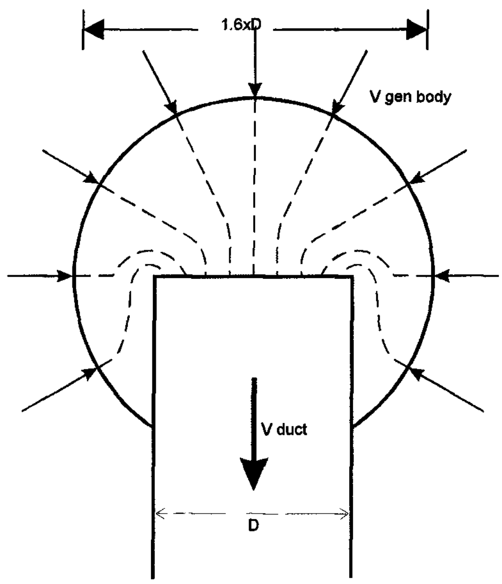


Figure 7.1 Sphere of influence around an exhaust duct inlet inside which the air velocity is greater than that of the general body airflow (approximate diameter = 1,6 x duct diameter). Taken from Wesley [1].

This indicates firstly, that at a distance of approximately 1,6 diameters away from a circular inlet, the air velocity has fallen to that of the general body airflow induced in a roadway and secondly, that a substantial proportion of the airflow drawn into the inlet is from behind, rather than in front of the inlet.

For optimum extraction hood, or scrubber inlet design, the required scrubber air flow rate is dependent on the capture velocity towards the hood along the centre line. The air velocity at the point of contamination must equal the capture velocity and the air must be directed so that the dust enters the scrubber inlet. A relationship developed by DallaValle[2] is shown below.

$$v = Q / (10.x^2 + A)$$

where v is the centre line capture velocity m/s

Q is the scrubber flow rate m^3/s

x is the distance from the scrubber inlet along the centre line m

A is the face area of the scrubber inlet m^2.

For a given scrubber inlet face velocity (ie ratio Q/A), the centre line capture velocity is greater for larger scrubber inlet face areas. Since the available space for scrubber inlets on mechanical miners is severely limited, with typical face areas of about 0,5 m^2 (see later), the above relationship shows that the significant parameters in achieving high centre line capture velocities (and hence high dust capture), are a high scrubber flow rate, Q, or a short capture distance, x. For example, for a 0,5 m^2 inlet area, at a distance 1 m from the scrubber inlet, the capture velocity is 0,1 m/s per m^3/s, ie for a scrubber flow rate of 10 m^3/s, the capture velocity at 1 m is 1 m/s (the face velocity at the scrubber inlet is 20 m/s). For dust that is released actively, as is the case in a heading at the cutting drum, the minimum recommended capture velocity is usually taken as 1 m/s. Thus this configuration is only just adequate for dust capture. The scrubber inlet is usually further than 1 m away from the cutting head with resultant inefficiency in dust capture.

Previous work by, for example, Fletcher[3], and Hemeon[4], has shown that the addition of flanges to the scrubber inlet increases the centre line velocity by 20-25 % (or reduces the required air quantity by 20-25 %). The main effect of the flange is to pull the dust-laden air from the effective zone of the scrubber inlet rather than from behind the inlet. Optimum flange width has been shown to be

- the square root of the inlet face area, or
- the hydraulic diameter of the scrubber inlet, or
- equal to the capture distance.

Because of the limited available space on a continuous miner or roadheader in a heading, these optimum dimensions are not practical. In any event, because the dust is not released at a 'point source' at the cutting drum, unless the dust can be directed into the scrubber inlet (see later), it will be advantageous to extract dust from zones which are not directly in front of the scrubber inlet.

Consequently, for effective capture of dust, the inlet must be located either very close to the source of dust or the dust must be pushed towards the capture zone of the inlet by some means.

These basic principles were effectively demonstrated during the development and underground trials of air curtain systems in the UK[5]. The two graphs shown below relate to a number of headings ventilated using simple exhaust systems. In each case, the heading was driven by a roadheading machine fitted with an axially rotating cutting head. The first graph relates the proportion of the total respirable dust from cutting which reached the machine operator's position to the distance of the exhaust duct inlet from the face, both with and without an air curtain system operating. All the results were obtained at a single site with a constant air velocity moving forward over the machine of 0,2 m/s. During cutting, the dust cloud near the face was disturbed by the influence of dust control sprays fitted to the cutting head together with the effect of falling material near the face. This disturbance caused dust to roll-back on the weakly ventilated, machine operator's side of the machine, furthest from the exhaust duct inlet. Without the air curtains operating, dust conditions at the operator deteriorated rapidly with greater distance of the exhaust duct inlet from the face. With the air curtains operating, dust capture was improved at all duct positions: the system opposed the dust roll-back and pushed the dust cloud towards the duct inlet thus improving the ventilation flow around the machine. However, the results still showed that dust levels at the operator's position deteriorated as the duct inlet was moved further from the face.

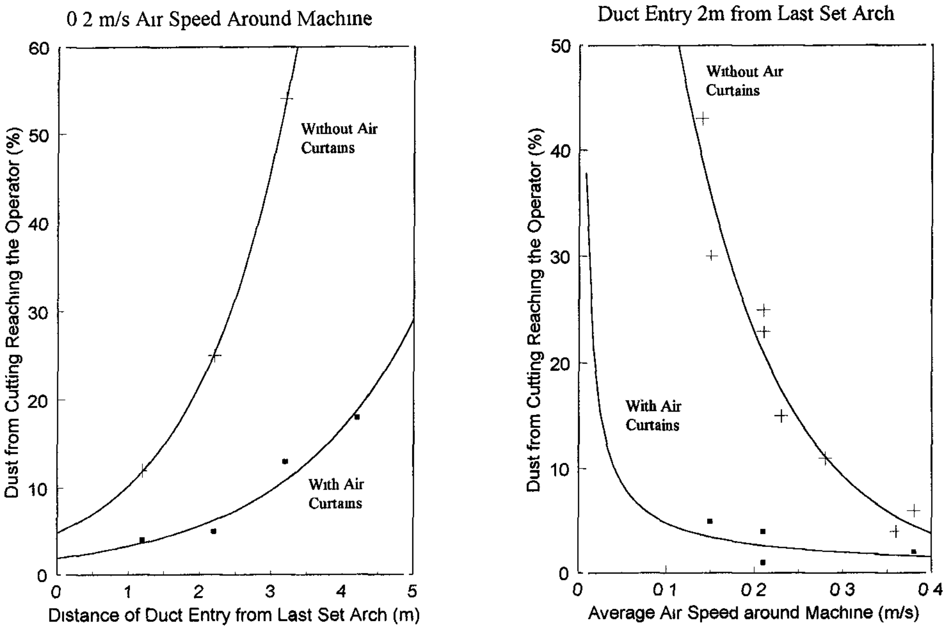


Figure 7.2 Effect of Air Curtains on Dust Back-up to the Operator at
(a) different duct entry positions and (b) varying forward airspeeds around the machine

The second graph, shown above, demonstrates a second important feature of any exhaust or scrubber system: that dust rollback is reduced and dust capture maximised through use of greater forward velocities around the machine, induced by greater exhaust/scrubber air quantities. The data were obtained from a number of different sites but relate to a consistent exhaust duct inlet position. The graph shows that with the exhaust ventilation alone, the effect of air velocity around the machine has a considerable effect on the extent of dust roll-back, as has the addition of the air curtain system. However, as the air velocity moving forward around the machine increases, the relative benefits of the air curtain system become less, mainly due to a reduction in dust roll-back.

In the present surface trials, relating to South African conditions, similar trends were identified with respect to the distance of the scrubber inlet from the face, although a single scrubber air quantity giving an air speed over the machine of 0,4m/s was used throughout. In these trials, sprayfan systems were used instead of air curtain systems to provide on-board forcing ventilation, but the normal layout and general effect of each system is very similar. Whichever system is used, to optimise the capture of dust by the scrubber system, it is necessary to locate the scrubber inlet at the position to which any forcing ventilation system directs the dust. This relates not only to siting the scrubber on the opposite side of the machine to the forcing ventilation system, but also its vertical position within in the section. Furthermore, it is important that the on-board forcing ventilation be balanced with that of the exhaust or scrubber system. If the on-board forcing ventilation effect is too great, dust from cutting can be pushed past the zone of influence of the scrubber or exhaust inlet at too high a velocity, resulting in dust evading capture and possibly recirculating around the machine. A similar effect can also result from the use of any additional forcing auxiliary ventilation system, such as jetfans or ducted forcing ventilation systems if these create too high a velocity at the face.

Taking these general principles into account, the following sections provide specific guidelines on the design of scrubber and sprayfan systems for both continuous miners and roadheading machines, together with a suggested procedure for balancing an on-board forcing system with the dust scrubber.

References

1. R Wesley. Airflow at Heading Faces with Forcing Auxiliary Ventilation. Proceedings of the 3rd International Mine Ventilation Congress, IMM/IME, Harrogate, England, 1984, pp 73-82.
2. J M DallaValle. Exhaust hoods. Industrial Press Inc., New York, 1982.
3. B Fletcher. Velocity profiles around hoods and slots and the effect of an adjacent plane. Ann Occup. Hyg., Vol 25, 365-372, 1982.
4. W C L Hemeon. Plant and process ventilation, Industrial Press Inc., New York, 1963.
5. V H W Ford and B J Hole. Air curtains for reducing exposure of heading machine operators to dust in coal mines. Ann. Occup. Hyg., Vol. 28, No.1, pp93-106, 1984.

7.2 Design Guidelines for Scrubber Systems

The design guidelines for scrubber systems outlined below are in addition to any stipulations contained in Ventilation Guidelines issued by the DME.

7.2.1 Continuous Miners

1. The scrubber discharge air should be directed upwards, towards the roof, at an angle of 30° to horizontal, by means of deflectors fitted to the dust collector outlet.
2. The scrubber inlet/inlets should be located as far forward on the machine as practicable.
3. Optimum capture of dust is achieved by extracting from the area beneath the machine jib, ideally using multiple inlets. The ideal forms for ductwork and inlets to achieve this depends upon the specific application:
   (a) *On new machines* - in the form of US-style on-machine scrubbers with ducting carried onto the jib providing 3 inlets on the underside of the jib frame, located on either side of the jib and above the conveyor (with at least 50% of the scrubber quantity being extracted from the inlet on the side of the jib immediately in front of the dust collector).
   (b) *On existing machines* - with an extension duct fitted to the dust collector, its inlet being kept as low as possible on the main body of the machine, the bottom of the duct ideally being level with the top of the rear of the loading shovel, while maintaining maximum width and minimum height to retain equivalent cross-sectional area to the dust collector inlet. A secondary inlet should be included to collect dust carried back through the conveyor tunnel.
4. To minimise resistance losses from of any form of ductwork fitted to the inlet of the dust collector, any transformations from round to rectangular and other changes in angle should be kept as smooth as possible or incorporate guide vanes where this is not possible. For short extension ducts, maintaining cross-sectional area throughout the duct length should be adequate to minimise resistance losses. However, where ducting is carried onto the machine jib, requiring transformation to wide and flat rectangular section duct, the dimensions of such ducting should be designed with reference to the concept of 'equivalent diameter' for comparison with circular duct cross-sections [1].
5. To significantly reduce noise emissions from the scrubber, silencers should be fitted on both sides of the dust collector, with that at the inlet end incorporated into the ductwork.

On new machines, the design of scrubber systems incorporating jib-mounted ductwork should be carried out by the machine manufacturers in order to maximise machine compatibility and minimise potential areas of damage. For existing machines, a duct extension design suitable for fitting to Joy 12HM31 machines, (which adopts Nos. 1 to 4 of the above guidelines), is shown in Figure 7.3. The suggested dimensions for the inlet to the scrubber are based on basic principles of extraction hood design, but the overriding factor in determining the overall dimensions is the available space on the continuous miner. It should be noted that the dimensions have been determined from engineering drawings rather than an actual machine and therefore require verification prior to manufacture. In this specific instance, a secondary inlet in the side of the extension duct, just behind the jib pivot point, has been incorporated in an attempt to capture dust from the conveyor. If, at a particular site, the carry back of dust by conveyor is effectively prevented by other means (eg water sprays) this secondary inlet could be blanked-off in order to maximise dust capture around the main inlet, nearer the face.

References

1. B B Daly, Woods practical guide to fan engineering", Woods of Colchester Ltd.

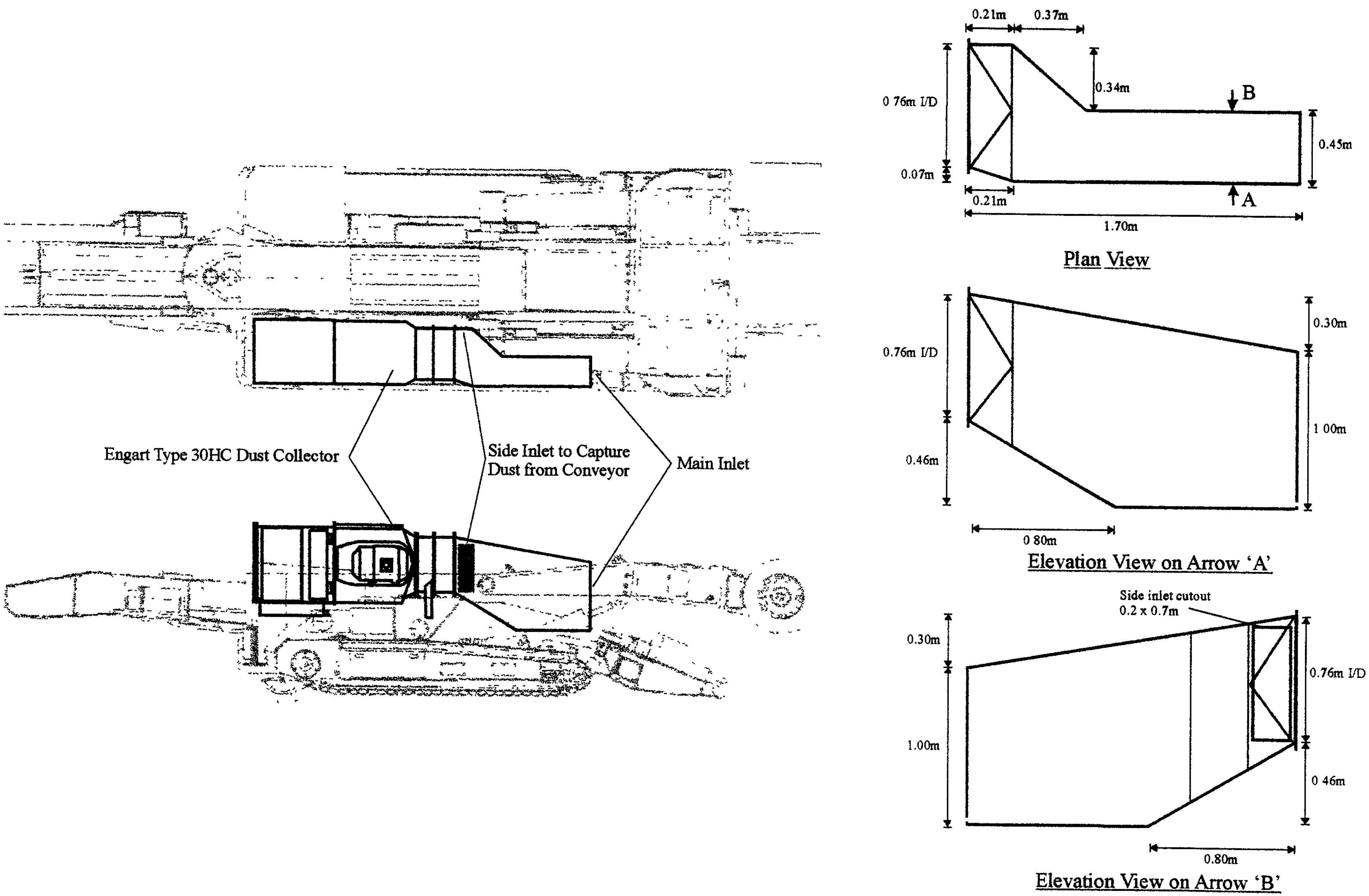


Figure 7.3 Design of Optimum, Fixed, Duct Extension for Joy 12HM31 Continuous Miner (Example only)

7.2.2 Roadheaders

Optimum capture of dust is achieved by extracting from the area around the jib itself, immediately behind the cutter drums. Such an inlet should be wrapped around the top of the jib and connected to the dust collector via flexible ductwork. However, given the large extent of movement and dual pivoting of the cutter jib such an arrangement would be difficult to engineer while also being susceptible to damage and blockage by cut material. A more practical option to improve dust capture is to use a fixed extension duct on the dust collector, with the complete scrubber system conforming to the following :

1. The scrubber discharge air should be directed upwards, towards the roof, at an angle of 30° to horizontal, by means of deflectors fitted to the dust collector outlet.
2. The scrubber inlet/inlets should be located as far forward on the machine as practicable.
3. The bottom of the duct should be kept low, ideally level with the top of the rear of the loading shovel.
4. The width of the duct should extend as close to the sidewall as possible, without becoming susceptible to damage when the machine turns a corner.
5. The width of the duct inlet should be maximised and its height minimised while being designed to maintain the cross-sectional area of the dust collector inlet throughout its length.
6. A secondary inlet should be included to collect dust carried back through the conveyor tunnel.
7. To minimise resistance losses from ductwork fitted to the inlet of the dust collector, any transformations from round to rectangular and other changes in angle should be kept as smooth as possible or incorporate guide vanes where this is not possible. For short extension ducts, maintaining cross-sectional area throughout the duct length should be adequate to minimise resistance losses.
8. To significantly reduce noise emissions from the scrubber, silencers should be fitted on both sides of the dust collector, with that at the inlet end incorporated into the ductwork.

A duct extension design for a Voest Alpine AM75 machine, (which adopts Nos. 1 to 7 of the above guidelines), is shown in Figure 7.4. The suggested dimensions for the inlet to the scrubber are based on basic principles of extraction hood design, but the overriding factor in determining the overall dimensions is the available space on the roadheader. It should be noted that the dimensions have been determined from engineering drawings rather than an actual machine and therefore require verification prior to manufacture. In this specific design, a secondary inlet for capturing dust from the conveyor has not been included. If such were required, this would be most easily achieved by attaching a length of 0.5m diameter flexible reinforced ducting between the rearmost end of the extension duct and the top of the plated cover over the conveyor behind the jib pedestal, beside the machine driver.

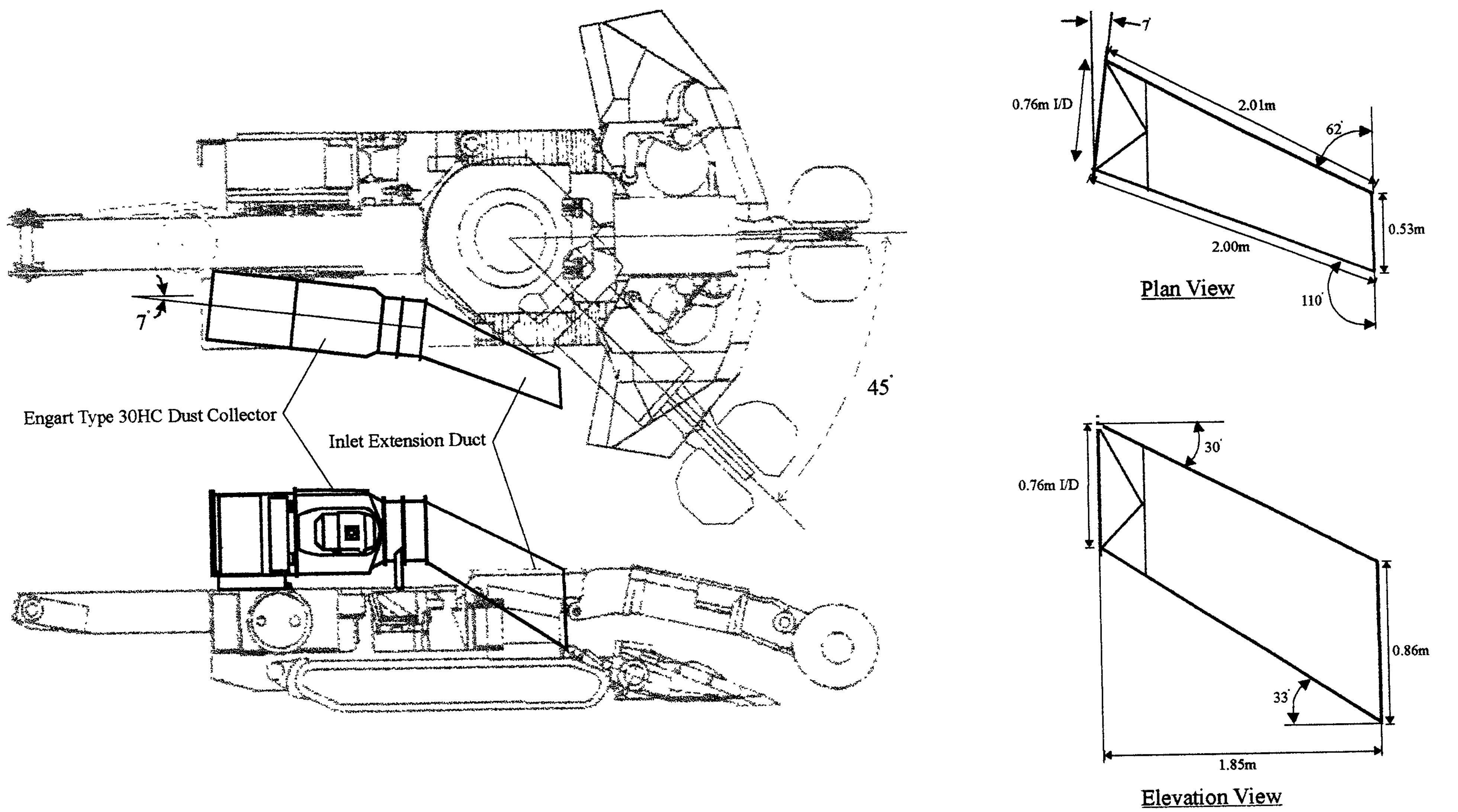


Figure 7.4 Design of Optimum, Fixed, Duct Extension for a Voest Alpine AM75 Roadheader (Example only)

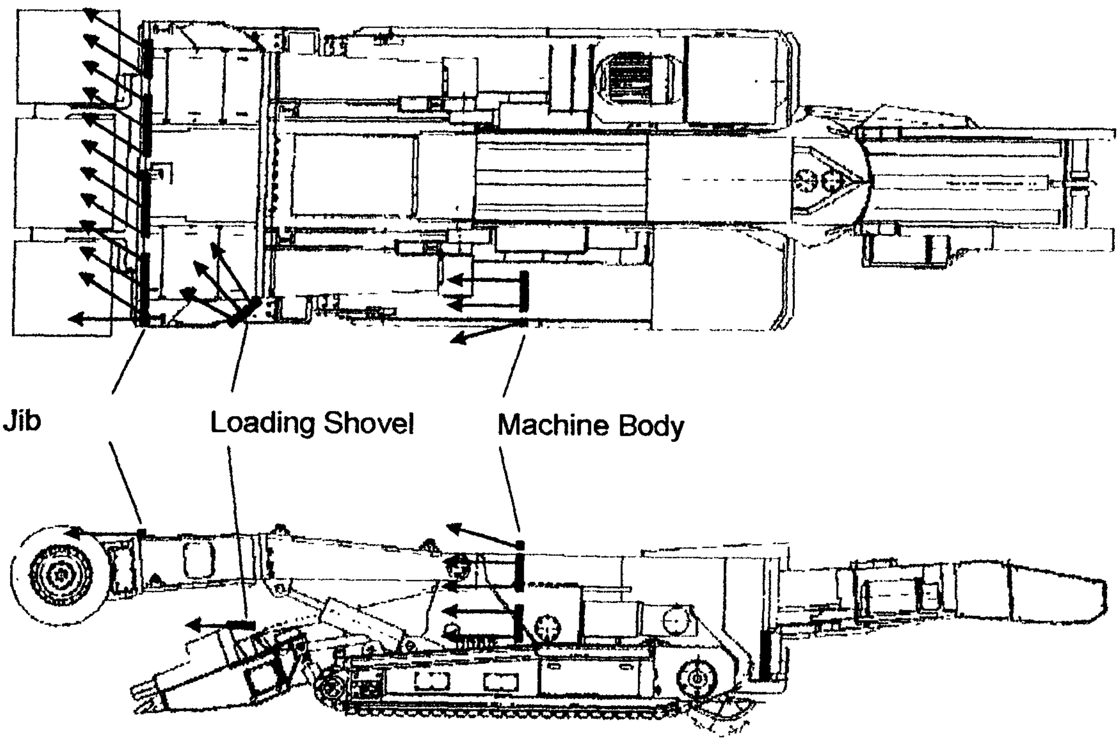
7.3 Design and Setting Up Procedures for Sprayfan Systems

During the course of this project, a large number of mechanical miners was inspected and observed in operation. On each type of machine, (roadheaders and continuous miners), the general form of the sprayfan system was similar, varying mainly in terms of spray numbers at various locations, nozzle sizes and operating pressures. All the systems observed during cutting (and that tested in the surface gallery work), appeared to be effective at providing the prime objective of the system, which is to ensure ventilation of the face at all times. However, as demonstrated in the surface gallery, if the effect of the sprayfan system is too great, the system can drive dusty air past the scrubber inlet resulting in poor dust conditions. Typically, this effect is due to the use of too high a water pressure in conjunction with large numbers of small-size nozzles, small orifice sprays being the most efficient at moving air. The use of higher water pressures is known to be more effective at suppressing dust. However, in the context of external sprays (sited away from the cutting head itself), the dust suppression efficiency is very limited, especially when a hollow cone form of spray is used. Consequently, increasing water pressures to marginally increase the sprayfan's dust suppression efficiency (but simultaneously reducing capture efficiency of the scrubber system), can make overall dust conditions worse. Therefore, although the basic design and layout of the sprayfan system is important with regard to providing adequate ventilation of the face, correct operation of the system with respect to its balance with the scrubber system is equally as important in the context of dust control. Given the wide variations in individual sites, machines, ventilation systems and water usage requirements, final setting up of the sprayfan system is best achieved on-site.

The following sections therefore describe the basic design features believed to be necessary in the design of sprayfan systems for both roadheaders and continuous miners in addition to a general procedure for optimising the system performance with respect to both ventilation and dust control at individual sites.

7.3.1 Design of Sprayfan Systems for Continuous Miners

The diagram below shows the *minimum* recommended layout for a sprayfan system for a continuous miner in terms of generalised spray positions.



The layout of the sprays is intended to move air around the machine i.e. guiding air forwards, towards the face on the operator side and across the face towards the scrubber inlet. Any additional sprays which may be fitted to the machine should be arranged such as to assist this flow rather than oppose it. The justification for these positions and a description of suitable additional (optional) spray positions are described in the following paragraphs: -

- On the machine body, forward of the machine operator's position, an arrangement of a minimum of 4 sprays mounted vertically (angled 15° out from the machine) plus 2-sprays horizontally (angled 15° upwards from the machine). These are required to ensure that, under minimum auxiliary ventilation conditions, fresh air is drawn from behind the machine and directed towards the corner of the face most remote from the scrubber inlet and hence most liable to be weakly ventilated. The effect of the vertically mounted sprays also opposes any tendency for dust roll-back to occur on this side of the machine. If dust roll-back at floor level is a problem at a particular site, consideration should be given to the use of additional sprays located below the vertically mounted sprays, but angled downwards by 15° to 25° towards the floor.
- At the rear corner of the shovel apron, a spray bar with at least 2 sprays, directed horizontally to ventilate the face area beneath the jib (which can be shielded from normal ventilation by the bulk of the jib in some cutting circumstances). Ideally,

these sprays should be arranged to give coverage of the majority of the face area beneath the jib. Good ventilation of this area is vital since freshly cut coal releasing methane at a relatively high rate can accumulate below the jib during shuttle car changeovers. In addition, the sprays mounted on the top of the jib tend to push gas and dust around the cut in a downwards direction into the area beneath the jib, the shovel sprays helping to dilute and push contaminated air from the cutting zone towards the return air side of the machine. In higher section roadways, additional sprays mounted on the underside of the jib frame and directed across the machine (to help ventilate the area beneath the jib at a higher level when cutting near the roof) are advisable.

- On top of the jib frame, just behind the cutter drums across the full width of the jib. Where possible, the majority of sprays should be angled at 30° across the face, with the direction of face ventilation to ensure a sweep of air across the face. However, at the end of the jib frame in front of the driver, a spray should be directed straight forward in order to ensure ventilation of the corner of the cut. Ideally, the sprays should be spaced evenly across the jib to ensure full and even coverage of the cutter drums, but this is not always practical given constraints of practical mounting arrangements for the spray bars. Alternative angling of some sprays may therefore be needed to provide even coverage of the cutting head, although the angled bias to one side of the machine should be maintained as far as possible. With typical 45-50° angle sprays, a minimum of 10 nozzles would typically be required to give full and even coverage of a 3.6m wide cutting head, although the use of greater numbers would give more overlap between sprays, acting to fill in gaps in the event of spray blockage. All sprays should be aligned with the top of the pick boxes to ensure optimum penetration of airflow into the cut at all times

- Additional sprays located on the underside of the jib immediately in front of the conveyor throat can reduce the amount of dust carried back from the face by the conveyor. Such sprays can also help ventilate the face area beneath the jib. However, such sprays are vulnerable to damage by cut material being loaded out.

- Additional spray nozzles directed at the end rings of the cutter drums from the sides of the jib are normally recommended by machine manufacturers for the purpose of lubricating the end ring picks and to help maintain their rotation within the pick holders. These sprays are not essential to the operation of the sprayfan itself and there is some doubt as to whether such sprays are effective at maintaining pick rotation. These sprays are therefore regarded as optional.

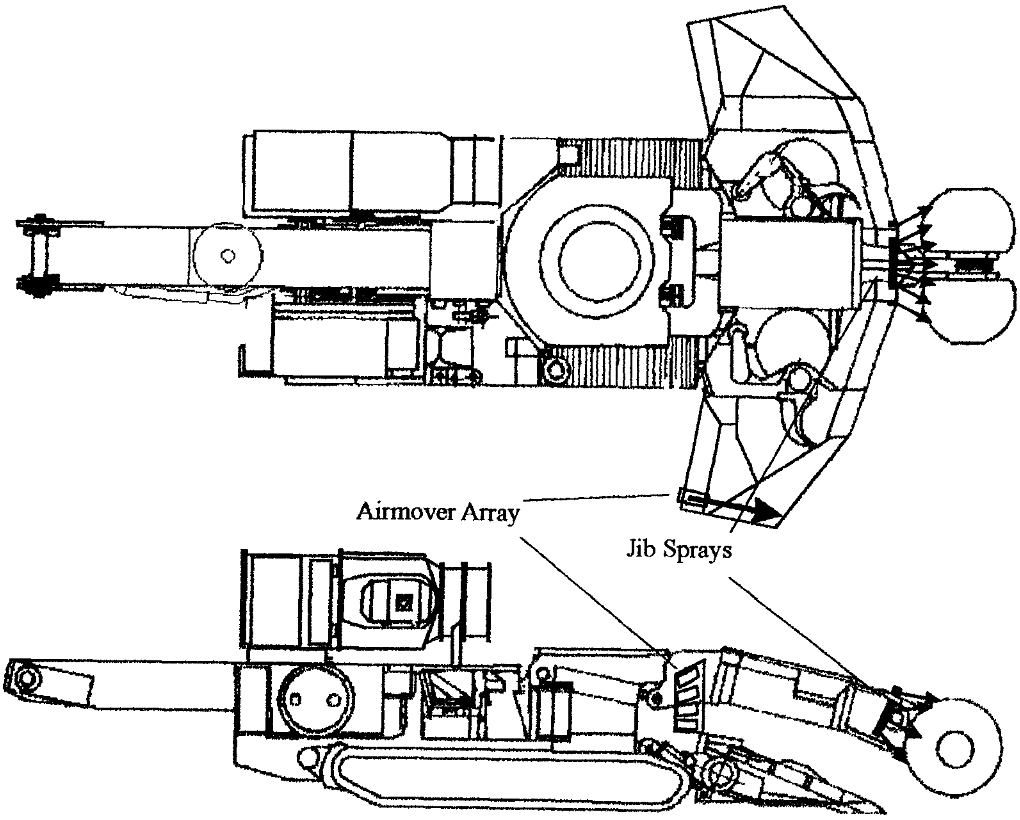
Spray Types

It has been noted that a variety of spray nozzles are commonly fitted to machines all of which are of hollow cone form, but with variable nozzle sizes ranging from 1.2 to 1.6mm and manufactured by either Spraying Systems or Colliery Dust Control Services. All such nozzles can be effective in sprayfan systems, but the choice of nozzle should depend upon site conditions in relation to the total water usage required, effectiveness of water filtration at a site (in relation to potential problems of blockage of smaller nozzle sizes) and also the intended operating pressure. With hollow cone sprays, air moving efficiency with respect to the volume of water used is greatest for smaller nozzles, larger nozzle sizes tending to move less air per unit volume of water due to the formation of larger droplets at equivalent pressures. However, in practice, there is a natural tendency for smaller nozzles to be used at higher pressures (limiting water usage while moving a lot of air) while larger nozzles are used at lower pressures (giving the required water volume but being less efficient at moving air). Consequently, the former system is liable to be too powerful, resulting in poor scrubber dust capture, while the latter system may not provide adequate ventilation of the face. Hence there is a requirement for individual systems to be set up on-site using the procedure described in the following section.

An alternative nozzle form may be considered for outlets located on top of the jib, behind the cutter drums. At this location, the use of solid cone sprays may give some benefits with regard to dust suppression at the cutting head by introducing a more even coverage of water than a hollow cone form. Solid cone sprays also move air, but not as efficiently as a hollow cone form. However, given the correct number and size of outlets in relation to the remainder of the sprayfan system, combined with optimised operating pressures and flows, they could provide adequate ventilation of the face. Despite possible benefits, the problem with such a system lies with the use of two types of spray on a single machine and the possibility of the incorrect spray being fitted at one location. Such problems may be overcome by adequate training or through use of differing spray fittings for each spray type.

7.3.2 Design of Sprayfan Systems for Roadheaders

The diagram below shows the *minimum* recommended layout for a sprayfan system for a roadheader in terms of generalised spray positions -



Use of an array of airmover tubes is an effective means of ensuring ventilation of the area of the face liable to be most weakly ventilated when auxiliary ventilation is not in use (the corner of the face in front of the operator's position). Located on the rear corner of the loading shovel, the air moved by this device carries from the corner, across the face, carrying dust and gas towards the scrubber inlet on the opposite side of the machine. For dust control and to help ventilate the immediate area around the cutter drums, spray nozzles are located above and to each side of the cutter drums. Given the geometry of the jib, it is not feasible for these sprays to be given an angled bias similar to the jib sprays of a continuous miner. The design criteria for each of these systems are described as follows: -

- The airmover array should be located near the outer corner of the loading shovel, directed towards the corner of the face in front of the machine operator. The number and angle of the tubes should be sufficient to cover the full height of the cut section.

- On the jib, it is recommended that an arrangement of three spray bars are used, one directed over the top of the cutter drums, and one located on each side of the jib directed towards the ends of the drums. In order to fully cover the top and sides of the cutting head, an array of 5 sprays will be required in the horizontal spray bar and 3 in each of the vertically mounted spray bars.
- Additional sprays located at the rear of the cover over the conveyor tunnel behind the jib and directed into the tunnel enclosure can be effective in preventing dust being carried back from the face by the action of the chain conveyor.

A relatively high water pressure will be required at the sprays of the airmover array in order to ensure that air reaches the face and provides an adequate standard of ventilation. However, the sprays sited on the jib will have a tendency to create turbulence around the cutting zone creating extensive disturbance and mixing of dust. To limit this effect, it is normal for large orifice nozzles to be used in the jib spray bars. Correct balance between the airmovers and the jib sprays should therefore be assessed during any set-up procedure. Varying the balance between the two systems may be effected by: -

- varying nozzle size;
- changing from hollow cone to solid cone sprays (solid cone sprays tend to move less air while also providing more complete water coverage for improved dust suppression);
- fitting a pressure restricter in the supply to the jib sprays.

Ultimately, the optimum set-up for a system will be governed by the particular layout of a site and its requirements with regard to water usage. Hence, the choice of technique for giving the correct balance of the system must be determined for individual sites, this ideally being determined during the setting up procedure described below.

7.4 On Site Test Procedure for Establishing Optimum Operating Parameters for On-Board Force Systems

The following test procedure is intended to achieve the optimum settings for the on-board force ventilation system to provide adequate ventilation of the face while not adversely affecting the ability of the scrubber system to capture dust. If the ventilating effect of the on-board force system is too weak, the face may not be adequately ventilated, increasing the possibility of frictional ignition of methane. Alternatively, if the ventilating effect is too great, it can push dust past the scrubber inlet, reducing the dust capture efficiency.

Although both the on-board force and scrubber systems are fixed to the machine and should each have a relatively constant performance (if kept well maintained), the balance between the two systems is subject to the variable effect of the auxiliary ventilation system during the advance of an entry. Under current ventilation guidelines, the first 12 m advance of a straight may be ventilated naturally by the flow in the LTR with auxiliary ventilation being required thereafter. The auxiliary ventilation, normally in the form of a jetfan, acts to reinforce the effect of the on-board force system, upsetting the balance between ventilation and dust control. However, the provision of adequate ventilation of the face for controlling methane must take precedence in all ventilation circumstances with the control of dust being a secondary consideration. Consequently, any test procedure must identify the absolute minimum requirements for the on-board force system under the weakest ventilation conditions and establish a reasonable operating point at some higher level to introduce a margin of safety to take account of possible spray blockage problems.

7.4.1 Site Set-up

The following procedure should be carried out with a machine in a 15 to 20m deep, straight cut with a flat, fully cut face. (A deep straight is required to minimise the influence of LTR ventilation while a flat face will aid observation of the effect of the on-board force system on the most remote side of the face. In addition, it should be noted that a flat face will also maximise any tendency for dust to evade capture by the scrubber). For continuous miner machines, the machine should be located to one side of the roadway with the operator's position closest to the sidewall (with the scrubber located at its furthest position from the sidewall, i.e. at the worst position for dust capture).

7.4.2 Equipment Required

1. A means of visualising airflow patterns, e.g. powder fire extinguishers.
2. A means of measuring the operating setting of the on-board forcing system. The present procedure specifically addresses water pressure for sprayfans but the methodology can bee applied to other systems, such as, static air pressure for air curtain tubes or hydraulic oil pressure and flow for hydraulic fans.

7.4.3 Test Procedure

Before commencing any tests, check that the environmental systems on the machine are in good order (i.e. the scrubber filter panel is reasonably clean, all sprays operating correctly, air curtain outlet slots clear etc.). The initial test configuration should be as follows: -

- machine jib raised to roof (roadheader jib angled to same side of roadway as the scrubber),
- auxiliary ventilation turned off, scrubber and on-board force system operating.

1. Release a short burst of powder on the operator's side of the machine and observe its behaviour with respect to effective ventilation of the face, and capture by the scrubber.
2. While repeatedly releasing short bursts of powder, adjust the water pressure setting of the on-board force system until ventilation of the face is judged to be the minimum required to ensure the effective scouring of methane. Make a note of this minimum setting.
3. At the minimum setting identified above, check the effectiveness of face ventilation at alternative jib positions, adjusting the minimum setting if necessary. At the same time, identify the jib position which appears to have the worst effect on scrubber dust capture.
4. With the jib located at the worst position for scrubber dust capture, identified in 3. above, increase the setting of the on-board force system, observing the effect on scrubber capture particularly on the return side of the machine until this reduces to an unacceptable level. Note this maximum setting.
5. Choose an operating point between the maximum and minimum levels previously identified to incorporate a realistic margin of safety. If this range is small, reassess the required minimum effect of the on-board force system with, for example, a realistic

number of sprayfan sprays blocked (or lengths of air curtain tube outlet slots covered). A realistic operating setting for the system may then be identified once the system is restored to its optimum configuration.

6. Switch on the auxiliary ventilation system and repeat steps 3 and 4 to give an indication of the likely worst situation for scrubber dust capture at the chosen operating setting of the on-board force system. If it is necessary to adjust the chosen operating level, compare conditions with the on-board force system switched on and off to observe any effect over and above that of the auxiliary ventilation system.

8. SUMMARY CONCLUSIONS

8.1 Mining Sequence

The mining sequence of a bord and pillar section has a great influence on both ventilation and dust control around the working face. The following conclusions were drawn relating to the optimum dust capture by the scrubber system :-

1. The air flow capacity of the scrubber must be maximised with respect to the force ventilation quantities while having regard to the limitations for recirculation within the DME Ventilation Guidelines.
2. The scrubber inlet should be sited as near to the face as practically possible.
3. The cutting sequence for partial and full cuts should be such as to maintain the scrubber close to the sidewall for both cuts.

8.2 On-Machine Forcing Systems/Sprayfans

The use of effective on-board force ventilation systems is vital to ensure a good standard of face ventilation during the first 12 m of cutting (when no force auxiliary ventilation is required).

The use of excessive pressures on water spray systems or excessive air quantity on air curtain systems can cause dust roll-back, with consequent reductions in scrubber dust capture efficiency. The optimum operating pressure on a continuous miner is of the order of 12 bar, measured at the spray nozzles. This gives good ventilation of the face while avoiding excessive dust roll-back. For a roadheader, the optimum operating pressure is of the order of 17 bar, measured at a the nozzles. It is recommended that at specific sites, the optimum pressure should be obtained through tests in a deep straight cut, with a flat, fully cut face.

Where dust roll-back occurs at floor level on the operator side of the machine, the use of additional sprays at the bottom of the vertical array on the body of the machine, directed forwards but towards the floor, should be considered.

A further area which can be a problem for dust control is at the mouth of the conveyor tunnel on a roadheader or at the conveyor throat on the jib of a continuous miner. On roadheader conveyor tunnels, a spray bar with a pair of hollow cone sprays directed towards the floor of the conveyor at an angle of 30° should be effective in creating sufficient forward movement of air through the tunnel to prevent the emission of dust. On continuous miners, a solution is to construct a short tunnel section over the conveyor, just behind the jib throat, with a spray bar mounted at its rear and sealed to the top of the jib using a conveyor belting flap seal. An alternative is to direct a water-powered airmover into the jib throat, angled from a suitable position on the machine body in front of the machine operator, to create a positive, forward air movement over the conveyor.

Auxiliary Ventilation Arrangement

The optimal arrangement for the scrubber system is for the treated discharge air to be ducted out of the heading, the scrubber unit either being mounted on-board the machine or off-board, in the LTR. Such an arrangement means that any dust remaining in the scrubber discharge air is released outside the heading and cannot be recirculated back to the face, raising the dust exposure of the machine driver. Of the two alternative layouts, an on-board scrubber with ducting on the discharge is preferable to an off-board unit with ducting on the inlet.

A practical system for engineering a trailing exhaust duct system, which allows the required freedom of movement for the machine in bord and pillar type work, has yet to be designed. Operation of on-board scrubber systems without ducting is therefore the most practical alternative. However, given the associated recirculation by the scrubber unit, this inevitably results in at least some, still contaminated, discharge air being recirculated back to the machine operator. The degree of recirculation of the scrubber discharge air can be minimised by ensuring that the discharge jet is projected as far away from the scrubber unit as possible, provided that this does not result in excessive entrainment of high concentration dust from the face. The dust aspect of recirculation is minimised through the use of highly efficient scrubber units, efficient both in terms of dust removal and dust capture.

Force ventilation systems may take two forms, a jetfan located at the entry to the heading or air being ducted to within 10m of the face from an auxiliary fan. From a practical viewpoint, the use of a jetfan has many benefits, mainly from being simple to locate and there being no necessity for additional ductwork to be installed and advanced. The release of any jet of air into a heading will involve some degree of entrainment of the general body air into the jet. Near to the face, the volume of air induced by a jetfan can be several times the magnitude of the scrubber capacity and can still be travelling at high velocity. Both these factors act against the requirement for a high efficiency of dust capture by the scrubber. Any excess volume will inevitably carry dust from the face past the scrubber while the velocity effect can drive dust past the scrubber inlet to a point where the energy reduces to such a level that it is either pulled back to the scrubber inlet or re-entrained into the air jet from the jetfan. Both effects result in dust being passed across the machine operator's position. However, the high velocity effect of the jetfan also makes it ideal for rapidly dispersing and diluting methane from the face.

With the jet fan sited at roof level, the air jet reaches the face unobstructed. When the jetfan is mounted at floor level, the bulk of the machine has an influence on the quantity and air flow patterns of the air jet. This influence is greatest for a continuous miner cutting on the same side of the heading as the jetfan. The ability of the jetfan to effectively ventilate the face at distances greater than 20 m depends on the exact alignment of the fan such that the 'wall effect' of the roof and sidewall help carry the jet to the face. Directing the jetfan towards the centre of the face at this distance reduces the penetration of the jet which only tends to reach as far as the rear of the machine.

In contrast, release of air from an auxiliary fan and duct is a much more controlled method of ventilating the face. The air jet is released from the duct with much lower energy than from a jetfan, therefore entraining much less air volume from its surroundings and creating lower velocities at the face. Such a forcing auxiliary ventilation system is therefore much more conducive to a high dust capture efficiency by the scrubber. While cutting the first split, a ducted system will produce both better ventilation of the face and better dust control, the duct being able to be turned into the split and directed towards the face, maintaining acceptable air flow patterns around the machine. In the equivalent situation with a jetfan, located at the entry to the straight heading, there is no direct ventilation effect at the face and the air jet travelling past the mouth of the split acts to trap dusty air within the split.

It must be noted that no specific underground trials were carried out to investigate different auxiliary fan/ducting or jetfan systems.

Design Guidelines for Scrubber Systems

An important factor with regard to the design of on-board scrubber systems is the configuration of the discharge jet. The short distance between the inlet and outlet of the scrubber means that any entrainment effect of the discharge jet will draw air from close to the inlet where dust concentrations are high. This entrainment results in dust by-passing the scrubber, possibly to be recirculated around the rear of the machine, back to the machine operator.

All scrubber units should be fitted with deflectors to prevent this entrainment. These should be aerodynamically designed so as to minimise resistance to air flow and consequent effect on scrubber quantity and noise levels. Consideration should also be given to incorporating a deflector plate arrangement into any silencer for fitting to the outlet of scrubber units.

Improvements in dust capture efficiency can be gained by siting the inlet as near to the face as practical. There are three benefits to be obtained. First, by increasing the distance between the inlet and discharge, the bypass of dust near the inlet into the discharge jet is reduced. Second, by retaining the dust cloud closer to the face and further from the machine operator, it reduces the extent of dust roll-back and improves visibility at the face. Third, by siting the scrubber inlet close to the face, it has an improved influence on face ventilation for the control of methane.

On continuous miners, an inlet sited close to the face also gives improvement to dust capture efficiency during the early stages of a partial cut, the coal buttock 'boxing-in' the scrubber inlet, reducing the escape of dust into the large open area to the side of the machine at an earlier stage of the cut.

By siting the inlet on the jib of the machine the greatest benefit can be obtained, since the scrubber can capture the dust close to the source of its production, before it is dispersed into the air around the face. On a roadheading machine, such an inlet is best engineered such as to wrap around the top and sides of the machine jib.

The optimum arrangement for a continuous miner is considered to be a US-style scrubber arrangement with a duct sited across the width of the machine jib giving three inlets beneath the jib: one on each side of the jib and one above the throat of the machine conveyor. With such a scrubber inlet arrangement, the optimum layout for the sprayfan sprays is with the sprays directed straight forward rather than angled to one side of the machine, so that the dust is directed down the face to travel back up the loading shovel towards the duct inlets. Similarly, sets of sprays should be sited on both rear corners of the loading shovel to help contain the dust beneath the jib, further promoting dust capture.

The design of the system is best carried out by machine manufacturers so that the various components can be an integral part of the machine structure. This would also ensure that the system is designed specifically for a particular machine, rather than representing 'add-on' components which are susceptible to damage.

Consideration should be given to incorporating a silencer into any inlet ductwork. For full effect, silencers need to be fitted to both the inlet and outlet of the scrubber, which should result in more significant reductions of the order of 5-10 dB(A).

9. ACKNOWLEDGEMENTS

The assistance of management and staff of collieries on which measurements, observations and discussions were carried out was an important aspect of the project and this assistance is clearly acknowledged.

During the course of the project a number of discussions were held with individual members of the Coleeag Committee.

Detailed discussions were held on numerous occasions with the following equipment manufacturers and their input to the findings of this project is acknowledged:

- *Colliery Dust Control Services*
- Howden Safanco
- Joy Manufacturing Company (Africa)
- Locked Torque-Africa
- Voest Alpine Mining and Tunnelling.

APPENDIX 1 - COMPARISON OF MINING SEQUENCE OPTIONS

During the course of the various colliery visits, it became apparent that there were many different views as to the optimum sequence of cutting operations, both from a mining viewpoint and an environmental perspective. It was also indicated that many mines were considering changing the mining sequence in an attempt to improve the control of dust. The sequence of operations has a large bearing on both the ventilation of the face and the control of dust. In this appendix, therefore, an evaluation of the various options for the cutting cycle is given.

The more complex situation of a continuous miner taking a first pass, partial cut and a second or final pass is discussed. However, the more general comments are also applicable to a single pass roadheading machine. The situation of LTR ventilation from Right to Left has been considered in combination with a scrubber sited on the left of the machine. The alternative layout is merely a mirror image of this and hence the same arguments apply.

1. Initial Cut of the First Split - Effect of Cut Direction

Cutting the first split is a complex situation to analyse since the options are many and the situation ever-changing. The basic comparison between taking the cut to the left or right of the heading is therefore considered for the start of the cut only in this section. The options for two subsequent stages of cutting the first split are considered separately in following sections.

<u>General</u>

For the first stage of the cut, the predicted airflow patterns indicate that the combination of the natural airflow into the entry and the jet fan on the opposite side will tend to recirculate contaminated air within the entry [Figure A1]. Any net outflow will be on the right hand side underneath the jet fan, having to cross the natural LTR ventilation inflow in order to reach the return. This means that some contaminated out-flowing air will be recirculated back into the entry. Further recirculation is caused by entrainment of the scrubber discharge air into the air jet from the jetfan.

The extent of recirculation around the machine depends upon the relative dispositions of the jet fan air and the discharge of the scrubber. The ability of the scrubber to both capture the dust and efficiently clean the air will therefore have a major impact on machine operator dust exposure.

Cut to Left

With a right handed machine (scrubber on the left) the scrubber inlet is maintained close to the rib wall during the first cut. This helps to maximise dust collection by the scrubber. However, the scrubber discharge is projected directly into the incoming jetfan air which will recirculate most of it back into the blind end of the entry. The CM operator is located within this recirculation zone and his exposure to dust will largely be determined by the scrubber filtration efficiency, provided that a high proportion of the dust made is indeed captured by the scrubber.

The physical bulk and layout of the continuous miner [CM] and Shuttle Car [SC] tends to promote recirculation in the blind end of the entry, operating to block and turn the outflow of air from the blind heading.

Recirculation would be minimised in this situation by using column ventilation to deliver fresh air directly into the blind end during the initial stages of the cut, subsequently moving the outlet into the split itself.

Cut to Right

Cutting a split to the right results in the jet fan delivering fresh air directly to the CM driver. However, whilst turning to the right the scrubber inlet is in free air, away from the sidewall. During the early stages of the cut some dust may therefore bypass the scrubber inlet. Some unfiltered dust could then be recirculated back to the CM driver in the jetfan air.

The physical bulk and layout of the machine and shuttle car will tend to increase the net inflow of fresh air into the split by deflecting air from the jet fan. In a straight entry, the arrangement also helps to provide a separation between the intake airflow on the right and the return airflow on the left which should reduce recirculation towards the front of the entry.

Conclusions

Recirculation around a machine and the end of a heading is liable to be greater when cutting to the left. However, during the first part of the cut, while the machine is turning in, the open space to the side of the scrubber inlet could result in poor dust capture by the scrubber. With no inlet extension duct on the scrubber, in the circumstances shown in Figure A1, it is possible that better dust control will be obtained by taking the split to the left, relying upon a high capture rate for the scrubber and maintaining the CM Operator in recirculated air from the scrubber, provided that it has a high filtration efficiency. However, the ideal would be to turn to the right to minimise recirculation for methane control while siting the scrubber inlet close to the face to maximise dust capture.

The differences can be summarised as follows:

a) Turn to Left - high dust capture rate (+ high filtration efficiency), high degree of recirculation, driver in filtered, recirculated air

b) Turn to Right - lower capture rate, less recirculation, driver in fresh air from the jetfan but this may be contaminated by a high concentration of uncaptured dust.

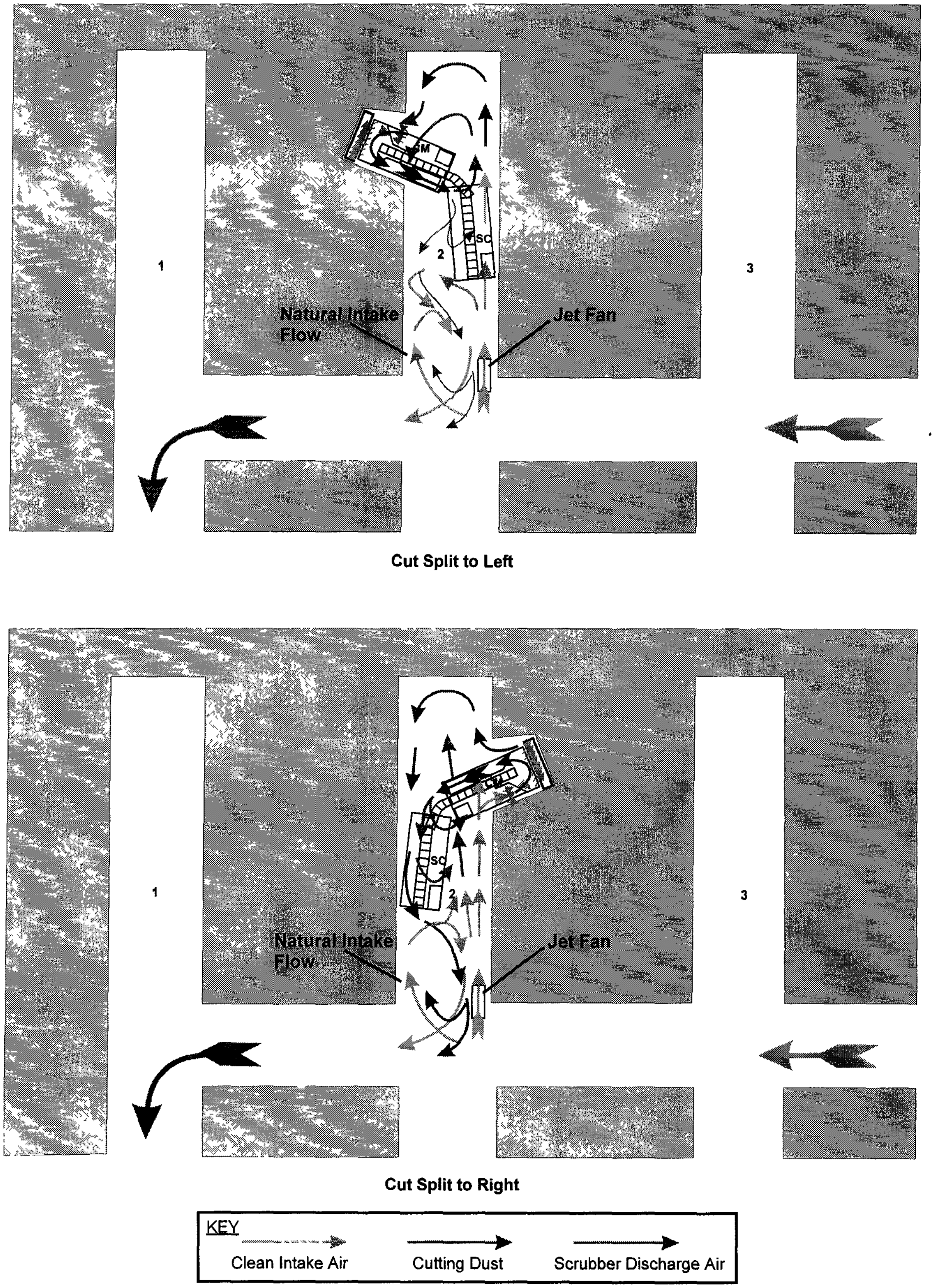


Figure A1 Cutting the First Split - Comparison of Cutting to the Right or Left

2. Cutting the First Split to the Left - Effect of Side of Partial Cut

General

Cutting deeper into a split to the left continues to promote recirculation around the end of the heading due to the scrubber exhaust being directed into the incoming jetfan air, as shown in Figure A2. The machine operator is within this recirculation zone at all times. The amount of fresh air reaching the face will be limited since it is not under the direct influence of the jetfan air and the scrubber will therefore tend to recirculate. Depending on the distance of the split from the LTR, and hence the extent of the jetfan jet expansion, the bulk of the CM and Shuttle Car may deflect some jetfan air away from the heading face. On the other hand, it may also help to deflect some air returning from the heading end into the split until such time that both machines are well into the split.

First Pass Cut

The CM operator is exposed mostly to recirculated air from the scrubber, diluted by intake air, irrespective of which side of the split is cut first.

If the first pass cut is taken on the right hand side, during the first 2-3m of cutting at the start of the cut the sprayfan system will tend to push dust from the cut into the open space to the left of the machine, away from the scrubber inlet. This dust will pass, uncontrolled, into the heading, from where a considerable amount is liable to be recirculated back to the face by the jetfan air, the remainder passing into the return. Once the cut is established, the left hand sidewall of the new cut will help to contain the dust, directing it towards the scrubber inlet.

If the first pass cut is taken on the left hand side, the sidewall will direct dust towards the scrubber inlet throughout the cut.

Second Pass Cut

Taking the second pass cut on the right hand side leads to the same problem outlined above, but throughout the entire cut. Taking the second pass on the left, however, maintains the scrubber inlet close to the sidewall at all times.

Conclusions

Problems at this stage of the cutting cycle are associated with keeping the scrubber inlet against the sidewall. This problem is common to both options, but if the first cut is taken on the right it only occurs for the first 2-3m of the cut rather than the complete cut for the alternative situation. The problem would be minimised by moving the scrubber inlet closer to the cutting zone.

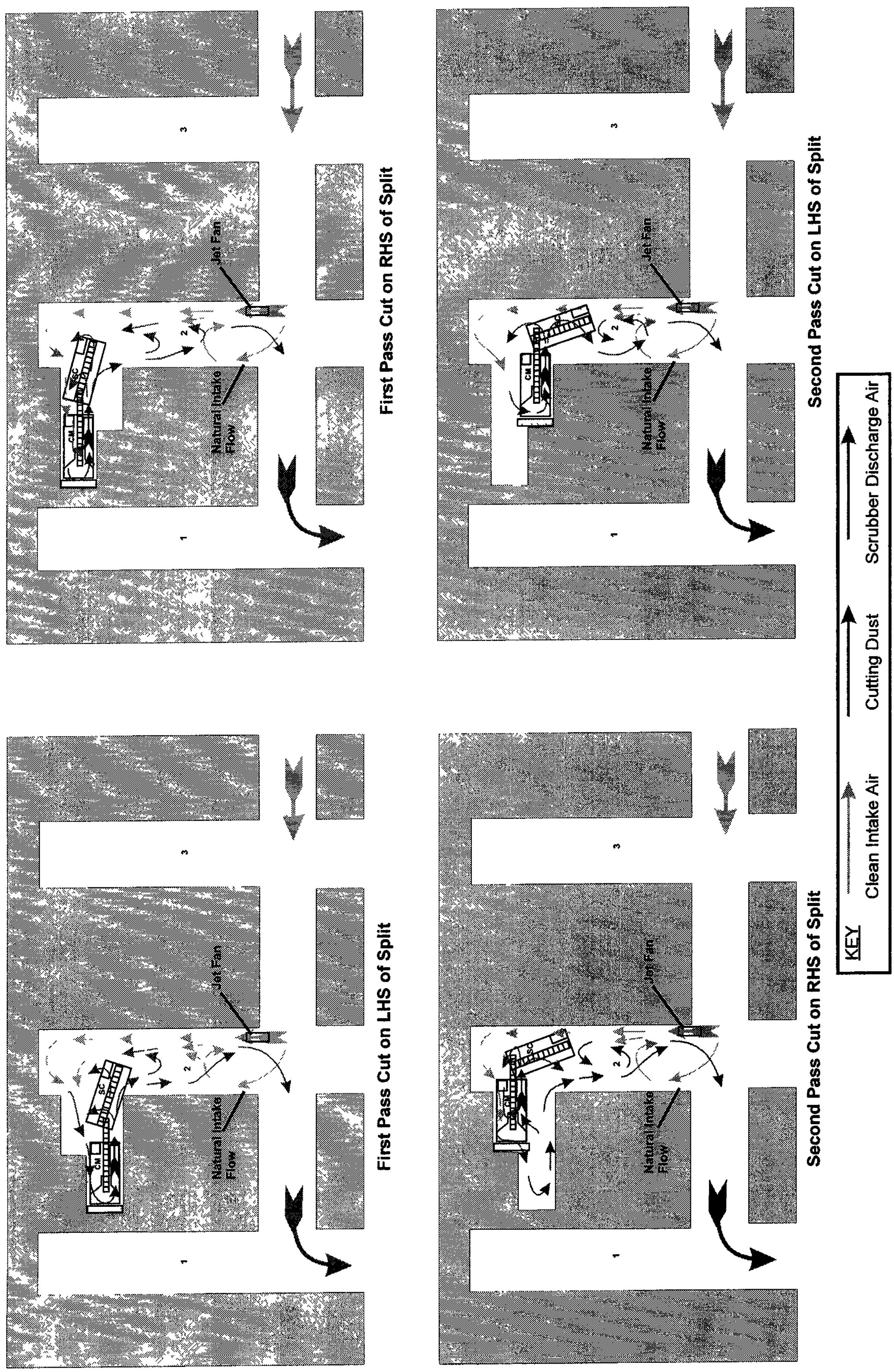


Figure A2 Cutting the First Split to the Left - Effect of Side of Partial Cut

3. Cutting the First Split to the Left - Effect of Side of Partial Cut on Holing-Through

General

Once the first cut holes into the adjacent roadway, there is a net airflow travelling through the split from behind the machine. Dust capture efficiency of the scrubber during the final, second pass cut is determined by which side of the machine the through-flowing air passes. The situation is shown in Figure A3.

First Pass Cut on the Left

With the split holed-through on the left, during the second pass cut the machine operator will be maintained in clean, intake air. The sprayfan system, together with the through-flowing air will push all the dust into the ventilation flow passing into the return. The scrubber will collect little dust, acting in opposition to the through ventilation. High dust levels will be present in the return which may be passed to other sections ventilated in series as intake contamination.

First Pass Cut on the Right

With the split holed-through on the right, the sprayfan system will direct air into the cut and push the dust back towards the scrubber inlet. The machine operator will be exposed to dust from the scrubber exhaust which is turned back towards the operator by the through-flow ventilation, although this will be diluted by the clean intake air. The scrubber should deal effectively with the dust produced, although the through-flow air may tend to suck some dust out of the cut and into the return air. This should be minimal, however, since the velocity will be higher against the far wall away from the cut. Overall, the operator will be exposed to filtered air from the scrubber, but far less dust will escape into the return.

Conclusions

Dust levels at the CM operator should be low in either situation, although taking the first pass on the right does mean that the machine operator is exposed to filtered air from the scrubber during both passes rather than just the first pass. The main difference is in the amount of dust passed into the return air which may be reused in other sections downstream. With this in mind, it is probably better to take the first cut to the right hand side of the split.

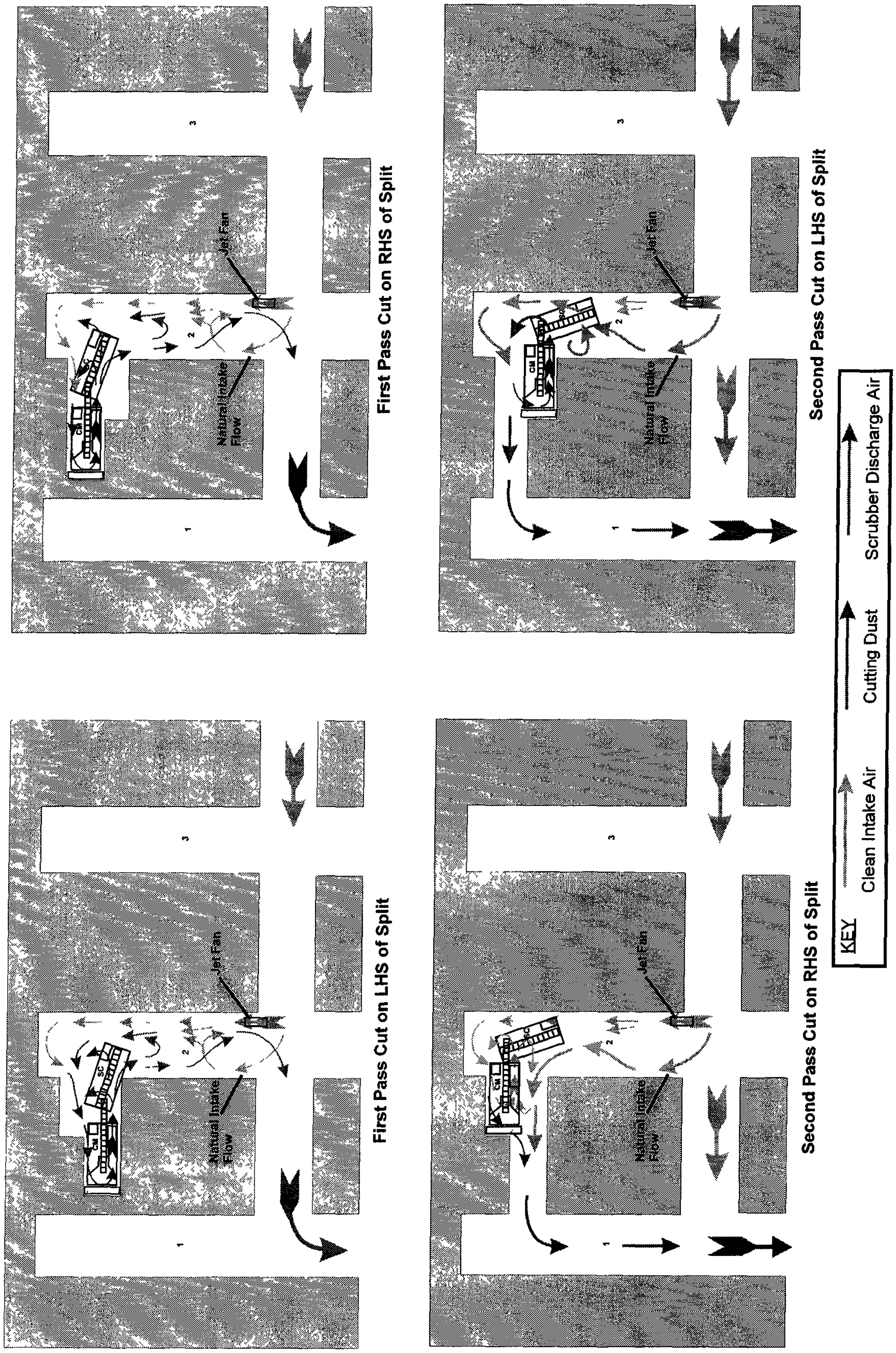


Figure A3 Cutting the First Split to Left - Effect of Side of Partial Cut on Thirling

4. Cutting the First Split to the Right - Effect of Side of Partial Cut

General

During the early stages of cutting a split to the right, the machine operator is kept on the fresh air side of the machine closest to the jetfan, irrespective of which side of the split is cut first (See Figure A4). Correspondingly, the exhaust from the scrubber will be pushed towards the blind end of the heading under the influence of the jetfan to travel outbye on the left of the heading behind the machine. Recirculation around the end of the straight and the machine will therefore be minimal since this arrangement does not encourage mixing of the intake and return air flows. Cutting to the right, the bulk of the shuttle car and machine will help to guide intake air from the jet fan into the split on the same side as the CM operator and sprayfan system until such time as both machines are well into the split. However, the face is not directly ventilated by the jetfan and hence there will be a tendency for the scrubber to recirculate once the CM is fully into the cut, the fresh air quantity reaching the face being limited.

First Pass Cut

If the first pass cut is taken on the right hand side, during the first 2-3m of cutting the sprayfan system will tend to push dust from the cut into the open space to the left of the machine, away from the scrubber inlet. This dust will then pass unfiltered into the return air in the heading, some of which will then recirculate back to the CM operator. Once the cut is established, the left hand sidewall of the new cut will direct cutting dust back towards the scrubber inlet, improving dust capture. This situation would be improved by locating the scrubber inlet closer to the face.

If the first pass cut is taken on the left hand side, the sidewall will direct the dust towards the scrubber inlet throughout the cut.

Second Pass Cut

Taking the second pass cut on the right hand side leads to the problem outlined above for the opposite condition, but throughout the cut. Taking the second pass on the left, however, maintains the scrubber inlet close to the sidewall at all times, which will improve dust capture.

Conclusions

Problems at this stage of the cutting cycle are associated with keeping the scrubber inlet against the sidewall. This problem is common to both options, but if the first cut is taken on the right it only occurs for the first 2-3m of the cut rather than the complete cut for the alternative situation. The problem would be minimised by moving the scrubber inlet closer to the cutting zone.

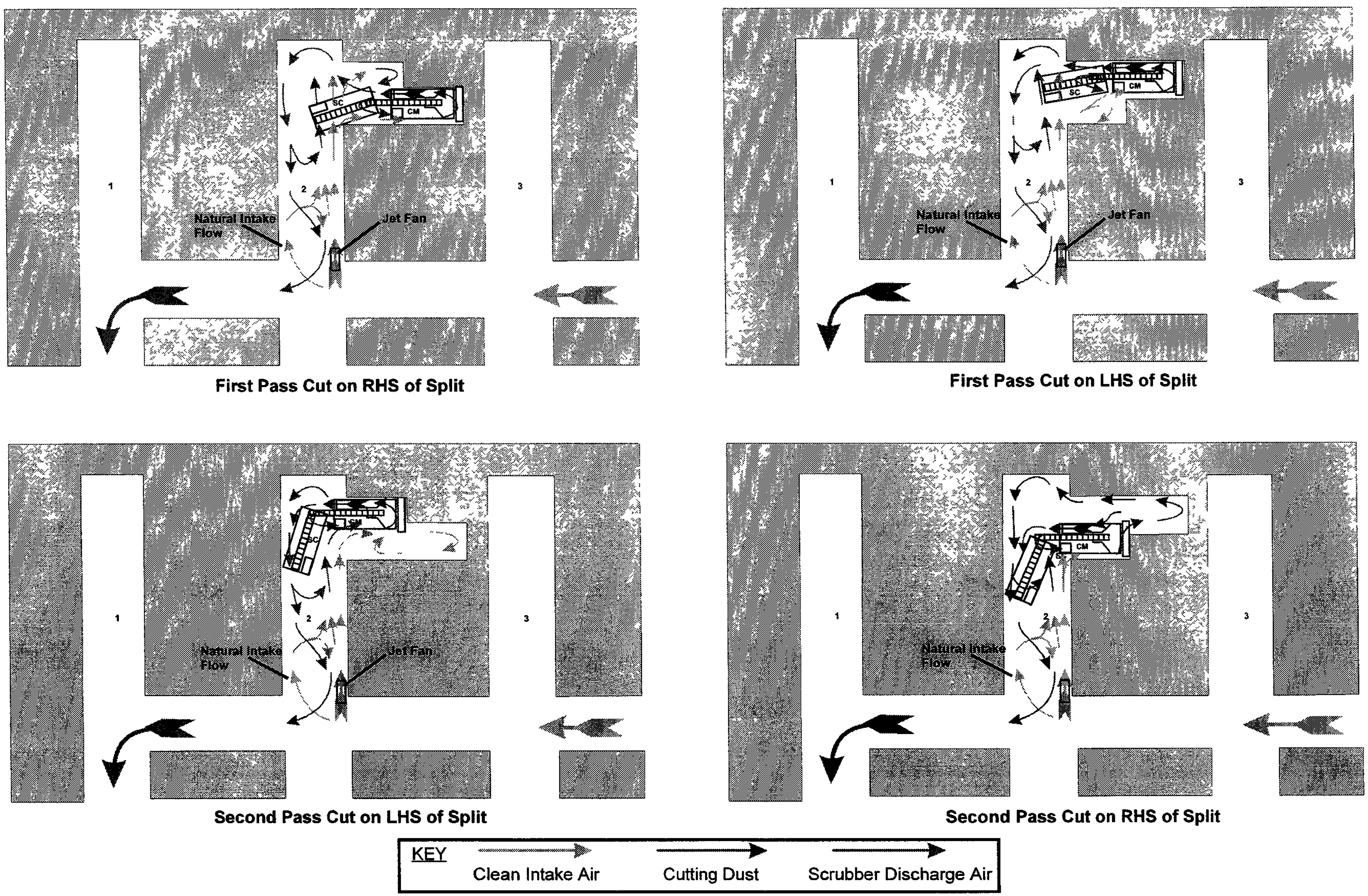


Figure A4 Cutting the First Split to Right - Effect of Side of Partial Cut

5. Cutting the First Split to the Right- Effect of Side of Partial Cut on Holing-Through

General

Once the first cut holes into the adjacent roadway, a ventilation circuit is made with the LTR ventilation direction tending to cause air to flow from Road 3 to Road 2 through the newly opened split, as shown in Figure A5. The jetfan in Road 2 opposes this natural flow direction. If left in this position, the jetfan will push dust and methane from further cutting through the split and outbye into the LTR along Road 3, allowing it to recirculate back into Road 2 via the jetfan. Such recirculation by the jetfan is not permissible under the ventilation guidelines so the jetfan in Road 2 must not be operated at this stage. A more positive ventilation of the split may be achieved by operating a jetfan in Road 3 during the final, second pass cut.

With the through-ventilation in the split now passing from the front to the rear of the machine, the dust capture efficiency of the scrubber during the final, second pass cut is determined by which side of the machine the through-flowing air passes.

First Pass Cut on the Right

With the split holed-through on the right, during the second pass cut the machine operator will be maintained in clean, intake air flowing through the split. The sprayfan system should push the cutting dust towards the left hand wall which is shielded from the through-flowing air and towards the scrubber inlet. The through-flow air may suck some dust out of the cutting zone in opposition to the sprayfan system, but this would be minimised by siting the scrubber inlet closer to the face where it will have a greater influence.

First Pass Cut on the Left

With the split holed-through on the left, during the second pass cut the sprayfan system will push all the cutting dust into the air flowing through the split. Only a small proportion of this will be passed through the scrubber which is sited in the main airflow. The CM operator will be exposed mostly to exhaust air from the scrubber exhaust drawn back to the face by the sprayfan system. High dust levels will be present in the return which may be passed to other sections ventilated in series as intake contamination.

Conclusions

Correct ventilation of the split after holing-through requires positive action in stopping the jetfan in the main entry before proceeding with the second pass cut - an action which may easily be forgotten. Depending on the particular positions of the two newly-linked roads in the section, a jetfan in the upstream road may also be required to supplement the natural ventilation flow through the split, adding a further complication.

Provided these changes to ventilation are carried out, during the final pass cut dust levels at the CM operator should be low in either situation, but a first pass taken to the right would result in lower dust exposure. The main difference is in the amount of dust passed into the return air which may be passed to other sections downstream. Hence, it is better to take the first cut to the right hand side of the split.

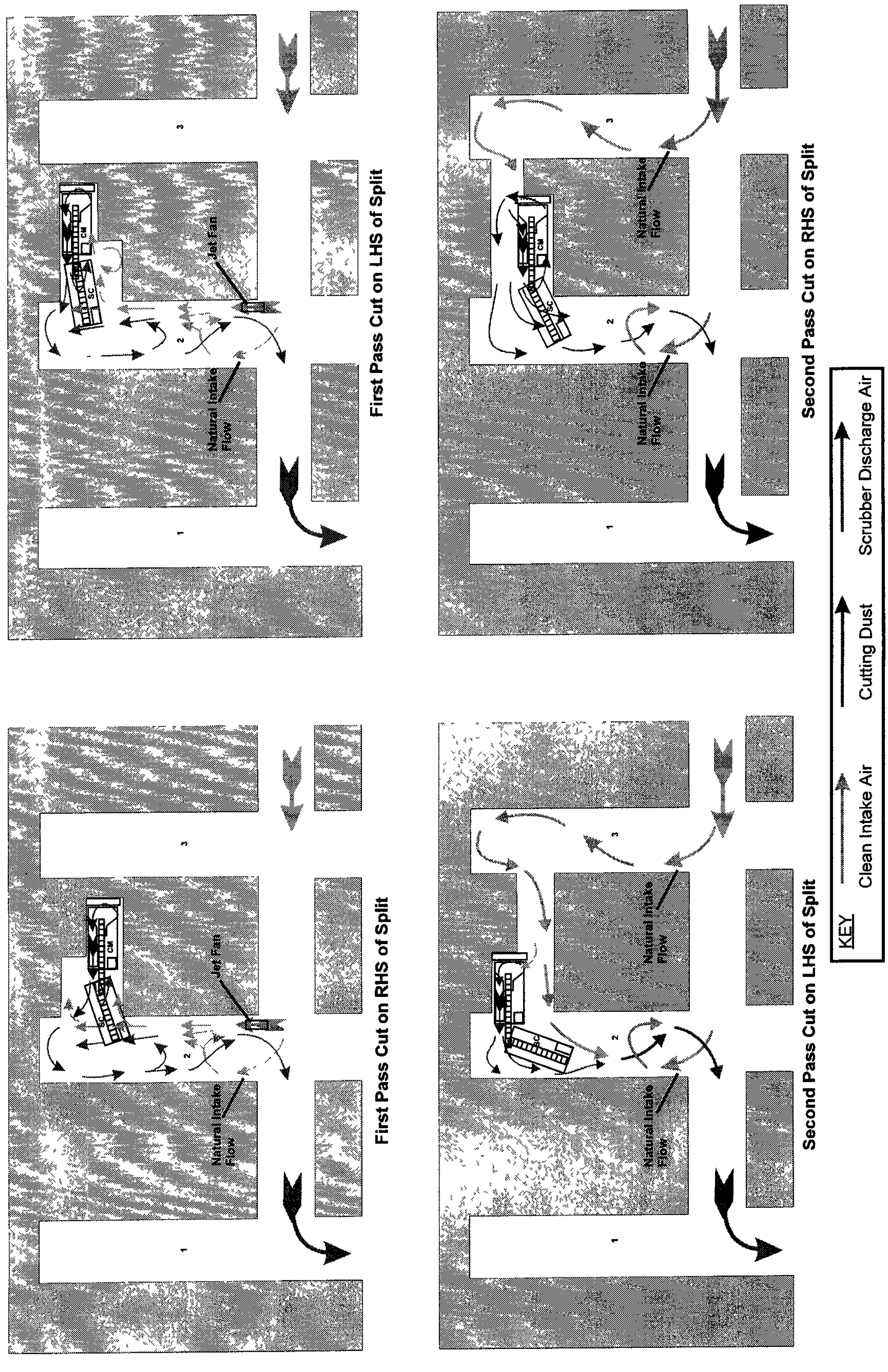


Figure A5 Cutting the First Split to Right - Effect of Side of Partial Cut on Thirling

6. Cutting Successive Splits in Same Direction as LTR Ventilation

General

When cutting successive splits in the same direction as the LTR ventilation, the split behind the machine naturally becomes the LTR and the machine may cut to a depth of 12m under the DME ventilation guidelines before a jet fan would have to be installed to supplement ventilation. The inherent problem with this cutting direction is the large air quantity in the LTR which will try to enter the new split being cut (due to its momentum while trying to turn the corner). This will be a major problem at the start of the cut, but should diminish as the cut deepens. Once the cut reaches a depth of 12m, a jet fan should be installed and the situation will be similar to cutting straights with a much lesser effect from the LTR airflow. The situation is shown in Figure A6.

First Pass Cut on RHS of the Split

Taking the first cut to the right hand side of the split means that the physical bulk of the shuttle car and CM will help to deflect the intake air around the pillar corner, reducing the quantity of air sweeping into the cut. However, until the scrubber inlet reaches the pillar corner, enabling it to direct the cutting dust into the scrubber inlet, unfiltered dust will escape into the return air. This escape of dust from the scrubber will be aided by the still relatively large quantity of intake air which will pass into the cut. To minimise the problem requires a high scrubber quantity and the inlet to be sited as close to the face as possible.

Taking the second pass cut on the left will result in poorer conditions. Here, the physical bulk of the machines act as a barrier for the LTR air which will cause more air to flow into the split being cut, overwhelming the scrubber. Dust will escape the scrubber on the left hand side of the machine due to this excess air even after the scrubber inlet passes the pillar corner. Again, in this situation, the problem will be minimised by a high scrubber quantity and the inlet sited as close to the face as possible.

In both circumstances, the CM operator should be kept in clean intake air at all times. The main problem being the amount of dust passed into the return air which may be re-used by another section. Scrubber dust capture is aided by the proximity of the sidewall for both cuts.

After holing-through on the right hand side, the last cut on the left should maximise scrubber capture, the dust produced being directed towards the scrubber inlet by the sprayfan system and the inlet sited away from the through-flowing air. The scrubber exhaust will recirculate back over the CM operator but will be highly diluted in the through-flowing air.

First Pass Cut on the LHS of the Split

Taking the first cut on the left hand side results in the physical bulk of the CM and shuttle car partially blocking the return airway and encouraging the LTR airflow into the cut. During the first few metres of the cut, this will push all the dust into the return, with little capture by the scrubber. Once the scrubber inlet reaches the sidewall, it will collect more dust, but it is likely that some will still escape, since the airflow into the cut will be greater than the scrubber airflow. This situation will continue until the cut is fully established, when the quantity of air from the LTR which reaches the cutting zone reduces below the flow through the scrubber.

During the second pass cut, scrubber capture will be poor due to the open space to the left (scrubber) side of the machine. The majority of cutting dust will pass unfiltered into the return throughout the cut.

In both circumstances, the CM operator should be kept in clean intake air at all times. The main problem being the amount of dust passed into the return air from the section. Scrubber dust capture is aided by the proximity of the sidewall for only the first cut.

After holing-through on the left (during the final cut), scrubber dust capture will be minimal, since the sprayfan system will push the dust directly into the through flowing air away from the scrubber inlet.

Conclusions

Cutting successive splits in the same direction as LTR ventilation in the arrangement shown should maintain the CM operator in clean intake air at all times, irrespective of which side of the split is cut first. However, a problem exists in both cases with dust bypassing the scrubber and being passed into the return air from the section. Scrubber capture is maximised when cutting the right hand side first (keeping the scrubber against the sidewall) but the problem will still exist at certain stages of the cut. This can be reduced by large scrubber quantities and siting the scrubber inlet as close to the face as possible.

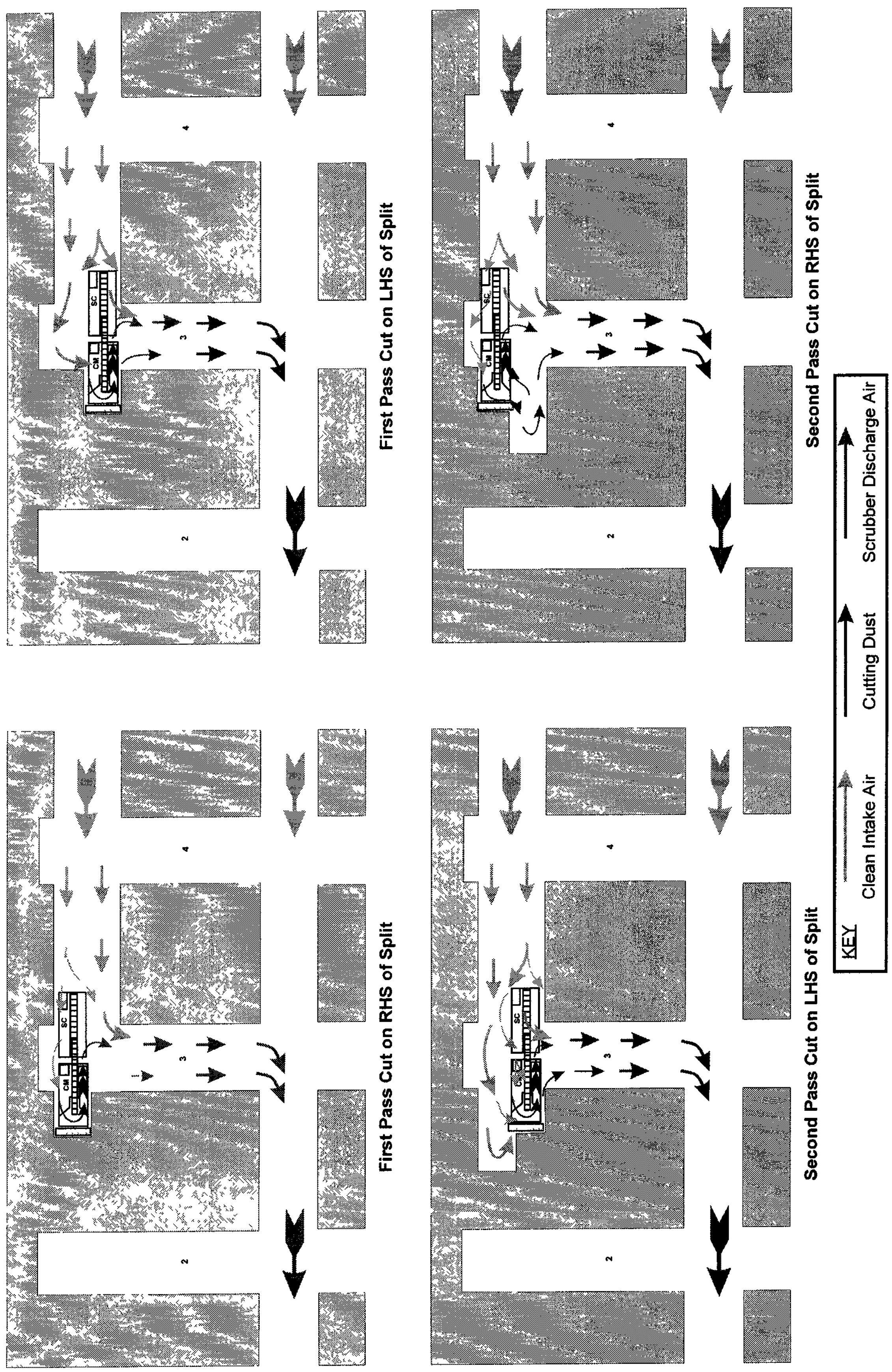


Figure A6 Cutting Successive Splits in Same Direction as LTR Ventilation

7. Cutting Successive Splits in Opposite Direction to LTR Ventilation

General

When cutting splits in the opposite direction to the LTR ventilation a brattice would normally be required in the outbye cross-cut to force air into the cross-cut being driven, in order to provide the 1.0m/s velocity to enable it to become the new LTR, as shown in Figure A7. This introduces mining problems in installing the brattice and also affects shuttle car routes. Once the cut reaches a depth of 12m, a jet fan should be installed at the entry to the split to prevent excessive recirculation around the machine and the situation will be similar to cutting straights. From a dust control aspect, this direction of cutting allows greater control of the ventilation within the split being cut with little interference from the LTR airflow.

During the early stages of the cut the LTR airflow passing over the machine will tend to push dust away from the scrubber inlet until the inlet reaches the pillar corner. The physical bulk of the machine and shuttle car will aid the inflow of intake air into the split being cut on the correct side of the machine.

On holing-through to the adjacent roadway, some LTR ventilation air will naturally flow from Road 4, in the Figure, passing from front to rear of the machine in the split. A jetfan located at the entry to Road 4 would aid this natural flow. Any jetfan that may be used for ventilating long splits from Road 3 should not be operated have to be turned off at this stage in order to prevent it from recirculating around the pillar.

First Pass Cut on the RHS of the Split

This cutting method keeps the scrubber against the sidewall throughout the cut which will aid dust capture. Dust will only escape into the return during the initial part of each cut before the scrubber inlet reaches the sidewall. The CM operator is kept in clean air at all stages of the cutting cycle except for the final stage when he may be exposed to some recirculated, filtered air.

On holing-through on the right hand side, the final cut on the left will still have optimum scrubber dust capture, the sprayfan system directing air towards the scrubber inlet which is sited in a position shielded from the through flowing air.

First Pass Cut on the LHS of the Split

The first cut in the split will be similar to that described above. During the second pass, however, the open space to the left, scrubber side of the machine will mean the scrubber capture is minimal with all the dust passing into the return air.

Upon holing-through during the final, second pass cut, the through-flow air will pass from front to rear of the machine directly past the scrubber inlet. Dust will be passed into this airflow and pushed back towards the scrubber inlet, but dust capture will be poor.

Conclusions

Cutting successive splits against the direction of LTR ventilation gives a much better control of ventilation in the split. However, there are significant mining problems to overcome to enable sufficient flow through the LTR. If this system were to be used, then better scrubber capture will be obtained by taking the first cut on the right of the split, keeping the scrubber inlet against the sidewall. Scrubber capture will be poor during the first part of the cut until the scrubber inlet reaches the sidewall since the LTR airflow will tend to push the dust away from the scrubber inlet. A scrubber inlet sited close to the cutting zone will minimise this problem. However, this will only affect the quantity of dust escaping into the return, since the CM operator will be maintained in intake air most of the time.

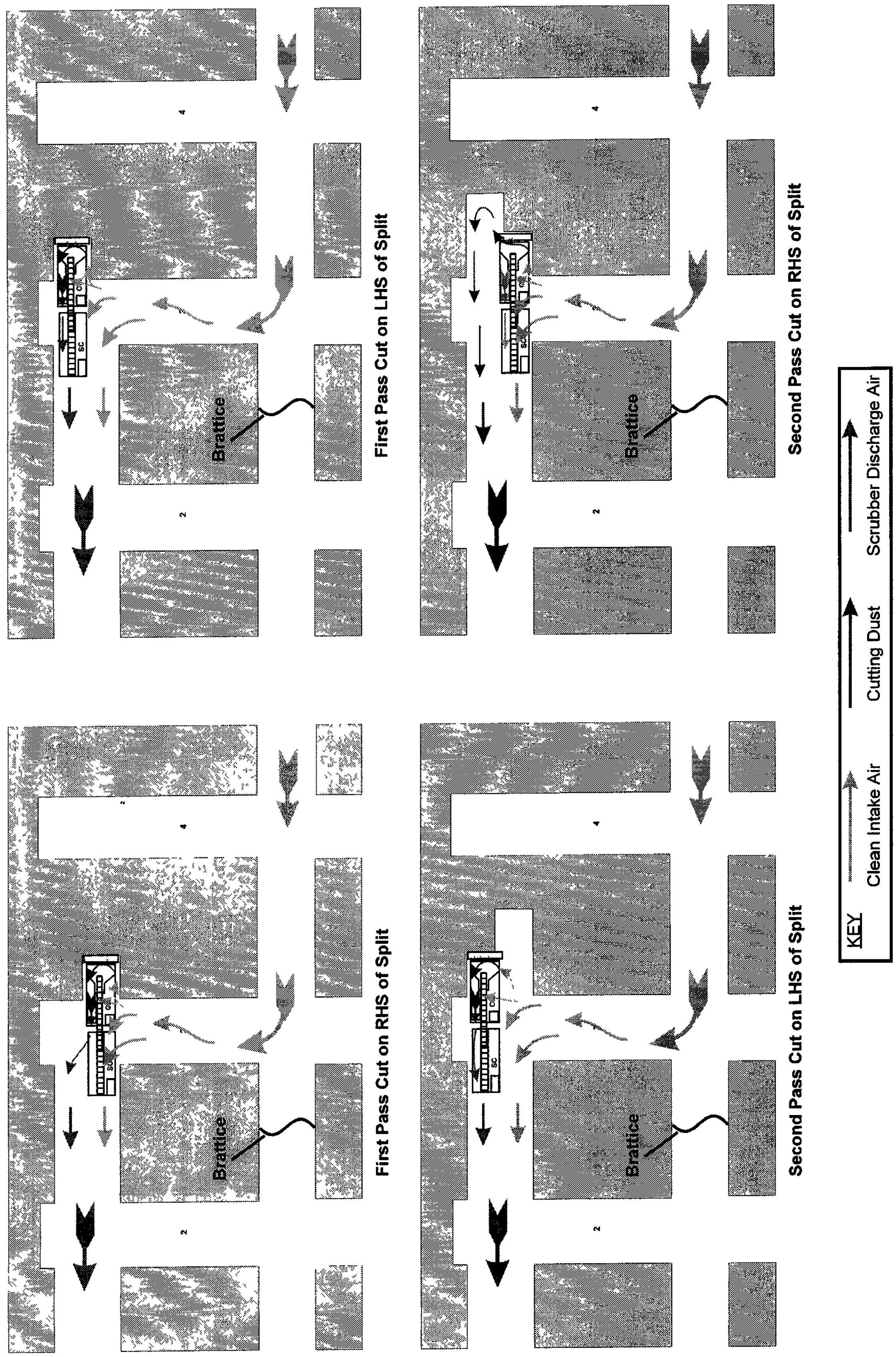


Figure A7 Cutting Successive Splits in Opposite Direction to LTR Direction

8. Cutting Straights - First, Partial Cut to the Right Hand Side

General

When cutting straights, a machine may cut to a depth of 12m, under the DME ventilation guidelines, before a jet fan has to be installed to supplement ventilation. As in previous circumstances, the general arrangement keeps the machine driver on the intake side and optimum conditions will be obtained by keeping the scrubber against the sidewall throughout the cutting cycle. Typical airflow patterns are shown in Figure A8.

Stage 1 - First Partial Cut to 12m deep

During the initial part of the cut the scrubber inlet will not be confined against the sidewall. Dust will therefore not be captured by the scrubber but swept into the return by the LTR airflow and the sprayfan system, but away from the CM operator. Once the scrubber inlet reaches the sidewall, dust capture by the scrubber will improve. The physical bulk of the CM and shuttle car will help to direct intake air into the heading. The CM operator will be in intake air during the first part of the cut until the scrubber starts recirculating air within the heading when he will be exposed to dust from the scrubber exhaust, diluted by the intake air.

Stage 2 - Second Cut to 12m deep

For the first part of the cut the LTR airflow will again push dust away from the scrubber inlet until it is confined by the sidewall. Even then, the tendency of the LTR air to flow into the heading beside the scrubber will disturb the airflow patterns, possibly reducing the scrubber dust capture. Once established, however, conditions will improve. The physical bulk of the CM and shuttle car will help to push intake air forwards on the open right hand side of the heading with the dust being pushed back to the scrubber inlet on the left.

Stage 3 - Partial Cut beyond 12m with Jet Fan installed.

Once a jet fan is installed, a recirculation zone is inevitably established at the junction with the LTR. The jet fan on the right of the entry, combined with the natural inflow of air on the left leaves only the area underneath the jet fan for the outflow of air from the heading. As this air flows out, it must cross and mix with the natural inflow air. As before, to maximise scrubber dust capture, the right hand side of the face must be cut first. The machine driver is sited in the intake airstream from the jet fan, but the recirculation of the scrubber will mean that some of the scrubber exhaust air will be carried back over the machine driver as it returns towards the face. As the cut advances, the quantity of fresh air reaching the face will decrease as the bulk of the rear of the shuttle car deflects more of the widening air jet from the jet fan towards the left hand side of the heading.

Stage 4 - Second cut beyond 12m with Jet Fan installed

When taking the second cut to the left hand side, the physical bulk of the CM and shuttle car will help confine the air jet from the jet fan along the open side of the heading on the right and into the open blind end of the partial cut. This will help the separation of intake and discharge air from the scrubber, minimising recirculation. However, some recirculation of the scrubber discharge air around the machine will still occur due to the excess scrubber quantity over and above the jet fan flow.

Conclusions

Provided that the first, partial cut is taken to the right, the path of the airflow forms a circuit with recirculation minimised, and fresh air can flow to the face for methane dilution. The CM operator will be kept on the intake air side at all times but will be exposed to an increasing proportion of recirculated air from the scrubber exhaust as the cut advances.

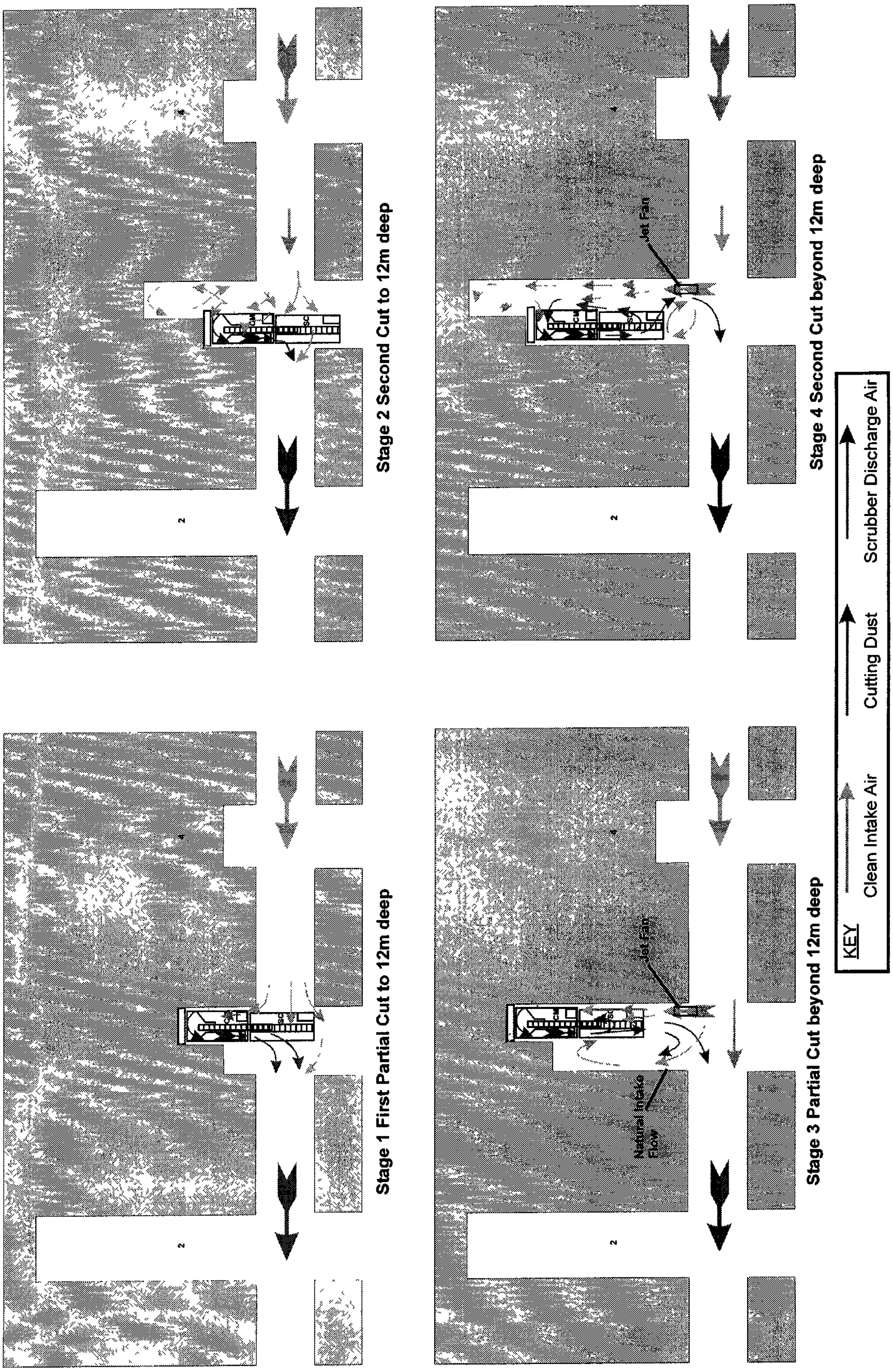


Figure A8 Cutting Straights - Partial Cut on the Right Hand Side

9. Cutting Straights - First Cut to the Left Hand Side

General

When cutting straights, a machine may cut to a depth of 12m under the DME ventilation guidelines before a jet fan has to be installed to supplement ventilation. Taking the first cut to the left leaves an open space around the scrubber inlet (when taking the second cut to the right which will decrease the dust capture ability of the scrubber). Typical airflow patterns are shown in Figure A9.

Stage 1 - First Partial Cut to 12m deep

During the initial part of the cut the scrubber inlet will not be confined against the sidewall. Dust will therefore not be captured by the scrubber but swept into the return by the LTR airflow and the sprayfan system, but away from the CM operator. Once the scrubber inlet reaches the sidewall, dust capture by the scrubber will improve. The physical bulk of the CM and shuttle car will help to direct intake air into the heading. The CM operator will be in intake air during the first part of the cut until the scrubber starts recirculating air within the heading when he will be exposed to dust from the scrubber exhaust diluted by the intake air.

Stage 2 - Second Cut to 12m deep

For the first part of the cut the LTR airflow will again push dust away from the scrubber inlet directly into the return airflow. The lack of a sidewall to the left of the machine will result in dust being pushed forwards into the blind end, away from the scrubber inlet. The high scrubber quantity means that most of dust should be captured by the scrubber as the air passes back out of the heading, but some will inevitably escape into the return airway. The physical bulk of the CM and shuttle car will help to push intake air forwards on the open right hand side of the heading with the dust being pushed back to the scrubber inlet on the left. The CM operator will be in intake air during the first part of the cut until the scrubber starts recirculating air within the heading, when he will be exposed to dust from the scrubber exhaust diluted by the intake air.

Stage 3 - Partial Cut beyond 12m with Jet Fan installed.

Once a jet fan is installed, a recirculation zone is established at the junction with the LTR. The jet fan on the right of the entry, combined with the natural inflow of air on the left leaves only the area underneath the jet fan for the outflow of air from the heading. As this air flows out, it must cross and mix with the natural inflow air. Cutting the left hand side first means that the jet fan is directed at the solid wall to the right of the machine. This means that this jet will be turned away from the cutting zone back outbye to the right hand side of the machine at floor level rather than reaching into the cut. This will disturb the airflow patterns around the rear of the machine and increase recirculation around the machine. This will reduce the fresh air quantity in the cutting zone, which has implications for methane control. The dust level at the operator position should be kept reasonable, however, since the scrubber should still capture most of the dust. It is debatable as to whether the CM operator will be exposed to a greater quantity of scrubber exhaust air than during the equivalent stage of taking the first cut on the right hand side.

Stage 4 - Second cut beyond 12m with Jet Fan installed

The scrubber dust capture around the machine is similar to that described for stage 2 of the cycle. However, the inclusion of the jet fan means that an additional recirculation zone is induced near the entrance to the heading which will increase the dust exposure of the CM operator. Some dust is again liable to be passed into the return airway.

Conclusions

Taking the partial cut to the left will increase the dust exposure of the CM operator once the jet fan is introduced into the system as compared with taking the first cut to the right and is also likely to result in increased dust levels in the return during stages 2 and 4 of the cutting cycle.

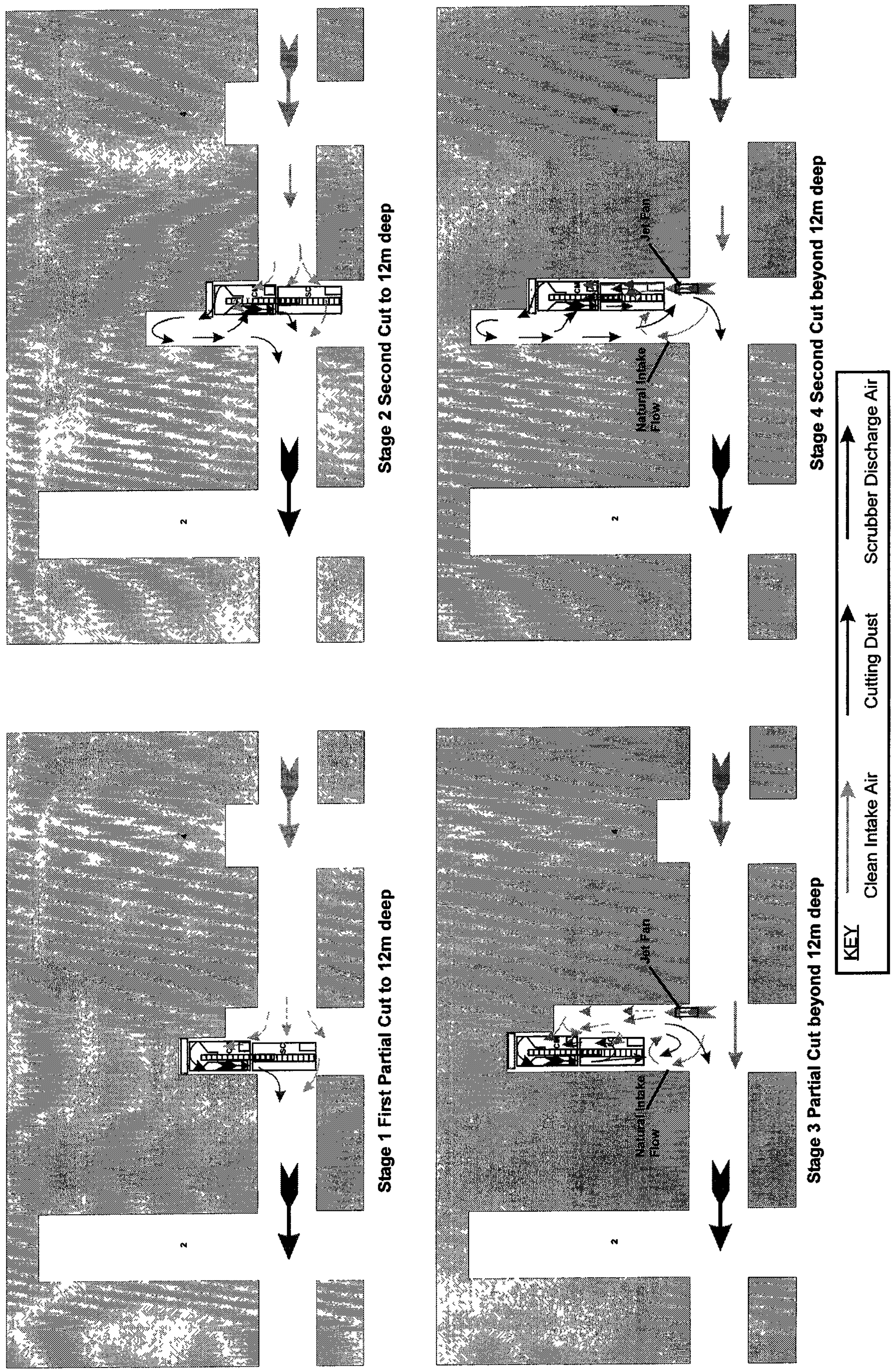


Figure A9 Cutting Straights - Partial Cut on the Left Hand Side

10. Summary Conclusions

First Split

This is the worst cutting situation for dust control since the air is effectively trapped in the heading by the combination of natural flow from the LTR and the jet fan causing recirculation at the entrance to the heading. In addition, when the machine and scrubber are turned to one side to form the split, a second recirculation zone is set up around the machine and blind end.

Overall, it is judged that the first split is best cut to the right of a heading, maintaining the machine operator towards the fresh air side of the machine. Cutting the split to the left places the operator in air recirculated from the scrubber. Cutting to the right should also minimise recirculation around the machine and the blind end of a straight, which has positive influence on methane control.

The first, partial cut should be taken to the right hand side of the split, irrespective of whether the split is taken to the left or right of a heading. This maintains the scrubber against the sidewall to maximise dust capture during both passes. Cutting the left hand side first (maintaining the CM operator against the sidewall) causes the sprayfan system to push dust away from the scrubber inlet resulting in high dust concentrations passing into the return airway during second pass cuts and after holing-through. During second pass cuts, recirculation within the heading will also lead to greater dust concentrations at the operators position.

(It is noted that, at some mines, where the CM operator is kept against the sidewall for protection from spalling from the roof and sidewall, it would still be advantageous to cut the split to the right to reduce recirculation and keep the operator on the fresh air side.)

Successive Splits

Cutting successive splits in the same direction as LTR ventilation is normal practice. As a split is completed, this naturally becomes the Last Through Road. However, this does mean that the air quantity flowing around the pillar corner at the back of a machine influences scrubber capture since a sizeable proportion of this airflow will naturally pass into the split being cut. This quantity will exceed the scrubber quantity, resulting in unfiltered dust passing into the return. The machine driver will be in clean air throughout the cut, however. In this situation, scrubber capture is maximised by keeping the scrubber against the sidewall, i.e. cutting the right hand side of the split first.

Cutting successive splits against LTR ventilation gives a much better control of ventilation in the new split, the air flowing away from the machine. However, there are significant mining problems associated with this cutting direction since a brattice must be used in the previous crosscut to cause sufficient airflow into new sets of splits. This brattice can also impede shuttle car routes. If these problems can be surmounted, then again it is better to cut the right hand side of the split first, keeping the scrubber against the sidewall.

Cutting Straights

The only option available in this instance is whether to cut the left hand or right hand side of the heading first. Cutting the right hand side first provides optimum conditions, maintaining the scrubber inlet close to the sidewall. Cutting the left hand side first decreases the dust capture ability of the scrubber, allowing increased dust levels in the return airway. When a jet fan is in use, recirculation around the machine will also be increased when cutting the left hand side, increasing the dust exposure of the CM operator and reducing the fresh air reaching the cutting zone.

Common to most of the above cutting situations, the following general comments relate to the optimum capture of dust by the scrubber :-

1. **Use the maximum scrubber quantity allowable with respect to jetfan quantity within the requirements of the DME ventilation guidelines.**
2. **The scrubber inlet should be sited as close to the face as possible.**
3. **The cutting sequence for partial and full cuts should maintain the scrubber against the sidewall for both cuts, provided that there are no over-riding reasons for doing otherwise.**

Ideal Cutting Sequence

From the above conclusions, an ideal mining sequence for the optimum control of dust has been formulated. It is not suggested that this exact sequence is suitable for all situations, nor that all 'mining' practicalities have been taken into account.

The ideal mining sequence, shown in Figure A10, would be to cut all splits from left to right, with all partial first cuts being taken on the right hand side. This could be in the form of taking alternate splits and straights working from the left hand boundary, as shown, allowing rapid support of the roof in poor conditions or alternatively taking all splits working from the left to the right hand boundary, and working back taking the straights. Irrespective of this, there are mining problems which should be considered. Normal practice would not be to take the first split from the boundary road since this inhibits shuttle car routes, particularly when section ventilation is limited and there is only one cross-cut left open. The problem here is that the waiting area for shuttle cars must be beyond the conveyor road, a long distance from the CM. The second problem is the necessity to install brattices in the last cross-cut to course the air through the new splits such that they may constitute the LTR. Not only must this brattice be moved up after each split is cut out, but in addition, the brattice impedes shuttle car routes.

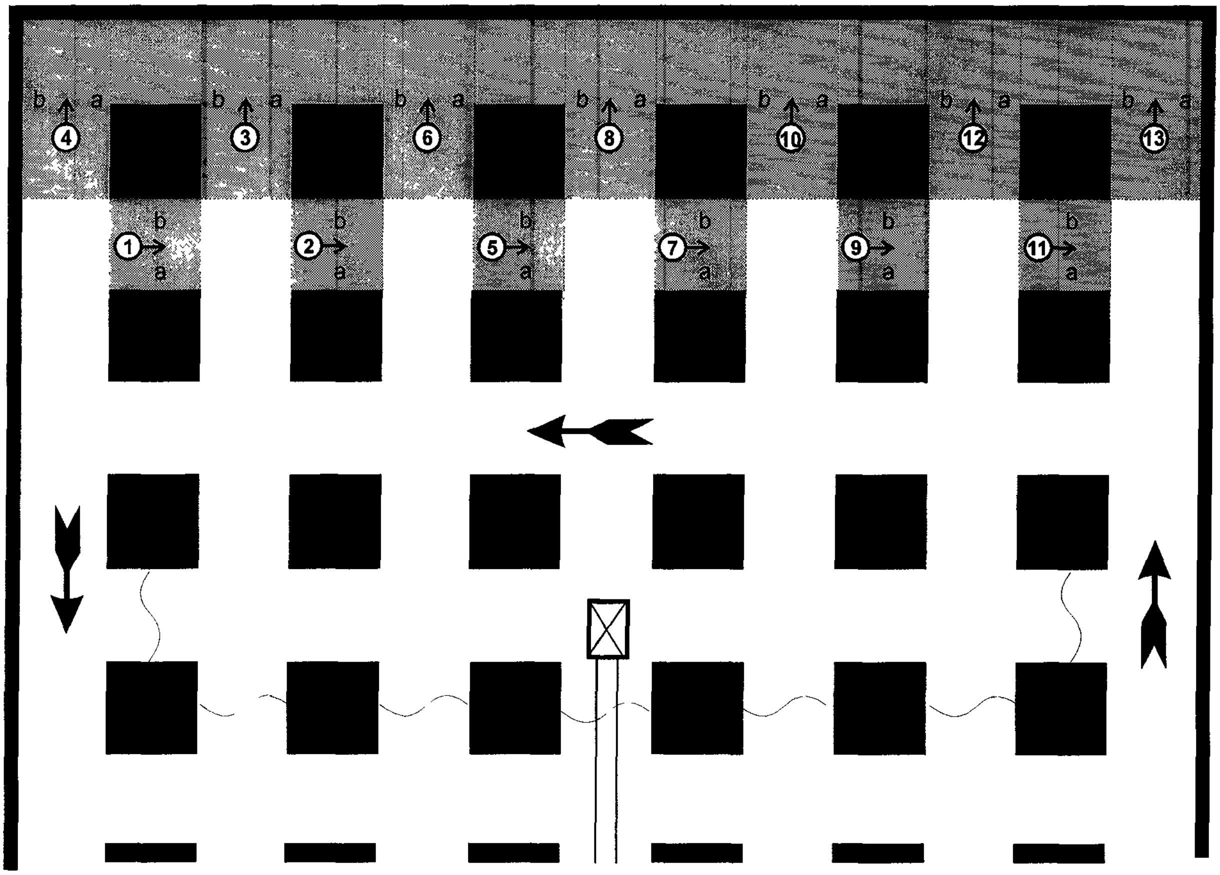


Figure A10 Ideal Cutting Cycle for Optimum Scrubber Dust Capture

LTR Ventilation Right to Left, RH Machine Operator