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EVALUATE FUNDAMENTAL APPROACHES TO LONGWALL DUST CONTROL SUBPROGRAM I - MINING PRACTICES

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Mine operators have long known that by changing certain mining practices they can reduce personnel dust exposures. The objective of this subprogram was to identify mining practices which inherently reduce personnel exposures. This was achieved through several tasks:

a. Modeling mining cycles to quantify reductions through altered practices; one key result showed the benefits of homotropal ventilation to reduce intake contamination.

b. An underground evaluation of homotropal ventilation, which revealed that intake contamination from the stageloader and crusher can be reduced by 60 to 70 percent.

c. A feasibility study of asymmetrical drums, showing that over 60 percent less cutting can be performed upstream of shearer operators during tail to head cutting.

d. Laboratory studies of the headgate cutout, showing that exposures during the cutout can be reduced by over 90 percent using special water spray and ventilation curtain techniques.

e. Underground studies of downwind dust from cutting and shield movement, showing how to best position personnel to reduce exposures from these sources.

The subprogram effort culminated in extensive technology transfer through two expert system computer programs, DUSTPRO and DRUMPRO.

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FOREWORD

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The technical effort was performed by the Mining Division of the Engineering Systems Group under the direction of Mr. Terry L. Muldoon, with Mr. Steven K. Ruggieri as Program Manager and Mr. Jonathan Kelly as Subprogram I Principal Investigator.

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EXECUTIVE SUMMARY

Mine operators have long known that by changing certain mining practices they can reduce personnel dust exposures. The objective of this subprogram was to identify mining practices which inherently reduce personnel exposures. This was achieved through several tasks, as discussed in the following paragraphs.

Modeling the Mining Cycle

One method employed on this subprogram to identify those cutting cycles and modifications favorable to reducing personnel dust exposures was to model several common cutting cycles in use on United States longwalls and to quantify the dust exposure received by key face personnel. With baseline levels established, modifications were implemented to each cycle and the resulting exposures were quantified. In this manner, levels of improvement for each modification could be determined. Through further analysis, it was possible to select the cutting cycle and appropriate modifications most effective in reducing the exposure of face personnel without sacrificing production.

The following mining cycles were evaluated for potential dust exposure through the use of the model:

a. Unidirectional cutting - headgate to tailgate: antitropal and homotropal ventilation

b. Unidirectional cutting - tailgate to headgate: antitropal and homotropal ventilation

c. Bidirectional cutting: antitropal and homotropal ventilation.

The results of the mining cycle modeling clearly illustrated the advantages of using homotropal face ventilation to eliminate intake pollution. Use of crushers mounted on stage loaders produces high concentrations of intake contamination. The application of crushers has steadily increased and homotropal ventilation can virtually eliminate the intake pollution problem.

Further benefits of changing the methods of operation in the various mining cycles were also documented to provide a cumulative improvement. Additional modeling compared the exposure to personnel when operating with conventional size cutting drums versus asymmetrical size drums. Asymmetrical drums showed the potential for reducing dust exposures by reducing the amount of upwind cutting activity.

Homotropal Ventilation

The results of the modeling task quantified the potential benefits of homotropal ventilation and highlighted the need for an investigation into actual operating experience. This study began with a field survey to longwalls utilizing homotropal ventilation and culminated in an underground evaluation on an operating homotropal face.

For the underground evaluation, Foster-Miller located a site that had both a homotropal and antitropal face. The two faces had similar stageloaders, face conveyers and shields and the extraction height in each was approximately 7 ft. The antitropal face was equipped with an Eickhoff 300 shearer with 66 in. diam cutting drums. The homotropal face was equipped with a smaller shearer, the Joy ILS, fitted with a 60 in. tailgate drum and 57 in. headgate drum.

On both faces, dust samples were taken simultaneously between the two shearer operators and in the intake (upwind of the shearer) to document the shearer operators' exposure to intake dust. On the cutting pass, the intake data was obtained immediately upwind of the shield movement. On the cleanup pass, the intake data was gathered immediately upwind from the shearer since no shield movement was taking place.

Comparing data from the two faces showed significantly lower intake contamination on the homotropal face. Intake dust levels on the homotropal face averaged 60 to 70 percent less than those on the conventional face.

Other important information was obtained during the underground work on this project. One key to the successful application of homotropal ventilation is the control of the auxiliary intake air to the headgate. It has to provide sufficient air to dilute dust in the headgate and must also provide a positive airflow towards the face to prevent contaminated face air entering the headgate. The balancing of the face airflow and auxiliary airflow is critical.

Another key to the successful application of homotropal ventilation is an open return through the gob at the headgate end of the face. In several of the mines the gob stood well enough that a path to the return crosscut was always open until the next return crosscut advanced beyond the stageloader. In other mines, cribbing was installed between the first shield and the rib to keep the gob open. In those mines, where maintaining an open gob is difficult, other techniques will need to be applied to maintain a fresh air split for the stageloader operator if homotropal ventilation is to be successfully applied.

Asymmetrical Cutting Drums

In addition to homotropal ventilation, the modeling task quantified the potential dust reduction benefit of asymmetrical cutting drums. The reduction is achieved through the application of a small cutting drum on the upwind ranging arm which cuts less coal, thereby generating less dust, which may pass over the operators' positions. The majority of the cutting (and dust generation) is transferred to the larger drum on the downwind ranging arm.

A feasibility study was conducted to estimate the limits on the potential dust control benefits of asymmetrical drums given certain physical constraints on the equipment. The sizes of the large/small cutting drums have practical limits on their maximum and minimum sizes based on maximum allowable peripheral speeds and the hub size of the ranging arms. In fact, the maximum and minimum sizes of the two drum diameters will be limited to approximately 76 and 50 in., respectively. If these size drums were used to replace a standard set of 60 in. drums on an average United States face of 7 ft seam height, then approximately 66 percent less cutting would be performed upwind of the shearer operators during a tail-to-head pass. This would help to significantly reduce operator dust exposures.

Headgate Ventilation Parameters

During underground evaluations on many Bureau of Mines programs, an apparent degradation of the performance of dust control techniques has been consistently noted towards the headgate end of the face. This degradation occurs whether the shearer is cutting towards the headgate or towards the tailgate. While this section of the cutting cycle is a small fraction of the total, the high increase of dust concentrations measured can significantly increase operators' full shift exposures.

The objective of this portion of the subprogram was to identify the control techniques most effective in improving the ventilation around the shearer while in the headgate area. Four major categories of techniques were evaluated. No single technique or category could adequately address all of the poorly ventilated zones but the use of airmoving water sprays produced the largest percentage improvements. The combination of control techniques which most effectively improved the headgate area ventilation while compromising between adequate dust and gas control was:

a. Shearer Clearer spray system

b. Additional airmoving sprays at the tailgate gearhead

c. Walkway ventilation curtain hung perpendicular to the face in line with the headgate operators' controls.

Downwind Dust Control

While many mines in the United States use unidirectional cutting to minimize the number of personnel working downwind of the shearer, a significant number cut bidirectionally. On a bidirectional face, jacksetters work downwind of the shearer for at least half of every cutting cycle and can be subjected to significant quantities of shearer-generated dust. In addition, shearer operators can be subjected to dust from upstream shield movement.

An underground study was conducted to evaluate respirable dust conditions downwind of the shearer during tail-to-head cutting and downwind of shield movement during head-to-tail cutting. The objective was to provide guidelines for minimizing the dust exposures of downwind personnel in these situations. The results of the study revealed the following:

a. A Shearer Clearer-like spray system is effective in maintaining a clean/dusty air split for a considerable distance downwind of the shearer (up to 70 ft). This should help to minimize the dust exposures of downwind personnel compared to conventional spray systems.

b. During tail-to-head cutting, with shield movement following downwind, shields should be pulled as closely behind the shearer as possible. This will take advantage of the tendency for shearer-generated dust to remain in the face area for a time as it travels downwind.

c. During head-to-tail cutting, with shield movement following upwind of the shearer, shields should not be pulled too closely behind the shearer. When pulled close to the shearer, shield dust will immediately impact the shearer operators. When pulled some distance upstream, shield dust disperses and dilutes rapidly with the face airflow, minimizing its impact on the shearer operators.

Expert Systems Technology Transfer

Expert systems are sophisticated computer programs designed to approximate the process of problem solving employed by a human expert by drawing on a vast store of specialized knowledge.

In the longwall mining application, the knowledge base, including use of judgment, rules of thumb, and experience, needed to make decisions and recommendations concerning mine specific applications of appropriate control technology is made available to the mine. Additionally, specific recommendations are made and information and references are provided.

As part of the effort on this subprogram, two expert systems have been made available to longwall operators to transfer the Bureau technology:

a. DUSTPRO, related to longwall dust control techniques

b. DRUMPRO, related to longwall drum design.

1. INTRODUCTION

In 1981, United States Bureau of Mines awarded Foster-Miller, Inc. Contract JO318097 - "Evaluate Fundamental Approahces to Longwall Dust Control." The overall objective of the contract was to evaluate the effectiveness of available dust control technology for double-drum shearer longwall sections in a few longwall test sections and to make the results available to the entire coal mining industry.

This program investigated 10 different dust control techniques within nine subprograms. The subprograms included:

a. Subprogram A - Passive Barriers/Spray Air Movers for Dust Control

b. Subprogram B - Practical Aspects of Deep Cutting

c. Subprogram C - Stageloader Dust Control

d. Subprogram D - Longwall Automation Technology

e. Subprogram E - Longwall Application of Ventilation Curtains

f. Subprogram F - Reversed Drum Rotation

g. Subprogram G - Reduction of Shield Generated Dust

h. Subprogram H - Air Canopies for Longwalls

i. Subprogram I - Mining Practices.

These nine subprograms encompassed a broad range of dust control techniques ranging from administrative controls to new hardware. They spanned not only presently employed methods but also those recently adopted in the United States and those proposed for the future.

The report constitutes the Final Technical Report for Subprogram I, "Mining Practices," summarizing the effort expended and the results obtained.

Companion volumes document the results of the other subprograms.

1.1 BACKGROUND

Most longwall faces in the United States have found it difficult to comply with present respirable dust standards. The ideal application of dust control measures to a longwall face which is out of dust compliance would have three steps, as follows:

a. Identification of problem dust sources

b. Location of endangered personnel

c. Implementation of control measures.

Detailed laboratory and underground dust concentration measurements conducted throughout the Bureau research projects have documented the complexity of dust concentration gradients on longwall faces. Dust sources vary with both position and time. These variations alone make interpretation of a miner's dust exposure a difficult proposition.

Ample evidence has been found in laboratory work that gradients of dust concentration within the regions through which personnel may be expected to range vary sharply. Mine operators have long appreciated the fact that by changing certain mining practices they can reduce personnel dust exposure. The most popular modification is to alter the mining cycle to cut unidirectionally. Mines, therefore, acknowledge and have demonstrated that variations in mining practices, specifically the cutting cycle, can reduce dust exposure.

There are, however, many other practices through which the dust exposure of face personnel can be reduced, including variations of:

a. Ventilation systems

b. Cutting cycles

c. Operating techniques and equipment

d. Face systems.

This reduction can be realized by removing personnel from the area of dust generation by the proper application of altered mining practices.

1.2 SUBPROGRAM OBJECTIVE

The objective of this subprogram was to identify those cutting cycles and modifications which inherently subject face personnel to low levels of dust exposure. This was achieved through several tasks:

a. Modeling mining cycles to quantify expected dust improvements as mining practices are altered

b. Underground evaluations of two key improved mining practices already used in the industry, homotropal ventilation and asymmetrical drums

c. Laboratory development of new control techniques

d. Underground studies of face ventilation and dust gradient phenomena.

The subprogram effort culminated in extensive technology transfer through a variety of publications and through the development of two expert system computer programs. Each of these tasks is discussed in detail in the following sections.

2. MODELING THE MINING CYCLE

One method employed on this subprogram to identify those cutting cycles and modifications favorable to reducing personnel dust exposures was to model several common cutting cycles in use on United States longwall and to quantify the dust exposure received by key face personnel. With baseline levels established, modifications were implemented to each cycle and the resulting exposures were quantified. In this manner, levels of improvement for each modification could be determined. Through further analysis, it was possible to select the cutting cycle and appropriate modifications most effective in reducing the exposure of face personnel without sacrificing production. The first portion of the study was aimed at changes in techniques <u>with existing equipment</u>. A smaller portion of the study addresses probable mining cycles <u>with new equipment</u>.

2.1 MODELING APPROACH

Initial efforts were concentrated on the development of a model through which mock cutting cycles could be evaluated for potential dust exposure to personnel. Through the analysis of each segment of a cutting cycle, a picture of how personnel are affected by different operations can be developed. For study purposes, personnel are treated as four subgroups. Six mining cycles are examined both as conventional baseline cycles and modified cycles. The modified cycles can be used to identify simple changes in the methods of operation which can result in dramatic improvements in personnel exposure.

Model development required a set of baseline conditions (dust levels) and assumptions. Values had to be generated for the dust make of each operation and its duration. To enable a realistic approach, data were analyzed from several previous longwall dust control demonstrations (Bureau programs). From the analysis, values of probable dust concentrations were derived for each shearer operator (and other key personnel) during all segments of the cutting and cleanup cycles. Average durations of each phase of the cycle were also deduced from the analysis of field data, allowing calculation of total dust exposure during the shift. Table 1 includes the values used by each model for the dust concentrations and durations of activities.

A longwall crew performs many complex tasks during a cutting cycle. Factoring all of them into the model would increase its complexity without contributing any further benefits. Different occupations on a longwall do, however, receive significantly different levels of

TABLE 1. - The concentration and duration of activities

Concentrations

a.	0.5 mg/m^3 shield movement	
b.	0.7 mg/m^3 intake and conveyor	
c.	3.8 mg/m^3 trailing operator	Cutting against ventilation
d.	5.7 mg/m^3 leading operator	
e.	2 mg/m^3 trailing operator	Cutting with ventilation
f.	3 mg/m^3 leading operator	
g.	4.2 mg/m^3 sumping against ventilation	
h.	2.1 mg/m^3 sumping with ventilation	
i.	0.76 mg/m^3 flitting	
j.	3.8 mg/m^3 downwind of shearer	

Activity Times

a. Cutting segment:
   1. 30 min conveyors
   2. 22 min shields
   3. 22 min shearer

b. Flit segment:
   1. 14 min conveyors
   2. 14 min shearer

c. Sump:
   1. 8 min shearer
   2. 8 min shields
   3. 8 min conveyors

d. Bidirectional flit at face end:
   1. 4 min shearer
   2. 4 min conveyors

exposure during operations. Accordingly, the face personnel have been treated as four separate categories for the purpose of modeling:

a. Headgate shearer operator

b. Tailgate shearer operator

c. Headgate operator

d. Shield operator.

A mathematical model of a mining cycle cannot factor in the endless combinations of variables affecting dust generation and operations realized during actual mining conditions. In order to evaluate different cycles (unidirectional, bidirectional), a set of baseline conditions was assumed in the model analysis. These conditions are listed in table 2.

TABLE 2. - Baseline conditions

<u>Assumptions made in analyzing cutting cycle</u>:

a. During the conventional cutting cycles, operators are located in their normal positions

b. Shields are designed for one-web back operation and moved over behind the shearer on the cutting run

c. Unidirectional cutting cycle takes 52 min

d. Bidirectional cutting cycle takes 84 min

e. On cutting into ventilation leading shearer drivers' exposure increases by 1.5

f. Ventilation velocity down the face is assumed to be constant

g. Total downward dust make from the shearer is the same for both directions of cutting

h. Ignored conveyor snaker on flit run

i. Assumed no additional dust control in modified cycles

j. All results expressed as exposure in milligram minutes per cubic meter

k. Coal is being converted from tailgate towards headgate.

With all the modeling information discussed above, individual cycles can be evaluated with different cutting directions, ventilation systems, and operating techniques (for example, shield movement). These changes can then be ranked in order of total impact on the exposure of face personnel.

2.2 ANALYSIS OF MINING CYCLES

The following mining cycles were evaluated for potential dust exposure through the use of the model:

a. Unidirectional cutting - headgate to tailgate: Antitropal and homotropal ventilation

b. Unidirectional cutting - tailgate to headgate: Antitropal and homotropal ventilation

c. Bidirectional cutting: Antitropal and homotropal ventilation.

Note: Antitropal ventilation exists when the primary airflow is in the <u>opposite direction to the face conveyor</u>. The direction of a face conveyor is from tailgate to headgate. Therefore, antitropal ventilation is from headgate to tailgate. For homotropal ventilation, the reverse is true; it flows from tailgate to headgate in the <u>same direction as the face conveyor</u>.

The data in the following sections will be presented to show the exposure experienced by personnel during a conventional mining cycle and the improvement gained by modifying the cycle.

2.2.1 <u>Unidirectional Cutting, headgate to tailgate</u>

2.2.1.1 Antitropal Ventilation (headgate to tailgate)

The shearer cutting headgate to tailgate with ventilation is probably the most popular method of operation. Using the model, each operation of the cycle was examined which generated exposure values for each category of personnel. The first column in table 3 shows the operator exposures (<u>for one complete cycle</u>) when cutting conventionally from headgate to tailgate. As can be seen, the headgate operator receives minimal exposure (37 mg min/m^3). The shield operators experience more dust (86 mg min/m^3), and the shearer operators have very heavy dust exposure (159 mg min/m^3).

TABLE 3. - Unidirectional cutting, headgate to tailgate

Personnel	Conventional ventilation headgate to tailgate	Modification no. 1	Homotropal ventilation tailgate to headgate	Modification no. 2
	(Dust exposures expressed in mg-min/m^3)			
Shield operators	86	45	99	60
Headgate operators	37	37	188	37
Tailgate shearer operators	159	117	141	37
Headgate shearer operators	158	47	116	53
(Tailgate and headgate shearer operators, bracketed)		82	129	45
			Impractical	

The second column in table 3 illustrates how modifications to the cutting sequence can reduce personnel exposure. In modification no. 1, the shearer operator benefits greatly by having his exposure reduced from 159 mg min/m^3 in the conventional cycle to 82 mg min/m^3 in the modified cycle.

To achieve the reduction, only relatively minor changes were made. The changes are listed in table 4. The four columns in table 4 are the operator categories. The values in the columns are the <u>percentage improvements over the conventional cycle</u> achieved for the operators by using a modified cycle.

Table 4 allows one to see the cumulative effect of each modification. Using the headgate shearer operator as an example, the effect of each modification can be seen as:

a. Using the tailgate (downwind) drum only during the cutting segment (28% reduction in exposure).

b. Using the tailgate drum only for the cleanup (flit) segment (10%).

c. Cutting out the headgate using only the leading drum so that the operation is performed by only one shearer operator. The second operator moves upwind of the shearer into fresh air (32%).

TABLE 4. - Modification no. 1, cutting headgate to tailgate, ventilation headgate to tailgate

% improvements obtained				
Shearer operator	Headgate operator	Tailgate shearer operator	Headgate shearer operator	Changes performed in modified cycle
-	-	13	28	Cutting segment use tailgate drum only
8	-	-	-	Cycle shearer operator during shield movement
-	-	4	10	Flit segment use tailgate drum only
-	-	-	32	Sump segment with headgate shearer driver upwind
-	-	9	-	Sump segment performed with headgate drum only and tailgate shearer driver
39	-	-	-	Move shields after sump is completed
47	0	26	70	Total percentage reduction for cycle

2.2.1.2 Homotropal Ventilation (tailgate to headgate)

This method of cutting into ventilation (from headgate to tailgate) is unlikely in practice; however, it was examined because it permits comparison between antitropal and homotropal ventilation. Homotropal ventilation (tailgate to headgate) has the advantage of eliminating intake contamination but results in high headgate operator exposure. The results from applying homotropal ventilation on a conventional cycle are shown in table 3, column 3. The shearer operator concentrations are reduced from 159 mg min/m using antitropal ventilation to 129 mg min/m^3 using homotropal ventilation. However, the exposure of the headgate operator (now working in return air) shows an increase (from 37 to 188 mg min/m^3) using homotropal ventilation. He is now the high risk occupation in this cycle.

The fourth column in table 3, modification no. 2, lists personnel exposures when operating a modified cycle with homotropal ventilation. These values represent the lowest exposures calculated when cutting headgate to tailgate. In table 5, the changes in the cutting cycle and the percentage improvements are listed. The main changes that resulted in reduced exposures were:

a. Moving shearer drivers to the least dusty locations

b. Fresh air split for headgate operator.

The data indicate that when a fresh air split is provided to the headgate operator, homotropal ventilation can be very beneficial for a headgate to tailgate unidirectional cutting cycle.

2.2.2 Unidirectional Cutting, Tailgate to Headgate

A tailgate to headgate cutting sequence is utilized when there is insufficient room for the coal produced by the leading drum to pass through the underframe. The aperture between the underframe and the conveyor acts as a restriction to coal flow. Cutting tailgate to headgate has the disadvantage that the shearer is cutting against the airflow thereby allowing shearer-generated dust to pass over both shearer operators.

2.2.2.1 Antitropal Ventilation (Headgate to Tailgate)

In the first column of table 6, it can be seen that conventional cutting produces high exposure levels for both shield and shearer operators. Both categories of operators are positioned downwind of the cutting.

The second column shows considerable improvements are obtained by modifying the cycle (modification no. 3). The shield operator concentrations are reduced from 133 to 98 mg min/m^3 - a reduction of 25%, while the shearer operator concentrations are reduced from 161 to 99 mg min/m^3 - a reduction of 38%. The modifications implemented to achieve these reductions are listed in table 7.

The shearer operators obtain the greatest benefit from the modified cycle with overall reductions of 29 and 55% for the tailgate and headgate shearer operators, respectively. However, even with the improvements, the shearer operators' exposure still remains high at an average of 99 mg min/m^3 exposure for one complete cycle.

TABLE 5. - Modification no. 2, cutting headgate to tailgate, ventilation tailgate to headgate

% improvements obtained				
Shearer operator	Headgate operator	Tailgate shearer driver	Headgate shearer driver	Changes performed in modified cycle
25	-	-	-	Cutting segment use tailgate drum only
-	-	65	40	Cutting segment shearer driver move to least dusty locations adjacent to shearer
6	-	-	-	Cycle shearer operator
-	80	-	-	Fresh air split for headgate operator
-	-	4	-	Flit segment tailgate shearer driver move to least dusty location
-	-	-	4	Flit segment use headgate drum only
-	-	4	9	Sump segment use headgate drum only; headgate only; tailgate shearer driver upwind
17	-	-	-	Move shields when sump segment is completed
48	80	73	53	Total percentage reduction for cycle

TABLE 6. - Unidirectional cutting, tailgate to headgate

Personnel	Conventional ventilation headgate to tailgate		Modification no. 3		Homotropal ventilation tailgate to headgate	Modification no. 4	
	(Dust exposure expressed in mg min/m^3)						
Shield operators	133		98		48	8	
headgate operators	37		37		178	37	
tailgate shearer operators	149	166 (combined with row below)	106	99 (combined with row below)	122	31	46 (combined with row below)
headgate shearer operators	173		91		122	60	

TABLE 7. - Modification no. 3, cutting tailgate-to-headgate, ventilation headgate to tailgate

% improvements obtained				
Shearer operator	Headgate operator	Tailgate shearer driver	Headgate shearer driver	Changes performed in modified cycle
20	-	19	-	Cutting segment use headgate drum only
5	-	-	-	Cycle shearer operator
-	-	-	48	Cutting segment move headgate shearer driver to least dusty locations
-	-	3	3	Flit segment use tailgate drum only
-	-	7	4	Sump segment use tailgate drum only
25	0	29	55	Total percentage reduction for cycle

2.2.2.2 Homotropal ventilation (tailgate to headgate)

In table 6, column 3, homotropal ventilation, again shows reduction for shield operators and shearer operators during conventional cutting in comparison to antitropal ventilation, column 1. By modifying this cycle (modification no. 4), personnel exposure is reduced even further.

Table 8 lists the modifications necessary for the reductions. It also illustrates that a fresh air split to the headgate operator is essential when homotropal ventilation is used. It reduces his exposure by 79%, from 178 to 37 mg min/m^3. The table also shows a large improvement

TABLE 8. - Modification no. 4, cutting tailgate to headgate, ventilation tailgate to headgate

% improvements obtained				
Shearer operator	Headgate operator	Tailgate shearer driver	Headgate shearer driver	Changes performed in modified cycle
-	-	36	18	Cutting segment use headgate drum only
-	79	-	-	Fresh air split for headgate operator
14	-	-	-	Cycle shearer operator
-	-	13	5	Flit segment use headgate drum only
-	-	25	-	Sump segment use tailgate drum only
-	-	-	28	Sump segment use only tailgate shearer driver
71	-	-	-	Move shields after sump is completed
85	79	74	51	Total percentage reduction for cycle

for the shield operators, however, their exposure with homotropal ventilation and no additional modifications was already low. This further reduction was an added bonus. Modified cycle no. 4 out-performs all other unidirectional cycles in terms of reducing personnel exposure. It also has the additional advantage that during the primary cut from tailgate to headgate, the size of the opening in the underframe is not a factor in limiting production.

2.2.3 Bidirectional Operation

Bidirectional cutting is considered the most productive cutting sequence. This is especially true in smaller seams where travel is restricted. The disadvantage of the cycle is that personnel dust exposure increases.

2.2.3.1 Antitropal Ventilation (Headgate to Tailgate)

Table 9 shows that when ventilation is from headgate to tailgate, use of the conventional mining cycle results in high concentrations of dust for the shield and shearer operators. Shield operators are exposed to 207 mg min/m^3 while the shearer operators exposure is 297 mg min/m^3 for a complete cycle. The values in the table appear high because a bidirectional cycle takes two complete cuts of the longwall. If the values are halved to normalize for production and compared with the unidirectional cutting cycles, the values are comparable. However, a unidirectional cycle takes 52 min to perform one cut while

TABLE 9. - Bidirectional cutting

(Dust exposures expressed in mg min/m^3)

Personnel	Conventional ventilation headgate to tailgate		Modification no. 5 headgate to tailgate		Homotropal ventilation tailgate to headgate		Modification no. 6 tailgate to headgate	
Shield operators	207		166		148		98	
Headgate operators	62		62		331		59	
Tailgate shearer operators	282	297	224	183	249	235	81	90
Headgate shearer operators	311		142		220		98	

a bidirectional cycle takes 84 min to complete two cuts. Therefore, although the bidirectional cycle is not inherently more dusty, a greater number of cycles are performed per shift which results in increased personnel exposure during the shift.

Modifications to the operational cycle shown in table 10 can help reduce personnel exposure during a bidirectional cutting cycle. However, since all the coal has to be cut in a single pass, the areas available for modifying the cycle and decreasing exposure are greatly reduced.

TABLE 10. - Modification no. 5, bidirectional cycle (headgate to tailgate and tailgate to headgate), ventilation headgate to tailgate

% improvements obtained				
Shearer operator	Headgate operator	Tailgate shearer driver	Headgate shearer driver	Changes performed in modified cycle
-	-	15	37	Cut each segment with shearer driver in least dusty location
6	-	-	-	Cycle shearer operator
-	-	1	2	Sump segment at tailgate with tailgate drum only
16	-	1	1	Move shields when sump is completed
-	-	3	15	Sump segment at headgate cut with headgate drum only, use only the tailgate shearer driver
22	0	20	55	Total percentage reduction for cycle

2.2.3.2 Homotropal Ventilation (tailgate to headgate)

The advantage gained by homotropal ventilation is again the elimination of intake contamination. A considerable reduction in dust exposure is achieved with no modifications on the face operations. With the modifications shown in table 11 incorporated into the cycle, the following reductions are realized:

a. Thirty-four percent for shield operators

b. Eight-two percent for headgate operators

c. Sixty-seven percent for tailgate shearer operators

d. Fifty-six percent for headgate shearer operators.

TABLE 11. - Modification no. 6, bidirectional cycle (headgate to tailgate and tailgate to headgate), ventilation tailgate to headgate

% improvements obtained				
Shearer operator	Headgate operator	Tailgate shearer driver	Headgate shearer driver	Changes performed in modified cycle
-	82	-	-	Fresh air split to headgate operator
-	-	51	36	Cut each segment with shearer driver in least dusty locations
11	-	-	-	Cycle shearer operator
-	-	12	15	Sump segment at tailgate cut with tailgate drum only using only tailgate shearer driver
23	-	-	-	Move shields when cycle is completed
-	-	4	5	Sump segment at headgate cut with headgate drum only
34	82	67	56	Total percentage reduction for cycle

These percentage improvements are derived from the comparison of modification no. 6 to homotropal ventilation.

If a comparison were made to measure the total percentage reduction obtained from a conventional bidirectional cycle (antitropal) in table 9, column 1 to modification no. 6 (homotropal), the percentage reduction would be:

a. Fifty-two percent for shield operators

b. Five percent for headgate operators

c. Seventy-one percent for tailgate shearer operators

d. Sixty-nine percent for headgate shearer operators.

2.3 CONCLUSIONS FROM THE MINING CYCLE ANALYSIS

Six longwall mining cycles have been examined and modeled for potential dust exposure. The exposure to four categories of face personnel was assessed assuming certain baseline conditions. The cutting cycles and operating procedures were then modified to reduce the exposure of personnel. The changes in the method of operation were aimed at keeping longwall personnel in fresh air and upwind of the shearer during as much of the mining cycle as possible.

Results clearly indicate that homotropal ventilation (primary airflow moving in the same direction as the face conveyor) holds the greatest single benefit to the face personnel. In the analysis of the mining cycle, a relatively low value of 0.7 mg/m^3 was assumed for intake contamination. Even so, it has a considerable influence on the results since it is continuous throughout the cycle and affects all face personnel. Homotropal ventilation virtually eliminates intake contamination since the airflow on the face has not passed over any transfer points or coal being conveyed before reaching face operators. Recent field data indicate that faces using stage loader crushers experience intake concentrations approaching 1.7 mg/m^3. In cases such as these, the impact of homotropal ventilation would be even more dramatic than indicated by the model.

Overall, results indicate that if homotropal ventilation is applied together with the other recommended modifications, 70% reductions in dust exposure can be achieved. The cycle resulting in least exposure to personnel is a modified half face (unidirectional) cycle cutting tailgate to headgate with homotropal ventilation.

Homotropal ventilation is also beneficial for a bidirectional cutting cycle. Through application of recommended modifications, personnel exposure for each cutting cycle is the same as a unidirectional cycle. However, the number of cutting cycles per shift is greater when cutting bidirectionally resulting in greater shift exposure (and also greater production).

2.4 AN ANALYSIS OF SIGNIFICANT MODIFICATIONS IN MINING METHODS

The work documented in the report up to now has examined the benefits of changing the method of operation and ventilation. Some of the modifications discussed may require minimal additional costs when implemented in the planning stages of a face. Others require no cost and may be implemented at any time.

The changes discussed in the following sections require new hardware and would be even more costly if applied midway through the life of the face.

2.4.1 Advancing Shields during the CleanUp (Flit) Segment of a Cutting Cycle

Some operators that have good roof conditions can cut through the face and advance the shields on the cleanup pass. The advantage of operating this method is to move the shield operators out of the shearer dust. Recent developments in shield design have resulted in load bearing cantilevers which give additional forward support. It is likely that faces equipped with this type of support will now have the option of advancing their shields during the cleanup pass under stable roof conditions.

Table 12 compares the exposure values from a conventional unidirectional cycle (previously shown in table 6) to the exposure values generated by the same cycle with modified shield advance. Shield operators' exposure is substantially reduced from 133 to 59 mg min/m^3 but shearer operators' exposure is slightly increased since they are now downwind from shield operations. This variation in shield movement may be an option to longwall operations cutting from tail-to-head with stable roof who are not willing to commit themselves to homotropal ventilation.

TABLE 12. - The advantage of advancing the shields during the flit segment of the cutting cycle

(Dust exposure expressed in mg min/m^3)

a. Unidirectional cutting

b. Direction of cutting tailgate to headgate

c. Ventilation direction headgate to tailgate

Personnel	Conventional cycle	Advancing shields during flit segment
Shield operators	133	59
headgate operators	37	37
tailgate shearer drivers	149	158
headgate shearer drivers	173	180

2.4.2 A Shearer Equipped with Asymmetrical Cutting Drums

A Bureau report on an investigational visit to Barnes and Tucker Coal Co. highlighted the benefits of using unequal size cutting drums. By locating the smaller drum on the upwind arm of the shearer, the shearer personnel are subjected to less dust generation. The smaller drum is cutting less coal and consequently produces less dust.

In table 13, a reduction from 235 to 148 mg min/m^3 is achieved by changing from conventionally sized drums to asymmetrical drums. The conventional baseline cycle in column 1 is obtained from column 3 in table 9 and lists personnel exposure for bidirectional cutting using homotropal ventilation. The results in column 2, table 13, model the mining cycle used at Barnes and Tucker. The results show a reduction in shearer operator exposure from 235 to 148 mg min/m^3.

This modification requires that the downwind drum be the same size as the seam height. Because of its limitations, it may be practical only in certain applications. Therefore, a less restrictive iteration was generated for a shearer equipped with drums that were 1/3 and 2/3 of the seam height. This arrangement permits the shearer to cope with changes in seam section by ranging the cutting drums. It is slightly less effective than the Barnes and Tucker arrangement but considered to be more

TABLE 13. - The changes in dust make produced by using a conventional 66%/66%, 100%/33% and 66%/33% cutting drum size

a. Cutting cycle: Bidirectional

b. Ventilation: Tailgate to headgate

c. Assumptions:

1. Conventional size drums 66% of seam height
2. Modification 100%/33%, headgate drum 100% and tailgate drum 33% of seam height
3. Modification 66%/33%, headgate drum 66% and tailgate drum 33% of seam height
4. The dust produced is proportional to the size of the drum

Personnel	Conventional 66%/33%		Modified 100%/33%		Modified 66%/33%	
Shield operators	148		148		148	
Headgate operators	331		331		331	
Tailgate shearer drivers	249	235	74	148	96	159
Headgate shearer drivers	222		222		222	

acceptable to the mining industry. Reducing the size of the downwind drum to 66% of seam height increased the shearer operator exposure from 148 to 159 mg min/m^3, an increase of only 7%. These results are shown in column 3 of table 13.

A similar set of results were generated for a unidirectional cutting cycle. Results again indicated that the operators' asymmetrical drums can reduce the shearer concentration considerably. Results show a reduction from 129 to 85 mg min/m^3, a 34% decrease (see table 14).

In applying the asymmetrical drum concept, a further improvement would be to use a very low rotational speed on the small drum. The small drum would require less torque than a normal drum permitting the ranging arm to withstand

TABLE 14. - The changes in dust make produced by using conventional size drums, 66%/66%, and modified, 66%/33%

a. Cutting cycle: Unidirectional, headgate to tailgate

b. Ventilation: Tailgate to headgate

c. Assumptions:

1. Conventional drums 66% of seam height

2. Modification 66%/33%, headgate drum 66% and tailgate drum 33% of seam height

3. Dust produced is proportional to drum size

Personnel concentrations (mg min/m^3)

Personnel	Conventional 66%/33%		Modified 100%/33%	
Shield operators	99		99	
Headgate operators	188		188	
Tailgate shearer drivers	141	129	53	85
Headgate shearer drivers	116		116	

the low speed. Reduced rotational speed and increased pick penetration would result in less dust make. Additionally, the majority of the dust suppression water can be applied to the small drum also on the upwind side of the shearer. This would help to further reduce shearer-generated dust and personnel exposure.

2.5 MODELING THE MINING CYCLE - SUMMARY

The model mining cycle enabled changes in the method of work and face operations to be quantified in terms of reduced personnel dust exposure. The model may not accurately represent all face conditions but it does provide an effective tool to test different mining practices and rank them in terms of the benefits they can provide.

The data clearly illustrate the advantages of using homotropal face ventilation which eliminates intake pollution. Use of crushers mounted on stage loaders produces high concentrations of intake contamination. The application of crushers is on the increase and homotropal ventilation would virtually eliminate the intake pollution problem.

Further benefits of changing the methods of operation in the various mining cycles is also documented to provide a cumulative improvement (in addition to those from homotropal). Additional modeling compares the exposure to personnel when operating with conventional size cutting drums and asymmetrical size drums. Changes of this nature are more costly but offer the possibility of cutting bidirectionally and remaining in compliance with Federal dust standards.

To develop the beneficial techniques determined through modeling of the mining cycles, the next stage in subprogram effort focused on:

a. A study of homotropal ventilation techniques

b. A feasibility study of large/small diameter cutting drum combinations.

3. HOMOTROPAL VENTILATION

3.1 OBJECTIVE

The results of the modeling task described in section 2 quantified the potential benefits of homotropal ventilation and highlighted the need for an investigation into actual operating experience. This study began with a field survey to longwalls utilizing homotropal ventilation and culminated in an underground evaluation on an operating homotropal face. During the course of the work, guidelines were prepared to help in planning a homotropal face and the impact of Federal Regulations on homotropal ventilation was studied.

3.2 FIELD SURVEY

Investigations during the modeling phase often resulted in negative feedback from the mining community with regard to homotropal ventilation. Many of the remarks were perceived as doubts and it was difficult to identify which were likely to be real problems. To clarify these ambiguities, a series of visits were arranged to homotropal mines in the Ebensburg, PA, region to enable direct discussions to take place. The object of the survey was to determine the following:

a. Reason for implementing homotropal ventilation

b. Operational problems and constraints

c. Special techniques and practices adopted

d. Applicability and enforcement of Federal Regulations

e. Ventilation plans and panel layouts

f. Real and perceived benefits.

All the mines to be visited had considerable experience in operating homotropal faces for many years.

The companies visited were:

a. Mine A - Rochester and Pittsburg Coal Co.

b. Mine B - Barnes and Tucker Co.

c. Mine C - Pennsylvania Mines

d. Mine D - Bethlehem Mines.

The conclusions and points raised from each visit are discussed in the following sections.

Mine A

Seam height:	42 to 54 in. (upper and lower freeport)
Shearer:	Eickoff 150L SD
Roof supports:	Kloeckner 4/440 chocks
Ventilation system:	Homotropal
Panel width:	355 ft

This company was one of the early exponents of homotropal ventilation. The primary reason for the adoption of homotropal ventilation was to help control methane. The company believed that the key to homotropal ventilation was to have the gob under a high negative pressure and control it through the bleeder system. In the headgate, they would normally remove a stopping in advance of the headgate operator. Air was bled over the operator into the gob. During the time that the company operated longwalls, they often experienced poor roof conditions. This did not present any additional problem in bleeding air into the gob. The mine did not utilize any special support systems in the tailgate. The seam was degassed prior and during cutting from a borehole on the surface.

Mine B

Seam height:	55 in. lower Kittanning
Shearer:	A.M. 300, D.D.
Roof supports:	Dowty, 4/700 chocks
Ventilation system:	Homotropal
Panel width:	550 ft
Capacity:	1,700 ton/shift

The company had two mines that used homotropal ventilation. They occasionally experienced poor roof conditions which packed tightly behind the headgate supports. When the situation occurred, they built wooden cribbing behind the supports ensuring an adequate airflow over the headgate operator. In this mine, they took special precautions to support the tailgate. The roof load fell ahead of the face and lead to poor tailgate conditions. This was overcome by additional wooden cribbing that was built as the face retreated. The mine maintained a track for materials and men in the tailgate. A water main was laid in the headgate track entry and was brought through the crosscuts into the belt entry. The mine brought air from the headgate track entry through a crosscut and up to the face. The belt entry velocities exceeded 100 ft/min and the mine, therefore, had to comply with Federal Regulations No. 75.1103-10 (discussed in more detail in section 3.3). MSHA required them to use a deluge system, sprinklers and automatic fire sensors. The faces were degassed prior to, during and after cutting from a methane borehole on the surface.

Mine C

Seam height:	48 in. lower Freeport
Shearer:	Eickhoff 170L, S.D.
Roof supports:	Gullick 6/510 chocks
Ventilation system:	Homotropal
Panel width:	460 ft

The company operated two longwall panels, both of which used homotropal ventilation. The mines often suffered from poor roof conditions; however, the tailgate entry did not need any additional support. The gob occasionally packed down tight in the headgate reducing the airflow over the headgate operator. The problem was overcome by building wooden cribbing behind the supports. The mines used a wing curtain in the headgate to ensure that fresh air coming up the belt entry went over the headgate operator.

Mine D

Seam height:	54 in. lower Kittanning
Shearer:	A.M. 300 S.D.
Roof supports:	Huwood 4/280 chocks
Ventilation system:	Homotropal
Panel width:	600 ft
Capacity:	1,175 ton/shift

The company owned probably the first mines in the United States to use homotropal ventilation. They used to have severe methane problems. In the early days, when ventilating headgate to tailgate, the ventilation would travel 3/4 of the way down the face and migrate into the gob. This generated a stagnant region of ventilation on the face. In an attempt to solve the problem, the face ventilation was reversed together with other changes. This modification improved the stagnant region and gas problem. Having arrived at an effective solution, this method of ventilation prevailed. The mine, as did others in the Ebensberg region, used surface methane drainage. They did not experience any significant problem in directing air over the headgate operator and into the gob. The air over the headgate operator came up the belt entry. Little methane was released by the cut coal on the belt. The majority of gas was released in the gob, and this was controlled by the bleeder system.

Several practical considerations arose from the survey. Protection of the headgate operator was accomplished by the use of a fresh air split routed through the headgate entry. This is illustrated in figure 1. The fresh air split combined with the face ventilation bled into the gob. Airflow restrictions due to a tight gob can cause the face ventilation to back up over the headgate operator. When this occurs, the operator may experience high dust concentrations because he is now on the return air side of face operations.

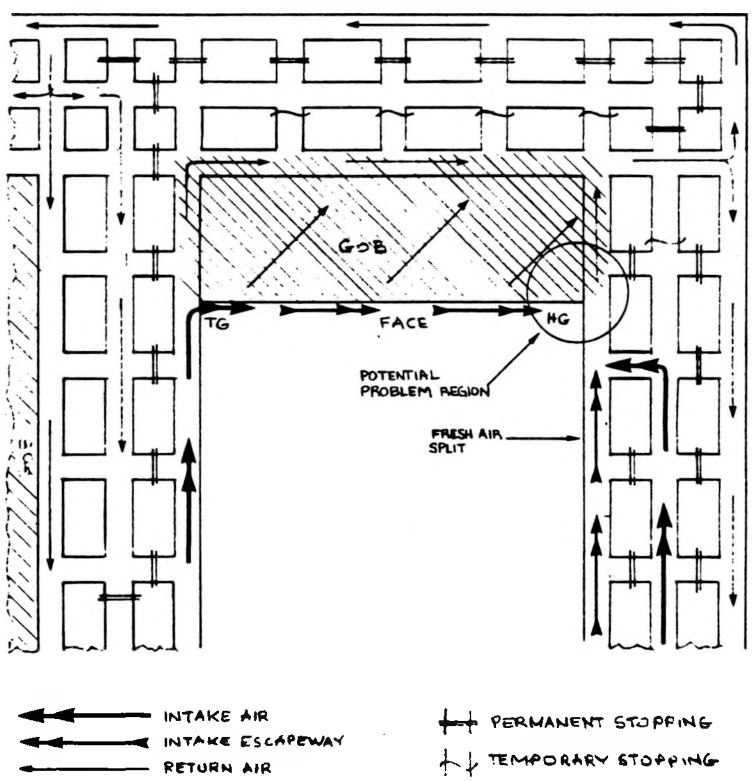


FIGURE 1. - Typical homotropal ventilation plan.

The problem of a tight gob can be alleviated by building cribbing behind the headgate supports. This operation was easily accomplished at the mines visited since they used chocks which gave access behind the supports. On a shield face, a buttress support may be required to give access to the gob.

Another point to arise from the interviews was the need to keep the tailgate entry in good condition. On a homotropal face, the air travels up the tailgate entries which are under additional roof loading because the adjacent panel is mined out. To ensure that these remained open, some additional cribbing is occasionally erected. This is not an additional task necessary for homotropal ventilation. The headgate and tailgate entries are both considered escapeways and are required to remain passable by law even if antitropal ventilation is used.

The following conclusions can be drawn from the field survey:

a. None of the mines encountered difficult problems in applying and operating homotropal ventilation.

b. The main reason for implementing homotropal ventilation was to overcome methane problems.

c. Reduction of intake dust contamination was considered an additional benefit

d. A few mines had to develop some simple techniques (cribbing) to cope with the air split in the headgate.

e. Some mines had to install fire protection equipment required by Federal Regulations (if belt air exceeded 100 ft/min).

f. Homotropal ventilation made it possible to maintain a track entry in the tailgate. This allowed access for materials and workers on both ends of the face.

3.3 IMPACT OF FEDERAL REGULATIONS ON HOMOTROPAL VENTILATION

During the development of the modeling task, discussions were held with a number of people involved in mining to explore the feasibility of some of the techniques. One element of the feedback was that the introduction of homotropal ventilation was limited by Federal Regulations and that those mines using homotropal ventilation had probably been granted a variance. The general belief was that the regulations did not allow intake air to be coursed up the tailgate entry next to old workings unless a variance was granted.

One of the main objectives of the field surveys was to determine the Federal Regulations pertaining to homotropal ventilation and the difficulties experienced in meeting the regulations. The subsequent interviews with the mines in the Ebensberg, PA, area disapproved the earlier information. The mines had experienced no difficulties in satisfying regulations. Telephone interviews with MSHA offices at Headquarters, District, and local levels confirmed that homotropal ventilation, as such, did not contravene Federal Regulations. The main statutory regulations which apply are contained in the Code of Federal Regulations, Mineral Resources, Title 30, Chapter 1, Section 75, pages 487 to 525. The regulations address the limitations of air velocities in belt entries and the additional fire precautions required when air velocities exceed 100 ft/min. The belt entry on a homotropal face provides the clean air split over the headgate operator and velocities there frequently exceed 100 ft/min which results in the implementation of these regulations.

A further point of concern to some officials was the damage that the tailgates were subjected to once the adjacent panel was mined out and the roof load shifted onto the tailgate pillars. Under certain roof conditions, the pillars crush out and damage can occur to the fire-proofed block stoppings. It was construed that this could result in contamination of intake air. This fear is unfounded since any leakage that does occur will be from the tailgate entry, under positive pressure, to the old workings which are under negative pressure. In planning the tailgate entries for a homotropal panel, intake air can be routed through two entries and the third used as the return. This design should overcome any reservations.

A further perceived constraint was the ability of mines utilizing homotropal ventilation to adequately maintain their tailgates in good condition. This aspect, however, is not related to homotropal faces only since antitropal faces are also required by law to maintain the tailgate entry as an escapeway.

During the investigation, a number of telephone interviews were held with MSHA offices. At one office, the ventilation inspector agreed that Federal Regulations would permit homotropal ventilation but was convinced that local state regulations would not. A subsequent letter to the State of West Virginia, Department of Mines, established that they had no reservations concerning this system of ventilation.

The investigation revealed that regulations appertaining to either State or Federal Codes do not in anyway restrict the application of homotropal ventilation. Mines contacted had experienced no greater difficulty in complying with the regulations applicable to homotropal ventilation than to conventional antitropal ventilation.

3.4 PLANNING FOR HOMOTROPAL VENTILATION

In planning for a homotropal panel, a mine should be aware of those issues critical to the success of the installation. This section contains information on the following subjects:

a. Panel ventilation layout

b. Face design

c. Cutting cycles.

On a multi-entry system, there are many acceptable and effective methods of ventilating the longwall. The mine involved, noting where its main airways are located, should then design the most economical and suitable layout. The cost and number of stoppings and overcasts will be of prime concern. In preparing their ventilation plan, interested mines will be aware that the control of the ventilation in the headgate region could be difficult. The face and headgate ventilation converge at the headgate end of the face to enter the gob as a combined airstream. It is apparent that, if the flow rates and pressures are out of balance, dead zones or regions of turbulence could be set up. The interviews with homotropal mines confirmed that the control of the ventilation in the headgate is not as difficult as it would first appear.

Any restriction of ventilation into the gob is overcome by building wooden cribbing behind the headgate support. The task can be performed without difficulty by the face crew on a chock face. A shield face may require a buttress support to provide adequate entry for this purpose. In practice, the headgate pillars and roof bolts usually provide good support in that region. It is unusual to get a tight gob at either end of a longwall face.

For faces wishing to minimize airflow through the headgate and ensure the protection of the headgate operator, the application of brattice cloth can be effective. This technique is brattice illustrated in figure 2. The low velocity air traveling up the belt entry is channeled over the headgate operator with the

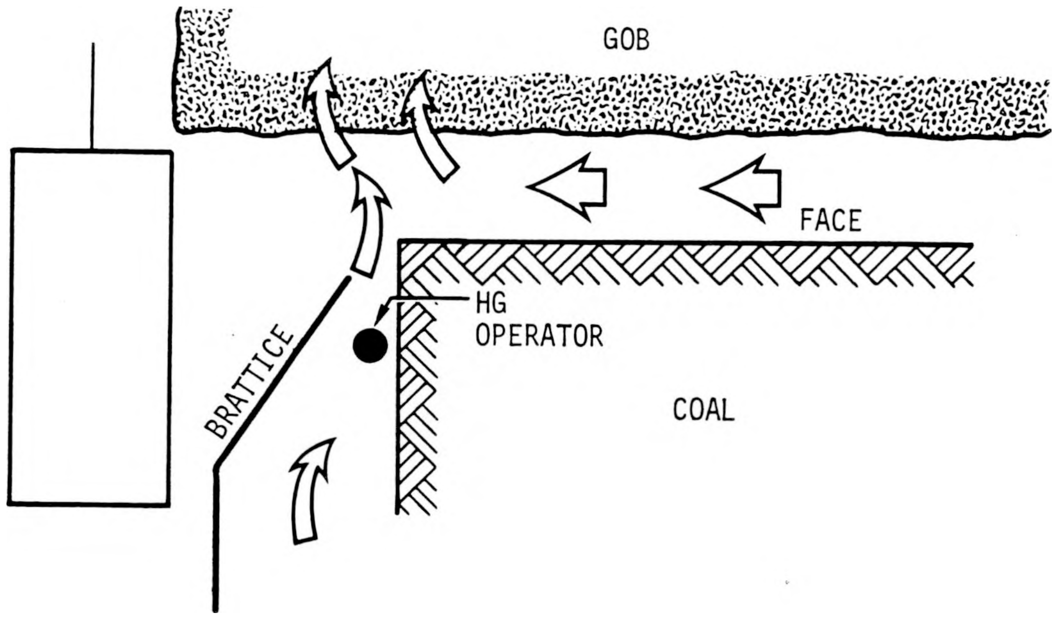


FIGURE 2. - Application of headgate ventilation curtain.

brattice curtain. The use of lower headgate velocities can reduce the level of fire precautions required under Federal Regulations. However, most mines find it more beneficial to use higher velocities and install the additional fire protection equipment since it is a one-time expenditure.

An additional benefit to mines considering homotropal ventilation is the potential for improved productivity and fewer operational problems through the use of a tail-to-head cutting cycle. The cycle has the potential for being very productive since the majority of the coal does not have to pass through the shearer underframe. This cutting cycle also gave the lowest exposures to all face personnel during the modeling study. The lower personnel exposure levels that arise will either enable mines to comply with the regulations or enable greater production levels before reaching the compliance standard. It is conceivable that homotropal ventilation combined with other effective dust controls could enable a bidirectional cut while maintaining compliance. Mines introducing homotropal ventilation should be reminded that the roof support controls will have to be modified to keep the operator upwind of the support being advanced. The majority of the latest modular-type support controls enable a rapid changeover of adjacent control from one side of a support to the other. However, older type controls require rehosing which is more labor-intensive.

The information presented has highlighted some potential problem areas for mines considering the introduction of homotropal ventilation. Even though these were often worst case scenarios, most problems were relatively easily overcome. The benefits of uncontaminated intake air, reduction of methane buildup, track entries in the tailgate, etc., were considered by the mines surveyed to far outweigh the minor operational problems encountered.

3.5 HOMOTROPAL EVALUATION AT OLD BEN

3.5.1 Mine Site Selection

The initial approach for the homotropal evaluation was to locate a cooperative mine which would change from antitropal to homotropal ventilation part way through the life of the panel. An A/B evaluation conducted in this manner would use exactly the same equipment and be in the same seam section and thus minimize other variables.

This test plan, however, would have required changing the adjacent hydraulic control of roof supports, reorientating the external spray system on the shearer and installation of the new ventilation system. Implementing all the changes plus retraining the face crew to operate under a different sequence of tasks was not considered practical and likely to disrupt production. The test plan, therefore, was modified to initially evaluate an antitropal face to establish baseline conditions and then follow-on with a homotropal evaluation at some later date under similar face conditions on a different panel. Old Ben, however, was able to offer Foster-Miller a site, mine no. 25, that had both a homotropal and antitropal face.

The two faces at Old Ben, no. 25, had similar stageloaders, face conveyers and shields. The extraction height was approximately 7 ft for the two faces which were both in the Herrin (no. 6) seam. The antitropal face, longwall no. 2, was equipped with an Eickhoff 300 shearer equipped with 66-in. diam cutting drums. The homotropal face, longwall no. 1, was equipped with a smaller shearer, the Joy ILS which was fitted with a 60-in. tailgate drum and 57-in. headgate drum.

The two faces, although in the same seam, did have different strata conditions. The antitropal longwall entries stood well and the shearer rarely had to mine any stone. Conditions on the homotropal longwall were slightly worse. The entries, both in the headgate and tailgate, had roof control problems. The tailgate entry, next to the rib, was heavily cribbed and posts were also used for additional support. The shearer on the homotropal face frequently had to cut some stone towards the tailgate end of the face.

3.5.2 Sampling Strategy

The evaluation on each of the two faces completed during the period July 18 to 29, 1983, consisted of the following:

a. Sampling intake dust levels upwind of the shearer

b. Sampling dust levels at the various operator positions to determine the impact of intake dust on their exposure

c. Mapping ventilation airflow patterns and dust concentrations in the headgate

d. Documenting face air velocities

e. Measuring dust concentration profiles in the walkway around the shearer.

3.5.3 Evaluation Results

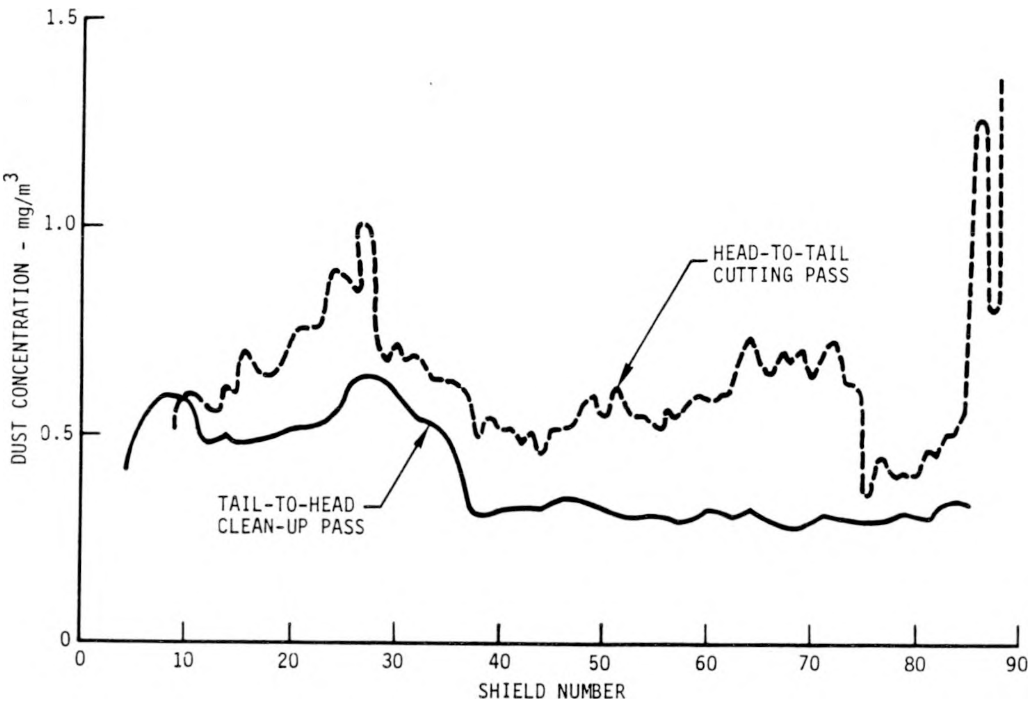
3.5.3.1 Intake Dust Concentration Data

Dust samples were taken simultaneously between the two shearer operators and in the intake (upwind of the shearer) to document the shearer operators' exposure to intake dust. On the cutting pass, the intake data were obtained immediately upwind of the shield movement. On the cleanup pass, the intake data were gathered immediately upwind from the shearer since no shield movement was taking place.

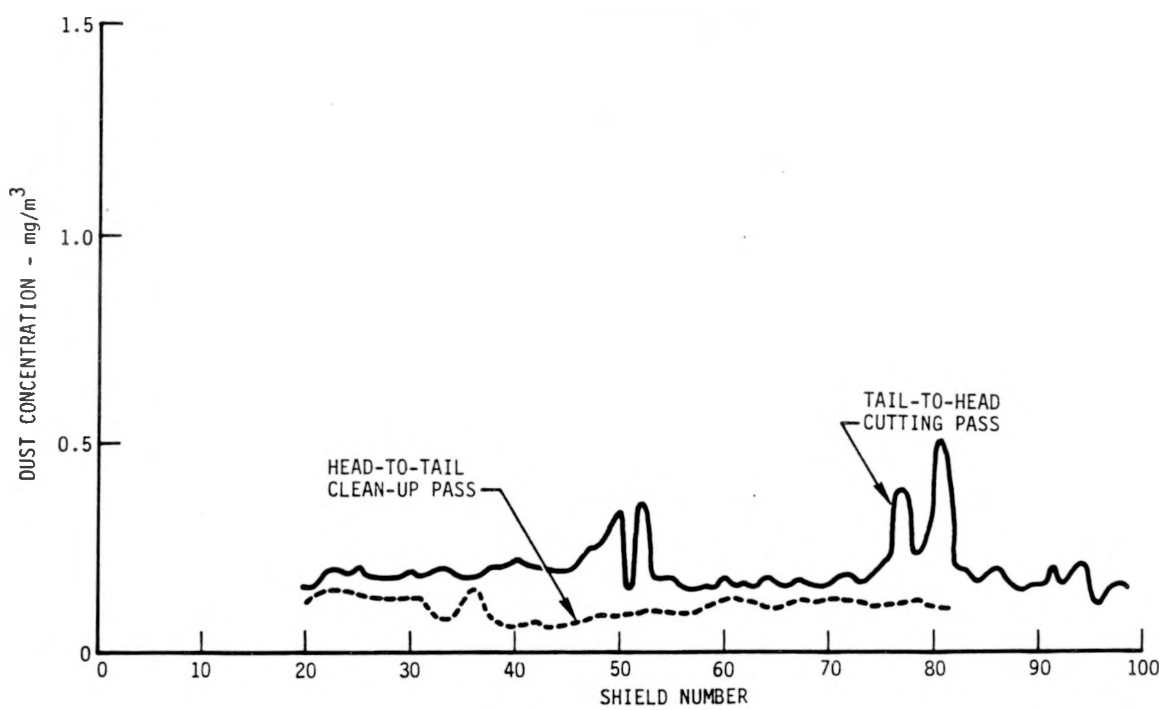
The data for two typical passes on the conventional face are plotted in figure 3 as a function of face position. The intake concentration on the cutting pass averaged 0.6 mg/m^3; on the cleanup pass, it averaged 0.25 mg/m^3. The lower concentrations on the cleanup pass are thought to be due to two factors:

a. There are less large lumps passing through the crusher on the cleanup pass.

b. The coal on the conveyor during the cleanup pass is more thoroughly wetted by the shearer water sprays.



A) CONVENTIONAL (ANTITROPAL) FACE



B) HOMOTROPAL FACE

FIGURE 3. - Comparison of face intake dust levels.

Data for two typical passes for the homotropal face are also plotted in figure 3. On the cutting pass, intake dust levels averaged approximately 0.2 mg/m^3, while on the cleanup pass they averaged 0.1 mg/m^3.

Comparing data from the two faces (table 15) shows significantly lower intake contamination on the homotropal face. Intake dust levels on the homotropal face average 60 to 70% less than those on the conventional face.

3.5.3.2 Headgate Dust Profiles

Conditions in the headgates of both faces were evaluated by mapping the dust concentrations using a RAM-1 dust sampler. A typical map for the conventional antitropal face is shown in figure 4.

On the conventional antitropal face, the dust levels in the headgate were higher than normally expected. The primary dust source appeared to be the stageloader to panel belt transfer point, in the belt entry. High concentrations of dust were also recorded in the vicinity of the headgate crusher. The dust generated by the crusher, however, had minimal effect on the headgate conditions due to rapid dilution by the intake air stream.

Conditions on the homotropal face were highly dependent on the location of the intake crosscut. When the return crosscut was inby, the stageloader operators position, the conditions in the headgate were excellent. In figure 5, the dust concentration of the intake air was below 1 mg/m^3 even though heavy concentrations of dust were present in the face air.

TABLE 15. - Comparison of average intake dust levels for the conventional and homotropal face

Pass	Conventional (antitropal) mg/m^3	Homotropal mg/m^3	Percentage improvement %
Cutting tailgate to headgate	0.6	0.2	60
Cleanup headgate to tailgate	0.25	0.1	66

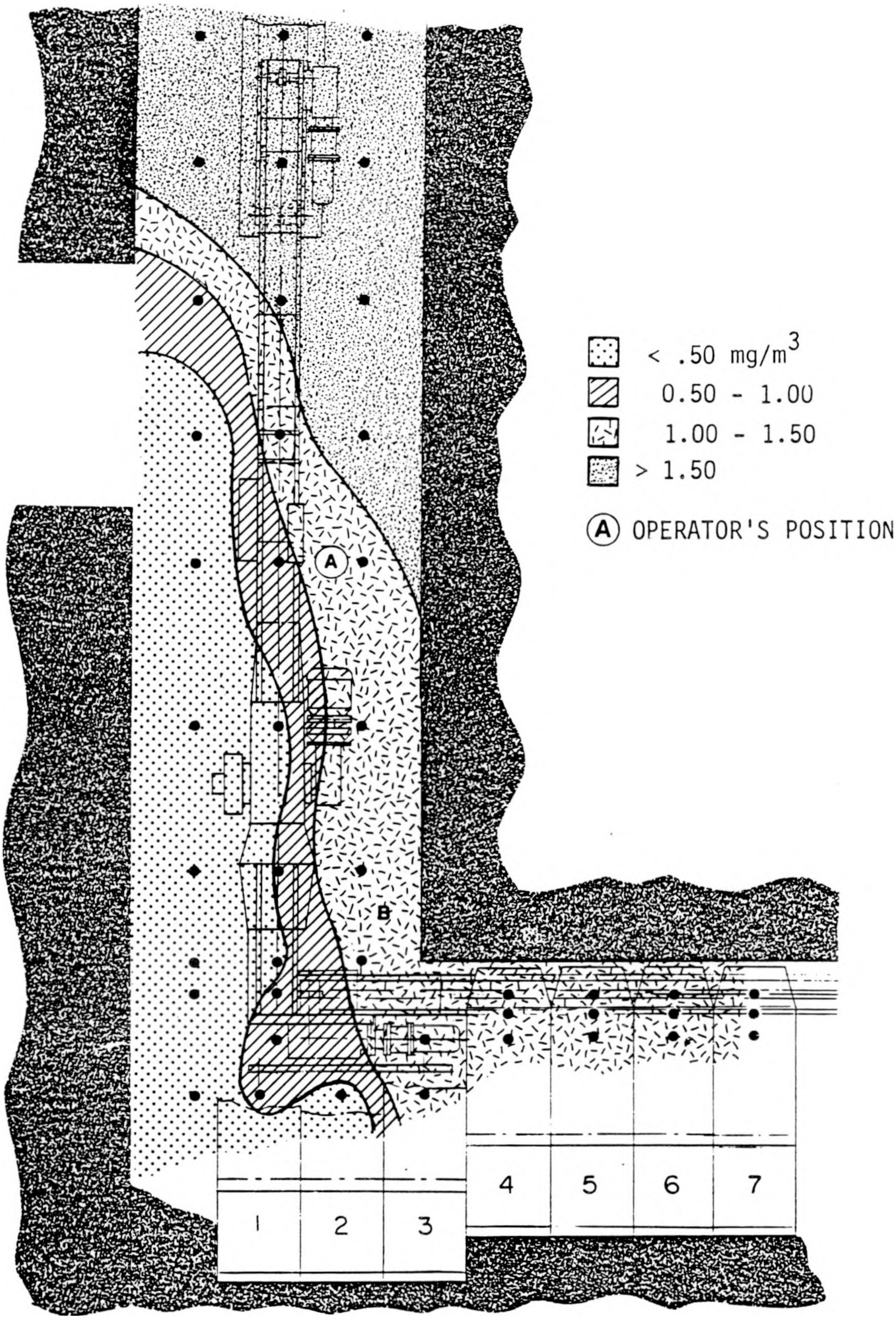


FIGURE 4. - Headgate dust concentration map, antitropal ventilation during head-to-tail (cutting) pass.

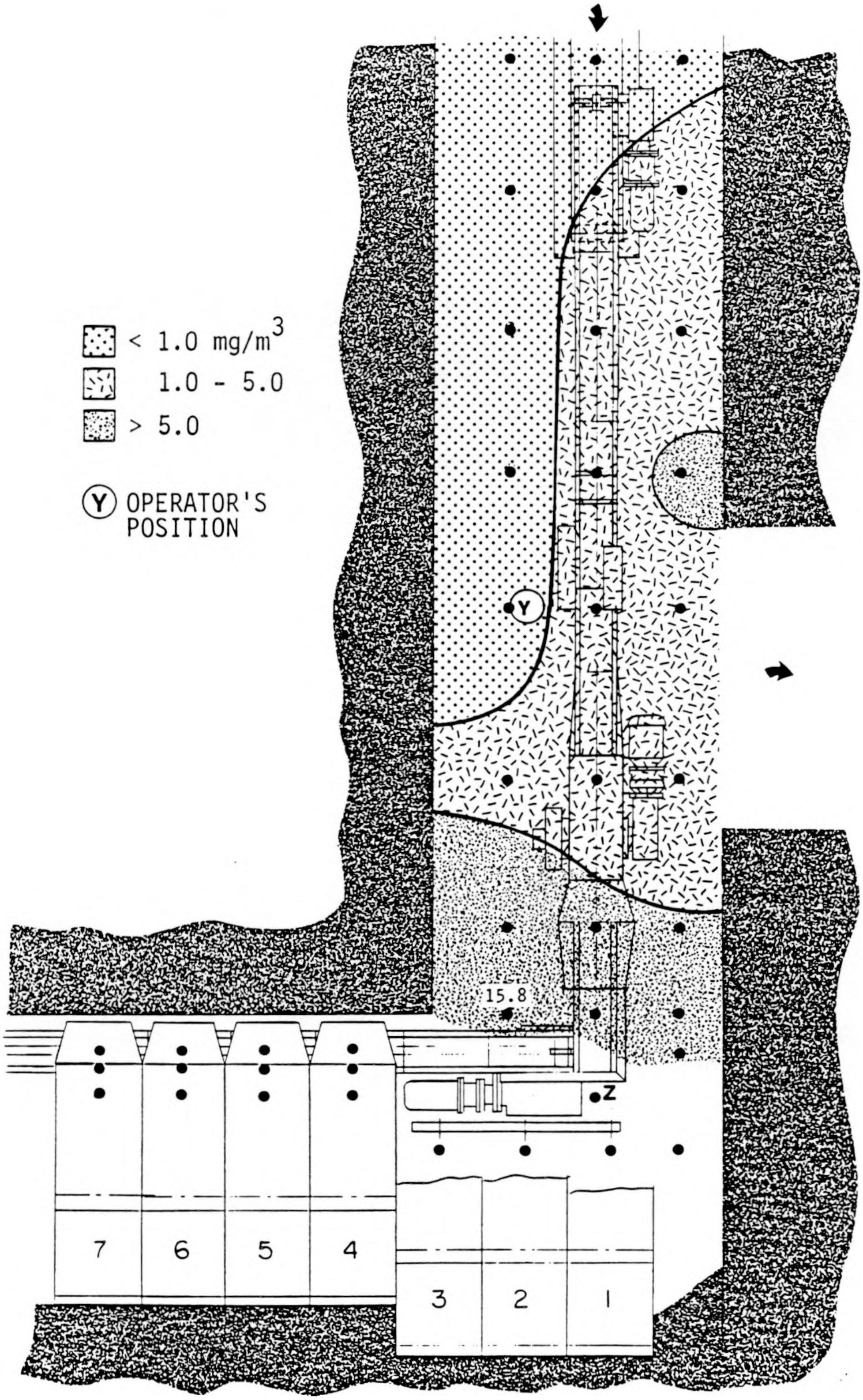


FIGURE 5. - Headgate dust concentration map, homotropal ventilation during tail-to-head (cutting) pass.

As this face advanced, the return crosscut became closed off by the gob. To maintain an airflow path to return for the face air, an outby crosscut was opened up by advancing the ventilation curtain in the second entry. The face air now flowed over the stageloader to reach the new return crosscut, thereby exposing the headgate operator to contaminated face air (figure 6). Under good conditions, this should not have occurred since the crosscut in the gob ideally would remain open.

At this mine, however, the roof conditions in the headgate had deteriorated since the start of the panel. The gob against the rib side had initially stood well but at the time of the survey would collapse close behind the supports. There was no room between the last headgate support and the rib side to build cribbing. The only cribbing that was built was in the crosscut.

In an attempt to improve conditions for the stageloader operator, a line curtain was installed by Foster-Miller to provide intake air to that location. The curtain and resulting conditions are illustrated in figure 7. Conditions greatly improved for the operator by the use of the curtain but it did interfere with his view of the stageloader delivery end onto the belt.

3.5.3.3 Summary and Conclusions of Old Ben Evaluation

The evaluation results showed that homotropal ventilation reduced intake contamination at Old Ben by 60 to 70%. The homotropal face, however, was not an ideal example of homotropal ventilation because of the gob conditions. Also, control of conditions in the headgate were difficult.

3.6 HOMOTROPAL FOLLOW-UP STUDIES

In addition to the full evaluation at Old Ben, a series of short follow-up visits to other mines using homotropal ventilation were conducted. The objective of the visits was to record the ventilation system, document any particular mining techniques implemented by the mines for homotropal ventilation and to perform a brief survey of dust and ventilation conditions.

The mines visited included:

a. Bethlehem no. 33

b. Jim Walters no. 4

c. Beth-Elkhorn no. 26L.

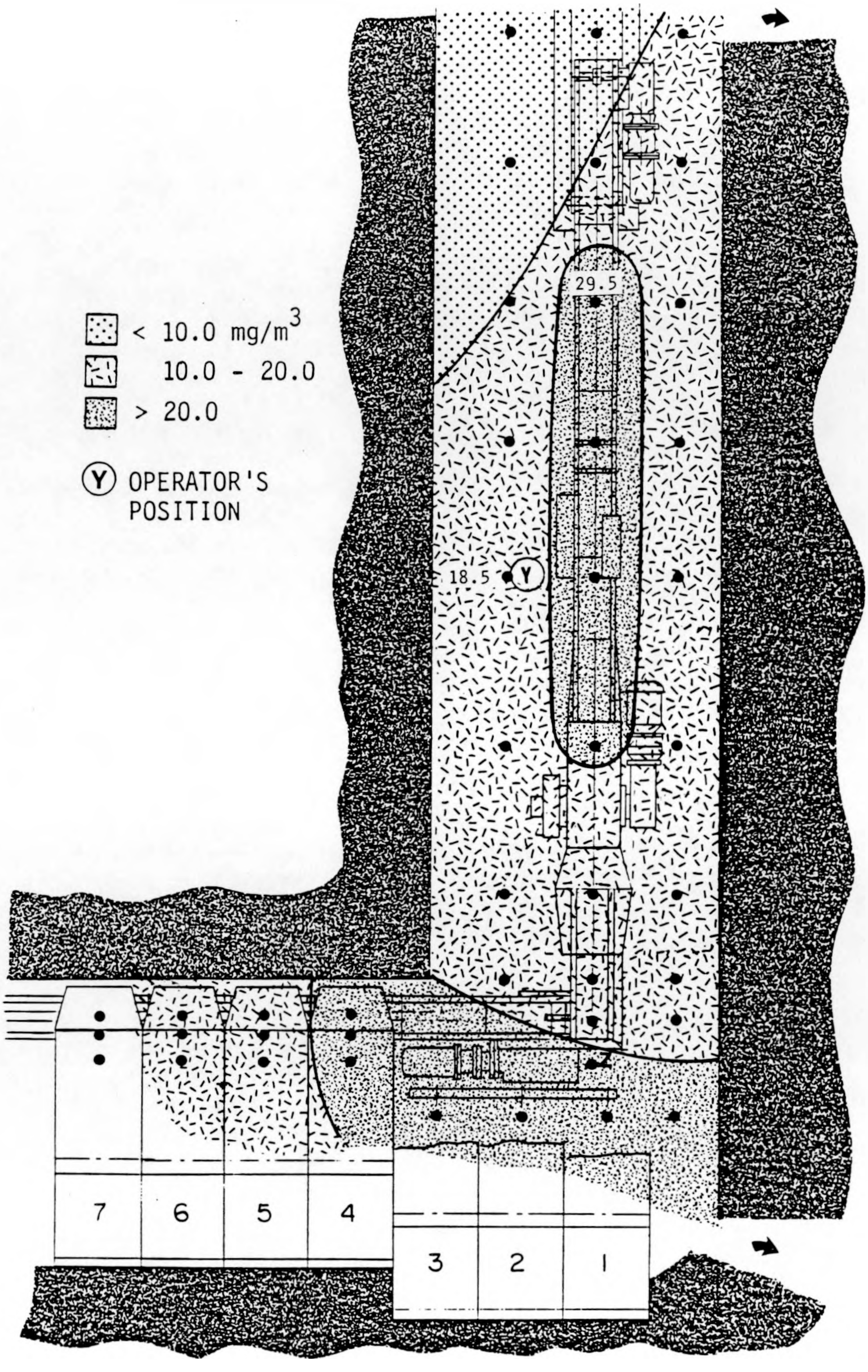


FIGURE 6. - Headgate dust concentration map, homotropal ventilation during tail-to-head (cutting) pass.

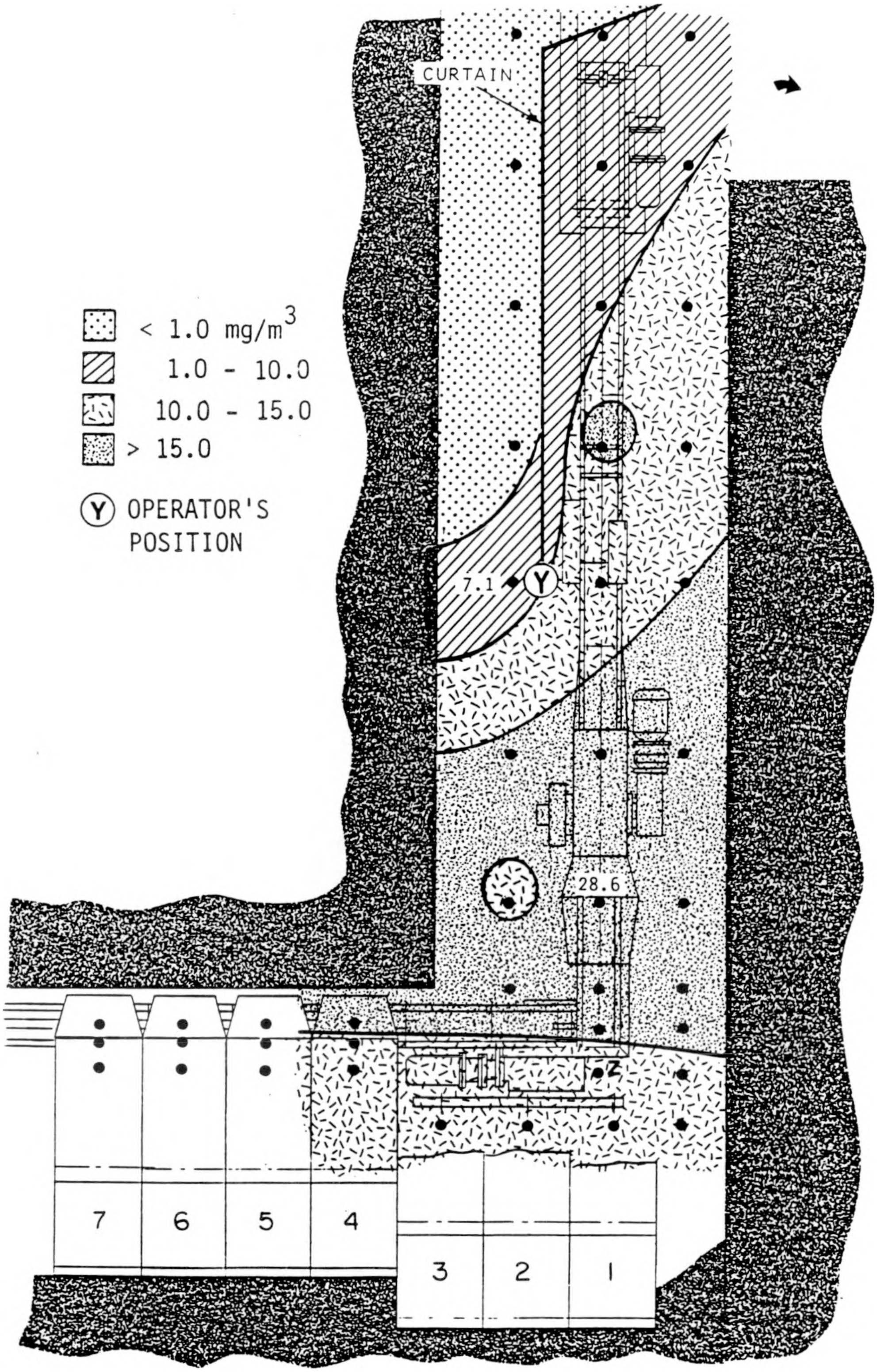


FIGURE 7. - Headgate dust concentration map, homotropal ventilation during tail-to-head (cutting) pass.

3.6.1 Bethlehem No. 33

The survey at Mine no. 33 was conducted between December 5 and 9, 1983. The shearer was a single ended fixed height rope haulage machine which cuts in both directions. The extraction height was 50 in. and the face was equipped with four-leg chocks. At the headgate end of the face, every second crosscut was broken through to route intake air down the headgate entry and over the headgate operator. Prior to each crosscut entering the gob, a substantial crib was built to support the crosscut entry. Those stoppings that remained were knocked through when the face conveyor was adjacent to the crosscut.

Ventilation surveys of the headgate were conducted with the return crosscut in the gob region. All surveys showed an average intake airflow through the headgate of 200 to 300 ft/min, giving excellent protection to the stageloader operator. The headgate air combined with face air at the end of the face and formed a combined airstream through the gob to the return crosscut.

A ventilation survey on the face monitored the air as it migrated through the chocks to the gob. It was reasoned that with the face air bleeding through the supports to the return, a region of low airflow would occur at the end of the face. The survey (figure 8) showed some decrease in ventilation velocity, but even under the worst situation, the velocity did not reduce below 100 ft/min.

Dust surveys of the headgate showed the intake dust concentration outby the stageloader/belt transfer point to be below 0.5 mg/m^3. As the air progressed up the headgate, dust levels increased slightly but remained below 1 mg/m^3.

Dust surveys of the face showed the intake dust levels averaging only 0.07 mg/m^3 during the head-to-tail pass and 0.3 mg/m^3 in the tail-to-head pass.

The face at Bethlehem no. 3 was an excellent example of homotropal ventilation. The face did not normally require any special techniques to ensure airflow into the gob. Occasionally poor headgate roof conditions require additional cribbing built between the last chock and the rib to keep the gob open.

3.6.2 Jim Walters No. 4

The survey at Mine no. 4 was conducted in conjunction with the reverse drum rotation evaluation. The survey was conducted over two separate weeks, January 16 through 20 and January 30 through February 3, 1984. The face was

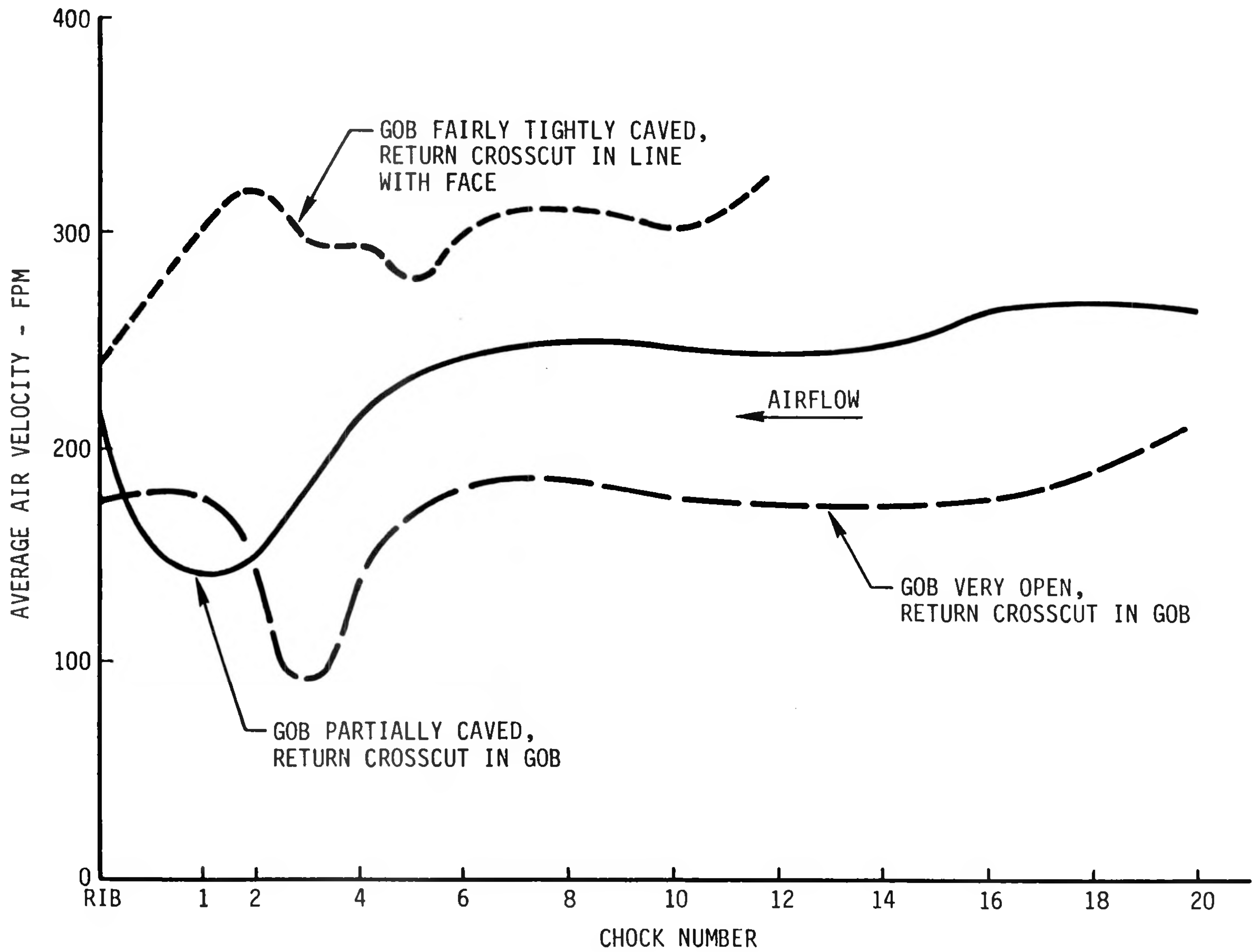


FIGURE 8. - Homotropal air velocity survey.

equipped with an AM500 double-ended ranging arm shearer fitted with 52-in. diam cutting drums. The primary cutting was from tailgate to headgate, with a cleanup pass from headgate to tailgate. The height of the face was 60 in. and it was equipped with two-leg shields. The height of the entries was 8 ft 6 in. Every crosscut was knocked through at the headgate end of the face to route intake air into the headgate.

During the survey, the return crosscut was always located adjacent to the end of the face or slightly into the gob. The crosscut was always open during the survey and was supported by three sets of concrete, wire-reinforced cribs.

The face air quantities recorded during the survey showed that the face air fluctuated from 35,600 to 60,000 cfm. The cause of the fluctuations was due to changes in the size of the opening onto the face at the tailgate. Conditions in the tailgate were temporarily abnormal due to strata control problems. The tailgate had experienced considerable roof convergence and the tailgate conveyor drive frame tended to climb. Consequently, the opening onto the face was severely reduced and its size varied depending on how effectively the shearer could cut out.

Ventilation surveys always showed a positive airflow from the auxiliary intake at the headgate. Having combined with the face airflow, no difficulty was experienced by the ventilation entering the return crosscut. Since both the face and headgate intakes originate from the same supply, fluctuations in face air quantities resulted in changes in the auxiliary headgate air.

Dust levels in the headgate ranged from 1 to 4 mg/m^3. These levels were higher than expected with no face air contamination. The reason for higher dust concentrations was the reduction in auxiliary intake air and dust sources within the headgate.

Intake dust levels for the face were measured upstream of the shearer, headgate to tailgate (cleanup pass) 0.15 mg/m^3 and tailgate to headgate (cutting pass) 0.43 mg/m^3. The intake dust levels measured during the cutting pass were higher than expected. These higher levels are suspected to be due to the face conveyor recirculating material to the tailgate during the cutting pass. With the exceptionally high velocities present at the tailgate, it is believed that some of the recirculated fraction of the respirable material became airborne.

3.6.3 Beth-Elkhorn No. 26L

The third mine visit was conducted at Beth-Elkhorn Mine 26L on March 6 to 7, 1984. The intake dust, as with other homotropal faces, was extremely low:

	Shearer cutting direction	
	Headgate to Tailgate mg/m^3	Tailgate to Headgate, mg/m
Intake dust levels	0.14	0.18

The shearer was a single-ended ranging shearer that cut in both directions. During the head-to-tail pass, the operator was exposed only to intake dust (0.14 mg/m^3). When cutting into ventilation, his exposure increased slightly to 0.51 mg/m^3. These low dust levels at the operator are largely attributable to the homotropal ventilation system.

On the first day of the survey, there was a positive airflow up the headgate providing protection to the stage loader operator. On the second day, however, the face ventilation had increased and there was less auxiliary air in the headgate. The change in ventilation conditions caused an increase in dust levels in the headgate due to less dilution.

On this face, the gob stood well and there was no apparent problem routing the ventilation into the gob. There was a 12-ft gap between the last chock and the rib side within which cribs could be built if necessary. The mine had smaller pillar sections than usual and, therefore, the return crosscut had to pass into the gob only a short distance before the next crosscut was able to become a return.

To protect the stageloader operator, his controls were positioned further outby than normal. In the event that the face had to prematurely open up a return crosscut and route face air a short way up the headgate, the operator would still be in intake air.

3.7 HOMOTROPAL EVALUATION CONCLUSIONS

The completed evaluations have clearly shown that homotropal ventilation significantly reduces intake air contamination. The majority of mines have also indicated that the system provides them with better methane control.

One key to the successful application of homotropal ventilation is the control of the auxiliary intake air to the headgate. It has to provide sufficient air to both dilute dust in the headgate and must also provide a positive airflow towards the face to prevent contaminated face air entering the headgate. The balancing of the face airflow and auxiliary airflow is critical.

Another key to the successful application of homotropal ventilation is an open return through the gob at the headgate end of the face. In several of the mines, the gob stood well enough that a path to the return crosscut was always open until the next return crosscut advanced beyond the stageloader. In other mines, cribbing was installed between the first shield and the rib to keep the gob open. In those mines, where maintaining an open gob is difficult, other techniques will need to be applied to maintain a fresh air split for the stageloader operator if homotropal ventilation is to be successfully applied.

3.8 TECHNOLOGY TRANSFER

A paper summarizing the homotropal ventilation research was prepared and presented during the course of this subprogram. The paper covered the complete scope of the homotropal study and discussed the significant reductions in intake dust observed at the Old Ben evaluation as well as the practical operational techniques implemented on the homotropal longwalls surveyed during the follow-up studies. The technology transfer conference selected for the presentation was the Coal Mine Dust Conference sponsored by West Virginia University on October 9, 1984. The paper presented to the conference is provided in appendix a.

4. ASYMMETRICAL CUTTING DRUMS

4.1 OBJECTIVE

In addition to homotropal ventilation, the modeling task described in section 2 quantified the potential dust reduction benefit of asymmetrical cutting drums. The reduction is achieved through the application of a small cutting drum on the upwind ranging arm which cuts less coal, thereby generating less dust, which may pass over the operators' positions. The majority of the cutting (and dust generation) is transferred to the larger drum on the downwind ranging arm.

The objective of this task was to investigate the applications, define the limitations, and evaluate the effectiveness of asymmetrical cutting drums.

4.2 ACTUAL OPERATING EXPERIENCE

During the development of the mining cycle model, the Bureau identified the use of asymmetrical cutting drums as a beneficial technique during a field study. The face highlighted in the survey was Barnes and Tucker Coal Co., Lancashire No. 20 Mine. They originally introduced the large/small drum concept for reasons other than dust control. They had experienced difficulty in training their shearer operators to steer the machine within the seam. The introduction of a large downwind drum, the same size as the seam, enabled them to use one operator and eased machine steering. The mine soon began to appreciate the dust control benefits for the shearer operator. They also found that the use of two unequal sized drums did not appear to have any detrimental effects on the shearer. No vibration effects were detected and the use of the asymmetrical drums did not result in decreased machine reliability.

The method of operation at Barnes and Tucker is illustrated in figure 9. Cutting into ventilation, the shearer takes the middle of the coal seam with the leading small cutting drum. The large trailing drum cuts and loads the coal remaining in the roof and floor. When cutting with ventilation, the leading large drum extracts the whole coal seam and no contribution is required from the small upwind trailing drum. The benefits of this method are:

a. Dust exposure is reduced for the operator.

    1. Cutting into ventilation, the volume of coal extracted by the small upwind drum is less than with a conventional size drum.

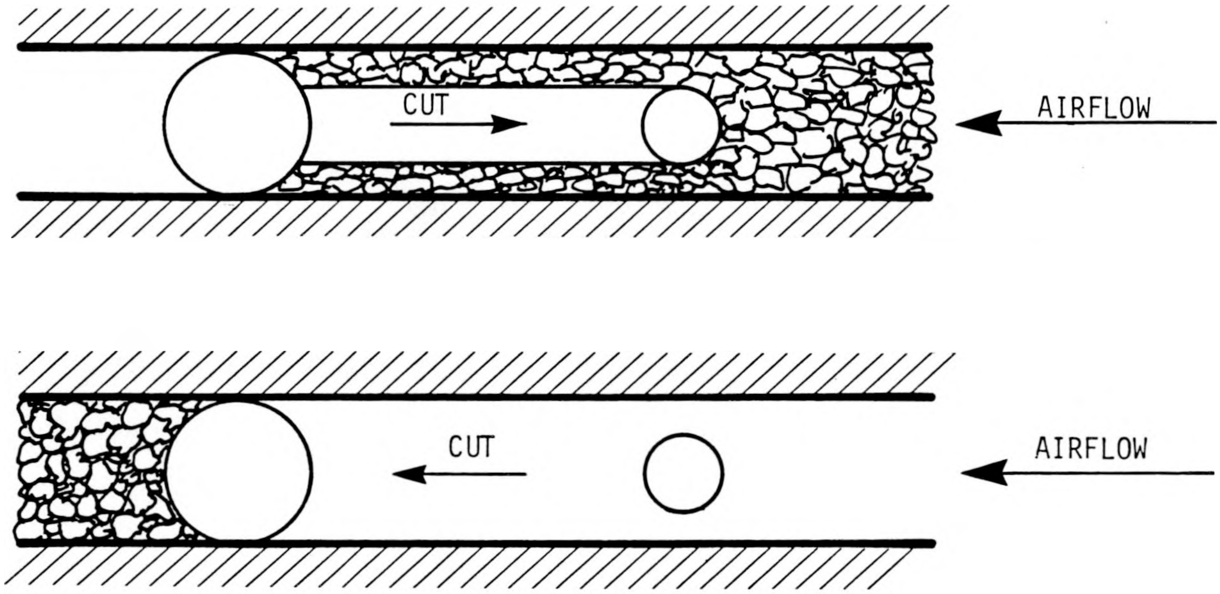


FIGURE 9. - Asymmetrical drum application - Barnes and Tucker.

2. Cutting with ventilation, all material is cut with the large downwind drum.

b. Steering of the shearer within the seam is simplified because the extraction height is fixed and the operator has to follow the seam with one drum only.

c. This method of operation requires only one operator who controls the large drum ranging arm.

A limitation to this method is that the large drum diameter is the same size as the seam height and it, therefore, requires a seam of constant thickness.

In the field survey of homotropal mines, one mine interviewed had briefly attempted to implement asymmetrical cutting drums. The attempt was not considered successful and the mine reverted back to conventional size drums. The problem that arose was that when the small drum was leading, the remaining roof coal would fall. Thus, the small drum was actually extracting as much coal as a conventional drum.

4.3 FEASIBILITY STUDY OF ASYMMETRICAL DRUMS

Several mine operators expressed concern as to whether the mechanical reliability of the shearer would be impaired by using unequal sized cutting drums. According to Barnes and Tucker personnel, there were no detrimental effects on their shearer.

The application of asymmetrical drums at Barnes and Tucker, while successful under their conditions, may not be as successful in thicker seams. The thin seams at Barnes and Tucker allowed taking the full seam height with the downwind drum and the type of shearer allowed the use of a very small drum on the upwind side. In thicker seams this type of application may not be possible.

The size of the large/small cutting drums have certain practical constraints on their maximum and minimum sizes. On the large size drums the peripheral speed should be limited to 600 ft/min if problems with material recirculation are to be avoided. Limiting the peripheral speed to 600 ft/min and using a practical minimum rotational speed of 30 rpm give a maximum drum diameter of 76 in. for the large drum.

The minimum diameter of the small drum is dependent on the hub size of the ranging arm. Since most manufacturers have an epicyclic final reduction gearbox in the hub of most ranging arm, the minimum drum size is quite large (46 to 54 in. depending on the type of shearer).

In the thicker seams it is desirable to load the majority of the coal onto the conveyor with the headgate cutting drum. Thus the material does not have to pass through the limited aperture of the shearer underframe which can result in stop-pages and reduce shearer haulage speed. The large drum, therefore, should be located on the headgate side of the shearer. The face ventilation then should be from tailgate to headgage (homotropal) to position the shearer operators upwind of the larger drum.

The maximum and minimum sizes of the two drum diameters are approximately 76 and 50 in., respectively. If these size drums were used to replace a standard set of 60 in. drums on an average United States face of 7 ft seam height, the change in amount of coal cut by the upwind drum on a homotropal face can be calculated (table 16). This is the maximum change that could be expected. By applying large/small drums, 66 percent less cutting is performed upwind of the shearer operators during a tail-to-head pass.

TABLE 16. - Improvements obtained by applying asymmetrical drums

Cutting direction	Seam section cut by headgate drum	Seam section cut by tailgate drum	Percentage reduction in seam section taken by small drum
Tailgate-to-headgate	60 in. conventional drum	24 in. conventional drum	(16 in.) 66%
	76 in. large drum	8 in. small drum	
Headgate-to-tailgate	24 in. conventional drum	60 in. conventional drum	(10 in.) 17%
	34 in. large drum	50 in. small drum	

During cutting from headgate-to-tailgate, the use of a large/small drum reduces the amount of coal extracted by the upwind drum by only 17 percent. In many cases, such a small improvement would be undetectable. In addition, if the smaller drum cuts the seam section next to the roof, the distance that the cut coal falls to the conveyor is greater. This increase in height may tend to produce more airborne dust, thus reducing the gain from cutting 17 percent less coal.

5. HEADGATE VENTILATION PARAMETERS

5.1 BACKGROUND

In the course of the field evaluations conducted on many Bureau programs, it has been shown that the "Shearer Clearer" and passive barriers can reduce operator exposure to shearer-generated dust by confining the dust cloud to the face. These systems, particularly effective on faces where the primary ventilation exceeds 250 ft/min, have been applied on a significant number of United States faces.

During underground evaluations of these systems, there was an apparent degradation of performance towards the headgate end of the face. This degradation occurred whether the shearer is cutting towards the headgate or towards the tailgate. While this section of the cutting cycle is a small fraction of the total, the high increase of dust concentrations measured can significantly increase operators' full shift exposures.

This increase in dust levels at the headgate end of the face is thought to be caused by a drop in primary airflow velocity, turbulence, and dead air zones. At the headgate, on faces ventilating from head-to-tail, the intake air is coursed through a crosscut, up the headgate entry, and around the corner onto the face. When the gob is not tight, a significant fraction of the ventilation enters the gob, flows behind the shields, and re-enters the face further downstream. The loss of air to the gob causes much lower ventilation velocities on the headgate end of the face. On many faces, this reduced ventilation zone extends down the face several shields.

On most faces, the face conveyor ramps up to discharge onto the stageloader. The face conveyor, therefore, blocks the primary ventilation flow path. This obstruction, coupled with the primary air being forced to change direction to enter the face, causes turbulence and dead air zones. This turbulence, dead air zones, and lower velocities due to gob losses make control of the shearer-generated dust cloud difficult. Measurements underground on shearers equipped with Shearer Clearer and passive barriers have shown dust levels several times higher than those measured further down the face.

Ventilation curtains installed between the first shield and the rib have been shown to significantly reduce air loss to the gob which increases air velocities at the headgate end of the face. While the use of a gob curtain does improve conditions, dust levels are still much higher than those measured further down the face with a Shearer Clearer operating. The turbulence and dead zones created by the face conveyor obstruction and the ventilation air turning the corner make confinement of the dust cloud difficult, and further improvement is needed.

5.2 OBJECTIVE

The objectives of this portion of the subprogram were to determine the impact of operating parameters and to develop techniques which will improve face airflow and respirable dust concentrations at the headgate end of longwall shearer faces. In addition to respirable dust, methane dilution was also investigated to the extent that dust controls developed under this subprogram impact airflow and methane gas buildup.

The study included a baseline evaluation of airflow patterns and dust concentration profiles over a range of primary ventilation quantities and gob leakage rates. After baseline data were established, improved control methods were developed and evaluated.

5.3 EVALUATION TECHNIQUES

The study was conducted in Foster-Miller's full-scale longwall test facility which included a headgate entry complete with a model stageloader, a ramped face conveyor and simulated airflow leakage to the gob. The facility is illustrated in figure 10.

A fan and ductwork network designed to accurately model and control gob leakage was installed opposite the headgate entry as shown in figure 10. The tracer gas release points were modified to represent dust/gas generation locations for each direction of cutting as illustrated in figure 11.

An array of tracer gas sampling points was installed in three horizontal planes in order to evaluate the following critical ventilation zones:

a. Headgate drum

b. Tailgate drum

c. Face side of the shearer body

d. Headgate operator

e. Tailgate operator.

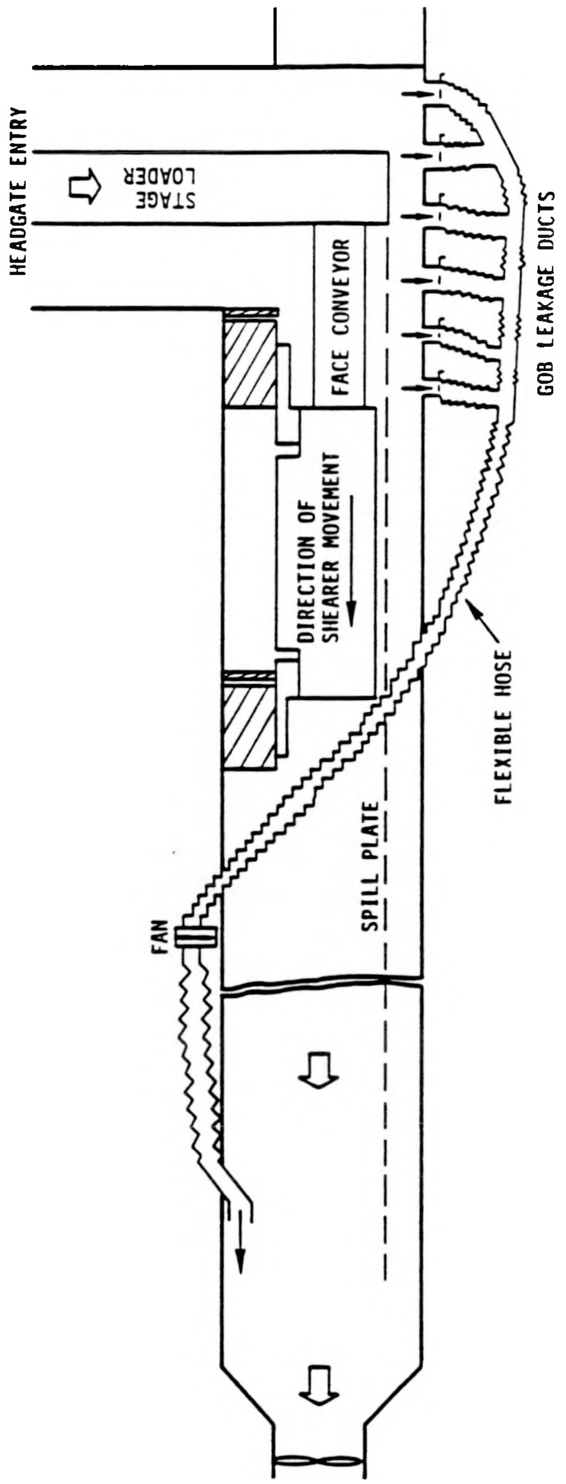


FIGURE 10. - Longwall test gallery layout (showing gob leakage ducts).

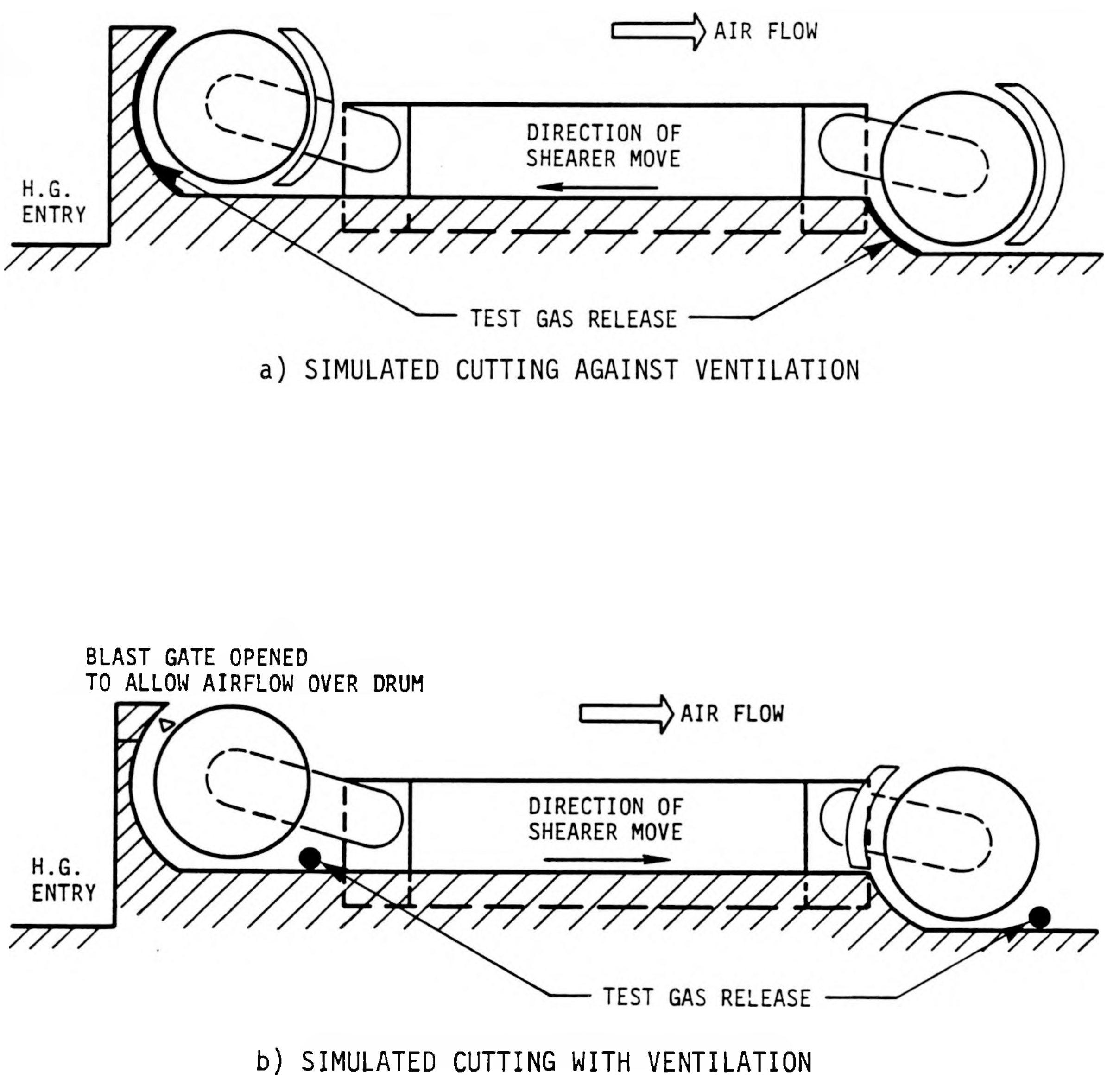


FIGURE 11. - Tracer gas release points for each direction of cutting.

The locations of the sampling points and the various zones are presented in figure 12. A cross section is included to show the vertical sampling locations.

An average concentration of the sampling locations within each zone was used to evaluate the level of contaminants in each area. The sampling volumes used to evaluate each zone are shown in figure 12 and described below:

a. Headgate drum zone - A six-point sampling volume between the splitter curtain and the headgate drum

b. Tailgate drum zone - A twenty-one point, three-tier sampling volume around the tailgate drum

c. Face side - The volume enclosed by the two drums, shearer body and face was divided into three volumes. The three volumes being:

   1. 0 to 8 ft from the headgate drum
   2. 8 to 16 ft from the headgate drum
   3. 16 to 24 ft from the headgate drum.

Tracer gas concentrations from twelve points in three vertical horizons were taken to evaluate each of the above volumes.

a. Headgate operator - Four point sampling volume near the headgate control station

b. Tailgate operator - Four point sampling volume near the tailgate control station.

The results from individual sampling points were also used to plot concentration profile maps of critical ventilation zones in three horizontal and one vertical plane. A typical concentration map is presented in figure 13. The concentration profile maps were used to locate potential ventilation problems and to assess the impact of mitigation techniques in improving them. Specifically, analysis of these maps resulted in a thorough understanding of:

a. Areas with little or no ventilation ("dead zones")

b. Flow patterns

c. Operator contamination problems.

Documentation of dead ventilation zones was considered very important in order to prevent high levels of methane gas buildup. Operator contamination levels were monitored with regard to respirable dust exposure.

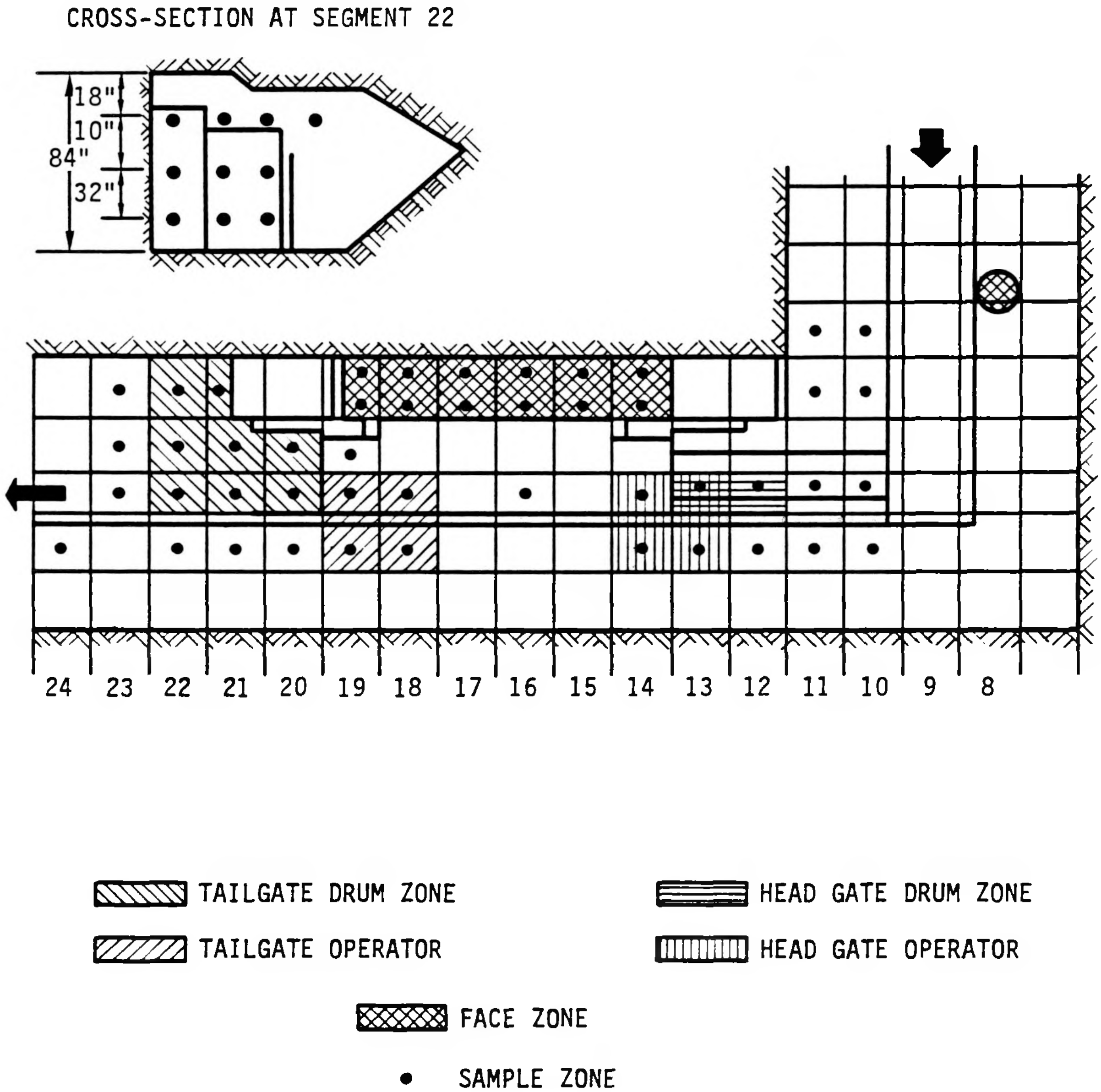


FIGURE 12. - Plan of longwall gallery showing sampling point location.

METHANE MAP

DATE: 12/15 1984 TEST NO. 34 TEST ENGINEER: ________ BM 8148

PRIMARY AIRFLOW: 12,285 CFM

GOB LEAKAGE: ☒ NO ☐ YES (______ CFM)

WING CURTAIN: ☐ IN PLACE ☒ NOT PRESENT

SHEARER CLEARER: ☒ OFF ☐ ON (_____ PSI, _____ GPM)

DRUM SPRAYS: ☐ OFF ☒ ON (100 PSI, 11 GPM)

OBSERVATIONS: WALKWAY CURTAINS IN PLACE

CUTTING AGAINST AIRFLOW

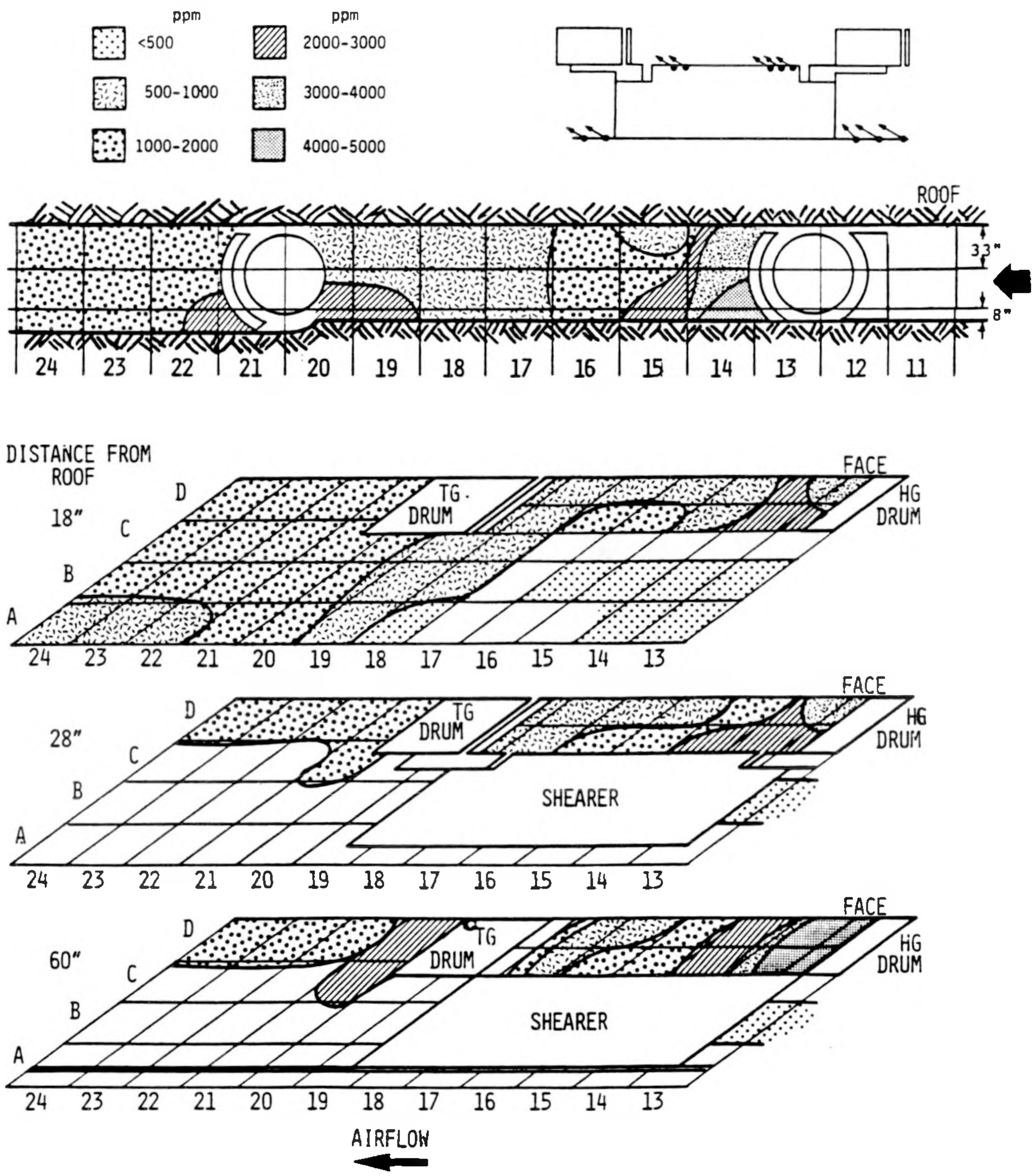


FIGURE 13. - Tracer gas concentration map.

Physical flow patterns were documented with smoke tubes and velocity profiles. These techniques were applied throughout the evaluation series to confirm or screen out conditions of promising techniques for further detailed tracer gas documentation.

5.4 BASELINE TESTING

The objective of the baseline testing was to determine the effects of primary ventilation quantity, gob leakage rate, and other headgate conditions on the ventilation patterns and dust distribution at the headgate end of the face. Baseline testing was conducted with the shearer cutting towards the headgate and then repeated with the shearer cutting towards the tailgate.

Tests were conducted varying one test parameter at a time, normally under two spray conditions:

a. Drums rotating with drum sprays operating at 100 psi water pressure

b. Baseline (as in a. above) with a Shearer Clearer spray system at 150 psi water pressure.

Baseline testing, under condition a., resulted in the identification of the ventilation and cutting cycle parameters under which the extent of dead zones and operator contamination levels increased. Baseline testing under condition b. (with the Shearer Clearer in operation) was conducted to reassess the condition a. results after attempting to improve the ventilation with a known technique. It was reasoned from past research that the Shearer Clearer system could significantly increase the ventilation flow around the shearer body and reduce the extent of dead-air zones, while reducing dust contamination levels in the walkway.

In the following sections, the impact of several major variables affecting headgate area ventilation patterns are assessed. They include:

a. Cutting direction

b. Primary airflow quantity

c. Gob leakage

d. Changes in shearer body profile.

Each section contains a brief description and summary of the tests conducted. Test results are presented in table form with average gas concentrations.

5.4.1 Cutting Direction

Each cutting direction (with and against the airflow) was evaluated with the baseline drum and Shearer Clearer spray systems. While cutting towards the headgate (against the primary airflow), the full web gas release was utilized as shown in figure 11a. The cowls were positioned on the downwind side of the cutting drums. The cowls were repositioned to simulate the start of the head-to-tail cleanup cut (with the primary airflow). While cutting with the airflow, a blast gate in the headgate entry was opened to allow airflow over the drum as if the breakout into the entry had occurred. The tracer gas was released at the positions indicated in figure 11 for each direction of cutting. All cutting direction tests were conducted with a primary airflow of 12,000 cfm. Table 17 presents the average gas concentrations from all zones monitored.

With only drum sprays in operation, it is evident that dead zones exist in both directions of cutting along the face side of the shearer and downstream of the tailgate gearhead unit. The results indicate that the potential for methane gas buildup is high in both directions of cutting but worse while cutting against the airflow, especially in the tailgate zone. Operation of the Shearer Clearer system provides additional air for dilution in all dead zones and significantly reduces the methane gas buildup. However, the gas concentrations immediately downstream of the headgate drum are still high.

Contamination levels at the operators' positions are much higher when cutting against the airflow with only the drum sprays operating. The Shearer Clearer system reduces the dust (gas) concentrations in each cutting direction at both operators' positions, except in the case of the tailgate operator when cutting with the airflow.

In conclusion, cutting toward the headgate entry (against the airflow) presents a more difficult ventilation situation both from a dust standpoint at the operators' positions and from a methane accumulation standpoint on the face side and downstream of the shearer body. Similar zones of inadequate ventilation exist while cutting with the airflow. However, the dust levels at the operators' positions are not nearly as high.

5.4.2 Quantity of Primary Airflow

This test series was conducted to determine the impact of primary airflow volume on dust contamination at the operators' positions and gas buildup around the shearer body while in the headgate area. Primary airflow

TABLE 17. - Effect of cutting direction

Cutting direction		Cutting with airflow Average tracer gas concentration (ppm)						Cutting against airflow Average tracer gas concentration (ppm)					
Drum sprays 100 psi	Shearer clearer 150 psi banks 1-4	Operator's TG zone			Face side			Operator's TG zone			Face side		
		HGO	TGO	21 point	0-8 ft	8-16 ft	16-24 ft	HGO	TGO	21 point	0-8 ft	8-16 ft	16-24 ft
Yes	No	50	258	3206	+5000	4425	3550	825	1763	+5000	+5000	4753	+5000
Yes	Yes	20	477	814	2548	1387	917	60	238	1586	3530	1577	1193

quantities of 7,500, 12,000, and 24,000 cfm were evaluated cutting with the flow, while 7,500 and 12,000 cfm were evaluated cutting against the direction of primary airflow. All tests were repeated with both baseline spray systems, drum sprays operating at 100 psi and the Shearer Clearers system operating at 150 psi.

The results presented in table 18 show that an increase in primary airflow will reduce "dust" concentrations at both operators' positions with either spray system through increased dilution. However, no discernible improvements take place in the size (or intensity) of the continuous volumes on the face side and downstream of the shearer body. These dead zones are physically sheltered or obstructed from the path of the ventilating air, and an increase in flow volume (and velocity) has no impact such as scruffing or eddying which could help to reduce the gas buildup. As in the previous test series (table 17), operation of the Shearer Clearer system significantly improved the conditions, but the relative impact of the airflow increase with the system operating was the same.

In conclusion, this test series determined that airflow had to be directed into the dead zones which exist around the shearer body in the headgate area. A simple increase in volume had no impact.

5.4.3 Air Leakage into the Gob

As discussed earlier, a significant fraction of the ventilating air can enter a gob area which is not tightly consolidated, resulting in reduction of air available in the headgate area. As previously presented in figure 10, a network of ductwork was installed into the shield line opposite the headgate entry to extract controlled quantities of airflow, thereby simulating various gob leakage conditions.

Several tests were conducted at different primary airflows, with and without gob leakage, with both baseline spray systems in operation. Results from four representative test areas are presented in table 19.

As indicated in table 19, a primary airflow of 17,000 cfm, with gob leakage of 5,000 cfm, gave similar results to a primary airflow of 12,000 cfm without gob leakage. The concentration profile maps of the headgate area also supported the conclusion that gob leakage simply had the same effect as reducing the primary airflow along the face. The results from this test series resulted in the elimination of gob leakage as a variable in future tests.

TABLE 18. - Effect of primary airflow quantity

		Drum sprays 100 psi Average tracer gas concentration (ppm)						Shearer clearer 150 psi banks 1-4 Average tracer gas concentration (ppm)					
		Operator's TG zone			Face side			Operator's TG zone			Face side		
Cut direction	Airflow (cfm)	HGO	TGO	21 point	0-8 ft	8-16 ft	16-24 ft	HGO	TGO	21 point	0-8 ft	8-16 ft	16-24 ft
With	7500	123	600	3162	+5000	4583	4353	35	543	1415	2830	1185	891
With	12000	50	258	3206	+5000	4425	3550	20	477	814	2548	1387	917
With	24000	55	188	2344	4507	2477	2096	5	365	973	+5000	1213	864
Against	7500	1913	2918	+5000	+5000	+5000	+5000	213	675	1916	2496	1266	1848
Against	12000	825	1763	+5000	+5000	4753	+5000	60	238	1586	3530	1577	1193

TABLE 19. - Effect of gob leakage

		1200 cfm primary airflow No gob leakage Average tracer gas concentration (ppm)			17000 cfm primary airflow 5000 cfm gob leakage Average tracer gas concentration (ppm)		
Drum sprays 100 psi	Shearer clearer 150 psi banks 1-4	HGO	TGO	Tailgate drum zone 10 pt average	HGO	TGO	Tailgate drum zone 10 pt average
Yes	No	42	215	3469	42	285	3506
Yes	Yes	17	450	1212	22	500	1198

5.4.4 Changes in the Profile of the Shearer Body

The previous baseline tests had identified zones around the shearer with little ventilation. One of these areas was downstream of the tailgate gearhead unit. Many shearers in operation have a large chunk breaker installed on the tailgate gearhead. This short test series was designed to assess the impact of a chunk breaker altering the profile of the shearer body and the resultant ventilation pattern. A full-size mockup of a chunk breaker was fabricated and installed on the tailgate end of the shearer body. Tests were conducted at a primary airflow of 12,000 cfm while cutting with the airflow with both baseline spray systems.

As shown in table 20, the presence of the chunk breaker had little effect on the dead zone downstream of the shearer body. The impact was one of simply shifting the poorly ventilated zone further downstream.

Once again, the Shearer Clearer improved the concentrations at all positions except the tailgate operator.

5.5 DEVELOPMENT AND EVALUATION OF IMPROVED CONTROL TECHNIQUES

Once baseline testing was completed and the impact of major baseline variables was established, the efforts to develop improved headgate ventilation control techniques were initiated.

The control techniques which were evaluated fall into the following major categories:

a. Ventilation curtains

b. Passive barriers

c. Airmoving water sprays

d. Altered mining practices.

The intent of each technique was to direct ventilating air into the poorly ventilated zones identified during the baseline tests. Within each category, one or more variations of the technique were tested under the appropriate combination of test conditions. Once again, the test results are summarized in table form with average gas concentrations.

TABLE 20. - Effect of shearer body profile

Chunk breaker		No chunk breaker Average tracer gas concentration (ppm)						Chunk breaker installed Average tracer gas concentration (ppm)					
		Operator's TG zone			Face side			Operator's TG zone			Face side		
Drum sprays 100 psi	Shearer clearer 150 psi banks 1-4	HGO	TGO	21 point	0-8 ft	8-16 ft	16-24 ft	HGO	TGO	21 point	0-8 ft	8-16 ft	16-24 ft
Yes	No	50	258	3206	+5000	4425	3550	125	218	2600	4888	4425	3550
Yes	Yes	20	477	814	2545	1387	917	10	455	780	2548	2545	917

5.5.1 Ventilation Curtains

Several configurations of ventilation curtains were evaluated during this test series including:

a. Wing curtain

b. L-shaped wing curtain

c. Ventilation curtain in the walkway

d. Two walkway ventilation curtains.

Although most of the tests involved the evaluation of only one curtain technique at a time, they are all illustrated in figure 14 for brevity. Tests were conducted at a primary airflow volume of 12,000 cfm with both baseline spray systems. In all cases, the curtain technique evaluated was intended to redirect ventilating air by restricting the cross-sectional area thereby selectively channeling airflow while increasing the air velocity.

The results of this test series are summarized in table 21. Test nos. 1 and 2 present the baseline results of drum sprays and the Shearer Clearer system in operation while cutting with and against the airflow.

The results of the wing curtain evaluation (see test no. 3) indicated that although the curtain effectively redirects the headgate entry airflow, the resultant ventilation pattern does not have any effect on the tracer gas concentrations on the face side of the shearer body. This is true with either baseline spray system - drum sprays or the Shearer Clearer - in operation. It should be pointed out, however, that the wing curtain has been proven effective in significantly reducing dust concentrations at the shearer operators' positions during the breakthrough into the headgate entry. It was not the intention of this evaluation to reconfirm this effect nor could it be properly modeled in a laboratory test facility.

A modified version of the wing curtain - an L-shaped wing curtain - was evaluated since it is frequently used on longwalls for dust control during the headgate cutout. Its configuration allows users to roll up the free end as the face retreats in order to avoid having to relocate the curtain with each pass. It was evaluated to assess the potential for gas accumulation within its enclosure and to identify any potential benefit on ventilation around the shearer body. Two different tracer gas release patterns were used. During test no. 4, tracer gas was released at the headgate corner and at the web release of the trailing drum. As shown in table 21, like the standard configuration of the wing curtain, no appreciable change in face side concentrations was monitored with either spray system. However, the concentration within the

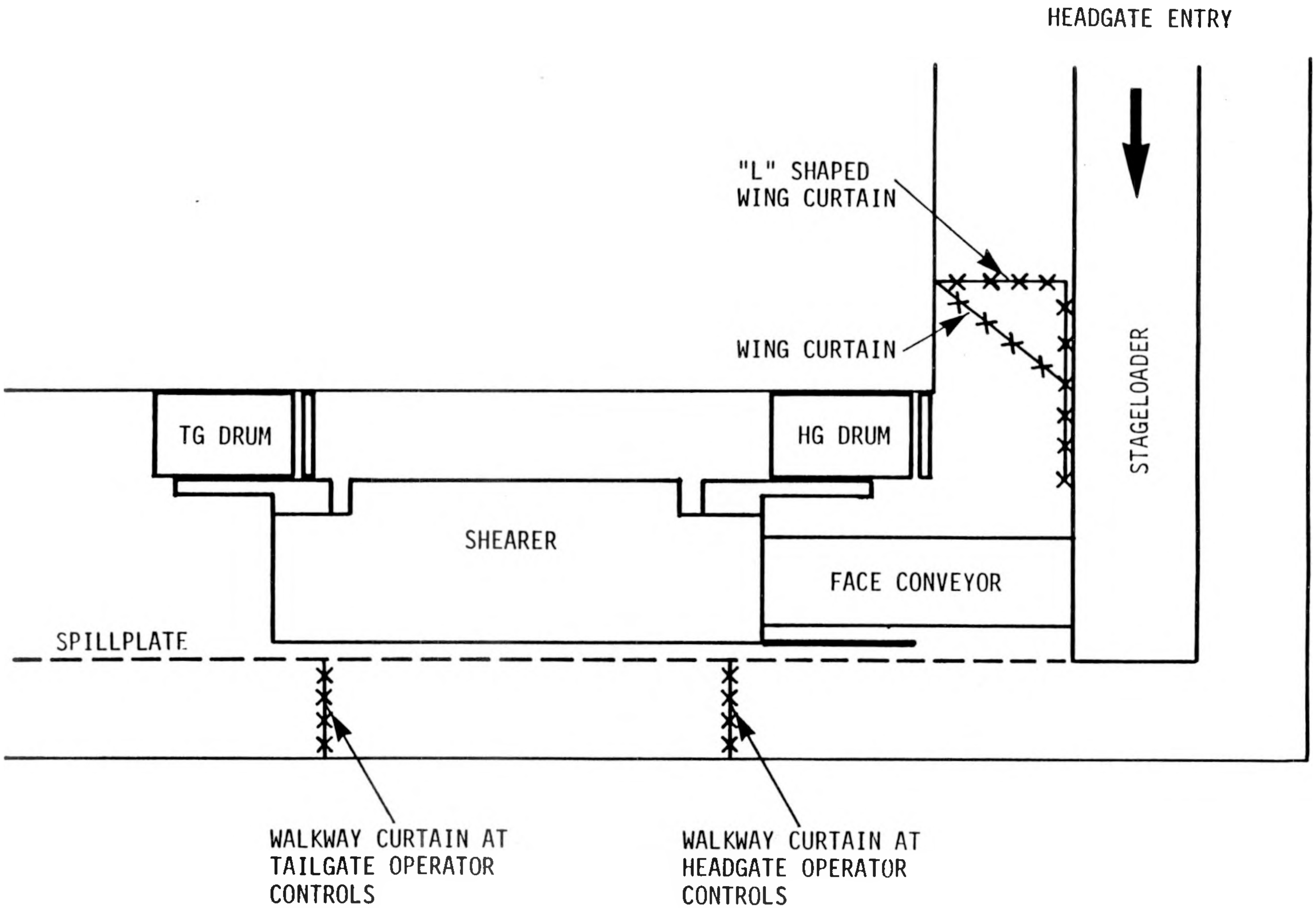


FIGURE 14. - Ventilation curtains.

TABLE 21. - Effect of ventilation curtains

Test no.	Cutting with airflow	Cutting against airflow	Curtain			Drum sprays, 100 psi Average tracer gas concentration, ppm						Shearer Clearer banks 1 to 4, 150 psi Average tracer gas concentration, ppm					
			Wing	L-shaped wing	Walkway	Operator's TO zone			Face side			Operator's TO zone			Face side		
						HOO	TOO	21 point	0 to 8 ft	8 to 16 ft	16 to 24 ft	HOO	TOO	21 point	0 to 8 ft	8 to 16 ft	16 to 24 ft
1	X					50	258	3,206	+5,000	4,425	3,550	20	417	814	2,548	1,387	917
2		X				825	1,763	+5,000	+5,000	4,753	+5,000	60	238	1,586	3,530	1,577	1,193
3		X	X			800	1,920	-	+5,000	+5,000	+5,000	68	360	-	2,545	1,227	1,012
4		X		X		1,763	2,210	+5,000	4,907	4,664	+5,000	135	450	1,468	-	1,186	980
5		X			X	20	782	1,924	3,177	1,558	1,671	5	235	1,395	2,095	1,107	800
6	X				X	5	803	1,340	2,562	1,223	772	13	528	1,261	2,125	1,102	735

curtained off area (not shown in table 21) did rise to 3,388 ppm. Operation of the Shearer Clearer system reduced this accumulation to 1,018 ppm. These results would suggest that a gassy mine should re-evaluate or closely monitor the use of an L-shaped wing curtain for dust control since it has the potential for accumulating a methane gas buildup. Another test (not presented in table 21) was conducted with the tracer gas release in the headgate drum cutting zone simulating conditions just before the headgate cutout. This test showed no measurable buildup of tracer gas within the curtained area.

The walkway curtain shown in figure 14 was hung perpendicularly across the walkway from a shield in line with the headgate operators' controls just prior to the breakout into the headgate entry. Since it effectively blocked the largest cross-sectional opening for the primary airflow (12K cfm), the resultant velocities over the shearer body exceeded 1,000 fpm. As a result, the impact of this curtain with the baseline drum sprays in operation was very similar to that of the full Shearer Clearer system in both directions of cutting along the face and tail sides of the shearer body. Although concentrations at the headgate operators' position were comparable, the level of contamination at the tailgate operators' position was significantly higher. With the Shearer Clearer in operation cutting against the airflow, the curtain further improved the ventilation in all face side zones, the tailgate area, and at the headgate operator position. When cutting with the airflow, the curtain produced only marginal improvements in all face side and headgate operators concentrations while causing a 50% increase in the tailgate zone concentrations. In an attempt to reduce the contamination at the tailgate operators' position, a single test was conducted with two curtains installed in the walkway as shown in figure 14. The results (not shown in table 21) indicated that the second curtain installed at the tailgate operators' position had no effect on the contamination at that location and in fact created recirculation in the walkway between the curtains. In summary, the single walkway curtain installed at the headgate operators' position provided nearly the same level of ventilation in the headgate area as the Shearer Clearer system.

5.5.2 Passive Barriers

Baseline testing had identified the area downstream of the tailgate gearhead unit as being poorly ventilated in both directions of cutting. The Shearer Clearer system did direct a large quantity of air over the shearer body and through this zone; however, pockets of high concentrations still remained directly over the panline just inby the gearhead. Since the Shearer Clearer was founded on the concept of a clean/dirty airsplit, passive barriers or splitters were used on the headgate and tailgate ends of the shearer body as illustrated in figure 15 during the tests. The volume around the headgate drum bounded by the headgate splitter was well ventilated. However, as previously mentioned, the volume below the shearer body bounded by the tailgate splitter was not well ventilated. It was reasoned that perhaps more airflow would be induced into the zone if the tailgate splitter were removed.

The results of this comparison are shown in table 22. The tests were conducted with a primary airflow of 12,000 cfm with both baseline spray systems with and without the tailgate splitter in place. The results relative to each baseline spray system showed little change in concentration downstream of the tailgate gearhead with or without the barrier in place. Removal of the barrier did not allow any additional airflow from the walkway to enter and ventilate the zone.

All of the Shearer Clearer testing to this point had resulted in varying degrees of improvement in all critical zones except the tailgate operator position. At this position, the airmoving power of the system created a rebound of contaminated air off the face and tail drum cowl into the walkway at the tailgate end of the shearer body. During the test series on ventilation curtains, it was noted that the use of the walkway curtain in

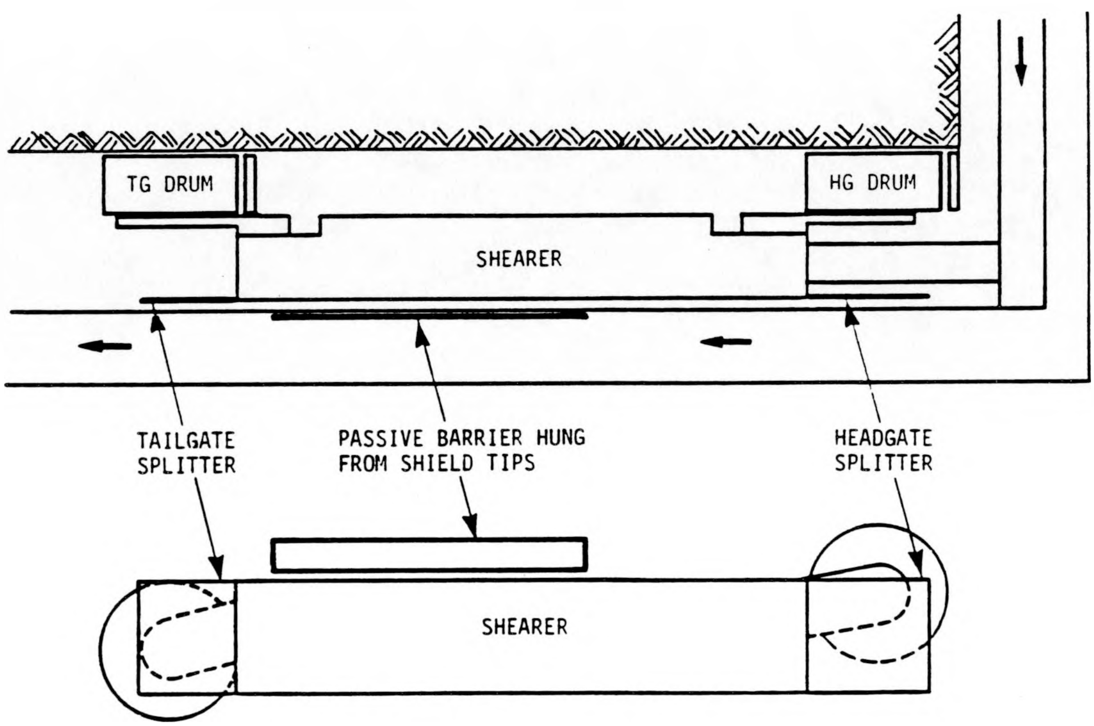


FIGURE 15. - Passive barriers.

TABLE 22. - Effects of passive barriers

Tailgate splitter	Passive barrier from shield tips	Drum sprays, 100 psi Average tracer gas concentration, ppm						Shearer clearer, 150 psi Average tracer gas concentration, ppm					
		HOO	TOO	21 point	0 to 8 ft	8 to 16 ft	16 to 24 ft	HOO	TOO	21 point	0 to 8 ft	8 to 16 ft	16 to 24 ft
X		60	195	3,539	-	-	-	20	492	803	-	-	-
		50	258	3,206	-	-	-	20	477	814	-	-	-
	X			with walkway curtain				0	325	-	-	-	-

conjunction with the Shearer Clearer resulted in further improvement in all of the critical zones on the face and tail sides of the shearer. However, the dust contamination at the tailgate operators' position did not improve. Since the results in all other zones were positive, it was determined that a barrier to shield the tailgate operator from the rebound effect should be evaluated. As presented in figure 15, a brattice cloth barrier (approximately 1 ft high x 10 ft long) was hung from the shield tips in the vicinity of the tailgate operator with the shearer approaching the headgate entry. The intended effect of the airflow pattern of the walkway curtain and the barrier is illustrated in figure 16. Test results (see table 22) showed a slight decrease in "dust" contamination from the use of the barrier but not enough to suggest its use underground.

5.5.3 Airmoving Water Sprays

Previous Bureau research on the Sprayfan (continuous miner ventilation) and Shearer Clearer (longwall shearer dust control) had established the fact that water sprays move air like small fans. Since the ventilating abilities of the Shearer Clearer system had been well documented, it was included as one of the baseline test conditions. It was reasoned that the system could be used as a starting

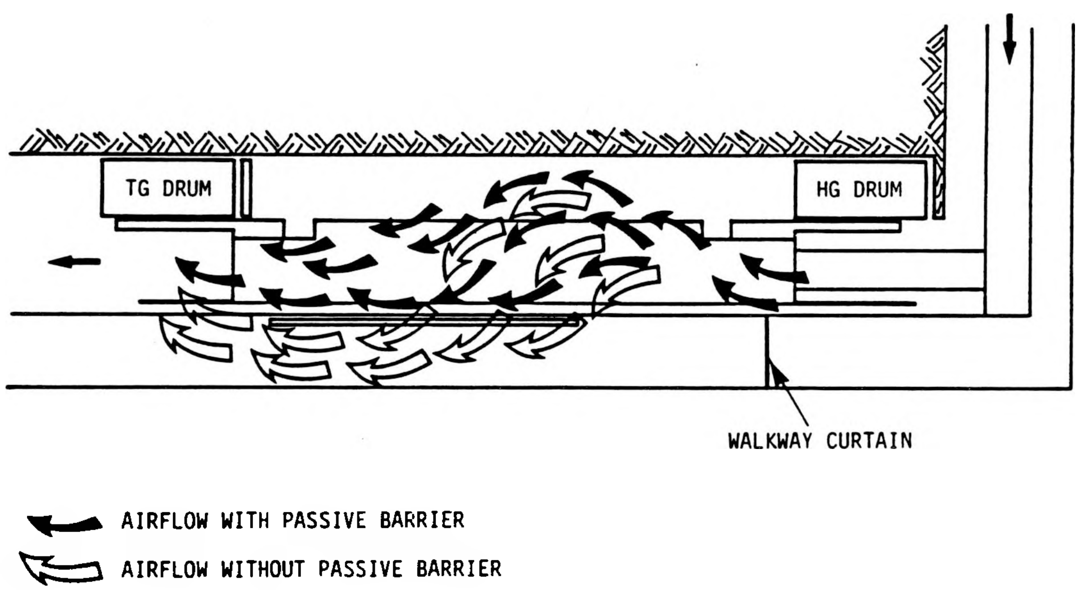


FIGURE 16. - Effect of passive barrier suspended from shield tips.

point for ventilation of the dead air zones identified during the baseline testing. Building upon the airmoving principles, three additional subsystems were evaluated, including:

a. Additional sprays (three) at the tailgate splitter/shearer interface (hollow cone BD 20-3 nozzles)

b. Crescent sprays mounted on the tailgate ranging arm (flat fan H 1/4 VV5008 nozzles)

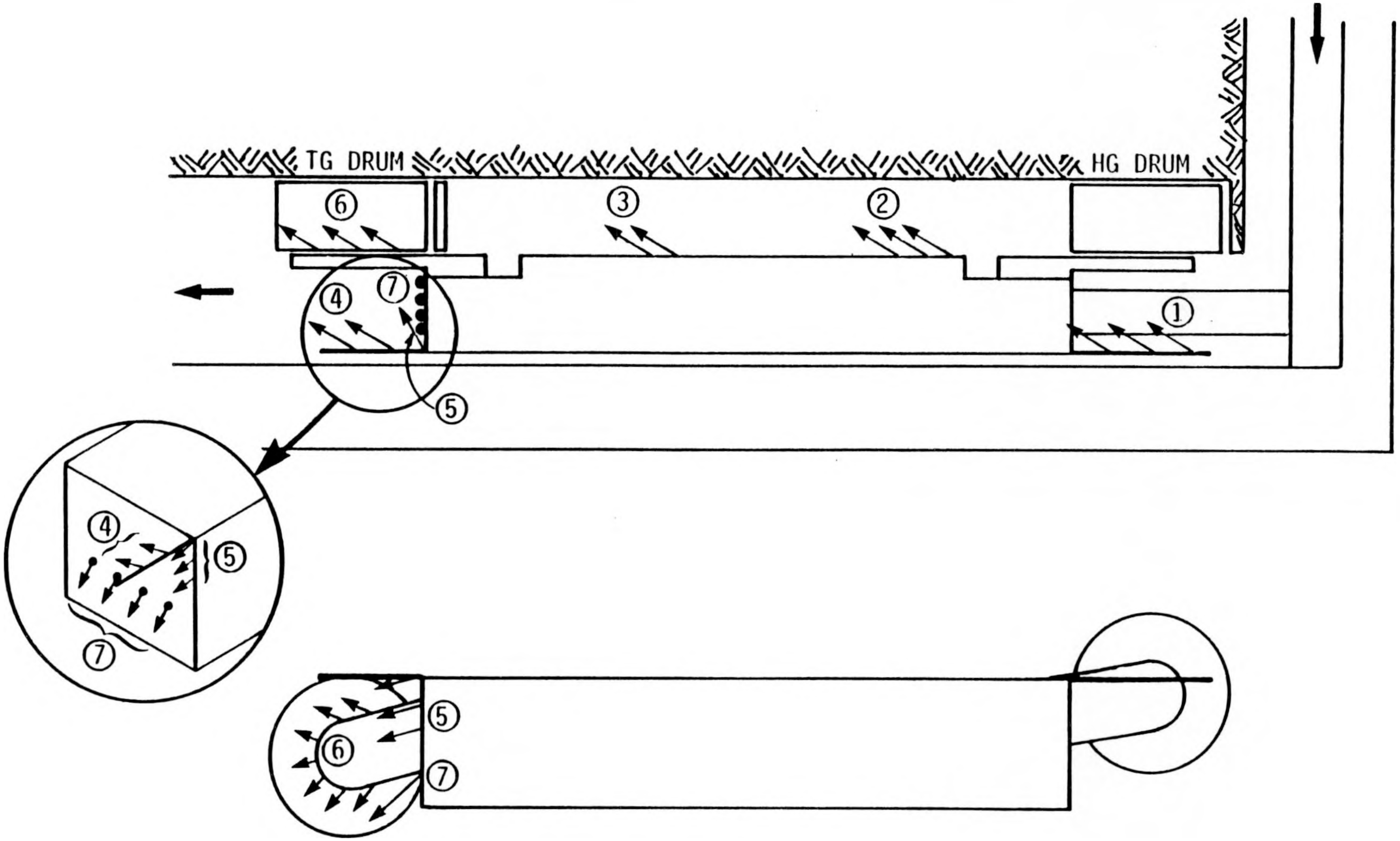
c. Cooling water spray nozzles discharging into the panline (hollow cone BD 20-10 nozzles).

All of the subsystems are illustrated along with the Shearer Clearer system in figure 17. The intent of all three was to select a practical mounting location and direct additional air into the poorly ventilated volume on the tail side of the shearer body.

The average tracer gas concentrations for the entire test series are presented in table 23. The primary airflow was held constant at 12,000 cfm. Several combinations of the baseline drum sprays and Shearer Clearer were evaluated in conjunction with the three subsystems. Test nos. 1 and 2 present the baseline concentrations for comparison purposes.

The additional sprays at the tailgate splitter/shearer interface were oriented to ventilate the volume behind the shearer body not affected by the Shearer Clearer system. As indicated in table 23, operation of this subsystem resulted in a marked decrease in the concentration of accumulated methane within the 21 point volume of the tailgate zone. This was true with both the baseline drum spray and the Shearer Clearer systems. Concentrations of dust contamination at the tailgate operators' positions did increase however. Operation of the flat fan crescent sprays with the drum sprays substantially decreased the tracer gas concentrations at the tailgate operator and drum zones. The impact of the crescent sprays was negligible when operated in conjunction with the Shearer Clearer sprays.

Since the cooling water is sometimes discharged onto the panline for dust suppression, it was reasoned that the water sprays may be used to mix and dilute the gas accumulation in the tailgate zone. The cooling water was discharged onto the panline from various heights on the tailgate gearhead unit. Although additional turbulence was created, there was little impact on the tracer gas concentrations.



①-④ SHEARER CLEARER SYSTEM

⑤ ADDITIONAL TAILGATE SPRAYS

⑥ RANGING ARM CRESCENT SPRAYS

⑦ COOLING WATER DISCHARGE SPRAYS

FIGURE 17. - Airmoving water sprays.

TABLE 23. - Effect of airmoving sprays

Test no.	Drum sprays, 100 psi	Shearer clearer, 150 psi	Three additional sprays, 150 psi	Crescent sprays, 150 psi	Cooling water	Cutting with airflow: Average tracer gas concentration, ppm						Cutting against airflow: Average tracer gas concentration, ppm					
						Operator's TO zone			Face side			Operator's TO zone			Face side		
						HOO	TOO	21 point	0 to 8 ft	8 to 16 ft	16 to 24 ft	HOO	TOO	21 point	0 to 8 ft	8 to 16 ft	16 to 24 ft
1	X					50	258	3,206	+5,000	4,425	3,550	825	1,763	+5,000	5,000	4,753	+5,000
2	X	X				20	477	814	2,548	1,387	917	60	238	1,586	3,530	1,577	1,193
3	X		X			-	-	-	-	-	-	741	2,273	2,731	+5,000	+5,000	+5,000
4	X	X	X			30	495	660	-	-	-	68	400	969	2,172	-	1,405
5	X				X	58	85	1,914	-	-	-	-	-	-	-	-	-
6	X	X			X	20	463	822	-	-	-	-	-	-	-	-	
7	X	X				20	385	878	-	-	-	-	-	-	-	-	-

In summary, this series showed that the additional tailgate sprays had a significant impact on the methane gas accumulation in that zone. More importantly, the use of the subsystem complemented and improved the baseline conditions of the Shearer Clearer system except for a slight increase in the tailgate operators' contamination when cutting against the airflow.

5.5.4 Altered Mining Practices

When the shearer is starting the head-to-tail cut, the cowls are rotated to the upwind side of the cutting drums shielding the drum from the primary airflow. Since the tailgate drum zone was poorly ventilated, it was reasoned that perhaps an alteration of the normal cowl position would allow additional airflow between the drum and the ranging arm. Figure 18 shows the new position of the cowl over the tailgate drum. This configuration was evaluated cutting with the airflow at a ventilation volume of 12,000 cfm. In addition to testing with both baseline spray systems, the Shearer Clearer was tested in conjunction with the additional tailgate sprays developed during the previous test series.

Table 24 presents the results of the tests with the tailgate cowl in both the normal (lowered) and altered (raised) cowl position. The modified mining practice of raising the cowl resulted in an increase in gas concentrations over all comparable previous tests with the cowl in the normal (down) position. Operation of the Shearer Clearer reduced the concentration by 50% (over drum sprays only) but this level was still over twice that

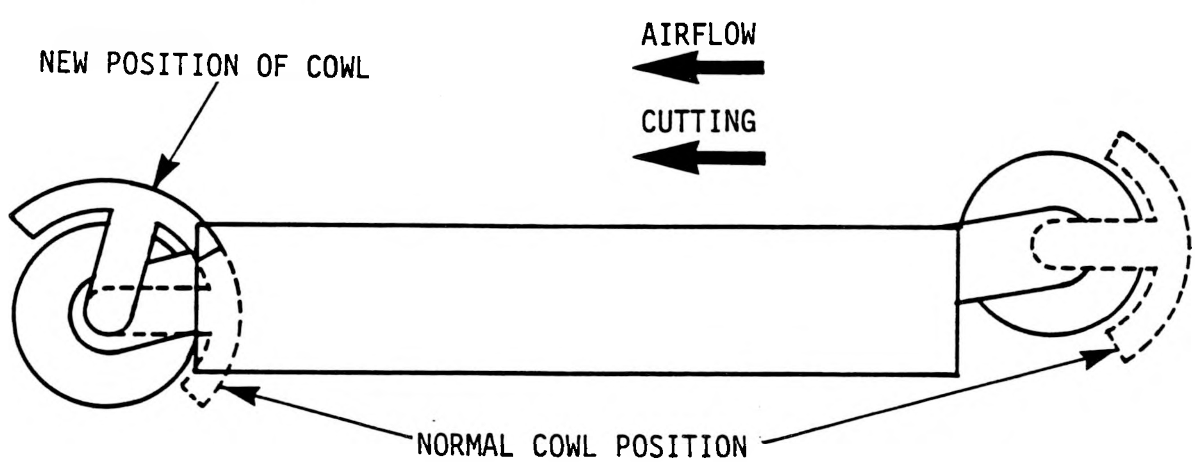


FIGURE 18. - Altered position of tailgate cowl.

TABLE 24. - Effect of altered cowl position

Cowl position	Drum sprays, 100 psi	Shearer clearer, 150 psi banks 1-4	Additional tailgate sprays, 150 psi	Average tracer gas concentration, ppm		
				Operator's TG zone		
				HGO	TGO	21 point
Up	X			98	965	3,964
Down	X			50	258	3,206
Up	X	X		25	283	2,004
Down	X	X		20	477	814
Up	X	X	X	25	330	813
Down	X	X	X	30	495	660

with the cowl down. It is interesting to note that the concentration at the tailgate operator position decreased slightly with the Shearer Clearer in operation. This may be a result of the induced face side airflow meeting less resistance (with the cowl raised) and not rebounding back into the walkway at the tailgate operator position.

5.6 EVALUATION SUMMARY

The objective of this development and evaluation effort was to identify the control techniques most effective in improving the ventilation around the shearer while in the headgate area. The baseline test series located the zones surrounding the shearer body which were not adequately ventilated including the face and tail side of the machine. These volumes are sheltered from the primary ventilation and consequently could develop pockets of high dust and gas concentrations. With the shearer in the headgate area, both directions of cutting (with and against the primary airflow) required improved ventilation in similar zones around the shearer body. Increases in the primary airflow surprisingly had no impact on the dead air zones. Gob leakage had the simple effect of increasing concentrations as much as new resultant airflow without gob leakage would. With no improvements emerging from variations in baseline parameters, the research effort turned toward development of control techniques.

The intent of the control techniques examined was to direct ventilating air into the critical zones identified earlier and reduce the concentrations without creating a dust problem in the walkway. Four major categories of techniques were evaluated. No single technique or category could adequately address all of the poorly ventilated zones but the use of airmoving water sprays produced the largest percentage improvements. The combination of control techniques which most effectively improved the headgate area ventilation while compromising between adequate dust and gas control follows:

a. Shearer Clearer spray system

b. Additional airmoving sprays at the tailgate gearhead

c. Walkway ventilation curtain hung perpendicular to the face in line with the headgate operators' controls.

Table 25 summarizes the test results from all critical zones in a comparative fashion with the most effective control techniques in both directions of cutting. Table 26 presents the percentage improvements over baseline conditions resulting from the use of the control techniques shown in table 25.

TABLE 25. - Effect of headgate ventilation control techniques

Test no.	Airflow (cfm)	Drum sprays, 100 psi	Shearer clearer, 150 psi banks 1-4	Three additional sprays, 150 psi	Walkway curtain	Average tracer gas concentration, ppm						
						Operator's TG zone			Face side			
						HGO	TGO	21 point	0 to 8 ft	8 to 16 ft	16 to 24 ft	
1	12,000	Yes	No	No	No	825	1,763	+5,000	+5,000	4,753	+5,000	
2	12,000	Yes	Yes	No	No	60	238	1,586	3,530	1,577	1,193	
3	12,000	Yes	Yes	Yes	No	68	400	969	2,172	-	1,405	Cutting against airflow
4	12,000	Yes	Yes	No	Yes	5	235	1,395	2,075	1,107	800	
5	12,000	Yes	Yes	Yes	Yes	0	363	1,162	2,182	1,158	1,011	
6	12,000	Yes	No	No	No	50	258	3206	+5,000	4,425	3,550	
7	12,000	Yes	Yes	No	No	20	477	814	2,548	1,387	917	
8	12,000	Yes	Yes	Yes	No	30	495	660	-	-	-	Cutting with airflow
9	12,000	Yes	Yes	No	Yes	13	528	1,261	2,125	1,102	735	
10	12,000	Yes	Yes	Yes	Yes	13	480	706	1,533	975	657	

TABLE 26. - Percentage improvement in headgate ventilation with control techniques

Test no.	Airflow (cfm)	Drum sprays, 100 psi	Shearer clearer, 150 psi banks 1-4	Three additional sprays, 150 psi	Walkway curtain	% improvement (+), % deterioration (-)						
						Operator's TG zone			Face side			
						HGO	TGO	21 point	0 to 8 ft	8 to 16 ft	16 to 24 ft	
1	12,000	Yes	No	No	No	-	-	-	-	-	-	Cutting against airflow
2	12,000	Yes	Yes	No	No	93	87	68	29	67	76	
3	12,000	Yes	Yes	Yes	No	92	77	81	57	-	72	
4	12,000	Yes	Yes	No	Yes	99	87	72	59	77	84	
5	12,000	Yes	Yes	Yes	Yes	100	79	77	56	76	80	
6	12,000	Yes	No	No	No	-	-	-	-	-	-	Cutting with airflow
7	12,000	Yes	Yes	No	No	60	(-)85	75	49	69	74	
8	12,000	Yes	Yes	Yes	No	40	(-)92	79	-	-	-	
9	12,000	Yes	Yes	No	Yes	74	(-)105	61	58	75	79	
10	12,000	Yes	Yes	Yes	Yes	74	(-)86	78	69	78	82	

6. DOWNWIND DUST EVALUATION

While many mines in the United States use unidirectional cutting to minimize the number of personnel working downwind of the shearer, a significant number cut bidirectionally. On a bidirectional face, jacksetters work downwind of the shearer for at least half of every cutting cycle and can be subjected to significant quantities of shearer-generated dust. In addition, shearer operators can be subjected to dust from upstream shield movement.

Through an underground study conducted on an operating United States longwall, the Bureau has evaluated respirable dust conditions downwind of the shearer during tail-to-head cutting and downwind of shield movement during head-to-tail cutting. The objective was to document the migration and gradients of respirable dust traveling downwind on the longwall face and to provide guidelines for minimizing the dust exposures of downwind personnel in these situations.

The details of this effort, including results and conclusions, were reported in a paper prepared for the Bureau entitled, "Optimizing the Relationship Between the Shearer and Shield Movement to Minimize Personnel Dust Exposures." This paper is presented in its entirety in appendix b.

7. EXPERT SYSTEMS TECHNOLOGY TRANSFER

The results of longwall research completed during the past several years has been made available to the coal mining industry in various forms including Bureau publications, journal articles, and conference presentation. In spite of this transfer of technology, many longwalls have not made effective use of the information. Usually the reason for this is that mine personnel are not aware of or do not understand all of the variations in technology suitable to their specific problems. This degree of knowledge can be expected only from an expert or consultant in the particular field of interest.

It is not realistic to expect that an "expert" can survey each United States longwall and make the appropriate recommendations. There is, however, a viable alternative in a type of computer program called an expert system. Expert systems are sophisticated computer programs designed to approximate the process of problem solving employed by a human expert by drawing on a vast store of specialized knowledge. This knowledge base is created by collecting and storing detailed information in the field in which the system will operate.

In the longwall mining application, the knowledge base, including use of judgment, rules of thumb, and experience, needed to make decisions and recommendations concerning mine specific applications of appropriate control technology is made available to the mine. The longwall operator simply answers a series of questions concerning his problems, current control techniques, etc., and the "expert system" selects the proper control techniques for the conditions at that site. Additionally, specific recommendations are made and information and references provided.

As part of the effort of this subprogram, two expert systems have been made available to longwall operators to transfer Bureau research technology:

a. DUSTPRO, related to longwall dust control techniques

b. DRUMPRO, related to longwall drum design.

These expert systems are briefly described in the following sections.

7.1 DUSTPRO - A LONGWALL DUST CONTROL EXPERT SYSTEM

DUSTPRO provides longwall operators with site-specific advice on the application of dust control techniques. The longwall dust control expert system is a PC-based computer program which is able to analyze and diagnose dust control problems, and recommend corrective actions which will reduce dust levels.

The system is structured into three major portions: primary, advanced and a la carte. The primary section provides advice for new users on the fundamental dust control measures which every longwall should employ. The advanced section covers several more refined approaches if the basic or primary measures do not achieve compliance. The last section is an a la carte menu for experienced users who have a specific interest such as modeling hardware changes necessary for higher water flow rates.

The dust control expert system requires no programming experience to operate and provides its own instructions. The system also supplies users with printouts of data sheets, survey forms and recommendations as well as graphics illustrating the use and application of recommended techniques.

A paper describing DUSTRPRO was presented at the 1987 Longwall USA Conference. A complete copy of the paper is provided in appendix c.

7.2 DRUMPRO - A LONGWALL DRUM DESIGN EXPERT SYSTEM

Under the Bureau Contract JO318097, Foster-Miller, Inc. has developed an expert system that provides longwall operators with site-specific advice on longwall drum design. The system is a PC-based computer program which analyzes and diagnoses drum design problems and makes specific recommendations to improve productivity.

The reasoning process employed by the program mimics that used by an actual drum expert. The program examines drum parameters, seam conditions, and current drum performance, then makes specific recommendations for improving the drum design.

The system requires no programming experience to operate and provides its own instructions. It provides users with printouts of data sheets, survey forms and recommendations, as well as graphics illustrating recommended design improvements.

A paper describing DRUMPRO was presented at the 1988 Longwall USA Conference. A complete copy of the paper is provided in appendix d.

APPENDIX A.--HOMOTROPAL RESEARCH

This appendix contains a paper summarizing the homotropal research conducted on this subprogram. The paper was presented at the Coal Mine Dust Conference sponsored by West Virginia University on October 9, 1984.

face. The air either bleeds through the gob into the return or, if the crosscut is in close proximity to the headgate, it enters the return crosscut directly.

Discussions with a number of these mines indicated that:

- The main reason for implementing homotropal ventilation was to overcome methane problems on the face
- The implementation of homotropal ventilation did not conflict with either MSHA or Pennsylvania State regulations
- Tailgate entries had to be maintained in good condition.
- Homotropal ventilation made it possible to operate track entries at both ends of the face. This permitted easier access to the face for men and materials, and was considered very beneficial for speeding up repairs during a breakdown.

All the mines surveyed believed that homotropal ventilation offered a significant advantage over antitropal ventilation.

The USBM and FMI, under Contract No. J0318097, investigated the use of homotropal ventilation as a possible cost-effective technique for reducing intake respirable dust contamination. Initially, a mathematical model was developed, using typical mining cycles and respirable dust data to analyze the potential impact of homotropal ventilation on respirable dust exposures. The analyses showed respirable dust exposures on any cutting cycle could be reduced using homotropal ventilation. During a tailgate to headgate cutting cycle, e.g., homotropal ventilation was predicted to reduce the shearer operator's exposure by 40 percent. Having theoretically established the potential benefits of homotropal ventilation, the USBM and FMI expanded the effort to:

- Quantify the benefits and potential problems of homotropal ventilation with underground evaluations
- Document the ventilation systems and mining techniques utilized by homotropal mines
- Provide technical information to the mining industry on the use of homotropal ventilation.

Underground Evaluation of Homotropal Evaluation

Documentation of the improvements in dust levels by using homotropal ventilation required evaluating conditions on both a homotropal and an antitropal face. Ideally such an evaluation would have been conducted on the same face with a switch of the ventilation during the life of the panel. Switching the ventilation, however, required:

- Changing the controls on the roof supports
- Reorienting shearer-mounted water sprays
- Building new stoppings and overcasts.

which were not practical.

We were, however, able to locate a cooperating mine with both a homotropal and antitropal ventilated longwall operating in the same seam. The two faces were equipped with similar stage-loaders, face conveyors and shields and both had an extraction height of approximately 7 ft.

The evaluation of the two faces consisted of the following:

- Sampling intake dust levels upwind of the shearer
- Sampling dust levels at the various operator positions to determine the impact of intake dust on their exposure
- Mapping ventilation airflow patterns and dust concentrations in the headgate
- Documenting face air velocities
- Measuring dust concentration profiles in the walkway around the shearer.

The evaluations were conducted using GCA RAM-1 instantaneous respirable dust monitors.

Dust levels measured upwind of the shearer for a typical pass on the conventional antitropal face is plotted in Figure 2. The intake dust concentrations averaged 0.6 mg/m^3 during the cutting pass and 0.25 mg/m^3 on the cleanup pass. The lower levels measured on the cleanup pass were thought to be due to two factors:

- There were fewer large lumps passing through the crusher on the cleanup pass
- The coal on the conveyor during the cleanup pass was more thoroughly wetted by the shearer drum water sprays.

EVALUATION OF HOMOTROPAL VENTILATION FOR LONGWALL DUST CONTROL

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INTRODUCTION

U.S. longwall operators still find compliance with Federal respirable dust regulations difficult to achieve and maintain. Foster-Miller, Inc., (FMI) and the U.S. Bureau of Mines (USBM) have found that a major problem on many faces is contamination of the face intake air.

Most U.S. longwall faces are currently ventilated from headgate to tailgate. Air is routed up one or more of the headgate entries, through a crosscut and down the face to a return entry at the tailgate. The intake air becomes contaminated prior to entering the face. The contamination comes from several dust sources, including:

- Intake entry - movement of men and materials
- Headgate - crusher, stageloader, and A.F.C. transfer points
- Face - material flow on the A.F.C. is opposite the ventilation which causes the relative velocity between the material and airflow to be 600 ft/min or more.

Studies performed by FMI and the USBM have frequently shown intake dust levels on conventionally (antitropal) ventilated faces to be between 1 to 2 mg/m^3 as it enters the headgate end of the face. These levels of intake dust cause more problems than many operators appreciate, for the following reasons:

- All face personnel are exposed
- Dust levels are fairly constant throughout the shift and are not directly related to production.

To better illustrate the problems caused by intake dust levels, we have used typical data to present the following example:

Face personnel exposed to intake dust = 6 hr out of an 8 hr shift

Average intake dust level = 1 mg/m^3

Full shift exposure from intake dust only = 6/8 x 1 mg/m^3 = 0.75 mg/m^3.

All face personnel in this example, therefore, would receive 38 percent of their permissible full shift exposure of 2 mg/m^3 from the intake dust levels alone.

Many mines using conventional (antitropal) ventilation perform their cutting from headgate to tailgate to protect both the shearer operators and shield men from shearer generated dust. While cutting from headgate to tailgate reduces dust exposures, it can also limit production. When cutting from headgate to tailgate, the haulage rate of the shearer is restricted by the material flow through the underframe. This problem is often more severe on faces that have to cut and load rock.

A number of mines in the United States, particularly in central Pennsylvania, have utilized homotropal (tailgate to headgate) ventilation for many years. Homotropal ventilation, Figure 1, routes the face ventilation from the tailgate to headgate. In practice, the main intake air to the face is routed up the tailgate and an auxiliary intake air split is routed up the headgate entry and through a crosscut into the headgate. The intake split protects the headgate operator from the heavily contaminated face ventilation. The face ventilation and headgate split combine at the headgate end of the

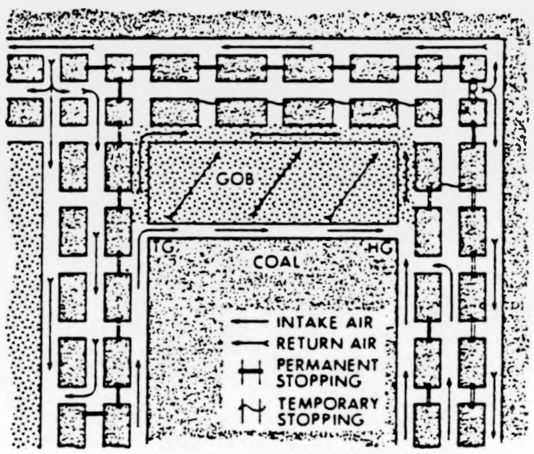

Figure 1. Typical Homotropal Ventilation Plan

COMPARISON OF FACE INTAKE DUST LEVELS

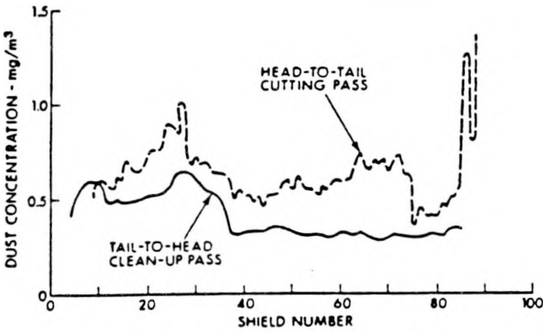

Figure 2. Antitropal Face

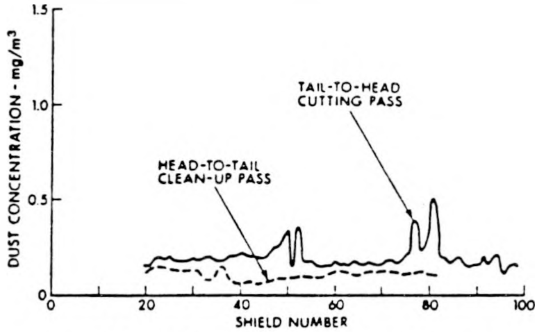

Figure 3. Homotropal Face

The data for a typical pass on the homotropal face are illustrated in Figure 3. The intake dust levels during the cutting pass averaged 0.2 mg/m^3, and 0.1 mg/m^3 on the cleanup pass. As shown, there was virtually no intake contamination on the homotropal face. The small amount of contamination that occurred was due to material being recirculated by the flights of the face conveyor. The conveyor discharged the finely ground material at the tailgate drive, where a portion of it became airborne.

Comparing the mean values for the two faces (Table 1) shows a significant reduction in intake dust levels on the homotropal face. Intake levels on the homotropal face are 60 to 66 percent lower than those on the conventional face. It should also be noted that the levels measured on the conventional face are well below those experienced by most mines. The reductions shown in Table 1 are, therefore, considered to be conservative.

Conditions within the headgate on both faces were evaluated by measuring and mapping dust concentrations and airflow patterns. A typical respirable dust concentration map for the headgate of the conventional face is shown in Figure 4. The dust levels shown are due to sources in the headgate - the stageloader to panel belt transfer point and the crusher. As can be seen, the levels produced by these sources were quickly diluted by the primary ventilation and levels measured at the stageloader operator were typically less than 2.0 mg/m^3.

On a homotropal face, the heavily contaminated face ventilation and the clean auxiliary intake split combine at the headgate end of the face and bleed through the corner of the gob into the return or enter the return crosscut directly. Ideally, the area behind the headgate shields remains open either because the strata is self-supporting or with the addition of cribbing between the first shield and the rib.

On this homotropal face, however, conditions had deteriorated since the start of the panel and the mine was experiencing roof control problems within both the headgate and tailgate. The roof would always collapse immediately behind the supports as they were advanced and there was no ventilation route through the gob at the headgate. Conditions in the headgate were, therefore, highly dependent on the location of the return crosscut.

When the return crosscut was inby the headgate operator, he was protected by the auxiliary intake air (Figure 5). Under these conditions, the dust concentrations at the stageloader operator were typically 1 mg/m^3 even though high dust concentrations were present in the face air.

As the face advanced, the return crosscut became closed off by the gob. To maintain an airflow path to the

Table 1. Comparison of Average Intake Dust Levels for the Conventional and Homotropal Face

Pass	Conventional (antitropal) (mg/m^3)	Homotropal (mg/m^3)	Percentage Improvement (%)
Cutting tailgate-to-headgate	0.6	0.2	60
Cleanup headgate-to-tailgate	0.25	0.1	66

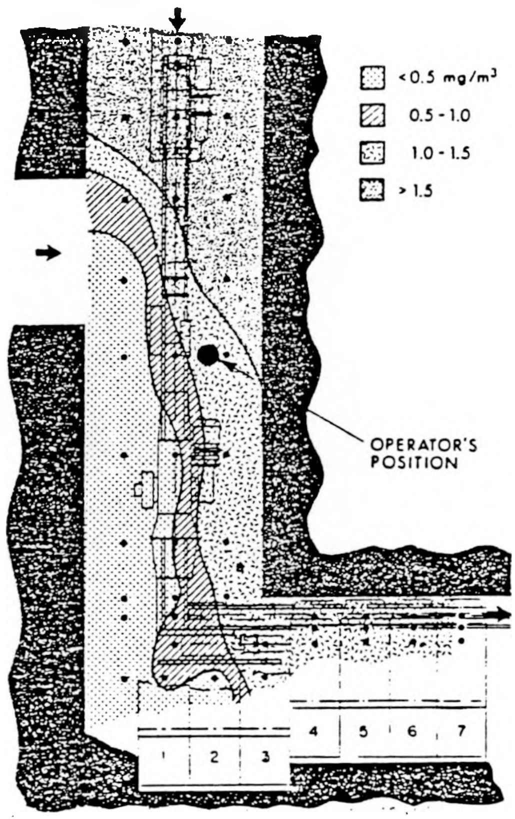

Figure 4. Headgate Dust Concentration Map, Antitropal Ventilation during Head-to-Tail (Cutting) Pass

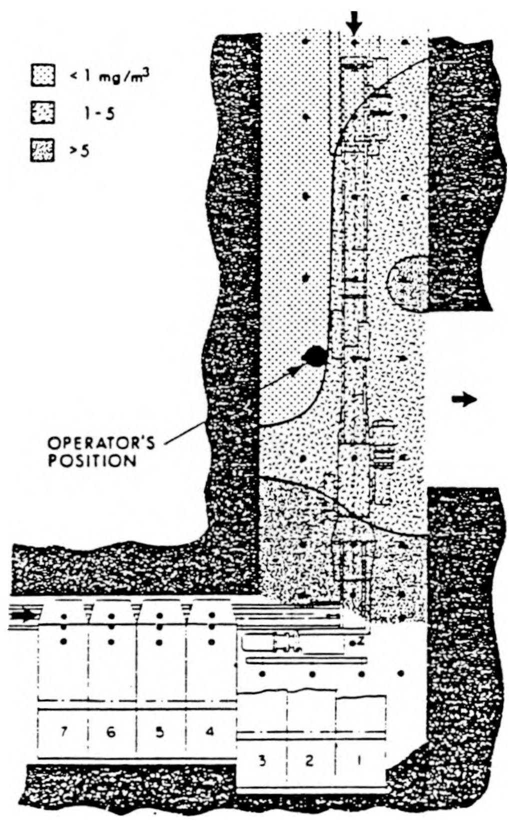

Figure 5. Headgate Dust Concentration Map, Homotropal Ventilation during Tail-to-Head (Cutting) Pass

return for the face air, an outby crosscut was opened up by advancing the ventilation curtain in the second entry. The face air then passed over the stageloader to reach the new return crosscut, thereby exposing the headgate operator to contaminated face air (Figure 6). Under this condition the headgate operator was exposed to respirable dust levels cutting as high as 18.5 mg/m^3.

In an attempt to improve conditions for the stageloader operator, a brattice curtain was installed to route intake air over the operator (Figure 7). Ideally, the curtain would have been extended inby the operator to give complete protection. The curtain, however, obstructed his line of vision and could not be fully extended. The resulting dust conditions with the curtain are illustrated in Figure 7. Even though the curtain was not ideally located, it still managed to improve the operator's exposure level by approximately 75 percent.

The application of a curtain to overcome poor headgate conditions, however, is not considered a permanent solution. The use of the curtain served to illustrate that should conditions deteriorate badly, it is quite feasible to temporarily overcome the problem, until a more permanent solution is available.

These results from this evaluation clearly showed the benefits of homotropal ventilation. Intake dust levels on the face were reduced by over 60 percent when compared to the conventional face even though levels on this face were already lower than those measured on the majority of faces in the United States.

The evaluation also clearly showed the potential problems which may be encountered under poor roof conditions in the headgate.

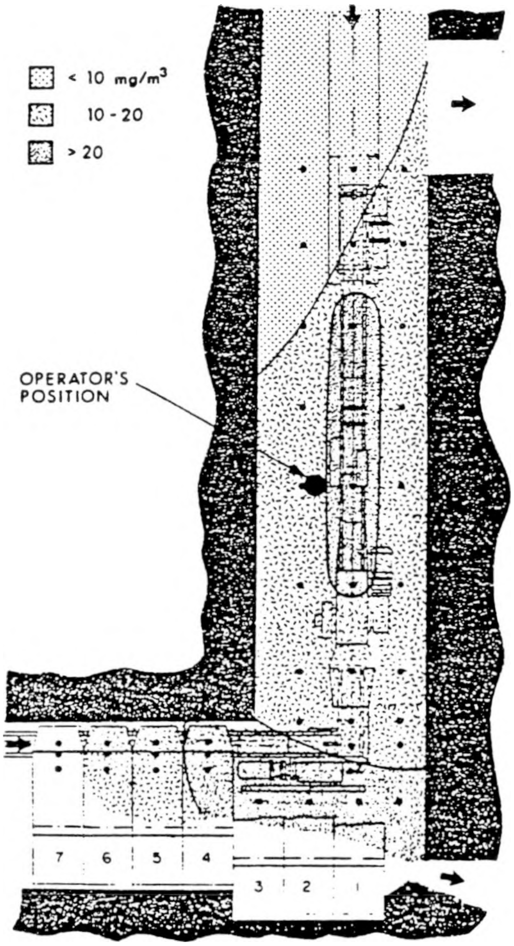

Figure 6. Headgate Dust Concentration Map, Homotropal Ventilation during Tail-to-Head (Cutting) Pass

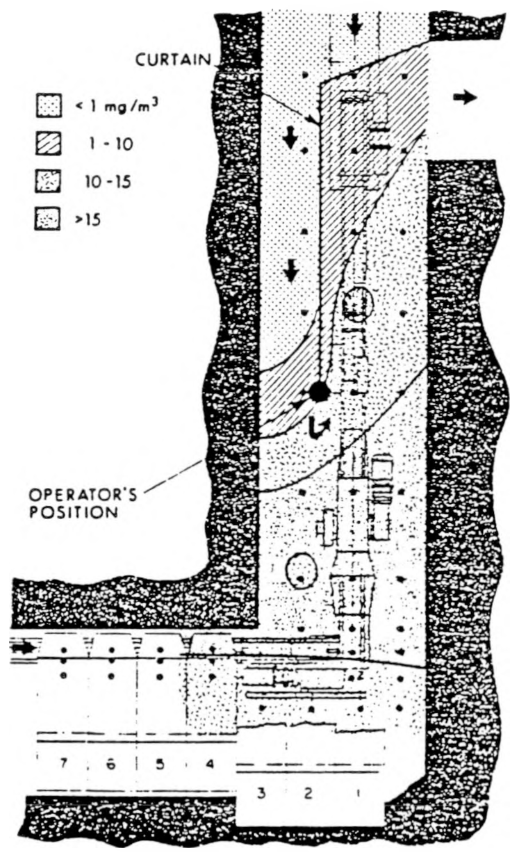

Figure 7. Headgate Dust Concentration Map, Homotropal Ventilation during Tail-to-Head (Cutting) Pass

Follow-Up Studies

To further document the benefits and problems of using homotropal ventilation, a series of brief follow-up studies were conducted at three mines using this ventilation system.

The first study was conducted on a face using a single ended fixed height rope haulage shearer which cut in both directions. The extraction height was 50 in. and the face was equipped with four-leg chocks. At the headgate end of the face, every second crosscut was broken through to route intake air down the headgate entry and over the headgate operator. Prior to each crosscut entering the gob, a substantial crib was built to support the crosscut entry. Those stoppings that remained were knocked through when the face conveyor was adjacent to the crosscut.

Ventilation surveys of the headgate were conducted with the return crosscut in the gob region. All surveys showed an average intake airflow through the headgate of 200 to 300 ft/min, giving excellent protection to the stageloader operator. The headgate air combined with face air at the end of the face and formed a combined airstream through the gob to the return crosscut.

A ventilation survey on the face monitored the air as it migrated through the chocks to the gob. It was reasoned that with the face air bleeding through the supports to the return, a region of low airflow would occur at the end of the face. The survey (Figure 8) shows some decrease in ventilation velocity, but even under the worst situation, the velocity did not reduce below 100 ft/min.

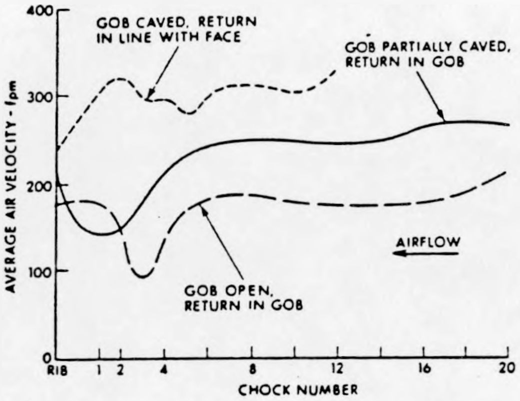

Figure 8. Homotropal Air Velocity Survey

Dust surveys of the headgate showed the intake dust concentration outby the stageloader/belt transfer point to be below 0.5 mg/m^3. As the air progressed up the headgate, dust levels increased slightly but remained below 1 mg/m^3.

The dust surveys on the face showed intake dust levels of 0.3 mg/m^3 during cutting from tail to head, and 0.07 mg/m^3 while cutting from head to tail.

The good conditions were mainly attributable to both excellent strata conditions and adequate ventilation in the headgate.

The second study was conducted on a face equipped with an AM500 double ended ranging arm shearer fitted with 52-in. diam cutting drums. The primary cutting was from tailgate to headgate, with a cleanup pass from headgate to tailgate. The height of the face was 60 in. and it was equipped with two-leg shields. The height of the entries was 8 ft 6 in. Every crosscut was knocked through at the headgate end of the face to route intake air into the headgate.

During the survey, the return crosscut was always located adjacent to the end of the face or slightly into the gob. The crosscut was always open during the survey and was supported by three sets of concrete, wire reinforced cribs.

The face air quantities recorded during the survey showed that the face air fluctuated from 35,600 to 60,000 ft^3/min. The cause of the fluctuations was due to changes in the size of the opening onto the face at the tailgate. Conditions in the tailgate were temporarily abnormal due to strata control problems. The tailgate had experienced considerable roof convergence and the tailgate conveyor drive frame tended to climb. Consequently, the opening onto the face was severely reduced and its size varied depending on how effectively the shearer could cut out.

Ventilation surveys always showed airflow towards the face from the auxiliary intake in the headgate. Having combined with the face airflow, no difficulty was experienced by the ventilation entering the return crosscut. Since both the face and headgate intakes originate from the same supply, fluctuations in face air quantities resulted in changes in the auxiliary headgate air.

The fluctuations in the headgate ventilation had a very detrimental effect when the velocity was reduced below 100 ft/min. Concentrations ranged from 1 mg/m^3 under good ventilation conditions to 4 mg/m^3 when the airflow was reduced.

Intake dust levels for the face were measured upstream of the shearer; tailgate to headgate (cutting pass) was 0.43 mg/m^3 and headgate to tailgate (cleanup pass) was 0.15 mg/m^3.

The intake dust level of 0.43 mg/m^3 during cutting was higher than expected. It is speculated that this occurred because the velocity of the air entering through the tailgate opening was up to 9,000 ft/min. This extremely high velocity picked up the fines recirculated by the face conveyor, and resulted in the higher than expected intake dust levels. It is of interest to note that even under these unusual conditions, the intake dust is still exceptionally low as compared to levels normally measured in antitropal faces.

The third survey was conducted on a face using an Eickhoff EDW 170L single ended ranging drum shearer. The shearer took a full cut in both directions. The seam height was 58 in. and the face was equipped with Joy four-leg chock shields. The face was equipped with a Huwood face conveyor and Huwood stageloader. The stageloader was fitted with a crusher which was inby the stageloader operator's controls. At the headgate end of the face, every crosscut was systematically knocked through to route intake air over the headgate operator. Prior to each crosscut entering the gob, three substantial wooden cribs were built in the crosscut.

On the first day of the survey, the mean velocity of intake air in the head-

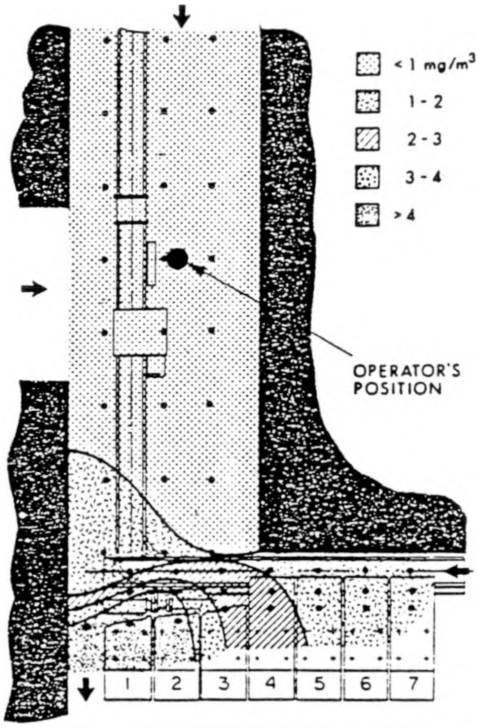

Figure 9. Headgate Air Velocity 150 fpm

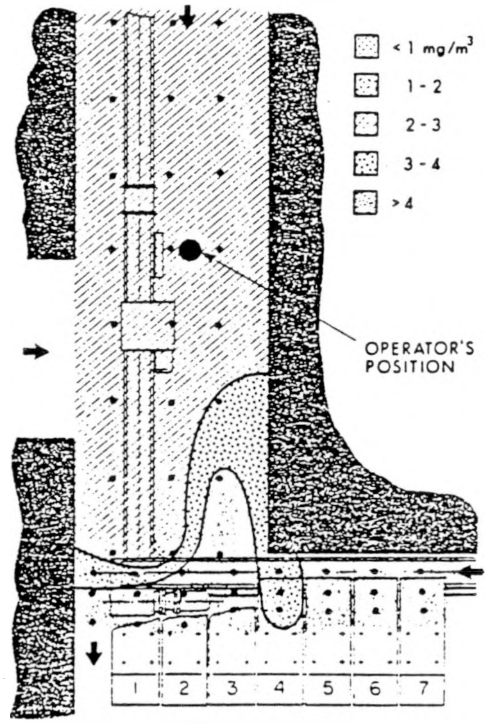

Figure 10. Headgate Air Velocity 50 fpm

gate was 150 ft/min (Figure 9). Excellent conditions were recorded in the headgate, with mean dust concentrations below 1 mg/m^3 during cutting from head to tail. On the following day, velocities in the headgate had reduced to 50 ft/min. At this velocity, much of the ventilation within the headgate was dominated by the electric motor cooling fans on the crusher and stageloader. It is interesting to note that even with these extremely low velocities, the contaminated face ventilation did not enter the headgate. The lack of ventilation resulted in dust concentrations in the headgate increasing to between 2 to 3 mg/m^3 (Figure 10). On this second day, with poor headgate ventilation, a face ventilation survey was performed. From Figure 11, it is apparent that from chock 13 to the end of the face, air was rapidly migrating into the gob. An important feature to observe was that, although the ventilation decreased towards the headgate, no stagnant region of ventilation occurred.

Intake dust levels were extremely low averaging 0.19 mg/m^3 on the tail to head cutting pass and 0.14 mg/m^3 on the head to tail cutting pass.

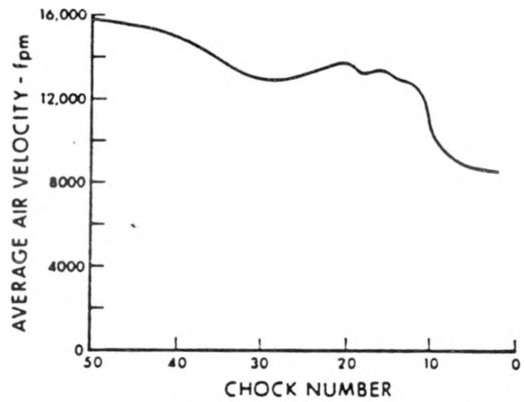

Figure 11. Face Ventilation Profile

In deciding to implement homotropal ventilation, this mine had adopted the following measures:

- The first chock was located 10 to 12 ft from ribside. This allowed room to build cribbing that would support the gob should it prove necessary

- The stageloader operator's controls were located well outby. In the event of having to open up a return crosscut in the headgate, the stageloader operator would not be in contaminated ventilation
- The transfer point between the side discharge face conveyor and the stageloader was redesigned. By modifying and improving the deflector plates on the conveyor, the operator did not have to go forward in the headgate to clear blockages
- A good dust control system was installed on the stageloader. Although it is possible to control dust levels within the headgate using the intake air split, the mine had fitted an effective control system.

Follow-Up Conclusions

The results of these evaluations and studies have clearly demonstrated the advantages of homotropal ventilation. At the same time they have highlighted certain potential problems and restrictions including:

- The tailgate entries must be maintained to provide adequate air to the face.
- A clean intake air split must be maintained to the headgate to protect the headgate operator. Air velocity within the headgate should be in excess of 100 ft/min.
- The gob at the headgate should remain open, which may require additional cribbing in the crosscut and between the last headgate shield and the pillar.

One of the main problems posed by homotropal ventilation is protecting the headgate operator. Mines can ensure maximum protection, under even the poorest conditions, by locating the stageloader control further outby. Thus, if face air is temporarily routed into the headgate to the return, the operator can still be clear of contaminated air. The recent improvements in the design of the AFC/stageloader transfer points and the introduction of side-discharge AFC's has reduced the need to station the stageloader operator close to the transfer point.

The major benefit derived from homotropal ventilation is a dramatic reduction in intake air contamination. Table 2 lists the average intake dust concentration at each of the four sites. A representative value for a conventionally ventilated antitropal face would be between 1 to 2 mg/m^3.

Homotropal ventilation, therefore can reduce intake dust levels by more than 50 percent.

Table 2. Mean Intake Dust Concentrations for the Four Mines

Location	Dust Concentration during Cutting Pass mg/m^3
Main Evaluation	0.2
Follow-up evaluation, Mine No. 1	0.3
Follow-up evaluation, Mine No. 2	0.43
Follow-up evaluation, Mine No. 3	0.19

Other benefits include:

- Better control of methane on the face
- Access to both ends of the face which will frequently result in reduced downtime.
- Improved production because the primary cut can be taken from tailgate to headgate while still keeping shield and shearer operators upwind of the shearer.

Bibliography

J.G. Bromilow, Descensional and Homotropal Ventilation, "Trans Inst Min Engrs," 1957-1958, 441-460.

J. Carver, Some observations on homotropal, Descensional and Ascentional Ventilation, "Min Engr," No. 8, 120, May 1960, 607-624.

A.M.Sullivan, Operators Fight Longwall Dust, "Coal Age," December 1978.

Research Liaison Committee Information Bulletin No. RLC/77/1, Homotropal Ventilation, "The Mining Engineer," Feb 1979.

AMC Meeting Report, J&L Looks at Longwall Ventilation Problems, "Coal Age," July 1979.

Eugene H. Jones and Joseph Kuti, Dust and Its Effect on Longwall Mining, "Mining Congress Journal," August 1979.

R.A. Jankowski and J. Hetrick, Longwall Cuts Dust Build-up, "Coal Age," June 1982.

APPENDIX B.--DOWNWIND DUST EVALUATION

This appendix contains a paper summarizing the research conducted on this subprogram related to downwind dust evaluations and control guidelines.

OPTIMIZING THE RELATIONSHIP BETWEEN THE SHEARER AND SHIELD MOVEMENT TO MINIMIZE PERSONNEL DUST EXPOSURES

By C. Babbitt, R. Jankowski, J. Burnett and S. Rajan

ABSTRACT

While many mines in the United States use unidirectional cutting to minimize the number of personnel working downwind of the shearer, a significant number cut bidirectionally. On a bidirectional face, jacksetters work downwind of the shearer for at least half of every cutting cycle and can be subjected to significant quantities of shearer-generated dust. In addition, shearer operators can be subjected to dust from upstream shield movement.

Through an underground study conducted on an operating U.S. longwall, the Bureau of Mines has evaluated respirable dust conditions downwind of the shearer during tail to head cutting and downwind of shield movement during head to tail cutting. The objective was to provide guidelines for minimizing the dust exposures of downwind personnel in these situations.

Detailed dust sampling using grid pattern, fixed-point instantaneous dust monitors was conducted at shields 50 and 70 along the face. The results of the study revealed the following:

- The shearer on the subject longwall employed an auxiliary water spray system similar to the USBM's Shearer Clearer system. This spray system was effective in maintaining a clean/dusty air split for a considerable distance downwind of the shearer (up to 70 ft). Shearer Clearer techniques should help to minimize the dust exposures of downwind personnel compared to conventional spray systems.

- During tail to head cutting, with shield movement following downwind, shields should be pulled as closely behind the shearer as possible. This will take advantage of the tendency for shearer-generated dust to remain in the face area for a time as it travels downwind.

- During head to tail cutting, with shield movement following upwind of the shearer, shields should not be pulled too closely behind the shearer. When pulled close to the shearer, shield dust will immediately impact the shearer operators. When pulled some distance upstream, shield dust disperses and dilutes rapidly with the face airflow, minimizing its impact on the shearer operators.

INTRODUCTION

On most longwall faces, shearer-generated dust is the largest contributor to the respirable dust exposure of face personnel. Consequently, personnel positioned downwind of the shearer (primarily jacksetters) can be exposed to particularly high concentrations of respirable dust.

One technique for minimizing the dust exposures of downwind personnel is to reduce their time of exposure in downwind locations. Many mines cut coal unidirectionally to keep jacksetters upstream of the shearer. This is generally accomplished by cutting from head to tail and pulling shields upstream of the shearer during the primary cut. Longwalls with roof conditions permitting will sometimes take a primary cut from tail to head, then pull the shields upwind of the shearer during the head to tail cleanup pass. Although many mines have adopted unidirectional cutting, a significant number still cut bidirectionally and the jacksetters must work downwind of the shearer for at least half the mining cycle.

To date, longwall dust control efforts have been primarily directed toward the shearer operator's dust exposures through improvements to ventilation and shearer-mounted water spray systems. Through that effort, the USBM's Shearer Clearer water spray system has emerged as one of the most significant advancements to dust control on longwall faces. The Shearer Clearer consists of strategically mounted water sprays and/or passive barriers which reduce dust levels in the operator's walkway by splitting the airflow on the upwind side of the shearer. Clean intake air is maintained in the walkway while contaminated air is confined to the face side of the shearer. Hence the dust cloud is kept away from face personnel as it travels downstream over the shearer body and beyond.

Shearer Clearer techniques have shown promise for dust control downwind of the shearer by extending the clean/dusty air split well beyond the downwind end of the machine. However, the full extent of its effect on downwind dust levels had never been documented. In addition, the effect of shield movement on the dust exposures of shearer operators (when shields are pulled upstream of the shearer) had not been documented in detail. A need has existed in the industry to study the downwind dust problem and to develop improved control techniques.

The USBM, through a research contract with Foster-Miller, Inc. conducted a special longwall downwind dust study to address this need. The study evaluated the effectiveness of Shearer Clearer concepts in reducing downwind dust exposures and provided general guidelines for improved mining practices to minimize dust exposures from both the shearer and shield movement. This report describes this effort and presents the resulting conclusions.

ACKNOWLEDGMENTS

The authors wish to thank the management of Westmoreland Coal Company's Holton Mine for allowing the study to be conducted on their longwall and gratefully acknowledge the assistance of all Westmoreland personnel who contributed to the success of the project.

SITE DESCRIPTION

The objective of this study was to conduct a thorough survey of dust conditions downwind of cutting and/or shield movement and to use the results to guide the longwall industry in minimizing dust exposures from upwind sources.

An important parameter was to locate a longwall face with mining conditions representative of the industry and which was using a Shearer Clearer-like auxiliary water spray system. This was considered important because of the trend in the industry toward the use of Shearer Clearer techniques and because of the known potential of the Shearer Clearer to provide improved downwind dust control.

The study was conducted on the longwall in Westmoreland's Holton Mine near Big Stone Gap, VA during October of 1985. Mining took place in the Taggart Seam cutting about 60 in. using a Joy 3LS double drum ranging arm shearer. The shearer cut a considerable amount of rock during the study, averaging about 15 to 20 in. in the upper portion of the seam. Air velocity along the face averaged about 375 ft/min and shearer tramming speed averaged about 7.5 ft/min. The mine cut bidirectionally, pulling shields behind the shearer after each pass.

The shearer at the Holton Mine was equipped with an auxiliary water spray system very similar to the Shearer Clearer. Shown in Figure 1, the system contained headgate and tailgate splitter arms plus a total of seven spray nozzles, most of which were oriented downwind as shown in Figure 1. The sprays operated at a water pressure of about 120 psi with all nozzles operating properly.

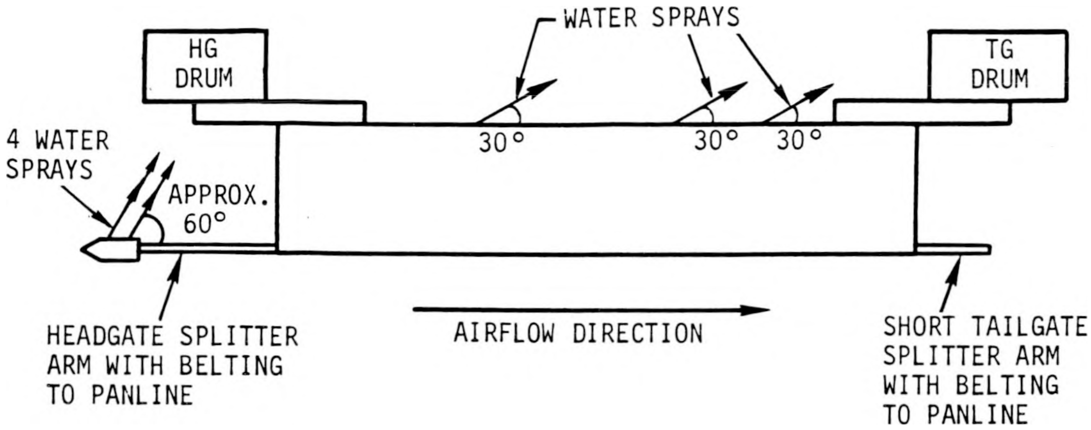

Figure 1. Shearer Clearer-like Spray System used on Westmoreland's Holton Longwall

Dust levels measured along the face from headgate intake sources were found to be very low during the study, averaging about 0.2 to 0.4 mg/m^3. The primary intake dust sources on most longwalls are the crusher and stageloader. The low levels at Holton were attributed to an excellent job of crusher/stageloader dust control achieved by enclosing them with cover plates. The low ambient intake levels provided the advantage of eliminating the need for removing intake dust concentrations from the data collected during the subject downwind study.

MONITORING PLAN

The primary objective of this study was to conduct detailed dust sampling for a considerable distance downwind of cutting and/or shield movement. This was accomplished through a grid point arrangement of fixed point samplers located at two shields along the face (shields 50 and 70 as shown in Figure 2). At each shield, three samplers provided a gradient of dust concentrations from the face to the walkway. Samplers were located over the panline, over the cable tray and in the walkway as shown in Figure 3.

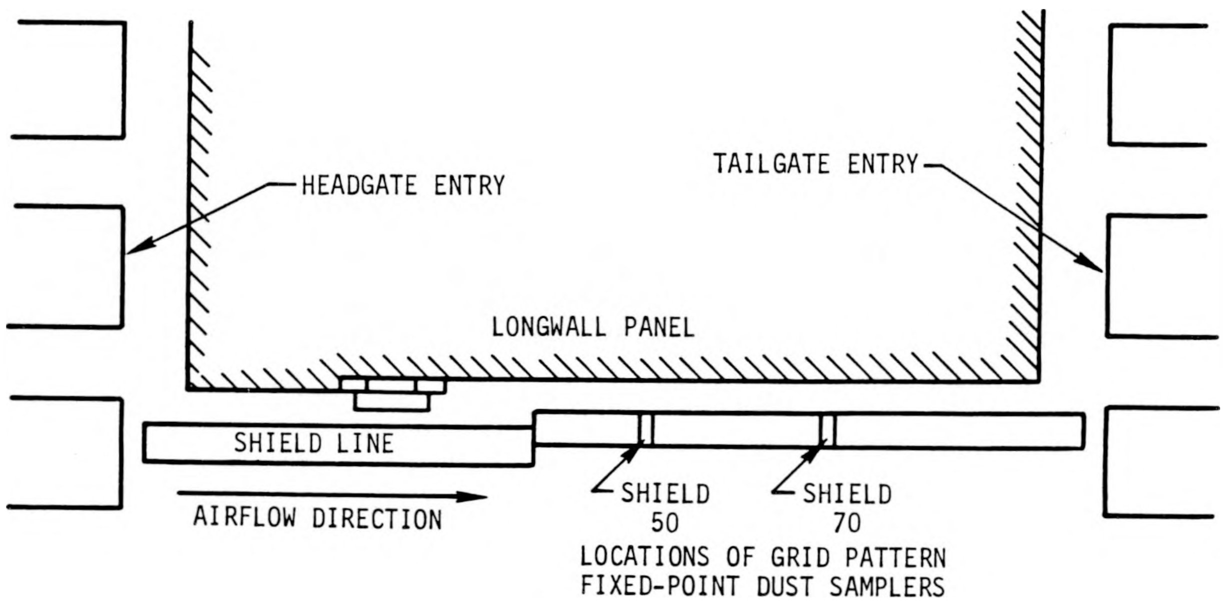

Figure 2. Layout of Dust Sampling Instrumentation on Longwall Face

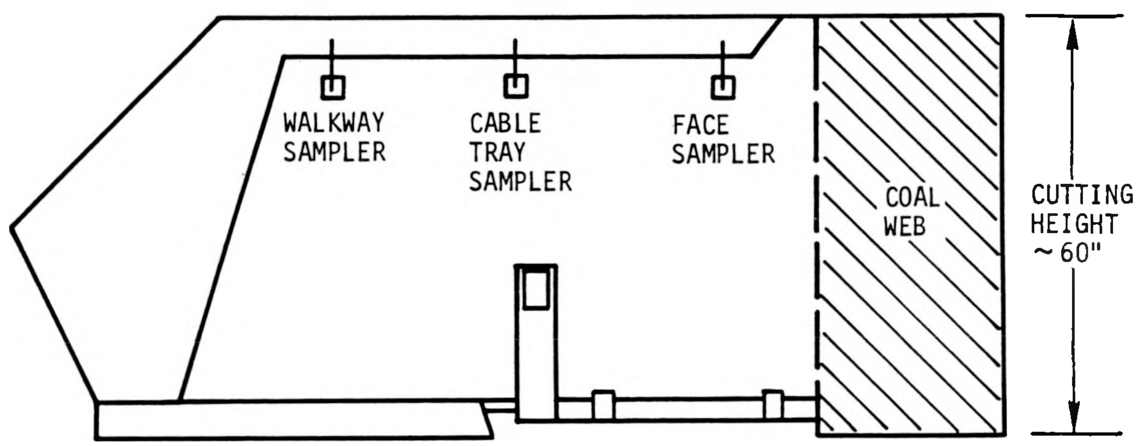

Figure 3. Grid Point Locations of Fixed-Point Dust Samplers at Shields 50 and 70

This fixed point sampling scheme allowed data to be gathered as the shearer approached, passed the stations and moved downstream during head to tail cuts and as the shearer passed the stations and moved upstream during tail to head cuts.

Each sampling station consisted of an instantaneous dust monitor connected to an automatic recording data logger which read and recorded an average dust level every 10 sec. Test personnel continually monitored all face activities through detailed time studies, focusing on cutting activity and shield movement.

A secondary objective of this study was to measure shearer operator dust concentrations to document the beneficial effects of Westmoreland's Shearer Clearer-like spray system. In addition, Westmoreland's Joy shearer was equipped with remote shearer operator controls. Another objective in measuring operator dust levels was to determine the benefits of remote control by comparing dust levels at the remote operator's location to a standard manual operator's location. Shearer operator dust concentrations were obtained by following along with the operator using an additional instantaneous monitor connected to an automatic recording data logger.

TEST RESULTS - DOWNWIND SAMPLING

Data Analysis Methods

Data were collected for multiple cuts over several test shifts, resulting in thousands of recorded dust concentrations representing a variety of face conditions, cutting situations and locations of shield movement. Data analysis began by categorizing all data according to the relationship between cutting and shield movement. Four primary situations were studied:

1. Shearer cutting tail to head with shields being pulled a considerable distance downwind of the shearer

2. Shearer cutting tail to head with shields being pulled very close to the downwind end of the shearer

3. Shearer cutting tail to head with shields being pulled a considerable distance upwind of the shearer

4. Shearer cutting tail to head with shields being pulled very close to the upwind of the shearer.

For each of situations 1 through 3, dust "profile maps" were generated showing dust concentrations obtained at the fixed point sampling stations. Detailed time study information was collected as the dust data were obtained. This information, documenting exact locations of shearer cutting and shield movement, was coupled with computer printouts of the dust data to create the maps. Each map simulates a "snapshot" of dust concentrations along the face and shows the dispersion of dust from all dust sources as it travels downstream from its point of generation.

The maps identify regions of high versus low dust levels within these downwind dispersion patterns. In this way it is possible to help locate the shield and shearer operators in the most favorable regions of low dust concentration. A better understanding of the dispersion of dust downwind during different portions of the cutting cycle also serves as a basis for recommending additional potential downwind dust control techniques.

Sufficient data were not collected for situation 4 above to allow creation of a detailed dust profile map. However, relevant data were obtained during one pass representative of head to tail cutting with shield movement close to the shearer. This was adequate to assess the impact of the situation on shearer operator dust levels.

Tail to Head Cutting

Figure 4 contains the profile map of dust concentrations downwind of the shearer while cutting tail to head with shields being pulled approximately 130 ft downwind of the machine. As seen in the map, dust concentrations are quite high at the 130 ft point where the first shield is being pulled (averaging 3 to 5 mg/m^3).

> ***Dust concentrations presented throughout this paper reflect <u>instantaneous</u> dust readings taken only while the shearer was cutting and loading coal. They cannot be compared to full-shift compliance samples.***

Figure 4 clearly shows the split between clean air in the walkway and dusty air in the face which is provided by the Shearer Clearer. Little or no migration of dusty air into the walkway occurs for the first 60 to 70 ft downwind of the shearer. Beyond 70 ft, dust movement from face to walkway begins to occur, building to concentrations of 3 to 5 mg/m^3 in the vicinity of the jacksetters.

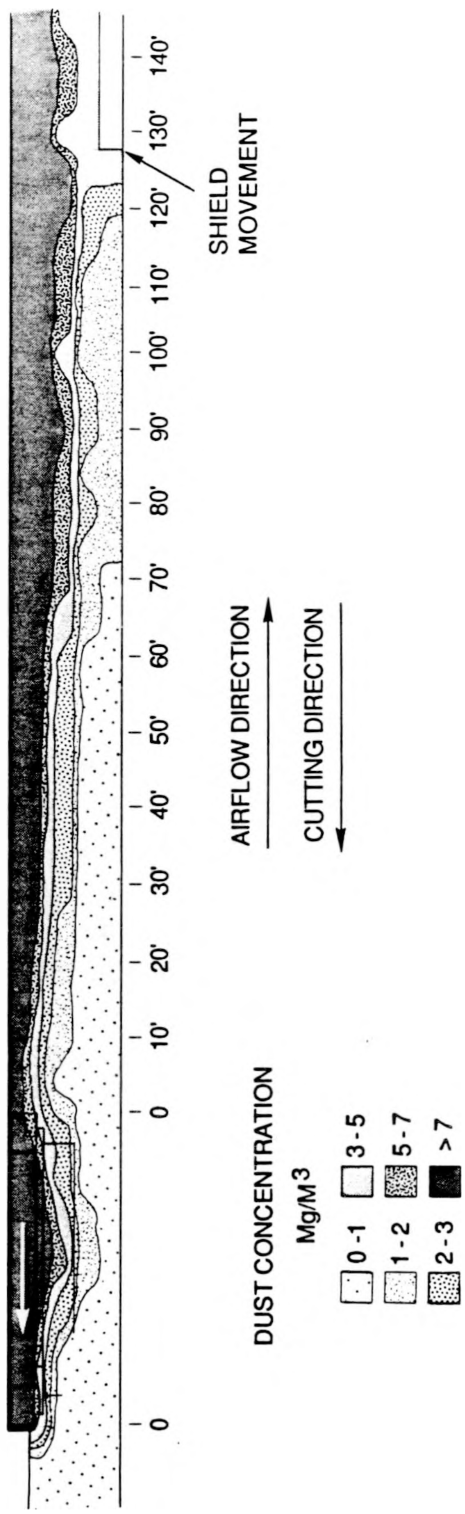

Figure 4. Dust Profile Map - Tail to Head Cutting with Shields Pulled Far Downstream (Approximately 130 ft)

Figure 4 indicates that shield movement should follow much closer to the shearer cutting activity to minimize dust exposures of jacksetters. This is confirmed in Figure 5, which contains the profile map of dust concentrations downwind of the shearer while cutting tail to head with shields being pulled approximately 30 ft downwind of the machine. As seen in the map, dust concentrations average less than 2 mg/m^3 in the vicinity of jacksetters in this situation. This illustrates the importance of keeping the jacksetters as close to the shearer as possible. On passes where the shield movement is over 70 ft downstream of the shearer, the exposure level of personnel can be two or three times as high.

Although maintaining shield movement closer to the shearer minimizes jacksetter dust exposures, it also provides an obstruction to airflow closer to the machine. This has the effect of interrupting the streamlined flow shown in Figure 4, leading to increased dust levels in the walkway around the shearer itself. However, this has little impact on the shearer operator positions as shown in Figure 5 and does not diminish the benefits of reduced dust exposures for the jacksetters.

Head to Tail Cutting

During head to tail cutting, the shield operators work on the upstream side of the shearer. Dust generated from shield movement can impact the shearer operators in this situation. Figure 6 contains the profile map of dust concentrations downwind of shield movement while cutting head to tail with shields being pulled approximately 100 ft upwind of the shearer.

As seen in the map, dust concentrations are quite high <u>in the immediate vicinity of shield movement only</u> (ranging from 2 to 5 mg/m^3). Beyond 10 to 20 ft downwind of shield movement, dust levels throughout the face area are very low, indicating that shield dust quickly spreads and dilutes within the main airstream. This would indicate that shield movement plays a minimal role in adding to shearer operator exposure levels <u>when it is occurring far enough upstream.</u> Figure 6 illustrates the advantage of keeping shield movement at least 40 ft (8 shields) upwind of the shearer to prevent excessive intake contamination of the shearer operators.

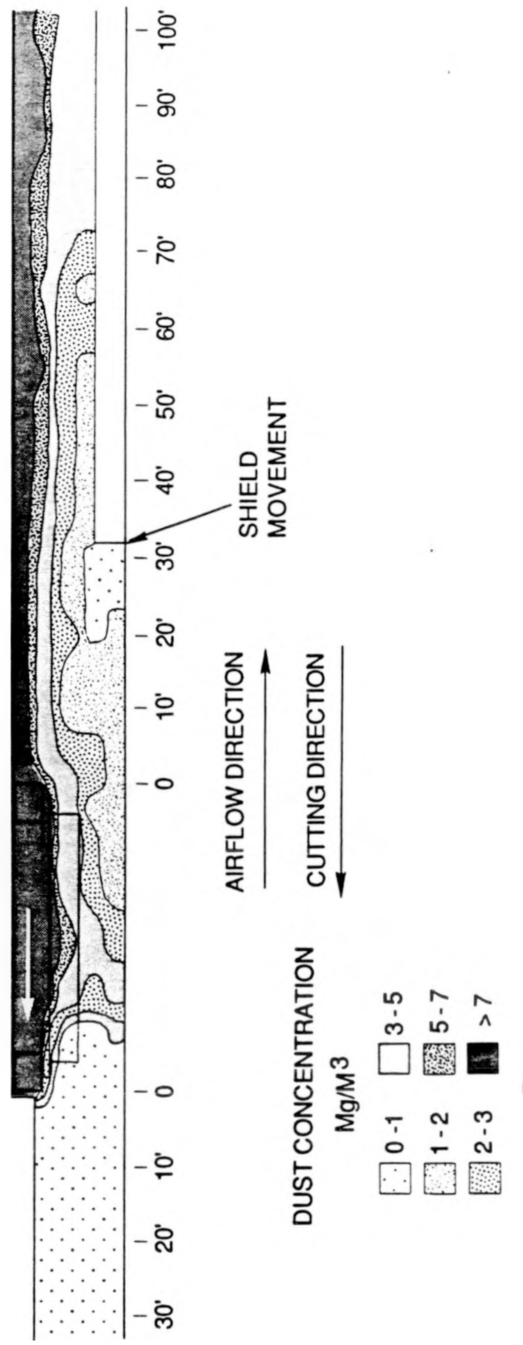

Figure 5. Dust Profile Map - Tail to Head Cutting with Shields Pulled Close to Shearer (Approximately 30 ft)

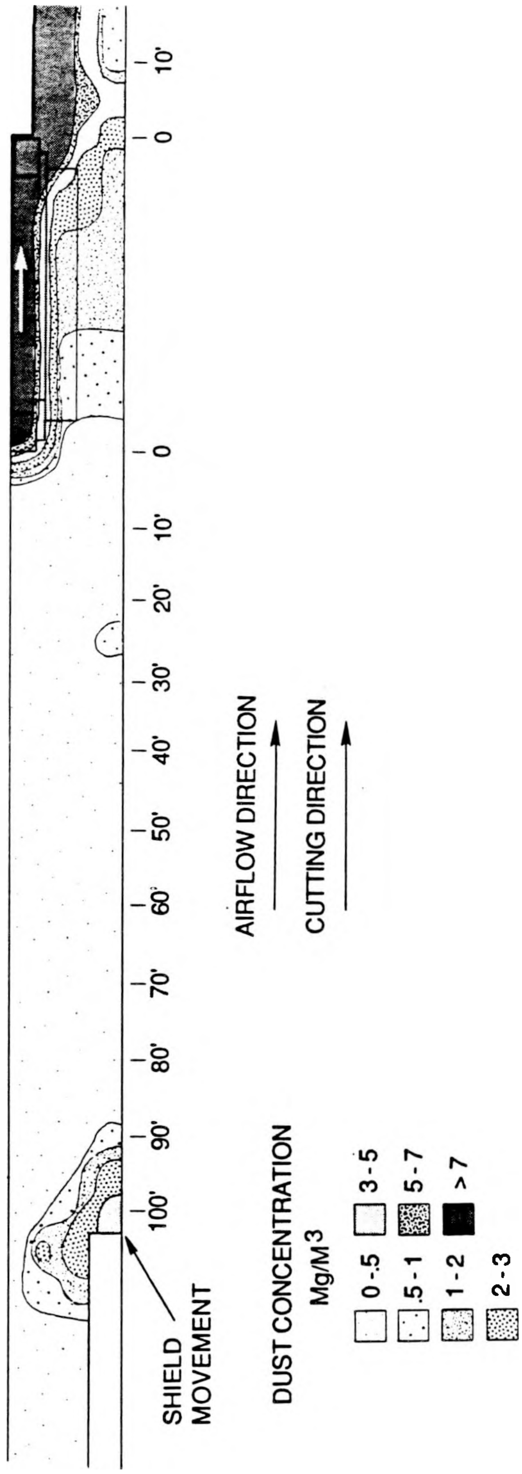

Figure 6. Dust Profile Map - Head to Tail Cutting with Shields Pulled Far Upstream (Approximately 100 ft)

A dust profile map could not be generated for the condition of head to tail cutting with shield movement close to the shearer due to insufficient data. However, Figure 7 contains a plot of dust levels measured during a single head to tail pass where shield movement occurred right over the trailing headgate drum. The plot indicates dust levels recorded at shield 70 as each shield indicated (from shield 32 to 70) was being pulled.

During the period when shields 65 to 70 were being pulled, dust levels in the walkway at shield 70 (approximate location of shearer operators) averaged 6.1 mg/m^3. Subtracting about 2 mg/m^3 of shearer generated dust (per the dust levels shown around the shearer in Figure 6), shield movement close to the shearer operators contributed about 4 mg/m^3 to their exposures. This confirms the importance of keeping shield movement some distance upstream of the shearer to reduce the impact of shield dust on the shearer operators.

TEST RESULTS - SAMPLING THE SHEARER OPERATOR'S POSITION

A brief secondary study of shearer operator dust concentrations was conducted to document the beneficial effects of two dust control techniques used by Westmoreland at the Holton longwall:

- A Shearer Clearer-like auxiliary water spray system
- Remote operation of the shearer controls.

Figures 8 and 9 present the results of this study and contain plots of dust concentrations versus shield number for tail to head and head to tail cutting passes, respectively. The data were obtained by following along with the leading drum shearer operator using an instantaneous dust monitor.

With the exception of the headgate cutout during the tail to head pass, dust levels throughout both cutting passes averaged less than 2 mg/m^3 at the operator's position despite the cutting of a significant amount of roof rock. This was attributed partly to good dust control offered by the Shearer Clearer water spray system.

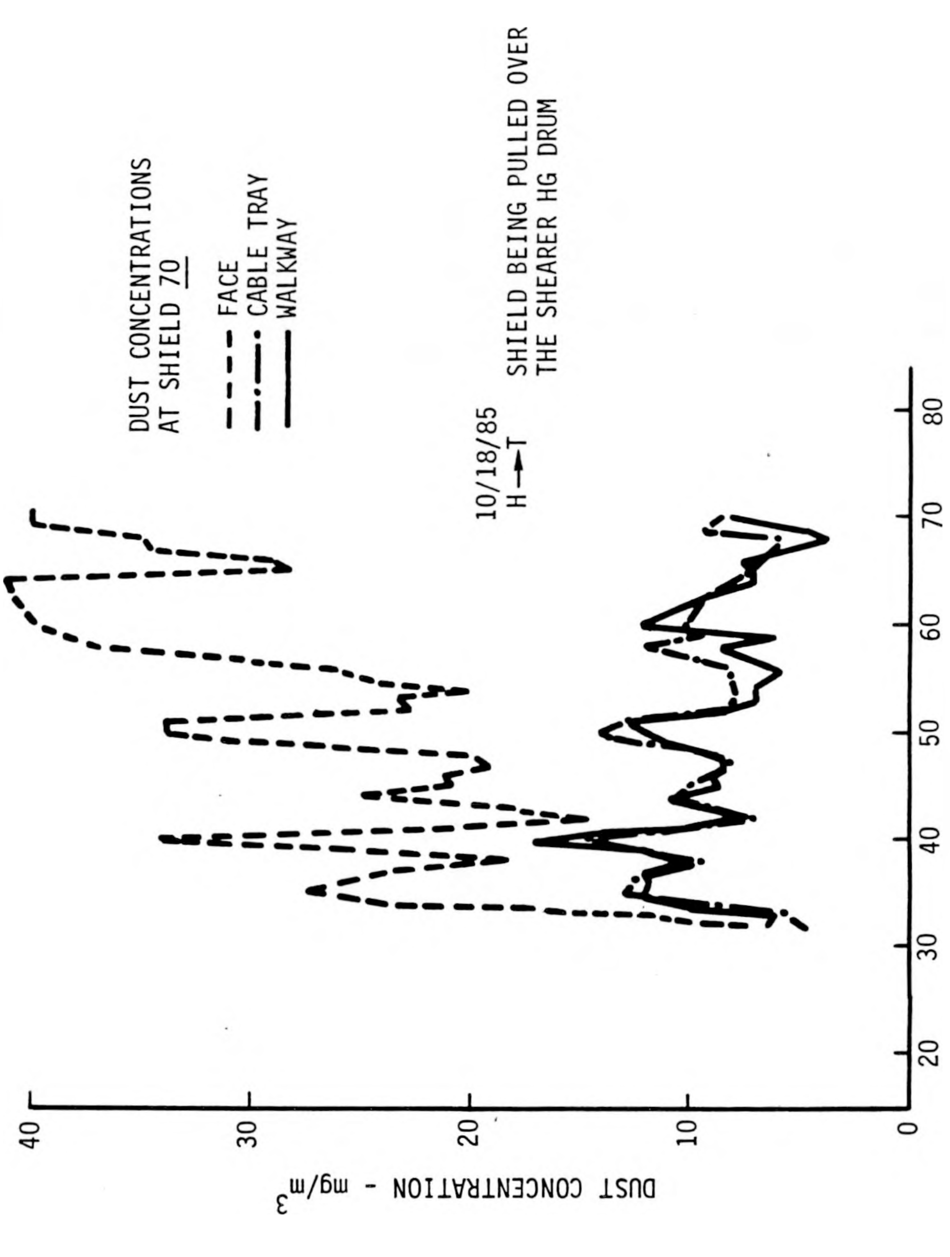

Figure 7. Plot of Dust Concentrations at Shield 70 as Shearer and Shield Movement Approach from Upstream (Head to Tail Cutting)

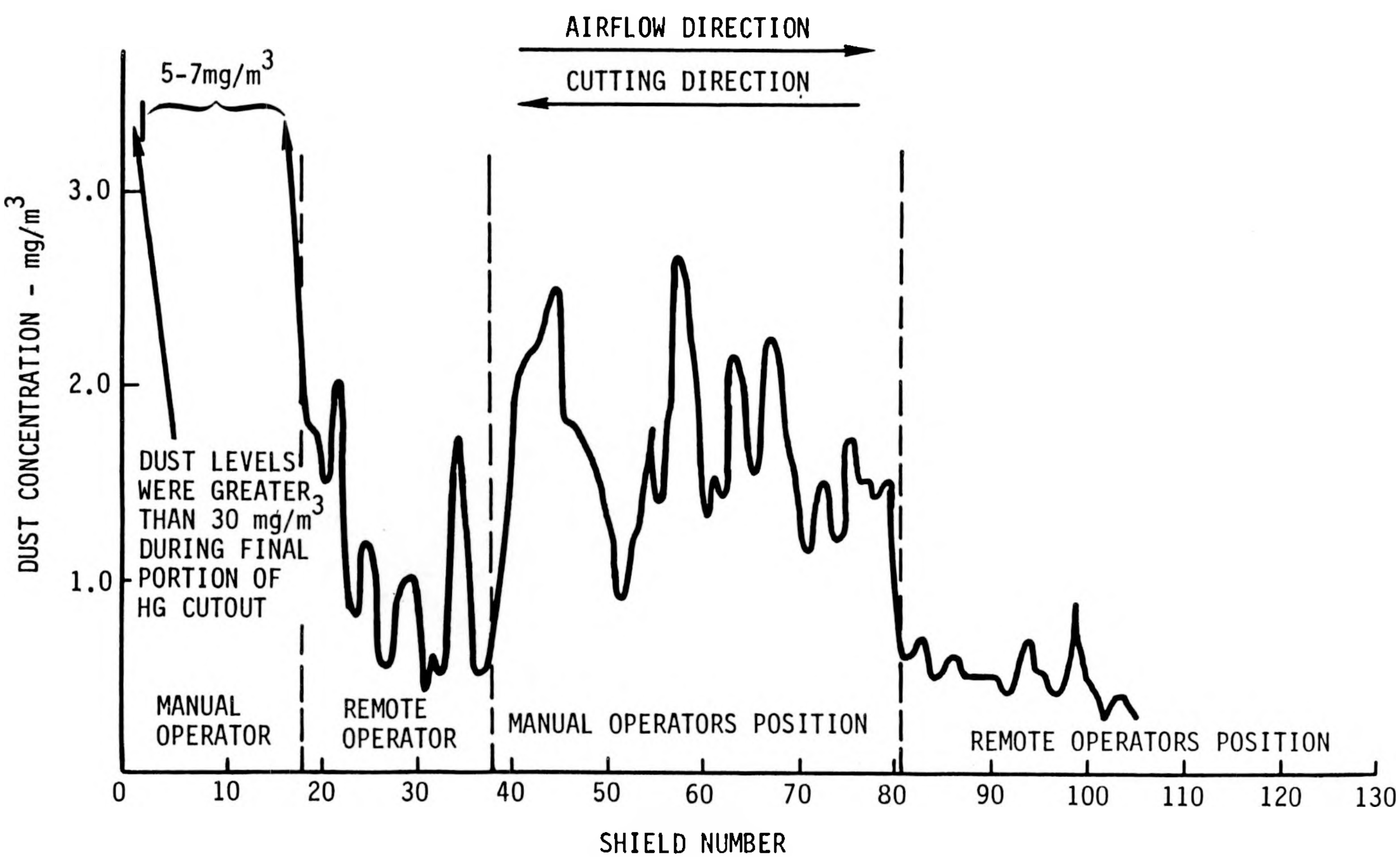

Figure 8. Dust Concentration at Headgate Shearer Operator's Position versus Shield Number (Tail to Head Cutting)

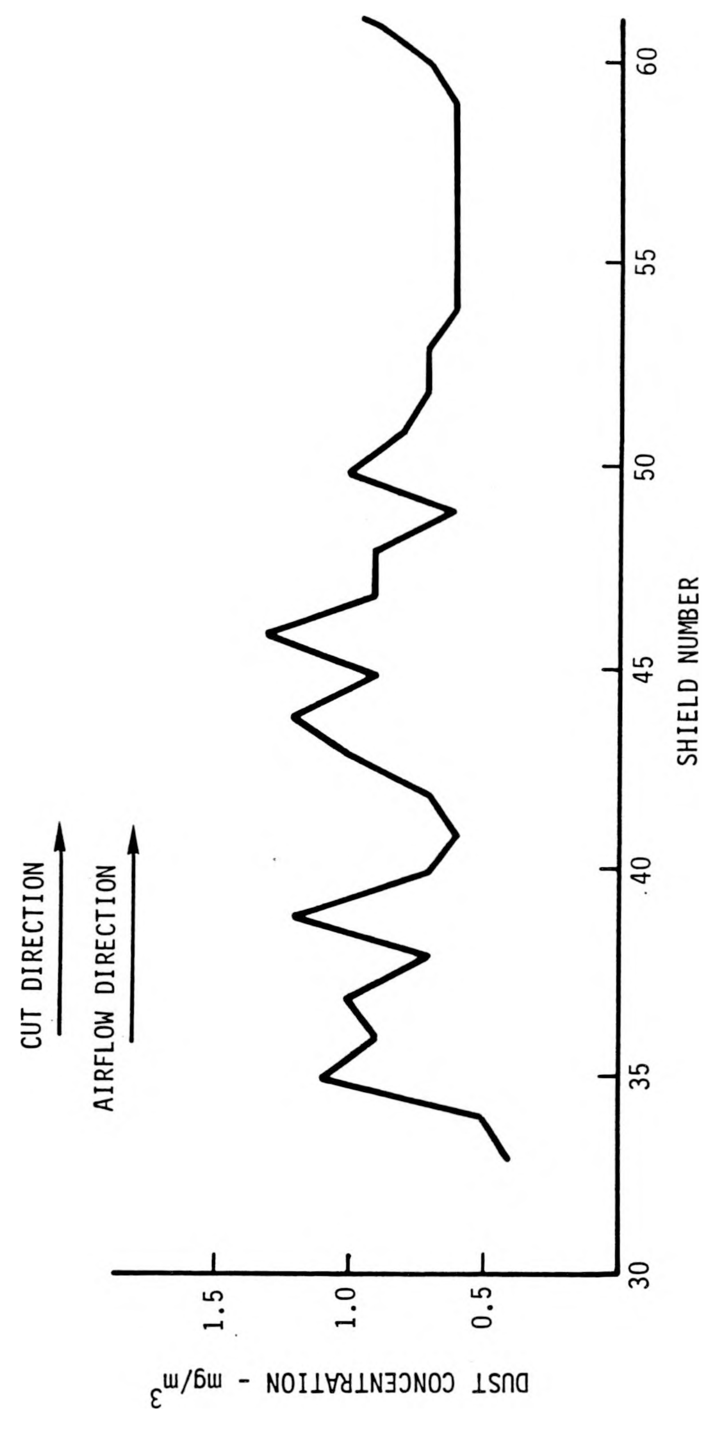

Figure 9. Dust Concentration at Tailgate Shearer Operator's Position versus Shield Number (Head to Tail Cutting)

Figure 8 illustrates dust concentrations measured for a time at both the remote headgate operator and manual headgate operator's position (the normal location of the operator without the remote control) during a tail to head pass. As reflected in the figure, respirable dust exposure levels at the manual operator's position were nearly three times higher than at the remote operator's position. The remote operator's position on the tail to head pass is typically at the leading edge of the headgate drum. This places him upwind of the majority of the shearer-generated dust, nearly in intake air. The manual operator's position, on the other hand, is approximately 8 ft downwind of the leading edge of the headgate drum. At this location, the operator is positioned well within the dust cloud that often boils out in front of the headgate splitter arm and travels down the walkway.

High dust levels at the operator's position are typically generated during the headgate cutout due to the head drum breaking through directly into the oncoming intake airstream. This was true during the study, as concentrations peaked at over 30 mg/m^3 during the final stages of the cutout (see Figure 8).

Figure 9 illustrates dust concentrations at the tailgate shearer operator's position during a head to tail pass. Dust levels were lower and more stable than during the tail to head passes since the primary cutting drum (tailgate) is downwind of the operators. Intake dust levels spot-checked during this pass averaged approximately 0.3 mg/m^3, including shield movement occurring far upstream.

SUMMARY AND CONCLUSIONS

The primary objective of this study was to document the dispersion of shearer-generated and shield-generated dusts as they travel along the longwall face toward downwind personnel. This information was used to provide guidelines for minimizing the dust exposures of downwind personnel. The results of detailed dust sampling using grid pattern, fixed-point instantaneous dust monitors at two locations on the longwall face showed the following:

- A Shearer Clearer-like water spray system, such as that used at Westmoreland, is effective in maintaining a clean/dusty air split for a considerable distance downwind of the shearer (up to 70 ft during tail to head cutting on the subject study). Shearer Clearer techniques should help to minimize the dust exposures of downwind personnel compared to conventional spray systems.

- During tail to head cutting, with shield movement following downwind, shields should be pulled as closely behind the shearer as possible. This will take advantage of the tendency for shearer-generated dust to remain in the face area for a time as it travels downwind.

- During head to tail cutting, with shield movement following upwind of the shearer, shields should not be pulled too closely behind the shearer. When pulled close to the shearer, shield dust will immediately impact the shearer operators. When pulled some distance upstream (40 ft or more should be sufficient), shield dust disperses and dilutes rapidly with the face airflow, minimizing its impact on the shearer operators.

APPENDIX C.--DUSTPRO

This appendix contains a paper, delivered at the 1987 Longwall USA Conference, describing the DUSTPRO expert system computer program for longwall dust control.

A LONGWALL DUST CONTROL EXPERT SYSTEM

BY
S.D. WIRCH[1], S.K. RUGGIERI[2], R.A. JANKOWSKI[3], F.N. KISSELL[4]

ABSTRACT

Under Bureau of Mines Contract J0318097, Foster-Miller, Inc. has developed an expert system that provides longwall operators with site-specific advice on the application of dust control techniques. The system is a PC-based computer program which analyzes and diagnoses dust control problems, and recommends corrective measures to reduce dust levels.

It is structured into three major portions: primary, advanced and a la carte. The primary section gives advice to new users on the fundamental dust control measures which every longwall should employ. The advanced section covers more refined approaches if the primary measures do not achieve compliance. The last section is an a la carte menu for experienced users who have a specific interest in a particular area.

The system requires no programming experience to operate and provides its own instructions. It also supplies users with printouts of data sheets, survey forms and recommendations, as well as graphics illustrating recommended techniques.

This is one of a series of expert systems, called the PRO series, being developed by the Bureau for the mining industry.

INTRODUCTION

High production longwalls normally use several dust control techniques to comply with federal respirable coal dust regulations. Since the location and magnitude of dust sources vary widely, longwall dust control techniques are not universally applicable. For instance, a longwall shearer in high coal will require more water for dust suppression than a shearer in medium coal. There are several different ways to increase the water flow to a shearer, depending upon the water supply system used. What changes need to be made to increase this water flow? Such dust control questions require at least one of the following approaches:

- Trial and error application of home-grown ideas
- An exhaustive literature search
- Consultation with an expert on longwall dust control.

Mines can apply good ideas of their own, but it takes time and resources to evaluate the effectiveness of unique dust control measures. Sifting through the available literature is time-consuming and those responsible for implementing new measures may lack the necessary hands-on experience. The best alternative is to consult a dust control expert who has the knowledge and experience to efficiently apply effective dust control technology A lack of resources and initiative, however, can limit the use of consultants at mines.

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1 Project Engineer, Foster-Miller, Inc., Waltham, MA
2 Senior Engineer, Foster-Miller, Inc., Waltham, MA
3 Supervisory Physical Scientist, Bureau of Mines, Pittsburgh, PA
4 Research Supervisor, Bureau of Mines, Pittsburgh, PA

A longwall dust control expert system is a computer program that can cost-effectively place the knowledge and experience of a consultant at every U.S. longwall face. It contains all pertinent literature on longwall dust control research and applies it as a human expert would. It asks for site-specific information, diagnoses the problem, and recommends corrective measures. The system has several advantages over trial and error application, literature searches, and even human experts. Its information comes from a wealth of tried and proven techniques; it is more efficient than a literature search and is more available than a consultant. The expert system will prioritize the applications and select the most effective techniques in an efficient manner.

Expert Systems

Expert systems are a class of computer programs that have the ability to analyze and diagnose problems, and to recommend solutions. Expert systems mimic the human thought process by using a knowledge base which has been reduced to computer code. The knowledge base is assembled from the available literature and interviews with experts in a particular field. They give laymen expert advice without actually having a consultant present. The longwall expert system discussed here has been designed to provide advice on the application and use of longwall dust control technology to all mines with access to an IBM compatible personal computer.

In developing an expert system, the literature is reviewed and recognized experts are consulted. Their thought processes, knowledge, and experiences are documented and organized for later translation into computer code. Depending upon the size and complexity of the knowledge base, the main topic is subdivided into discrete manageable areas. Software design is initiated by determining the objectives of the program as well as the interrelationship between the topic areas. The program content and flow are then refined and tested until the program reflects the thought process of an expert in the field.

Since the longwall expert system was targeted for on-site use in mines, a primary requirement was that it be PC-based. A commercially available expert system "shell," was selected for program development. Its use reduced the cost of programming and debugging. The selected shell, Insight 2+ *, is a collection of interactive compilers and debuggers which make writing of a user-friendly computer program in a logic oriented programming language easier. It provides a user friendly front end, as well as an interface to compiled Pascal or BASIC programs.

Design of Longwall Dust Control System

The longwall expert system is designed for use by mine safety departments and Federal or state regulatory agencies. It can help engineers and inspectors determine changes needed on a longwall panel to reduce the dust levels, even if computer programming experience is lacking. The program is controlled with single stroke "function" keys and menus.

New users must prepare the system for use on their equipment by executing a short installation program, using explanatory information provided with the expert system. After the expert system is started, users are presented with the initial sign on message which provides a brief description of the program's objective. The next display (Figure 1) familiarizes users with the function keys, which allow them to easily interact with the expert system. Once familiar with these keys, users can go on to the first menu.

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*Reference to specific brands or trade names does not imply endorsement by the Bureau of Mines.

The longwall dust control system has been divided into eight areas: ventilation, water management, water sprays, intake dust, deep cutting, cutting sequence, shield dust, and remote control. The first menu (Figure 2) allows the user to select one of three ways to cover these eight areas:

- Primary dust control techniques
- Advanced dust control techniques
- A la carte menu.

When the appropriate level has been selected, the system asks the user about conditions at the face and the current dust control methods. This information is continually processed and affects the program's questions and responses. The system first checks the fundamentals, and then moves on to the more advanced techniques such as deep cutting and cut sequence. All recommendations are "customized" for site specific conditions. The system also provides the user with survey forms, instructions for installing dust control systems, graphic illustrations of applications, and results of applicable longwall dust control research.

System Implementation

First time users should select primary dust control techniques from the main menu to ensure that they are using ventilation, external sprays, and water appropriately to reduce dust levels. They are generally viewed to be the three most important areas of longwall dust control and should be applied before more sophisticated techniques are implemented.

When primary dust control techniques are selected from the first menu, the computer will query the user to determine:

- Type of external sprays
- Condition of drum sprays
- Total water volume to the shearer
- Air velocity on the face.

The following example illustrates how the user would interface with the the water volume portion of the program. The program first asks the user to input the seam height and total water flow to the shearer; the seam height is used to calculate what the optimal flow should be. If the water flow to the shearer is 40 gpm and the seam height is 85 in., the program will tell the user that his water flow is too low and should be at least 65 gpm for that seam height.

The user is then asked for additional information to determine how the water supply system can be modified to provide 65 gpm during normal operating conditions. With the user's consent, the computer prints out a special survey form (Figure 3) requesting data on water pressure, water flow, hose diameters, and hose lengths. This information is measured underground and then input into the system. The expert system analyzes the information by checking the following:

- Are the values within an expected range specified in the program?
- Is the current water supply system capable of supplying 65 gpm to the shearer?
- Are the spray nozzles, or line restrictions on the shearer limiting the water flow?
- Is water flow on the shearer being "dumped" or lost through an open pipe or hole?

If the diameter of the trailing hose is less than 1-1/2 in., the system:

- Calculates the increase in pressure and flow obtainable with 1-1/2 in. diam hose
- Checks to see if trailing hose replacement will increase the water flow to 65 gpm at 200 psi.

If hose replacement is not sufficient, the system determines the pump characteristics necessary to increase the water flow to 65 gpm at 200 psi. Based on the above analysis, the proper recommendations are displayed and made available for print-out.

Example

To illustrate the expert system's analysis of some actual data, we assume the user has completed the survey and has input the following values.

Flow: 65 gpm
Pressure: 100 psi
Trailing hose measurements:
Inside diameter: 1-1/4 in. Length: 300 ft
Supply hose measurements:
Inside diameter: 1-1/2 in. Length: 450 ft

The system first checks that the input values are realistic and if the water supply system can supply 65 gpm at 200 psi. Since the pressure is less than 200 psi when the flow is 65 gpm, the water supply system needs upgrading. The sprays are not limiting the flow. Since the flow is not greater than 65 gpm, and the water pressure is between 20 to 200 psi, the system determines that the water flow on the shearer is probably not being "dumped." The system then checks the diameter of the trailing hose, which is 1-1/4 in. Most experts believe that all mines can fit a 1-1/2 in. hose in the cable handler. The system calculates the pressure at the shearer using a 1-1/2 in. hose and finds the water pressure increases to 234 psi. The expert system then displays the message shown in Figure 4, encouraging the user to increase the trailing hose diameter to 1-1/2 in.

The external spray and ventilation portions of the primary level are treated in a manner similar to the above example. Improvements to the spray system will be suggested, with graphic illustrations. If the longwall's air velocity is too low, the user will be encouraged to perform a survey of the section ventilation system and input the air measurement data. The computer diagnoses what the problems are and decides what needs to be replaced or changed. For instance, if excessive air leakage is occurring between the last open crosscut and the beginning of a face, a "gob curtain" is suggested as shown in Figure 5. The illustration and accompanying text provide the information necessary for the proper application and installation of the curtain.

If the primary dust control techniques have been properly applied and compliance remains a problem, the user is encouraged to select the advanced dust control option from the main menu. This covers more refined techniques including:

- Intake dust sources - The system checks for ventilation flow direction, sources of intake dust, and recommends control techniques
- Deep cutting - The system calculates the depth of cut and recommends any needed changes

- Cut sequence - The system analyzes shearer and shield movement and recommends the best possible cut sequence

- Shield dust - The system provides advice on support movement based upon movement currently being used and location of face personnel

- Remote control - The system checks to see if and what type of remote control is used. If appropriate, the system recommends the proper remote control system and its proper use as a dust control/safety technique.

Experienced users or users with a specific interest can use the third option - a la carte. This option allows direct access to any of the eight areas of longwall dust control. It allows the user to play "what if" scenarios within an area and to optimize the application of a specific dust control technique, i.e., deep cutting, by modeling the changes on the computer before applying them underground.

Summary

Expert systems offer the mining industry a powerful new tool. The longwall expert system acts as an on-site longwall dust control consultant and guides the user through the process of determining what the problem is and how to apply the necessary corrective actions.

During a preliminary test release, the longwall expert system has received favorable reviews from industry sources. The program is currently undergoing final revisions and will be ready for general release to the coal mining industry in the near future. The Bureau has also initiated the development of additional expert systems in the areas of continuous miner dust control, gob sealing, and longwall drum design. This series of expert systems for the mining industry is called the PRO series. To receive a copy of this Longwall Dust Control Expert System or for additional information on the PRO series contact Fred Kissell, U.S. Bureau of Mines, Department of the Interior, Box 18070, Pittsburgh, PA 15236 (412) 892-6679.

```
Beginning of the Longwall Dust Control Expert System ver 2.0

     The program is menu and function key driven; just follow the
directions I give you. A few added facilities follow:

        * The function keys are labeled F1 through F10, and on most
          IBM PC's and compatibles are on the extreme left of the keyboard.
          The functions of these keys are listed on the bottom of the screen.

        * Function key F3 brings you back to the beginning of the program.

        * Function key F5 gives you further explanation on a question.

        * Function key F7 gives you a hardcopy listing of messages.
          This does not work for questions.

        * Function key F8 returns you to the last question or the menu that
          you were viewing.

        * Function key F10 allows you to exit the program and return to
          DOS.
                               Press F1 to view the rest of this message ...
                               Press F2 to continue ...

1 PAGE  2 CONT  3 STRT                6 WHY?  7 PRNT  8 MENU  9 HELP  10 EXIT
```

Figure 1. Preliminary Instructions Given to the User

```
Beginning of the Longwall Dust Control Expert System ver 2.0

                               MAIN MENU

     Please select the area you want to focus on by pressing the space
bar to move the cursor in front of your choice, and then pressing the carriage
return (↵).
                 (Press F5 for an explanation)

→Primary Dust Control Techniques - suggested option for new users.
          This option covers - External Sprays, Water Management, and Ai

   Advanced Dust Control Techniques - suggested option for second time users.
          This option covers - Intake Dust Sources, Deep Cutting, Air,
                               Cut Sequence, Shield Dust, Remote Control,
                               and Water Management.

   Ala Carte Menu - suggested option for experienced users.
          This option allows you to steer your own course through the
                               Knowledge Based Expert System.

  2 UNKN  3. STRT         5 EXPL  6 WHY?          8 MENU  9 HELP
```

Figure 2. Main Menu of the Longwall Dust Control Expert System

SURVEY INSTRUCTIONS

The following steps should be taken before completing this survey:

* Fabricate the test rig shown below. Make sure to install the flowmeter in the correct direction. If the shearer has a pressure gauge near the water inlet, use it for taking pressures.
  If the shearer does not have a pressure gauge near the water inlet, install one. Use at least 1 - 1/4 inch pipe fittings throughout the test rig.

* Check to make sure all valves in the water supply line to your section and to your shearer are fully open.

* Check all sprays to make sure they are operable, including drum sprays, cooling water sprays, external sprays, stageloader sprays, transfer point sprays, and belt sprays.

* If at all possible, perform the survey while other nearby sections are producing coal so that the line water pressure is normal.

FLOW TEST RIG

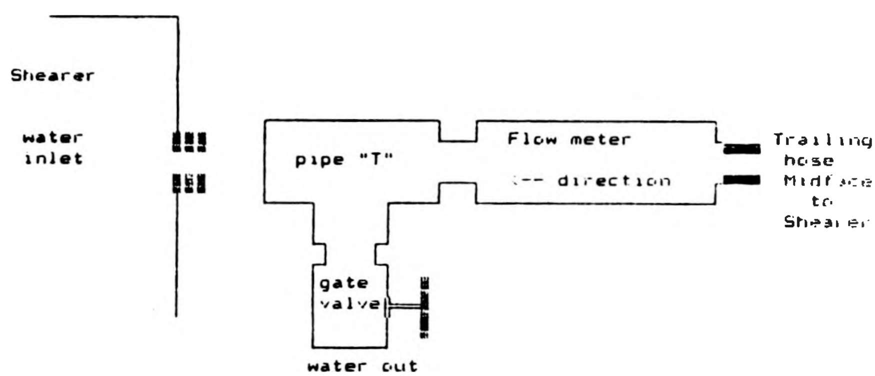


Figure 3. Water Survey Instruction Sheet, and Data Form

Water Survey

1.) Follow survey instructions (above).

2.) Turn off water to shearer. Install test rig shown above at inlet to shearer. Fully close gate valve.

3.) Turn on water to the shearer. If the flow meter reads less than 65 gpm, open the gate valve on the test apparatus until 65 gpm is achieved.

4.) When 65 gpm is reached, record the pressure on the gauge. Note: if gate valve is fully open and 65 gpm cannot be reached, record the maximum flow and pressure that was obtained.

Pressure __________psi. Flow ________gpm.

5.) Turn off water to shearer and disconnect the test rig.

6.) Record the inside diameter and length of the trailing hose from shearer to midface (measure to 1/32 inch).

Inside diameter ______in. Length _________ft.

7.) Record the inside diameter and length of the hose from the section supply manifold (hardpipe) to midface (measure to 1/32 inch).

Inside diameter ______in. Length _________ft.

8.) Rerun the longwall expert system and enter the numbers when you are presented with the water survey printout/analysis menu. Do not use the above flow until asked for the water survey values.

Figure 3. Water Survey Instruction Sheet, and Data Form (Continued)

Water Management Subprogram

If you replace the hose running from the midface to the shearer, with 1 1/2 inch hose, your water pressure at the shearer should increase to 234psi from your present pressure of 100psi. This will probably alleviate your water pressure problems.

Press F2 to continue ...

2 CONT 3. STRT 6 WHY? 7 PRNT 8 MENU 9 HELP 10 EXIT

Figure 4. A Typical Recommendation Given by the Longwall Expert System

Ventilation Subroutine

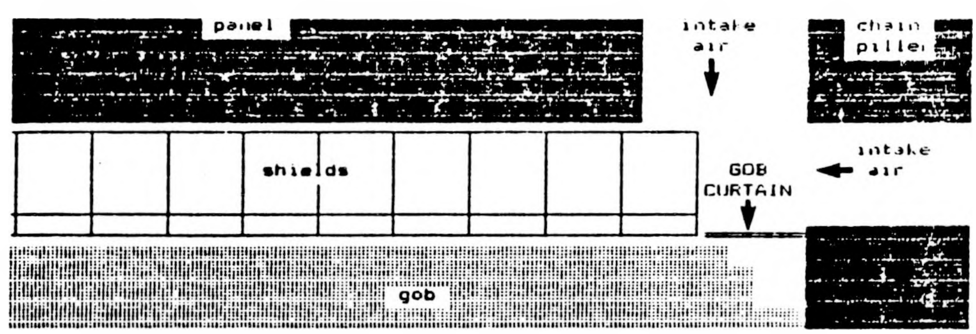
The volume at the beginning of your face (traverse four) is lower than the volume at the headgate. This means you are losing excessive amounts of air into the gob. Excessive air loss to the gob typically occurs :

* at the beginning of a new panel before the gob has fallen (fallen gob is an effective barrier to air movement behind the shields).
* when the gob is "loose" and allows air movement behind the shields.

In either case I would like you to try adding a gob curtain in the headgate to help block air from leaking into the gob.

Press F1 to continue ...

1 PAGE 2 CONT 3 STRT 6 WHY? 7 PRNT 8 MENU 9 HELP 10 EXIT



By placing a gob curtain to block the air from entering the gob, air velocities along the face can be raised significantly.

Press F2 to continue

1 PAGE 2 CONT 3 STRT 6 WHY? 7 PRNT 8 MENU 9 HELP 10 EXIT

Figure 5. A Typical Graphic Illustration of a Recommendation Given by the Longwall Expert System

APPENDIX D.--DRUMPRO

This appendix contains a paper, delivered at the 1988 Longwall USA Conference, describing the DRUMPRO expert system computer program for longwall drum design.

A LONGWALL DRUM DESIGN EXPERT SYSTEM

By S. D. Wirch[1] and J. S. Kelly[2]

ABSTRACT

Under Bureau of Mines Contract J0318097, Foster-Miller, Inc. has developed an expert system that provides longwall operators with site-specific advice on longwall drum design. The system is a PC-based computer program which analyzes and diagnoses drum design problems. It recommends corrective measures to reduce dust problems and improve productivity.

The system requires no programming experience to operate and provides its own instructions. It also supplies users with printouts of data sheets, survey forms and recommendations, as well as graphics illustrating recommended corrective actions.

The reasoning process employed by the program reproduces that used by an actual drum expert. The program examines drum parameters for obvious flaws, seam conditions, and performance during cutting.

This is the third of a series of expert systems, called the PRO series, being developed by the Bureau for the mining industry.

INTRODUCTION

High production longwalls use a trial and error approach to improve their shearer drum designs. Since the number of variables on a shearer drum is great (number of vanes, bit type and placement, etc.) a number of approaches may be used to determine which, if any, variables need to be changed when drums are rebuilt or fabricated. The more typical approaches to improving drum design include:

- o Trial and error application of homegrown ideas.
- o An exhaustive literature search, coupled with complex calculations.
- o Consultation with an expert on longwall drum design.

Mine personnel can apply good ideas of their own, but it takes time and resources to evaluate the effectiveness of unique drum designs. Sifting through the available literature is time-consuming and those responsible for implementing new drum designs may lack the necessary hands-on experience. The best alternative is to consult a drum design expert who has the knowledge and experience to efficiently apply effective dust control technology. A lack of resources and initiative, however, can limit the use of consultants at mines.

The longwall drum design expert system is a computer program that can cost-effectively place the knowledge and experience of a consultant at every U.S. longwall face. It contains all of the pertinent knowledge on longwall drum design research and applies it as a human expert would. It asks for site-specific information, diagnoses the problem, and recommends corrective measures. The system has several advantages over trial and error application, literature searches, and even human experts. Its information comes from a wealth of tried and proven techniques; it is more efficient than a literature search and is more available than a consultant. The expert system will prioritize the applications and select the most effective techniques in an efficient manner.

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EXPERT SYSTEMS

Expert systems are a class of computer programs that have the ability to analyze and diagnose problems, and to recommend solutions. Expert systems mimic the human thought process by using a knowledge base which has been reduced to computer code. The knowledge base is assembled from the available literature and interviews with experts in a particular field. They give laymen expert advice without actually having a consultant present. The drum design expert system discussed here has been designed to provide advice on the application and use of longwall drum design technology to all mines with access to an IBM compatible personal computer.

In developing an expert system, the literature is reviewed and recognized experts are consulted. Their though processes, knowledge, and experiences are documented and organized for later translation into computer code. Depending upon the size and complexity of the knowledge base, the main topic is subdivided into discrete manageable areas. Software design is initiated by determining the objectives of the program as well as the interrelationship between the topic areas. The program content and flow are then refined and tested until the program reflects the though process of an expert in the field.

Since the longwall drum design expert system was targeted for on-site use in mines, a primary requirement was that it be PC-based. A commercially available expert system "shell," was selected for program development. Its use reduced the cost of programming and debugging. The selected shell, Insight 2+[3] is a collection of interactive compilers and debuggers which makes writing of a user-friendly computer program in a logic oriented programming language easier. It provides a user friendly front end, as well as an interface to compiled Pascal or BASIC programs.

DESIGN OF THE LONGWALL DRUM DESIGN SYSTEM

The drum design expert system is designed for use by mine safety/engineering departments, drum manufacturers, and federal or state regulatory agencies. It can help engineers and inspectors determine changes needed to a drum design to reduce the dust levels, even if computer programming experience is lacking. The program is controlled with single stroke "function" keys and menus.

New users must prepare the system for use on their equipment by executing a short installation program, using explanatory information provided with the expert system. After the expert system is started, users are presented with the initial sign-on message which provides a brief description of the program's objective. The next display (Figure 1) familiarizes users with the function keys, which allow them to easily interact with the expert system. Once familiar with these keys, users can go on to the first menu.

The longwall drum design expert system has been divided into three levels: Little, Moderate, or Extensive Drum design experience. Users with less experience are offered more explanatory information concerning input data and recommendations. When the appropriate level has been selected, the system asks the user about conditions at the face and the current drum design. This information is continually processed and affects the program's questions and responses. The system first checks the fundamentals, and then moves on to the more advanced techniques such as deep cutting and force fluctuations. All recommendations are "customized" for site specific conditions.

SYSTEM IMPLEMENTATION

A typical first-time user should select the lowest level of drum design experience. This will allow the user to become familiar with the layout of the software, the terminology used, and the primary dependent drum design variables.

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[3]Reference to specific brands or trade names does not imply endorsement by the Bureau of Mines.

The user will be offered a printout of a data sheet which details some of the "generic" input variables (drum diameter, vane angle of wrap, etc.). The program will then begin an interactive question and answer session. As design/operational flaws are detected they will be pointed out. The user is able to back up and change values, or proceed with analysis of the existing input data.

After the program has collected the drum dimensions and face conditions, a series of recommendations are given which detail steps which should be taken to reduce dust levels and improve drum performance. Thousands of combinations of recommendations are possible. Global areas include:

- o Operational (drum speed, cut sequence).
- o Design (two start versus three start, bit spacing).
- o Calculations (discussion of loading performance, forces).

Following the final recommendation screen, the user is given the option of producing a summary printout of the session. If an IBM Proprinter compatible printer is available, bit lacing and breakout diagrams (Figure 2) and force torque diagrams (Figure 3) are given. Following the summary screen, the user is routed to the beginning of the program (if the user does not exit the program).

Moderately experienced (second time) users are spared the task of answering individual questions in order to modify/input their drum parameters and face conditions. Data input tables (Figure 4) are used to collect/modify the data. To modify an existing value, the cursor is positioned over the existing value, and the new value is entered. The corresponding on-screen display is then updated to reflect the new value.

After proceeding through the three data input screens, users with moderate drum design experience are given a series of recommendations screens detailing the performance of their drum, and what they should do to reduce dust, and improve performance.

Users with extensive drum design experience (engineers and drum manufacturers) are given much more flexibility in determining which screens they see. Experienced users are able to "jump" to any screen in the program, and are given the ability to modify the way the program calculates forces and depth of coal breakage.

All users are given the ability to store and retrieve data files to and from the disk drives. In this manner, and experienced user may position the program on one recommendation screen (force calculations) and compare several data sets against one another by retrieving them from the disk.

Every attempt has been made to allow the drum design expert system to interactively relate in a usable manner to every conceivable type of user, from a college student that knows very little about drum design, to a drum design expert that has been laying out drums for years.

SUMMARY

Expert systems offer the mining industry a powerful new tool. The drum design expert system acts as an on-site longwall drum design consultant and guides the user through the process of determining what the problem is and how to apply the necessary corrective actions.

During a preliminary test release, the longwall drum design expert system has received favorable reviews from industry sources. The program is currently undergoing final revisions and will be ready for general release to the coal mining industry in the near future. This is the third in a series of expert systems called the PRO series. Previous expert systems cover the topics of longwall dust control and continuous miner dust control. The bureau has also initiated the development of additional expert systems in the areas of gob gas sample interpretation, scrubber design, and dust sampling layout/analysis. To receive a copy of this Expert System or for additional information on the PRO series contact Fred Kissell, Bureau of Mines, U.S. Department of the Interior, Box 18070, Pittsburgh, PA 15236, telephone (412) 892-6679.

Beginning of the Drum Design Expert System (ver .1)

This program has been designed to explain itself as you go along. Extra help can be found by using the function keys (F1 thru F10 on your keyboard). The active function keys are shown at the bottom of the screen. The facilities offered by these keys follow:

F2	CONT,	moves you to the next table/display.
F7	UTIL,	allows you to make print outs, get data files, change screen colors, and convert units.
F8	BACK,	makes the computor backup a step.
F9	HELP,	an explanation of what is going on.
F10	EXIT,	leaves DrumPRO

Press function key 2 (F2) to continue
Press function key 9 (F9) for additional info

1 2 CONT 3 4 5 6 7 UTIL 8 BACK 9 HELP 10 EXIT

Figure 1. Preliminary instructions given to the user.

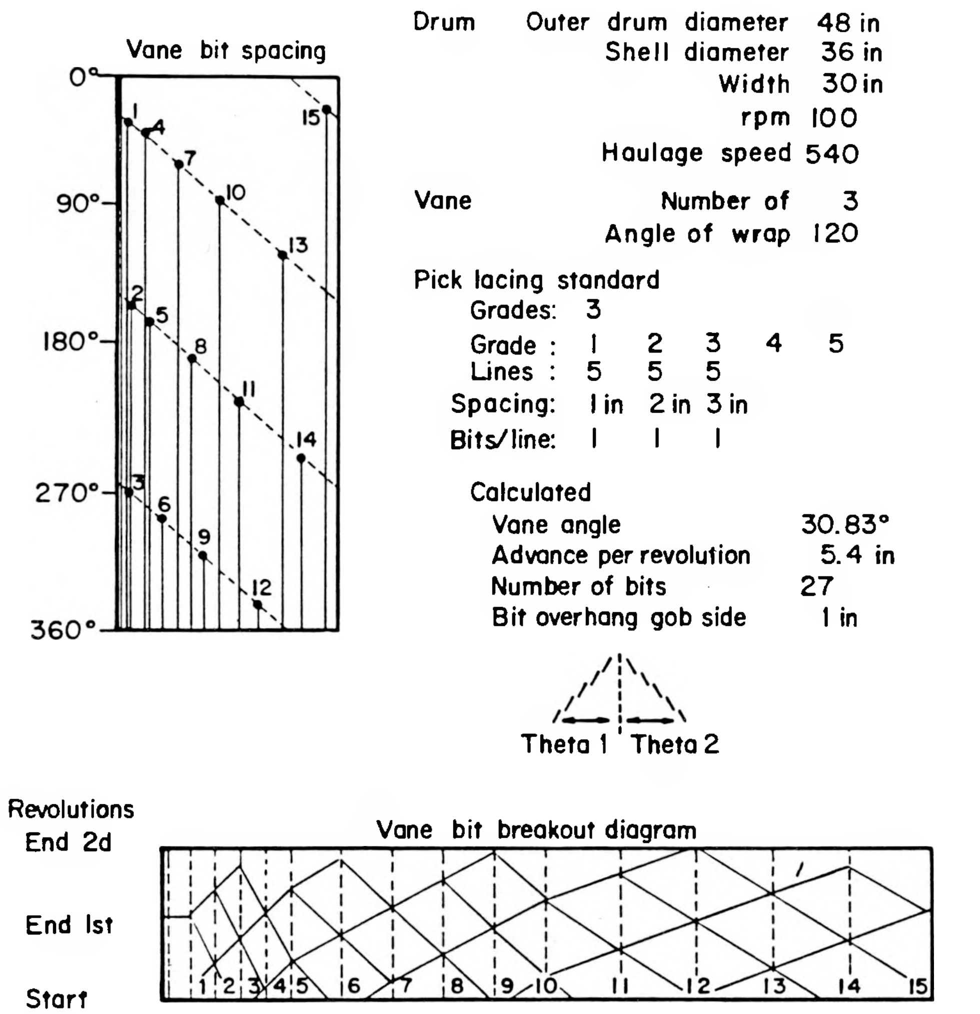
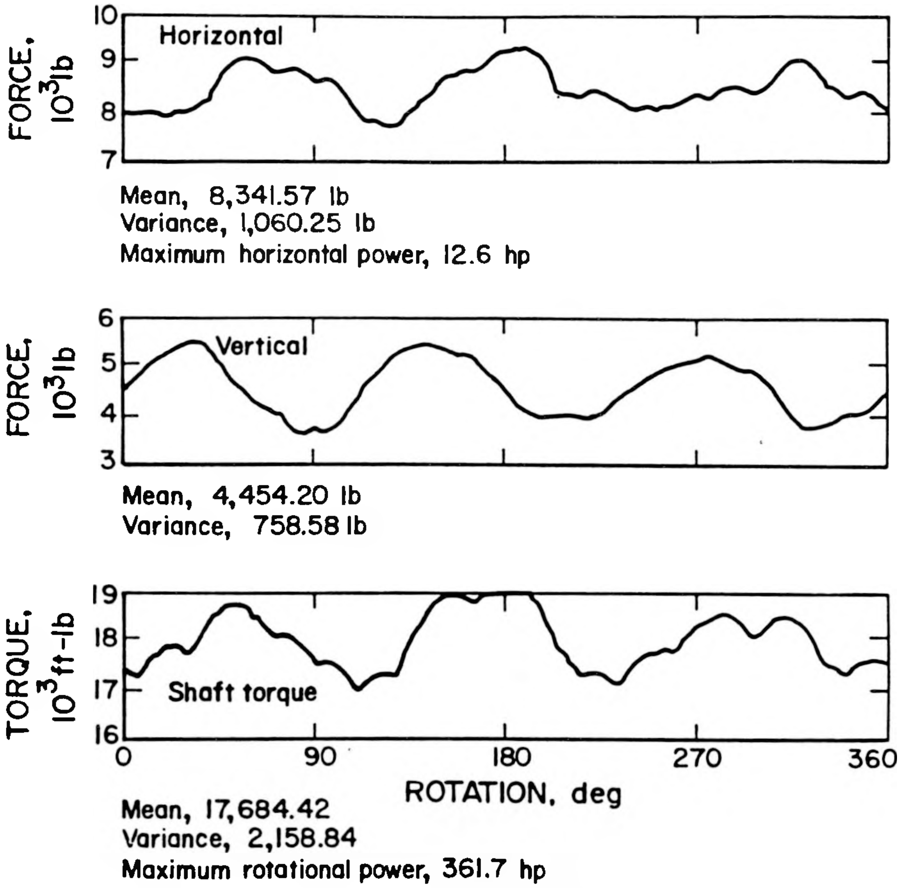


Figure 2. Printout of vane bit lacing and vane bit breakout diagrams produced by drum PRO.



DESCRIPTION

Carbide tip radius, 10.00	Drum speed, 100 rpm
K radial slope, 11,864	Haulage speed, 540 fpm
K radial intercept, 0.00	Advance per revolution, 5.4 in
K theta slope, 20,984	Number of bits, 27
K theta intercept, 0.00	Vanes, 3
Coal angle, 180°	Drum width, 32.5 in
Cutting width, 30.00 in	Vane angle, 38.83°
Breakage angle, 70°	Backplate lacing, ECADBA
Drum diameter, 48 in	Total angle of wrap, 360°

Figure 3. Printout of force-torque curves calculated by drum PRO.

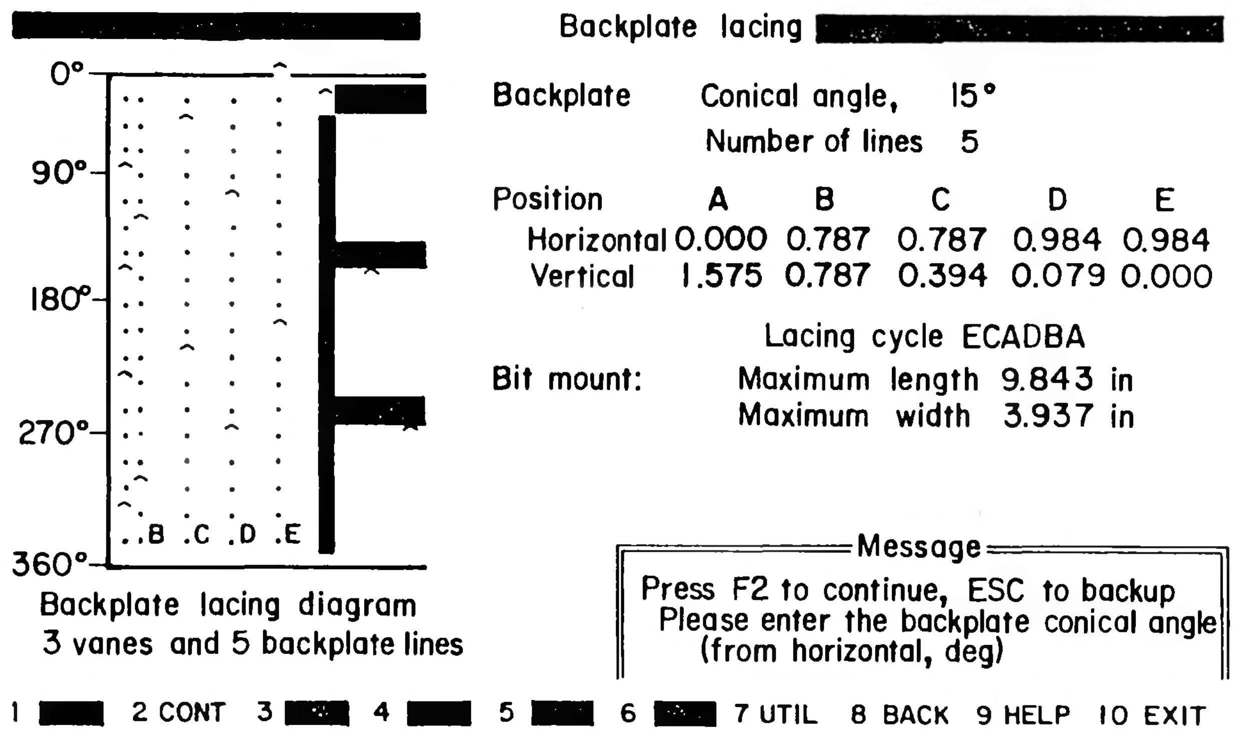


Figure 4. Example data input table.