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EVALUATE FUNDAMENTAL APPROACHES TO LONGWALL DUST CONTROL

Phase III Report

By
C. Babbitt
P. Bartlett
J. Kelly
J. Ludlow
A. Mangolds
S. Rajan
S. Ruggieri
E. Varga

March 31, 1984

Work Performed Under Contract No. AI01-81FE00016

Foster-Miller, Inc.
Waltham, Massachusetts

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DOE/FE/00016-T26
(DE84008571)
Distribution Category UC-88

EVALUATE FUNDAMENTAL APPROACHES TO LONGWALL DUST CONTROL

PHASE III REPORT

BM-8148

Prepared for:

U.S. Bureau of Mines
P/BAO Procurement Unit
4800 Forbes Avenue
Pittsburgh, PA 15213

Prepared by:

C. Babbitt, P. Bartlett, J. Kelly, J. Ludlow,
A. Mangolds, S. Rajan, S. Ruggieri, E. Varga

Under USBM Contract No.
J0318097

Foster-Miller, Inc.,
350 Second Avenue,
Waltham, MA 02254

31 March 1984

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TABLE OF CONTENTS

Section		Page
1.	INTRODUCTION	12
2.	SUBPROGRAM A - PASSIVE BARRIERS/SPRAY AIR MOVERS FOR DUST CONTROL	15
2.1	Summary of Phases I and II	15
2.2	First Field Evaluation - Kaiser Steel Corporation, Sunnyside No. 1 Mine	16
2.2.1	Summary of System Design, Installation and Evaluation - Completed During Phase II	16
2.2.2	Evaluation Results	17
2.3	Mine Site Selection for the Second Field Evaluation	29
2.3.1	Price River Coal Company - Helper, Utah	29
2.3.2	ARMCO Steel - Montcoal, West Virginia	31
2.4	Second Field Evaluation - ARMCO Steel, No. 7 Mine	31
2.4.1	Field Surveys	31
2.4.2	Evaluation Testing Strategy	35
2.4.3	Test Results	37
2.4.4	Summary and Recommendations	44
2.5	Additional Passive Barrier Study	45
2.6	Future Effort	45
3.	SUBPROGRAM B - PRACTICAL ASPECTS OF DEEP CUTTING	47
3.1	Overall Program Objectives	47
3.2	Phase I Results	48
3.3	Phase II Objectives	48
3.4	Phase II Results	49
3.5	Phase III Objectives	49
3.6	Technology Transfer Article	49
3.7	Completion of Final Report	64
4.	SUBPROGRAM C - STAGELOADER DUST CONTROL	66
4.1	Overall Objective	66
4.2	Summary of Phase I and Phase II	66
4.3	Phase III Activity	68
4.3.1	Florence Mine - Preliminary Visit	68
4.3.2	Wilberg Mine - Preliminary Visit	69
4.3.3	Test Planning for Third Stageloader Evaluations	70
4.4	Phase IV Effort	70

TABLE OF CONTENTS (Continued)

Section		Page
5	SUBPROGRAM D - LONGWALL AUTOMATION TECHNOLOGY	72
5.1	Overall Program Objectives	72
5.1.1	Phase I Results	72
5.2	Phase II Objectives	73
5.2.1	Synopsis of Phase II Results	73
5.3	Phase III	74
5.3.1	Phase III Objectives	74
5.3.2	Shearer Remote Control	75
5.3.3	Longwall Roof Support Automation	80
5.3.4	Immediate Forward Support	80
5.4	Phase IV Activity	80
6.	SUBPROGRAM E - LONGWALL APPLICATION OF VENTILATION CURTAINS	82
6.1	Summary of Phases I and II	82
6.2	Phase III Effort - Site Selection for the Second Field Evaluation	84
6.2.1	Price River Coal Company - Helper, Utah	84
6.2.2	ARMCO Steel - Montcoal, West Virginia	85
6.2.3	Kaiser Steel Corporation, York Canyon Mine Raton, New Mexico	86
6.3	Planned Phase IV Effort - Second Evaluation at Kaiser Steel	88
7.	SUBPROGRAM F - REVERSED DRUM ROTATION	91
7.1	Overall Objectives	91
7.2	Phase II Summary	91
7.3	Phase III Activity	93
7.3.1	Mine Site Selection	93
7.3.2	Reverse Drum Evaluation at Jim Walter Resources, Inc., No. 4 Mine	96
7.4	Phase IV Activity	112
8.	SUBPROGRAM G - SHIELD GENERATED DUST	114
8.1	Introduction	114
8.2	Phase II - Summary	115
8.3	Phase III - Activity	116
8.4	Literature Search/Discussion of Roof Geology	116
8.5	Mine Site Selection/Pilot Studies	120
8.6	Objectives/Strategy for Field Evaluation	122
8.7	Future Effort	123
9.	AIR CANOPIES FOR LONGWALLS	124

TABLE OF CONTENTS (Continued)

Section		Page
10.	SUBPROGRAM I - MINING PRACTICES	125
10.1	Overall Objective	125
10.2	Phase I and II Summary	125
10.3	Phase III Activity	127
10.4	Homotropal Evaluation at Old Ben	128
10.4.1	Sampling Methods/Evaluation Plan	129
10.4.2	Evaluation Results	129
10.5	Homotropal Followup Studies	136
10.5.1	Evaluation of Bethlehem Mining Corps., Mine No. 33, Cambria Division	137
10.5.2	Evaluation of Jim Walter Resources, Inc. Mine No. 4., Longwall No. 2	139
10.5.3	Evaluation of Beth-Elkhorn, Mine 26L	140
10.6	Homotropal Evaluation Conclusions	141
10.7	Asymmetrical Cutting Drum Investigation	141
10.8	Strategy for Locating a Cooperating Mine Site	144
10.9	Phase IV Effort	145

LIST OF ILLUSTRATIONS

Figure		Page
1-1	Revised master program schedule	14
2-1	Combination passive barrier/shearer clearer system with diverted cooling water	18
2-2	Respirable dust concentration versus face location. Head-to-tail pass; shearer clearer system; without passive barriers	22
2-3	Respirable dust concentration versus face location. Head-to-tail pass; conventional system; without passive barriers	22
2-4	Respirable dust concentration versus face location. Head-to-tail pass; complete shearer clearer system; without passive barriers	24
2-5	Respirable dust concentration versus face location. Head-to tail pass; reduced shearer clearer system (spray banks C & D) without passive barriers	24
2-6	Respirable dust concentration versus face location. Tail-to-head pass; shearer clearer system; without passive barriers	27
2-7	Respirable dust concentration versus face location. Tail-to-head pass; conventional system; without passive barriers	27
2-8	Layout of shearer spray system - September 1983	32
2-9	Layout of shearer spray system after ARMCO modifications	34
2-10	Shearer operator dust concentration versus water pressure at three airflow velocities; tail-to-head cutting	35
2-11	Shearer operator dust concentration versus airflow velocity at three water pressures; tail-to-head cutting	39

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
2-12	Shearer operator dust concentration versus water pressure at three airflow velocities; head-to-tail cutting	43
2-13	Shearer operator dust concentration versus airflow velocity at three water pressures; head-to-tail cutting	43
2-14	Diagonal passive barrier system - Bethlehem No. 60 Mine	46
3-1	Dust make and shearer power consumption as a function of drum speed and the number of picks per line	52
3-2	Pick penetration and shearer speeds	55
3-3	Components of cutting reaction at the pick tip	55
3-4	Normal and tangential forces at the pick tips and the resulting reaction moment and forces at the drum axis (two dimensional case).	56
3-5	Effect of depth of cut (d) on volume of coal removed	56
3-6	Shearer drum components (most picks omitted).	61
4-1	Dust concentrations, shearer cutting from tailgate-to-headgate - Emergy Mining Corp's., Wilberg Mine	69
5-1	Shearer dust profiles Quarto No. 4, 4 South Longwall	78
6-1	Dust concentrations at headgate shearer operator's position during headgate cutout, tail-to-head cutting - Price River Coal Company	85

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
6-2	ARMCO's use of brattice and belting to control headgate airflow patterns	86
6-3	Kaiser's use of a unique wing curtain - gob curtain - stageloader curtain system for headgate cutout dust control	87
6-4	Dust concentration versus shield number; tail-to-head cutting - Kaiser Steel; Corporation, York Canyon Mine	89
7-1	Reversed drum rotation	92
7-2	Location of sampling positions	101
7-3	Dust levels around the shearer (above the cable tray) during cutting from tailgate-to-headgate	104
7-4	Dust levels around the shearer (above the cable tray) during tramming from headgate-to-tailgate	105
7-5	Average dust concentrations of five tail-to-head cutting passes - reversed drum rotation	106
7-6	Average face dust concentrations of six tail-to-head cutting passes - conventional drum rotation	106
7-7	Average dust concentrations of five head-to-tail tramming passes - reversed drum rotation	107
7-8	Average dust concentrations of six head-to-tail tramming passes - conventional rotation	107
7-9	Comparison of shearer dust levels	108

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
8-1	Chercher shield spray system	118
10-1	Comparison of face intake dust levels	130
10-2	Headgate dust concentration map, antitropal ventilation during head-to-tail (cutting) pass	132
10-3	Headgate dust concentration map, homotropal ventilation during tail-to-head (cutting) pass	133
10-4	Headgate dust concentration map, homotropal ventilation during tail-to-head (cutting) pass	134
10-5	Headgate dust concentration map, homotropal ventilation during tail-to-head (cutting) pass	135
10-6	Homotropal air velocity survey	138
10-7	Asymmetrical drum application - Barnes & Tucker	142

LIST OF TABLES

Table		Page
2-1	A-B comparative test strategy - Kaiser Steel evaluation	19
2-2	Results of dust monitoring - May and August, 1982 field surveys	19
2-3	Dust concentrations for conventional versus shearer clearer system with and without passive barriers during head-to-tail cutting passes	21
2-4	Dust concentrations for conventional versus shearer clearer system with and without passive barriers during tail-to-head cutting passes	24
2-5	Average shearer generated dust concentrations at the headgate shearer operator's position between shields 15 and 4 during headgate cutouts	28
2-6	Dust Concentration Survey, Price River Coal Co., 10th West Longwall	30
2-7	Conditions during the September 1983 survey	31
2-8	Average dust concentrations - September 1983 survey	32
2-9	Conditions during the October and November 1983 surveys	34
2-10	Average dust concentrations - September and October 1983 surveys	35
2-11	Average dust concentrations at the shearer operator's position for selected water pressure and air velocity conditions - tail-to-head cutting	39

LIST OF TABLES (Continued)

Table		Page
2-12	Average dust concentrations at the shearer operator's position for selected water pressure and air velocity conditions in head-to-tail cutting	42
2-13	Results of A-B comparison testing on passive barriers - Bethlehem No. 60 Mine	46
3-1	Outline of subprogram final report	65
5-1	Summary of remote control data from ARMCO Wathonde No. 7 mine	76
5-2	Summary of remote control data from Quarto No. 4, 4 South Longwall	77
5-3	Comparison of dust exposure levels at Quarto No. 4, 3 North Longwall	79
7-1	Comparison of operator's exposure showing disproportionate exposure of upwind (headgate) operator	95
7-2	Reversed drum evaluation site description	97
7-3	Dust levels around the shearer during cutting under reversed and conventional rotation conditions	103
7-4	Summary of average dust levels	110
10-1	Comparison of average intake dust levels for the conventional and homotropal face	131
10-2	Improvements obtained by applying asymmetrical drums	144

1. INTRODUCTION

This document constitutes the Phase III Report of Foster-Miller, Inc.'s current contract with the U.S. Bureau of Mines J0318097 - "Evaluate Fundamental Approaches to Longwall Dust Control."

> The overall objective of the contract is to evaluate the effectivensss of available dust control technology for double-drum shearer longwall sections in a coordinated, systematic program at a few longwall test sections and to make the results available to the entire coal mining industry.

Longwalling has been the primary technique for underground coal mining in Europe for twenty years. With the impetus for increased coal production, the trend to high production longwalling has firmly taken root in the United States. Increased levels of coal production on longwalls has brought with it higher levels of dust generation. Most United States longwalls have difficulty complying with federal dust standards which are much stricter than those imposed in Europe.

Longwall operators faced with a longwall that is "out of compliance" have implemented a variety of practices in attempts to reduce dust levels. These practices may reflect ideas of their personnel, practices identified in literature, practices at other mines or mere desperation. They are usually applied with little documentation and even less control on important variables that may influence the effectiveness of their "solution." Often, two or more techniques are tried simultaneously. The only sampling performed during this period is the full shift gravimetric sampling required to establish compliance - a notoriously poor technique for establishing the effectiveness of a particular control technology.

At some point, the gravimetric samplers indicate that the face is "in compliance." It is quite possible that the reduction in dust level is totally independent of the controls adopted. Nevertheless, all dust control measures in effect at that time are required by the regulatory agencies to be continued.

This program offers the mining industry the opportunity to "sort out" and share assessments of the dust control techniques in use today and those proposed for the future. This objective is being achieved through laboratory and field evaluations of both available and proposed dust control practices using innovative sampling procedures and state-of-the-art respirable dust monitors and instrumentation. In this manner, the effectiveness or lack of effectiveness of longwall dust control techniques can be quantified, thereby providing the information necessary for proper application of these techniques.

This program is investigating nine different dust control techniques. These nine subprograms encompass a broad range of dust control measures ranging from administrative controls to new hardware. They span not only presently employed methods but also those recently adopted in the United States and those proposed for the future. This report documents the Phase III effort on each of the subprograms. For clarity, the report is divided in sections by subprogram as follows:

- Section 2: Subprogram A - Passive Barriers/Spray Air Movers for Dust Control
- Section 3: Subprogram B - Practical Aspects of Deep Cutting
- Section 4: Subprogram C - Stage Loader Dust Control
- Section 5: Subprogram D - Longwall Automation Technology
- Section 6: Subprogram E - Longwall Application of Ventilation Curtains
- Section 7: Subprogram F - Reversed Drum Rotation
- Section 8: Subprogram G - Reduction of Shield Generated Dust
- Section 9: Subprogram H - Air Canopies for Longwalls
- Section 10: Subprogram I - Mining Practices

A revised schedule for this fifty-two month effort is presented in Figure 1-1.

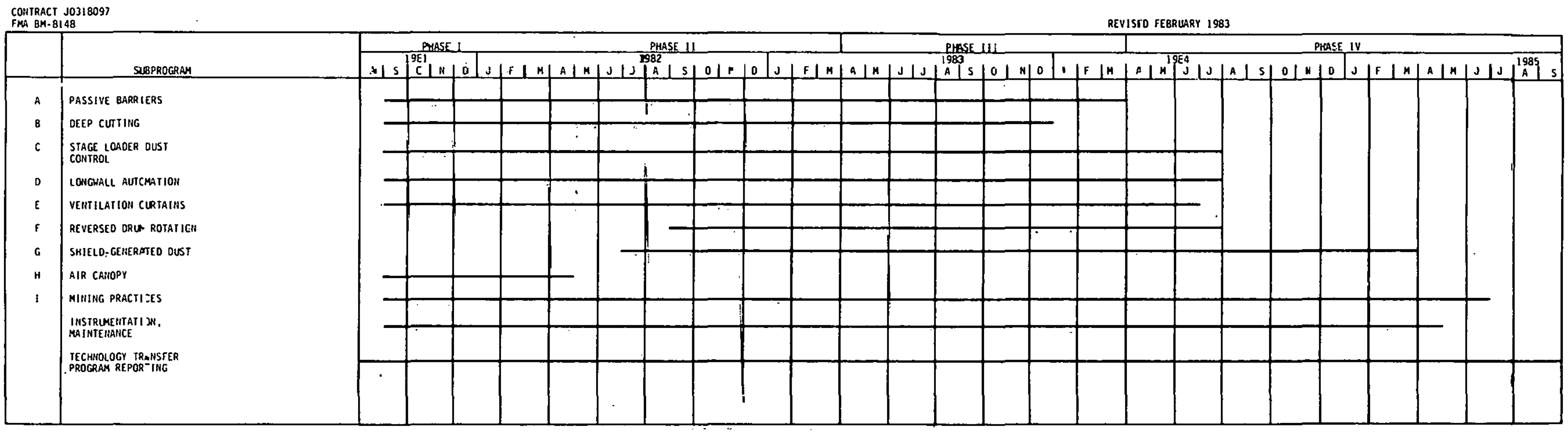

FIGURE 1-1. - Revised master program schedule.

2. SUBPROGRAM A - PASSIVE BARRIERS/SPRAY AIR MOVERS FOR DUST CONTROL

The objective of this subprogram is to evaluate the dust control effectiveness of a passive barrier blocking the area between the top of the shearer and the underside of the roof supports. The barrier is being tested in combination with a modified "shearer clearer" air-moving spray system to screen operators from shearer-generated dust.

2.1 Summary of Phases I and II

The following tasks briefly described below were completed during the first two phases of effort:

- Preliminary investigations - This task consisted of telephone surveys of 17 mining operations. Results revealed that a majority of the longwalls contacted had used splitter arms and sprays as air movers, but only three had used passive barriers as a dust control technique.

- Laboratory development and testing - Initial efforts focused on the airflow pattern modification effects of a variety of passive barrier systems. Results demonstrated the need for effective control of contaminated air immediately upstream of the leading end of the shearer. Hence continued testing began with an emphasis on control of the "upwind plume." A number of passive barrier configurations were evaluated both "wet" and "dry" (with and without a shearer clearer spray system in operation) in the worst case "cutting against the airflow" condition. The results showed that barriers without sprays cannot adequately control the upwind plume at the leading drum. However, the traditional and practical "gob-side" passive barrier system, combined with the shearer clearer, reduced contamination levels at the headgate operator's position by 86 percent over a baseline condition of headgate splitter arm only, with no water sprays. The effectiveness of this combination system was also confirmed through a series of "cutting with the airflow" tests.

  To allow additional testing of the effects of barriers and sprays on contamination levels downstream of the shearer, the longwall gallery was extended by 50 ft.

Test results showed the gob-side barrier with the shearer clearer reduced contamination levels by 65 percent up to 50 ft downstream of the shearer.

- Field surveys - Six mine sites were surveyed to document the use of passive barrier/spray techniques and to search for suitable evaluation sites. Results of the surveys were included in the Phase I and Phase II reports. Kaiser Steel Corporation's Sunnyside No. 1 Mine in Sunnyside, Utah was chosen as the first evaluation site for the following reasons:

  - The face height would soon extend to 10 ft with a large gap over the shearer body, providing an ideal condition for testing passive barriers in high seam mining

  - Mining was half-face bidirectional with high shearer dust levels recorded at the shearer operator's position in both cutting directions

  - Very little dust was contributed by head-to-tail shield movement

  - The opportunity was available to perform a shop installation of the spray/barrier system.

2.2 First Field Evaluation - Kaiser Steel Corporation, Sunnyside No. 1 Mine

2.2.1 Summary of System Design, Installation and Evaluation - Completed during Phase II

As a direct result of the laboratory development and testing, a final combination system design was created for use in the underground evaluation. The design incorporated the following practical advantages:

- "Low-profile" sprays at shearer body level, allowing for solid steel block construction

- "Face side" spray banks of closely grouped sprays, allowing for single, multispray manifold construction

- A simplified, gob-side passive barrier system, allowing for ease of installation and maintenance.

Figure 2-1 illustrates the combination system as it was installed on Kaiser's Eickhoff shearer during the shop rebuild.

The test strategy for the underground evaluation was designed to determine the effectiveness of the new system in controlling shearer-generated dust. This was to be accomplished through comparative A-B pass-by-pass testing with the "new" and "conventional" systems in operation. Table 2-1 outlines the fundamental A-B comparative tests planned for the evaluation. The comparisons were designed to determine:

- The effectiveness of the new system versus conventional system both with <u>and</u> without passive barriers
- The effectiveness of alternative spray systems for each cutting direction
- The effectiveness of rerouted cooling water sprays.

2.2.2 Evaluation Results

2.2.2.1 Introduction

The 18th Left longwall panel at Sunnyside No. 1 Mine was visited in May 1982 and again in August 1982.

Table 2-2 provides a synopsis of dust data averages collected during the two preliminary visits. During both of the preliminary visits the face was mining a relatively low seam (about 6-1/2 ft) using a Joy shearer with a fairly shallow cut and high drum rotational speed.

The dust data collected during the evaluation in February 1983 was remarkably different from that discussed above. Very *high* levels of intake dust due to upstream shield movement (5-10 mg/m^3) were recorded during the evaluation on head-to-tail passes. Low levels were recorded during the preliminary visits. Possible reasons for this difference include:

- Only one shift per day was mined during the evaluation, allowing the face and roof to dry out longer between production shifts
- Geological conditions in the roof may have changed since two coal seams merged to produce the higher coal encountered during the evaluation

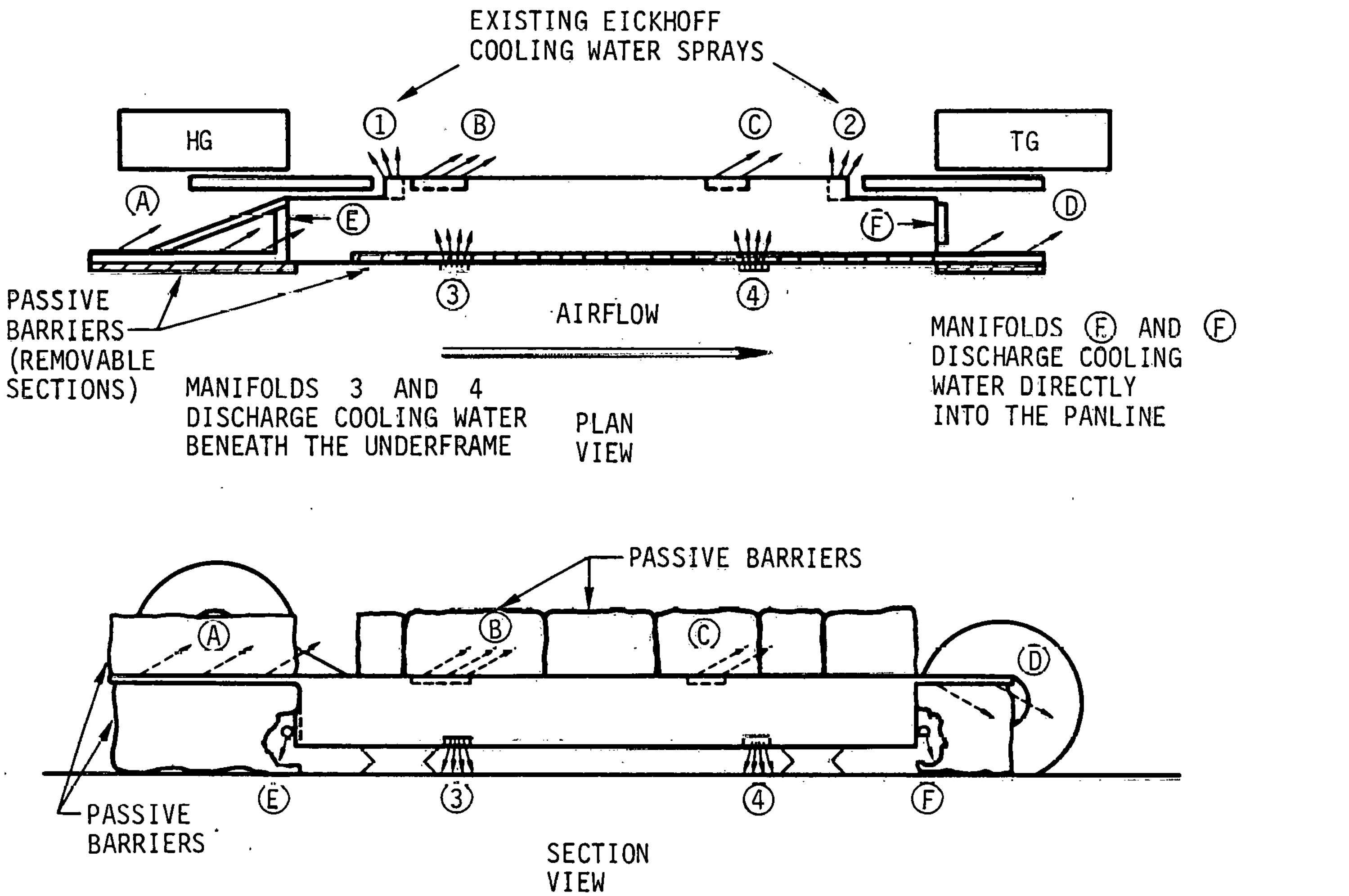

FIGURE 2-1. - Combination passive barrier/shearer clearer system with diverted cooling water.

TABLE 2-1. - A-B comparative test strategy - Kaiser Steel evaluation

Pass	System	Cutting Direction	
		Head-to-tail	Tail-to-head
A	Barriers Spray system Cooling sprays	Removed C, D only E, F, 3, 4	Removed A, B, C, D E, F, 3, 4
B	Barriers Spray system Cooling sprays	Removed Drums only 1, 2, 3, 4	Removed Drums only 1, 2, 3, 4
A	Barriers Spray system Cooling sprays	Installed C, D, only E, F, 3, 4	Installed A, B, C, D E, F, 3, 4
B	Barriers Spray system Cooling sprays	Installed Drums only 1, 2, 3, 4	Installed Drums only 1, 2, 3, 4

Note: A = "New" system;
B = Mine's "conventional" system

TABLE 2-2. - Results of dust monitoring - May and August, 1982 field surveys

Date	Shearer direction	Average Concentrations (mg/m^3)		
		Shearer	Intake	Shearer-generated dust (shearer minus intake)
May 1982	Head-to-tail cut Tail-to-head cut	4.7 10.3	1.8 1.8	2.9 8.5
August 1982	Head-to-tail cut Tail-to-head cut	3.6 5.8	0.6 0.5	3.0 5.3

- The increased height of the roof supports during the evaluation allowed them to be set against the roof at a much higher pressure.

Very *low* levels of shearer-generated dust (1-4 mg/m^3) were recorded during the evaluation on tail-to-head passes. High levels were recorded during the preliminary visits. Following are potential reasons for this difference:

- The increased seam height encountered during the evaluation caused more pronounced face sloughage on head-to-tail passes which resulted in less coal cutting during tail-to-head passes.

- The Eickhoff shearer used during the evaluation made a deep cut at low drum rotational speed. These conditions are known to reduce dust generation.

- Water flow through the Eickhoff drum sprays may have been greater than that through the Joy shearer drum sprays.

2.2.2.2 Head-to-Tail Cutting Results

Table 2-3 contains a synopsis of the average dust concentrations for all head-to-tail cutting passes. Figures 2-2 and 2-3 show representative plots of dust concentration versus face location (shield no.) for both the shearer clearer and conventional systems. Both sets of plots are of head-to-tail passes completed on the same day during the first week of testing.

The contribution of upstream shield movement to the intake dust levels shown in Table 2-3 and Figures 2-2 and 2-3 caused intake levels to be *greater* than shearer levels in every case. This made it impossible to use the analysis technique of subtracting intake levels from shearer levels to calculate "shearer-generated" dust concentrations. Nonetheless, the plots in Figures 2-2 and 2-3 show the shearer clearer to be effective in reducing the dust exposures at the operator's position compared to the conventional system. The shearer clearer "shearer position" dust levels are lower despite higher "intake position" levels.

Because of the difficulty in *differentiating between amounts of shield-generated dust and shearer-generated dust* during head-to-tail passes, the following special tests were performed during the second and third weeks of the evaluation:

TABLE 2-3. - Dust concentrations for conventional versus shearer clearer system with and without passive barriers during head-to-tail cutting passes.

Sampling period	Passive barriers	Average Dust Concentrations (mg/m^3)			
		Shearer clearer system		Conventional system	
		Shearer	Intake	Shearer	Intake
Week 1	Removed	3.50	6.76	3.85	7.84
Week 2	Installed	4.01	5.88	3.81	4.47
Week 3 (Day 1)	Installed	6.61	11.27	4.60	7.04
Week 3 (Day 2 & 3)	Removed	3.45	4.49	4.72	5.77
All Passes	Installed	4.44	6.78	3.97	4.98
All Passes	Removed	3.47	5.62	4.14	7.15

- "Decay sampling" of dust levels at the normal intake and shearer sampling positions during periods of shearer shutdown. Readings were taken at fixed locations on 5 to 10 sec intervals with shield movement continuing upstream.

- "Gradient sampling" of dust levels on a grid pattern upstream of the shearer during cutting.

The results of these special tests showed that shearer-generated dust levels were too low to accurately quantify shearer clearer system effectiveness, particularly due to the shield dust levels.

It was hoped that computer analysis would help to show the effects of shearer clearer operation versus conventional system operation during head-to-tail cutting passes. As a sample data run, all head-to-tail passes for the first testing week (passive barriers removed) were input into the computer. Then the data was separated according to spray system in operation and

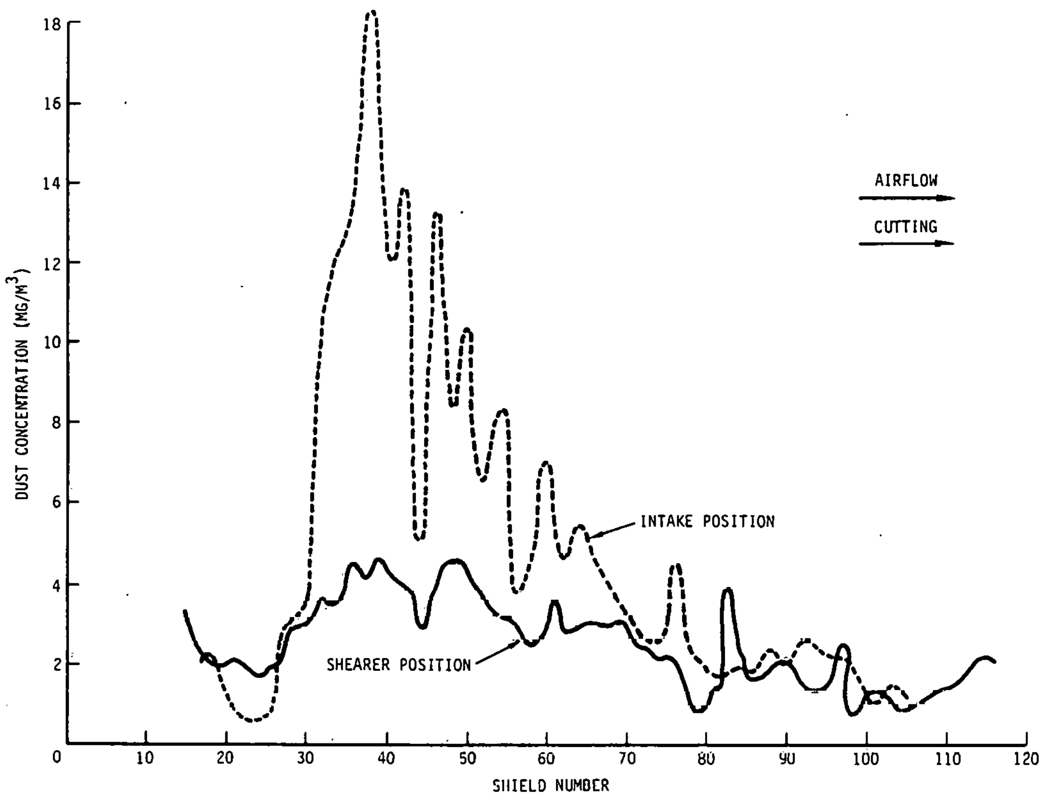

FIGURE 2-2. - Respirable dust concentration versus face location. Head-to-tail pass; shearer clearer system; without passive barriers.

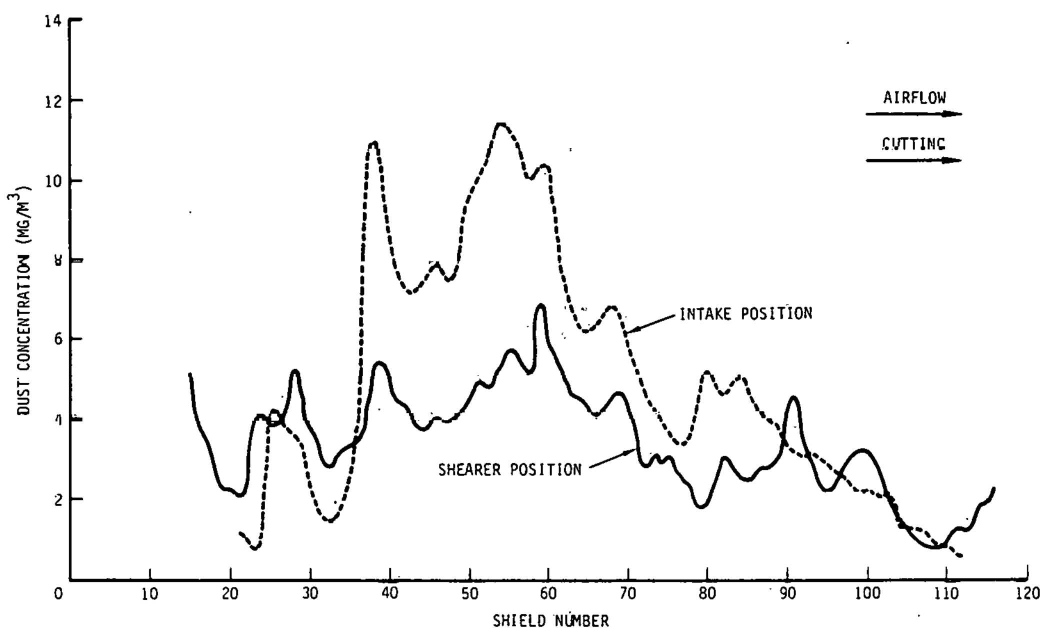

FIGURE 2-3. - Respirable dust concentration versus face location. Head-to-tail pass; conventional system; without passive barriers.

an "analysis of covariance" was run. The analysis of covariance was designed to show the degree of confidence with which the spray system in use could be assumed to affect the shearer-generated dust levels measured at the shearer position. Shearer position levels were a combination of intake dust levels (shield dust plus headgate intake sources) and shearer-generated dust levels not accounted for by variations in intake levels.

The results of the analysis showed that dust levels at the shearer position were strongly dependent on intake position levels (a fact also confirmed through manual analysis). However, shearer-generated levels were not dependent on spray system operation to a degree sufficient to quantify shearer clearer system effectiveness. The analysis of covariance showed a 70 percent degree of confidence that shearer generated dust levels measured at the shearer position were affected by spray system changes. For this reason, further efforts at computer analysis were terminated.

Extensive laboratory testing led to the shearer clearer design used at Kaiser. The results of this testing indicated that the shearer clearer would operate most effectively with the *entire system* in use when cutting tail-to-head and a *reduced system* in use when cutting head-to-tail. The reduced system consisted of spray banks C and D shown in Figure 2-1. Because of the unexpected contribution of shield dust to the head-to-tail results at Kaiser, it was decided to test a variety of other head-to-tail systems to determine their potential effects on shield dust control. These included:

- All spray banks A, B, C, and D
- Spray banks A, B, and D only
- Spray banks C and D only
- Spray bank D only.

The results revealed that because of the high shield dust levels, the best dust control when cutting head-to-tail is attained with *all* spray banks operating. Spray banks A and B appeared effective in pulling shield dust from the walkway area and confining it to the face area. These results are illustrated in Figures 2-4 and 2-5, showing dust concentration versus face location for two head-to-tail passes: one with all sprays operating and one with only spray banks C and D operating. Levels at the shearer operator are approximately 20 percent lower with all sprays operating despite higher intake levels.

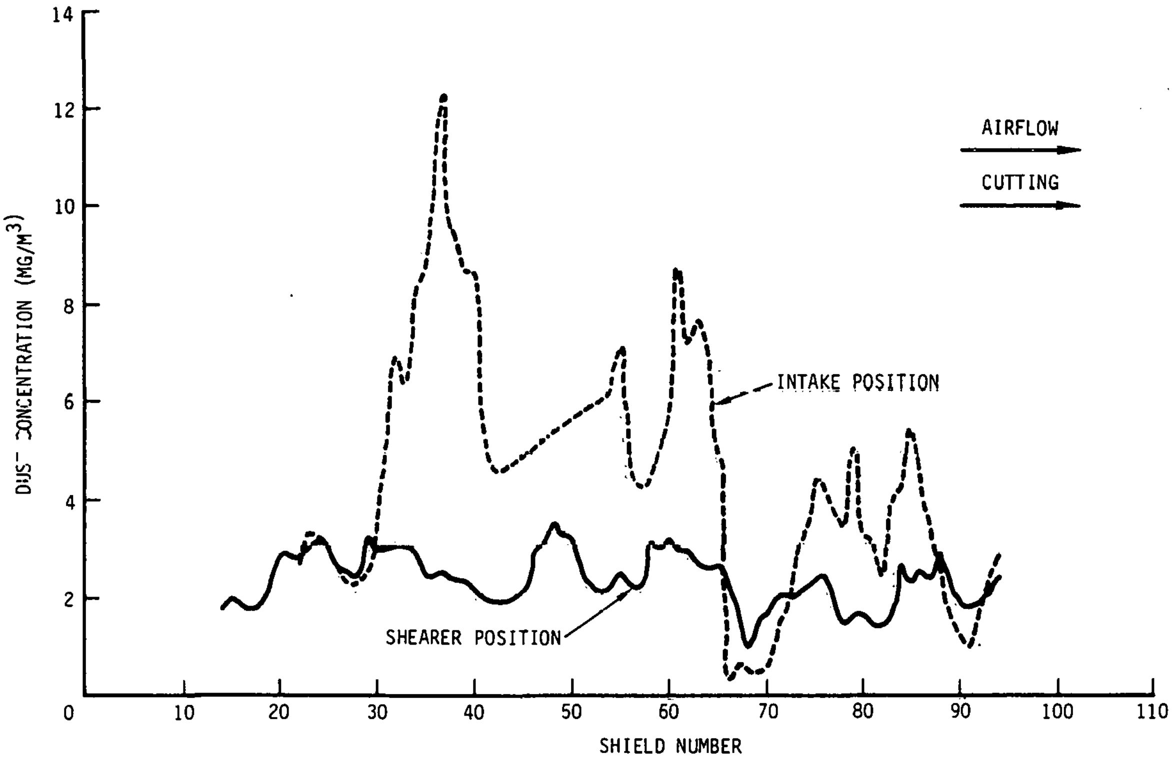

FIGURE 2-4. - Respirable dust concentration versus face location. Head-to-tail pass; complete shearer clearer system; without passive barriers.

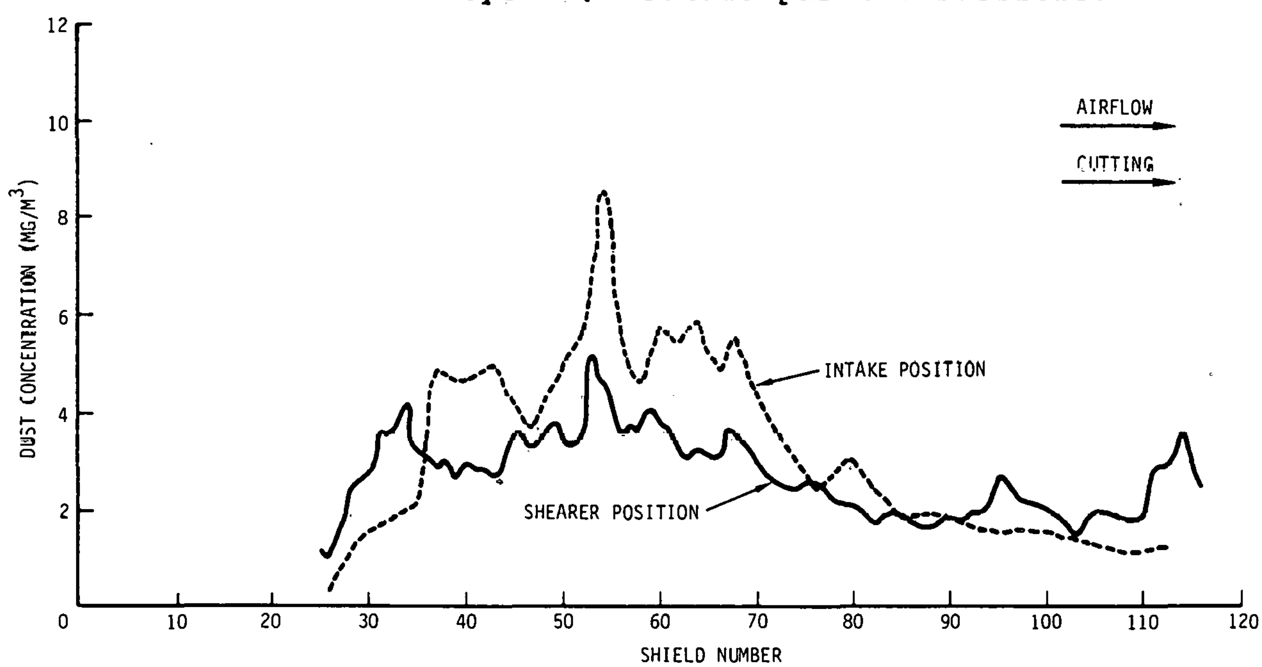

FIGURE 2-5. - Respirable dust concentration versus face location. Head-to-tail pass; reduced shearer clearer system (spray banks C & D) without passive barriers.

2.2.2.3 Tail-to-Head Cutting Results

During tail-to-head cutting, intake contamination levels remained reasonably constant over all passes, resulting in measurable quantities of shearer-generated dust. Table 2-4 contains a synopsis of the average dust concentrations for all tail-to-head cutting passes. Following are highlights of comparisons drawn from the data in Table 2-4.

- Shearer clearer spray system versus conventional spray system
  - In all cases, the shearer clearer reduced the levels of shearer-generated dust when compared to the conventional system.
  - The *greatest* reductions were realized when the passive barriers were removed (53 percent reduction versus an 11 percent reduction with the barriers installed).
- Effects of passive barriers on each spray system
  - Shearer-generated dust levels *increased* by 40 percent when passive barriers were added to the shearer clearer system
  - Shearer-generated dust levels *decreased* by 27 percent when passive barriers were added to the conventional system.

Dust concentration plots comparing the shearer clearer against conventional systems are shown in Figures 2-6 and 2-7. Both sets of plots are of tail-to-head passes completed on the same day during the first week of testing. Intake concentrations were similar for both passes, averaging about 0.60 mg/m^3.

The shearer position concentrations were considerably higher and more erratic with the conventional system operating than with the shearer clearer system operating. Excluding the headgate cutout, the shearer clearer reduced average dust concentrations at the operator's position from about 3.0 mg/m^3 to about 1.0 mg/m^3, for a 66 percent reduction.

Special emphasis was placed on the results of headgate cutout data due to the high levels of shearer-generated dust recorded during the cutouts (see Table 2-5).

TABLE 2-4. - Dust concentrations for conventional versus shearer clearer system with and without passive barriers during tail-to-head cutting passes

Average Dust Concentrations (mg/m³)									
		Shearer Clearer System			Conventional System			Shearer-Generated Percent Reduction Shearer Clearer Versus Conventional
Sampling Period	Passive Barriers	Shearer	Intake	Shearer-Generated (Shearer Less Intake)	Shearer	Intake	Shearer-Generated (Shearer Less Intake)	
Week 1	Removed	1.19	0.84	0.35	1.82	0.90	0.92	62
Week 2	Installed	1.18	0.43	0.75	1.35	0.55	0.80	6
Week 3 (day 1)	Installed	3.06	2.37	0.69	2.40	1.47	0.93	26
Week 3 (days 2 and 3)	Removed	2.64	1.73	0.91	3.52	1.96	1.56	42
All passes	Installed	1.55	0.81	0.74	1.56	0.73	0.33	11
All passes	Removed	1.67	1.14	0.53	2.38	1.25	1.13	53

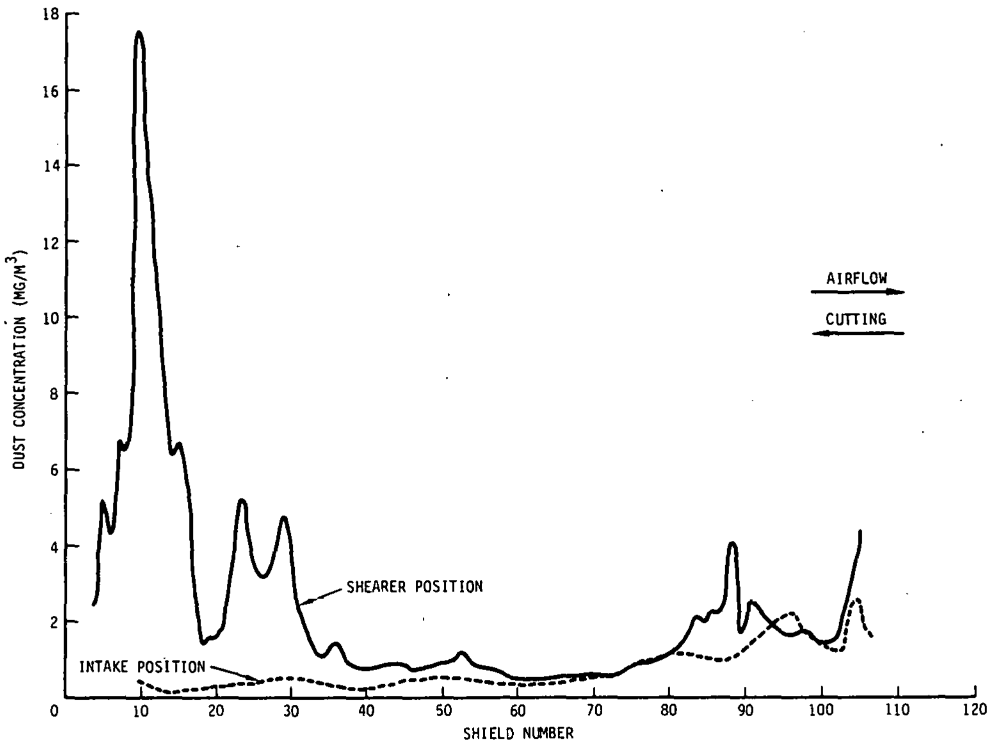

FIGURE 2-6. - Respirable dust concentration versus face location. Tail-to-head pass; shearer clearer system; without passive barriers.

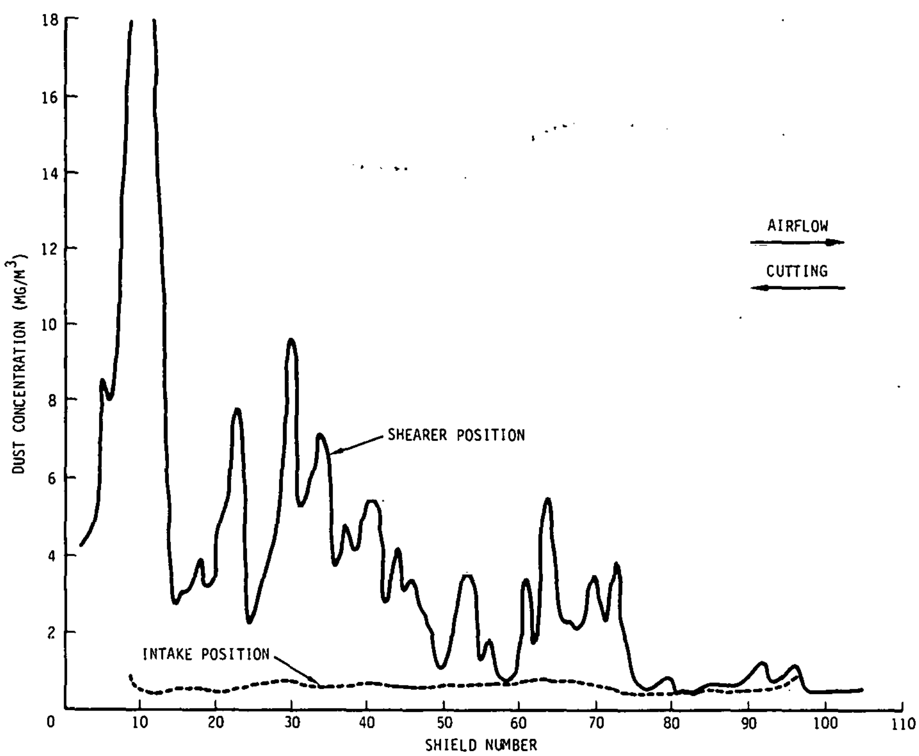

FIGURE 2-7. - Respirable dust concentration versus face location. Tail-to-head pass; conventional system; without passive barriers.

TABLE 2-5. - Average shearer generated dust concentrations at the headgate shearer operator's position between shields 15 and 4 during headgate cutouts

Sampling Period	Passive Barriers	Average Shearer-Generated Dust Concentrations (mg/m^3) Shearer Clearer System	Conventional System	Percent Reduction Shearer Clearer Versus Conventional
Week 1	Removed	4.69	7.62	38
Week 2	Installed	6.31	7.93	20
Week 3	Varied	1.93	9.20	79
All Cutouts	Installed	5.24	8.06	35
All Cutouts	Removed	3.70	8.40	56

Analysis of the headgate cutout data confirmed the general results of tail-to-head cutting passes described above. Highlights of the cutout analysis included:

- In all cases, the shearer clearer significantly reduced the levels of shearer-generated dust as compared to the conventional system
- The *greatest* reductions were realized when the passive barriers were removed (56 percent reduction versus 35 percent)
- Shearer-generated dust levels *increased* by 42 percent when passive barriers were added to the shearer clearer system
- Shearer-generated dust levels *decreased* by 4 percent when passive barriers were added to the conventional system.

2.2.2.4 Summary

The shearer clearer spray system was very effective in reducing the levels of shearer-generated dust during tail-to-head cutting passes (especially during headgate cut-outs). However, the combination of passive barriers with the shearer clearer system resulted in a decrease in its effectiveness. The use of passive barriers with the conventional system caused an increase in effectiveness of that system. It was concluded, therefore, that a passive barrier system is most effective when used with an ineffective spray system which causes dust to boil out into the walkway over the top of the shearer. An effective spray system, such as the shearer clearer, will provide sufficient control of the dust cloud over the shearer body and will not benefit from a passive barrier system.

The three week test period was conducted with virtually no required repairs, further demonstrating the system's mine-worthiness and ease of maintenance. Valuable practical experience was gained to support the reliability of using system components specifically designed to withstand the mining environment:

- Hinged and spring-loaded splitter arms
- "Low-profile" solid steel manifolds of closely grouped sprays, located beneath protective steel cover plates
- A gob-side passive barrier system of easily removable, modular sections of thick conveyor belting.

In addition, the filtration system (hydrocyclones and Y-strainers) installed for the evaluation resulted in *no nozzle clogging* during the entire three week period.

2.3 Mine Site Selection for the Second Field Evaluation

2.3.1 Price River Coal Company - Helper, Utah

Field surveys conducted at Price River during 1982 had shown their No. 5 Mine longwall panel to be suitable as an evaluation site. However, delays in completion of an existing panel and scheduling conflicts with other dust control evaluations had resulted in the Kaiser Steel evaluation being performed first. Consequently in July, 1983 a return field visit was made to Price River's 10th West Longwall to reconfirm its suitability as the second evaluation site.

Table 2-6 below contains a summary of the dust data collected over the five cutting passes sampled during the two-day visit.

TABLE 2-6. - Dust Concentration Survey, Price River Coal Co., 10th West Longwall

Cut Direction	Venturi Sprays	Average Concentrations (mg/m^3)	
		Shearer Operator	Intake
T→H	on	1.3	0.4
H→T	on	0.8	0.5
T→H	off	0.7	---
H→T	off	0.8	---
T→H	on	0.6	0.2

As shown in the table, dust levels at the shearer operator's position were very low in each cutting direction, both with and without their external venturi spray system operating. Dust at the shearer operator's position is a function of such factors as face air velocity, spray water pressure and flow, cutting speed and intake contamination levels. The survey at 10th West revealed that all of these factors contributed to the low exposure levels:

- A high average air velocity along the face of over 900 ft/min which provided dilution to the dust cloud and helped to hold it against the face as it traveled downstream

- High water spray pressure and flow at the cutting drums (approximately 50 gpm at 200 psi total to both drums) for effective dust suppression

- A relatively low shearer tramming speed of approximately 15 ft/min

- Fairly low intake contamination levels (approximately 0.2-0.4 mg/m^3 cutting head-to-tail with upstream shield movement).

Because of the extremely low dust concentrations measured in both cutting directions, Price River was rejected as an evaluation site.

2.3.2 ARMCO Steel - Montcoal, West Virginia

Three separate field surveys to ARMCO's No. 7 Mine during September, October and November 1983 resulted in the choice of ARMCO as the second evaluation site. Details of the surveys and the evaluation are presented in the next section.

2.4 Second Field Evaluation - ARMCO Steel, No. 7 Mine

2.4.1 Field Surveys

At the invitation of ARMCO management, a field survey was conducted on the 1 West, 3rd Left Longwall during September 1983. The 1 West, 3rd Left panel had been out of compliance for some time with a 1.4 mg/m^3 reduced dust standard due to quartz and ARMCO was interested in upgrading and improving their dust control methods.

Conditions on the 3rd Left Longwall during the September field survey are summarized in Table 2-7. Figure 2-8 illustrates the layout of the combination splitter arm, passive barrier, and shearer spray system encountered during the survey. The results of dust monitoring are presented in Table 2-8.

TABLE 2-7. - Conditions during the September 1983 survey

Longwall Water Supply System	- Single Jeffrey Satellite booster pump with 20 hp motor installed at end of section hard pipe - 1-1/4 inch water hose from booster pump to shearer
Dynamic Water Pressure and Flow at Shearer Inlet	- Approximately 105 psi, 50 - 60 gpm
Average Face Air Velocity	- 140 fpm; panel was new, gob had not fully fallen and consolidated
Depth of Roof Rock Cut	- Approximately 4 inches average

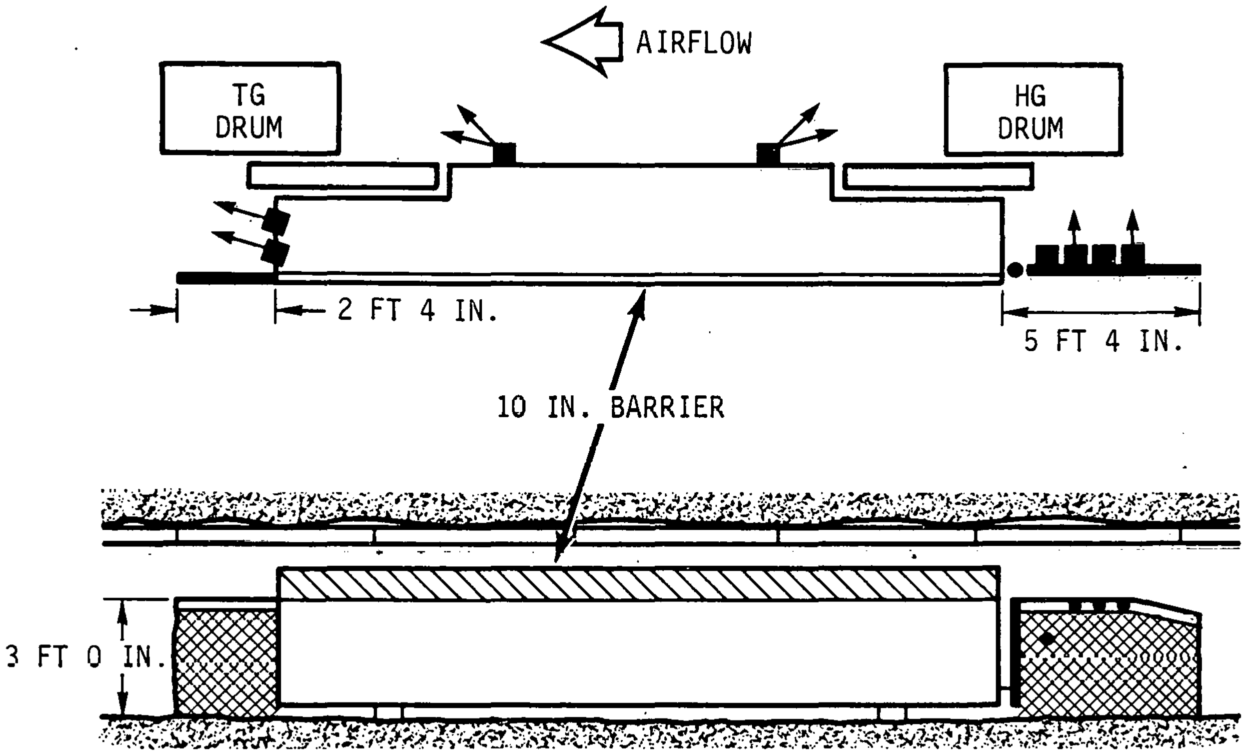

FIGURE 2-8. - Layout of shearer spray system - September 1983

TABLE 2-8. - Average dust concentrations - September 1983 survey

Cut Direction	Average Concentration (mg/m³)	
	Shearer Operator	Intake
Head to Tail	6.5	0.5
Tail-to-Head	12.3	0.5

The dust sampling results indicated that shearer-generated dust was the most predominant dust source on the face. Intake concentrations were very low by comparison, even during head-to-tail cutting when shield dust was a component of intake levels. From these results specific recommendations were made to ARMCO management regarding the reduction and control of shearer-generated dust. These included:

- Increased face ventilation to increase dust dilution
- Upgraded water supply systems to increase the quantity and pressure of supply water to the shearer
- Reoriented cooling water discharge to eliminate dust "boil out" into the walkway
- Redesigned and properly oriented external water sprays to keep shearer-generated dust confined to the face
- Effective use of drum sprays to enhance dust suppression.

Modifications actually completed by ARMCO shortly after the September survey included:

- An increase in airflow quantity along the face of nearly 100 percent
- Installation of an additional booster pump in the water supply system
- An increase in the size of water hose from the end of the hardpipe to the shearer from a 1-1/4 in. diam to a 2 in. diam (hardpipe to midface) and a 1-1/2 in. diam (midface to shearer)
- An increase in height of the shearer-mounted, gob-side passive barrier from 10 in. to 15 in., nearly always sealing itself against the underside of the roof supports
- Relocation of the headgate-end shearer cooling water sprays to discharge directly into the panline
- Reorientation of all external venturi sprays to aim in the direction of the primary airflow
- Installation of large orifice, high capacity, low pressure drum sprays.

To investigate the impact of these modifications on face dust levels, two brief additional field visits were conducted at 3rd Left. The visits were conducted by a USBM test engineer and an FMI test engineer on October 26 and November 16 respectively. Conditions on the longwall during the surveys are summarized in Table 2-9. Figure 2-9 illustrates the layout

TABLE 2-9. - Conditions during the October and November 1983 Surveys

Conditions	October	November
Longwall Water Supply System	- Two Jeffrey Satellite booster pumps with 20 hp motors installed in parallel at end of the section hardpipe - 2-in. water hose from booster pumps to midface - 1-1/2 in. water hose from midface to shearer	- Identical to October
Dynamic Water Pressure at Shearer Inlet	- Approximately 150 psi, pumps not operating properly	- Approximately 250 psi; both pumps operating
Average Face Air Velocity	- 270 fpm	- 360 fpm
Depth of Roof Rock Cut	- N/A	- Approximately 2-3 in.

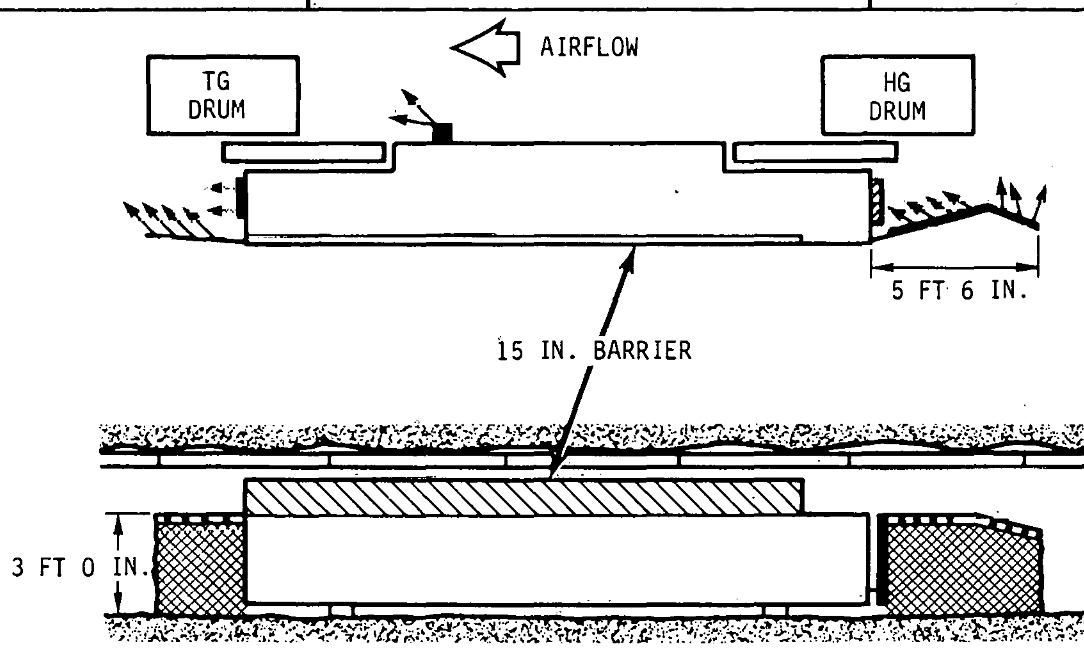

FIGURE 2-9. - Layout of shearer spray system after ARMCO modifications.

of the shearer spray systems, reflecting the improvements made by ARMCO. Table 2-10 contains the results of dust monitoring performed during the surveys. For easy reference, the results of the original September survey are repeated in Table 2-10.

The reduction in dust concentrations at the shearer operator's position between the September survey and those in October and November was dramatic (an average of 81 percent for head-to-tail cutting and 84 percent for tail-to-head cutting). Intake levels remained roughly similar at less than 1.0 mg/m^3. The significance of these reductions led to the decision to return to ARMCO for a 2-week evaluation to further investigate the major improvements which ARMCO implemented. It was clear that the improvements had produced a dramatic reduction in face dust levels, but it was not clear *which* factor was most important or *to what extent* each factor was responsible for the reductions.

2.4.2 Evaluation Testing Strategy

The evaluation focused on "A-B-C" comparison testing to isolate and then quantify three of the most significant dust control variables changed by ARMCO:

- Shearer-mounted passive barrier system
- Shearer water pressure and flow levels
- Face airflow quantities.

The testing strategy involved initially lowering water flow and airflow levels. This was done to approximate the conditions and face dust levels observed in the initial September field visit to the degree possible. Waterflow and airflow levels were

TABLE 2-10. - Average dust concentrations - September and October 1983 surveys

Survey Date	Average dust concentration (mg/m^3)			
	Head-to-tail cut		Tail-to-head cut	
	Shearer	Intake	Shearer	Intake
September	6.5	0.5	12.3	0.5
October	2.03	0.96	3.38	0.48
November	0.45	-	0.60	-

then methodically changed over a variety of ranges. The intent was to measure the dust control effects by increasing each factor separately, and both together, back up to the improved levels. To document the effectiveness of the shearer-mounted passive barrier, testing at most waterflow and airflow conditions was performed both with and without the barrier installed on the shearer.

An exact duplication of the conditions and dust levels of the September field visit was impossible, since the conditions on longwall panels change continually. Factors which may well have changed between the September survey and the December evaluation include:

- Extent of rock being cut
- Coal characteristics (hardness, moisture, content, etc.)
- Overburden pressure, gob consolidation.

The dust sampling methodology used during the evaluation was very similar to that used during the original field survey. However, in addition to the traditional "shearer" and "intake" dust sampling positions, a "downstream" position was employed as well. The downstream position was maintained approximately 25 feet downwind of the tailgate end of the shearer, over the center of the panline and about midway between the panline and the roof support canopies. The purpose of the downstream position was to quantify the impact that passive barriers and changes of water flow and face airflow had on *total return air dust* downwind of the shearer. The downstream position was maintained consistently throughout the evaluation; the intake position was monitored on a periodic basis only, to ensure the stability of intake dust levels. In addition to dust sampling, test engineers also monitored:

- General face conditions and activities such as depth of roof rock being cut and activities of the shearer

- Face air volume levels at every tenth shield along the face.

The evaluation was completed over nine production shifts between 14 and 22 December 1983. A total of 32 cutting passes were surveyed, 18 in a head-to-tail direction and 14 in a tail-to-head direction (ARMCO cuts bidirectionally).

Water pressure and flow levels to the shearer were varied over the following ranges:

- High: 250-320 psi (70-82 gpm) -- existing full water pressure
- Medium: 180-240 psi (60-68 gpm) -- approximately 26 percent reduction
- Low: 100-150 psi (40-55 gpm) -- approximately 56 percent reduction.

Two water pressure test strategies were used:

- Maintain a constant given pressure during a full cutting pass
- Purposely vary the pressure over the different ranges within a given cutting pass.

Face airflow velocities were also varied over three ranges:

- High: 400-410 fpm: maximum air velocity encountered
- Medium: 350-370 fpm: approximately 11 percent reduction
- Low: 250-300 fpm: approximately 32 percent reduction.

These variations resulted from an overall ventilation change made by ARMCO engineers midway through the evaluation. Additional efforts by Foster-Miller test engineers to lower airflows in the headgate resulted in further reductions. Face airflow evaluations spanned full shifts; ranges were not varied during any given shift. However, a full matrix of water pressure and airflow conditions were tested. Each of the three airflow velocity ranges contained testing at all three water pressure ranges.

2.4.3 Test Results

2.4.3.1 Passive Barriers

As shown in Figure 2-9 the shearer at ARMCO was equipped with a 15-in. high passive barrier (conveyor belting) mounted along the full length of the gob-side edge of the shearer body. A series of A-B comparison tests were performed to determine the effectiveness of the barrier at reducing the dust exposures of the shearer operators. A-B testing was performed over six of the nine evaluation shifts by removing the barrier for one half of each shift.

Prior to the Foster-Miller September field survey, the shearer operators had apparently been subjected to large amounts of spray mist (and therefore dust) passing over the shearer body into the walkway. The body-mounted passive barrier was installed to alleviate this condition and was apparently very effective at doing so.

Between the September survey and the December evaluation, however, several improvements were made to the external spray system and the splitter arms. When the passive-barrier was removed during the December evaluation, no spray mist was present in the walkway even at maximum water pressures. In addition, an analysis of the dust monitoring results has shown that use of the passive barrier made no significant difference in dust concentrations either at the shearer operator or return sampling positions.

This confirmed the conclusion reached during the first evaluation at Kaiser Steel: that a passive barrier system is most effective when used with an ineffective spray system containing improperly oriented nozzles which cause dust and mist to boil out into the walkway over the top of the shearer. An effective spray system, using nozzles properly oriented in the direction of the primary airflow, will provide sufficient control of the dust/spray mist cloud over the shearer body. Such a system will not benefit from a passive barrier on the gob-side edge of the shearer. Nonetheless, the shearer operators at ARMCO preferred to operate with the barrier installed. They had adapted to its minimal visual constraints and felt it helped to protect them from falling rock and flying debris from cutting.

2.4.3.2 Tail-to-Head Cutting Results

The greatest emphasis was placed on *tail-to-head* cutting because its impact on the dust exposure of face personnel is considerably greater than that of head-to-tail cutting. Dust concentrations at the jacksetters and panline snaker positions are greater when cutting tail-to-head, since they are located downstream of the shearer. During head-to-tail cutting, these personnel are upstream of the shearer in fresh air.

A summary of the results of dust monitoring at the shearer operator's position during *tail-to-head* cutting is presented in Table 2-11. The dust concentrations shown in the table represent the averages of dozens of dust levels recorded over a variety of locations along the face while the shearer was cutting coal during the particular water pressure and air

Table 2-11. - Average dust concentrations at the shearer operator's position for selected water pressure and air velocity conditions - tail-to-head cutting

		Dust Concentration/ % Reduction from Baseline		
		Shearer Water Pressure		
		Low 40-55 gpm 50-150 psi	Medium 60-68 gpm 180-240 psi	High 70-82 gpm 250-320 psi
Face Airflow Velocity	Low 250-300 fpm	17.54/ Baseline	7.86/ 55.2%	6.84 61.0%
	Medium 350-370 fpm	8.67/ 50.6%	4.03/ 77.0%	3.53/ 79.9%
	High 400-410 fpm	4.99/ 71.6%	3.77/ 78.5%	2.97/ 83.1%

velocity conditions given. "Low" water pressure and "low" airflow velocity was the *baseline* condition against which the others were compared. The percent reduction values matched with each dust concentration represent the decrease in dust level (from the *baseline* level of 17.54 mg/m^3) achieved when cutting coal at each set of conditions.

EXAMPLE: The average dust concentration at the shearer operator's position when cutting tail-to-head at a "medium" water pressure range and a "medium" air velocity range is 4.03 mg/m^3. This is a 77 percent reduction from the average *baseline* dust concentration of 17.54 mg/m^3.

The three dust concentrations associated with the condition of "low" airflow were somewhat higher than anticipated because a greater than normal amount of roof rock was being cut during a portion of the mining shifts when the airflow was lowered. Consequently, the percent reductions shown in Table 2-11 may be slightly higher than they would have been under normal rock conditions. However, the data *trends* would remain the same.

An examination of the data in Table 2-11 illustrates the relative degrees of improvement obtained by varying water pressure or air velocity levels separately or together. Many interesting comparisons can be made. The greatest improvement (an 83.1 percent dust reduction) was realized when both factors were increased to the "high" levels. However, an improvement *nearly as great* (77.0 percent reduction) was attained by increasing both factors to only the "medium" levels.

The same data is displayed graphically in Figures 2-10 and 2-11. As shown in both figures, the largest portion of the dust reduction from increased airflow velocity *versus* water pressure occurred when those increases took place between the "low" and "medium" ranges. Relatively small additional dust reductions were achieved by increasing those factors from the "medium" to the "high" ranges.

The results of the dust monitoring *downstream* of the shearer followed trends similar to that of the shearer operator's position. Dust concentrations decreased steadily as water pressure and face air velocity levels were increased. The greatest improvements were realized when both factors together were increased through the ranges to the "high" levels.

2.4.3.3 Head-to-Tail Cutting Results

A summary of the results of dust monitoring during *head-to-tail* cutting is presented in Table 2-12 and graphically in Figures 2-12 and 2-13. The organization of the data and the analysis techniques are identical to those previously discussed.

Shearer position data trends are somewhat different than those for tail-to-head cutting because:

- The percent reduction figures are considerably smaller, indicating that the effect of increased water pressure and airflow is greater on tail-to-head cutting than on head-to-tail cutting.

- The dust reductions are more uniform with increasing levels of the two factors.

In addition, the average dust concentrations themselves were dramatically lower for head-to-tail cutting than for tail-to-head cutting. Since the primary cutting drum (tailgate) was downstream of both operators, most of the dust generated by the shearer did not pass over their positions.

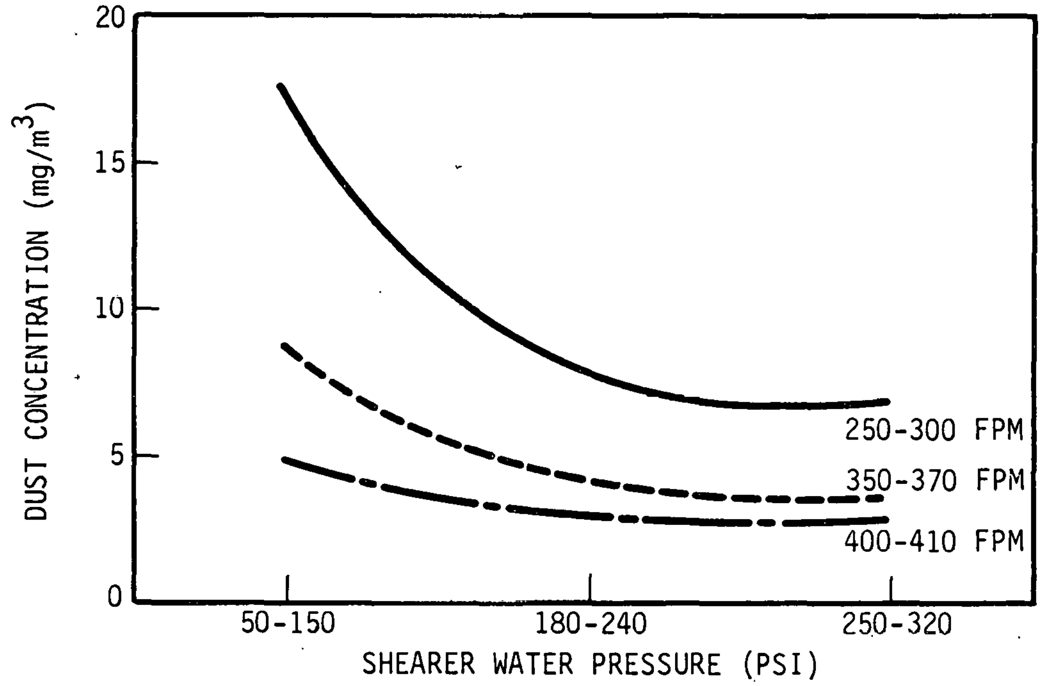

FIGURE 2-10. - Shearer operator dust concentration versus water pressure at three airflow velocities; tail-to-head cutting.

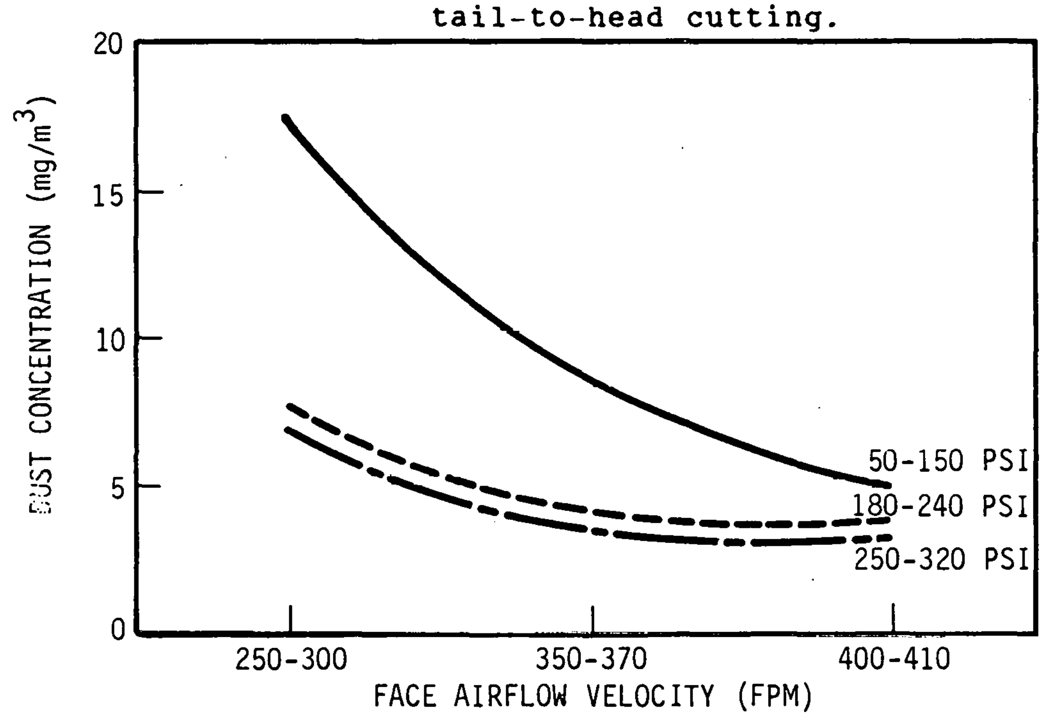

FIGURE 2-11. - Shearer operator dust concentration versus airflow velocity at three water pressures; tail-to-head cutting.

Table 2-12. - Average dust concentrations at the shearer operator's position for selected water pressure and air velocity conditions in head-to-tail cutting

		Dust Concentration (mg/m^3)/ % Reduction from Baseline		
		Shearer Water Pressure		
		Low 40-55 gpm 50-150 psi	Medium 60-68 gpm 180-240 psi	High 70-82 gpm 250-320 psi
Face Airflow Velocity	Low 250- 300 fpm	1.84/ Baseline	1.76/ 4.3%	1.41 23.4%
	Medium 350- 370 fpm	1.37/ 25.5%	1.17/ 36.4%	1.09/ 40.8%
	High 400- 410 fpm	1.11/ 39.7%	1.00/ 45.7%	0.75/ 59.2%

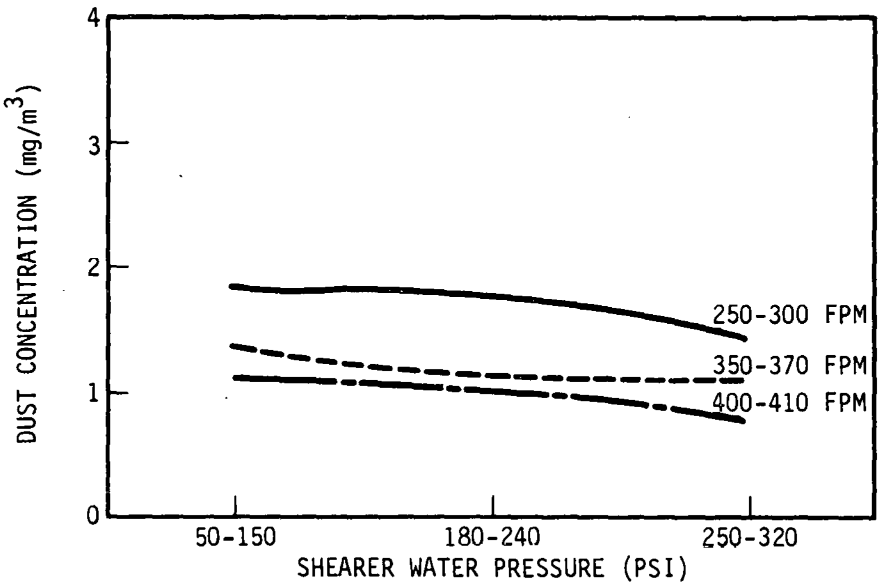

FIGURE 2-12. - Shearer operator dust concentration versus water pressure at three airflow velocities; head-to-tail cutting.

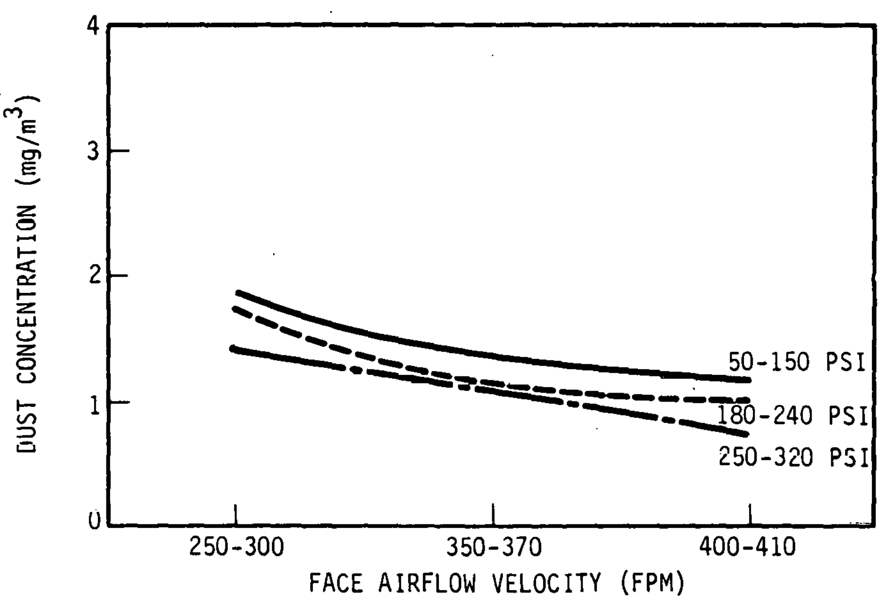

FIGURE 2-13. - Shearer operator dust concentration versus airflow velocity at three water pressures; head-to-tail cutting.

The upwind drum was lowered and cutting only a very small portion of the coal face. This illustrates the dust control benefits to unidirectional longwall faces of taking the primary cut in a head-to-tail direction.

Return position data trends for head-to-tail cutting were similar to those for tail-to-head cutting: increases in water pressure and/or air velocity resulted in decreased dust concentrations in the return airstream downstream of the shearer.

As evidenced by the data previously presented, dust concentrations measured during the October and November surveys were somewhat lower than those measured under the same face conditions in December. However, two primary differences existed in December:

- Considerably more rock was cut during most passes than in October and November

- The effectiveness of the external spray system and splitter arms was diminished due to damage from roof support canopies in regions of low clearance; the spray system and splitter arms had been recently installed during the October survey.

2.4.4 Summary and Recommendations

It has long been known that increased shearer water pressure and face airflow can be used to reduce dust concentrations on longwall faces. However, guidelines have not been available to mine operators indicating how to most efficiently use those techniques: how to *maximize* dust reductions while *minimizing* water consumption and use of ventilating air.

The results of the ARMCO evaluation has provided valuable insight to help guide in the effective use of these methods. A summary of the conclusions drawn from the evaluation follows:

- Increasing water pressure *or* face air velocity will result in decreased face dust concentrations; however, increasing *both together* will significantly accelerate the extent to which dust levels are reduced.

- Eventually a "point of diminishing returns" is reached beyond which further increases in either water pressure or face air velocity will no longer produce substantial decreases in dust concentrations.

- Generally, increasing both factors together to "medium" levels will provide optimum dust reductions while maintaining reasonable degrees of water consumption and use of ventilating air.

The key to effective use of these techniques is to determine *where* the "points of diminishing return" are and which "medium" levels of water pressure and face air velocity to use. These will vary on a longwall-to-longwall basis and can be discovered through a simple program of experimentation and dust monitoring.

2.5 Additional Passive Barrier Study

An additional passive barrier study was performed at Bethlehem Mines Corporation's No. 60 Mine in September-October 1983 during the evaluation of another dust control technique. At the start of that evaluation, the shearer was equipped with two diagonal passive barriers on top of the shearer as shown in Figure 2-14. Using smoke tests to determine airflow patterns, it was shown that the barriers directed dust from the face side of the shearer into the walkway and over the operators. This detrimental effect was confirmed through dust monitoring as illustrated in Table 2-13.

Removing the barriers resulted in a 30-percent reduction in dust concentrations at the operator's position for both the tail-to-head and head-to-tail passes. This directly confirmed the results of earlier laboratory testing conducted on diagonal passive barriers. In those tests the barriers blocked the airflow over the machine directing contamination from the headgate drum into the walkway. Smoke tests revealed that eddy currents were produced behind the barriers forming contamination pockets which were also drawn into the walkway.

2.6 Future Effort

The only task remaining to be performed under Phase IV of this subprogram is completion of the final report.

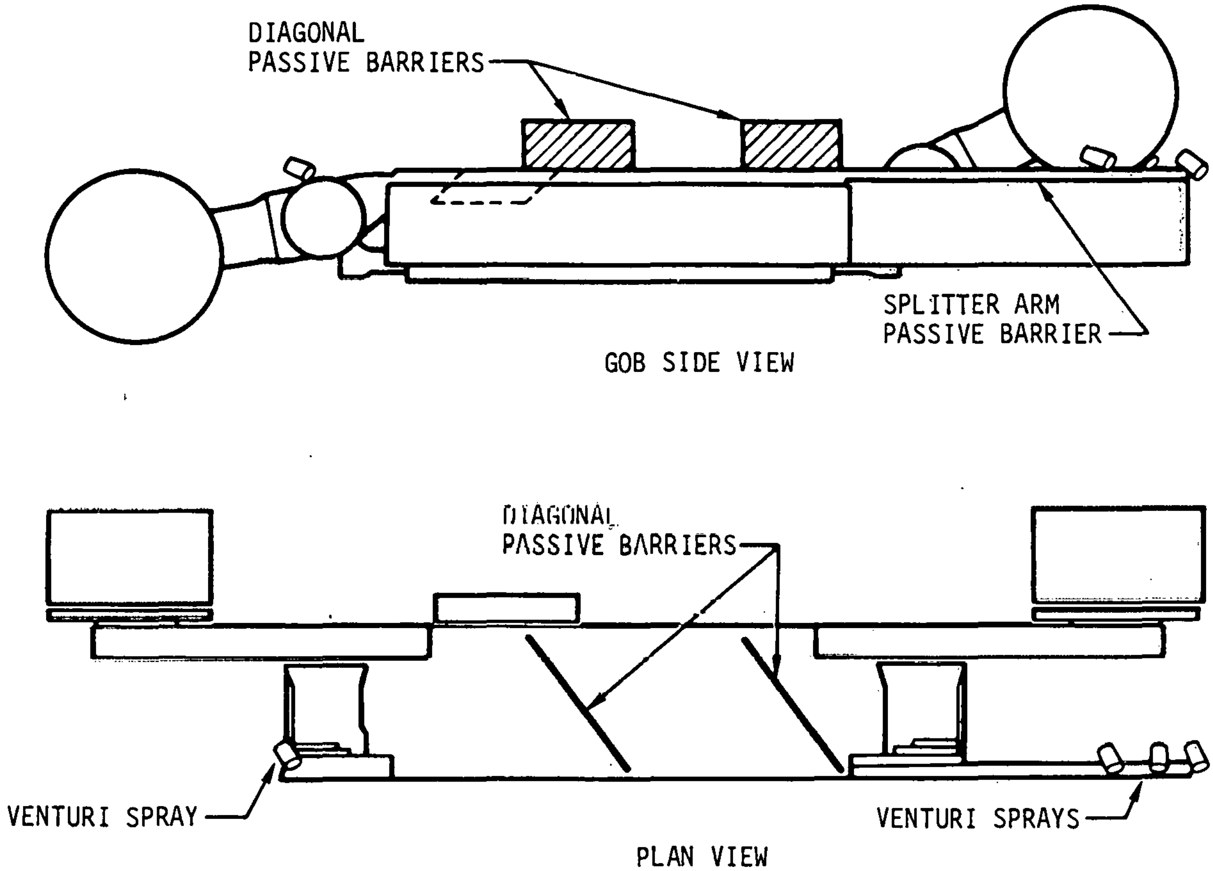

FIGURE 2-14. - Diagonal passive barrier system - Bethlehem No. 60 Mine.

TABLE 2-13. Results of A-B comparison testing on passive barriers - Bethlehem No. 60 Mine

Cutting direction	Sampling location	Diagonal Barrier		Improvement (%)
		On (mg/m^3)	Off (mg/m^3)	
Headgate-to-tailgate pass	Shearer operator's total dust concentration	3.30	2.31	30
	Shearer-generated dust at operator	2.35	1.18	49
Tailgate-to-headgate pass	Shearer operator's total dust concentration	11.28	7.94	30
	Shearer-generated dust at operator	10.36	7.25	30

3. SUBPROGRAM B - PRACTICAL ASPECTS OF DEEP CUTTING

3.1 Overall Program Objectives

This subprogram was originally conceived with the aim of explaining and promoting the use of "deep cutting" on United States longwalls. Deep cutting is defined in this context as increased pick penetration cutting achieved by a combination of slow drum speed and high shearer haulage speed.

Operating with a drum speed of less than 40 rpm was adopted as a working definition of deep cutting. Sixty percent reductions in the concentration of respirable dust generated have been documented in field trials through the use of deep/slow cutting. This reduction is attributable to both the larger fragment sizes resulting from deep cutting and the reduced fanning action of the drums at the lower rotational speeds.

The original program was to consist of surveys of United States practice and equipment availability, mining and engineering impact studies, and technology transfer activities. This last was considered to be the most important part of the effort. The program started with an initial survey of the application of deep cutting on United States longwalls, which revealed that appropriate equipment was available and that although deep cutting was not extensively practiced, there was a relatively wide appreciation of its utility. In light of this information, the program was rescoped to include the following principal components.

- A complete survey of United States longwall practice with respect to deep cutting.
- A survey of equipment availability.
- A review for publication of the benefits and constraints associated with deep cutting.

The review referred to above was to include a treatment of both the mining and engineering impacts of cutting with slower drum speeds.

3.2 Phase I Results

The Phase I effort consisted principally of the preliminary survey of current United States longwall practice with respect to deep cutting and an initial survey of equipment availability.

The survey of United States practice consisted of telephone interviews during which the operators of 43 longwalls were questioned regarding current practices, future plans and beliefs relating to drum speed and dust levels.

Although only a quarter of this survey sample used deep cutting (defined as slower than 40 rpm drum speeds), the majority of the remainder planned to use slow drum speeds in the future. Three quarters of those questioned accepted that slow drum speeds lead to lower dust levels.

A survey of equipment suppliers showed that most of the modern high capacity machines (300 kW or higher) are available with low drum speeds. This was not true of low seam or medium capacity machines which tended towards higher drum speeds.

3.3 Phase II Objectives

At the conclusion of Phase I, the scope of work was redrawn to include the following:

- Complete the survey of operators to remove the uncertainty due to a limited sample.
- Gather further information from equipment suppliers to obtain more reliable estimates of current availability, engineering constraints and future developments.
- Produce and disseminate a state-of-the-art review of deep slow cutting to the longwall community, to define:
  - The benefits to be achieved
  - The equipment which is available
  - The engineering constraints
  - The prevailing misconceptions and pitfalls.

Particular attention was to be paid to pointing out the effect of speed change on drum design and cutting parameters, since this is an area in which even the most progressive operators are prone to misconceptions.

3.4 Phase II Results

The survey started in Phase I was completed by contacting the majority of the remainder of U.S. longwall operators. The results of this survey were tabulated and included in the Phase II report.

A similar exercise was conducted with respect to the shearer manufacturers who supply the U.S. market. There were contacted and information was gathered to update the picture on the availability of equipment for deep cutting.

At the same time that this information was being obtained an analysis was performed on the impact of deep or slow cutting on the performance of the shearer and on the longwall mining system as a whole. At the end of Phase II this information was assembled into a draft review of the effects of deep/slow cutting which was to form the basis of a publication

3.5 Phase III Objectives

The objectives of Phase III of this subprogram consisted solely of refining the draft review of the "state-of-the-art" of deep/slow cutting into a form suitable for publication in a mining journal. The journal Mining Engineering (a publication of the Society of Mining Engineers) was identified as a suitable medium and a draft submitted for their consideration. Following various editorial revisions, a feature article was accepted for publication in the March 1984 edition. This draft article is reproduced below.

3.6 Technology Transfer Article

A longwall operator can make few changes to increase output, significantly reduce respirable dust, and decrease power consumption. Reducing drum speed, and thereby cutting with increased pick penetration, is one.

This article defines the benefits of deep cutting in terms of reduced dust production and power consumption. It also identifies the practical aspects of high pick penetration in terms of shearer performance and coal loading.

Before examining some practical aspects of reducing drum speed and looking at the theoretical background, it is worthwhile to summarize what is meant by high penetration and deep cutting, and what potential benefits and pitfalls may be expected.

Deep cutting (in the sense of high penetration rather than wide web) can be defined in one or more of the following ways:

- Cutting with an average pick penetration distance higher than that used in ther past.
- Cutting with a pick penetration higher than the longwall operator would have used if the advantages of deep and slow cutting were not considered.
- Cutting with a well-designed shearer drum below 40 rpm.

All these definitions are slightly arbitrary. They are given to provide a basis for discussion and to make the point that any move towards deeper, more efficient cutting can result in operational benefits.

The benefits of deep cutting appear in many different areas. The most noticeable benefit, provided suitable instruments are available, is the reduction of airborne respirable dust. During an experiment on a longwall in the Pittsburgh seam, a nearly four to one reduction in dust levels was seen when drum speed was halved. Not all studies have shown such a big reduction, but it seems that some benefit is almost always obtained when drum speed is reduced.

Production rate and specific power consumption are also affected (in a positive sense) by reducing drum speed or increasing pick penetration. Although these changes may not be as spectacular as those in dust level, they contribute to the economic return of the longwall operation. Similarly, improved washability through fines reduction may have a beneficial economic effect.

Cutting with shearer drums operating at lower speeds does have some possible deleterious impacts that an operator should be aware of.

For example, cutting reactions -- loads imposed on the picks by the coal being cut -- will be increased as a deeper cut is used. Steps must, therefore, be taken to ensure the stability of the shearer and provide an adequate haulage effort. These increased cutting reactions also result in higher loads on the power transmission system (gearboxes, ranging arms, pick boxes, etc.) from the shearer motor(s) to the pick tip. These higher loads must be anticipated and provided for with the necessary hardware. In particular, extra haulage power must be provided with low drum speeds, since haulage effort required increases roughly in proportion with pick penetration.

Because the drum will be rotating more slowly or will have fewer picks, the load on shearer components will also be more variable. If suitable, robust equipment is not used, this increased vibration will decrease reliability.

Benefits of Deep Cutting

Lower dust levels, decreased specific power consumption, and improved product washability are the most noticeable benefits of reduced drum speeds. Although the benefits will vary greatly with mining conditions and the type of coal, some examples of what can be expected are described below.

Reduced Dust Levels

Figure 3-1 shows principal results of a study on the effects of reduced drum speed conducted on a longwall in the Pittsburgh seam (Ludlow, 1981). This figure shows that average dust production was reduced by about 70 percent when drum speed was halved. By making some assumptions about such quantities as coal density, it is possible to apply this proportional reduction to the quantity of respirable dust liberated per ton of coal mined. When this is done, two kinds of results are obtained:

- At 70 rpm about 1 g (15 gr) of airborne respirable dust is created for every ton mined (roughly one part per million). At 35 rpm, only 0.28-0.37 g/t (3.9-5.1 gr per st) of coal mined became airborne respirable dust.

- At 35 rpm, nearly four times the amount of coal may be mined before the compliance level is exceeded, compared with 70 rpm.

These results depend on many factors, such as ventilation velocity, dust monitor position, and mining cycle. They show however, the tiny proportion of coal that becomes airborne respirable dust, and the potential impact on achievable production that results from reducing dust make.

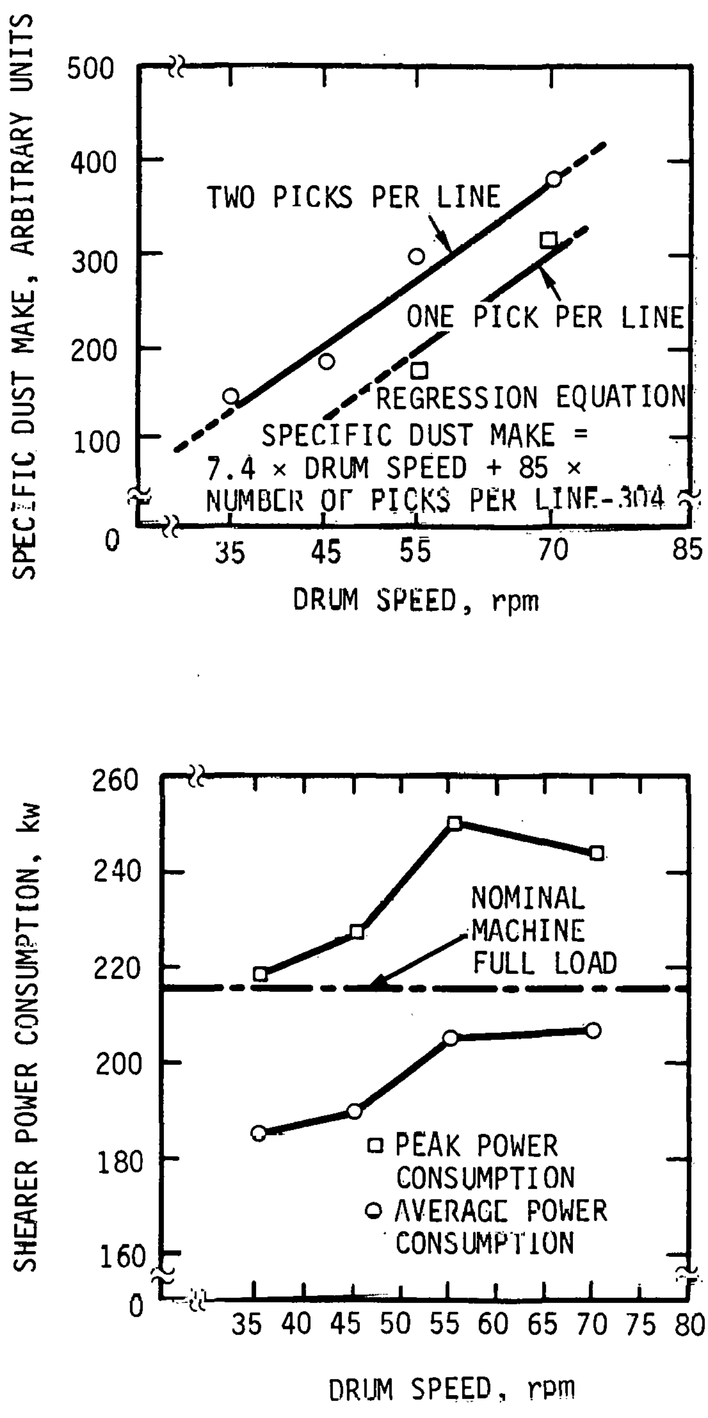

FIGURE 3-1. - Dust make and shearer power consumption as a function of drum speed and the number of picks per line.

Specific Energy Reduction

Although the theoretical association between specific dust make and specific power consumption is widely accepted, it does no harm to point out that when the two quantities are derived from observed measurements, the expected relationship does occur.

During the deep cutting shearer trial, the average values for shearer speed and power consumption were obtained at each drum speed. It was possible, therefore, to derive the following estimates of specific power (or energy) consumption at each of the four drum speeds:

Drum speed (rpm)	Specific energy (kW per st)
35	0.28
45	0.30
55	0.42
70	0.41

These figures show a reduction of about 35 percent in overall specific energy between higher and lower speeds. This difference was due to a reduction in overall power consumption and an increase in production rate at lower drum speeds.

There have been few direct measurements of the power required to cut and load coal. In moderate cutting conditions, however, the required shearer power commonly used is 0.33-0.5 kW/pert. (0.3-0.45 kW per st). The results referred to above confirm this practice.

These results and conclusions again relate to a single set of measurements in a mine chosen to represent an "average" U.S. longwall. Although they cannot be presented as definitive, they do confirm widely accepted principles.

Improved Washability

All available evidence suggests that increasing the cut depth produces a product containing few fines. Depending on the kind of washing or preparation used, deep or slow cutting will either cut costs or improve coal preparation efficiency. Principal coal preparation areas where improvement or economic savings may be achieved are fugitive dust control, fines dewatering, replacement of separating media, and tailings disposal.

What Happens at the Pick When Drum Speed is Reduced?

The maximum pick penetration per revolution is determined only by shearer haulage speed, drum speed (rpm), and number of picks per line. Figure 3-2 shows how these are related.

In deeper cutting, as the pick engages a bigger bite of coal, the force required to remove the chip of coal in front of the pick increases. This increase is about in proportion with the increase in penetration depth. Figure 3-3 shows where the forces (F) acts and how it may be broken into two components.

When picks are arranged around a drum as shown in Figure 3-4, the normal component (F_N) and tangential components (F_T) of the cutting reaction act in many different directions with respect to the shearer hub. These forces can be summed to yield two perpendicular forces and a torque at the drum hub.

Drum torque (T_C) and the reactions F_{HC} and F_{VC} increase as the depth of cut increases. If, however, the pick is made to bite deeper by slowing down the drum's rate of revolution (see Figure 3-5), the power required to cut the coal (proportional to the product of T_C and N) may not increase. In reality, the increase in F_C is nearly always smaller than the reduction of N. Thus, the power required to cut a specific volume of coal is reduced as drum speed is reduced. The increase in the horizontal component (F_{HC}) is not matched by any reduction in the shearer haulage speed (V). The haulage power required (proportional to F_{HC} times V) will, therefore, increase as depth of cut increases.

Engineering Impacts

Cutting and Haulage Loads

The manner in which the cutting forces change with pick penetration depth was noted above. In summary, cutting torque (tangential force) requirements will be greater as penetration increases. This rise, however, will be less than the increase in pick penetration (and material removed). Horizontal reaction will also increase as pick penetration increases. This results in a steady increase in the required haulage effort. Therefore, at high drum speeds, the machine's ability to produce is limited by the high overall power requirements of

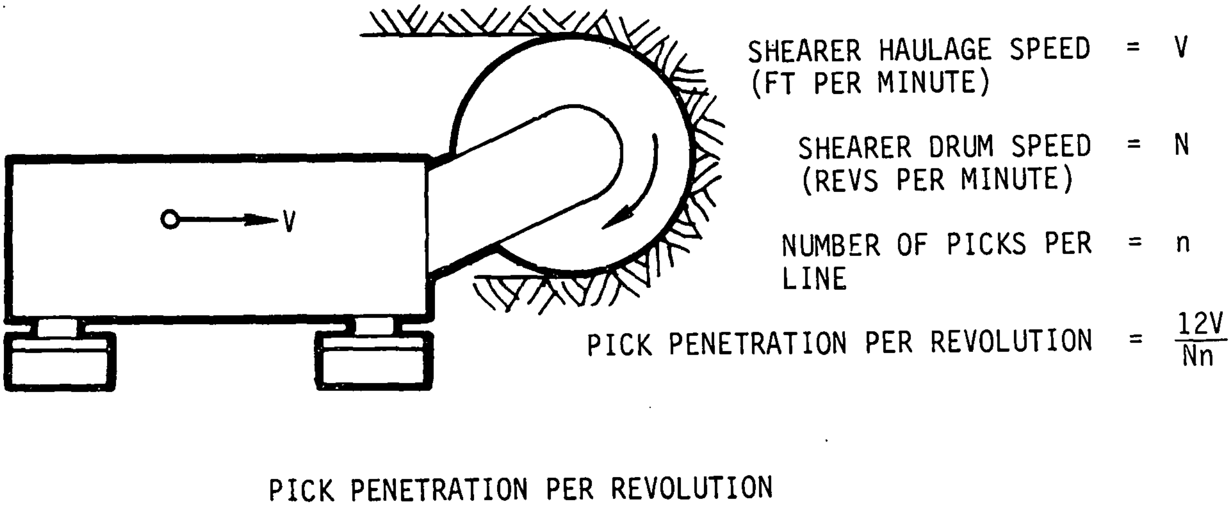

FIGURE 3-2. - Pick penetration and shearer speeds.

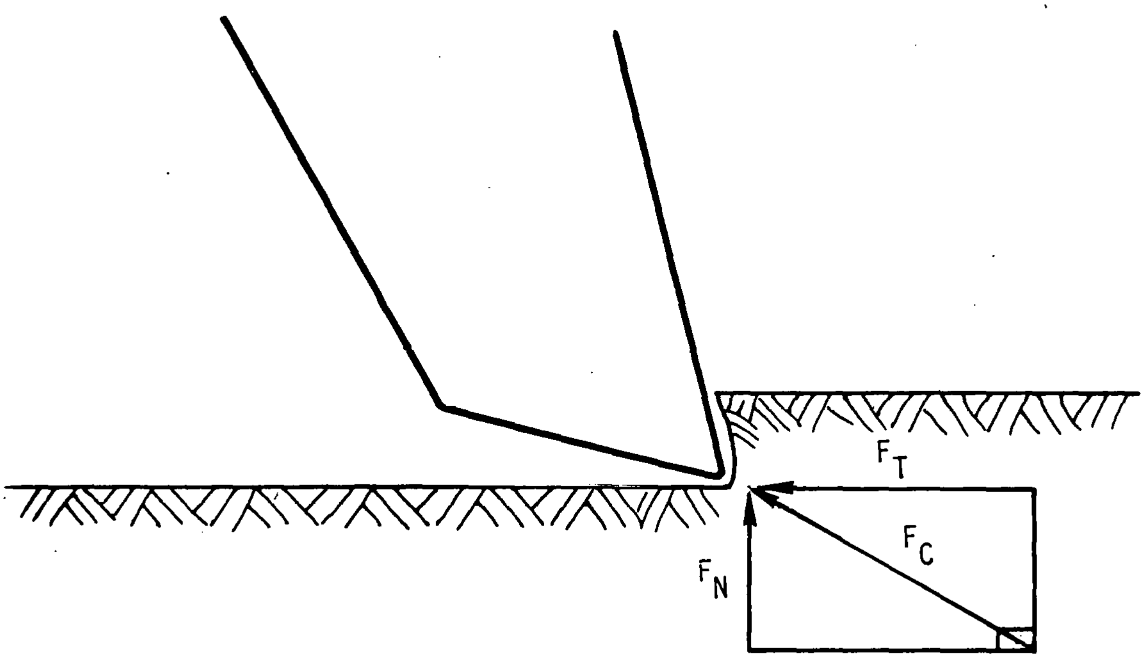

FIGURE 3-3. - Components of cutting reaction at the pick tip.

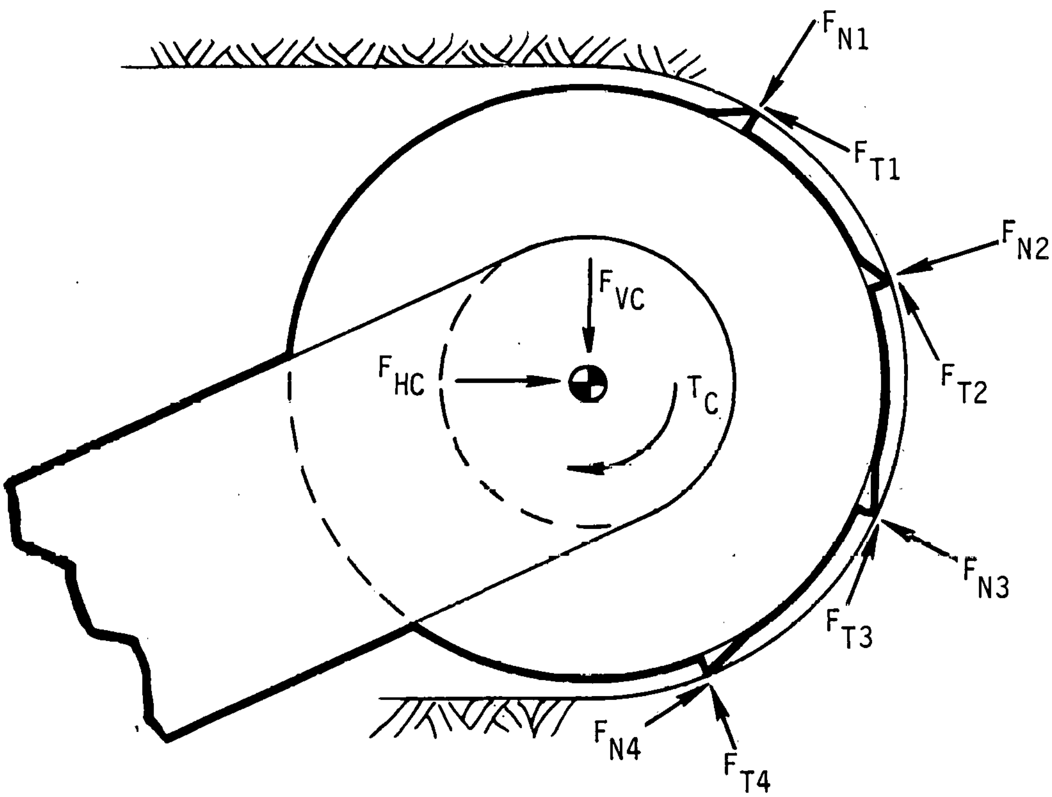

FIGURE 3-4. - Normal and tangential forces at the pick tips and the resulting reaction moment and forces at the drum axis (two dimensional case).

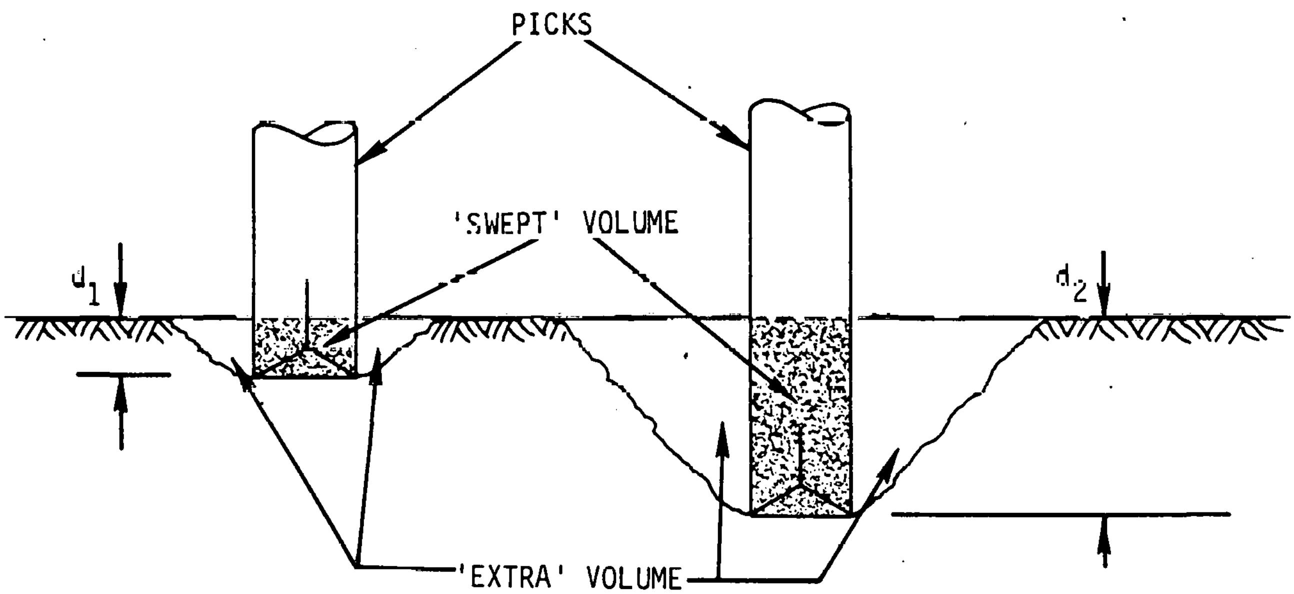

FIGURE 3-5. - Effect of depth of cut (d) on volume of coal removed.

inefficient cutting. At low drum speeds, the ability to produce is likely limited by required increased haulage effort and the high torque (not power) requirement of deep cutting.

Changes required to reap the benefits of deep cutting with slow-speed drums are:

- Increase the haulage effort that the shearer can safely generate to take advantage of a situation in which horizontal reaction forces increase with cutting efficiency.

- Provide a haulage system that is mechanically or hydrodynamically capable of propelling the shearer at a speed high enough to take advantage of efficient cutting.

- Recognize that, although cutting power may be reduced as drum speeds are lowered, there will be an increase in average torque levels in all parts of the power transmission patch.

The trend towards higher haulage efforts has continued since the introduction of the shearer. Chainless haulage has the potential to absorb higher haulage loads. It also does not present the safety hazard or dynamic instability problems caused by energy stored in a stretched haulage chain.

A shearer's "top speed" is often avoidably limited by haulage system design. Most modern systems are hydraulic or dc electric traction driven. In hydraulic haulage, speed is determined by pump input speed (fixed) and maximum pump displacement (variable). The need to reduce flitting time when unidirectional cutting is employed also suggests that tramming speeds should be increased.

Changes in the horizontal force balance, as a consequence of reduced drum speed, increases the crabbing moment, which must be resisted by the shearer's trapping and guidance system. This moment is a consequence of the horizontal reaction (at the drums) and the haulage forces being in different vertical planes. The result is a moment around a vertical axis through the shearer, which tends to crab the shearer into the face.

Gear Loading and Reliability

As drum speeds are reduced, the mean value of the torque transmitted to the drum by the gear transmission will be increased. A more radical increase will also take place in the momentary peak values of torque, since cutting loads are shared between fewer picks. This change in the mean value of load and the dynamic duty cycle will have considerable impact on the performance and reliability of power transmission gearing.

Gear tooth failure may then occur as a result of fatigue from high peak loads and surface effects due to high contact loads. Both modes are exacerbated by the need to choose deep tooth profiles that will accept the distortion occurring in the ranging arm. If drum speeds are reduced, bearings will also experience additional duty.

The shearer designer faces the problem of incorporating as much speed reduction as possible in the final gear stages close to the cutting drum, enabling the remainder of the transmission to operate at high speeds and low torque. In a conventional machine, initial speed reduction occurs at bevel gears on the motor's output. Further reduction occurs at the fixed gearhead. Little or no reduction occurs in the ranging arm, where the gears are coplanar to minimize ranging arm thickness and the effects of bending. The final speed reduction occurs at the end of the ranging arm within the drum hub. Volume constraints present the greatest challenge to designers of shearer transmissions.

Epicyclic gearing is used to maximize the reduction that can be taken in a given diameter. The useful speed ratio of a single stage epicyclic gear set is in the range of five or six to one. Therefore, if a minimum speed of 200 rpm is specified for the transfer gears in the ranging arm, a lower limit to drum speed in the 30-40 rpm range must be accepted.

As a response to this constaint, Gebrüder Eickhoff has employed a two-stage planetary gear in the special ranging arm for the EDW 300 shearer. It operates at 27 rpm. As a consequence of the two-stage gear's axial length, the shearer drum is offset slightly. As a result, the distance between the roof support and new coal face is increased.

Tool Loading

When drum speeds are reduced, overall cutting loads increase. The number of picks sharing this overall load is decreased. Higher cutting loads usually first reveal any inadequacy in picks and pick boxes (lugs). Later, some latent transmission problems will become apparent.

As pick penetration increases to 70-100 mm (3-4 in.), the number of picks employed to achieve a vane pick line spacing to penetration ratio of 1:1 falls to less than 10. Since the cutting process is discontinuous, it is possible for the full cutting effort to fall on a small number of picks. This is especially true if a discontinuity, such as a sulfur ball, is suddenly encountered. If 224 kW (300 hp) is delivered to a single pick, the resulting cutting load can be about 178 kN (40,000 lbf), with no allowance made for the torque multiplying properties of an induction motor or inertia loading.

Special attention must, therefore, be payed to pick specification, pick box design, and mounting on the shearer. The forward attack pick has some significant structural advantages, since cutting loads are usually directed along the axis of the pick and are born in compression rather than bending.

The detail design of the transmission of cutting load to the pick holder is of great importance. If the load is transmitted by line or point contact, local distortion of the pick box will occur. The resulting sloppy fit of the pick in the box will result in rapid deterioration and possible breakage.

Side loads on picks will also increase, along with loads in the cutting plane and loads in misaligned pick boxes. When low speeds and lower pick densities are used, the consequences, in terms of increased loads on adjacent picks of a single damaged or missing pick, are much greater. Particular attention must be paid to timely replacement.

Mining Impacts

Effect of Drum Speed on Drum Design

The shearer drum performs two functions. First, it transmits torque to an array of picks that are arranged in a suitable manner for coal cutting. Second, it removes broken coal from the cutting zone and deposits it on an armored flexible conveyor. The overriding constraint on drum design is that a pick must be located where there is a vane to support it.

Coal Loading from Shearer Drums

The modern shearer drum can be thought of as a short-length screw conveyor with a large diameter hub and flights of relatively low height. This screw conveyor usually has two or three starts. The flights never achieve more than one complete revolution around the hub. The flights terminate as a circular end plate (referred to as the back plate) that has the same overall diameter as the flights. The trough, or shroud, within which the screw conveyor is located, retains the conveyed material and is formed by uncut coal and the loading cowl. Various shearer drum components are shown in Figure 3-6.

The limited amount of information available on the performance of the shearer drum as a screw conveyor seems to agree with the rules and recommendations incorporated in various design guides for screw conveyors (FMC Corp, 1973). The most important guidelines are that the maximum speed determined by conveyor dimensions should not be exceeded, and the conveyor should not be more than about 30 percent full. These two considerations set an upper and lower speed range for reasonably efficient loading. Above the maximum speed (determined by diameter and vane angle), the material will not slide on the vane but will be carried with the vane on a radial path and be recirculated or thrown out of the drum somewhere along its length. Below the minimum speed, the drum will choke and overfill. Consequently, there will be recirculation, abnormally high power consumption, and considerable dust-producing mechanical coal breakage in the drum.

Drum Design for Low Drum Speed

The "fill factor" is the most important parameter when low drum speeds are considered. If it exceeds a critical value (about 30 percent), the drum will choke.

The fill factor is determined by the volume of coal passing through the drum, divided by the volume available for loading. Although no accepted model is available for the loading action of shearer drums, some guidance can be obtained from simple geometry. For instance, if numerous small effects are neglected, the fill factor can be approximated by the volume of (cut) coal loaded per minute divided by the volume swept by the vane helix in one minute.

To keep the fill factor low as production increases, three changes can be made to drum design:

- The drum speed can be increased
- The vane depth can be increased by increasing overall drum diameter or reducing the drum hub diameter (or both), and
- The vane angle can be increased.

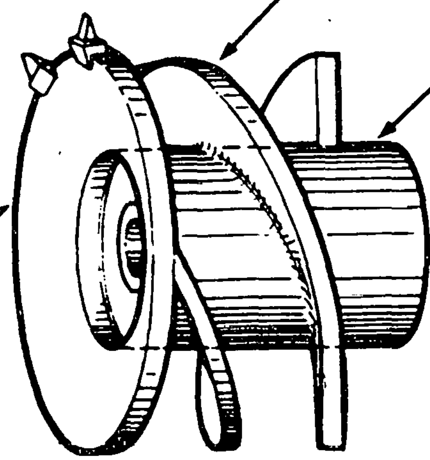

FIGURE 3-6. - Shearer drum components (most picks omitted).

The first approach is patently undesirable. The second is likely constrained by practical considerations, such as the diameter of the ranging arm hub or seam height. An increase in drum diameter is, however, an effective way of reducing the drum fill factor. The increase in swept volume is proportional to diameter cubed, while the increase in volume of coal to be loaded is proportional to the first power of diameter.

Increasing the vane angle is a viable means of counteracting the effect of reduced drum speed on loading efficiency. Care must be taken, however, to avoid increasing the pitch to the point at which recirculation becomes excessive.

The need to avoid choking the drum is only one factor that must be considered as drum speed is reduced. Steepening the vane angle has many significant effects. The most important of these is the reduction of vane length, which can result in the vane wrapping around less than half of the drum circumference (180 deg) between the face side and the gob side. The portion of the circumference covered by a vane is referred to as the "wrap". For a two-start design, the minimum feasible wrap is about 200 deg - each vane must overlap by 20 deg. If vane angle is steepened and a shorter wrap results, the designer is forced to a three-start design, which has important implications for pick spacing and lacing. Since a two-pick per line design is no longer feasible, a choice must be made between one and three picks per line. At a haulage speed of 6 m/min (20 fpm) and 30 rpm, the drum advance per revolution is 203 mm (8 in.). At this speed, there is excessive penetration at one pick per line. However, at three picks per line, the penetration achieved (68 mm or 2.7 in.) is lower than optimal.

A second effect of shorter vanes is that vane length may not accommodate the number of picks that must be mounted on it. Each pick box (lug), water spray, and supporting vane material may require 255 to 305 mm (10 to 12 in.) of vane length for each pick.

This analysis suggests that when drums are specified for deep-slow cutting, attention must be paid to optimizing their design. Strategies that might optimize drum performance include using graded pick lacing and vanes that are steeper on the gob side.

Other Mining Impacts

When low drum speeds are used, there may be other impacts on the mining environment, such as roof and floor condition. If significant coal or rock is left between adjacent pick lines at the roof or floor, the phenomenon is referred to as coring. The use of high pick penetration will promote the use of widely spaced cutting lines to achieve the optimum penetration to spacing ratio. At the roof and floor where penetration is zero, spacing is excessive and coring may result. If coring is extreme, difficulties in roof control due to deteriorated contact between the canopy and the roof may be encountered. Similarly, a badly cored floor may affect conveyor advances.

Effective horizon control is a second potential difficulty, since unbalanced cutting forces will increase at lower drum speeds. If these increased forces make it more difficult to maintain or change horizon smoothly, difficulties in roof control or support operation may be encountered.

Equipment Availability

Until recently, the longwall shearers market has been dominated by foreign manufacturers who have not found it necessary to design specifically for U.S. longwall mine conditions. Shearers delivered to the United States have, therefore, reflected mine requirements of the manufacturers' home market or other dominant markets. Anderson Mavor (United Kingdom), Eickhoff (West Germany), and Sagem (France) are dominant foreign manufacturers. Joy Manufacturing Co. of Franklin, PA, has recently joined these companies as a leading manufacturer.

When high-powered machines are considered - 335 kW (450 hp) - all these manufacturers offer equipment that will operate with drum speeds of 30 to 40 rpm. Eickhoff, Anderson Mavor, Joy, and Mining Supplies (American Longwall) can supply machines with low drum speed settings in the high 20s to low 30s, which represents the lower limit of drum speed currently supplied and warranted.

Smaller machines, ironically, tend to be available only with 45 rpm or higher drum speeds. Eickhoff offers a double planetary version of the EDW150-2L. It has a drum speed of 31 rpm, although none has, so far, been put into service in the United States.

When shearer manufacturers were questioned about the lowest feasible drum speeds, it became apparent that the amount of torque that could be carried by the gear train in the ranging arm was seen as a major constraint. Although answers were not unanimous, it was clear that if a 300 to 375 kW (400 to 500 hp) machine is considered, 25 rpm might represent the lowest feasible speed. If a more modest power consumption was considered (150 kW or 200 hp), speeds in the 15 to 20 rpm range might be achievable. In fact, such a low speed ranging arm has recently been tested by the National Coal Board.

Conclusions and Recommendations

The use of low drum speeds to achieve deeper cutting is becoming more widespread in the United States. Longwall operators should, therefore, consider using low drum speeds in light of the following factors:

- Slower drum speeds and increased pick penetration will lead to a reduced dust make. This will likely be coupled with an appreciable increase in production, if other constraints are not encountered.

- Achieving increased pick penetration by reducing the number of picks per line does not seem to be as effective as obtaining the same increase by reducing drum speed.

- The impact on the shearer's operating environment should be examined when low drum speeds are considered. In particular, the tendency of machines operating at low drum speeds to require increased haulage effort and improved trapping must be recognized.
- The drum's capacity to adequately load coal at reduced speed should be examined, and appropriate changes be made in drum design.
- The principal engineering impacts of reduced drum speed are increased loads on all power and load transmission elements, from the pick up to the shearer gearhead. Picks and pick boxes (lugs) must be designed for this load, as must the gearhead and ranging arm gearboxes. The lack of significant reports or reduced shearer reliability by U.S. longwall operators using low drum speeds suggests that shearer suppliers have been cautious in ensuring adequate design margins.

Acknowledgements

The authors acknowledge the assistance provided by numerous longwall operators and equipment suppliers whose opinions and experience were solicited. This article summarizes work performed under U.S. Bureau of Mines Contracts JO318097 and JO199092 between 1979 and 1982.

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3.7 Completion of Final Report

The only remaining substantial activity on this subprogram will be the completion of the final report. This will be based upon the state-of-the-art review assembled in Phase 2 and updated as necessary. The outline of the report which is given in Table 3-1 lists the major topics which this report will address.

TABLE 3-1. - Outline of subprogram final report

1.	Introduction
2.	Theoretical and Experimental Background to Deep/Slow Cutting 2.1 Theoretical Approach 2.2 Experimental Results
3.	Underground Experience with Deep Cutting 3.1 The Large Pick Shearers 3.2 Deep Cutting Continuous Miners 3.3 The Deep Cutting Shearer Evaluation
4.	Benefits of Deep Cutting 4.1 Reduced Dust Levels 4.2 Reduced Specific Energy 4.3 Improved Washability
5.	Engineering Impacts 5.1 Cutting and Haulage Loads 5.2 Gear Loading and Reliability 5.3 Tool Loading
6.	Mining Impacts 6.1 Coal Loading and Drum Design 6.2 Coal Loading from Shearer Drums 6.3 Drum Design for Low Drum Speeds 6.4 Other Mining Impacts
7.	Equipment Availability 7.1 Current Equipment 7.2 Future Trends
8.	Conclusions and Recommendations
References	
Appendix A	Survey of U.S. Longwall Operations

4. SUBPROGRAM C - STAGELOADER DUST CONTROL

4.1 Overall Objective

Intake air contamination on antitropal longwall panels has been documented as representing as much as 50 percent of the eight (8) hour time weighted respirable dust exposure for face personnel. An important goal of dust control research on longwalls is to reduce intake contamination levels originating from the stageloader, crusher, and transfer points. To meet that goal, the specific objectives of this subprogram are to design, develop and evaluate a system to control airborne respirable dust generated by equipment in the headgate area. These objectives are being accomplished through the following tasks:

- Field Evaluations of various dust control measures at three mine sites to quantify the effectiveness of a total stageloader dust control system.

- Laboratory Investigations of system components which appeared to be practical and effective after the first two in-mine evaluations. This study will result in an optimized dust control package for the third and final field trial.

- Manufacturer's Survey to determine design parameters for the control system components and to document dust control features (current and future) being designed into and supplied with stageloader equipment packages.

4.2 Summary of Phase I and Phase II

During Phase I, a three week field evaluation was conducted at Emery's Deer Creek Mine. A water powered scrubber was installed outby the crusher on an uncovered stageloader. Early in the investigation the need for additional techniques to control the major sources of intake contamination became apparent. This resulted in the development of a system of both active and passive controls consisting of spray air movers and brattice and belting. The final system reduced intake contamination levels along the face by 50 percent while reductions at the headgate operators controls approached 85 percent. Operational problems at the mine during the study prevented the determination of the effectiveness of each component separately. A detailed account of the first field investigation was included in the Phase I report.

During Phase II a second evaluation was conducted at Price River Coal Company at Helper, Utah. The evaluation was planned so that the effectiveness of specific dust controls could be evaluated. The system design was forwarded to Price River in preparation for the installation and evaluation. Prior to the start of the evaluation, Price River enclosed the stageloader and installed a commercial water powered scrubber on the outby side of the stageloader crusher.

The evaluation attempted to quantify the effect of the following conditions on dust levels within the headgate and in intake to the face.

- Open stageloader
- Partially enclosed stageloader
- Fully enclosed stageloader
- Fully enclosed stageloader plus spraybars
- Fully enclosed stageloader plus commercial scrubber
- Fully enclosed stageloader plus spraybar and commercial scrubber.

The following conclusions were drawn from the Price River evaluation and a confirming laboratory evaluation:

- Respirable dust concentrations as an average of measurements at the first 20 shields were reduced by approximately 81 percent by:
  - Enclosing the stageloader with a steel top
  - A "J-SAM" scrubber outby the crusher
  - A spraybar within the stageloader enclosure inby the crusher
  - A venturi spray at the transfer point to the main belt.
- Most of the respirable dust within the enclosed stageloader was generated on the inby side of the crusher. Inby the crusher is, therefore, the preferred location for installing a scrubber, and outby the crusher location may not have been a fair test of scrubber performance.

- Within an enclosed space, such as a stageloader, a spraybar with BD8-1 or BD-5 nozzles is more effective for reducing respirable dust concentrations than a "J-SAM" scrubber with 1/4 VV4002 nozzles at comparable water pressures.

A detailed account of the Price River evaluation and confirming laboratory study was included in the Phase II Report.

4.3 Phase III Activity

The effort during Phase III focused on locating a site for a third evaluation of stage loader dust controls and preliminary test planning for the evaluation.

The following subsections present the results of preliminary site visits to:

- Florence No. 1 Mine - North American Coal Co.
- Wilberg Mine - Emery Mining Co.

Preliminary plans for the third evaluation are also presented.

4.3.1 Florence Mine - Preliminary Visit

On June 8 and 9, 1983 a preliminary visit was made to the Florence No. 1 Mine, North American Coal Corp. During the visit dust concentrations were sampled within the headgate and along the face to establish the contribution of the stageloader to intake contamination on the face. The stageloader was fully covered and fitted with spraybars. Sprays were also fitted on all the transfer points.

Dust levels measured close to the crusher averaged approximately 1.5 mg/m^3. Intake dust levels measured over the first twenty shields on the face averaged 1.6 mg/m^3. The ventilation in the headgate, however, was only 12,000 cfm. This ventilation rate was half the airflow normally on the face and was considered only temporary. It was concluded, therefore, that when the full ventilation airflow was restored dust concentration within the headgate and in the face would be approximately 1/2 of these measured.

The predicted lower levels of dust within the headgate and on the face made this site marginal for the evaluation.

4.3.2 Wilberg Mine - Preliminary Visit

On February 2, 1984, a preliminary visit was made to Emery Mining Corp's., Wilberg Mine. The face was equipped with an Eickhoff EDW 400 double ended ranging drum shearer that cut approximately 9 ft. The primary cutting pass was from tailgate to headgate, with cleanup on the headgate to tailgate pass. Every other shield was pulled up, on the cutting pass with the remainder advanced during the clean-up pass. During normal operation the shearer cuts with the leading drum lowered and trailing drum raised.

During the survey, two cutting passes were monitored. Dust levels upstream of the shearer and at the shearer operators position were measured. The results showed low intake dust levels as the shearer began its cutting pass from the tail-gate. By the time the shearer had cut to shield 20, however, the intake dust was above 2 mg/m^3.

Figure 4-1 shows dust levels measured in the intake, (upwind of the shearer) and at the shearer operators position as a function of shield number for the cutting pass. Intake dust levels were contributing up to 75 percent of the dust level measured at the operator. In a meeting after the underground

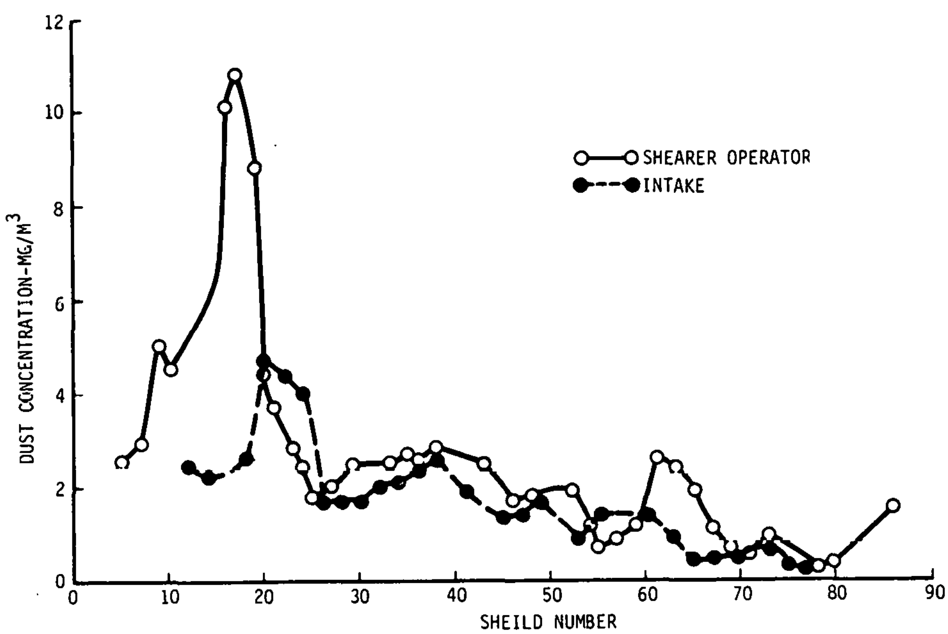


FIGURE 4-1. - Dust concentrations, shearer cutting from tailgate-to-headgate - Emery Mining Corp's., Wilberg Mine.

visit, mine management expressed interest in cooperating with Foster-Miller in a stageloader dust control evaluation.

Since the visit a letter has been sent to Wilberg Mine officially requesting their cooperation for the evaluation. The request is currently being reviewed by Emery's cooperate headquarters.

4.3.3 Test Planning for Third Stageloader Evaluations

Previous stageloader evaluations have been conducted by mapping the headgate and intake regions using instantaneous dust monitors. This technique was the best available approach when the last evaluation was performed. The problem with this method, however, is that conditions within a headgate are dynamic. Manual sampling takes 20 min to completely sample all points within the headgate. During this time conditions can change and influence the test results. To minimize the effects requires simultaneous sampling and recording at each test point.

Since the last survey, Foster-Miller has been granted MSHA approval for an instrumentation system using a multichannel data logger. This system will allow the placing of continuous monitors in strategic locations within the headgate and the face. Using this system it will be possible to characterize the dust levels under changing conditions.

We currently plan to conduct the third evaluation in three phases:

- Baseline testing with open stageloader and no controls applied
- Totally enclosed stageloader, with no controls applied
- Totally enclosed stageloader with spraybars placed to achieve optimum control.

4.4 Phase IV Effort

The remaining major tasks on this subprogram include:

- Third in-mine evaluation of a stageloader dust control system
- Transfer of technology to industry and final reporting.

It is expected that an agreement will soon be reached with Wilberg Mine. The proposed schedule for the evaluation shows it being completed by May, 1984.

Once the third evaluation is completed, the results will be documented in a mine report. The results of the entire effort will be prepared for inclusion in the Final Report. A paper will also be prepared summarizing the results of this program and our recommendations to transfer the technology to the mining industry.

5. SUBPROGRAM D - LONGWALL AUTOMATION TECHNOLOGY

5.1 Overall Program Objectives

The automation of the longwall face is an elusive goal that has been pursued intermittently during the last twenty years. The potential benefits of automation are in the areas of improved production and increased safety.

Although automation has not yet been widely adopted on United States longwalls, it appears that several components of the automated longwall have significant potential for reducing dust exposure of face personnel. The Longwall Automation Technology subprogram was conceived to assess the benefits of automatic and remote operation of longwall equipment and to identify the problems, both real and perceived, stalling its introduction and use on United States longwalls.

5.1.1 Phase I Results

The principal areas in which automation can be applied on longwall faces are as follows:

- Horizon control
- Face alignment
- Support advance
- Shearer control.

At the initial stage of this subprogram, the last two methods of automation were identified as having the greatest potential for actual application and impact on operator dust exposure.

The first practical step taken was to conduct an industry survey to identify the equipment that was available and the extent of its application. To this end, contacts were made with various manufacturers and mine operators.

The principal conclusions of this initial survey were:

- Automated roof supports had several advantages relating to roof control and face operations. The most obvious disadvantage was the complexity of the automatic systems relative to current systems and the level of expertise available for maintenance. Penetration of the United States longwall market was, at that time, currently limited to two or three faces.

- Shearer remote control systems were much more common since most manufacturers offer either radio or remote control. Actual use of radio remote control appeared to be very limited since most installations appear to be specified as insurance against future dust problems or against face spalling and "rock throwing" hazards in high coal.

- Umbilical remote control was found to be more practical and was in use on several faces.

5.2 Phase II Objectives

The initial aims of the second phase of this subprogram were to:

- Determine the availability of longwall equipment suitable for automation or remote control. This was to be achieved by meetings with equipment suppliers and review of appropriate publications

- Further investigate the acceptance of automation and remote control by the longwall community by means of telephone contacts and mine visits

- Quantify the reduction in operator dust exposure that could be expected through the combination of various types of auto/remote control equipment with different mining cycles and mining conditions.

The effort on each of these investigations was to be divided between automation of roof supports and remote control of shearers.

5.2.1 Synopsis of Phase II Results

5.2.1.1 Availability and Acceptance

Shearer Remote Control

The meetings that were held with shearer manufacturers confirmed that all manufacturers offered some kind of remote control. Where the method of remote control was by radio, there was a very low level of utilization even when it was fitted to the shearer. The reason for the low level of utilization was the relative complexity and low reliability of the equipment. Some shearer designs such as the Joy 1LS allow umbilical remote contact to be implemented with comparative ease. It appears that where umbilical remote control is provided it will be used for at least part of the cutting cycle.

Automated Roof Supports

In the Phase II report the availability of the Dowty electronic automatic control system was noted. This system greatly simplifies the "plumbing" of automatic (strictly speaking - remote) support operation while increasing its flexibility. During Phase II none of these systems had been installed in the United State although several are reported to be in use in the UK and Australia. At the time of the Phase II report the only automatic support systems employed in the United States were at AEP's Martinka mine in West Virginia.

5.2.1.2 Impact on Dust Exposure

Two mine site visits occurred in Phase II which resulted in data that compared conventional and remote shearer operator dust levels. Data from Meigs Mine showed that the headgate shearer operator experienced 46 percent less dust during cutting (to the tailgate) if he operated the machine with a 15 ft umbilical.

A more detailed study at Quarto No. 4 compared exposure of operators on each segment of the longwall cycle. This study showed no benefit to the tailgate drum operator from moving 20 ft outby. This was due to dust generated by the upwind drum. The operator at the headgate end of the machine was spared 75 percent of potential dust exposure by moving 20 ft upwind.

5.3 Phase III

5.3.1 Phase III Objectives

The longwall automation subprogram was conceived as being conducted with intermittent effort. It was expected that the program schedule would be designed to maximize potential for cost-sharing by taking advantage of meetings and visits arranged for other subprograms. With this in mind a relatively limited scope was defined for Phase III of the subprogram.

In the area of shearer remote control this included:

- The generation of further data on the benefits and practicality of shearer remote control

- A meeting with a user of radio remote control to get the user's point of view on the maintenance/ reliability issue.

Similar goals were set with respect to automatic/remote support operation. Specifically these included:

- Measurements to establish the benefit of remote support operation

- A meeting with the sole current United States user of remote operation

- Evaluation of the use of canopy extensions to provide immediate roof support (IFS).

An additional objective of Phase III was the generation of a "Tech News Brief" on remote shearer operation.

5.3.2 Shearer Remote Control

5.3.2.1 In Mine Studies

Two studies were conducted during this phase which were aimed at further defining the effect of moving shearer operators further away from the shearer.

ARMCO Walhonde No. 7

The first of these took place at the ARMCO Walhonde No. 7 mine in Montcoal, West Virginia. At this mine an Eickhoff 170 shearer was employed to extract 66 in. of coal. The mining cycle employed was full bidirectional. The situation on this face at this time was notable for the high level of dust at the shearer operator's position. Foster-Miller observers ascribed this to the following factors:

- The extraction of several inches of roof and floor/rock and an 8 in. thick midstream parting

- A low ventilation velocity of under 150 ft/min

- Low water pressure and flow to the cutting drums

- A shearer configuration that produced a very distinct upwind plume of dust.

Two pairs of measurements were made in an attempt to define the effect of moving the operator to different positions. In these measurements the actual shearer operator's exposure was monitored along with the exposure at a nominal "remote" operator's position. This procedure was repeated for remote positions 12.5 and 50 ft upwind of the shearer. The results which are shown in Table 5-1 suggest that in this situation only slight relief was available by moving a modest distance (10 to 15 ft) from the machine while at a much greater distance (50 ft) a notional operator was in a much improved environment.

This survey was conducted as part of another evaluation and the results above are based upon a very small data set. However, it is clear that in this case the operator would have to move a significant distance from the machine in order to avoid the upwind dust cloud. It is unlikely that the machine could be adequately controlled from the kind of distance (greater than 30 ft) that this would require .

A more extensive evaluation took place at Quarto No. 4 which involved measurements on both the 4 South and 3 North Longwall at that mine.

North American Coal Quarto No. 4

The 4 South Longwall at Quarto operates in the Pittsburgh seam and extracts approximately 66 in. with a Joy 1LS cutting

TABLE 5-1. - Summary of remote control data from ARMCO Wathonde no. 7 mine

Measurement number	Measurement position	Average level (mg/m^3)	Percentage
1	Shearer operator	13.7	100.0
1	Shearer operator + 12.5 ft	9.3	68.0
2	Shearer operator	16.7	100.0
2	Shearer operator + 50 ft	1.1	6.1

with a full bidirectional cycle. Once again, simultaneous measurements were made at both conventional and potential remote control locations during representative parts of the cutting cycle. Table 5-2 shows the relative dust exposures that were calculated for these positions. It is apparent that the headgate operator will benefit greatly from a move 20 ft upwind but that a similar move for the tailgate man would result in a substantial increase in dust exposure. In order to determine the reason for these changes the dust profiles around the shearer were examined. These profiles, which are illustrated in Figure 5-1, show that, when the shearer is cutting into ventilation, there is a large peak in dust level close to the headgate operator. If the tailgate man moves from one end of the machine to the other he will in this case be moving from a low to a high dust concentration. Unfortunately data was not available to fully describe the dust profile around the shearer during head to tail cutting.

The 3 North Longwall at Quarto differed from 4 South in that it was fitted with a "shearer clearer" system which is designed to confine dust to the face side of the shearer, thereby providing improved operator environment. The opportunity was, therefore, taken to compare exposures at the two operators' positions with and without the shearer clearer.

TABLE 5-2. - Summary of remote control data from Quarto No. 4, 4 South Longwall

Activity	Dust exposure at measurement position - $(mg/m^3) \times min$		
	Tailgate operator	Headgate operator	Headgate operator plus 20 ft
Cutting to headgate (shield 75 to cutout)	44.7	91.3	10.5
Cutting to tailgate (shield 25 to cutout)	30.7	41.8	19.2

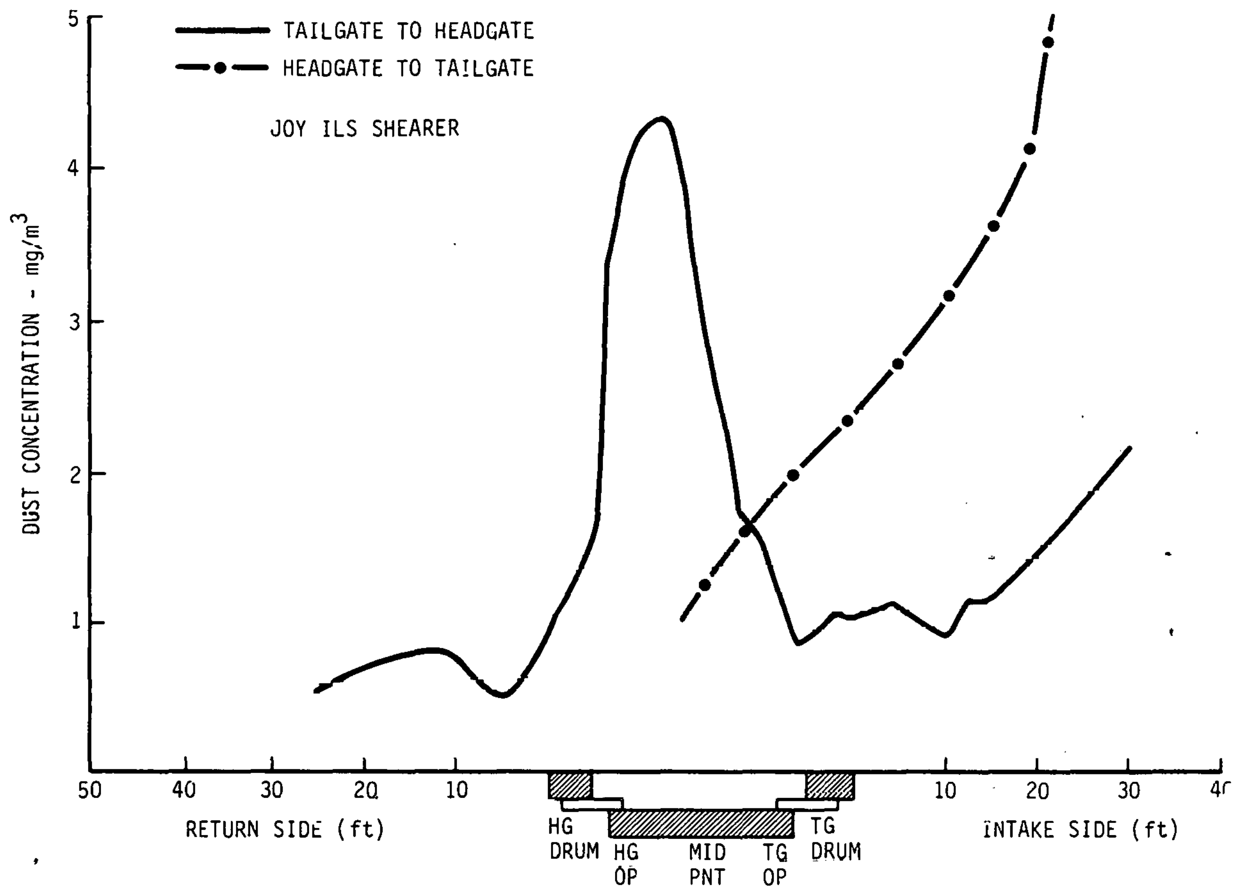


FIGURE 5-1. - Shearer dust profiles Quarto No. 4, 4 South Longwall.

Table 5-3 shows the dust exposures calculated for the various conditions. These data, which were based on only one full cycle of cutting in each direction, show that the shearer clearer was apparently <u>very effective</u> in reducing dust exposure at both operator positions. While the shearer clearer was operating, the two operators received similar exposures. With the system turned off dust exposures were much higher and the tailgate operator received slightly higher exposure than the headgate operator.

The brief measurements (two full cycles) made on this face suggested that there is a small potential improvement in environment to be obtained by moving the tailgate operator 20 ft upwind (to the headgate position). This conclusion only applies if the shearer clearer is not operating. Once it is used the exposure at both ends of the machine becomes comparable.

5.3.2.2 <u>Shearer Remote Control Conclusions and Recommendations</u>

The results of the mine studies of shearer remote control have been incorporated in a "Tech News Brief" that is currently

TABLE 5-3. - Comparison of dust exposure levels at Quarto No. 4, 3 North Longwall

Activity	Shearer clearer status	Dust exposure at measurement position - (mg/m^3)x min	
		Tailgate operator	Headgate operator
Cutting to headgate (shield 75 to cutout)	Shearer clearer on Shearer clearer off	77 353	88 269
Cutting to tailgate (shield 25 to cutout)	Shearer clearer on Shearer clearer off	64 114	60 135

awaiting publication. The note presents the data from the studies on the two Quarto longwalls together with the conclusions that:

- Moving the headgate operator 20 ft upwind to a position from which the machine is easily controlled will normally result in a substantial drop in dust exposure.
- A similar move applied to the tailgate operator in the absence of other means of reducing dust around the machine may produce an increase in exposure.

The Tech News Brief recommended umbilical remote control to longwall operators as a "low-tech," relatively rugged means of removing at least one operator from a region of high dust exposure.

5.3.2.3 Planned Radio Remote Studies

U.S. Steel's Lynch, Kentucky, mine is believed the only operation in the United States that routinely uses radio remote control on a shearer. The equipment in question is fitted to a AM500 shearer cutting approximately 10 ft of coal. A formal request has been sumbitted to U.S. Steel for a visit to this operation to discuss radio remote control and to obtain data on its effectiveness as a dust control measure. The proposed measurement strategy is similar to that used for the previous remote studies with the exception that the "remote" position will be that of the actual shearer operator.

5.3.3 Longwall Roof Support Automation

5.3.3.1 Planned Mine Studies

The lack of an operating automatic/remote longwall roof support system in the United States during most of this year has greatly hampered this part of the subprogram. Earlier in the year agreement was reached with Martinka for a visit which would combine discussion of the practicalities and maintenance aspects of automated support operation with a data gathering effort aimed at quantifying the improvement in support operator environment. This would be achieved by simultaneously monitoring the actual (automatic) support operator position and the location required for manual operation.

Unfortunately, each time that a potential cost sharing mine visit was available, the visit to Martinka had to be postponed. This was due either to face moves or problems with the support control equipment. A suitable opportunity to visit Martinka is still being actively sought.

5.3.4 Immediate Forward Support

The potential for using canopy extensions to reduce or eliminate the need of support operators to work downwind of the shearer was identified in the Phase II report. In the United States it is unusual for roof supports to be fitted with canopy extensions. Instances where extensions are maintained and are used in day-to-day operation are even rarer. Vepco's Laurel Run mine in West Virginia has a face that is so equipped and the management of this mine report that the extensions are used routinely. Agreement in principle has been reached for a visit to examine this operation and to discuss the practical aspects of using canopy extensions as a routine part of the mining cycle.

5.4 Phase IV Activity

It is anticipated that the remaining field work required on this subprogram can be completed in a single trip. This will involve visits to the following mines for the stated objectives:

- Lynch, Kentucky - Radio remote control study
- Martinka, West Virginia - Automatic support operation study
- Laurel Run, West Virginia - Canopy extensions study.

Each of these visits will consist of underground data gathering to assess the efficiency of automation or remote control, and discussion with mine personnel to obtain information on practical matters such as maintenance requirements and reliability.

At the same time a contact will be maintained with support manufacturers who currently report a renewed interest in automatic/remote support systems. Several such systems have recently been bid. There could be a large relative increase in the number of United States longwalls with automatic supports in the near future. These installations, if they occur, will be of the electronic type described in the Phase II report. The stimulus to this renewed interest may well be the reported success of these systems in Australia. An effort will be made to obtain definitive information on this Australian experience.

The subprogram will conclude with a report that will contain a full description of the results of the evaluations and other aspects of the investigation. The requirements of further technology transfer will also be addressed.

6. SUBPROGRAM E - LONGWALL APPLICATION OF VENTILATION CURTAINS

Brattice curtains can be used in a number of specific applications on longwall faces to improve ventilation and dust control. These are:

- A "wing" curtain to provide localized control of ventilating air during the headgate "cutout"
- A "gob" curtain at the headgate shield line to minimize "short-circuiting" of primary ventilation into the gob
- "Walkway" curtains along the face suspended from shields perpendicular to the airflow - keeping shearer generated dust near the face
- An "extended spillplate" technique used to partition the contaminated face air from the walkway.

The objective of this subprogram is to conduct laboratory and field evaluations of these techniques and to recommend improvements in their application.

6.1 Summary of Phases I and II

The tasks completed under the first two Phases of effort included the following:

- Preliminary investigations - This task consisted of telephone surveys to 17 longwall operations. The results showed that most mines used or knew of gob curtains; only a few used wing curtains, and none used walkway curtains.
- Laboratory testing - Walkway curtain effectiveness was evaluated in the longwall gallery using a variety of curtain lengths, angles and spacings. Testing results indicated that all curtain configurations caused eddying of the airflow into walkway spaces and an increase in walkway contamination levels. Further effort to study the technique was terminated.

  Preliminary extended spillplate tests, conducted in the old longwall gallery without a shearer in place, showed that only a full height spillplate produced an improvement in walkway contamination levels. Subsequent tests were performed in the new longwall gallery, with a shearer in place, both with and without a combination shearer clearer/passive barrier dust control system in operation on the shearer. With the dust control system off, walkway contamination levels around the shearer were actually higher with an extended spillplate than with a standard height spillplate. The higher spillplate helped to contain contaminated air within the headgate drum region; the contamination simply poured over the edge of the shearer into the operator's position, producing higher levels. With the dust control system on, virtually no difference was recorded in contamination levels around the shearer between the standard height and extended spillplate. Because of the lack of improvement when using an extended spillplate, further study of the technique was terminated.

- Field surveys - Three mines were visited to gain information on the use of wing and gob curtains and to search for suitable evaluation sites:

  - Price River Coal Company, No. 5 Mine, Helper, UT
  - U.S. Steel Corp., No. 34A Mine, Chesapeake, WV
  - Southern Ohio Coal Company, Meigs No. 1 Mine, Athens, OH.

  U.S. Steel's No. 34A Mine was selected as the first evaluation site.

- Field evaluation - The first evaluation, completed at U.S. Steel's No. 34A Mine, focused on two wing curtain configurations: a novel design used by U.S. Steel and the traditional design more commonly used in the industry. Following is a synopsis of the results:

  - Shearer operator dust surveys were performed during two headgate cutouts, one with the U.S. Steel wing curtain installed and one with it removed. Use of the curtain reduced peak dust concentrations during the cutout by approximately 70 percent.
  - Smoke trace and air velocity surveys demonstrated the wing curtains' effectiveness in channeling intake air around the headgate cutout region.

- Air volume surveys indicated that the use of wing and/or gob curtains made very little difference in the amount of air volume available at specified locations along the face.

- The U.S. Steel curtain configuration proved to be a more effective and streamlined design than the traditional configuration, allowing for more uniform flow of air around the curtain corner. It also offered the ability to "peel back" the curtain over several cutouts before needing to completely reposition it.

6.2 Phase III Effort - Site Selection for the Second Field Evaluation

Two ventilation curtain field evaluations are called for under this subprogram. The results of the first evaluation at U.S. Steel during Phase II pinpointed several areas of study on which the second evaluation should focus:

- A-B comparison dust data during headgate cutouts

- Further investigation of the interactive effects of wing and gob curtains on face velocities and airflow volumes

- Further studies on the effects of wing and gob curtains on transfer point dust entrainment

- The feasibility of a permanent wing curtain design which advances with headgate equipment.

Phase III effort was confined to a search for suitable evaluation sites. Screening surveys were conducted at three mines as part of general program dust source surveys or during other evaluations. Sites visited include:

- Price River Coal Company; No. 5 Mine; Helper, Utah
- ARMCO Steel; No. 7 Mine; Montcoal, West Virginia
- Kaiser Steel; York Canyon Mine; Raton, New Mexico.

6.2.1 Price River Coal Company - Helper, Utah

During a field survey at Price River's 10th West longwall in July 1983, the headgate was analyzed as a potential site for the second ventilation curtain evaluation. The results of the analysis showed that shearer-generated dust levels were too low under present face conditions to permit a ventilation curtain evaluation at that site. The maximum headgate cut-out dust level recorded was approximately 2.5 mg/m^3. Figure 6-1 shows plots of dust concentration versus face location (shield number) for two headgate cutouts monitored during the survey on tail-to-head cutting passes. Both plots illustrate consistent shearer operator dust concentrations of approximately 0.5 mg/m^3 approaching the cutouts, with peak cutout concentrations of only 2.0 mg/m^3 and 2.5 mg/m^3. The low concentrations were the result of high face air velocities, high shearer water pressure and flow, low tramming speed and low intake contamination levels.

6.2.2 ARMCO Steel - Montcoal, West Virginia

A major evaluation in progress under another subprogram precluded consideration of ARMCO as a ventilation curtain test site. A period of downtime during the other evaluation, however, provided an opportunity to document ARMCO's use of brattice and belting to control headgate-to-face airflow patterns. As shown in Figure 6-2, an angled curtain on the off-face side of the stageloader, combined with belting hanging into the face conveyor from the tips of the second and third shields, helped divert intake air away from the gob and direct it over the top of the shearer. Smoke traces showed the system

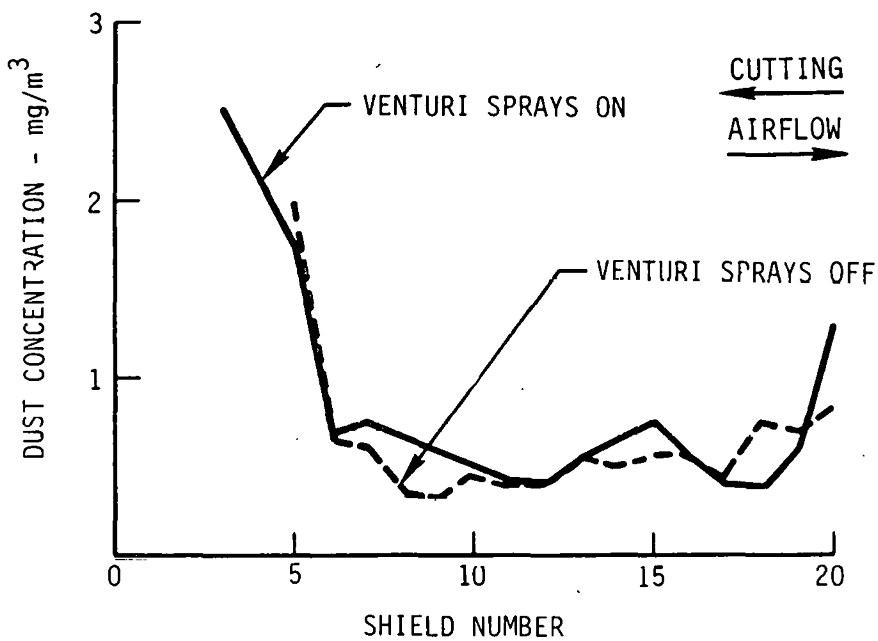


FIGURE 6-1. - Dust concentrations at headgate shearer operator's position during headgate cutout, tail-to-head cutting - Price River Coal Company

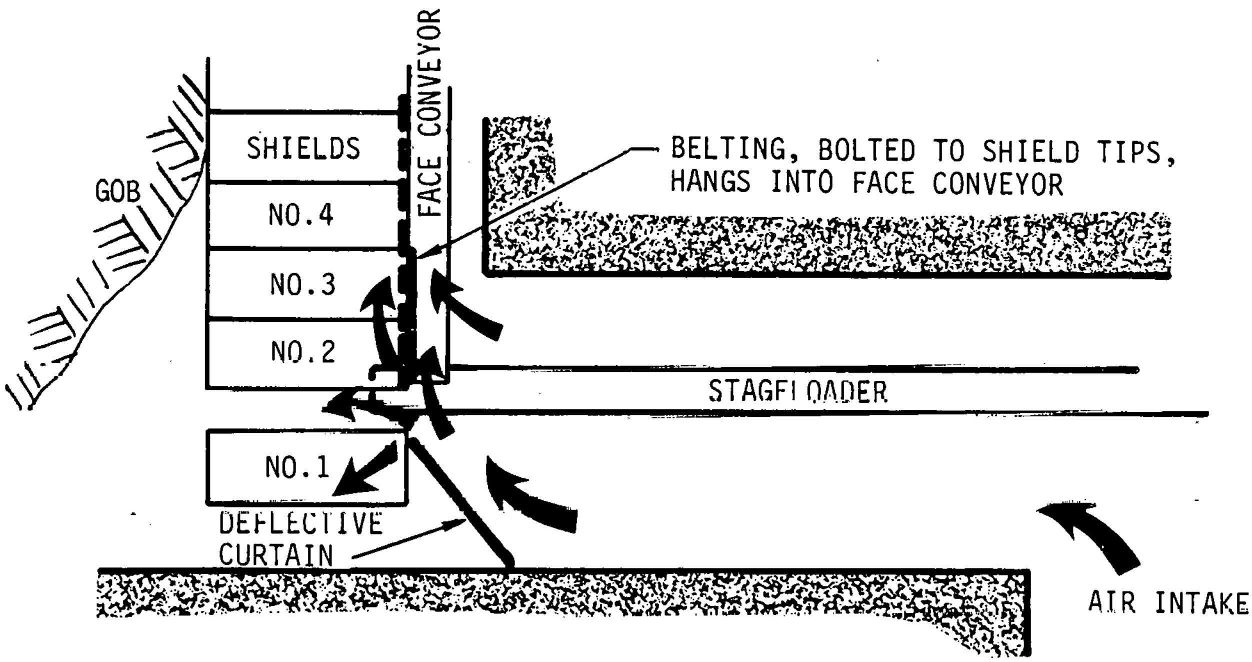


FIGURE 6-2. ARMCO's use of brattice and belting to control headgate airflow patterns.

to be very effective in rerouting air patterns as illustrated in Figure 6-2. Very little gob leakage occurred between Shield No. 1 and the chain pillar rib. However, significant gob leakage did occur between Shields 1 and 2 due to the gap between the curtain and the belting and the large gap between Shields 1 and 2. When the curtain was removed, airflows of 200-300 fpm short-circuited directly to the gob between Shield 1 and the chain pillar rib as well as between Shields 1 and 2.

During the headgate cutout, the belting on Shields 2 and 3 appeared visually to help reduce the amount of dust and spray mist impacting the headgate shearer operator.

6.2.3 Kaiser Steel Corporation, York Canyon Mine - Raton, New Mexico

A general dust source survey was performed on the longwall at Kaiser's York Canyon Mine during February, 1984. The purpose of the survey was to delineate dust sources and pinpoint appropriate control techniques, which would coincide with subprograms in need of evaluation sites. During the survey, it was noted that Kaiser had designed and used a unique combination of the wing curtain/gob curtain ventilation techniques. As shown in Figure 6-3, the system consisted of three separate components:

- A removable gob curtain positioned at the traditional location between the first shield and the chain pillar rib
- A semi-permanent "stageloader" curtain located along the off-face side of the stageloader extending for about 36 ft from the inby end of the stageloader past the crusher
- A sliding "shower-curtain" wing curtain extending from the face rib, over the stageloader, and intersecting with the stageloader curtain.

During the majority of Kaiser's cutting sequence (head-to-tail primary cut with a tail-to-head clean-up pass), the gob curtain was installed and the wing curtain retracted ("bunched up" against the face rib). This allowed the primary airflow to pass around the face corner while being blocked from short-circuiting to the gob. As the shearer approached the headgate cutout during the tail-to-head pass, the headgate operator

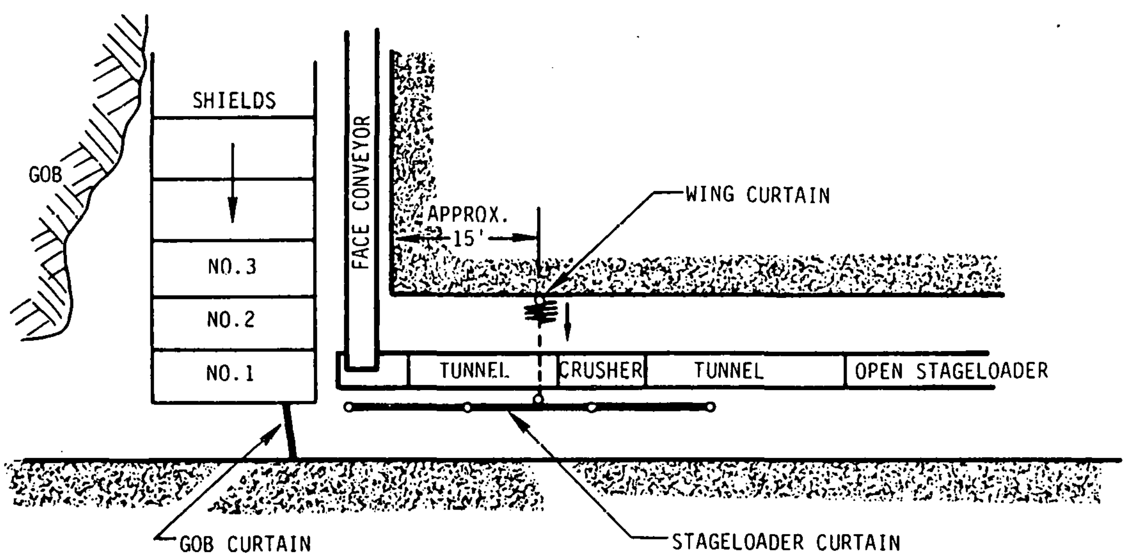


FIGURE 6-3. - Kaiser's use of a unique wing curtain - gob curtain - stageloader curtain system for headgate cutout dust control.

pulled the wing curtain tight across the stageloader and removed the gob curtain. This effectively blocked nearly all of the intake air from passing over the headgate drum during the cutout and purposely short-circuited a portion of the primary airflow to the gob. The short-circuited airflow reentered the face downstream of the headgate.

During dust monitoring, as the shearer approached the headgate for a cutout, the shearer operator's dust concentration started to increase. When the shearer was at shield number 10, the wing curtain was installed and the gob curtain removed. This resulted in a dramatic decrease, approximately 55 percent, in the dust concentration at the shearer operator's position, as illustrated in the plot of dust concentration versus face location (shield number) shown in Figure 6-4.

The preliminary survey at Kaiser showed the potential of their unique curtain system to control headgate airflow patterns and reduce headgate cutout dust concentrations at the shearer operator's position. The system warrants further study and Kaiser has agreed to allow a full evaluation to be completed under Phase IV.

6.3 Planned Phase IV Effort - Second Evaluation at Kaiser Steel

Dust from shield movement was shown to be a major dust source at Kaiser's York Canyon Mine, and a two-week field evaluation of shield dust is planned for the Spring/Summer of 1984. It is expected that the second ventilation curtain evaluation will be "piggybacked" onto this evaluation to document and quantify the effectiveness of Kaiser's curtain system. Emphasis will be placed on airflow pattern modifications and headgate cutout dust control effectiveness of a variety of curtain scenarios, including:

- Kaiser's existing procedure: wing curtain pulled tight; gob curtain removed
- Wing curtain tight, gob curtain remaining intact
- Wing curtain retracted, gob curtain intact
- Both curtains removed.

Because of the mineworthiness of Kaiser's existing system, the evaluation will likely require no installation and maintenance

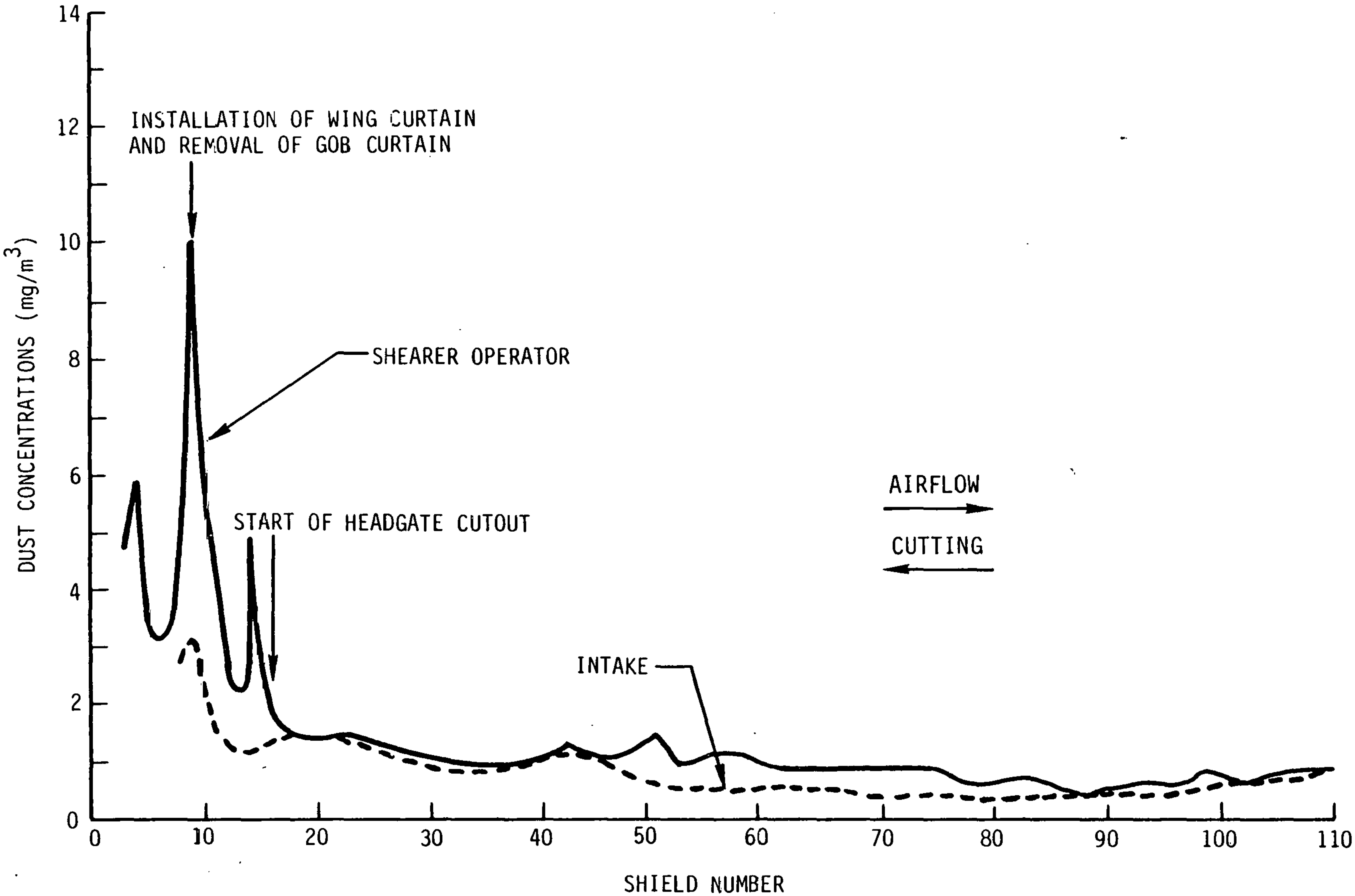


FIGURE 6-4. - Dust concentration versus shield number; tail-to-head cutting - Kaiser Steel; Corporation, York Canyon Mine.

of new hardware or curtain hanging methods. Any appropriate system modifications or curtain usage practices that may be identified, however, will be investigated.

Specific tasks to be performed under Phase IV of this subprogram will include:

- Completion of a cooperative agreement and test scheduling for the Kaiser-York Canyon evaluation

- Submission of a formal test plan to the USBM

- Performance of the evaluation, data analysis and drafting of a mine report

Once the evaluation at Kaiser is completed, the results of the entire subprogram effort will be prepared for the Final Report. A technology transfer paper describing the use of ventilation curtains, including practical recommendations and specific curtain design alternatives, will also be written.

7. SUBPROGRAM F - REVERSED DRUM ROTATION

7.1 Overall Objectives

There is reason to believe that shearer operator's dust exposure can be significantly lowered by reducing the amount of dust generated and liberated during the loading process. The technical literature and various experiments suggest that loading conditions will be significantly improved if the direction of drum rotation is reversed. This is because with reverse rotation, both drums will experience less obstructed loading. In the case of the leading drum, the time that the coal remains in the drum and the distance travelled by the coal within the drum will also be reduced. Reverse rotation will, therefore, reduce recirculation and coal breakage by allowing unobstructed loading and increasing the capacity of the drum.

The objective of this subprogram is to conduct an evaluation of this hypothesis which will provide guidance for the application of this principal to other longwalls.

The major tasks necessary to achieve this goal are:

- Preliminary planning
- Field trial planning
- Instrument selection and approval
- Installation
- Underground evaluation
- Data analysis
- Technology transfer and reporting.

The first three tasks were initiated during Phase II. These were completed and the underground evaluation was carried out during Phase III. The current report contains a brief description of prior activity and a full report on the work completed during Phase III.

7.2 Phase II Summary

The primary tasks in Phase II consisted of gathering background data that related to reverse drum rotation and establishing the criteria for underground evaluation sites and procedures.

The background search was undertaken by approaching the three U.S. longwall operators with experience using reverse drum rotation and obtaining information on their experience. Two of these operations (Consol/Itman and U.S. Steel-Gary District) had withdrawn their longwalls due to the depressed coal market. In the third case, practical input was provided by a visit to U.S. Steel's Morton No. 34 mine where a single drum shearer was operating in reverse drum mode. Figure 7-1 indicates the loading zone observed at the Morton installation with reversed rotation in each direction of cutting. Although the preliminary survey at Morton did not quantify the utility of reverse rotation, it did provide an example of an operation where it had proved feasible from a mining and mechanical standpoint to use reverse drum rotation.

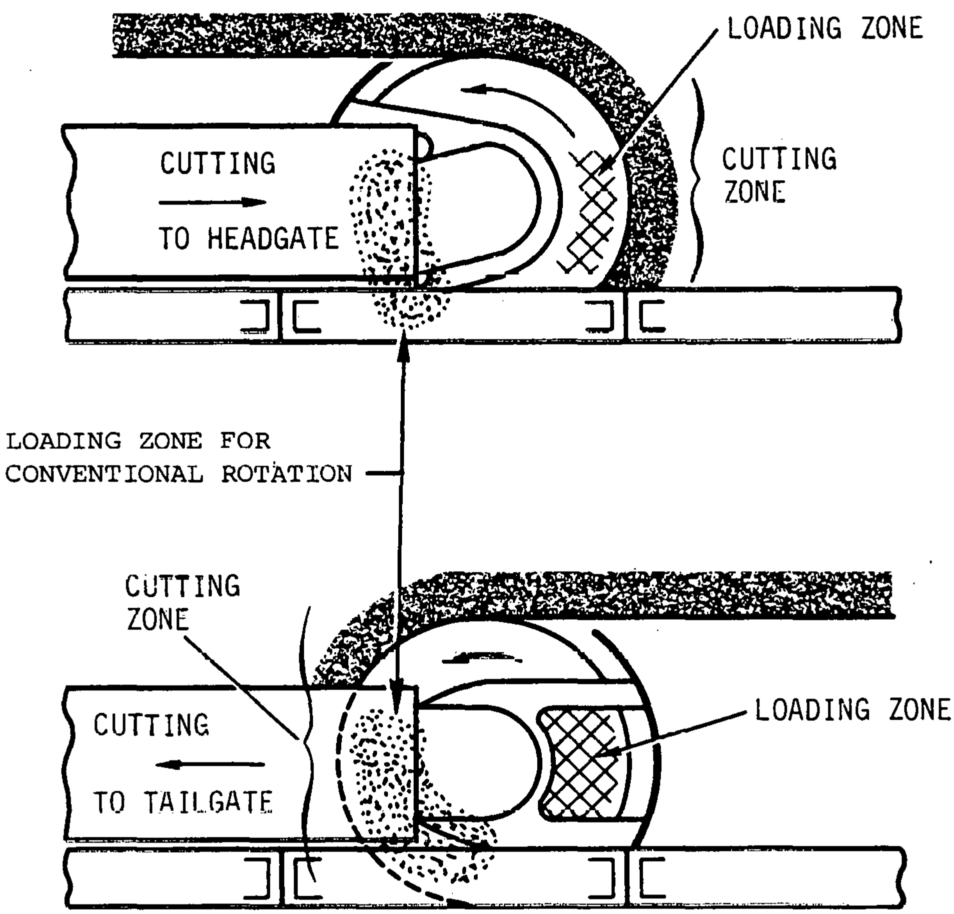


FIGURE 7-1. - Reversed drum rotation.

Mine site selection criteria were developed during the Phase II effort to assist in identifying a suitable site for the underground evaluation. The list of criteria included:

- Cutting cycle
- Bench extraction
- Drum size
- Drum speed
- Ventilation
- Mechanical feasibility of the drum switch and reversal.

Near the end of Phase II the management of both Consolidation Coal Company and North American Coal Company expressed an interest in the reverse drum concept although no formal agreement was reached.

7.3 Phase III Activity

The major objective of Phase III was to conduct a comparative underground evaluation of the reverse drum rotation concept. In order to do this the following tasks had to be completed:

- Refinement of mine site criteria
- Determination of suitable mine site
- Conclusion of agreement with the operator of a suitable mine
- Preparation of a test plan.

The paragraphs that follow describe how these objectives were achieved.

7.3.1 Mine Site Selection

Although mine site selection criteria had been previously developed, these were further refined when the search for a mine site began in earnest. The criteria established in Phase II centered around two requirements: mechanical feasibility and mining environment.

The mechanical feasibility consists mainly of the ability to reverse the direction of drum rotation with reasonable ease and without compromise to other shearer functions such as auxiliary drive or tramming motors. The other concerns fell under the heading of mining environment and related to the need for the site to:

- Operate in a mode where the trailing drum loads an appreciable quantity of coal
- Employ a drum of modern design with adequate vane height and which operates with at least average pick penetration
- Provide seam conditions which allow consistent production.

During informal discussions with potential mine sites it became apparent that the obvious additional criterion - the willingness of potential mine sites to take part in the evaluation - was strongly determined by the mining organization's perception of the degree of risk (of lost production) associated with a drum change. Once this was perceived a further component was added to the mine site search strategy. This was to seek out sites where the shearer type and the availability of spare drums allowed the direction of one drum at a time to be changed. This can be achieved on a "two motor" shearer such as the Joy 1LS and the Eickhoff 150-2L by changing the direction of one motor (such as the headgate motor) and mounting the spare drum from the wrong (e.g. tailgate) end of the machine.

The suggested procedure in this case is to change the direction of the headgate drum alone until it could be established that the performance of the machine was not unduly compromised. The attraction of this procedure lies in the relative ease with which the headgate drum can be accessed and changed compared with the tailgate end of the machine.

In the early stages of planning of the evaluation, the following mining organizations were identified as actual or potential users of reversed drum rotation.

- U.S. Steel, Gary District
- Consol/Itman
- U.S. Steel, Dakota District (formerly Carbon Fuel).

By the time that the program was established the first two companies were no longer operating longwalls. The third mine, U.S. Steel's Morton No. 34, was using a single drum machine which was not suitable for a full scale trial.

In order to broaden the search for a mine site, discussions were held with the following organizations:

- Consolidation Coal (headquarters)
- North American Coal Company (Quarto)
- Kaiser Steel Mining
- U.S. Steel (headquarters)
- Eastern Associated Coal Company.

At an early stage in the proceedings, Quarto indicated interest in providing a mine site and a two-day visit was arranged in June of 1983. During this visit data was gathered on both longwalls at Quarto No. 4. Following the visit a report was prepared for Quarto management which described the potential benefit of reverse drum rotation. This was hypothesized by demonstrating the disproportionate exposure suffered by the trailing drum operator during head-to-tail cutting. The basic situation is shown in Table 7-1.

TABLE 7-1. - Comparison of operator's exposure showing disproportionate exposure of upwind (headgate) operator

Longwall	Activity	Exposure at operator's position $[(mg/m^3) \times min]$	
		Headgate operator	Tailgate operator
2	Cutting to HG	91.3	44.7
2	Cutting to TG	41.8	30.7
1	Cutting to HG	87.5	77.0
1	Cutting to TG	59.8	63.7

Despite their original interest Quarto, citing economic conditions, eventually declined to participate in the evaluation. Following renewed inquiries a similar response was received from U.S. Steel and Consol.

At about this time Kaiser Steel agreed in principle to provide a site on a face equipped with a Joy 1LS at Sunnyside, Utah. Unfortunately this mine was then closed due to a combination of natural disasters (mud slides) and soft markets. Eastern Associated Coal was then approached. The response received was positive but Eastern declined to express a firm interest due to being "overbooked" with other research programs.

A decision was then taken to approach Jim Walter Resources Inc., (JWR), which, despite operating in conditions that are not typical of U.S. longwalls, offered a number of advantages as a mine site. Among these was a machine that was by this date operating normally with reversed drum rotation and a management who regarded "floor-to-roof" cutting as a realistic alternative to current practice rather than defiance of convention. As a consequence, an agreement was reached that would allow FMI to monitor a changeover from reverse to conventional rotation that was scheduled to occur at Jim Walter's No. 4 mine. This visit was originally conceived as a small scale pilot study since a change of rotation would also involve a change of drums. The drums involved, however, were built to the same basic specification.

Following further discussions, JWR agreed to change direction with the existing set of drums, thus allowing an evaluation in which the effect of drum direction would not be confused with that of changing to new drums. It should be noted that JWR management consider the reverse rotation setup to be the less dusty option and also believe that other practical advantages result from this approach.

7.3.2 Reverse Drum Evaluation at Jim Walter Resources, Inc., No. 4 Mine

7.3.2.1 Site Description

The site selected for the evaluation at JWR was the No. 2 Longwall at JWR No. 4 mine near Brookwood, Alabama. This longwall operates in the Warrior basin at a depth of approximately 2000 ft. The vital statistics of the longwall are given in Table 7-2. The salient features that affect the evaluation are summarized in the paragraphs below.

- Ventilation - This face is ventilated in the homotropal (tail-to-head) direction. This fact, taken by itself has little effect on the reverse drum evaluation except in that it results in intake dust levels that are lower than they might otherwise have been. The ventilation quantity, however, was very high with a nominal 50,000 cfm on the face. This results in a face velocity over the panline in the region of 800 to 1000 ft/min.

- Mining cycle - The mining cycle used is a variation of the conventional modified half face method. The modification involved is the inversion of the cycle so that the bulk of cutting is done from tailgate-to-headgate (with ventilation and coal flow). Some supports are pulled behind the shearer on the

TABLE 7-2. - Reversed drum evaluation site description

Jim Walter's No. 2 mine No. 2 longwall	
Panel depth	2000 ft
Panel length	600 ft
Extraction height - face - face ends	66 in. 96 in.
Ventilation direction	Tail-to-head
Ventilation quantity	50,000 cfm (typical)
Face cross section	60 ft^2
Roof support type	Thyssen, 2 leg lemniscate shield (IFS canopies)
Mining cycle	Modified half-face
Shearer type	Anderson Manor 500, DERDS
Drum - diameter - web - loading vanes - sprays	62 in. 32 in. 2 start Conflow staple-lock, 1 per pick
Face conveyor	Mining supplies 2x26 mm inboard chain

tail-to-head (cutting) pan. The remainder are advanced during the flit from head-to-tail.

- Extraction height and seam condition - The longwall operates at a nominal extraction height of 66 in. At this height the main seam (of just under 60 in.) is extracted fully along with some floor. The immediate roof is formed by the "middleman" stone parting which supports a rider seam. Both parting and rider average about 12 in. At the face ends both rider and parting are taken to provide additional headroom. The number 2 longwall is in its second panel and front and side abutments loads are fully developed. As a consequence of this and other factors, the face sloughed extensively both between passes of the shearer and immediately in advance of the drums when the machine was cutting. Delays due to large lumps hanging up at the headgate transfer point were common on the cutting run while stoppages due to slabs jamming under the shearer tended to punctuate the flit to the tailgate.

- Face equipment - The roof supports consist of Thyssen two leg lemniscate "one web back" shields of conventional design. The shearer is an Anderson Manor AM 500 double ended ranging drum machine. In the context of this trial the machine had four notable features.

  - Two drum rotation speeds were selectable at each gearhead. The "high" and "low" speeds were 39 and 27 rpm respectively. The machine was normally operated in the low speed setting at 27 rpm. This speed is on the lower bound of current practice.

  - A form of shearer clearer was fitted to the machine. This consisted of spray bars located just outboard of each gearhead and two venturi sprays mounted on the face side of the shearer body. A passive barrier approximately 6 in. in height was mounted 9 in. from the gob side edge of the machine.

  - No cowl was fitted to the headgate drum.

  - The operators' positions at both ends of the machine coincided with the ends of the gearheads. The operators were, therefore, within 1 or 2 ft of the plane of the trailing edge of the drums.

7.3.2.2 Evaluation Planning and Strategy

Two principal concerns had a major effect in determining the content of the test plan. The first of these was the requirement that the drum change be scheduled in advance to fit in with other mine activity. There was, therefore, little or no leeway if good data was not gathered in the first week (reverse condition). It was assumed that at least four good shifts of data would be available during this week and that between five and ten cycles of data could be obtained. A similar effort would then follow during the week of operation with conventional rotation. Following this week the drums would be changed to an experimental drum with a larger pick.

The other main concern was the need to define measurement locations and methodology that would maximize the potential for detecting dependence of dust levels on drum rotation direction. It was decided that this would best be achieved by sampling with RAM-1 instruments at three positions that would move with the shearer. These positions were:

- Upwind of the shearer (intake position)
- Downwind of the shearer (return position)
- At a shearer operator's position.

7.3.2.3 Underground Evaluation

The reversed drum evaluation commenced on Monday, 16 January. The plan at that time was to sample for the balance of that week in the reverse drum condition, to swap the drums during the weekend of 21/22 January and to gather data in the conventional rotation mode during the week beginning 23 January.

On Monday, 16 January the face was operational and upon arrival of the team at the longwall it was surveyed to allow measurement locations to be chosen. This procedure involved the measurement of shearer dust profiles to allow a suitable measurement position to be chosen at the shearer, and the taking of data at two positions on the return side of the shearer to allow the correct downwind position to be located.

The initial profile along the shearer indicated that a position approximately at the center of the machine was representative of the operator's exposure. The intake sampling location was set at 20 ft upwind of the shearer drum leading edge while the downwind location was located 30 ft from the drum edge. The upwind sampling point was approximately 9 in. above the spillplate. The choice for the downwind location was between the spillplate position and one that was biased towards the face above the panline.

Following an initial cycle of data gathering in each position the "above the pan" location was selected. This was because the plane of the spillplate represented the mixing zone between the dusty air from the machine and the relatively clean air that had passed around the machine in the travelling way. The decision to use the panline position was made despite some procedural difficulties that had to be overcome. These involved taking special care to ensure that the cyclone intake did not block and that the cyclone itself was not inveted accidentally when it was held out over the conveyor on an anemometer wand. When sampling began the procedure employed was to take data at each shield from the 100th to the 20th shield (Figure 7-2). This range represented normal cutting or tramming and was not influenced by sumping or variations in ventilation at the face ends.

During the first week valid data was obtained on each of the next three days (Tuesday through Thursday). On Thursday, however, it became apparent that the shearer had suffered bearing failures that required the full attention of the JWR maintenance crew during Friday and the weekend. No data was gathered on the Friday due to the failure, and the decision was taken to return to Boston since JWR would not be able to swap drums during the coming weekend.

Following the repair of the shearer, the drums were swapped on Saturday, 28 January and data was taken during the subsequent week from 30 January to 3 February.

7.3.2.4 Evaluation Results and Analysis

The evaluation resulted in a data set with the following major components:

- Full cycle mobile dust data sampled on a once per shield basis at <u>three</u> positions around the shearer
- Shearer dust profile data taken in "floater" positions
- Gravimetric sampler data from a return crosscut.

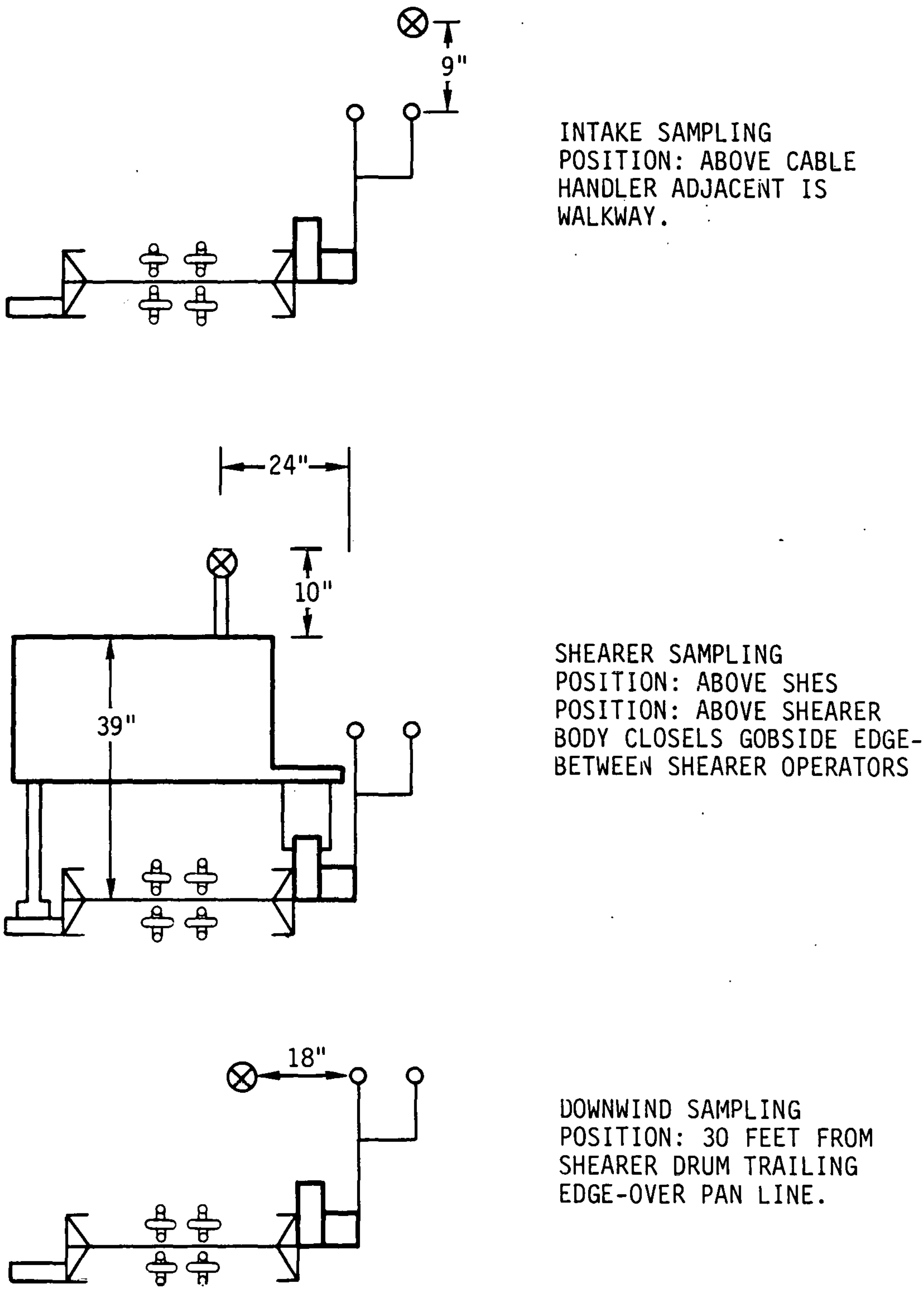


FIGURE 7-2. - Location of sampling positions.

The first analysis involved the shearer dust profile data. These consisted of three and four passes in the reversed drum and conventional condition respectively. The profiles for each condition were superimposed and the mean value calculated for each 5 ft increment between the position approximately 35 ft downwind at the shearer headgate drum and 25 ft upwind of the tailgate drum. These average values are tabulated in Table 7-3 and are shown graphically in Figures 7-3 and 7-4. The figures also include an indication of the range of values encountered. The measurements, which were made in the vertical plane that includes the spillplate, allow a commparison to be made of the distribution of dust around the shearer.

While the shearer is cutting it would appear that dust levels both upwind and downwind of the machine are broadly similar in both the reversed rotation and the conventional configuration. There is a big difference, however, along the body of the machine. This is manifest over the upwind two-thirds of the machine by conventional rotation dust levels that are several times higher than those for reverse rotation. The position used for the mobile sampling was within this area. The other noticeable difference is the peak that occurs for reverse rotation near the leading drum (and just downwind of it).

There is less difference between the dust profiles for tramming and loading (from headgate-to-tailgate), though there is some suggestion that levels are more variable during conventional rotation.

The main data set from the mobile sampling was analyzed by taking five cycles of data representing complete reversed rotation mining cycles, and six conventional cycles. These were tabulated and averaged so that "average dust levels" were available for each shield, broken down as follows:

- For each measurement position; e.g., 30 ft downwind on the shearer and 20 ft upwind
- For each direction of rotation
- For cutting (tail-to-head) and tramming (head-to-tail).

These valves were calculated for each shield between shield 20 and shield 100. The results are plotted in Figures 7-5 to 7-8 which show the relationship between the dust levels measured at the three positions relative to the shearer

TABLE 7-3. - Dust levels around the shearer during cutting under reversed and conventional rotation conditions

Position	Average dust level (mg/m^3)	
	Reversed rotation	Conventional rotation
-40[1]	7.9	
-35	10.8	
-30	8.3	6.1
-25	8.6	6.3
-20	8.0	7.1
-15	6.7	6.6
-10	6.2	5.3
- 5	10.7	6.5
Drum leading edge	13.5	6.9
Drum centerline	5.7	4.9
Drum trailing edge	3.5	-
Operator position	3.9	2.9
Gearhead	1.2	2.0
Dust monitor	0.9	2.8
Haulage control	0.5	-
Gearhead	0.6	2.2
Operator position	0.7	3.7
Drum leading edge	-	-
Drum centerline	0.7	4.4
Drum trailing edge	0.7	4.7
+ 5	0.4	0.7
+10	0.4	0.7
+15	0.3	0.4
+20	0.4	0.5
+25	-	-
+30	-	0.3

Note: Negative indicates downwind of the shearer, positive indicates upwind (intake side) of the shearer; the machine is cutting with ventilation.

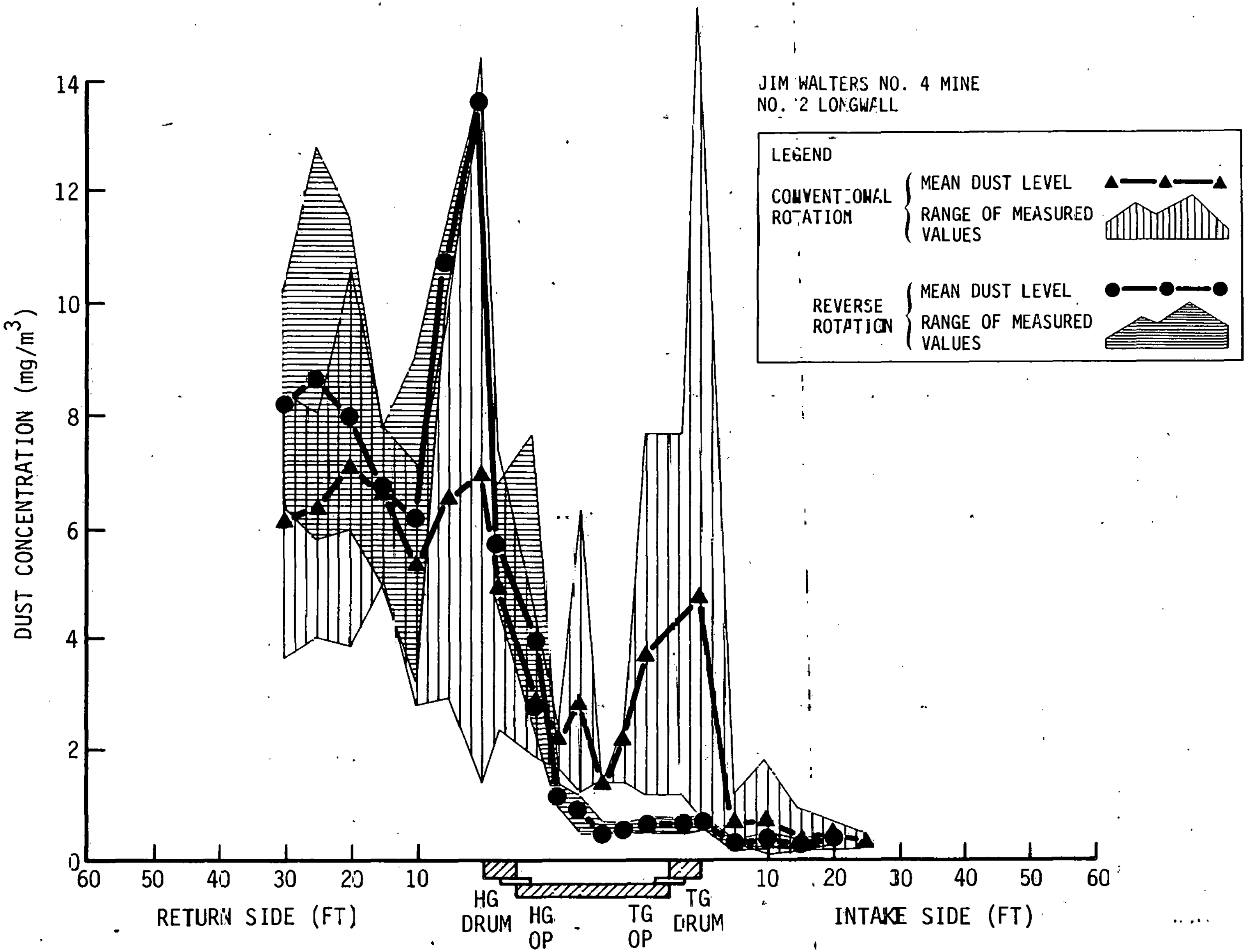


FIGURE 7-3. - Dust levels around the shearer (above the cable tray) during cutting from tailgate-to-headgate.

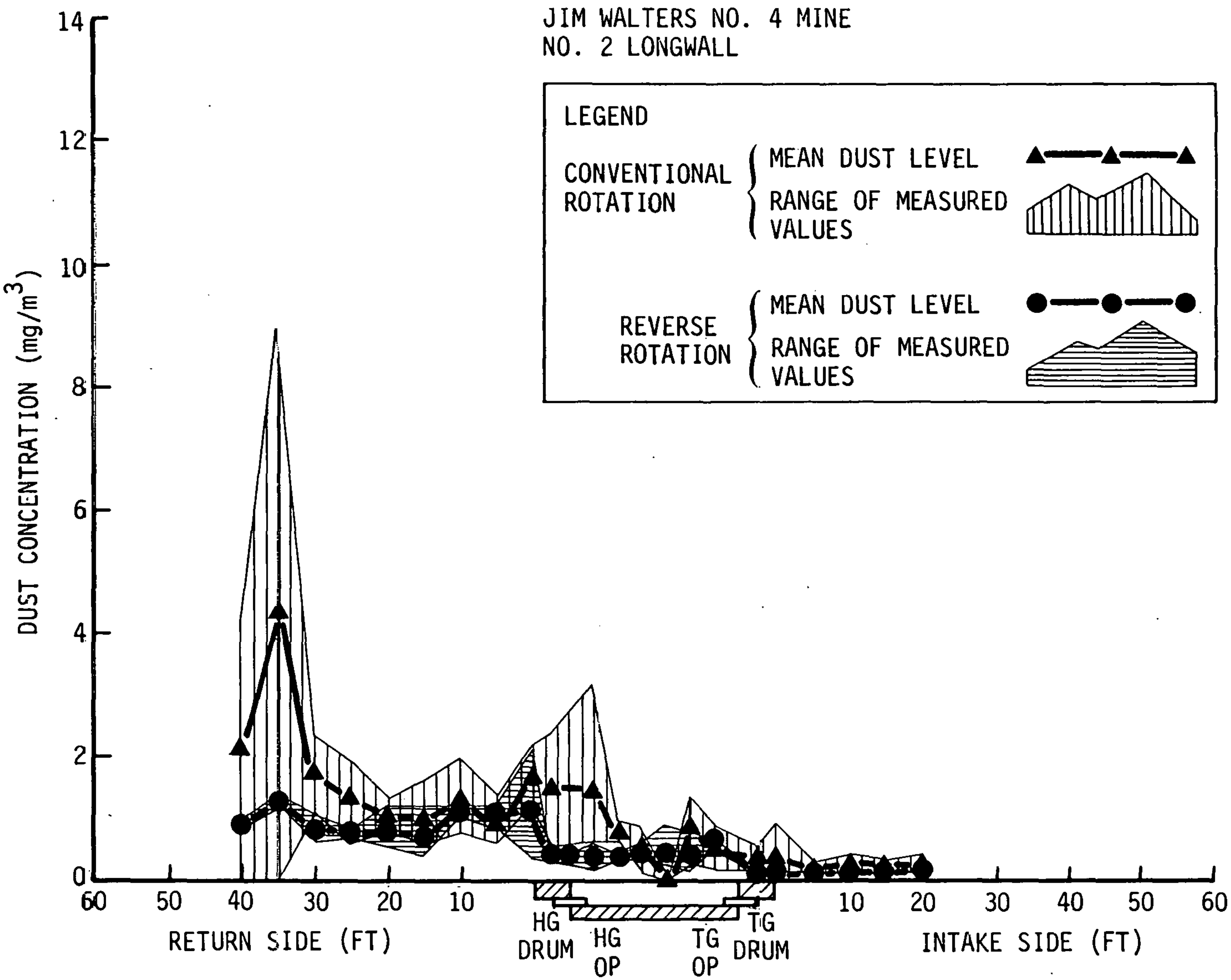


FIGURE 7-4. - Dust levels around the shearer (above the cable tray) during tramming from headgate-to-tailgate.

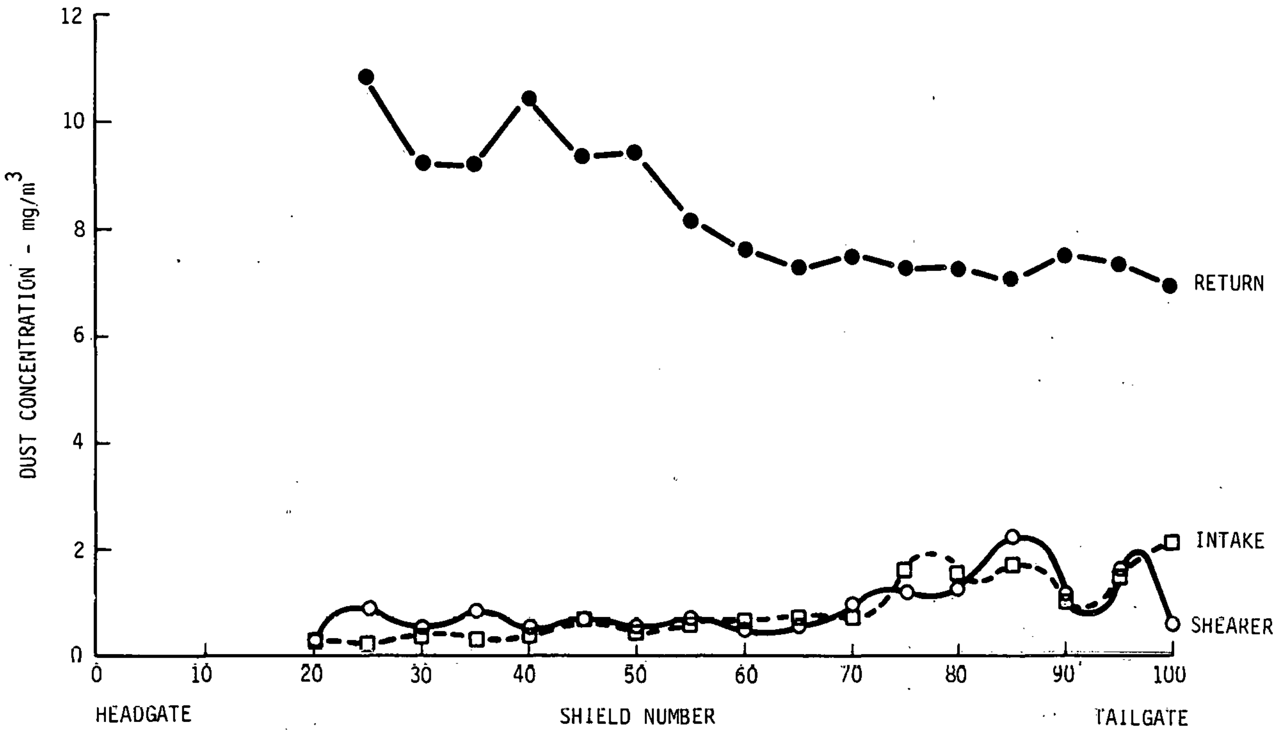


FIGURE 7-5. - Average dust concentrations of five tail-to-head cutting passes - reversed drum rotation.

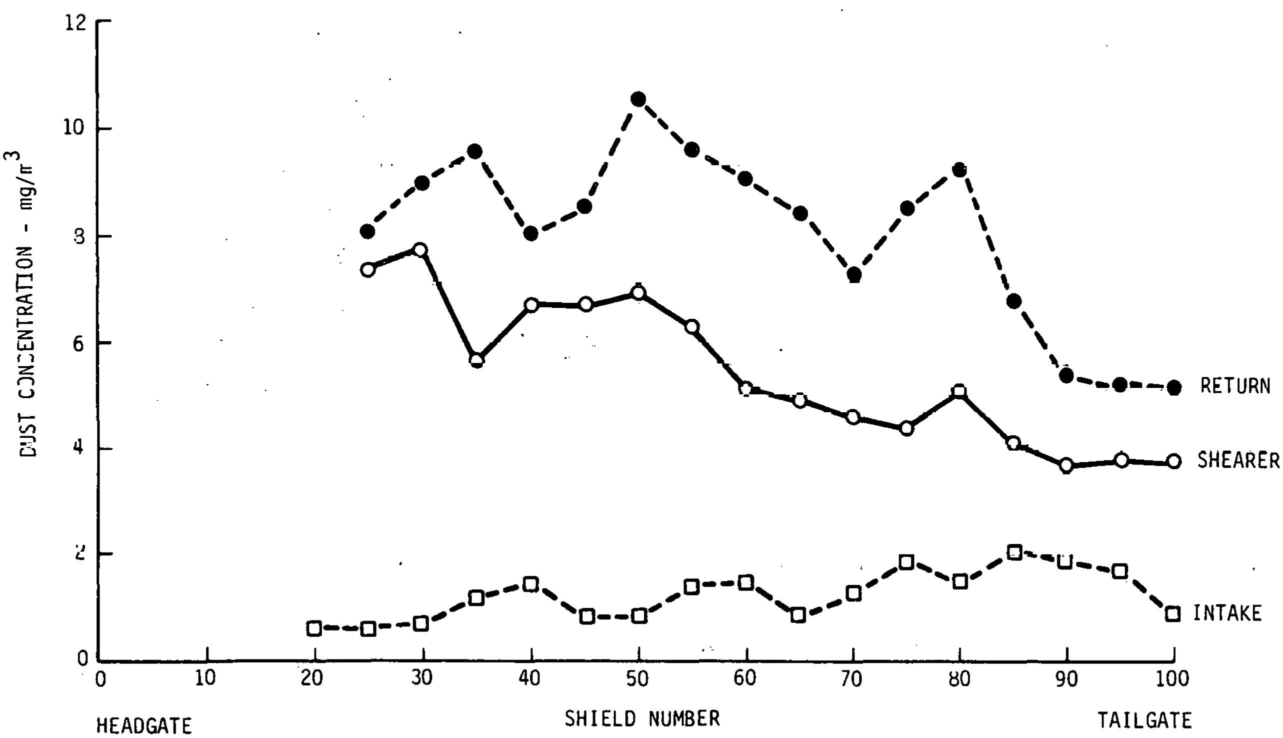


FIGURE 7-6. Average face dust concentrations of six tail-to-head cutting passes - conventional drum rotation.

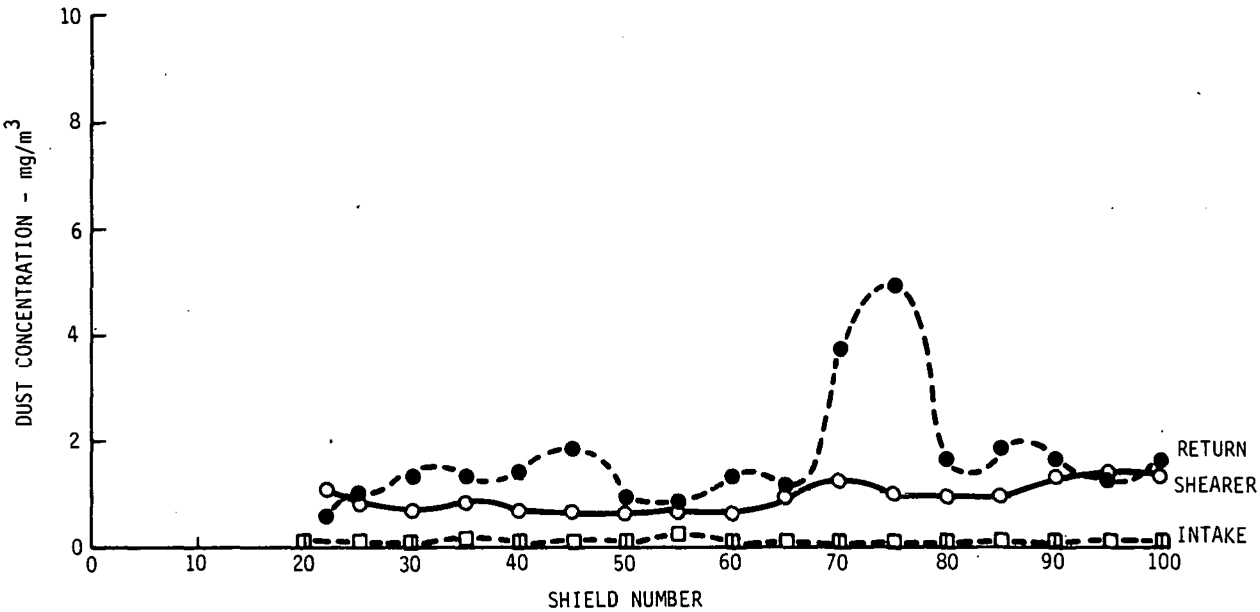


FIGURE 7-7. Average dust concentrations of five head-to-tail tramming passes - reversed drum rotation.

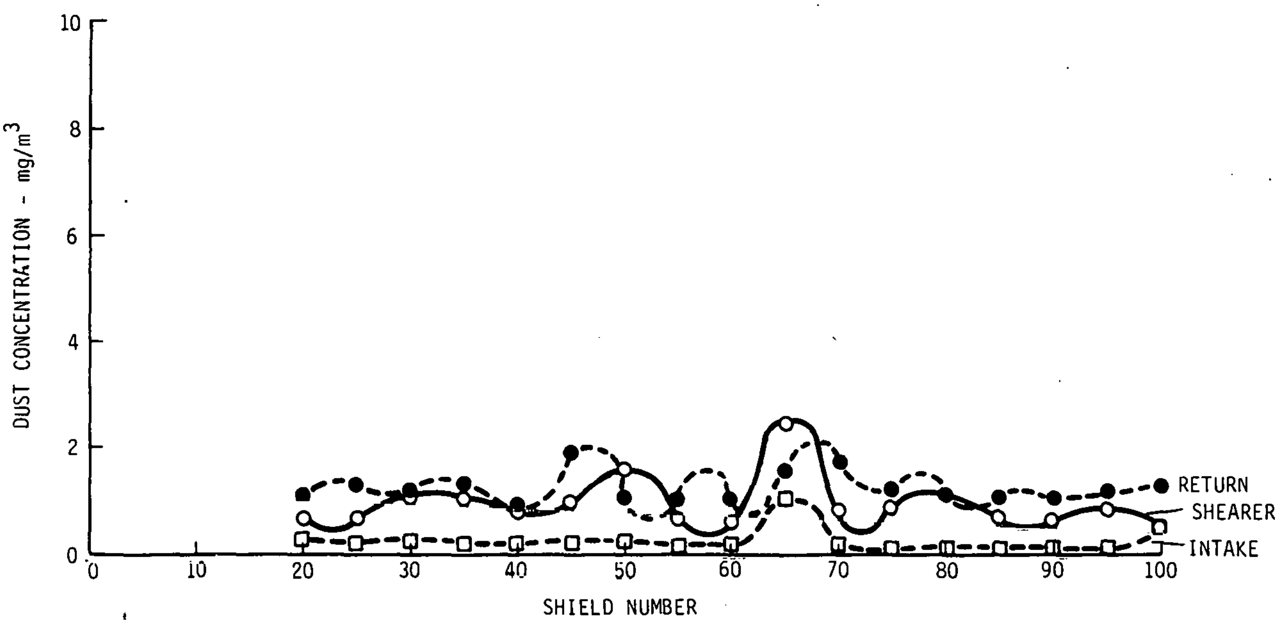


FIGURE 7-8. - Average dust concentrations of six head-to-tail tramming passes - conventional rotation.

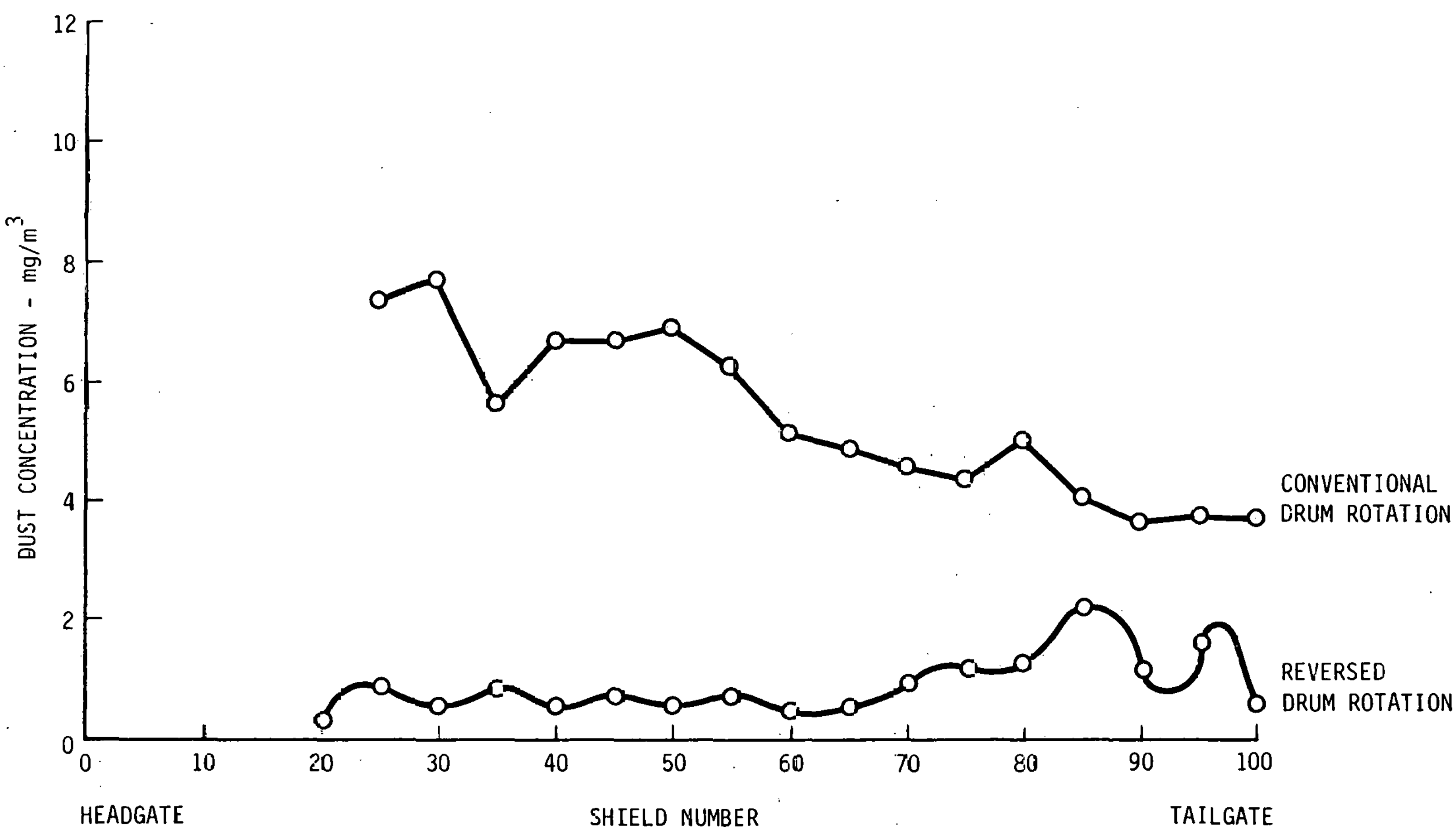


FIGURE 7-9. - Comparison of shearer dust levels.

and under the two rotation regimes and shearer travelling directions.

Figures 7-5 and 7-6 allow comparison of the dust levels measured during cutting from tail-to-head. Comparison of these figures yields the following conclusions:

- Intake dust levels on both weeks were comparable although there was slightly more intake dust during the conventional rotation week.

- Intake dust levels tend to be higher on the tailgate half of the face. This reflects the practice of pulling every other shield in this area.

- Conversely, the downwind dust levels in both cases tend to be higher at the headgate end of the face. This probably reflects some underlying mining condition.

- Finally, when <u>reverse</u> drum rotation is employed, the dust level at the shearer operator's position closely reflects the intake dust level. When <u>conventional</u> rotation is used, the shearer operator levels are several times higher and approach those measured downwind of the shearer.

Figure 7-9 shows a comparison between the shearer operator position dust levels during cutting in each rotation condition.

Figures 7-8 and 7-9 show similar dust profiles for the tramming run from headgate-to-tailgate. In both cases intake dust levels were low and largely invariant. Dust levels measured at each sampling position were comparable under both the reverse and conventional rotation condition. The only excursion from normality is a single "hump" in the downwind face dust profile at shield 75 in the reversed drum condition.

The comparisons that were made above in terms of graphical data can also be made on a numerical basis. In order to do this, average dust levels for each cycle were calculated and the mean taken to provide an overall average dust level for each condition and measurement position.

Table 7-4 shows the results of this activity and provides a numerical basis for the conclusions mentioned above. For example:

TABLE 7-4. - Summary of average dust levels

Type of operation (cutting T→H or tramming H→T)	Measurement position	Average dust level (mg/m^3) Reverse rotation	Conventional rotation
Cutting[1]	Return	8.53	8.05
	Intake	0.81	1.33
	Shearer	0.83	5.48
Tramming[1]	Return	1.54	1.20
	Intake	0.15	0.31
	Shearer	0.90	1.0

Note 1 Averages are based upon 5 or 6 passes with measurements made between the 100th and 20th shields.

- The average intake dust levels during reverse and conventional operation were 0.8 and 1.3 mg/m^3 respectively.
- The downwind dust levels averaged 8.5 mg/m^3 for reversed rotation and 8.1 mg/m^3 for conventional rotation.
- The shearer position averaged 0.8 mg/m^3 for reversed rotation which is the same (after rounding) as the intake dust level.
- In conventional mode the same position recorded 5.5 mg/m^3. This is 68 percent of the downwind level and 412 percent of the intake level in this mode.
- The average dust level at the shearer position during reversed rotation was 15 percent of that at the same position during conventional rotation.

The tramming to the tailgate data in Table 7-4 does not show any consistent variation between reversed and conventional rotation.

7.3.2.5 Reversed Drum Evaluation Conclusions

The use of reverse drum rotation on the No. 2 longwall at Jim Walter's No. 4 mine results in a significant reduction in dust levels, during cutting with the ventilation, in the areas occupied by the shearer operators.

This conclusion is supported by both the dust profile data (Table 7-3) and the full pass data (Table 7-4). It is also strongly evident in terms of visual observation (float dust) supported by comments from the shearer operators.

At this site the reduction of dust level produced by drum reversal (at the point halfway between the operators' positions) was in the ratio of 6:1. This degree of reduction was determined by the ratio of shearer dust make to intake dust levels since there was little or no evidence of shearer generated dust at this position in the reversed drum mode.

There was no evidence that the dust levels downwind (on the return side) of the shearer were different in the reverse rotation or conventional mode. Similarly, the direction of rotation did not have any significant effect on dust levels during tramming from head-to-tailgate.

The use of reversed rotation did have a slight negative impact on the operation of this particular face. This was due to the relatively inefficient way in which a reverse rotating drum loads rocky lumps or slabs. This problem can be viewed in terms of the varying results which occur when the drum meets a lump of strong material. In the conventional case, the drum vane picks are descending and will trap and probably cut (or break) the lump against the AFC or floor. A reverse rotating (floor to-roof) drum will introduce picks <u>under</u> the lump and may move it without breaking it.

On the Jim Walter's face it was observable that stoppages to clear blockages at the AFC/stageloader transfer point occurred more frequently during reverse rotation. This problem was, to an extent, due to the temporary absence of a lump breaker from this position. It is noteworthy that the mine management did not consider this increase of short stoppages to be too high a price to pay for the other benefits of reverse rotation.

In addition to the reduced operator dust levels, these benefits include a better size range of run-of-mine product from reversed drum cutting. The mine operator reports that the reversed mode reduces the proportion of fines in the product, and that the preparation plant throughput, which is governed by fines handling capacity, is greatly improved when reverse rotation is used.

The results of this evaluation provide documented evidence of a significant reduction of operator dust levels that occurred when reversed rotation was used during cutting with ventilation. While there can be no guarantee that the results obtained on one coal face will be repeated on another, there is strong circumstantial evidence that a large part of the reduction in dust level was a result of the improved loading ability of the trailing drum. Unfortunately, there is another factor which may have had some influence on loading from the trailing drum. This complicating factor is the variation of the amount of coal left unloaded by the leading drum which was not fitted with a cowl. In this condition, it is reasonable to expect that a conventionally rotating leading drum would leave more coal on the bench to be loaded by the trailing drum. The poorer loading conditions in the trailing drum during conventional rotation might, therefore, have been exacerbated by having to handle a higher volume of coal.

Even allowing for this factor, this evaluation has presented strong empirical evidence for the thesis that states that when loading from an upwind trailing drum is improved, a substantial reduction in airborne dust will result. This improvement can be produced by adopting "reverse" floor-to-roof drum rotation. The extent of the reduction vis à vis conventional rotation will depend upon drum design, mining conditions and cowl layout.

Longwall operators should be encouraged to actively consider this low cost dust control option if their mining cycle is appropriate.

7.4 Phase IV Activity

Various tasks remain to be accomplished before the reverse drum subprogram is completed. These include the following:

- Completion of analysis of data from Jim Walter Resources No. 4. This will involve examination of the gravimetric sampler data and addition of the data on coal size distribution that will shortly be available from the mine.

- <u>Preparation of a report on the evaluation</u>. This report will consist of a complete description of the evaluation and a full record of its conclusions.
- <u>Technology Transfer</u>. The best means of disseminating the results of this evaluation will be determined. This may take the form of a journal article or a Tech News Brief.
- <u>Final Report Preparation</u>.

8. SUBPROGRAM G - SHIELD-GENERATED DUST

8.1 Introduction

As shield-type supports become more popular and experience with combatting shearer dust improves, many mines have noticed that a principal respirable dust contributor is associated with support movement. This observation is confirmed by the European mining community (ECSC) and has caused the formation of a special committee to study support related dust abatement techniques.

Although the ECSC committee has studied the support dust problem since the early 1970's, the rapid development and acceptance of shield-type supports has made much of the more specific recommendations obsolete This is particularly true of the well published but chock-oriented British research. Eighty-seven percent of all United States longwalls use shield-type supports. Furthermore, the geologic and operating conditions in the United States differ considerably from European situations.

The study of shield dust is made difficult by the complexities of the myriad variables and their interactions. While numerous studies have been made on general face ventilation, the more subtle effects of eddies, cross flows, blockages from equipment components (other than the well documented shearer and spillplate) and gob leakages (in and out of the face) are not well established. As a result, the simple mechanics of shield dust mobilization and pathways are neither well documented nor understood.

Furthermore, the tremendous range in lithologies, mechanical properties, stress and rubblization histories. moisture contents, rates of consolidation, etc., complicates the simple identification of the cause of support dust. Finally, the differences between support models, set and advance pressures between adjacent supports, and operator variables make simple extrapolation of research results impossible.

The principal objective of this program, therefore, is twofold:

- To isolate and document the mechanics of support dust generation and mobilization

- Devise procedural or physical control methods applicable to United States mining conditions.

This will be accomplished by:

- Reviewing the state-of-the-art
- Testing various hypotheses under laboratory conditions in the longwall gallery mockup
- Field test and document the more promising candidates in operating mines which are experiencing shield dust problems.

8.2 Phase II - Summary

Subprogram initiation efforts during Phase II focused on the following tasks:

- Literature review
  - State-of-the-art review
  - Probable sources
- Laboratory studies
  - Documentation of airflow patterns around canopies under varying conditions
  - Evaluation of water sprays and passive barriers for shield dust redirection
- Development of field test plan
  - Map shield dust pathways
  - Isolate and define mechanisms
  - Evaluate procedural changes.

The literature search, as expected, turned up some interesting concepts for shield dust abatement; but none which were both practical and effective. The laboratory tests examined the cause and effect of flow patterns in detail so they could be readily identified in the field. Additionally, potential dust avoidance techniques were assessed. This effort provided the basis for a Phase III field investigation.

8.3 Phase III - Activity

The level of the Phase II effort was reduced from the original schedule due to the closure of many of the potential mine-test sites. Reports of foreign research are continuing to be collected and evaluated, however, no new revelations appear to have emerged.

Brief mine surveys at North American's Quarto, and Armco's No. 7 mines confirm the air flow patterns observed in the longwall gallery. Both sites were cutting up to and into roof rock at the time of the survey so that little shield-related dust was noted. Another survey performed at Kaiser's York Canyon Mine did indicate significant shield dust levels and a letter of intent describing a more detailed survey and test program was sent. Initial verbal conversations indicate that a field test will be approved for the latter part of April or early May. Old Ben Coal had also been contacted regarding a test comparison of their shield mounted 'walkway' sprays and FMI's shield gap sprays. While a letter had been sent and initial contacts appeared favorable, no further progress has been made.

An Automated Data recorder ML-10 has been modified for the field experiments. The frequency of sample readings have been increased from 10 sec to 2 sec in order to insure better definition of dust plumes.

8.4 Literature Search/Discussion of Roof Geology

The French mining community (Chercher) is presently assigned the task of investigating shield dust for the ECSC, while the West Germans have recently published the results of their 5-year study. The West German report notes that dust generation is as much a function of the local geology as it is of the shield design. While they did not quantify the geologic variables, the friability of the roof rock, and the caving characteristics of the gob appear to be the significant contributors.

Referring to the West German investigation, it is their opinion that shield dust enters as much from the gob side as it does from the canopy. Unfortunately no quantitative data was presented to substantiate this feeling. The cause of "gob-side shield dust" was also not discussed; however, FosterMiller feels that three sources must be considered, including:

- Simple gravity entry during support advance and, picked up by eddy currents
- Wind generated by roof fall during advance
- Back flushing of gob ventilation into the face area which typically occurs in the midface region.

The West German researchers concentrated on redesigning the shields to minimize the gob shield gaps, and to supply water sprays on the shields as a quick-fix knockdown system. Other techniques were also attempted including the use of foils and vacuum collection systems which did not offer any practical advantage and were described in the previous phase report.

Numerous combinations of sprays were attempted, but all used the principle of dust capture or knockdown. In all cases the sprays were oriented perpendicular to the plane on which they were mounted. The spray systems were tested at four mines with varying degrees of success, ranging from 35 to 60 percent reductions. The amount of mist introduced into the walkway aggravated the workers and it was noted that maintenance of the system would probably be of the last priority.

Although the French have only just begun their research, they appear to be concentrating on water spray knockdown systems initially explored by the German research community. As many as 10 sprays are located on a given shield, pressurized at 15 bars and producing a flow of 20 l/min. Figure 8-1 illustrates the location of the sprays.

Spray actuation occurs automatically via hand plumbing to the shield advance and control hydraulics. As a transducer senses a pressure drop of 150 bars in the support legs, the sprays are activated. The check plate sprays on the already advanced, adjacent shield are also turned on, while the gob sprays of the other adjacent still retreated shield are run. Initial reports indicate a significant reduction (80 to 90 percent) in dust, however, a danger of drowning has been introduced. Further work is presumably being done on optimizing the water flows and spray locations.

In the United States, it has been noticed that high productivity shifts tend to produce less support dust. A theory explaining this phenomena is that the roof is still damp from

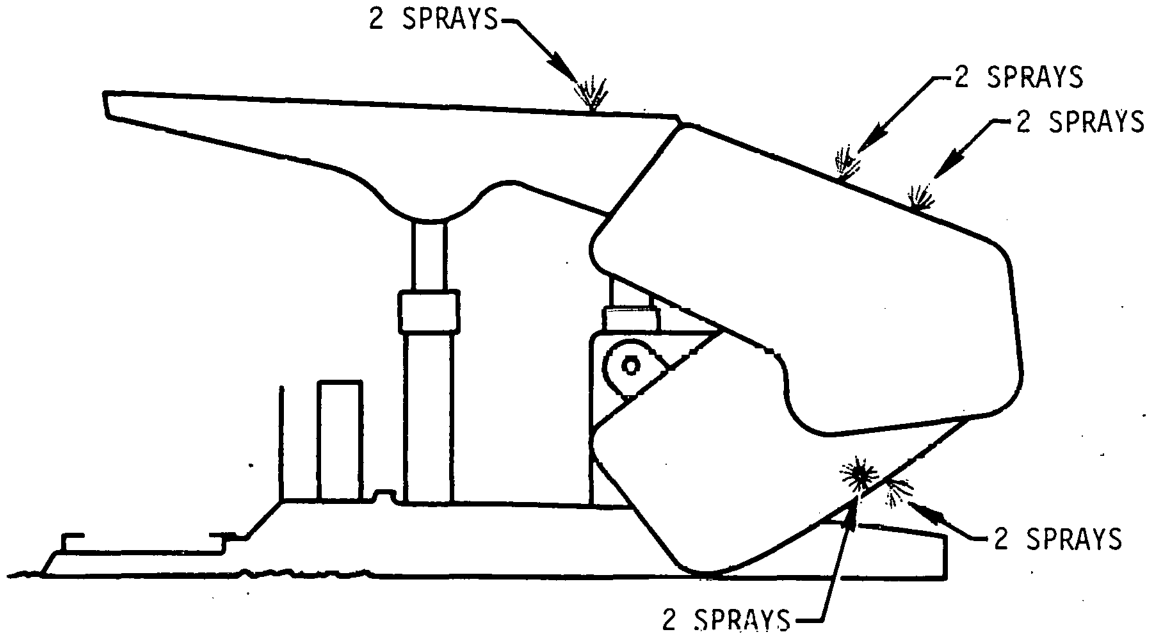


FIGURE 8-1. - Chercher shield spray system.

the shearer pass which tends to bind loose dust. It also may be that the roof did not have a chance to break up, or that the roof was inherently stable permitting a high production shift. Experiments are being contemplated that would examine the relative dust make of wet and dry roofs.

Foster-Miller attempted to determine the crushing charac teristics of typical roof lithologies, namely shale, siltstone, sandstone and coal, in order to develop a relationship between lithology and respirable dust generation. While several qualitative reports are available, a more quantitative relationship cannot be drawn. The degree of brittleness is to a large part, a function of the local geology (the binding matrix and mechanics), and the mechanics of loading.

In essence, it would appear that coals and sandstones tend to deform in a more brittle fashion and therefore would create more dust during crushing. The sandstones would naturally be associated with high quartz or silica contents. The siltstones and shales are more plastic and do not fail as catastrophically. Quartz generation with shales should be minimal.

however, the very definition of siltstones (particle sizes less than 0.062 mm) indicates that respirable factions will be generated with comminution. In summary, not taking local geology variations into account, dust penetration should be in the order of coal, sandstone, siltstone and shale.

The rate of energy application and the geometry of the loaded specimen will also have some bearing on the degree of fines generation. Assuming a constant rate and magnitude of load application, a point loading condition will tend to crush the specimen in contact with the loading platens (e.g. roof and canopy). Small stiff specimens will fail explosively in tension (Brazilian condition) if the rate of internal energy increase is high, will fail in shear if the aspect ratio is low, and in compression if the aspect ratio is very low. Since the canopies are essentially load control systems, further crushing of the diminished particles will occur until the set pressure limits are achieved

At some point the integrated strength and surface area of the canopy debris will match the set pressure and no further crushing will occur. At lower set pressures this occurs sooner (theoretically less dust). Also where the strata are conformable with the canopy surface little crushing should occur due to the low unit pressure applied. Lithologies such as competent shales tend to exhibit strong cleavage parallel to the bedding plane and incidently to the canopy top. Again competent shales should generate less dust due to the tendency for slow convergence and even loading. Coal on the other hand or other friable roof strata (such as weak shales) will form natural asperities in addition to the machine irregularities (e.g., pick grooves) which will cause uneven loading and subsequent crushing. It is out of the concern to minimize loading of asperities and producing a more even stress distribution that the idea of using compliant canopy materials is born. Several support manufacturers hinted that compliant materials were being investigated, however, it is being done on a priority basis.

This all would imply that contact advance should in fact produce less dust by limiting the amount of debris pile up and subsequent crushing. Contact advance should also limit the amount of canopy drop and cross-canopy flow which would mobilize the dust. The potential fallacy in the above discussion is the grinding action associated with contact advance. Most shields are not true contact advance systems, and must be lowered a few inches to relieve pressure on the leminscate structure. The small gap therefore promotes rolling or abrasion of the canopy debris and this action is an even more efficient producer of dust than compressive loading. The French have been talking about designing a system with hydraulic linkages which would yield under high loads and permit advancing while under greater vertical loads.

It is the difference in the above two philosophies that need to be monitored in field trials. The experiment should include different roof lithologies to insure that the model is not more sensitive to rock type than advance procedures.

8.5 Mine Site Selection/Pilot Studies

Several field investigations were scheduled for this past phase of work; however, the failing market conditions delayed or cancelled all of the potential test sites. Hawk's Nest appears to be closed for the long-term. Kaiser's Sunnyside Mine is on a severely reduced work schedule; however, they are still interested in participating in any field trials. For the moment, Sunnyside has been bypassed as an evaluation site until a more consistent work schedule can be assumed.

Wilberg had also expressed some interest; however, they felt it was more prudent to concentrate on shearer-related dust first. Other mines including Carbon County, Armco, U.S. Steel, and Consol were also contacted; however, either market or security reasons prevented a more active role.

Preliminary site visits were made to North American's Quarto No. 4, 34 South and 3 North longwalls and Armco's No. 7, 3W longwall in order to determine whether any of FosterMiller's dust subprograms could be beneficial to the mine operation. At both mines smoke tracer studies were performed as well as instantaneous dust readings upstream and downstream of shield movement.

The following qualitative observations were made from the smoke tracer experiments:

- Cross-canopy flow (first noted during Phase II laboratory studies) is a well developed phenomena, particularly during advance.

- Some cross-canopy flow exists even in the set position, primarily as a function of the inter-canopy gap and the degree of canopy-debris pileup.
- Shield advance parallel with airflow did not appear to cause as strong a cross-canopy flow as those sequences advancing into the ventilation (tail to head).
- Re-entrance of gob-side air in the midface region appears to increase the inter-shield dust infiltration.
- Gob-side airflow appeared to be less for shields advancing tail-to-head.
- Increased canopy gaps tended to produce stronger (cleansing) eddies than tight gaps.
- Smoke introduced in the walkway remained in the walkway and did not drift out into the face region.
- Higher airflows tended to exaggerate all of the above effects.

While it must be emphasized that all of the above observations were highly qualitative, they tend to confirm the results noted in the gallery tests, and must therefore be considered as guidelines for further experimentation.

A series of dust readings were taken upstream and downstream of shield movement during a head-to-tail pass to quantify shield contribution to face respirable dust levels. Shield movement was delayed so that the shearer advanced far enough downstream to eliminate any effects from shearer-generated dust. A fixed sampling position was located approximately 60 ft downstream of shield movement and dust levels were recorded manually as shield movement approached. A second sampling position followed upstream of shield movement in order to subtract out transfer point, crusher and conveyor related dust. All readings were recorded manually on 15-sec intervals using GCA RAM style instruments.

The results from the Quarto evaluation indicated shield-related dust levels in the range of 0.6 to 0.8 mg/m^3, while at Armco downstream readings ranged from 0.24 to 0.55 mg/m^3 for the limited three sets of (ten) number of shields reviewed. It must be noted that the above experiments were extremely limited in nature and only occurred in the headgate area of the face. In both cases roof rock was often cut leaving a very clean, stable roof with no canopy buildup. By being stationed near the headgate region where face velocities were lowest, cross-canopy flow was insignificant. At Armco, the basic face air velocity was so low (100 to 130 fpm) that air movement had little general effect.

The above experiments were made in conjunction with many other observations as part of an initial investigation for selection of the most appropriate subprogram. While the individual sites were not appropriate for further shield dust evaluations, they did serve to validate many of the assumptions made in gallery testing.

Additional surveys performed by Foster-Miller have indicated potential shield dust problems at Old Ben Coal and Kaiser Steel's York Canyon Mine. Both operations have been contacted and appear willing to participate in a more extensive examination of shield-generated dust. Old Ben is particularly interesting since they are evaluating a spray system which is structured to move upstream dust laden air out into the walkway and into the face area. The sprays are to be mounted on every fifth shield. Foster-Miller had previously developed a similar approach of installing sprays within the canopy gap on every shield which would draw any cross-canopy flow out into the face area. From initial test trials in the longwall gallery, the Old Ben - every fifth shield approach, is set too far apart and may actually aid in the introduction of gob-related dust. However, the system does warrant further investigations.

The York Canyon Mine typically leaves roof coal which is felt to cause higher levels of shield dust. The results of a quick survey involving 10 shields indicate that shieldgenerated dust often forms the majority component of nonshearer-related dust.

8.6 Objectives/Strategy for Field Evaluation

The principal objectives of the upcoming field evaluation remain the same as previously stated namely:

- Map the pathway of the dust flow, from the entry point (zone) to downwind mixing

- Isolate and define the mechanisms which influence dust creation, mobilization and migration (e.g., roof lithology, debris accumulation)

- Evaluate the effectiveness of several procedural changes namely:

  - Contact versus noncontact advance

  - Check plate pressure or gap variations

  - Wetting the roof

- Evaluate spoiler systems, and in particular the canopy gap spray concept.

The test methodology remains essentially the same as noted in the previous phase report. The major modification has been the altering of Automated Data's ML-10 data logger. The system, which could previously sample on only 10-sec intervals, has been revised to sample at 2-sec intervals (with the sacrifice of five channels). Since the identification of dust pathways is a critical component of the program and shield movement is cyclic in nature, it is necessary to sample at faster intervals. This will permit a clearer definition of the shape of the dust plume-pulse during shield movement. For example, if airflow is 300 fpm, a puff of shield dust released during initial canopy drop would have travelled 10 shields using the standard sampling interval. Another version would be if a dense plume of 6-sec duration was caused by shield advance. It is entirely possible that the entire pulse would be missed and is highly probable that the peak would not be recorded. Since the dust plume-peak probably will flatten out with distance the measured difference would appear to be slight. The change in recorder mechanics should considerably improve the sampling procedure.

8.7 Future Effort

The major thrust of future work will be a detailed field evaluation of the mitigation concepts. In particular the canopy gap spray system needs in-field testing. As previously noted, Old Ben and Kaiser's York Canyon Mines appear to be the most likely candidates, although other sites are being contacted.

9. AIR CANOPIES FOR LONGWALLS

The effort on this subprogram has been completed. The results are included in the Phase I Report.

10. SUBPROGRAM I - MINING PRACTICES

10.1 Overall Objective

Many longwall faces in the United States have difficulty in complying with the Federal dust standards. The regulations do not control the amount of respirable dust produced, they only limit the maximum exposure level personnel can be subjected to. This permits reductions in personnel exposure by relocating personnel in less dusty environments.

In order to achieve this result, the overall objective of this subprogram is to identify and evaluate:

- Ventilation systems
- Cutting cycles
- Operating techniques
- Face systems.

which inherently subject face personnel to lower levels of dust exposure.

10.2 Phase I and II Summary

The initial Phase I effort concentrated on the development of a model through which cutting cycles could be evaluated for potential dust exposure to personnel. The model categorized the personnel, major dust sources, mining cycle segments, and durations. The model enabled prediction of the levels of exposure that personnel were subjected to during each segment of various standard cutting cycles. Once baseline levels were established, modifications were then implemented and the resulting changes in exposure were calculated. In this manner, levels of improvement for each modification were determined. The study was divided into two sections. The first section was aimed at changes and techniques that could be performed with existing equipment. The second section highlighted changes in the mining cycle requiring new equipment.

During the first portion of the study, three mining cycles were examined:

- Unidirectional cutting - headgate-to-tailgate
- Unidirectional cutting - tailgate-to-headgate
- Bidirectional cutting.

Each cycle was analyzed for antitropal and homotropal ventilation in addition to various changes in operating techniques and procedures. The most significant improvements were achieved by introducing homotropal ventilation. The high risk occupation, shearer operator, showed 67 percent improvement by using homotropal ventilation in conjunction with modified operating techniques. Significant improvements were also shown for the headgate operator position.

The second section of the modelling program examined fundamental changes in the mining cycle requiring the purchase of new equipment. A number of techniques were examined but the most promising was the use of asymmetrical cutting drums. A USBM survey highlighted the potential of large/small drums for transferring the shearer generated dust downstream of the operators. This is accomplished by locating the larger drum on the downwind ranging arm and cutting less coal with a small drum on the upwind ranging arm. The model incorporating asymmetrical drums showed that by maximizing the size ratio between the two drums the operators' exposure could be reduced by as much as 60 percent.

The results of the Phase I effort study highlighted the potential of homotropal ventilation and asymmetrical cutting drums for reducing longwall dust exposures. The Phase II effort was, therefore, directed toward further investigation of the application and utilization of homotropal ventilation and asymmetrical cutting drums.

The Phase I effort had highlighted the potential benefits of homotropal ventilation systems. There was, however, little documented operating experience and its use appeared to be limited. A short field survey consisting of four one-day mine visits was conducted in central Pennsylvania. The mines all had been operating homotropal faces for a number of years. The visits consisted of a face tour and discussions with mine management.

The following conclusions were drawn from the survey:

- None of the mines encountered difficult problems in applying and operating homotropal ventilation.
- The main reason for implementing homotropal ventilation was to overcome methane problems.
- Reduction of intake dust contamination was considered an additional benefit.

- A few mines had to develop some simple techniques (cribbing) to cope with the air split in the headgate.
- Most mines had to install fire protection equipment required by Federal Regulations (if belt air exceeded 100 ft/min).
- 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.

While homotropal ventilation was being successfully used by these mines, its use was limited to the central Pennsylvania area. This limited use was suspected to be due to restrictions imposed by either federal or state regulations. Further investigation, however, showed that compliance with regulations was not a factor.

A general lack of knowledge concerning the positive benefits of homotropal ventilation appeared to be the primary reason why its use was not more widespread. In response to this need for information, a handout describing the critical features for successful homotropal ventilation was prepared and distributed. As a result, several mines started to implement homotropal ventilation on their faces.

The effectiveness of asymmetrical cutting drums is achieved by locating a small cutting drum on the upwind ranging arm and a large drum on the downwind arm. Thus, the bulk of the cutting is performed downwind of the shearer operators. The USBM has identified the use of this technique at Barnes and Tucker's Lancashire No. 20 mine. The B&T application, however, uses a large downwind drum the same size as the seam. For many mines this method of cutting is not practical, because the system cannot easily accommodate changes in seam section. A feasibility study was conducted to examine the application of asymmetrical drums in thicker seam sections for both bidirectional and unidirectional cutting. The study also examined the practical limitation of the drums' peripheral speed and the practical minimum drum sizes for the various types of shearers.

10.3 Phase III Activity

The Phase III effort included:

- Full homotropal evaluation at one mine
- Homotropal follow-up studies
- Asymmetrical drum investigation.

The results of these efforts are discussed in the following sections.

10.4 Homotropal Evaluation at Old Ben

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, re-orientating 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. diameter 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.

10.4.1 Sampling Methods/Evaluation Plan

The evaluation on each of the two faces completed during the period July 18-29, 1983, 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.

10.4.2 Evaluation Results

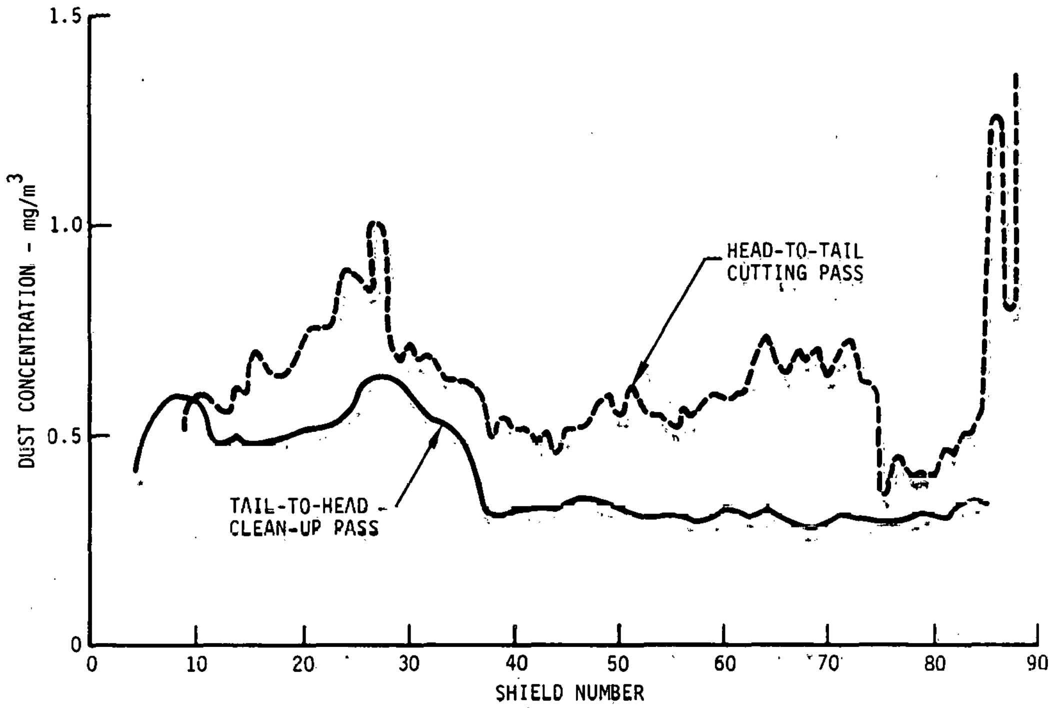
Intake Dust Concentration Data

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 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.

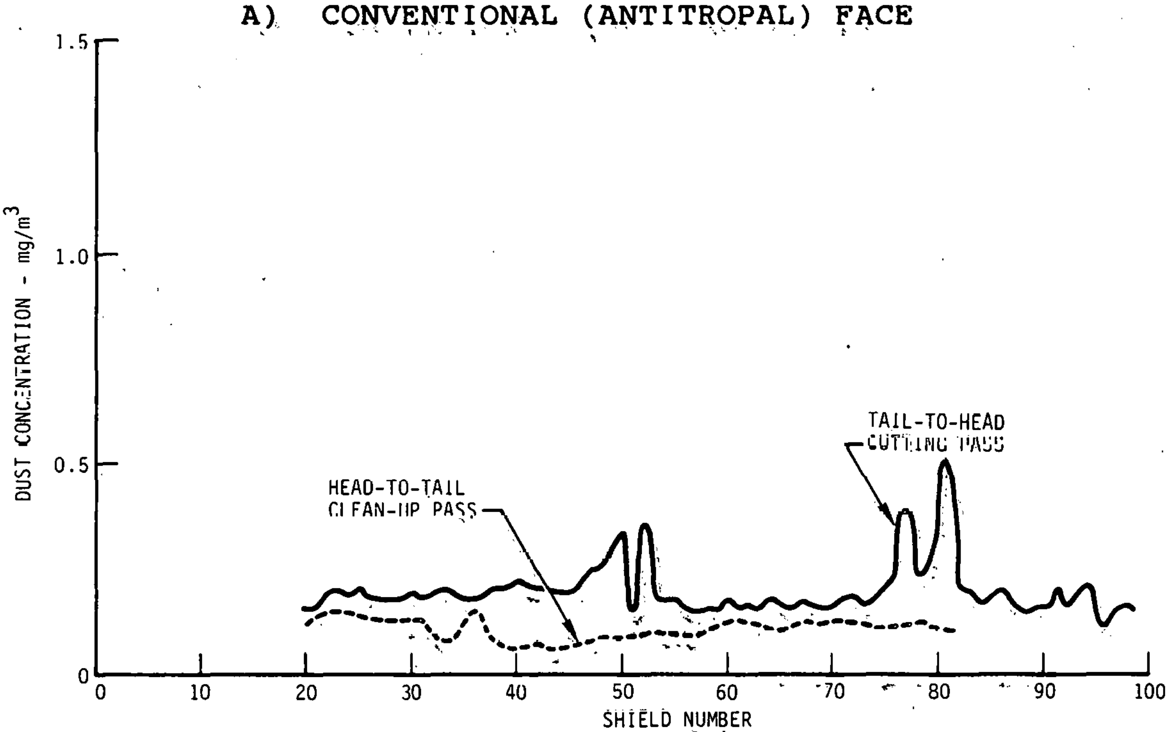
The data for two typical passes on the conventional face are plotted in Figure 10-1 as a function of face position. The intake concentration on the cutting pass averaged 0.6 mg/m^3; on the cleanup pass it averaged 0.25 mg/m^3. The lower concentrations on the cleanup pass are thought to be due to two factors:

- There are less large lumps passing through the crusher on the cleanup pass.
- The coal on the conveyor during the cleanup pass is more thoroughly wetted by the shearer water sprays.

Data for two typical passes for the homotropal face are plotted in Figure 10-2. 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.



A) CONVENTIONAL (ANTITROPAL) FACE



B) HOMOTROPAL FACE

FIGURE 10-1. - Comparison of face intake dust levels.

Comparing data from the two faces (Table 10-1) shows significantly lower intake contamination on the homotropal face. Intake dust levels on the homotropal face average 60 to 70 percent less than those on the conventional face.

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 10-2.

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 10-3 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.

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

TABLE 10-1. - 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 mg/m^3	0.2 mg/m^3	60
Cleanup headgate-to tailgate	0.25 mg/m^3	0.1 mg/m^3	66

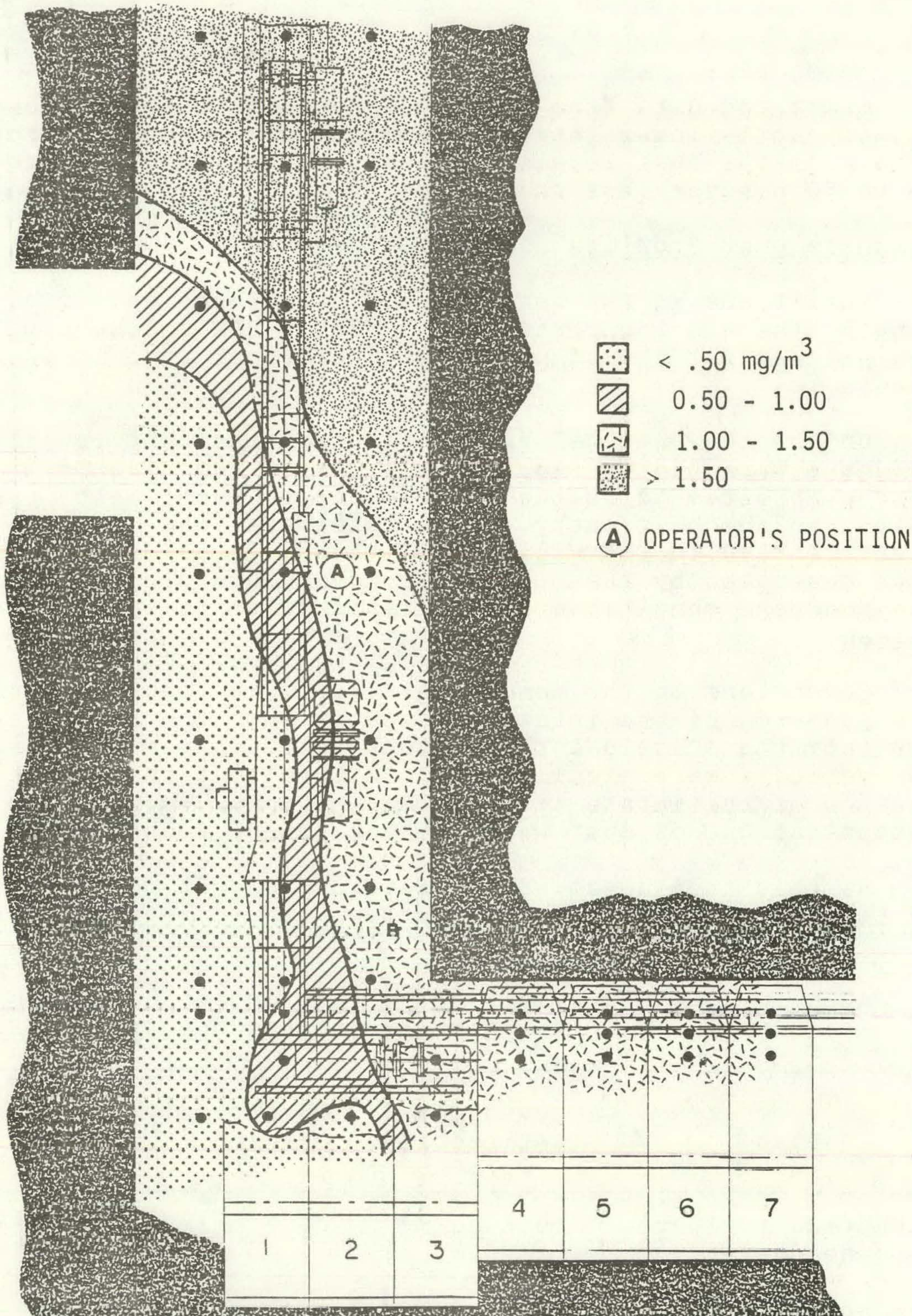


FIGURE 10-2. - Headgate dust concentration map, antitropal ventilation during head-to-tail (cutting) pass.

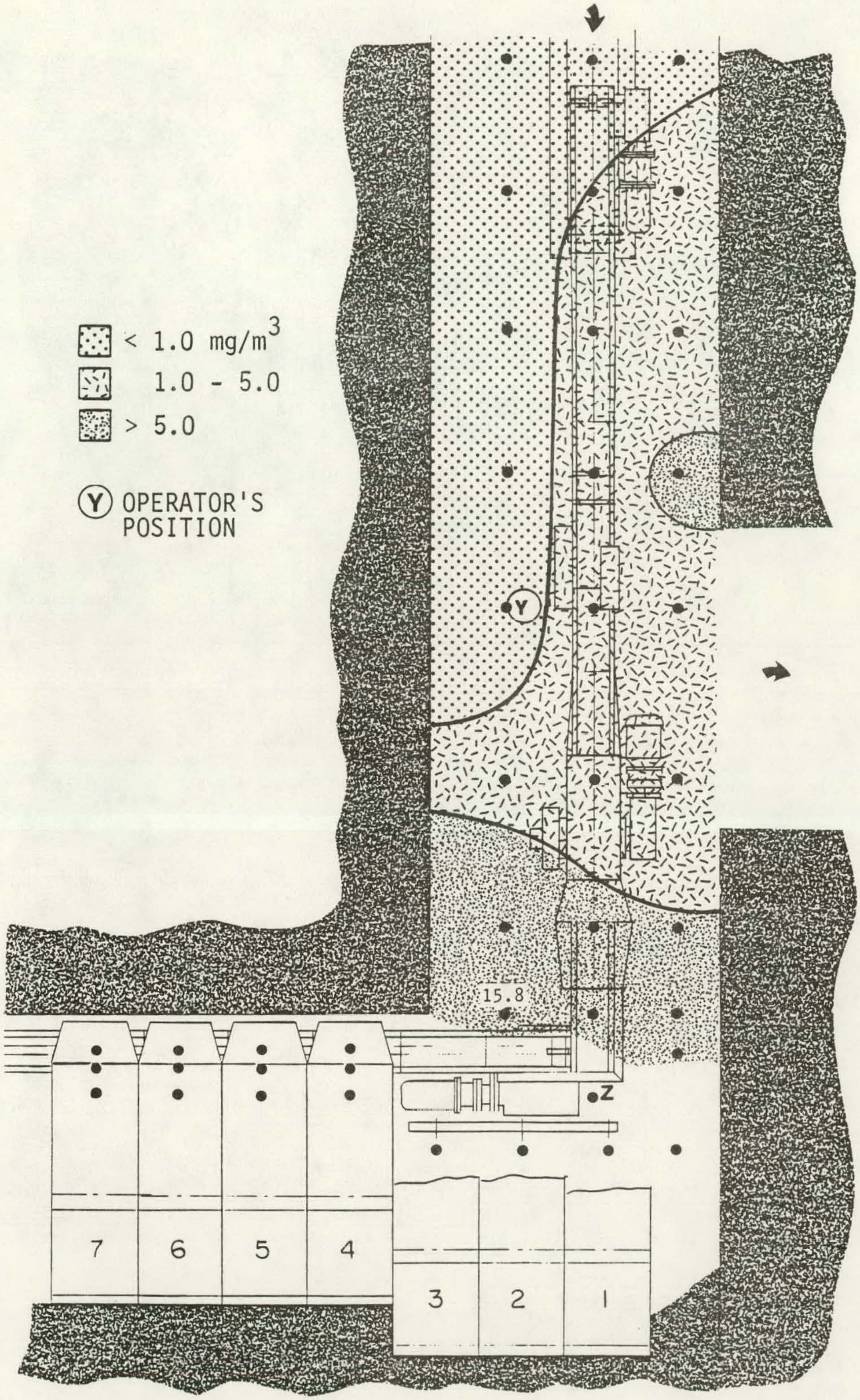


FIGURE 10-3. - Headgate dust concentration map, homotropal ventilation during tail-to-head (cutting) pass.

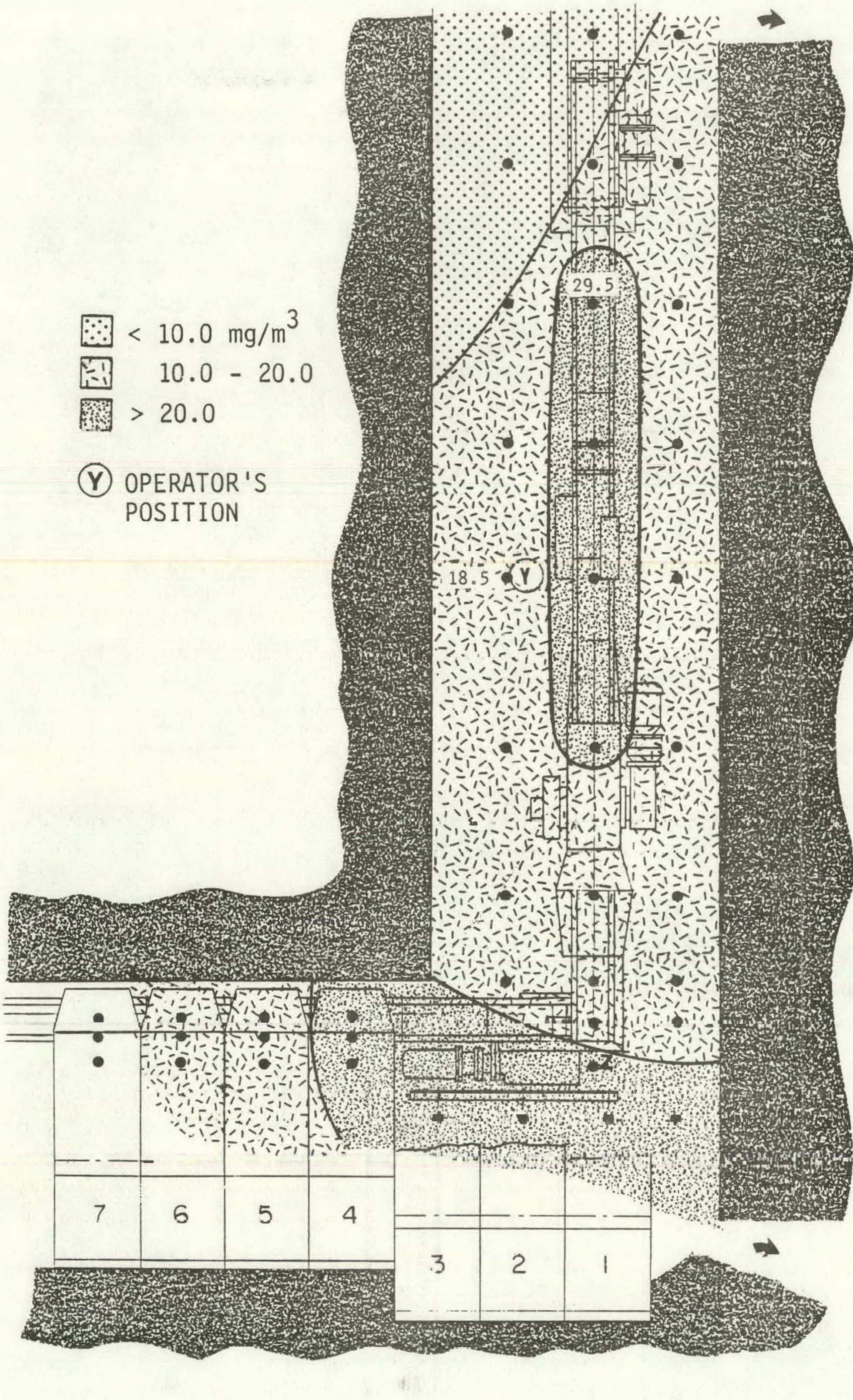


FIGURE 10-4. - Headgate dust concentration map, homotropal ventilation during tail-to-head (cutting) pass.

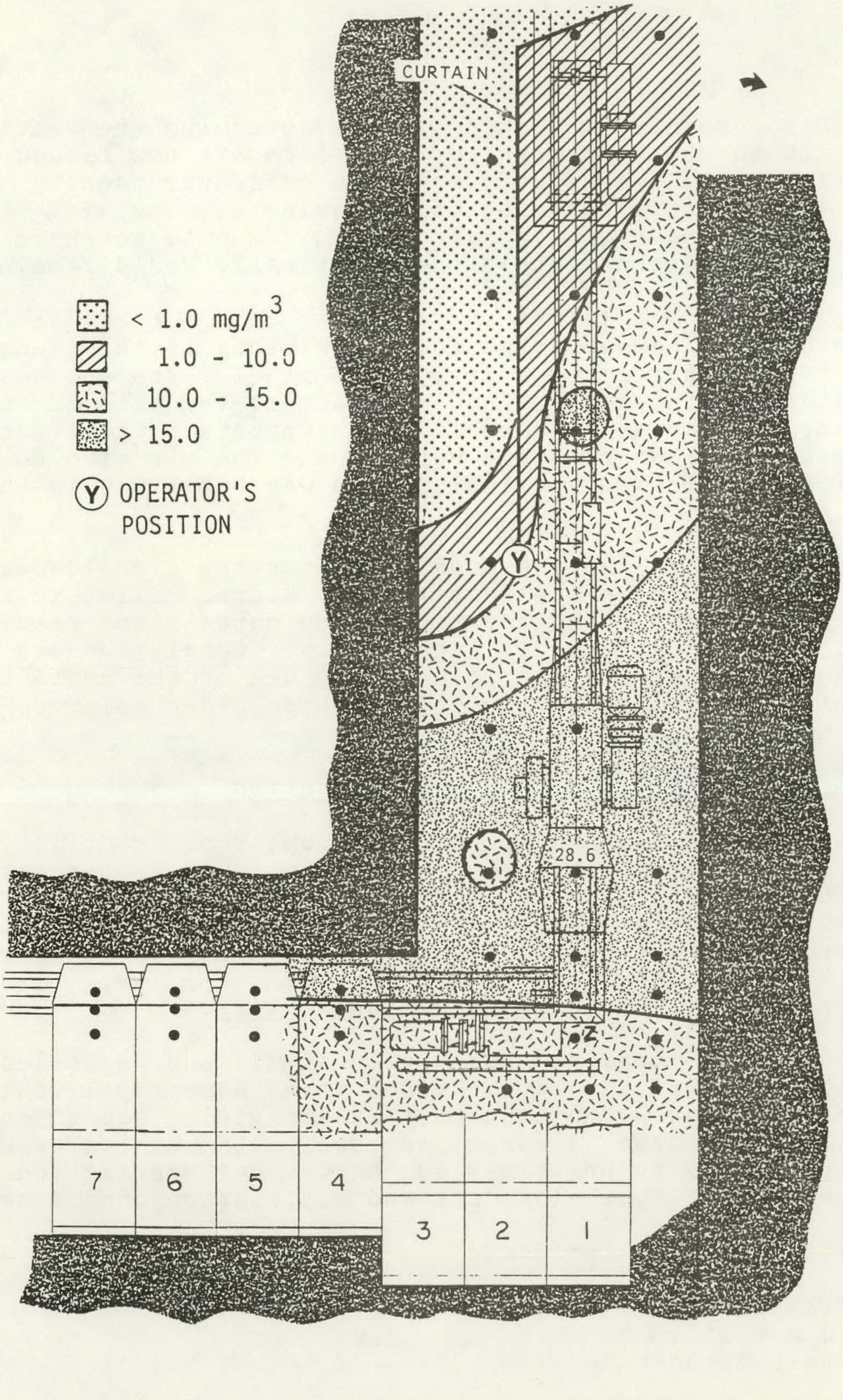


FIGURE 10-5. - Headgate dust concentration map, homotropal ventilation during tail-to-head (cutting) pass.

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 10-4). 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 our 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 10-5. Conditions are 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.

Summary and Conclusions of Old Ben Evaluation

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

10.5 Homotropal Followup 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:

- Bethlehem No. 33
- Jim Walters No. 4
- Beth-Elkhorn No. 26L.

10.5.1 Evaluation of Bethlehem Mining Corps., Mine No. 33, Cambria Division

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 200-300 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 10-6) shows 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.

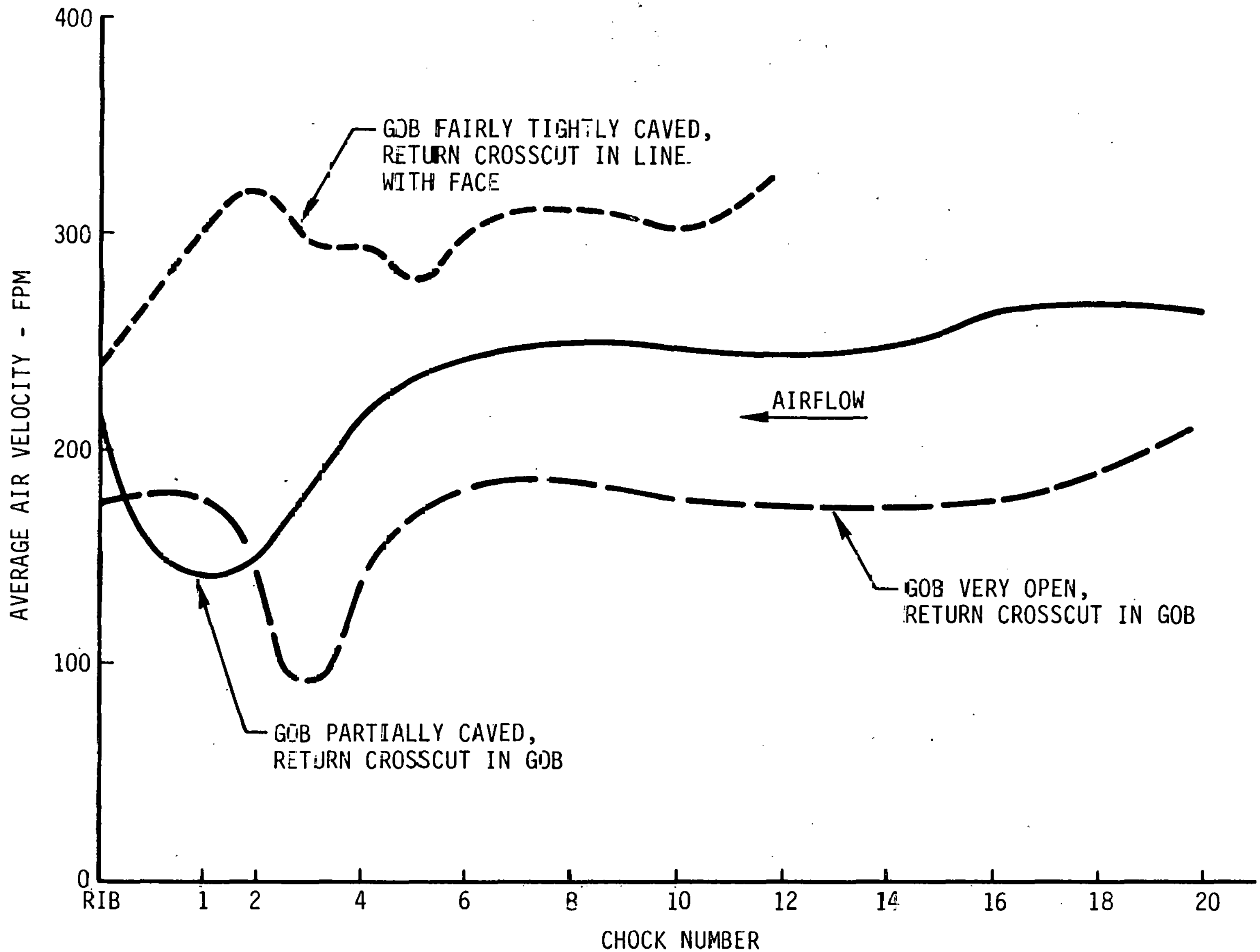


FIGURE 10-6. - Homotropal air velocity survey.

10.5.2 Evaluation of Jim Walter Resources, Inc. Mine No. 4, Longwall No. 2

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 equipped with an AM500 double ended ranging arm shearer fitted with 52 in. diameter 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 (clean-up 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.

10.5.3 Evaluation of Beth-Elkhorn, Mine 26L

The third mine visit was conducted at Beth-Elkhorn Mine 26L on March 6-7, 1984. The data has not yet been fully analyzed but the following general information can be reported. The intake dust, as with other homotropal faces, was extremely low:

	Shearer cutting direction	
	Headgate-to-tailgate	Tailgate-to-headgate
Intake dust levels	o 14 mg/m^3	o 18 mg/m^3

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 stageloader 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 only had to pass into the gob 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.

10.6 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.

10.7 Asymmetrical Cutting Drum Investigation

The Phase I modeling task quantified the potential dust reduction benefit of asymmetrical cutting drums. The reduction was 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 project was to investigate the applications, define the limitations, and evaluate the effectiveness of asymmetrical cutting drums.

During the Phase II effort the following tasks were performed:

- Analysis of field operating experience
- Feasibility study of asymmetrical drum
- Analysis of practical considerations and limitations.

The analysis of field operating experience examined the use of asymmetrical cutting drums by Barnes and Tucker at Lancashire No. 20 Mine. The use of asymmetrical drums at Barnes and Tucker was identified by a USBM survey. Barnes and Tucker introduced large/small drums to improve horizon control for the shearer. The longwall had a homotropal ventilated face and the large downwind headgate drum was the same diameter as the seam (Figure 10-7). Steering of the shearer, therefore, only required one operator. His task was to keep the large drum in the coal seam. The smaller drum, which cuts the middle of the seam, requires little if any control.

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.

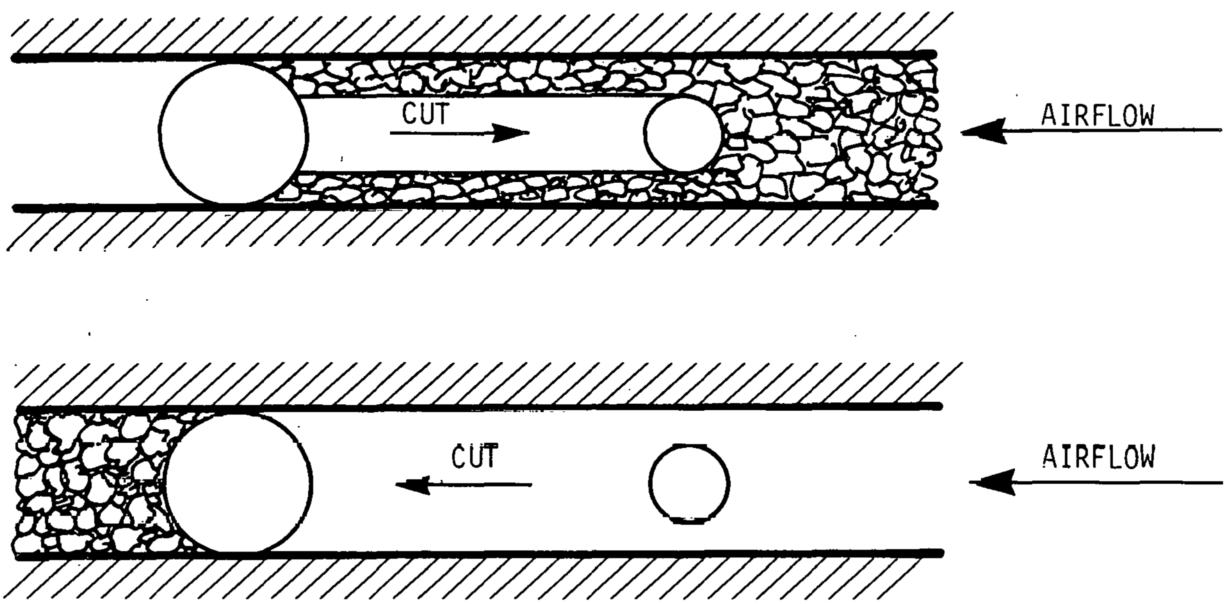


FIGURE 10-7. - Asymmetrical drum application - Barnes & Tucker.

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 B&T 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 gives 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 arms the minimum drum size is quite large (46 in. 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 stoppages 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-headgate (homotropal) to position the shearer operators upwind of the larger drum.

The maximum and minimum sizes of the two drum diameters are approximately 76 in. 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 10-2). 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.

During cutting from tailgate-to-headgate the use of a large/small drum only reduces the amount of coal extracted by the upwind drum by 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

TABLE 10-2. - 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	

in height may tend to produce more airborne dust, thus reducing the gain from cutting 17 percent less coal.

10.8 Strategy for Locating a Cooperating Mine Site

Since methods of operation were defined for the asymmetrical drums a handout has been circulated to the following companies:

- Quarto Mining Company
- Eastern Associated Coal Corporation
- Consol (Fairmont Division)
- Consol (Blacksville Division)
- Old Ben Coal Company
- Kaiser Steel Corporation
- Island Creek Coal Company.

The handout prompted some initial responses but as yet has failed to produce a cooperative mine site.

The test plan for evaluating the system will be an A/B type comparison. The initial weeks' testing with conventional sized cutting drums will provide data on the baseline conditions. The drum changeover to asymmetrical drums would be planned for a weekend and the assessment of the drums would follow immediately.

The location of a suitable site is becoming more critical. As stated earlier, to maximize the benefits of asymmetrical cutting drums while minimizing the potential for any production losses the face should have homotropal ventilation. Therefore the cooperating mine has to either already be operating with homotropal ventilation or be prepared to adopt both homotropal ventilation together with asymmetrical drums. Assuming that it is more likely that agreement will be reached with a homotropal mine, there are relatively few sites available with a suitable seam height. The alternative is to persuade an antitropally ventilated mine to accept a complete package of homotropal ventilation, plus asymmetrical cutting drums.

10.9 Phase IV Effort

The homotropal project is almost complete. The recent visit to Beth-Elkhorn Mine 26L is the last of the followup visits. The data from the visit will be analyzed in the near future and a mine report will follow. A detailed account of the findings and conclusions of the homotropal survey will be produced for a journal article. The objective of the article will be to provide the mining industry with the technology and information required to successfully implement this ventilation system. The section of the final report documenting and recording the effect performed in homotropal ventilation during the program will also be prepared.

The asymmetrical cutting program requires a field evaluation during Phase IV. A revised technical handout will be produced and circulated to all mines with suitable seam sections. A telephone survey will follow to locate interested mines. The evaluation of the asymmetrical cutting drums will take two weeks. The first week will establish baseline data using conventional sized drums, the following week will evaluate the asymmetrical drums. On completion of the evaluation a mine report will be produced. At the end of Phase IV a final report will be produced documenting the mine results and providing recommendations for the successful application of asymmetrical drums.

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