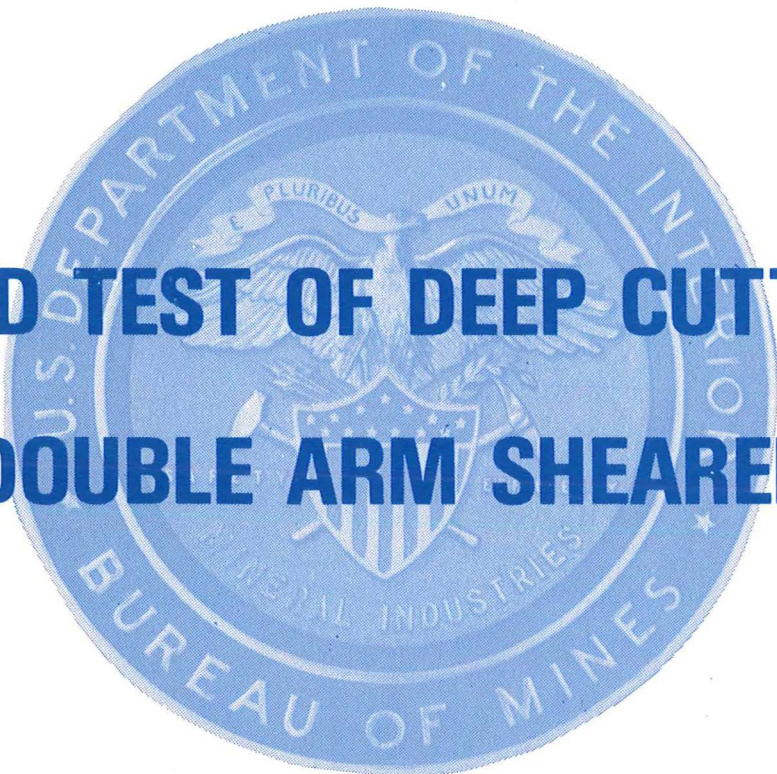


201,030
**A minerals research contract report
31 March 1981**

U.S. DEPARTMENT OF LABOR MSHA



00026608



**FIELD TEST OF DEEP CUTTING
DOUBLE ARM SHEARER**

Contract J0199092
Foster-Miller Associates, Inc.
350 Second Avenue
Waltham, Massachusetts 02154

MSHA INFORMATIONAL SERVICE
LIBRARY
P. O. BOX 25367
DENVER, CO 80225

OFR
81-118

BUREAU OF MINES ★ UNITED STATES DEPARTMENT OF THE INTERIOR
Minerals Health and Safety Technology

DISCLAIMER NOTICE

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies or recommendations of the Interior Department's Bureau of Mines or of the United States Government.

1. Report No.	2.	3. Recipient's Accession No.	
4. Title and Subtitle Field Test of Deep Cutting Double Arm Shearer		5. Report Date March 1981	
		6.	
7. Author(s) Jonathan E. Ludlow		8. Performing Organization Report No. BM-7948	
9. Performing Organization Name and Address Foster-Miller Associates, Inc. 350 Second Avenue Waltham, MA 02154		10. Project/Task/Work Unit No.	
		11. Contract or Grant No. J0199092	
		13. Type of Report Final Report	
12. Sponsoring Organization Name and Address United States Bureau of Mines Twin Cities Mining Research Center Twin Cities, MN 55111		14.	
15. Supplementary Notes			
16. Abstract A field test was conducted to demonstrate and quantify the relationship between deep cutting and the creation of airborne respirable dust for longwall mining with a double-ended ranging drum shearer. The testing program was carried out on the 3 North longwall of North American Coal Company's Quarto No. 4 mine in Clarington, Ohio. Continuous recordings of the dust levels were made at both the midface and tailgate areas. Data were collected during 27 shifts during which time 81 complete mining cycles took place. Both drum speed and the number of picks per line were varied systematically during the testing program to alter the depth of cut while the production rate was held constant by maintaining a constant haulage speed. The test results indicated that at the midface position, airborne respirable dust was strongly dependent upon the depth of cut as influenced by both the drum speed and number of picks. Drum speed had a much stronger effect than number of picks over the experimental range, since a halving of drum speed reduced dust levels by approximately 60 percent while removal of every other vane pick resulted in only a 20 percent reduction at constant production. At the tailgate position, however, neither effect was strongly apparent. A tendency for the slower drum speeds to be associated with reduced power consumption and higher haulage speeds (and therefore production rates) was also noted. It is recommended that longwall operators operate at the lowest available drum speed wherever possible.			
17. Originator's Key Words Underground coal mining Longwall dust control Shearer		18. Availability Statement Release unlimited	
19. U. S. Security Classif. of the Report Unclassified	20. U. S. Security Classif. of This Page Unclassified	21. No. of Pages 158	22. Price

FOREWORD

This report was prepared by Foster-Miller Associates, Inc., Longwall Mining Division, Waltham, Massachusetts, under USBM Contract J0199092. The contract was initiated under the Coal Mines Health and Safety Program. It was administered under the technical direction of Twin Cities Research Center with Mr. Brad Johnson and Mr. Rick Wilson acting as the Technical Project Officers. Ms. Stephanie Davis was the contract administrator for the Bureau of Mines.

TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
1.	EXECUTIVE SUMMARY AND ACKNOWLEDGEMENTS	14
	1.1 Executive Summary	14
	1.2 Acknowledgements	18
2.	TECHNICAL BACKGROUND TO DEEP CUTTING AND DUST CONTROL	19
	2.1 Improvement of Cutting Conditions	19
	2.2 Design for Cutting and Loading	23
	2.2.1 Cutting	23
	2.2.2 Loading	26
	2.3 Dust Suppression	26
3.	MINE SITE SELECTION	29
	3.1 Mine Site Criteria and Candidate Mines	29
	3.2 Mine Site Selection	19
4.	MINE SITE DESCRIPTION	31
	4.1 Panel Specification	31
	4.2 Panel Layout	32
	4.3 Shearing Machine	32
	4.4 Drum Design	37
	4.4.1 Existing Drums	37
	4.4.2 Test Drum	38
5.	TEST PLANS	44
	5.1 Aim of the Test Plan	44

TABLE OF CONTENTS (Continued)

<u>Section</u>		<u>Page</u>
5.2	Variables	44
5.3	Experimental Plan	45
6.	INSTRUMENTATION, APPROVALS AND INSTALLATION	49
6.1	Available Instrumentation	49
6.1.1	Dust Measurement - Continuous Monitoring	49
6.1.2	Shearer Operating Parameters	50
6.1.3	Other Instrumentation	50
6.2	Instrumentation Layout	50
6.3	Instrumentation Approvals	50
6.4	Instrument Integration	53
6.5	Instrument Installation	56
7.	DATA GATHERING	62
8.	DATA REDUCTION	65
8.1	Initial Reduction	65
8.2	Preparation for Statistical Analysis	68
8.2.1	Dust Make per Unit of Face Cut During Fully Sumped Cutting	68
8.2.2	Dust Make From Sump in During the Cut to the Tailgate	70
8.2.3	Dust Make over Single Whole Cycles	70
8.3	Ventilation Velocity Correction	70
8.4	Data Preparation for Statistical Analysis	71

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Page</u>
8.5 Primary Statistical Analysis	71
8.5.1 Transformations	71
8.5.2 Data Selection	71
8.5.3 Data Analysis	73
 9. TRIAL RESULTS	 76
9.1 New Drums - Two Picks Per Line	77
9.1.1 Dust Make Per Shield	77
9.1.1.1 Midface	77
9.1.1.2 Tailgate	82
9.1.2 Dust Make During Cut to Tailgate	86
9.1.2.1 Midface	86
9.1.2.2 Tailgate	88
9.1.3 Dust Make During the Complete Cycle	92
9.1.3.1 Midface	92
9.1.3.2 Tailgate	93
9.2 New Drums - One and Two Picks Per Line	95
9.2.1 Midface	97
9.2.2 Tailgate	97
9.3 Old Drums	97
9.4 Intercorrelation Between Midface and Tailgate	100
9.5 Other Results	100
9.5.1 Ventilation Profile	100
9.5.2 Shearer Power Consumption	103

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Page</u>
9.5.3 Shearer Speed	105
9.6 Summary of Dust Level Analysis	110
10. CONCLUSIONS	112
11. REFERENCES	115
APPENDIX A - REAL-TIME AEROSOL MONITOR, MODEL RAM-1 FOR SHORT-TERM AND CONTINUOUS MEASURE- MENT OF DUST, SMOKE, FUMES, AND MISTS	116
APPENDIX B - MINE SITE AGREEMENT	122
APPENDIX C - FORTRAN PROGRAM FOR TRANSFORMATION OF RAW DUST LEVEL TO CUMULATIVE EXPOSURE LEVELS	126
APPENDIX D - DATA SET FOR STATISTICAL ANALYSIS DATA ARRANGED AS DESCRIBED IN TABLE 7 ON PAGE 73	129
APPENDIX E - SPSS INSTRUCTION LIST	132
APPENDIX F - REGRESSION OF DRUM SPEED, NUMBER OF PICKS AND VENTILATION VELOCITY ON DUST LEVEL DATA	134
APPENDIX G - MEANS AND STANDARD DEVIATIONS	154
APPENDIX H - RESULTS RELATING TO THE OLD DRUMS	157

LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1	Dust make per shield (CH1) at midface as a function of drum speed (SP) and number of picks per line (pks)	16
2	Lacing pattern (above) and breakage patterns at different horizons of the original MRE large pick drum	21
3	Respirable dust in air return versus total specific energy (SpE) to cut coal (45 deg bit angle, 4 in. spacing, no machine losses)	22
4	Radial and forward attack picks	24
5	Example of arrangement of clearance-kerf tools	25
6	Panel layout	33
7	Thyssen two-leg shield	34
8	Face installation and headgate area	35
9	Anderson Mavor AM500 DERD shearer	36
10	Old drum lacing diagram	39
11	Old drum mounted on shearer	40
12	Old drum removed from shearer	41
13	Test drum lacing diagram	42
14	Test drum on shearer	43
15	Forward attack and radial picks	43
16	Field test instrument layout	51
17	Test instrumentation circuit diagram	54

LIST OF ILLUSTRATIONS (Continued)

<u>Figure</u>		<u>Page</u>
18	Tailgate RAM	55
19	Midface RAM and recorder box	55
20	Shearer monitoring package	56
21	RAM intake	57
22	Tailgate RAM in position	57
23	Midface RAM in position	58
24	Shearer monitor in position	59
25	Speed sensor mounting	59
26	Change gears installation	60
27	Instrument batteries recharged at face power center	61
28	Dust level and elapsed time data	66
29	Output of dust level data transformation	67
30	Example of event listing	69
31	Correlation matrix at midface	78
32	Scattergram of ventilation velocity and drum speed	79
33	Scattergram of normalized midface dust make per shield and drum speed	83
34	Scattergram of midface dust make per shield (raw data) and drum speed	84
35	Correlation matrix at tailgate	85

LIST OF ILLUSTRATIONS (Continued)

<u>Figure</u>		<u>Page</u>
36	Correlation matrix at midface - including sump	87
37	Scattergram of midface dust make exposure (including sump) and drum speed	89
38	Scattergram of midface dust make including sump (raw data) and drum speed	89
39	Scattergram of tailgate dust exposure (including sump) and drum speed	91
40	Scattergram of tailgate dust exposure including sump (raw data) and drum speed	91
41	Correlation matrix for complete cycles at midface	92
42	Scattergram of midface dust exposure (whole cycles) and drum speed	94
43	Scattergram of midface dust exposure for whole cycles (raw data) and drum speed	94
44	Scattergram of tailgate dust exposure (whole cycles) and drum speed	96
45	Dust make per shield (CH1) at midface as a function of drum speed (SP) and number of picks per line (PKS)	98
46	Total dust make at midface cutting from sump to tailgate (CH1S) as a function of drum speed (SP) and number of picks per line (PKS)	99
47	The correlation matrix of CH1, VCH1, CH2, VCH2, SP, and VENT	101
48	Velocity profile with handheld (no stick) anemometer	102

LIST OF ILLUSTRATIONS (Continued)

<u>Figure</u>		<u>Page</u>
49	Shearer power distribution at 35 and 45 rpm, old drums	104
50	Shearer power distribution at 35, 45, 55 and 70 rpm, two picks per line, new drums	106
51	Shearer power distribution, 55 and 70 rpm at one and two picks per line	107
52	Power consumption as a function of drum speed	108
A-1	GCA Respirable Aerosol Monitor RAM-1	117

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Experimental plan	47
2	Pick penetration - desired number of data gathering shifts	48
3	Field test instrumentation	52
4	Data gathering schedule	63
5	Distribution of successful data gathering shifts	64
6	Data for statistical analysis	72
7	Dependent variables	73
8	Shearer drum and haulage speeds	109
9	Comparison of the effect of drum speed on dust level over various parts of the mining cycle at midface and tailgate - new drums, two picks per line	111
F-1	Regressions	153
H-1	Comparison of dust production rates - new and old drums	158

1. EXECUTIVE SUMMARY AND ACKNOWLEDGEMENTS

1.1 Executive Summary

The following is the final report on United States Bureau of Mines (USBM) Contract No. JO199092 "Field Test of Deep Cutting Double Arm Shearer."

The purpose of this report is to describe the aims and background to this trial, the manner in which it was carried out, and to record and discuss the results achieved.

The first 11 sections of the report are dedicated to this purpose. They are followed by various appendices in which certain raw data and analysis routines are recorded.

The tendency for high dust levels to be associated with shallow depths of cut and vice versa has been observed in the laboratory and in field trials. Particular examples of these trials are that of the deep slow cutting continuous miner in the United States and those of the large pick shearer drums in the United Kingdom. The overall aim of the trial described in this report was to demonstrate a practical association between depth of cut and airborne respirable dust (ARD) level on a typical United States longwall. The trial was, therefore, conducted on a modern longwall coal face in the Pittsburgh seam using an Anderson Mavor AM500 Shearer. The shearer was fitted with a drum that was purposely designed for the trial and operated at constant web depth but with drum shaft speed varied systematically on a shift-to-shift basis between four speeds encompassing the range of 35 to 70 rpm.

A smaller effort was also made to observe the effect on dust make of the reduction of the number of picks per line from two to one. Additionally, shearer haulage speed, production rate, and power consumption were measured in a manner which could be related to drum speed.

Over a period of approximately 5 weeks, dust levels were recorded at 10-sec intervals at midface and at the tailgate on one shift per day. The ventilation velocity, the shearer haulage speed, position, activity and power consumption were also recorded. Combinations of these data allowed the following analyses to be carried out:

- a. Effect of drum speed/depth-of-cut relationship on dust make per unit volume of coal mined during fully sumped operation.

At midface, despite an association with ventilation velocity, it was established that specific dust make was strongly dependent upon drum speed with the lowest speed (35 rpm) producing approximately 60 percent less dust than the highest (70 rpm) (Figure 1).

At the tailgate, this effect was barely observable. It appeared that the degree of ventilation flow through the gob area is the primary determinant of dust level in this area.

- b. Effect of drum speed/depth-of-cut relationship on dust make during that part of the mining cycle starting with sumping in close to the headgate area and mining with ventilation flow towards the tailgate.

At midface, the dust exposure due to this part of the mining cycle, was clearly dependent on drum speed being reduced approximately 60 percent when speed was changed from maximum (70 rpm) to minimum (35 rpm).

At the tailgate, the apparent dependence was slight.

- c. Effect of drum speed/depth-of-cut relationship on total dust make during complete mining cycles.

Once more the selection of low drum speeds substantially reduced overall ARD exposure at the midface position even though a substantial portion of dust at this point originates from the headgate drum, the speed of which was not changed.

The dependence of ARD exposure at the tailgate on drum shaft speed could not be proven.

- d. The effect of the increase of pick penetration by the removal of alternate vane picks was investigated at 55 and 70 rpm and was observable as a reduction of approximately 20 percent in specific dust make at 55 and 70 rpm. This part of the trial was of necessity not extensive.
- e. Data concerning shearer power consumption were analyzed to yield distributions of levels at each speed/pick condition when the shearer was encountering normal cutting conditions. Comparison of these distributions revealed that at the lower drum speeds overall power consumption was significantly reduced and that at the

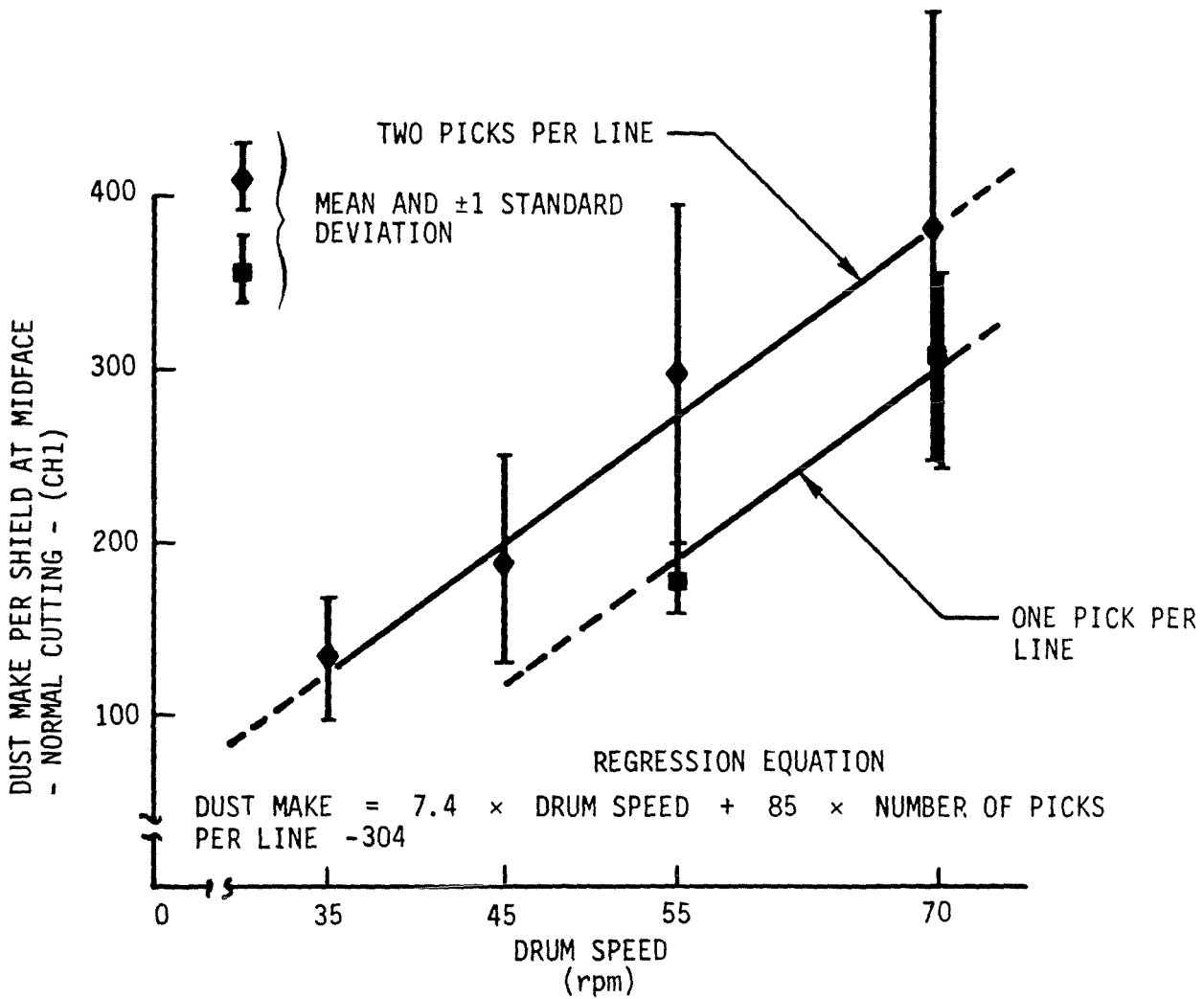


FIGURE 1. - Dust make per shield (CH1) at midface as a function of drum speed (SP) and number of picks per line (pks).

higher drum speeds the shearer was frequently constrained by power demands that exceeded the rating of the system.

- f. While the drums were fully sumped the production rate of the shearer was in the range of 14 to 16 tons/min. At the higher drum speeds the shearer tended to the lower part of this range. At the lower speeds the shearer tended to maintain the higher production rates. It was not possible to conclude whether this tendency was caused by maximum power or haulage force levels being exceeded.

This trial of a principle that is widely accepted but not extensively applied sought to show that *significant* reductions in ARD levels may be achieved by the adoption of deep cutting through the use of reduced drum speeds. This objective was achieved by demonstrating a 60 percent reduction in ARD during normal cutting at midface.

It was also possible to demonstrate certain secondary effects such as the limited reduction of ARD resulting from pick removal and the benefits to be gained in terms of reduced power consumption that are associated with deep/slow cutting.

It is recommended that the United States longwall industry continue to follow the tendency toward the application of deep/slow cutting through the purchase and use of longwall shearers fitted for the minimum practical drum speed. Where machines are used that offer two drum speeds, it is important that foremen and other supervisors recognize the importance of using the lower speed wherever possible.

This recommendation has significant impact on the design of shearer drums for cutting and loading. It is the author's opinion that in the context of conventional shearer design and use, the relationship between pick spacing, number of picks per line and depth of cut (drum speed) would repay further study.

1.2 Acknowledgements

The trial described in this report was carried out in the Quarto No. 4 Mine of the Quarto Mining Company, Clairington, OH, during the summer of 1980.

Foster-Miller Associates, Inc. (FMA) would like to offer thanks to Bill Goddard, Operations Vice President of North American Coal Co., the parent company, and to George Bartlett of Quarto Mining for agreeing to provide a site for the trial. Thanks are also due to Bill Burrows, Longwall Manager, for providing valuable advice and assistance during the planning and execution stage of the study.

FMA would also like to acknowledge the practical assistance provided and tolerance shown by Bill Dennison, the 3 North Longwall Coordinator and by the section foreman, mechanics and crew.

During the planning stage of this trial, Mike Brooker of the National Coal Board (NCB) Mining Research and Development Establishment (MRDE) provided valuable assistance as did Murdoch Spence and the staff of Winster Engineering Ltd. The author would also like to thank Robin Ferguson and others at Anderson Mavor (USA) Inc. for their advice and cooperation.

The author would like to acknowledge the part played by his colleagues Tim Hawkes, Paul Kovsek, Gary Mezack and Tom Short during the underground phase of this study when they worked long and odd hours in difficult conditions to bring home the data.

2. TECHNICAL BACKGROUND TO DEEP CUTTING AND DUST CONTROL

The aim of this section is to report on the state of the art of ARD control with respect to shearer application and design. This will be done by breaking down the subject into the following categories:

- a. Design for improved cutting conditions
- b. Improvement of loading
- c. Dust suppression.

The following subsections are not intended as an exhaustive and detailed survey of this subject, but as a review of current practice and development which will provide a context for the deep cutting shearer drum trial.

2.1 Improvement of Cutting Conditions

The theoretical requirements of efficient coal cutting had been studied both in the United States and Great Britain for the past 20 years. These theoretical studies have been validated by several laboratory tests involving the measurement of cutting forces and dust levels.

In the United Kingdom, Evans and Pomeroy (1) laid the foundation by determining that the principal mechanism for breakage of coal by a single pick was tensile failure preceded by initial crushing. They also noted the marked relationship between the energy required to cut coal and the depth of cut. Pomeroy and Brown (2) also reported on laboratory tests which demonstrated among other things that a significant degree of interaction occurs between adjacent cutting lines, and that a relieved cut requires considerably less energy than a single cut. The relationship between specific energy consumption and dust production has always been assumed, though at the time that the large pick (deep cutting) shearer drum trials were initiated in the United Kingdom, adequate dust monitoring instrumentation had not been introduced.

The early trials of the large pick shearer drums were described by Baker and others (3). These trials were a success in that dust levels were subjectively reduced and the proportion of large coal produced was increased to the benefit of the coal

preparation plants and the domestic heating market. The "Mark I" large pick shearer drum was not widely adopted, however, due to the loads imposed on the shearer by the drum configuration employed. The use of a minimal (less than 12) number of picks caused wide variation of cutting loads, especially those associated with cutting on the clearance kerf.

Figure 2 shows the lacing pattern of an early large pick shearer drum. In this case, opportunity has been taken to "counterlace" the drum. This is the procedure whereby the cutting line proceeds around the drum in the opposite direction to the vane. The purpose of this arrangement is to balance cutting forces across the drum and reduce instability.

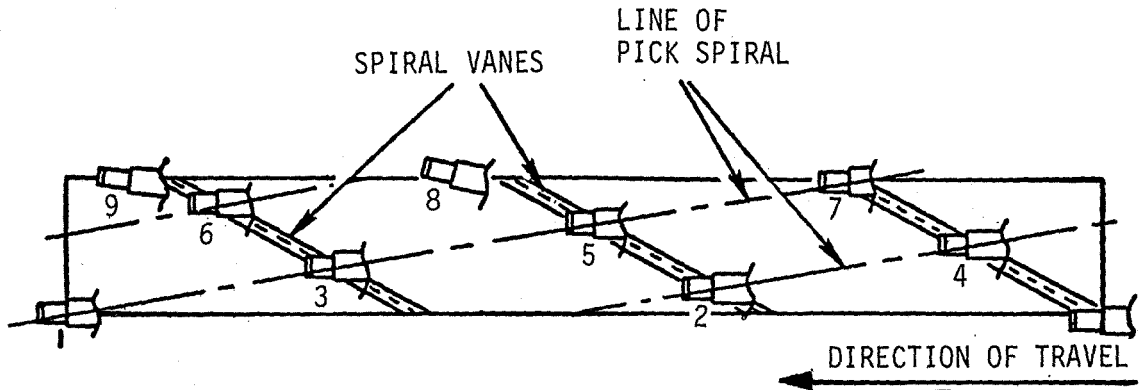
The instability associated with the large pick drum was the stimulus for the changes seen in the Mark II version. In this arrangement, conventional pick lacing was employed on the back face clearance ring where cutting conditions are not severe (4).

Drums derived from "large pick shearer drum" experience are widely used in the United Kingdom though the extremely large chisel pick is normally replaced with a slightly larger number of forward attack bits.

In the United States, longwall coal mining does not predominate. Attention has, therefore, been focused in laboratory and field studies towards the type of cutting regime encountered by continuous mining machines.

The principal laboratory studies (5, 6) have concentrated on the types of tools employed by this class of machines, these being predominantly conical or radial bits. In terms of specific energy and dust production, however, this concentration has not affected the conclusions drawn which have been broadly similar to the United Kingdom experience. This is to say that both dust production and unit power consumption appear to be strongly related to depth of cut and pick cutting depth/spacing ratio and that optimization of these parameters will yield significant benefits.

The practical application of these principles in the United States has for the most part concerned their demonstration with respect to continuous miners. Warner (7) published results of an empirical study in 1970 that showed that power consumption and, by implication, dust production per ton of coal mined is reduced as drum revolutions per minute decrease. This trend towards increased pick penetration via reduced drum speed was



PICKS 1, 3, 5, 7 FIRST PATTERN
 PICKS 2, 4, 6, 8 SECOND PATTERN
 PICK 9 ADDITIONAL CLEARANCE PICK

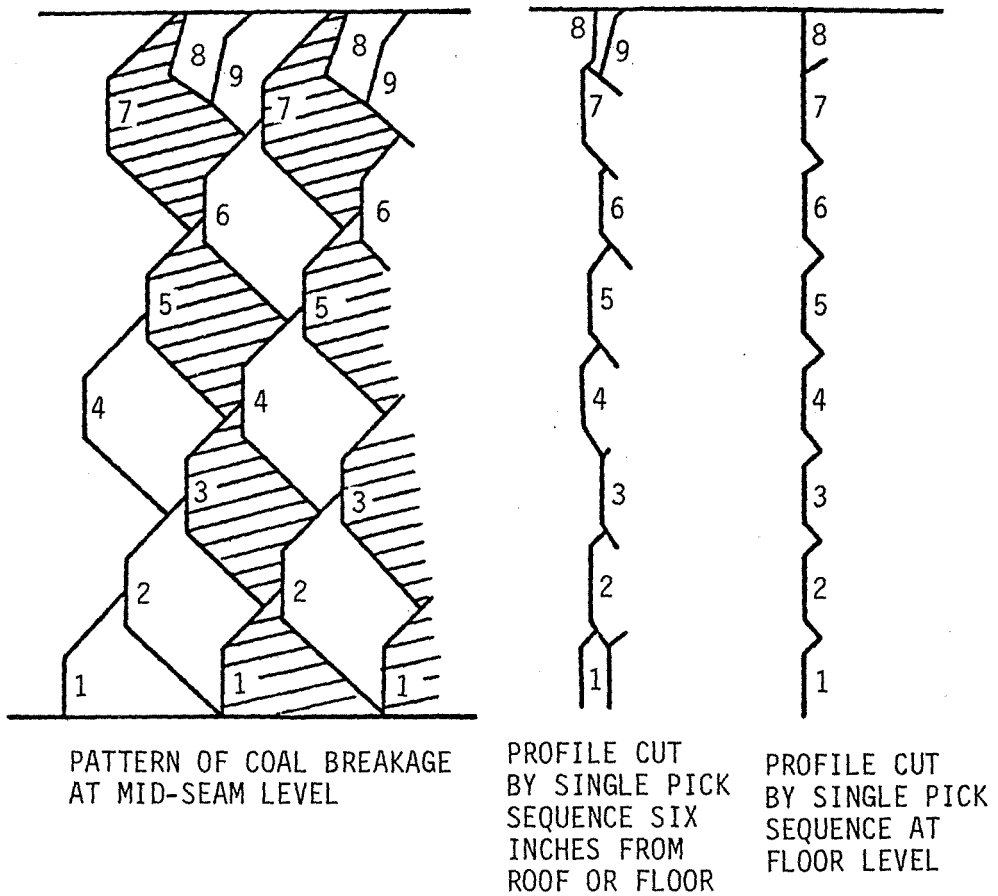


FIGURE 2. - Lacing pattern (above) and breakage patterns at different horizons of the original MRE large pick drum.

followed by two USBM demonstration projects. In the first (8) a special test rig (the Microminer) was employed on which sump and shear rates could be accurately controlled. Results showed that specific dust production was strongly dependent upon depth of cut. In order to further demonstrate this effect, a full size continuous miner was built which has the capability of operating over a wide range of drum speeds and with the facilities for automatic control of shear speed. Results obtained with this Lee Norse HH456 (9) showed that outby a machine the specific dust production was strongly dependent on pick penetration and practically independent of drum speed (pick speed). Figure 3 represents a summary of the results of the testing with the Lee Norse HH456. It shows clearly that specific dust production and energy consumption are closely related to each other and to depth of cut.

The experience gained by the NCB with large pick drums and the results obtained by the USBM using research continuous miners suggested that a demonstration of these principles on a United States longwall would be appropriate.

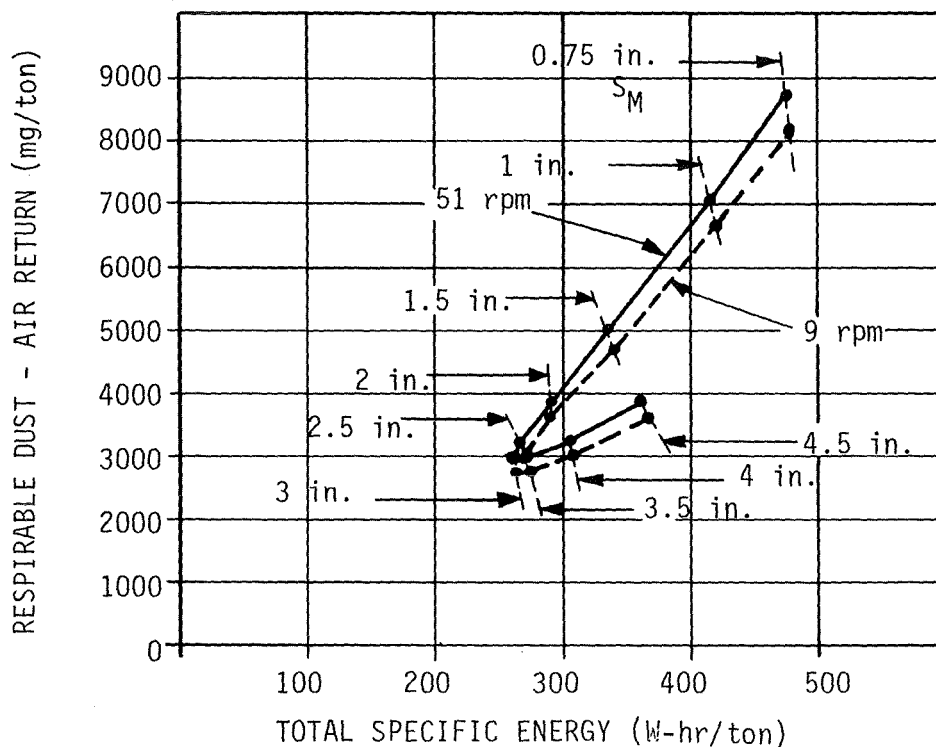


FIGURE 3. - Respirable dust in air return versus total specific energy (SpE) to cut coal (45 deg bit angle, 4 in. spacing, no machine losses).

2.2 Design for Cutting and Loading

The preceding represents the background of the proposed trial. In the subsections that follow, the impacts of various design parameters associated with cutting and loading are assessed.

2.2.1 Cutting

Depth of Cut

The effect of depth of cut in terms of pick penetration is the subject of the proposed demonstration. It should be noted, however, that when a depth of cut is stated it always refers to the maximum depth of cut achieved by the leading drum. The minimum depth of cut achieved by both leading and trailing drum is *always* zero. This fact constrains the maximum pick spacing that can be used if coring at the roof and floor is to be avoided.

Pick Type

Current practice consists of the use of either radial or "forward attack" picks on longwall shearer drums. The use of continuous miner-type conical bits is not now common.

The distinction between radial and forward attack tools is more significant in terms of the practicality of mounting and integrity of the bits than in terms of primary dust production. Figure 4 shows that the presentation of the cutting element to the coal may be the same in either case though the mounting of the forward attack pick requires more space on the drum. This factor may prohibit its use on the backface where pick density is high. The forward attack pick has structural advantages in that a high proportion of cutting loads is transmitted to the drum in compression rather than bending/shear.

Pick Placement

The placement of the picks on the circumference of the shearer drum will determine the cutting depth/pick spacing ratio of a given pair of picks. On the backface where cutting forces are highest, normal practice is to maximize the number of picks sharing the duty. It is also important to radius the top and bottom of the kerf to provide adequate clearance for the back of the drum. This results in the placement of picks in the manner shown in Figure 5. On the vanes, pick placement will be constrained by the number and angle of loading vanes. If a design

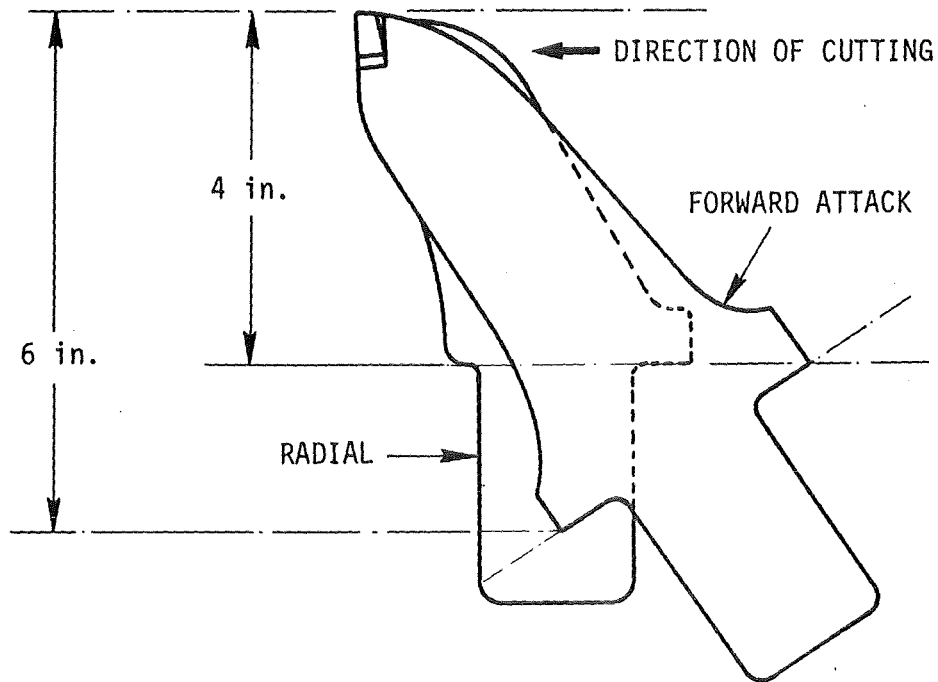


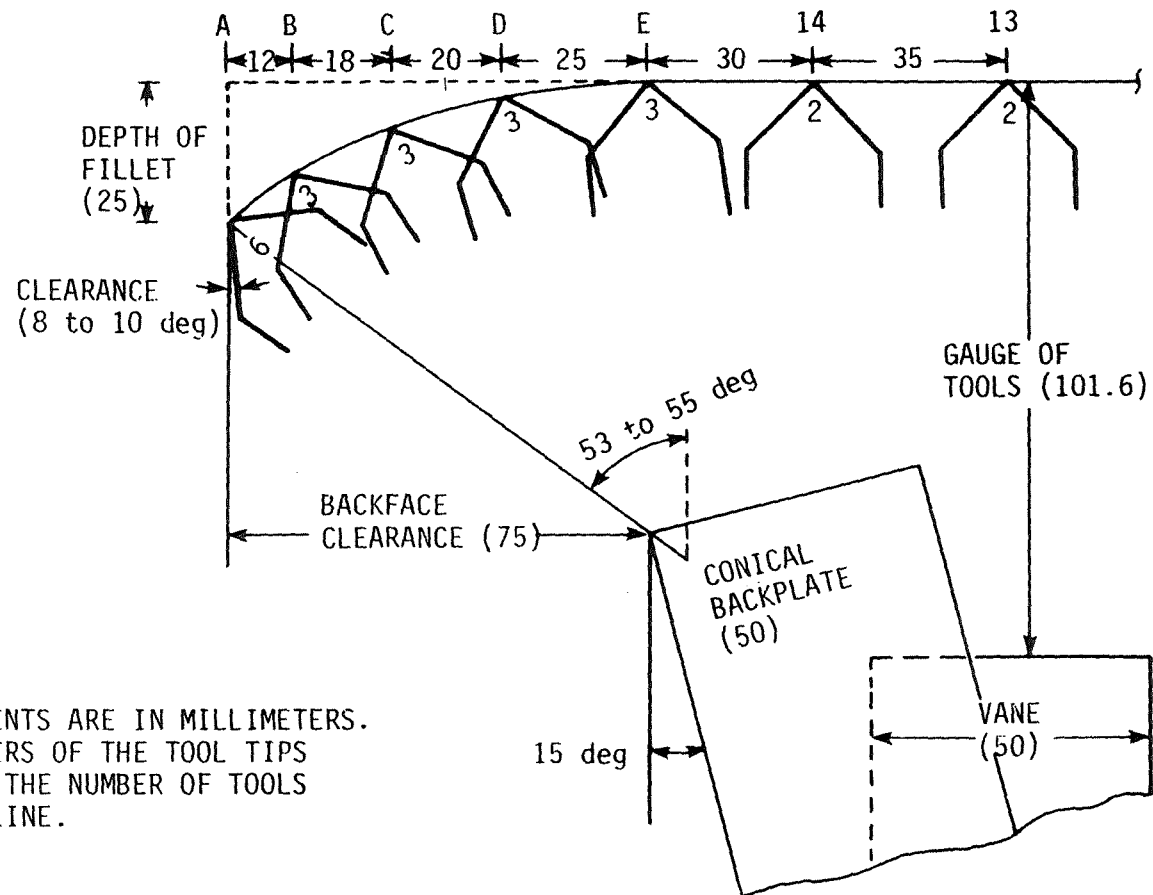
FIGURE 4. - Radial and forward attack picks.

involving a small number of vanes at a high angle of inclination is adopted, the number of forward attack picks that may be mounted will be low.

Overall, the requirement is that the number and position of picks reflect the cutting duty they will experience *and* that their location and spacing be accurately maintained during fabrication.

Shearer Design Speed

It is apparent that at a set drum shaft speed the penetration of a given pick (advance per revolution) will be determined by the haulage speed. It is also apparent that at a given web depth the rate of production will be proportional to haulage speed. At the present time there is a tendency for operators to fit drums of wider webs in order to maintain production or to improve mining conditions. This trend will lead to reduced pick penetration if drum shaft speed and production rates are maintained. In general, the use of a wide web drum should be



NOTE:
 MEASUREMENTS ARE IN MILLIMETERS.
 THE NUMBERS OF THE TOOL TIPS
 INDICATE THE NUMBER OF TOOLS
 IN EACH LINE.

FIGURE 5. - Example of arrangement of clearance-kerf tools.

accompanied by a reduction in drum shaft speed so that pick penetration (and cutting efficiency) is maintained. In cases where a reduction of drum shaft speed will impair loading efficiency, a reduction in the number of picks per line should be considered.

2.2.2 Loading

When coal is loaded from the shearer drum, opportunities exist for secondary breakage which will act as a further primary dust source and for various processes which provide opportunities for respirable dust to become airborne.

Secondary breakage will occur if the drum chokes and coal fails to progress towards the AFC. Under these circumstances, coal will be broken by friction and by passage of the picks and boxes.

The primary cause of additional airborne dust generation is recirculation of cut coal over the drum. This results in coal being projected into the airstream.

The state-of-the-art solution to this problem consists of applying knowledge of the appropriate relationship between drum pitch speed and diameter. Choking is avoided if a "fill factor" of less than 25 to 30 percent is assumed.

Cowls and, to the lesser extent, loading doors have a significant effect on the contribution of loading to airborne dust production. Their principal effect is to retain the coal in the drums until it is positioned for discharge onto the AFC and to deflect the ventilation current from the unloaded coal.

2.3 Dust Suppression

Various means are employed to prevent respirable dust from becoming airborne or to remove airborne dust from the general airstream.

Water Sprays

Water is used for both of the purposes described above. It is supplied to nozzles positioned close to each active pick on the shearer drum. If the spray is directed at the front of the pick, the process is referred to as pick face flushing (PFF). The exact requirement in terms of location and type of nozzle is open to discussion, but it is apparent that for a system to be effective the sprays must be well maintained and supplied with well filtered water at adequate pressure.

The modulation of water supply to individual picks to coincide with their cutting cycle (phased water supply) is not widely applied in the United States.

External sprays, however, are widely used and their provision is frequently insisted upon by safety and operating personnel. Their efficiency is dependent upon how well they are maintained. Potential drawbacks include the possibility that the provision of external sprays will significantly reduce the water pressure available to the PFF system and the potential for such sprays to influence the ventilation pattern around the ranging arms in such a way as to promote the passage of dust laden air into the general airstream.

Extraction System

Systems for the extraction and purification of dust laden air have been tested on longwalls on a number of occasions.

In the United Kingdom a degree of success has been achieved with an extractor system incorporated in a double ended conveyor mounted trepanner (DECMT) while in the United States attention has been paid to the use of flooded bed scrubbers mounted on the shearer.

A particularly promising development is the extractor cowl which incorporates a water-driven scrubber in the drum cowl, thereby doing away with the need for extensive ducting between intake points and the scrubbing device.

Hollow Shaft Ventilation (HSV)

HSV is normally considered as a means of ensuring that hazardous accumulations of methane gas do not occur at the back of the web. There exists, however, a body of opinion which considers that the delivery of a large quantity of wet dust laden air to this area of hard cutting assists in reducing the overall level of airborne respirable dust.

Other Systems

Various other adaptations of the longwall shearer have been proposed or demonstrated with respect to airborne respirable dust control. Among these are the use of *wider webs* whose proponents suggest that dust levels are reduced principally due to the following factors:

- a. A wider web shields more of the cutting zone from ventilation airflow.
- b. On a per-ton basis, there are fewer feet of cutting and loading. This reduces the proportion of coal cut from the clearance-kerf and the number of roof support moves per ton.

Spray fans for operator protection have been successfully demonstrated in surface tests. In this system shearer mounted sprays deflect dust laden air from the operator's positions.

Remote control is another dust reduction measure which removes the operator from the hazardous area without affecting the level of dust production.

This list could be continued to include some of the more exotic means of shearer dust control that have been proposed, such as the use of steam instead of liquid water, but this would not be relevant to the purpose of this section which is to provide a context for a demonstration of a single means of shearer dust control.

3. MINE SITE SELECTION

3.1 Mine Site Criteria and Candidate Mines

The major criterion for mine site selection was that of representativeness. The mine chosen had to be one at which the dust problem was significant. (This ruled out very few United States longwalls.) The mine selected also had to be applying up-to-date technology and methods, thus being representative of as yet uninstalled systems as well as current practice. It was a requirement that the mine be a reasonably efficient operation not beset by development, roof control, or equipment problems which would artificially restrict production, thereby reducing the amount of data gathered during a field trial of a given duration.

The mine also had to be one that was willing to cooperate in a study of this type and the personnel of which understood the input required of them.

Initially, FMA received the agreement in principal of two mining companies who were prepared to provide a test site. The salient characteristics of these mines are as follows:

<u>Seam</u>	<u>Height</u>	<u>Shearer</u>	<u>Supports</u>
Eagle	72 in.	DTS 400 DERDS	Two-leg leminscate shields
No. 8 Pittsburgh	78 in.	AM 500 DERDS	Two-leg leminscate shields

Visits were made to both mines and discussions held with both managements. During this time FMA was assisted by Mr. C. M. Brooker of the NCB Mining Research and Development Establishment.

3.2 Mine Site Selection

The criteria above were all fulfilled to a reasonable degree by both of the mines considered. Factors differentiating the candidate mines were as follows:

- a. Mine No. 1 was about to start a new panel in a previously unmined area. In Mine No. 2 the panel was more mature.
- b. In Mine No. 1 there was a significant change in seam section as the face retreated. There was also a sandstone intrusion at the tailgate end of the face. This, however, reduced the section in the direction of retreat. Mine No. 2 had a rock band present throughout the whole mine of 4- to 12-in. thickness.
- c. Mine No. 2 was equipped with a shearer for which change gears were readily available and which could be fitted with reasonable ease underground. There was considerable doubt about the availability of such gears for the shearer at Mine No. 1 which would in any case require the removal of a gearhead for fitting.
- d. The shearer at Mine No. 2 would already have been instrumented with the package to be used in this trial during a previous investigation carried out by FMA engineers.
- e. Mine No. 2 has a fully lighted face.

The above considerations steered the choice toward Mine No. 2 with whom a mine site agreement was concluded. The mine site agreement is included in this report as Appendix B.

4. MINE SITE DESCRIPTION

4.1 Panel Specification

The following section contains a description of the physical conditions and the equipment employed on the longwall at the chosen mine site.

As mentioned in the preceding section, one of the main criteria for mine site selection was that the chosen site should represent state-of-the-art technology applied to United States conditions. The chosen site fulfilled this criterion and employed the following equipment and layout:

Panel length, 5000 ft

Panel width, 500 ft

Shield type, two-leg leminscate Thyssen, IFS one-web back

Seam height, 78 in.

Shearer, Anderson Mavor AM500

Type, double ended ranging drum

Horsepower, approximately 486

Haulage types, hydraulic

Method, chainless (rollrack)

Mining method, modified half face

Ventilation, antitropical

Face conveyor, Mining Supplies 764 × 222 mm twin inboard

Stage loader, Mining Supplies 650 × 178 mm

Face lighting, Ocenco

Coal clearance, 42-in. panel belt to mine car haulage

Lump breaker, no

Face voltage, 1000V

Water supply, 70 gal/min at 400 lb/in.².

4.2 Panel Layout

The face on which the trial was carried out was a retreating longwall that was recently installed at the time of the trial. The panel was the second in that part of the mine. Its layout and relationship to the preceding panel can be seen in Figure 6.

Ninety-four Thyssen two-leg leminscate shields (Figure 7) were employed in the one-web back mode. Figure 8 shows these shields during installation on the preceding panel and the head-gate area of the current panel. The excellent lighting conditions and the unobstructed travelling way can be seen from this figure.

4.3 Shearing Machine

The shearer at the chosen mine site was an Anderson Mavor AM500 DERD shearer equipped with a rollrack chainless haulage system. The general arrangement of the shearer is shown in Figure 9.

This machine represents one version of the state of the art in shearer design and may be considered to be typical of the power loading machines to be installed in medium to high seams during the next decade.

The most important factor in relation to the shearer was the availability of appropriate drum shaft speeds. The AM500 at the chosen site was fitted with the following shaft speeds that may be selected by the use of a lever on the gear head:

- a. Fast, 45 rpm
- b. Slow, 35 rpm.

This represents a ratio of 1.29:1 which is well below that required for this test.

Change gears were available, however, that provided other speeds. The most suitable of these provided the following speeds:

- a. Fast, 70 rpm
- b. Slow, 55 rpm.

Change gear part numbers were 32335-384 and 32335-309.

The shearer haulage system is a chainless haulage driven by a motor/pump mounted within the shearer body.

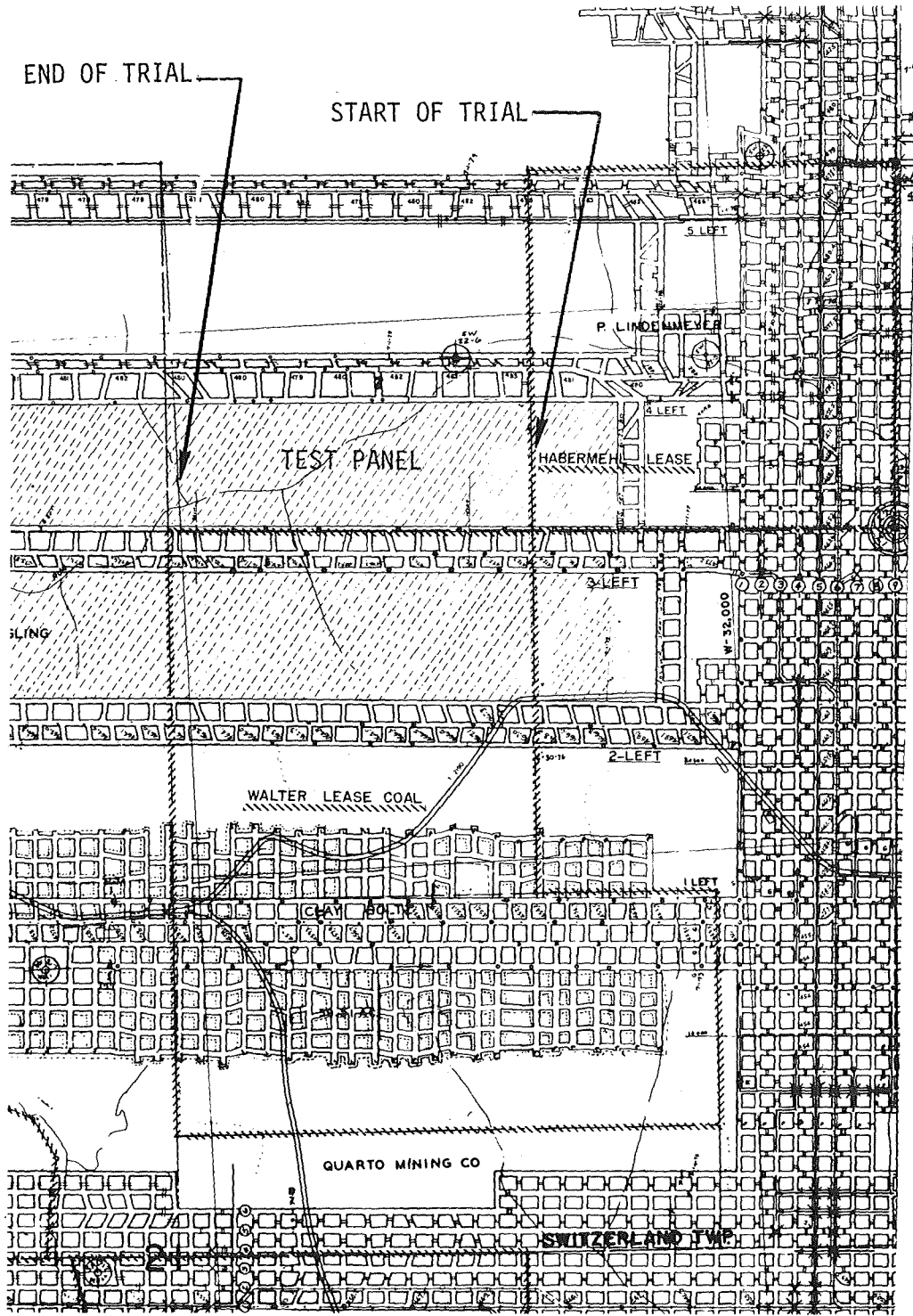


FIGURE 6. - Panel layout.

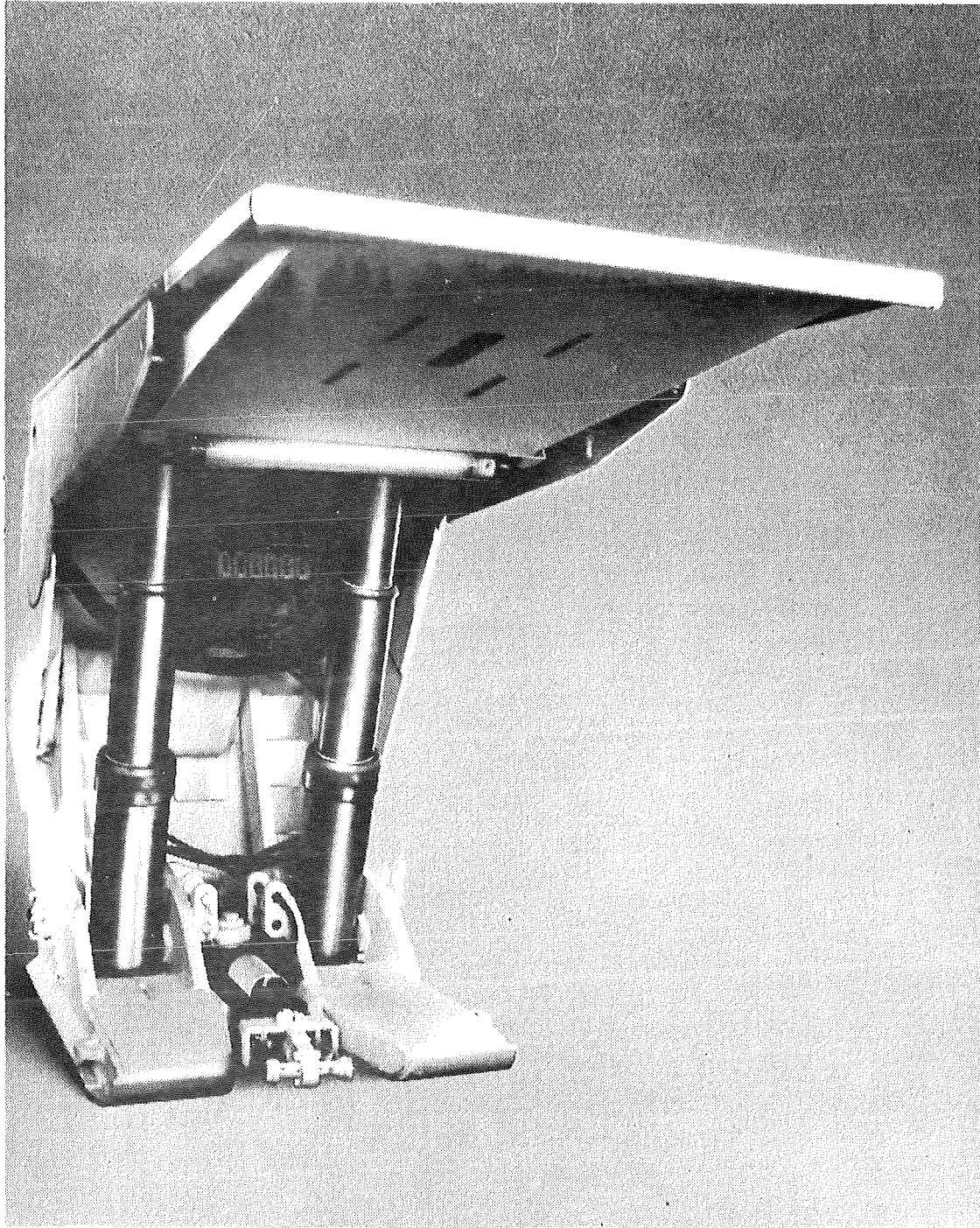
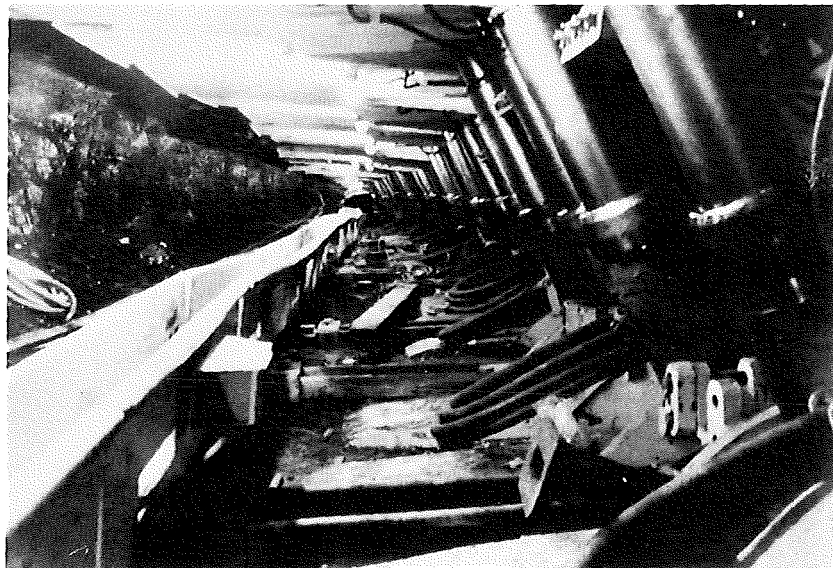


FIGURE 7. - Thyssen two-leg shield.



a) HEADGATE AREA



b) FACE AREA

FIGURE 8. - Face installation and headgate area.

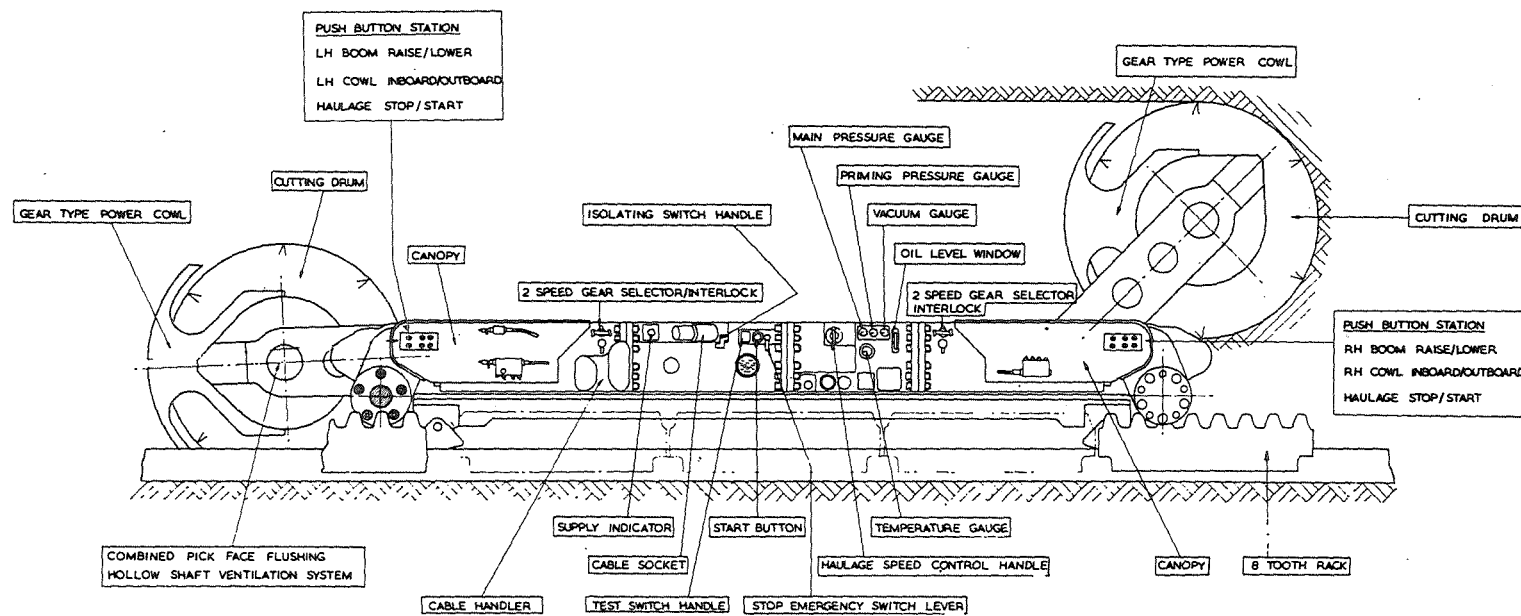


FIGURE 9. - Anderson Mavor AM500 DERD shearer.

The rollrack chainless haulage consists of a driven pinwheel and a continuous rack incorporated in the face conveyor gob side furniture.

The setup described above was particularly suitable for the following reasons:

- a. A chainless haulage eliminates both a major impediment to loading (the chain) and the inevitable jerking experienced with chain haulage.
- b. The hydraulic haulage system exhibits a degree of speed control.

4.4 Drum Design

4.4.1 Existing Drums

The drums used on the AM500 face at the mine site were also supplied by Anderson Mavor (USA) and are of conventional design. The basic parameters are as follows:

Diameter, 1524 mm (60 in.)

Web, 760 mm (30 in.)

Start, 2

Vane wrap, 270 deg

Vane angle (pick tip), 17.5 deg

Picks per line, 2

Vane pick spacing, 38 mm (ungraded)

Backface clearance, 75 mm

Backface pick spacing, 2 at 20 mm, 3 at 25 mm

Backface cutting order, ABDACE

Dust suppression water, PFF on all picks *except* the gob side line

Pick type, positive rake radial (3-in. gauge).

These drums are operated in the conventional leading drum cutting from roof-to-floor mode at the higher of the two shaft speeds (45 rpm) giving a penetration of 2.7 in. at a haulage speed of 20 ft/min.

It has been demonstrated, however, that the machine would operate satisfactorily at the slower speed (35 rpm) at a penetration of 3.4 in. This is in excess of the pick gauge length and demonstrates the occurrence of a degree of overbreak.

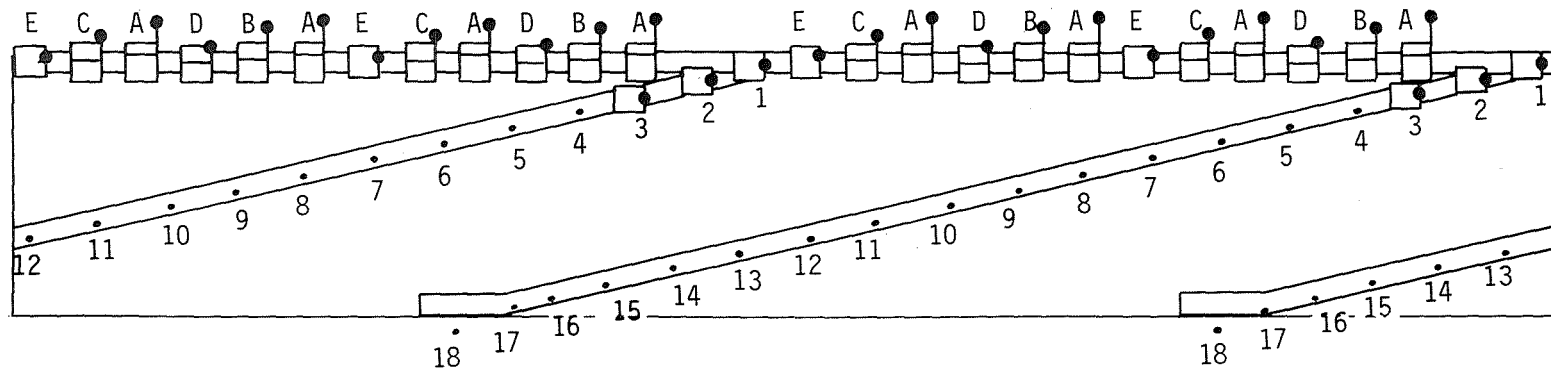
A lacing diagram and cross-section of this drum are shown in Figure 10. The only nonstandard feature of the drum is the lack of provision for dust control water on the three gob side pick lines and the change in vane angle at the gob side end. This was due to previous experience of wear at the vane end. The vane has, therefore, been angled to increase clearance between it and the ranging arm. The water galleries for the gob side PFF sprays were omitted due to the tendency for wear to result in exposure of these galleries with consequent impairment of the effectiveness of the dust suppression system. Figure 11 shows this drum fitted to the shearer, in this case, on the tail end of the machine. Figure 12 shows some detail of the same drum after its removal from the machine.

4.4.2 Test Drum

The drums supplied for the deep cutting test were constructed to the following specifications which were jointly developed by FMA, Winster Engineering, and the NCB Mining Research and Development Establishment represented by Mr. C. M. Brooker:

Diameter, 1525 mm
 Web, 760 mm
 Start, 2
 Vane wrap, 360 deg
 Vane angle (pick tip), 8.2, 9.2, and 10.2 deg
 Picks per line, 2
 Vane pick spacing, 1 at 60 mm, 3 at 50 mm, 5 at 45 mm,
 5 at 40 mm, and 1 at 35 mm
 Backface clearance, 75 mm
 Backface pick spacing, 12, 18, 20, 25, and 30 mm
 Backface cutting order, ABDACE
 Dust suppression water, PFF to all except two gob side picks
 Pick type - vane, 6-in. forward attack (4-in. effective
 gauge) backface, 4-in. radial.

DEVELOPMENT AT BASE OF BOSS



VANE ROOT ANGLE 17 deg VANE WRAP 270 deg
 PFF TO ALL PICKS EXCEPT 16, 17, AND 18

FIGURE 10. - Old drum lacing diagram.

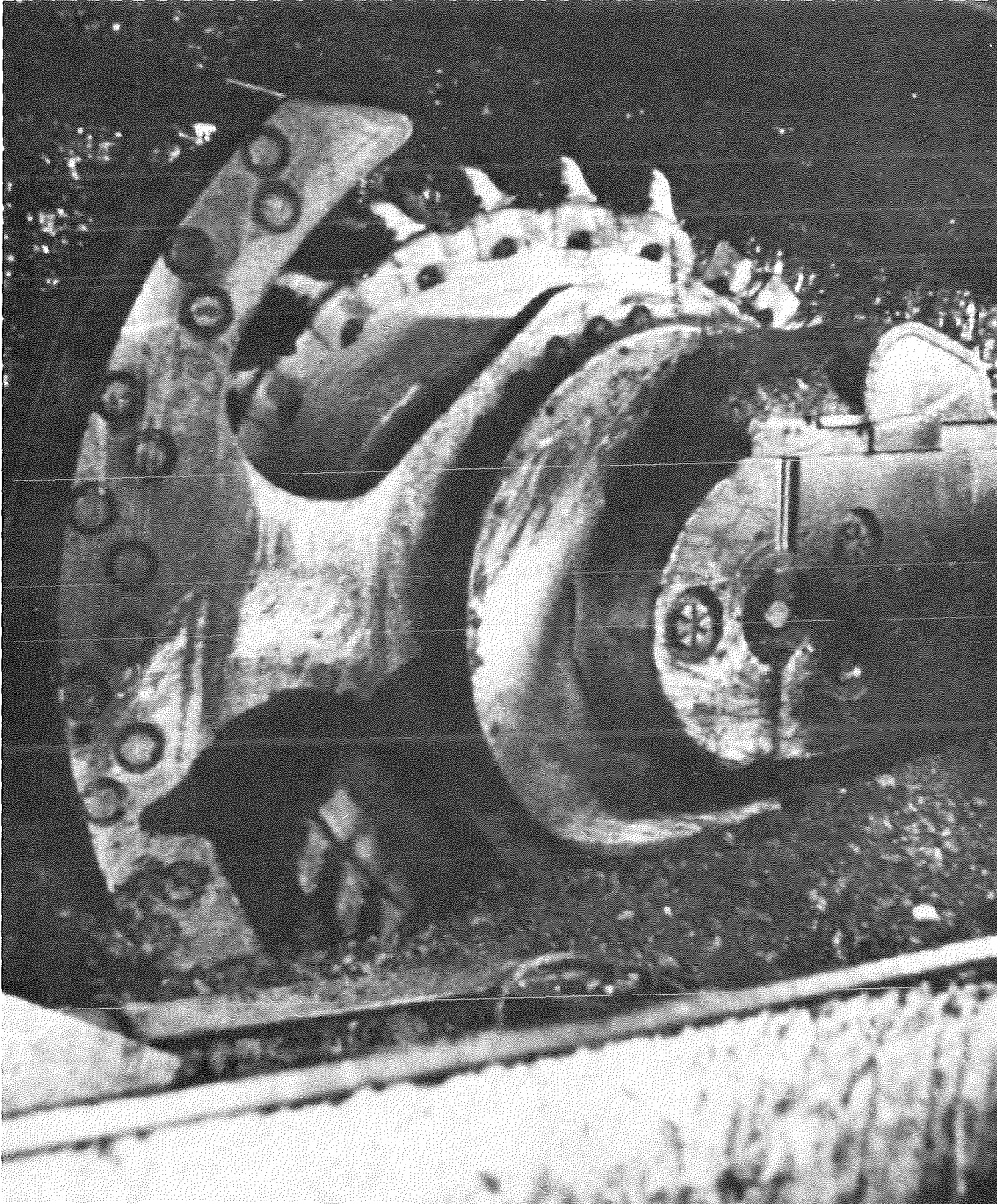


FIGURE 11. - Old drum mounted on shearer.

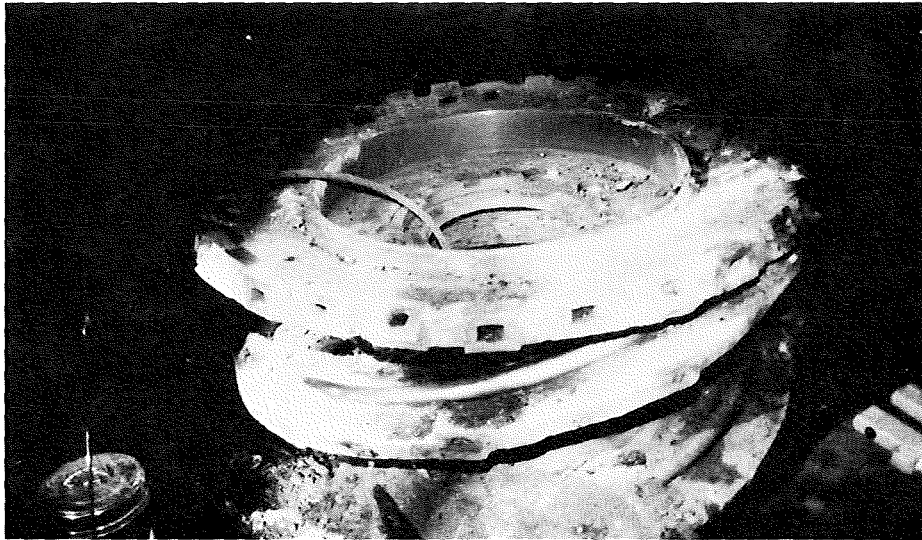
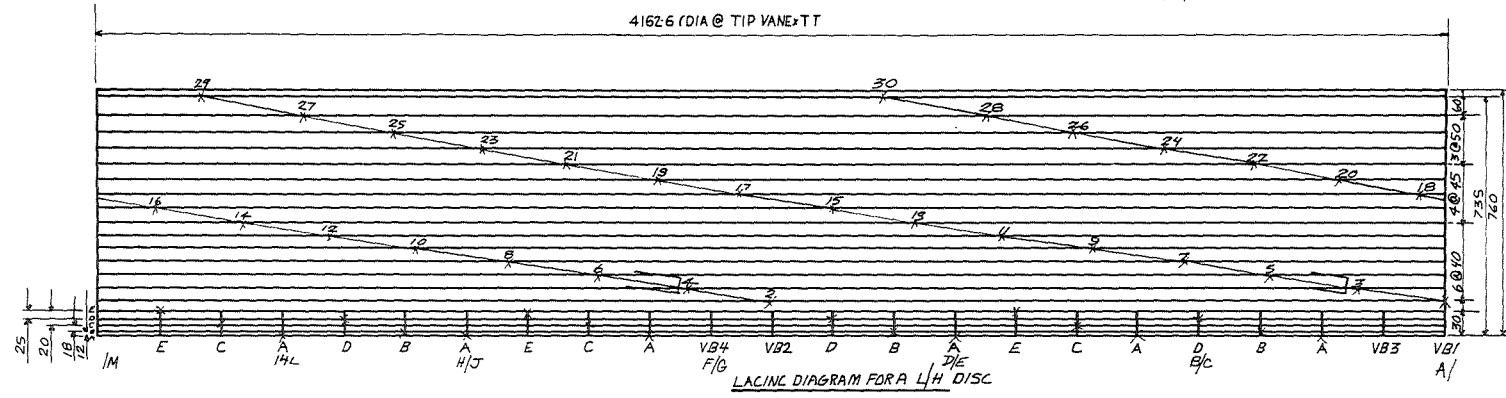


FIGURE 12. - Old drum removed from shearer.

The primary feature of this drum design is that both the backface and the vane pick spacing is graded (see Figure 13). The backface graded spacing is normal practice and is provided to even out the duty of the picks and to generate the required kerf profile.

The vane picks are laced on vanes that have three different pitch angles between the face and gob sides. This again allows the spacing to match the cutting duty and provides the minimum length of vane required to mount each pick box, this being considerably greater for forward attack than for radial picks. Figure 14 shows one of these drums mounted on the shearer and fitted with forward attack picks. The forward attack and radial picks employed on the vane and backface, respectively, are shown in Figure 15.



PFF READ TO ALL PICKS EXCEPT VB 29 & VB 30

BF BOXES VB1, VB2, VB3 & VB4 ARE HALL PICKS A3-233-24 23 REQD

BOXES VB5 TO VB30 ARE HALL PICKLE A3-1010-184 26 REQD.

NOTE: VANES TO FINISH FLUSH WITH TOP OF TUB & TUBE TO FINISH 2MM BELOW WEB

VANE PROFILE DRG. NO. V1525/25

BF PROFILE DRG. NO. BF 1525/27

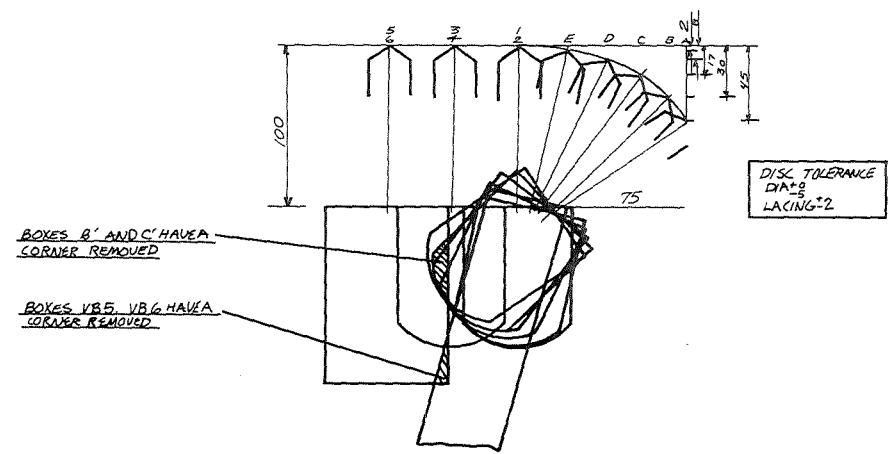


FIGURE 13. - Test drum lacing diagram.

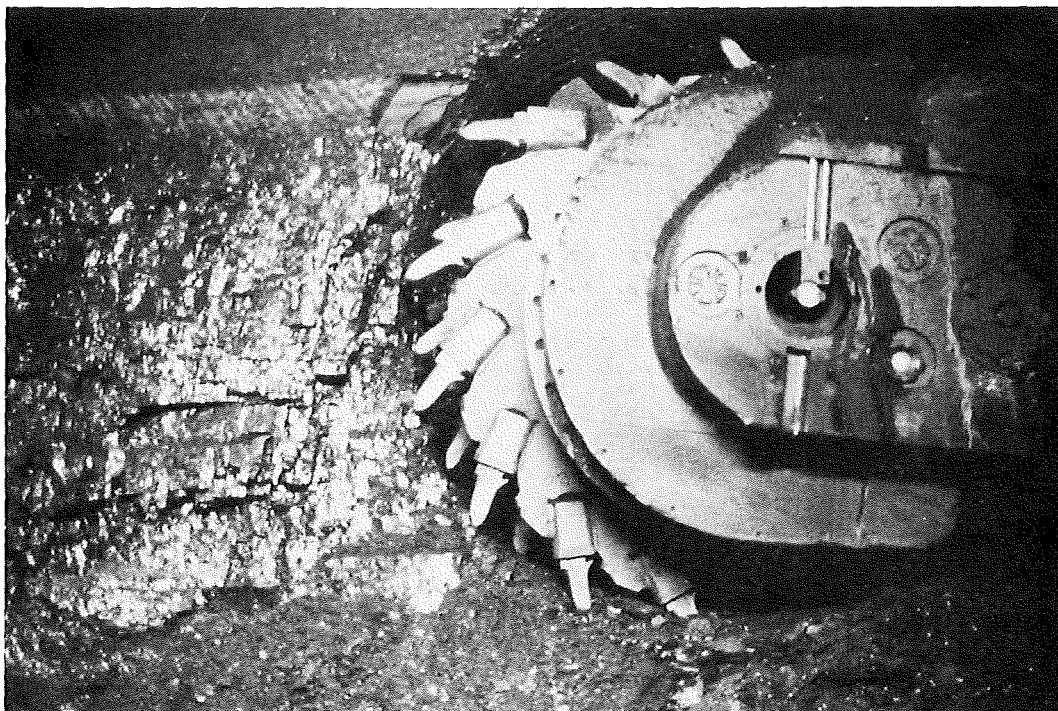


FIGURE 14. - Test drum on shearer.

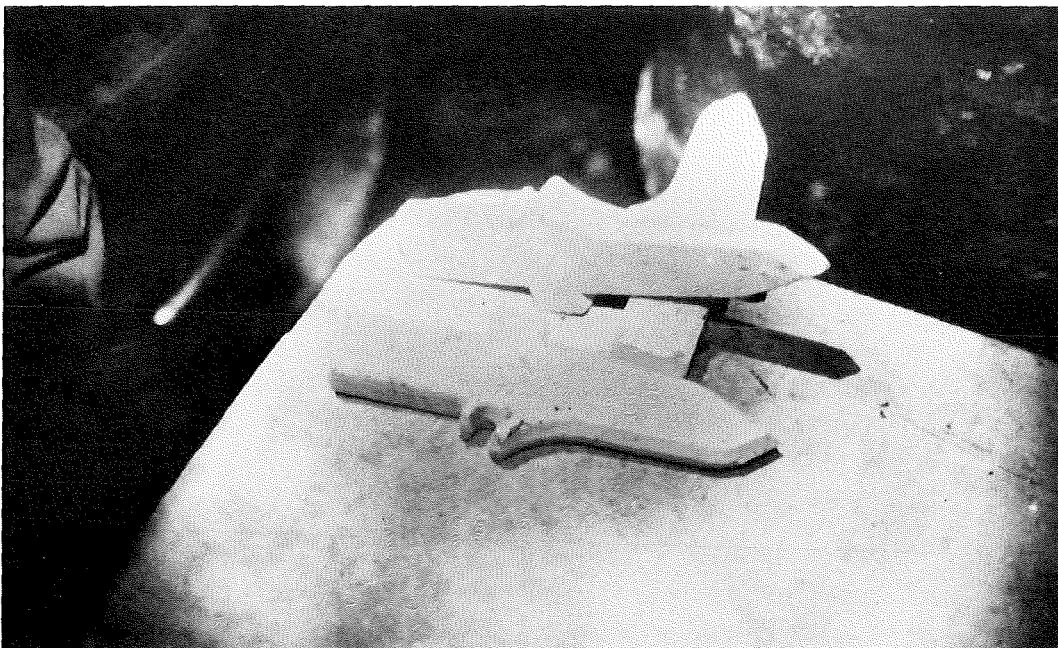


FIGURE 15. - Forward attack and radial picks.

5. TEST PLANS

5.1 Aim of the Test Plan

In planning the underground test, it was borne in mind that conditions in underground coal mines can never be accurately predicted and that the test plan must be adapted as the trial proceeds in order to give the best results. Having said this, it must be remembered that the whole process can be undermined if another variable is allowed to confound the effect under study.

The overall aim of the plan was to:

- a. Distribute the measurement effort in proportion to the significance of the effect being measured in terms of the goals of the experiment
- b. Control as many of the nonexperimental variables as possible
- c. Provide an experimental procedure which will accommodate the requirements of normal operation of the long-wall section to as great an extent as possible
- d. Keep to a minimum the amount of down time or maintenance shift activity required for drum or gear changes and pick changing.

5.2 Variables

The dependent variables in this test were the dust levels measured by the dust measuring devices that were deployed. They may also include results from the shearer operating parameter instrumentation which may be viewed as either dependent or independent variables.

The independent variables were identified as follows:

- a. Pick penetration
- b. Drum shaft speed
- c. Haulage speed
- d. Direction of cutting
- e. Pick condition

- f. Drum type
- g. Day of week
- h. Previous experimental condition
- i. Water supply pressure
- j. Water spray condition
- k. Position on the face
- l. Support position
- m. Main or immediate roof condition
- n. Ventilation flow
- o. Intake contamination
- p. Shearer power consumption (see also above)
- q. Instantaneous and overall production rate
- r. Differences between individual machine operators.

Each of the above was either monitored by instrumentation, observed by personnel on the face during the trial, or at least partially controlled in the experimental design.

5.3 Experimental Plan

An experimental plan was evolved which included the following variables:

- a. Drum - Old drum supplied by Anderson Mavor; new drum supplied by Winster Engineering
- b. Speed - Four drum shaft speeds: 35, 45, 55 and 70 rpm
- c. Direction - Cutting with or against the airflow
- d. Number of picks per line: two picks, one pick
- e. Penetration - Seven different penetrations (at constant haulage speed) ranging from 1.7 to 6.9 in. (at 20 ft/min)
- f. Week of test - 6 weeks with data taking on a total of 30 shifts.

The experimental plan derived is shown in Table 1. The plan required only one change of drums, this occurring at a week-end. Change gears would, however, have to be fitted between shifts.

The schedule also required removal and fitting of picks between shifts.

The initial period involved measurement with the existing drums for a period of five shifts. The purpose of this operation was to:

- a. Allow comparison with the new drums
- b. Provide a break-in period for the face crew, the data gathering team, and the instrumentation.

Although this period corresponds to the baseline measurement described in the proposal, this nomenclature is perhaps misleading since it is inappropriate to refer all the other data to this condition (which is associated with a drum which is an unknown quantity).

Constant haulage speed would be maintained where possible in the 18 to 20 ft/min range by appropriate adjustment of the setting of the hydraulic haulage relief pressure. It was understood from Anderson Mavor that this would determine the maximum available haulage speed.

The main goal of the experiment was to observe the effect of variation of pick penetration. This variation was achieved in two ways:

- a. By changing drum shaft speed (in a 2:1 ratio)
- b. By changing penetration per revolution (at constant shaft speed) by removing the second pick on each line.

The range of penetrations and the desired number of data gathering shifts at each penetration, with the new drum cutting with the airflow, is shown in Table 2.

TABLE 1. - Experimental plan

Week	1	2	3	4	5	6
Drum	Old	New	New	New	New	New
Speed	21212	12121	34343	21211	43433	21212
Direction	WWWWA	WWWWA	WWWWA	WWWWA	WWWWW	WWWWW
Picks per line	2	2	2	2	11221	22111
Penetration		4343	2121	4343	35125	34676
Direction		Speed (rpm)		Penetration (depth of cut) (at 20 ft/min) (in.)		
W = With air flow		1 = 35		1 = 1.7		
A = Against air flow		2 = 46		2 = 2.2		
		3 = 54		3 = 2.6		
		4 = 72		4 = 3.4		
				5 = 4.4		
				6 = 5.2		
				7 = 6.9		

TABLE 2. - Pick penetration - desired number of data gathering shifts

Penetration depth (in.)	1.7	2.2	2.6	3.4	4.4	5.2	6.9
Number of shifts with two picks/line	3	3	5	5	-	-	-
Number of shifts with one pick/line	-	-	-	1	2	2	1
Total number of shifts	3	3	5	6	2	2	1
<p>Note: This table includes only shifts with the new drum cutting with the airflow.</p>							

6. INSTRUMENTATION, APPROVALS AND INSTALLATION

6.1 Available Instrumentation

The instrumentation requirements of the field test were identified early as centering around a means of continuously monitoring dust levels at a fixed location(s) on the face in a manner which would allow subsequent correlation with face operations. It was also noted that conventional gravimetric full-shift sampling would be appropriate as would some means of recording the shearer operating conditions.

6.1.1 Dust Measurement - Continuous Monitoring

Instrumentation for the continuous monitoring has become available only in the last 5 years. Each of the instruments that have found application for or been specially developed for use in coal mines is based upon the light scattering principles. These are:

- a. GCA Inc. RAM-1 (Real-time Aerosol Monitor)
(United States)
- b. SIMSLIM II (Safety in Mines Scattered Light Meter)
(United Kingdom)
- c. Leitz TM Digital (West Germany).

These instruments differ in the angle at which the scattered light is received and are thus subject to varying degrees of sensitivity to errors due to particle size and density changes. However, for the purpose of this test, where the nature of the material *and* the size distribution are unlikely to change grossly between trials, instruments of this type offer distinct advantages.

The GCA RAM-1 was selected for this test due to the availability of Government Furnished Equipment (GFE).

Appendix A contains a specification for the RAM-1 instrument. In the application of this instrument to this test it provided a signal to a recording device. The RAM-1 was set to update the dust level reading every 2 sec.

Data recording was accomplished at the shearer and in the tailgate by AD Data Systems, Inc., ML-2 digital data loggers. Paper chart recorders were also used as a backup to the data loggers and as the principal recording medium in the headgate.

6.1.2 Shearer Operating Parameters

The package of instrumentation developed for DOE Contract ET-78-C-01-3160 concerned with measurement of constraints to the increase of shearer haulage speed was available for this trial. This instrumentation can measure directly:

- a. Total shearer power consumption
- b. Shearer haulage pressure
- c. Shearer haulage speed.

These data allow the following parameters to be derived:

- a. Shearer haulage power consumption
- b. Power consumed by cutting and loading
- c. Shearer position.

6.1.3 Other Instrumentation

Conventional vane anemometers, two of which were available, were used to spot-check face ventilation velocity both in terms of mean level and gate-to-gate cross-section profiles. The face data gathering crew were issued stopwatches and permissible memo (tape) recorders.

6.2 Instrumentation Layout

The disposition of the instrumentation is shown graphically in Figure 16 and in tabular form in Table 3.

6.3 Instrumentation Approvals

The instrument package employed was based upon three main elements:

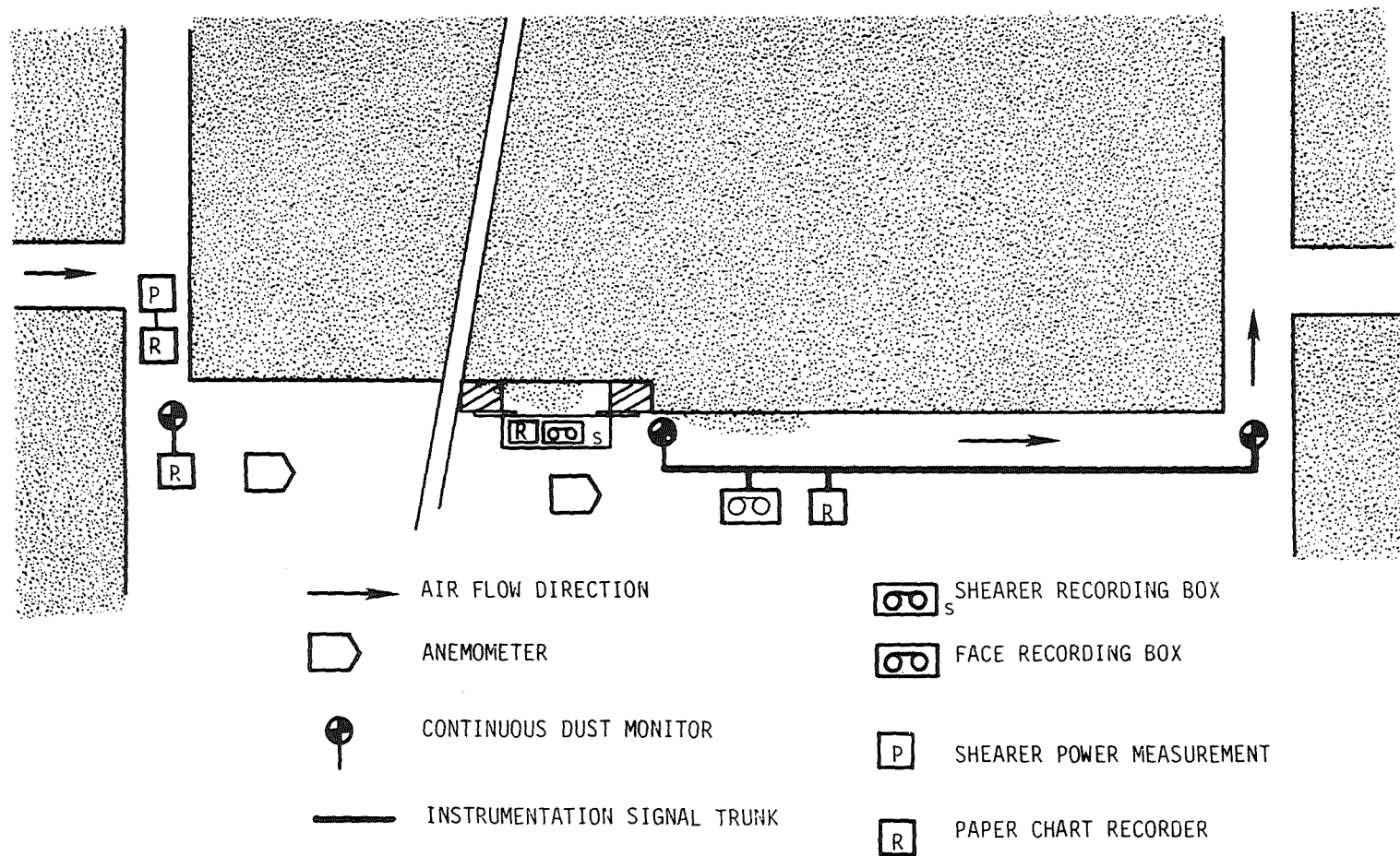


FIGURE 16. - Field test instrument layout.

TABLE 3. - Field test instrumentation

Location	Instrument	Parameter	Recorder
Headgate	Power Transducer	Total shearer power consumption	Paper chart
	GCA RAM-1	Instantaneous dust level	Paper chart
Shearer	Pressure Transducer	Haulage pressure	Data logger
	Speed Transducer	Haulage speed	Data logger
Coal face	GCA RAM-1	Instantaneous dust level	Data logger
Tailgate	GCA RAM-1	Instantaneous dust level	Data logger

- a. Continuous dust monitors - GCA RAM-1's
- b. Paper chart recorders - Gulton Rustrak 288
- c. Shearer performance recording system.

The recording system consists of a number of explosion-proof boxes housing instrumentation and recorders in a configuration that had recently received a series of experimental permits from MSHA. The GCA RAM-1's have been designed to Intrinsic Safety (IS) standards and had received experimental permit approval by MSHA.

The Gulton Rustrak recorders were used in a configuration that has received MSHA's IS approval for experimental permits.

The IS and explosion-proof parts of the package required separation by appropriate zener barriers. The installation of these represented the only change required to the explosion-proof boxes.

Figure 17 shows the equipment layout drawing submitted to MSHA. Also supplied were component and electrical circuit drawings of each of the explosion-proof boxes.

6.4 Instrument Integration

Dust measurement and recording instruments were assembled at the USBM Bruceton facility. Figure 18 shows the single RAM-1 to be positioned at the tailgate mounted in a NEMA-4 enclosure with the remote intake and provision for signal output. Figure 19 shows the accompanying midface RAM-1 mounted in a NEMA-4 enclosure together with a Rustrak recorder. Signals from this RAM-1 and that at the tailgate were led to the junction box mounted on the lid of this enclosure from whence they were distributed to the Rustrak recorder and the ML-2 digital data logger in the adjacent explosion-proof box.

A third RAM-1 was mounted together with a Rustrak recorder in a NEMA-4 enclosure to provide a self supporting dust measurement system which was principally employed to check intake contamination levels.

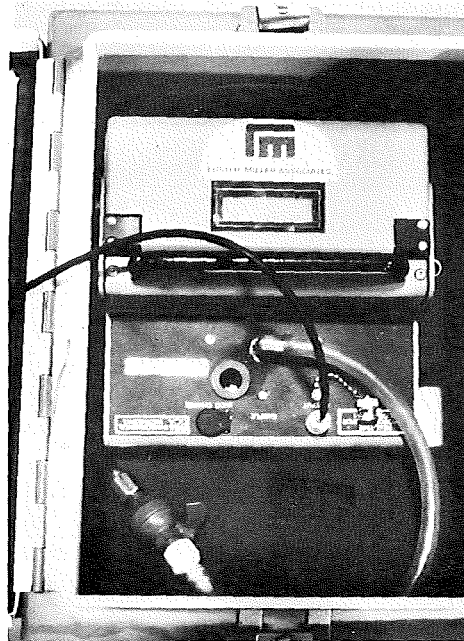


FIGURE 18. - Tailgate RAM.

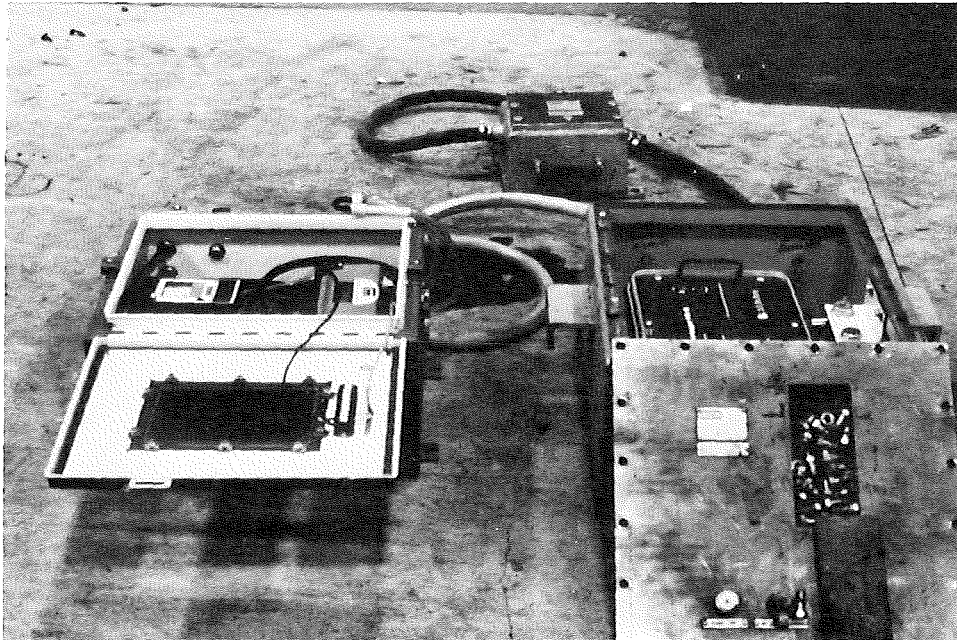


FIGURE 19. - Midface RAM and recorder box.

The shearer monitoring package consisted of an explosion-proof box to be mounted on the top of the shearer body (Figure 20). Connected to the box are a Rustrak recorder and a battery power enclosure.

6.5 Instrument Installation

The instrumentation referred to above was first installed in the mine on 20 June 1980. The tailgate dust measurement system was installed with the intake cyclone attached to the face lighting system support lug on the 91st shield by a special bracket manufactured in situ from discarded welding rod (see Figure 21). The RAM-1 enclosure was secured to the upper left hand gob shield linkage on this shield (Figure 22).

The midface RAM-1 was installed in a similar manner on the 53rd shield (Figure 23), the recorder box being placed in a similar position within the 54th shield. The electrical connection between the tailgate monitor and the midface recorder was made via a cable attached to the cable handler bracket on the face conveyor furniture. In order to protect the cable at the points where transition was made from the conveyor to the shield, a length of 4-in. rock dusting hose was used at each location as an outer covering.

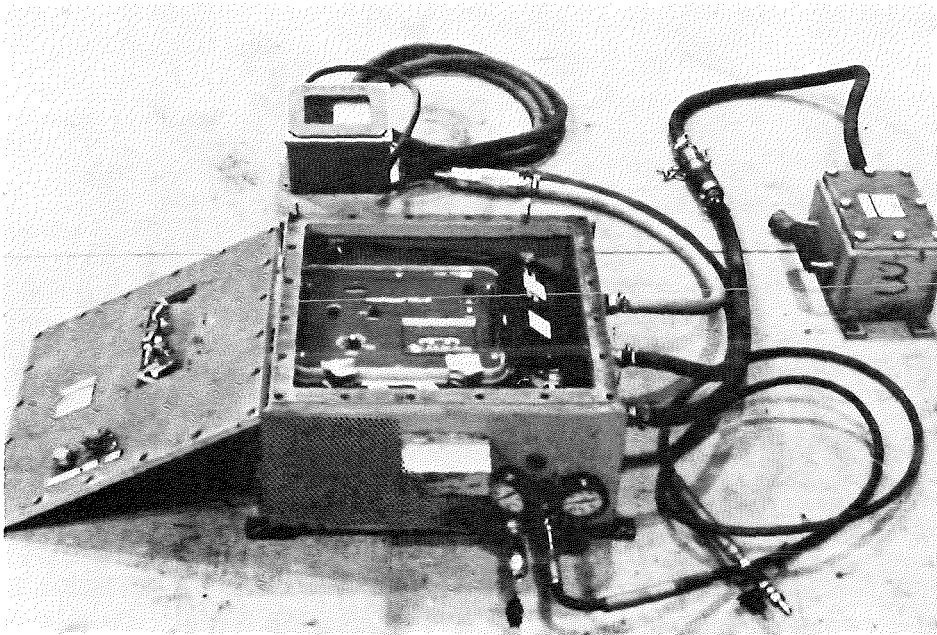


FIGURE 20. - Shearer monitoring package.



FIGURE 21. - RAM intake.

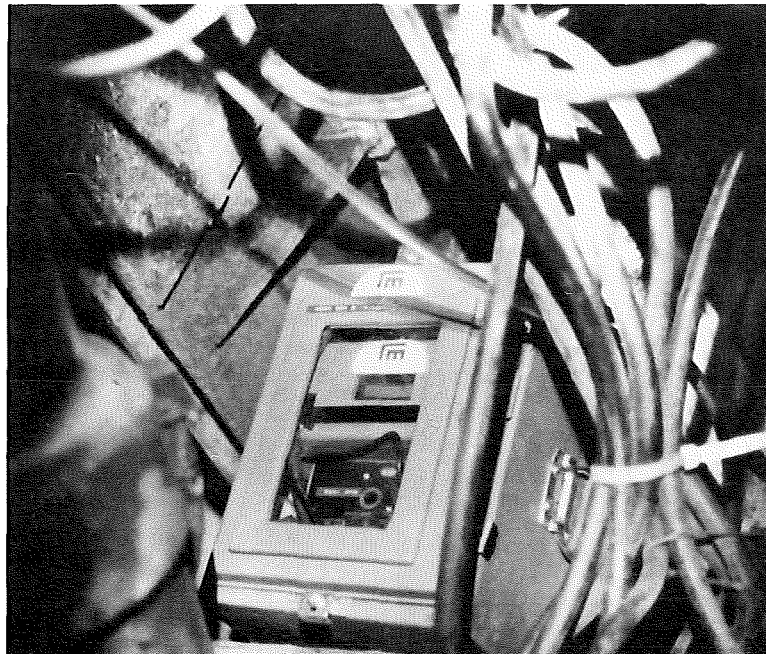


FIGURE 22. - Tailgate RAM in position.

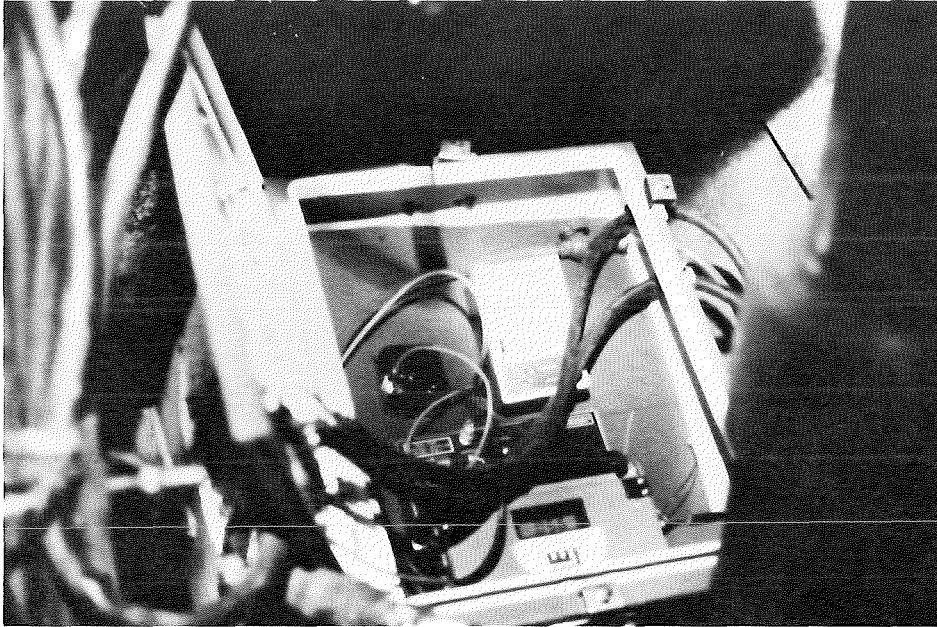


FIGURE 23. - Midface RAM in position.

The shearer monitoring package was mounted on the top of the shearer body (Figure 24) with the speed sensor positioned in an aperture cut in the "fender" of the headgate chainless haulage roller (Figure 25).

The third RAM-1 package was positioned in the headgate area as was the recording wattmeter which was connected into the main shearer power supply cable adjacent to the face electrical control boxes.

Among other practical matters of note were the steps taken to obtain the required speed range via the use of change gears. After 2 weeks of data taking at 35 and 45 rpm, the two change gears (Figure 26a) were fitted to the tailgate gearhead of the shearer in approximately one shift (Figure 26b). Also worthy of note was the use made of the face power center to recharge batteries between data gathering shifts. The availability of 110 Vac at this point allowing RAM and data logger batteries to be recharged underground was a considerable convenience (see Figure 27).



FIGURE 24. - Shearer monitor in position.

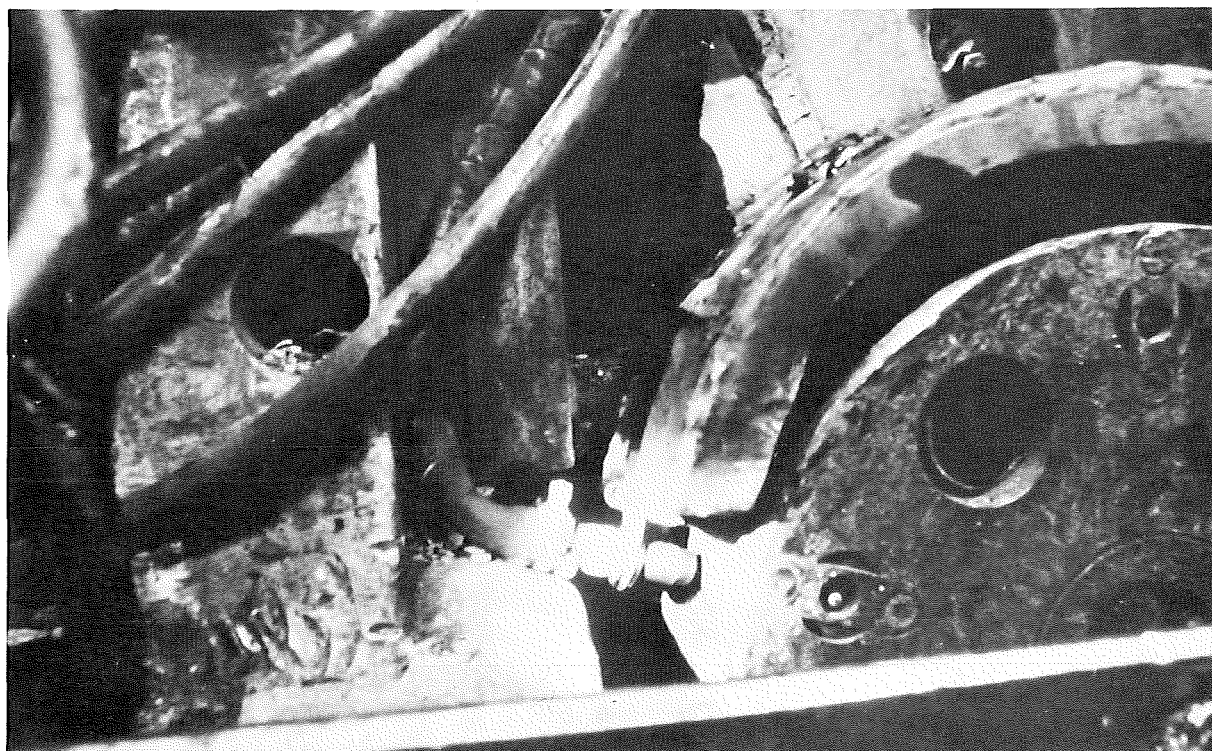
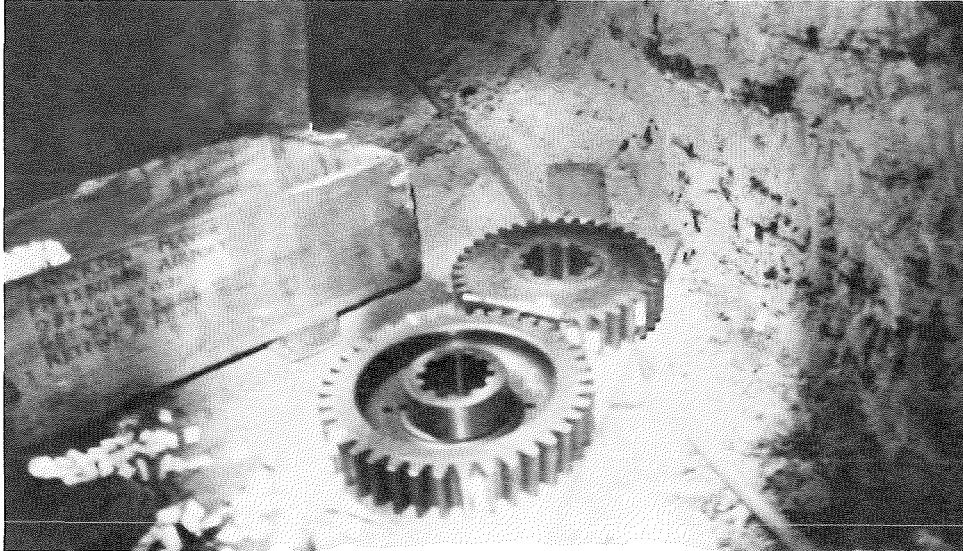
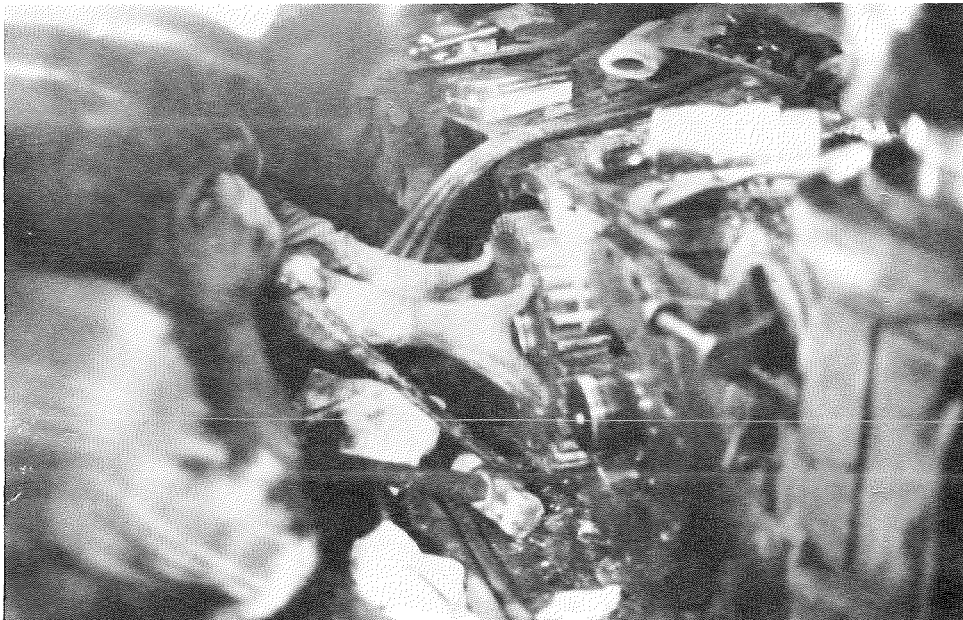


FIGURE 25. - Speed sensor mounting.



a) CHANGE GEARS



b) INSTALLATION

FIGURE 26. - Change gears installation.

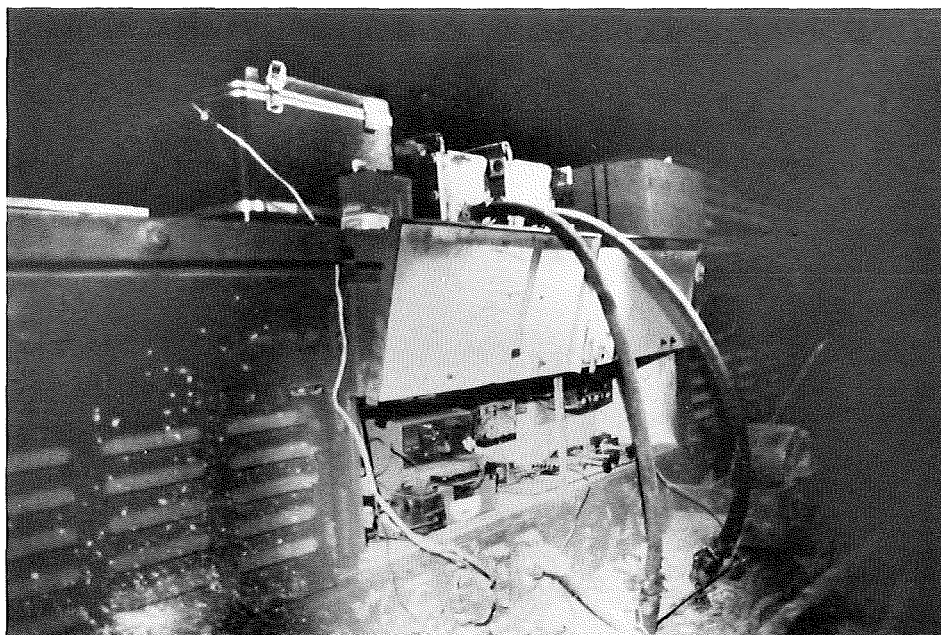


FIGURE 27. - Instrument batteries recharged at face power center.

7. DATA GATHERING

The underground data gathering phase of this trial commenced with installation of the face instrumentation on 20 June 1980. Due to difficulties encountered by the mine operator, the instrumentation was withdrawn following checkout and reinstalled on 26 July. Data gathering commenced on 28 July and continued until 19 September.

During this period, data were gathered on 27 full shifts. The schedule of data gathering is illustrated in Table 4.

As has been noted it was decided to follow a single crew through their weekly shift rotation cycle and to thereby reduce the effect due to different operators. That the data gathering schedule differs markedly from the experimental plan was due to the exigencies of underground operation. For instance:

- a. It was considered realistic to make only one complete cycle of change gear fitting (installation and removal) rather than the two called for in the original experimental plan, since the mine was unwilling to commit the additional labor.
- b. It was not possible to operate at the extreme of the penetration range (5.2 and 6.9 in. corresponding to 45 and 35 rpm at one pick per line), since it was evident that the next highest penetration (4.4 in., 55 rpm, one pick per line) was at extreme of the range at which the stability of the machine was preserved.
- c. The distribution of drum speeds was biased towards 45 and 70 rpm since the tendency was for the operators to insist on what they considered to be the "normal" gear setting when difficult cutting conditions were encountered.
- d. Cutting against the airflow was not conducted in a systematic manner since the mine's ventilation and dust control plan did not allow this. However, data were gathered whenever face realignment required that extended cuts towards the headgate take place.

TABLE 4. - Data gathering schedule

Date	Drums	Speed (rpm)	Picks per line	Remarks
7/29	0	45	Two	0 = old drums
7/30	0	45	Two	
7/31	0	35	Two	
8/1	0	35/45	Two	
New drums fitted				
8/4	N	45	Two	N = new drums
8/5	N	35	Two	
8/6	N	45	Two	Some Bi-Di cutting
8/7	N	45	Two	Some Bi-Di cutting
Change gears fitted				
8/11	N	70	Two	All dust data corrupt
8/12	N	55	Two	
8/13	N	55/70	Two	
8/14	N	70	One	
8/15	N	70	Two	
8/18	N	70	Two	
8/19	N	55	One	
8/20	N	70	Two	
8/21	N	70	Two	
8/22	N	55	Two	
8/25	N	70	One	
Change gears removed				
9/8	N	35/45	Two	
9/9	N	35/45	Two	
9/10	N	35/45	Two	
9/11	N	35	Two	
9/15	N	45	Two	
9/16	N	45	Two	
9/17	N	45	Two	
9/18	N	45	Two	
9/19	N	45	Two	No headgate cowl

```

915402
MIDFACE REC 9/15 40 EG 35AND45 2PPL
5.0
5.151
1+0018 2+0762 1+0018 2+0761
1+0018 2+0760 1+0017 2+0761
1+0017 2+0759 1+0017 2+0768 00003
1+0018 2+0764 1+0019 2+0765
1+0017 2+0766 1+0018 2+0761
1+ 018 2+0761 1+0018 2+0761 000100
1+0017 2+0761 1+0017 2+0761
1+0017 2+0761 1+0018 2+0761
1+0018 2+0761 1+0017 2+0761 000130
1+0017 2+0761 1+0017 2+0761
1+0017 2+0761 1+0017 2+0761
1+0017 2+0761 1+0017 2+0761 000200
1+0017 2+0761 1+0017 2+0761
1+0017 2+0761 1+0017 2+0761
1+0017 2+0761 1+0017 2+0761 000230
1+0017 2+0761 1+0017 2+0761
1+0016 2+0761 1+0017 2+0761
1+0017 2+0761 1+0017 2+0761 000300
1+0016 2+0761 1+0016 2+0761
1+0016 2+0762 1+0016 2+0761
1+0017 2+0762 1+0016 2+0761 000330
1+0017 2+0761 1+0017 2+0761

```

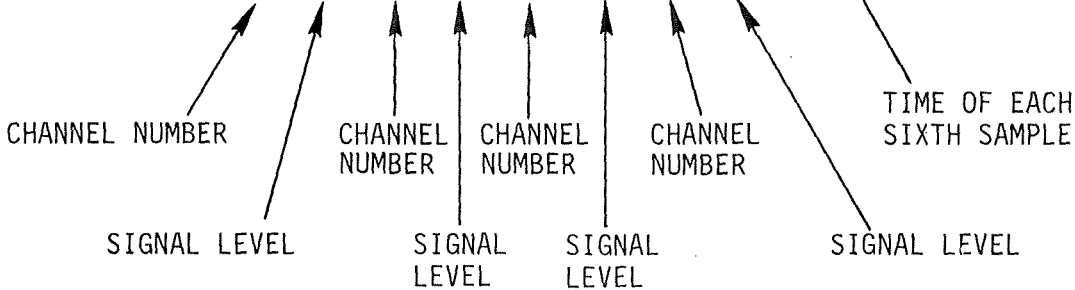


FIGURE 28. - Dust level and elapsed time data.

38	5.81	28	5.30	17.42
50	5.85	28	5.32	17.50
81	5.92	28	5.35	17.58
88	5.99	29	5.37	17.67
88	6.06	29	5.39	17.75
101	6.15	28	5.42	17.83
100	6.23	28	5.44	17.92
98	6.31	28	5.46	18.00
100	6.40	28	5.49	18.08
106	6.48	28	5.51	18.17
110	6.58	28	5.53	18.25
112	6.67	28	5.56	18.33
120	6.77	29	5.58	18.42
139	6.89	29	5.61	18.50
161	7.02	30	5.63	18.58
179	7.17	33	5.66	18.67
202	7.34	38	5.69	18.75
216	7.52	42	5.73	18.83
226	7.71	47	5.76	18.92
261	7.92	55	5.81	19.00
305	8.18	60	5.86	19.08
356	8.47	65	5.91	19.17
403	8.81	71	5.97	19.25
456	9.19	79	6.04	19.33
493	9.60	78	6.11	19.42
550	10.06	80	6.17	19.50
611	10.57	82	6.24	19.58
603	11.07	84	6.31	19.67
594	11.57	96	6.39	19.75
603	12.07	104	6.48	19.83
651	12.61	118	6.57	19.92
642	13.15	132	6.68	20.00
657	13.69	145	6.81	20.08
643	14.23	161	6.94	20.17
606	14.73	153	7.07	20.25
600	15.23	194	7.23	20.33

KEY:

Column 1 - Dust level, Channel 1 (midface)
Column 2 - Cumulative dust level, Channel 1
Column 3 - Dust level, Channel 2 (tailgate)
Column 4 - Cumulative dust level, Channel 2
Column 5 - Elapsed time (minutes)

FIGURE 29. - Output of dust level data transformation.

events was noted. These tapes were transcribed to provide an event listing of the form shown in Figure 30 which was then available for combination with the cumulative dust exposure data.

8.2 Preparation for Statistical Analysis

The two principal data sets, the cumulative dust level exposures and the face activity logs existed in a form suitable for examination. The remaining data required for the dust level analysis consisted of records of drum type, speed, number of picks per line and ventilation velocity.

Since ventilation velocity had been measured on a once per shearing cycle basis it was appropriate to make the individual cycle the basis for the statistical analysis. To this end the following quantities were extracted from the cumulative exposure listings.

8.2.1 Dust Make per Unit of Face Cut During Fully Sumped Cutting

This quantity was obtained by determining the increase in dust level exposure during the period that the machine took to cut between two given shields upwind of the monitor in question.

In the case of the midface monitor this was generally for a distance of 10 to 15 shields between the thirtieth and fiftieth shield and in that of the tailgate monitor 30 to 40 shields between the fiftieth and ninetieth shields.

Although transit times would be significant for dust generated at the fiftieth shield measured at the tailgate, *differences* between the individual cycles were assumed to be trivial and no attempt was made to account for this factor.

Having derived a figure for dust make over a known number of shields this was then divided by the number of shields involved to generate a quantity with the dimensions of milligrams per cubic meter times minutes per shield. This quantity, although clumsily dimensioned, is a measure of dust make during the part of the cutting cycle that is of principal interest and is insensitive to minor delays during cutting and incorporates an integration (averaging) over a length of face that will reduce the impact of uncontrolled changes in cutting conditions.

REMARK	SPEED (ft/min)	POSITION (SHIELD)	TIME
.	.	.	.
.	.	.	.
		45	02:46:52
BAD TOP	16.7	47	02:47:28
SS			47:54
SRM			48:04
		49	48:18
ARM VIBRATION	18.2	51	02:48:51
	18.8	53	02:49:23
27 in. WEB SLABBING IN FRONT OF SHEARER	20.0	55	02:49:53
NO ARM VIBRATION	23.0	58	02:50:32
	20.0	59	50:47
.	.	.	.
.	.	.	.
.	.	.	.

SRM = SHEARER RESUMES MOTION
SS = SHEARER STOPS

FIGURE 30. - Example of event listing.

8.2.2 Dust Make From Sump in During the Cut to the Tailgate

On each cumulative exposure listing the point at which the shearer entered the sump (at approximately the twentieth shield) when traveling towards the tailgate was noted and the increase in cumulative exposure between this point and the time at which the shearer cut past the sensors (at the fifty-third and ninety-first shields) noted. Thus, a quantity was obtained representing the exposure at the two measurement positions due to that part of the cycle during which the tailgate drum was the principal dust producing element.

8.2.3 Dust Make over Single Whole Cycles

This quantity represents the increase in cumulative exposure at a given location from the time that the shearer first entered the sump at the twentieth shield (traveling to the tailgate) and the time when it returned to that location to commence a new cycle.

These statistics were prepared for each cycle recorded on the 27 shifts on which data were recorded. However, certain cycles were discarded due to atypical operation such as oversumping, fly cutting or instrument problems. Eighty-one cycles of "good data" were obtained though each statistic was not available for all cycles since, though it was nearly always possible to obtain figures for dust make per shield, the dust make per whole cycle required that the whole cycle be recorded and this was not always done for the first or last cycle on a given shift.

It can be seen that each of these quantities will reflect progressively more influence of nonexperimental dust sources and will therefore require a greater effect of the experimental variable - depth of cut - for a significant influence to be shown.

8.3 Ventilation Velocity Correction

It became apparent during the preliminary week of data gathering with the old drums that the face ventilation velocity varied significantly in a nonsystematic manner. It was also apparent that the velocity would have to be measured on a per cycle basis and the dust level data adjusted to take account of the dilution effect.

For this reason the six basic dust level statistics described above (for example, dust make per shield, dust make per sump cycle, and dust make per whole cycle at midface and tailgate), were normalized to a ventilation velocity of 200 ft/min by multiplying by the actual velocity and dividing by 200. In this way an inverse dependence of dust level on ventilation velocity was assumed and adjusted for. The validity of this assumption is discussed and to some extent tested in Section 9.

8.4 Data Preparation for Statistical Analysis

The bulk of the statistical analysis of the dust level data was conducted using a suite of computer programs known as the Statistical Package for the Social Sciences (SPSS). This package, though designed, as its name implies, for the social sciences, is a very powerful analysis tool which may be employed to process any data which can be arranged in a consistent case-by-case manner. The version of SPSS that was employed was Version 8.0 implemented on the CDC 6000 series and running in the time share mode on the Cybernet NOS interactive system.

The data prepared for SPSS consisted of those items listed in Table 6 for each of the 81 shearing cycles. The abbreviations in the right hand column represent the SPSS system names assigned to each variable and will be used during the discussion of results in the following section. These data are listed in Appendix D in the form in which they were presented for analysis.

8.5 Primary Statistical Analysis

8.5.1 Transformations

As noted above the dust level data provided in the data set were normalized to a ventilation velocity of 200 ft/min by the assumption of inverse proportionality between dust level and ventilation velocity. In order to assess the validity of this assumption the original "raw" dust level was recomputed by the analysis program.

8.5.2 Data Selection

The overall data set may be considered to contain three subsets within and between which comparison may be made. These are:

TABLE 6. - Data for statistical analysis

Variable	Values	SPSS name	Column
● Drum type	1 = old, 2 = new	DM	1
● Date	0729 = seventh September	DATE	2 to 5
● Drum speed	1 = 35, 2 = 45, 3 = 55, 4 = 70	SP	6, 7
● Number of picks per line	1 or 2	PKS	8
● Dust generated per shield measured at midface (channel 1) and adjusted for ventilation velocity	} Three-digit integer = absolute value × 100	CH1	9 to 11
● As above at the tailgate (channel 2)		CH2	12 to 14
● Dust generated from sumping during cut to tailgate measured at midface (channel 2) and adjusted for ventilation velocity	} Three-digit integer representing absolute value	CH1S	15 to 17
● As above at the tailgate (channel 2)		CH2S	18 to 20
● Dust make over a whole cycle measured at the midface (channel 1) and adjusted for ventilation velocity		CH1C	21 to 23
● As above at the tailgate		CH2C	24 to 26
● Ventilation velocity	Feet per minute to three significant figures	VENT	27 to 29

- a. Data derived from the old drum at 35 and 45 rpm at two picks per line
- b. Data derived from the new drum at 35, 45, 55 and 70 rpm at two picks per line
- c. Data derived from the new drum at 55 and 70 rpm at one pick per line.

In the analysis that follows, the main data set is considered to be that relating to the new drum with two picks per line.

8.5.3 Data Analysis

In the majority of the analyses that were conducted, drum speed, which is analogous and inversely proportional to depth of cut, at constant pick lacing and machine haulage speed, is the primary independent variable.

The initial analysis was conducted systematically to assess the effect of drum speed and other variables such as ventilation velocity on a number of dependent variables which are listed in Table 7 below.

TABLE 7. - Dependent variables

Quantity	Corrected for ventilation velocity	Uncorrected for ventilation velocity
Dust make per shield	CH1, CH2	VCH1, VCH2
Dust make per sump cycle	CH1S, CH2S	VCH1S, VCH2S
Dust make per whole cycle	CH1C, CH2C	VCH1C, VCH2C

The nomenclature used in naming these variables is as follows:

- a. CH1 - Channel 1, midface position on fifty-third shield
- b. CH2 - Channel 2, tailgate position on ninety-first shield
- c. Suffix
 - No suffix = dust make per shield
 - S = dust make from sumping in at twentieth shield to passing RAM intake during cut to tailgate
 - C = dust make during a complete cycle
- d. Prefix
 - No prefix = normalized to a ventilation velocity of 200 ft/min (measured at midface)
 - V = unnormalized raw data.

The principal tools of statistical analysis were the following:

- a. First Order Zero Moment Correlation Coefficients - There are simple correlation coefficients measuring the degree of association between two variables. A correlation of +1 or -1 implies a perfect correlation while zero implies no association. Between these extremes the reality of an observed degree of association may be assessed by computing a value of significance for the observed correlation and the number of cases. This means that if the correlation coefficient is calculated and the number of cases is known the "significance" of this degree of correlation can be calculated in terms of the probability (P) that the degree of correlation observed could have been observed by chance. For example, a correlation of 0.5 based upon 40 cases will be observed by chance less than one time in a hundred ($P \leq 0.01$).
- b. Partial Correlation Coefficients - Where a danger exists that improper conclusions may be drawn due to the association of the dependent variable with an independent variable which is itself associated with

a second independent variable, the last mentioned variable may be partialled out to remove the effect of the second independent variable.

- c. Multiple Linear Regression - In this form of analysis the dependence of the dependent variable on one or more independent variables is examined. In the form used, the variables are entered into the regression equation in a specified order. At each stage, the degree to which the variable(s) in the equation has accounted for the observed variability of the dependent variable is computed along with the regression coefficients which are the values of a in the following equation.

$$y = a_1x_1 + a_2x_2 + \dots a_nx_n + c$$

In the multiple regression procedure the significance of the regression and the confidence in the regression coefficients a_1 to a_n and the intercept c are also computed.

- d. Breakdown/Two-Way Analysis of Variance - If one variable is discontinuous or may be categorized, it may be convenient to calculate the value of the dependent variable for each of the several discrete values of the dependent variable. Having arrived at a figure for the mean value and standard deviation associated with each value of the independent variable, an analysis of variance can be conducted. Data relating to the mean and standard deviation for each of the experimental conditions are contained in Appendix G.

The analyses were performed by issuing instructions to the SPSS program to read, select and transform the data set and then to perform the required analysis procedures. Appendix E contains a sample SPSS instruction list.

In the section that follows, the results of these analyses are first reported and discussed with reference to the three data sets. The concluding subsection refers to measured values of shearer haulage speed and power consumption and their interaction with drum speed.

9. TRIAL RESULTS

The purpose of this trial was the determination of the relationships between a number of variables. As was expected, these relationships were found to be complex, and their detection and evaluation required the use of statistical tools which may not be familiar to the general reader.

In the next four subsections, the outcome of this trial is reported and discussed in terms of the results of these statistical analyses. At the conclusion of this section, however, subsection 9.6 is included which contains a summary of the results of this analysis in simple language rather than in statistical jargon.

ARD levels were measured at the midface and tailgate and three separate statistics relating to different kinds of cumulative exposure were calculated for each position. In addition, both normalized (for ventilation) and raw dust exposure levels were calculated for each case. This combination of data sets, measurement location, exposure statistics and normalization yields a potentially unwieldy range of dependent variables.

It is intended that the results of the statistical analysis should be presented systematically in the following manner:

- a. The order in which the results will be presented is as follows:
 - New drum - two picks per line
 - New drum - one and two picks per line
 - Old drum - two picks per line.
- b. Where it is appropriate, data relating to dust make per shield will be first examined followed by dust make per sump cycle and dust make per overall cycle.
- c. Precedence will in each case be given to the data recorded at midface prior to that recorded at the tailgate.
- d. The normalized (for ventilation velocity) results will be compared with raw data.

- e. At the conclusion of the analysis of dust level data results concerning shearer haulage speed and power consumption will be presented.

Since the presentation of results will be unavoidably repetitive, it is intended that explanation of statistical tests will not be repeated for every case.

The first data set to be examined will be that concerning the new drums operating with two picks per line.

9.1 New Drums - Two Picks Per Line

This data set consists of the results of 56 cutting cycles at speeds ranging from 35 to 70 rpm.

9.1.1 Dust Make Per Shield

9.1.1.1 Midface

Dust levels were sampled at the fifty-third shield during the main run of cutting between the thirtieth and fiftieth shields during fully sumped cutting. The dust exposure at the fixed point per shield of shearer advance was calculated, normalized for ventilation velocity in the manner referred to in subsection 8.2, and designated CH1. The unnormalized dust make per shield is VCH2.

Correlation

Figure 31 shows the correlation matrix calculated for CH1, VCH1, VENT (ventilation velocity), and SP (drum speed).

It can be seen that both CH1 and VCH1 are positively associated with SP ($r = 0.7418$ and $r = 0.6349$, respectively). Both of these values represent correlation at a significance above the 0.1 percent level and indicate the association of higher drum speeds (and lower penetrations) with high dust levels.

The improvement represented by the higher correlation of the normalized variable CH1 suggests the appropriateness of this normalization since CH1 accounts for 55 percent of the variance in SP (or vice versa) rather than the 40 percent associated with VCH1.

	CH1	VCH1	SP	VENT
CH1	1.0000 (0) P=*****	.9360 (44) P= .001	.7418 (44) P= .001	.6150 (44) P= .001
VCH1	.9360 (44) P= .001	1.0000 (0) P=*****	.6349 (44) P= .001	.3180 (44) P= .018
SP	.7418 (44) P= .001	.6349 (44) P= .001	1.0000 (0) P=*****	.5900 (56) P= .001
VENT	.6150 (44) P= .001	.3180 (44) P= .018	.5900 (56) P= .001	1.0000 (0) P=*****

KEY:
 CH1 (S,C) - NORMALIZED DUST LEVEL AT MIDFACE
 VCH1 (S,C) - RAW DUST LEVEL AT MIDFACE
 SP - DRUM SPEED
 VENT - VENTILATION VELOCITY

FIGURE 31. - Correlation matrix at midface.

The above represents the results that are to be expected from a trial of this kind. What was not expected was the association between VENT and SP ($r = 0.59$, $p = 0.001$). This turns out to be an experimental artifact which was not amenable to control and is a result of some extremely low ventilation velocities being associated with the lower drum speeds, particularly 35 rpm. Figure 32 shows a scattergram of VENT and SP and it can be seen that ventilation velocities of less than 175 ft/min are only associated with the lower two drum speeds (35 and 45 rpm).

In the context of this experiment it must be assumed that this association of ventilation velocity with both dust level and drum speed is a potentially confounding factor which may undermine the validity of the conclusions drawn from the trial.

The first step taken to determine whether this was so was to determine whether VENT was associated with dust level in the absence of change of drum speed. To this end partial

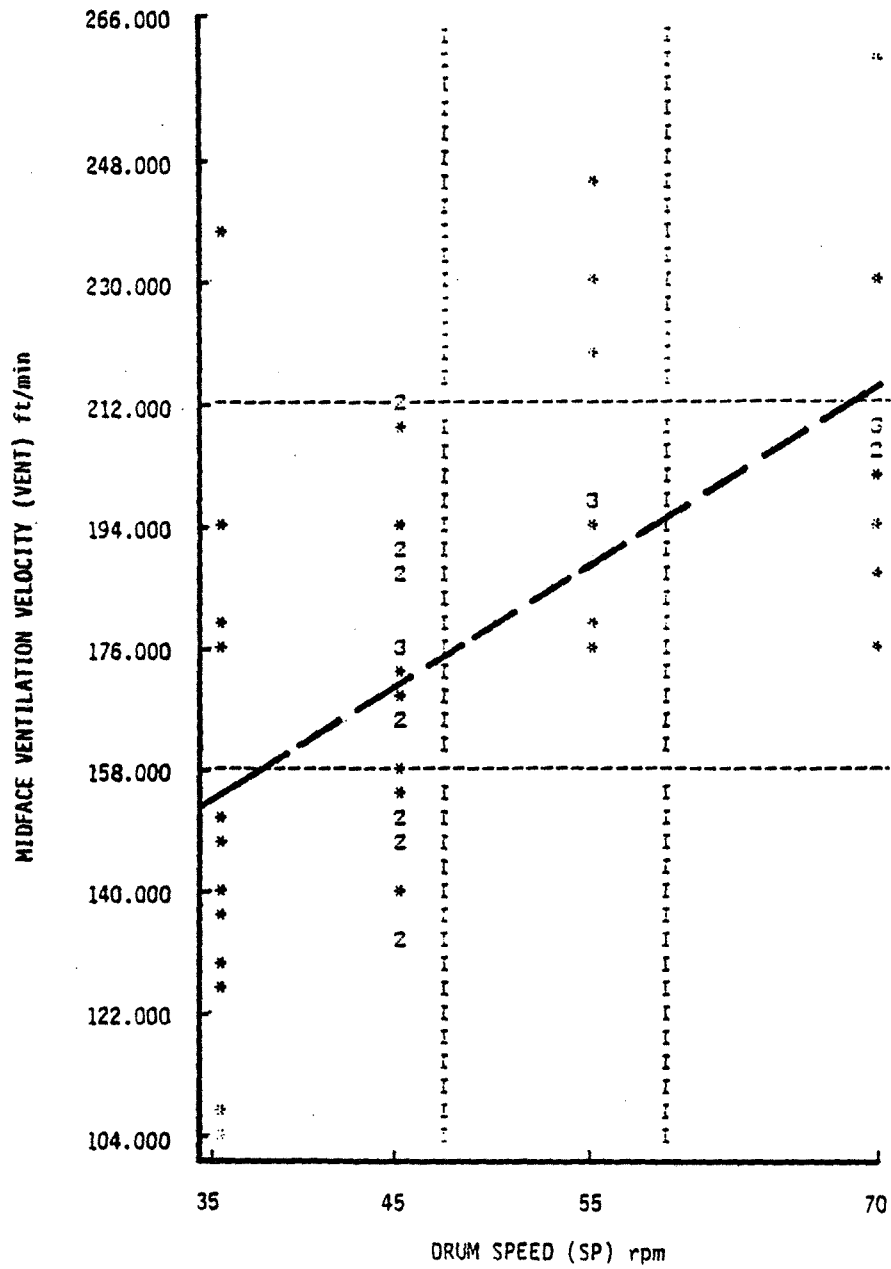


FIGURE 32. - Scattergram of ventilation velocity and drum speed.

correlation coefficients were calculated with CH1 and VCH1 as the dependent variables, VENT as the independent variable and SP as the controlled "partialled out" variable.

The results of this calculation were as follows:

- a. CH1 with VENT controlled for SP: $r = 0.2933$,
 $0.05 \geq P \geq 0.01$
- b. VCH1 with VENT controlled for SP: $r = 0.1264$,
 $P \geq 0.05$.

The first of these shows a marginally significant association of CH1 with VENT which is in a positive direction. This suggests that at higher ventilation velocities the dilution effect assumed in the hypothesis used to normalize for ventilation velocity does not hold and more dust than anticipated is observed in the air-stream. This effect may possibly be due to pickup of dust by higher velocity airflow.

The second correlation coefficient shows a nonsignificant association between the raw dust level (VCH1) and VENT. Though the correlation is not significant it is in the direction that would be suggested by the dilution hypothesis (more air equals less dust). The dilution hypothesis cannot be rejected on this evidence alone; and since other tests reinforce its utility it has been retained and the normalized dust level (CH1, etc.) retained as the principal dependent variable.

When this effect of VENT was partialled out and CH1 and VCH1 correlated with SP with VENT controlled, the following results were obtained:

- a. CH1 with SP controlling for VENT: $r = 0.5821$,
 $p = 0.001$
- b. VCH1 with SP controlling for VENT: $r = 0.2933$,
 $0.05 \geq p \geq 0.01$.

The first of these results may be taken as a confirmation of the hypothesis that this trial was set up to test at this position on the face: that at high drum speeds (low penetration) dust levels tended to be high and that this tendency would not be expected to be observed by chance more than one time in one thousand.

The second coefficient associated with the raw data passes the classical test of significance ($p \leq 0.05$) but is less than that corresponding to the normalized dust level. This suggests that in this case the normalization for ventilation velocity was the correct procedure.

Regression

Stepwise multiple regressions were performed with CH1 and VCH1 as the dependent variables and SP and VENT as the independent variables. In both cases the regression was constrained so that SP alone was entered into the regression equation at the first step.

The first stages of regressions of SP on CH1 and VCH1 both confirm the conclusions drawn from correlation analysis that in both cases SP is a predictor of dust level and that the normalized dust level is the superior predictor ($R = 0.742$, $F = 51.38$ against $R = 0.635$, $F = 28.36$).

The inclusion of VENT as the second term in the multiple regression slightly improved the R^2 term while reducing overall significance and yielding nonsignificant regression coefficients for VENT in both cases.

The conclusion drawn from this is that even though there is an ecological correlation between CH1 and VENT the effect over and above that allowed for by normalization is not quite strong enough to show significance with these data. In the case of VCH1 the suggestion is of an inverse relationship (more VENT, less dust), but one which does not take a linear first order form (for example, $VCH1 + \text{constant} \times VENT$) rather than the one assumed ($VCH1 \times \text{constant}/VENT$).

The regression equations achieved with the normalized variable CH1 are as follows:

- a. Simple: $CH1 = 7.33 \times SP - 131.2$
- b. Multiple: $CH1 = 5.79 \times SP + 0.97 \times VENT - 228.9$.

The results and statistics associated with the regressions referred to above are included in Appendix F.

Scattergrams

In order to illustrate the regression equations referred to above, scattergrams, plots of CH1 and VCH1, were generated on which the equations could be drawn. Also determined were the mean and standard deviation of CH1 and VCH1 at each drum speed.

Figures 33 and 34 show this information for CH1 and VCH1, respectively. The calculations of means and standard deviations included a test of linearity which in neither case revealed a significant nonlinearity.

9.1.1.2 Tailgate

Dust make per shield sampled at the ninety-first shield during the main run of cutting from the thirtieth to the ninetieth shields during fully sumped cutting is available in normalized form as CH2 and in raw form as VCH2.

Correlation

Figure 35 shows the matrix of correlation calculated for CH2, the normalized dust make at the tailgate, VCH2 its raw equivalent, VENT and SP. All correlation coefficients are significant at, at least, the 5-percent level with the exception of that between VCH2 and VENT. Again SP is correlated with VENT so partial correlation coefficients were calculated to provide further insight into the relationships.

When VENT was controlled neither CH2 or VCH2 shows significant correlation with drum speed (SP), though in both cases the nonsignificant correlations are positive. When speed (SP) is controlled, a positive correlation ($r = 0.306$ $0.05 \geq p \geq 0.01$) results between CH2 and VENT indicating that at this location higher ventilation velocities are associated with high values of normalized dust make. This coupled with the fact that VCH2 is negatively, though not significantly, correlated with VENT (SP partialled out - $r = -0.222$, $p = 0.062$) suggests that though a dilution effect assumed in the normalizing process may be present, its action at the tailgate is not as strong as the model used assumes. This may be due to either shortcomings in the methodology (VENT was measured between the thirtieth shield and mid-face) or to a dust pickup/deposition mechanism.

The lack of correlation between CH2 or VCH2 and SP when VENT is controlled suggests that the effect under study was not quite powerful enough *at the tailgate* to be observed under these circumstances.

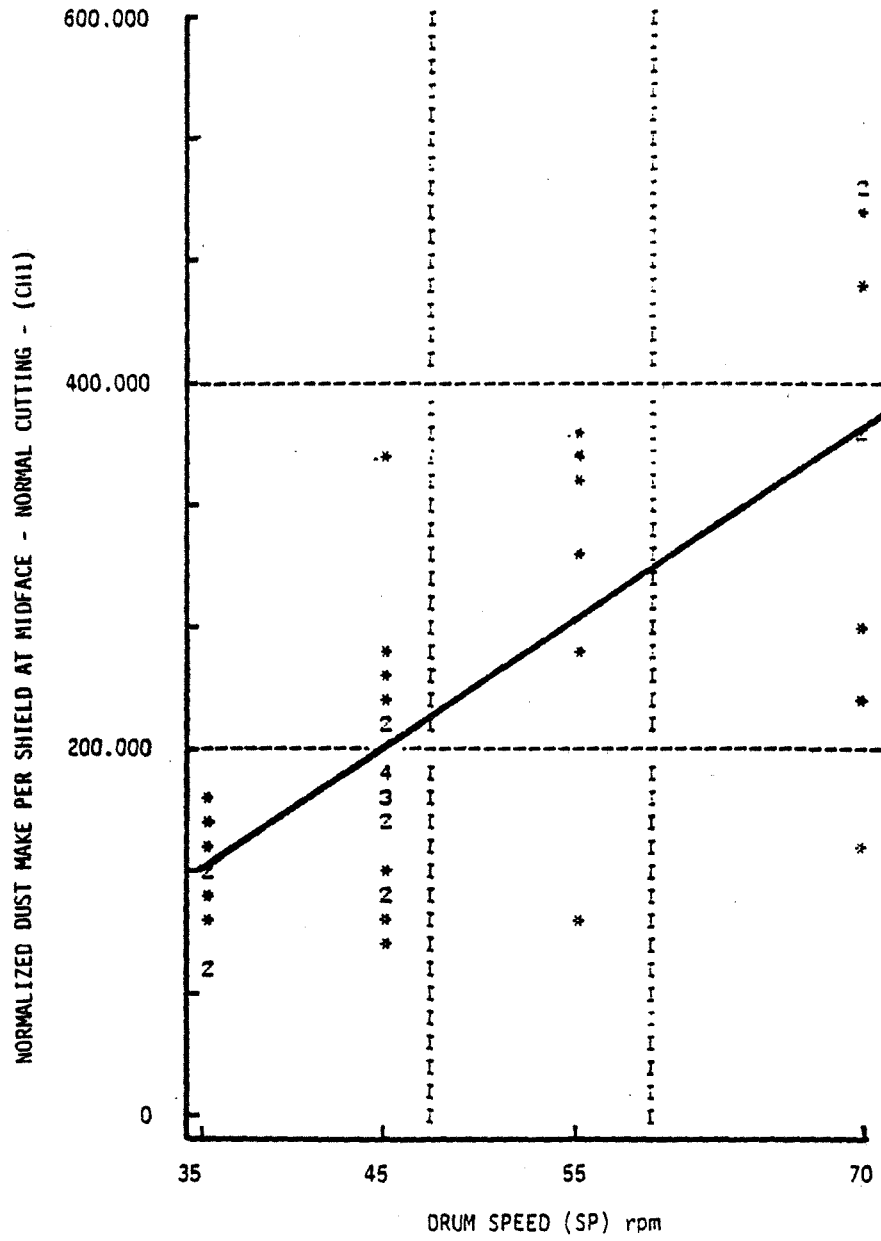


FIGURE 33. - Scattergram of normalized midface dust make per shield and drum speed.

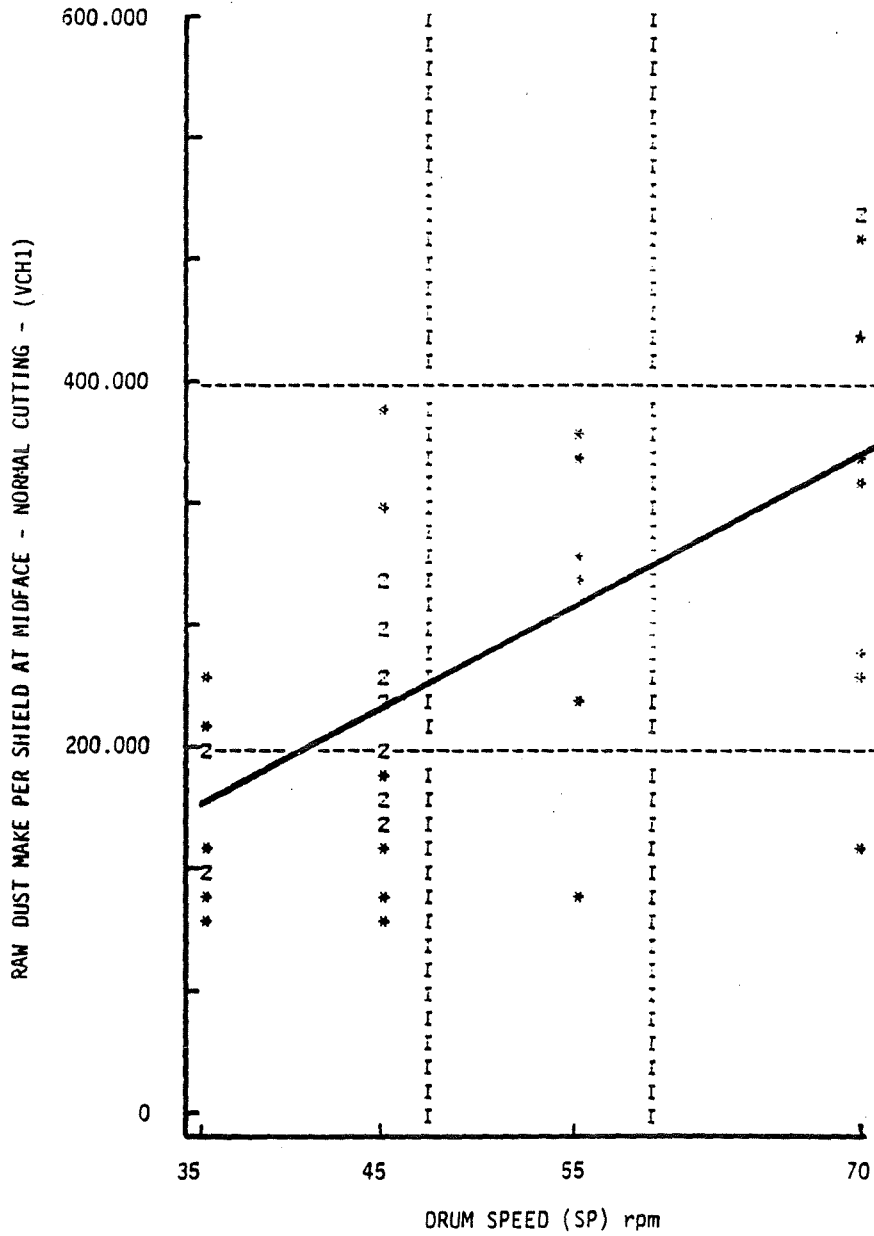


FIGURE 34. - Scattergram of midface dust make per shield (raw data) and drum speed.

	CH2	VCH2	SP	VENT
CH2	1.0000 (0) P=****	.7968 (50) P= .001	.3495 (50) P= .006	.4371 (50) P= .001
VCH2	.7968 (50) P= .001	1.0000 (0) P=*****	.0148 (50) P= .459	-.1719 (50) P= .116
SP	.3495 (50) P= .006	.0148 (50) P= .459	1.0000 (0) P=*****	.5900 (50) P= .001
VENT	.4371 (50) P= .001	-.1719 (50) P= .116	.5900 (50) P= .001	1.0000 (0) P=****

KEY:

CH2 (S,C) - NORMALIZED DUST LEVEL AT TAILGATE
VCH2 (S,C) - RAW DUST LEVEL AT TAILGATE
SP - DRUM SPEED
VENT - VENTILATION VELOCITY

FIGURE 35. - Correlation matrix at tailgate.

Regression

The above processes are reflected in the results of the regression analysis which yielded a significant association when CH2 and SP were alone related ($F = 6.68$, $p = 0.013$) though when the second independent variable (VENT) was entered, the predictive effect was transferred to VENT with the coefficient of VENT being positive and R^2 equal to only 0.204.

The regression equation is of the form $CH2 = 0.546 \times SP + 0.485 \times VENT + 30.47$ with the standard error of the coefficient of SP being 0.618. Regression of the raw dust make VCH2 with VENT and SP yielded no significant (in the statistical sense) results.

Appendix F contains a full set of the results of these regressions.

Scattergrams

Calculations of means and standard deviations and the plotting of scattergrams yielded no significant results with these data beyond a reinforcement of the conclusion that association of dust level and drum speed was very weak and that the majority of any observed effect at this location was due to the normalized dust level (itself a function of ventilation velocity) interacting with the drum speed due to its (drum speed) accidental association with ventilation velocity.

9.1.2 Dust Make During Cut to Tailgate

9.1.2.1 Midface

Dust levels were sampled and cumulated during the cut to the tailgate on normal modified half face cycles. Data gathered at the midface was cumulated from the point at which the sump began when the tailgate drum was at approximately the twentieth shield to the point at which the headgate drum passed the midface dust monitor intake at the fifty-third shield.

The dust level measurements were normalized for ventilation velocity to yield CH1S. The raw data are referred to as VCH1S. These quantities do not represent a dust make per unit distance of shearer travel as in subsection 9.1.1 above but total dust make for a given portion of the mining cycle.

A similar form of analysis to that described in subsection 9.2.1.1 was performed.

Correlation

The correlation matrix of CH1S, VCH1S, VENT, and SP (Figure 36) produced values similar to those produced when normalized dust make per shield (CH1 and VCH1) was considered. The only significant departure was the reduced correlation between raw dust level VCH1S and ventilation velocity which just failed to meet the 5-percent significance test.

Partial correlations were again examined and both the normalized and raw dust level statistics showed significant correlation with drum speed when ventilation velocity was controlled.

	CH1S	VCH1S	SP	VENT
CH1S	1.0000 (0) P=*****	.9171 (40) P= .001	.7244 (40) P= .001	.6010 (40) P= .001
VCH1S	.9171 (40) P= .001	1.0000 (0) P=*****	.5685 (40) P= .001	.2508 (40) P= .059
SP	.7244 (40) P= .001	.5685 (40) P= .001	1.0000 (0) P=*****	.5900 (56) P= .001
VENT	.6010 (40) P= .001	.2508 (40) P= .059	.5900 (56) P= .001	1.0000 (0) P=*****

KEY:
 CH1 (S,C) - NORMALIZED DUST LEVEL AT MIDFACE
 VCH1 (S,C) - RAW DUST LEVEL AT MIDFACE
 SP - DRUM SPEED
 VENT - VENTILATION VELOCITY

FIGURE 36. - Correlation matrix at midface - including sump.

Controlling for VENT, the values are:

- a. CH1S with SP: $r = 0.547$, $p = 0.001$
- b. VCH1S with SP: $r = 0.553$, $p = 0.001$.

The partial coefficients achieved when SP was controlled were both not significant at the 5-percent level.

Controlling for SP:

- a. CH1S with VENT $r = 0.240$, $p = 0.070$
- b. VCH1S with VENT $r = -0.198$, $p = 0.113$.

Again the direction of the correlation coefficients agree with the hypothesis that dust levels are diluted by increased ventilation but that the model used slightly overestimates the overall effect.

Regression

The results of regression of SP and VENT on CH1S and VCH1S were almost precisely similar to those reported in subsection 9.1.1.1 where CH1 and VCH1 were involved. In each case the regression of the dependent variables (CH1S and VCH1S) with SP as the single independent variable was highly significant while the addition of VENT to the regression equation, while it did not result in a significant regression coefficient, did marginally increase the R^2 term.

The regression equations for CH1S were as follows:

- a. Simple: $CH1S = 1.771 \times SP - 21.24$
- b. Multiple: $CH1S = 1.418 \times SP + 0.207 \times VENT - 41.14.$

The complete regression statistics are printed in Appendix F.

Scattergrams

Scattergrams were produced for both CH1S and VCH1S as a function of SP. They are reproduced as Figures 37 and 38. There was no indication of significant nonlinearity in either case.

9.1.2.2 Tailgate

Total cumulative dust make during cutting to the tailgate measured at the ninety-first shield is available in the form of CH2S and VCH2S (raw). These statistics represent the total cumulative exposure from the point that the tailgate drum sumps in at approximately the twentieth shield to the point that the machine passes the monitor intake at the ninety-first shield.

Correlation

Once again the correlation matrix generated between CH2S, VCH2S, VENT and SP was broadly similar to the equivalent one described in subsection 9.1.1.2 which concerned dust make per shield. Examination of partial correlation coefficients also showed a similar picture though in this case the correlation between CH2S and VCH2S with SP were significant at the

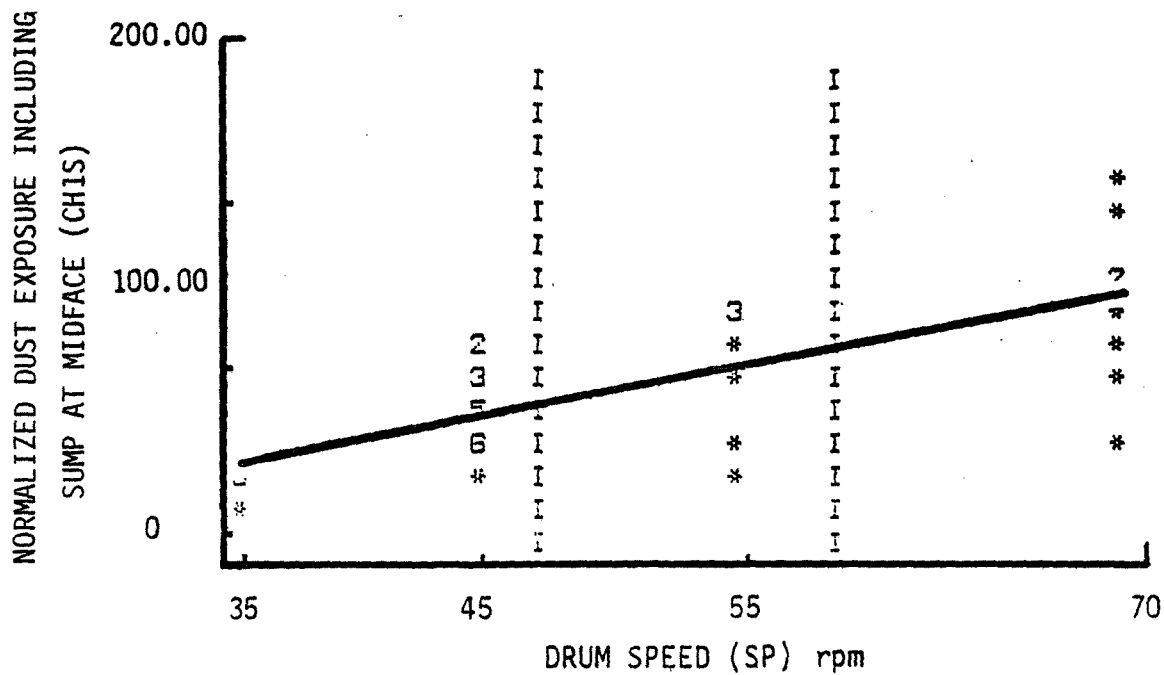


FIGURE 37. - Scattergram of midface dust make exposure (including sump) and drum speed.

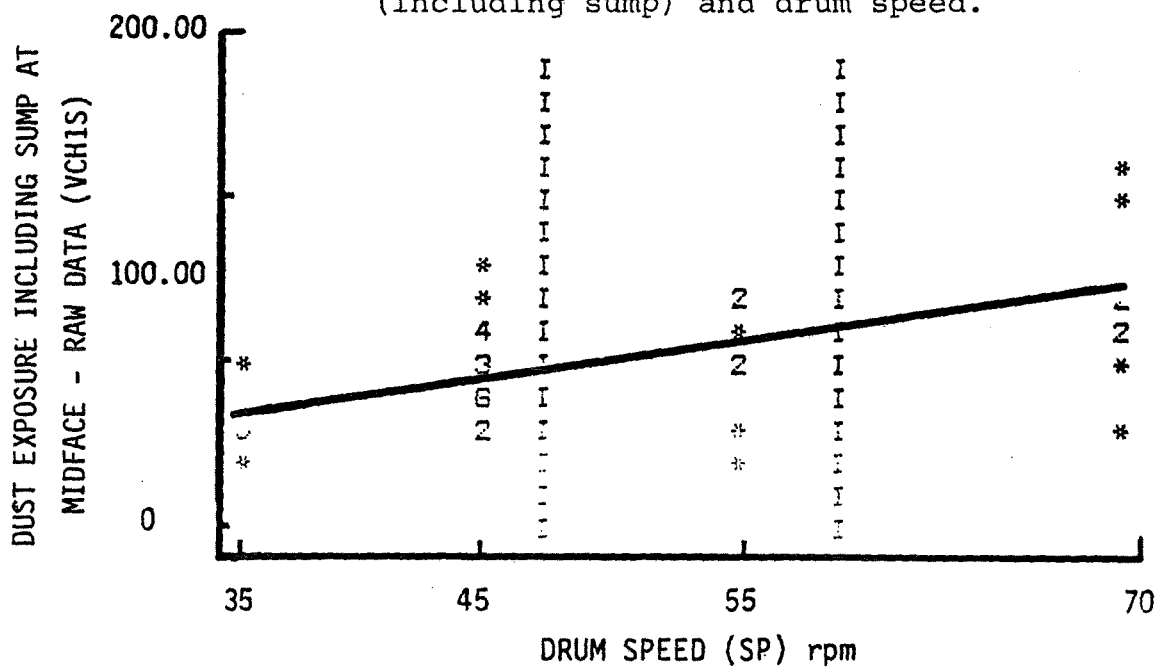


FIGURE 38. - Scattergram of midface dust make including sump (raw data) and drum speed.

5-percent level when VENT was controlled, for example, controlling for VENT:

- a. CH2S with VENT, $r = 0.296$, $p = 0.03$
- b. VCH2S with VENT, $r = 0.3034$, $p = 0.02$.

When SP was controlled, the coefficients were again non-significant but barely so, for example, controlling for SP:

- a. CH2S with VENT, $r = 0.228$, $p = 0.07$
- b. VCH2S with VENT, $r = 0.244$, $p = 0.06$.

The signs of these coefficients again suggest that a dilution effect is present but that the model used to allow for variation in ventilation velocity overestimates its effect at the tailgate location.

Regression

Simple regression of CH2S with SP was significant as was the multiple regression when VENT was added. In the second case, however, the individual regression coefficients were not significant at the 5-percent level.

When the same tests were applied to VCH2S overall significant regression equations were not obtained. The significant equations were:

- a. Simple: $CH2S = 1.22 \times SP + 22.29$
- b. Multiple: $CH2S = 0.83 \times SP + 0.23 \times VENT + 0.01$.

The complete regression statistics are provided in Appendix F.

Scattergrams

Scattergrams were produced for CH2S and VCH2S as a function of SP. These are reproduced in Figures 39 and 40.

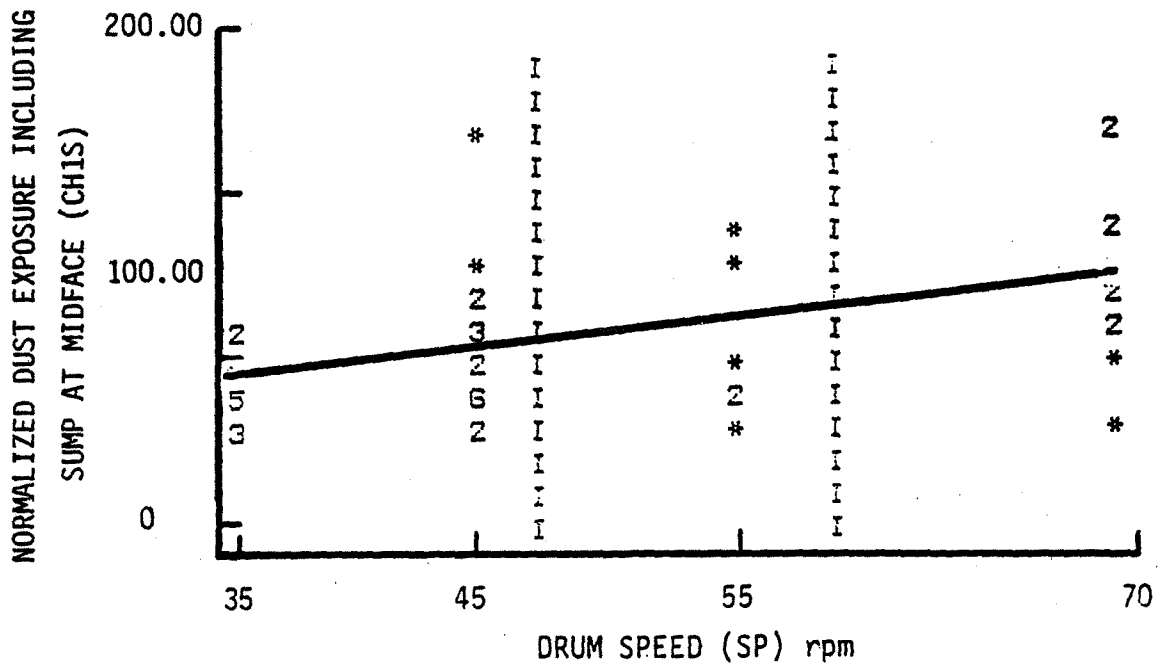


FIGURE 39. - Scattergram of tailgate dust exposure (including sump) and drum speed.

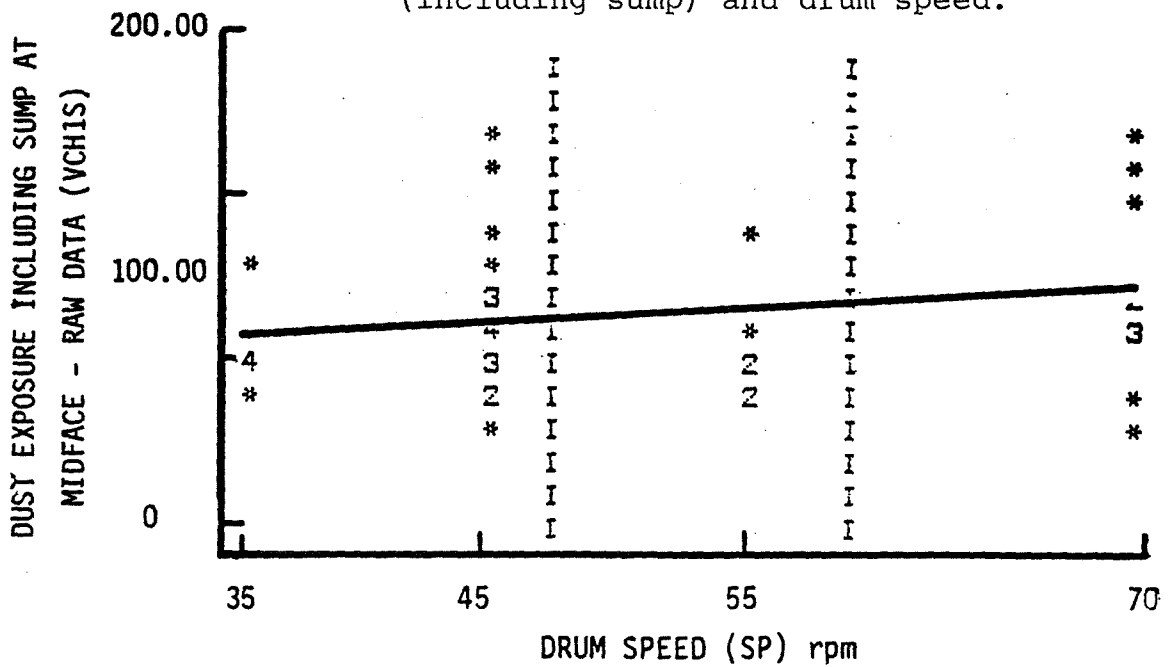


FIGURE 40. - Scattergram of tailgate dust exposure including sump (raw data) and drum speed.

9.1.3 Dust Make During the Complete Cycle

9.1.3.1 Midface

Where possible, cumulative exposure was determined for complete cycles from commencement of sumping at the twentieth shield cutting towards the tailgate to a return to this location. The number of cycles in the data set for which this information is available is unfortunately not large at 24 compared with the 40 to 50 available for the statistics examined above. This was due to the fact that on any given shift the first and last cycles out of an average of three or four were usually incomplete.

Correlation

The normalized, for ventilation velocity, and raw dust exposure statistics were defined as CH1C and VCH1C, respectively. These were included in a correlation matrix with SP and VENT to yield a matrix in which the only nonsignificant correlation was that of VCH1C with VENT (Figure 41).

	CH1C	VCH1C	SP	VENT
CH1C	1.0000 (0) P=*****	.7904 (24) P= .001	.7092 (24) P= .001	.8263 (24) P= .001
VCH1C	.7904 (24) P= .001	1.0000 (0) P=*****	.4989 (24) P= .007	.3176 (24) P= .065
SP	.7092 (24) P= .001	.4989 (24) P= .007	1.0000 (0) P=*****	.5900 (56) P= .001
VENT	.8263 (24) P= .001	.3176 (24) P= .065	.5900 (56) P= .001	1.0000 (0) P=*****

KEY:

CH1 (S,C) - NORMALIZED DUST LEVEL AT MIDFACE
VCH1 (S,C) - RAW DUST LEVEL AT MIDFACE
SP - DRUM SPEED
VENT - VENTILATION VELOCITY

FIGURE 41. - Correlation matrix for complete cycles at midface.

Partial correlation showed a dependence of both CH1C and VCH1C on SP when VENT was controlled, for example, controlling for VENT:

- a. CH1C with SP: $r = 0.421$, $p = 0.02$
- b. VCH1C with SP: $r = 0.406$, $p = 0.03$.

When SP was controlled CH1C showed the expected strong association with VENT (it after all is a function of VENT) while VCH1C revealed an unusual phenomenon - the correlation coefficient of exactly zero (to four places of decimal), for example, controlling for SP:

- a. CH1C with VENT: $r = 0.690$, $p = 0.001$
- b. VCH1C with VENT: $r = 0.000$, $p = 0.5000$

Regression

Regression analysis involving CH1C showed relatively high correlation, R^2 , and significance at all stages with both SP and VENT passing 5 percent significance tests at all stages.

The prediction of VCH1C was not improved, however, when VENT was added to SP as an independent variable due to its precise lack of correlation with VCH1C in the presence of SP.

The regression equations involving CH1C are as follows:

- a. Simple CH1C = $2.40 \times SP + 13.08$
- b. Multiple CH1C = $1.04 \times SP + 0.75 \text{ VENT} - 53.02$.

The complete regression statistics are provided in Appendix F.

Scattergrams

Scattergrams of CH1C and VCH1C with SP were produced and are presented in Figures 42 and 43.

9.1.3.2 Tailgate

At the tailgate, total cumulative exposure was available for the whole of each of 25 cycles in the form of (normalized) CH2C and (raw) VCH2C. These represent cumulative exposure to ARD based on whole mining cycles.

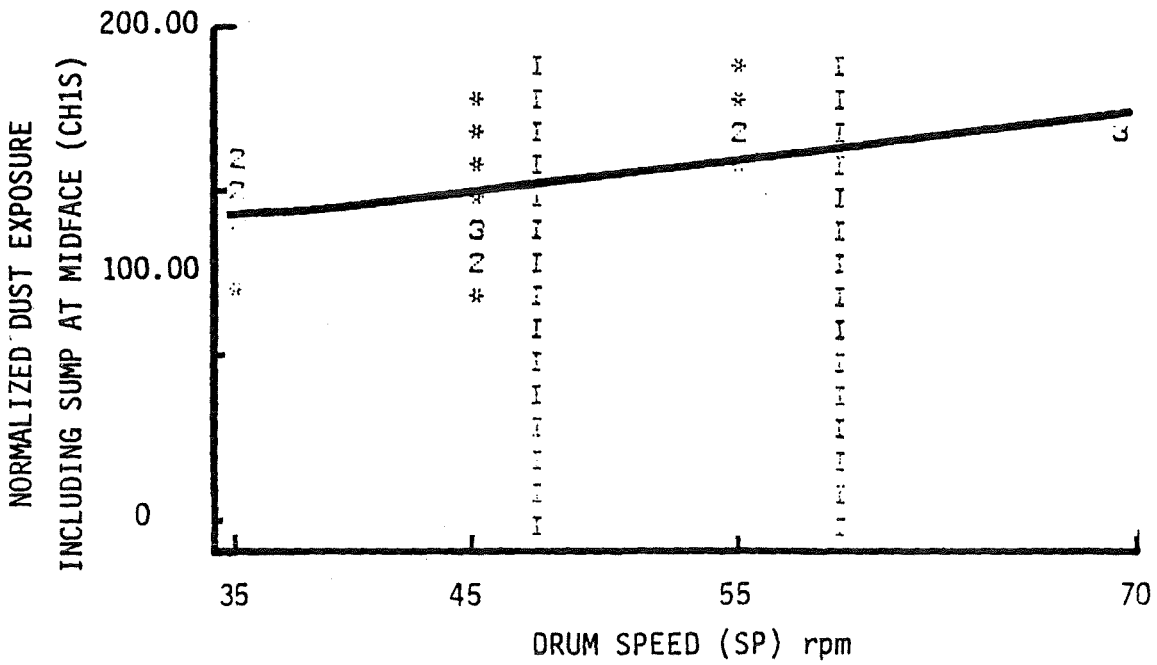


FIGURE 42. - Scattergram of midface dust exposure (whole cycles) and drum speed.

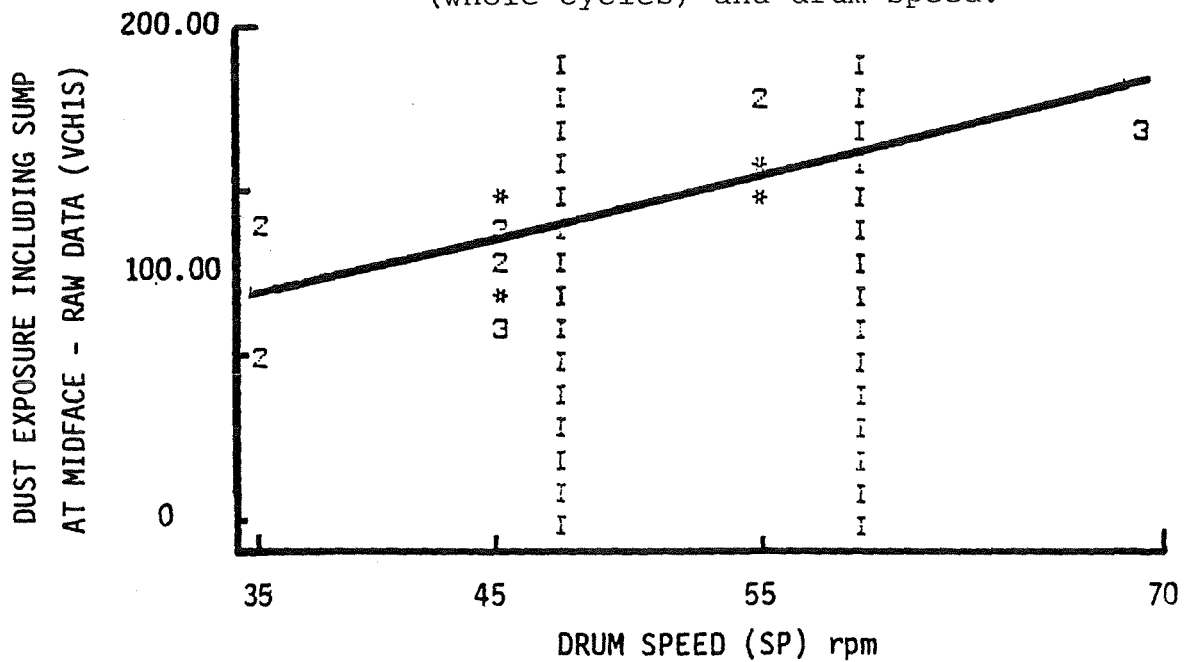


FIGURE 43. - Scattergram of midface dust exposure for whole cycles (raw data) and drum speed.

Correlation

The simple correlation matrix showed no significant association between either CH2C or VCH2C and SP. When the partial correlations controlling for VENT with SP were examined, significant relationships were not found.

Controlling for SP produced a strong correlation between CH2C and VENT indicative of the normalization process. The correlation between VCH2C and VENT was almost zero ($r = -0.003$, $p = 0.495$), suggesting that in this region, too, that dust exposure over the whole cycle was practically independent of ventilation velocity measured at midface.

Regression

In the light of the failure of the partial correlation coefficients to reveal a true relationship between CH2C and SP it is not surprising that simple regression of CH2C and SP did not reveal significant results.

When VENT was added to the equation a significant result is achieved due only to the relationship between CH2C and VENT which is inherent in the normalization. Regression results are shown in Appendix F.

Scattergrams

Despite the nonsignificant correlation between CH2C and SP a scattergram was plotted which revealed that though the relationship failed to pass a rigorous test of significance, the tendency of CH2C to increase with increasing SP was clear. Figure 44 shows this tendency.

9.2 New Drums - One and Two Picks Per Line

The test drums were designed so that removal of approximately half the vane picks was feasible to yield a drum with one pick per line lacing. As has been mentioned in Section 7, it only proved possible to operate in this condition at 55 and 70 rpm. In order to assess the effect of operating in this condition statistical analysis was conducted on a data set consisting of dust level information relating to both one and two picks per line.

The principal tool of this analysis was stepwise multiple regression in which independent variables were entered in the following order:

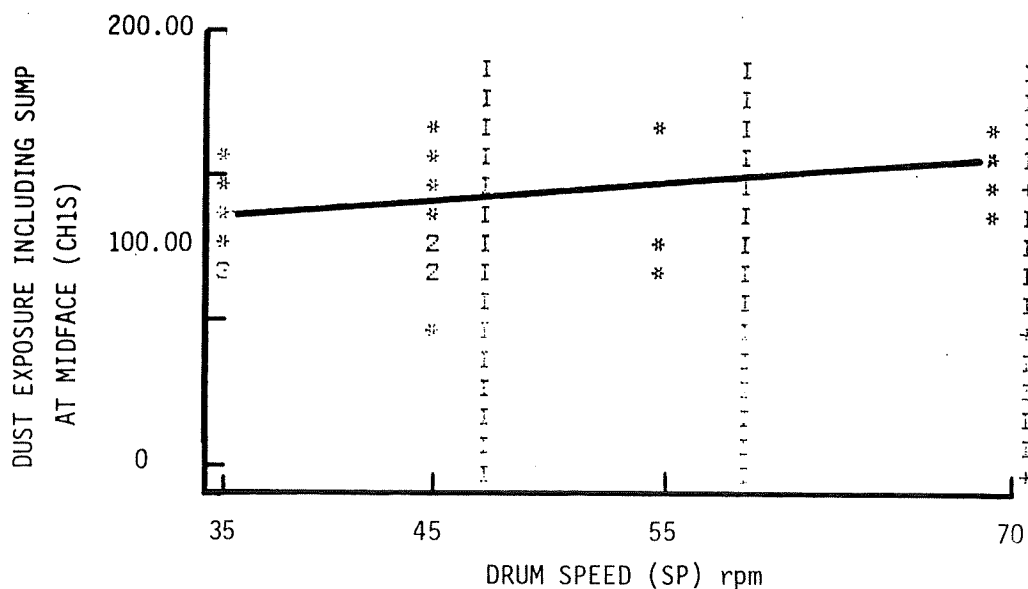


FIGURE 44. - Scattergram of tailgate dust exposure (whole cycles) and drum speed.

- a. SP - Drum speed
- b. PKS - Number of picks per line
- c. VENT - Ventilation velocity.

The dependent variables were as follows:

- a. CH1
- b. CH2
- c. CH1S
- d. CH2S
- e. CH1C
- f. CH2C.

This follows the same nomenclature as that employed in subsection 9.1. Regression was not employed with the raw dust level data VCH1, VCH2, etc., since the conclusion drawn from subsection 9.1 was that the normalized dust levels were the better dependent variables for this analysis. The results of the regression analyses are shown in Appendix F.

9.2.1 Midface

At this location, the regression of SP, PKS and VENT on CH1, and CH1S produced significant equations. In both cases the addition of PKS increased the effectiveness of the prediction. In the case of CH1C however no data were available concerning one pick per line operation at 55 rpm and the regression was not, therefore, reliable enough for valid conclusions to be drawn.

The regression equations for SP on PKS on CH1 and CH1S are as follows:

a. $CH1 = 7.39 \times SP + 85.2 \times PKS - 304$

b. $CH1S = 1.87 \times SP + 15.3 \times PKS - 56.7.$

In both cases it can be seen that the effect of drum speed is more powerful than that of number of picks. This is borne out when the data are plotted graphically on Figures 45 and 46. The fits of the regression lines on the data are not particularly good in the one-pick per line cases and this reflects the low number of cases (10) available for plotting.

9.2.2 Tailgate

At the tailgate, the results achieved were less clear since in no case, except where the number of cases was too low to be valid (CH2C), did the number of picks per line prove to be a significant prediction of dust level. It should be noted, however, that the addition of the cases relating to the PKS = one condition strengthened SP as a predictor of CH2 and CH2S at this position to yield significant regression equations when the single independent variable (SP) was used.

9.3 Old Drums

Since the old drums that were fitted to the shearer during the first week of data gathering were an unknown quantity, the data generated during this period were not included in the data sets used for the preceding analysis. A second and equally pertinent reason was that, for the majority of these early data, measurements of the face velocity were made that were not compatible with those made during the balance of the trial. Nevertheless it was thought worthwhile to examine these data briefly since an appreciable effort had been expended in gathering them. The results of this analysis are contained in Appendix H.

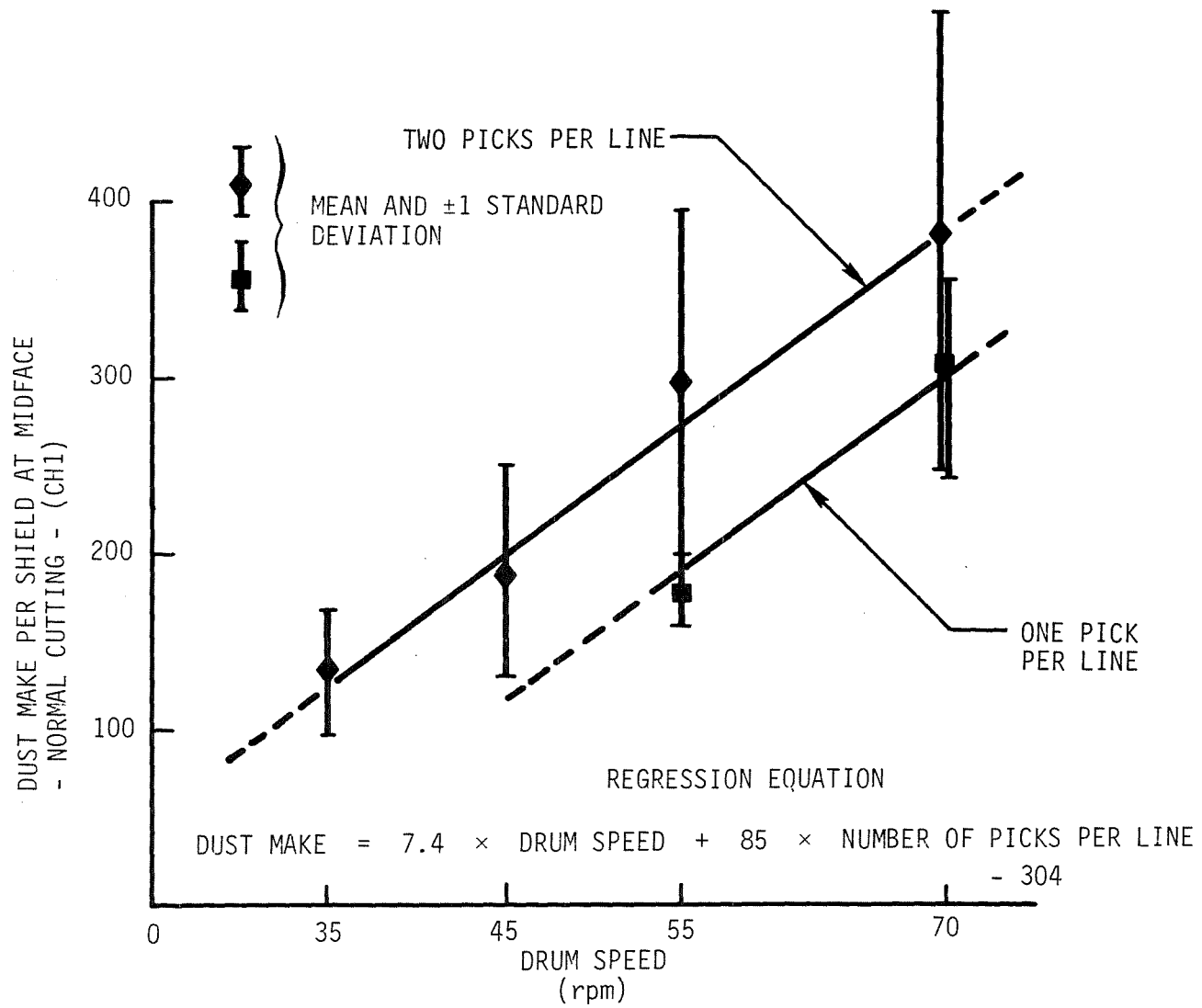


FIGURE 45. - Dust make per shield (CH1) at midface as a function of drum speed (SP) and number of picks per line (PKS).

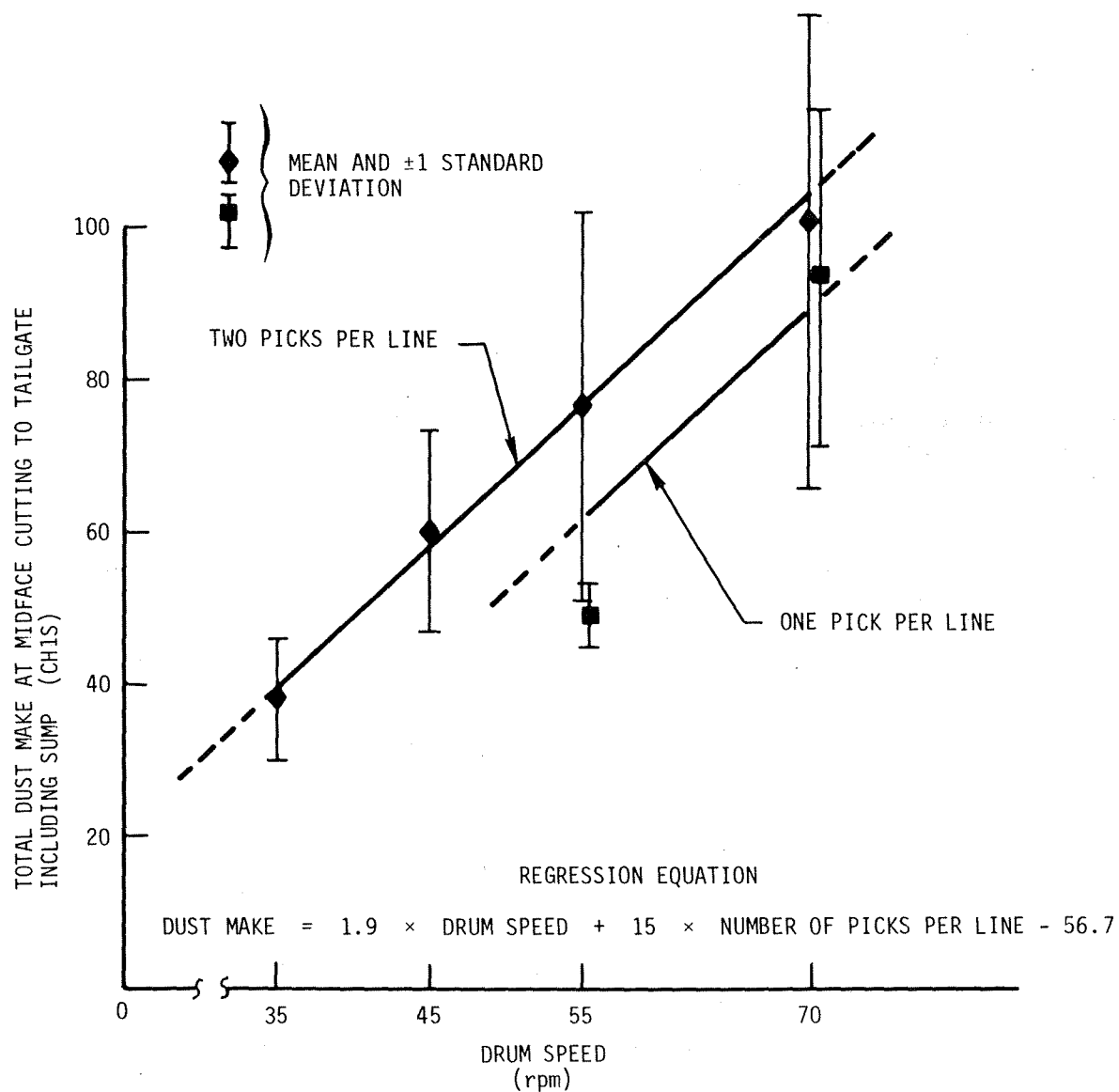


FIGURE 46. - Total dust make at midface cutting from sump to tailgate (CH1S) as a function of drum speed (SP) and number of picks per line (PKS).

9.4 Intercorrelation Between Midface and Tailgate

Since it has become apparent that conclusions that hold for the effect of cutting parameters on dust levels at *midface* do not necessarily hold true at the tailgate. It was worthwhile to examine briefly the relationship between dust levels measured at the two locations.

Figure 47 shows a correlation matrix between CH1, VCH1, CH2, VCH2, SP and VENT.

It is apparent that though correlation between raw and normalized levels at midface and tailgate exists, it is relatively low. For example:

- a. CH1 and CH2: $r = 0.532$
- b. VCH1 and VCH2: $r = 0.378$.

This would suggest that processes are operating to vary dust levels at one location which have little or no impact at the other.

Also worthy of note is the fact that while on one hand the correlation between VCH1 and VENT is positive, probably reflecting the ecological correlation between VENT and SP, the correlation between VCH2 and VENT is negative inferring that in this area the dilution effect associated with high ventilation and low dust levels predominates.

9.5 Other Results

9.5.1 Ventilation Profile

In order to illustrate the manner in which the ventilation velocity varied over the length of the face, Figure 48 is provided which shows that within a single shift a two-to-one variation in ventilation velocity might be experienced between the headgate region, say the tenth shield, and the area of the tailgate. This effect was apparently due to a tendency of ventilation air to circulate in the gob area behind the shields and to reappear on the face towards the tailgate. This conclusion is reinforced by the observed dependence of ventilation velocity on the condition of the headgate wing (brattice) curtain and the degree of compaction of the gob.

	CH1	VCH1	CH2	VCH2	SP	VENT
CH1	1.0000 (0) P=*****	.9326 (54) P= .001	.5318 (46) P= .001	.2759 (46) P= .032	.7025 (54) P= .001	.6105 (54) P= .001
VCH1	.9326 (54) P= .001	1.0000 (0) P=*****	.4595 (46) P= .001	.3778 (46) P= .005	.5717 (54) P= .001	.3030 (54) P= .013
CH2	.5318 (46) P= .001	.4595 (46) P= .001	1.0000 (0) P=*****	.8281 (58) P= .001	.3703 (58) P= .002	.3810 (58) P= .002
VCH2	.2759 (46) P= .032	.3778 (46) P= .005	.8281 (58) P= .001	1.0000 (0) P=*****	.0429 (58) P= .374	-.1824 (58) P= .085
SP	.7025 (54) P= .001	.5717 (54) P= .001	.3703 (58) P= .002	.0429 (58) P= .374	1.0000 (0) P=*****	.6205 (66) P= .001
VENT	.6105 (54) P= .001	.3030 (54) P= .013	.3810 (58) P= .002	-.1824 (58) P= .085	.6205 (66) P= .001	1.0000 (0) P=*****

KEY:
 CH1 (S,C) - NORMALIZED DUST LEVEL AT MIDFACE
 VCH1 (S,C) - RAW DUST LEVEL AT MIDFACE
 CH2 (S,C) - NORMALIZED DUST LEVEL AT TAILGATE
 VCH2 (S,C) - RAW DUST LEVEL AT TAILGATE
 SP - DRUM SPEED
 VENT - VENTILATION VELOCITY

FIGURE 47. - The correlation matrix of CH1, VCH1, CH2, VCH2, SP, and VENT.

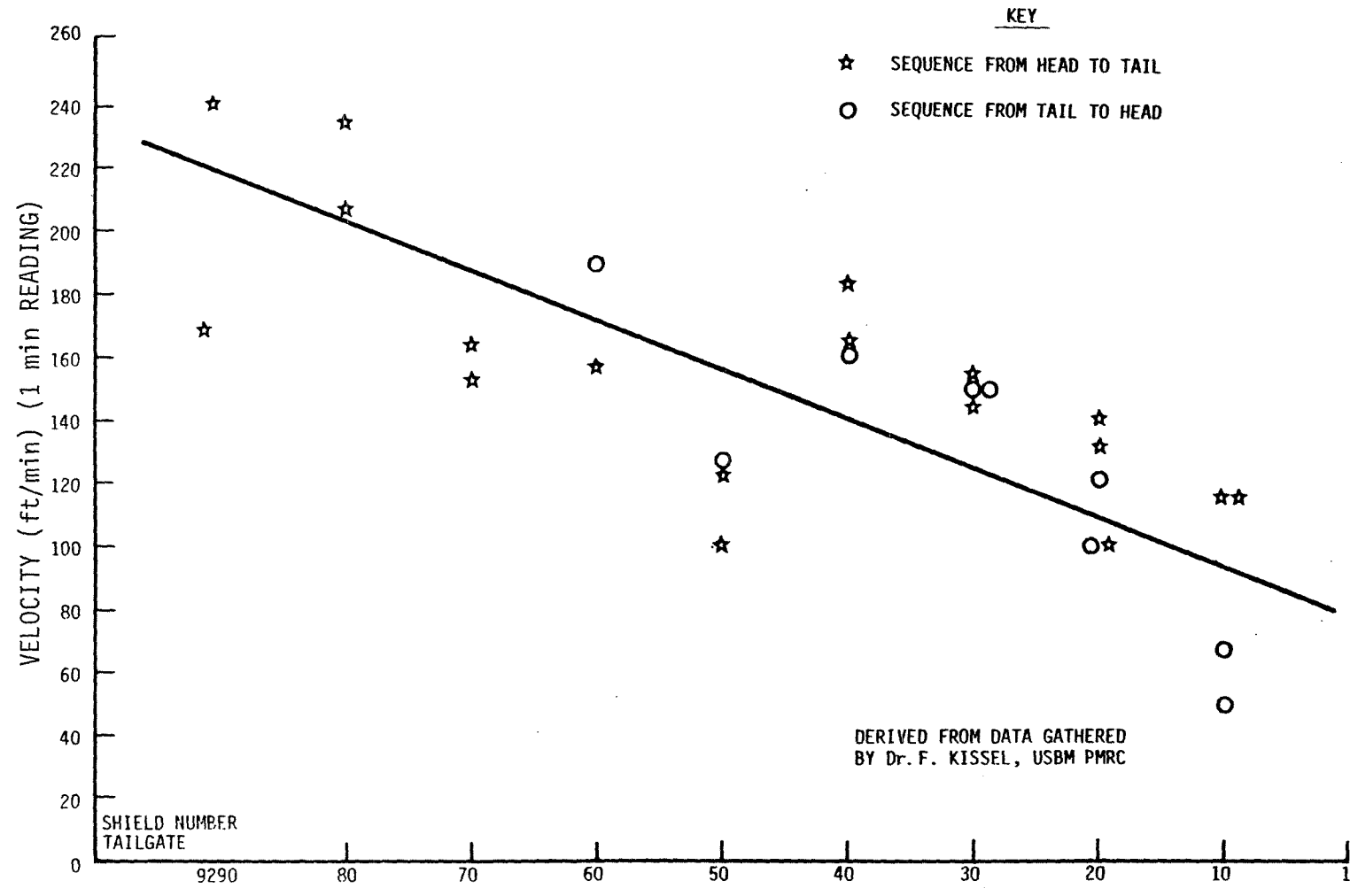


FIGURE 48. - Velocity profile with handheld (no stick) anemometer.

9.5.2 Shearer Power Consumption

The total power consumed by the shearer was monitored for the majority of data taking shifts by a single phase wattmeter positioned at the headgate adjacent to the face control box. The output from this device was recorded on a paper chart recorder.

In analyzing these data the following protocol was observed:

- a. All tapes were scaled to yield a time factor in minutes per millimeter.
- b. Periods of normal cutting from headgate to tailgate were identified. These were the same periods of normal cutting with the drums fully involved that were used to yield the CH1 and CH2 dust level data referred to in subsection 8.1.
- c. Within each of these periods of normal cutting, approximately eight samples of power consumption level were taken.
- d. These samples were combined with all other samples relating to the same drum type per number of picks per drum speed and the distribution of the resulting data set calculated in terms of the number of samples falling within each 10-kW interval.

Results of these calculations referring to the old drums at 35 and 45 rpm are shown in Figure 49. On this figure the distributions of power levels are compared in two ways. These are:

- a. The frequency distributions of two sets are plotted in the lighter weight lines.
- b. The cumulative probabilities of exceedance of a given power level are plotted with the heavier lines.

Overall the cumulative probability distributions provide the better means of comparing power consumption at the two speeds since they show that over the vast majority of the range (of power consumption) the higher speed (45 rpm) setting was associated with higher consumption than the lower speed (35 rpm).

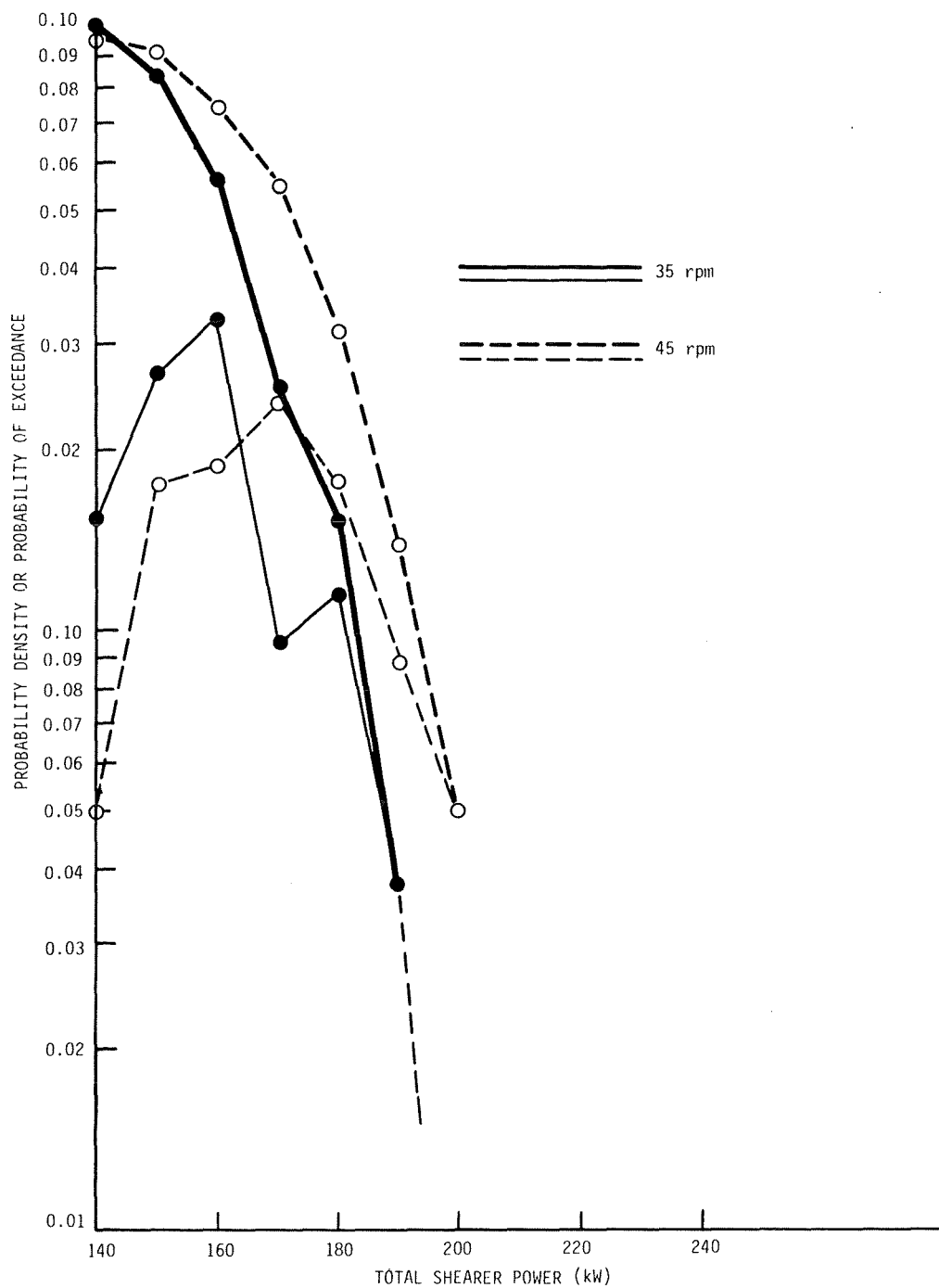


FIGURE 49. - Shearer power distribution at 35 and 45 rpm, old drums.

A similar comparison was made of power consumption at the four speeds at which the new drum was run at two picks per line. Figure 50 shows that power consumption increased consistently as speed increased from 35 through 45 to 55 rpm, though no further increase was noted at 70 rpm.

Figure 51 compares power consumption distribution at 55 and 70 rpm at the one- and two-pick per line conditions. In both cases a reduction of power consumption was observed at the one-pick per line condition, though that at 55 rpm was slight, possibly due to the shortage of data in this condition.

These figures were presented because they allow an appreciation of the variation of the usual power level - say that occurring 50 percent of the time - as well as the level achieved during brief periods of high demand - say 10 percent of the time. This distinction is made since, though a machine may have adequate power available to sustain it during average cutting conditions, it may not be able to function in an unconstrained manner when atypical demands are made on it.

Figure 52 shows how the average power consumption level, 50 percent exceedance (L50) level, and 10 percent exceedance level varied with drum speed.

It is the author's opinion that these results show that at the higher two speeds (55 and 70 rpm) the machine was operating in the region of 125 percent full load, where continuous operation could not be long sustained. It also appeared that semi-continuous operations at above 100 percent full load were not feasible.

These conclusions are tentative since the full picture concerning the shearer's operating parameters was not available since power consumption can also be limited by haulage pressure which may exceed a preset value above which haulage speed is reduced at overall power consumption levels below full (electrical) load. It is noted though that average power consumption increased with drum speed but showed evidence of having reached a limiting value at 55 and 70 rpm.

9.5.3 Shearer Speed

It was the intention at the outset of this program to monitor the actual haulage speed of the shearer and to have this variable available in a form that would allow correlation with

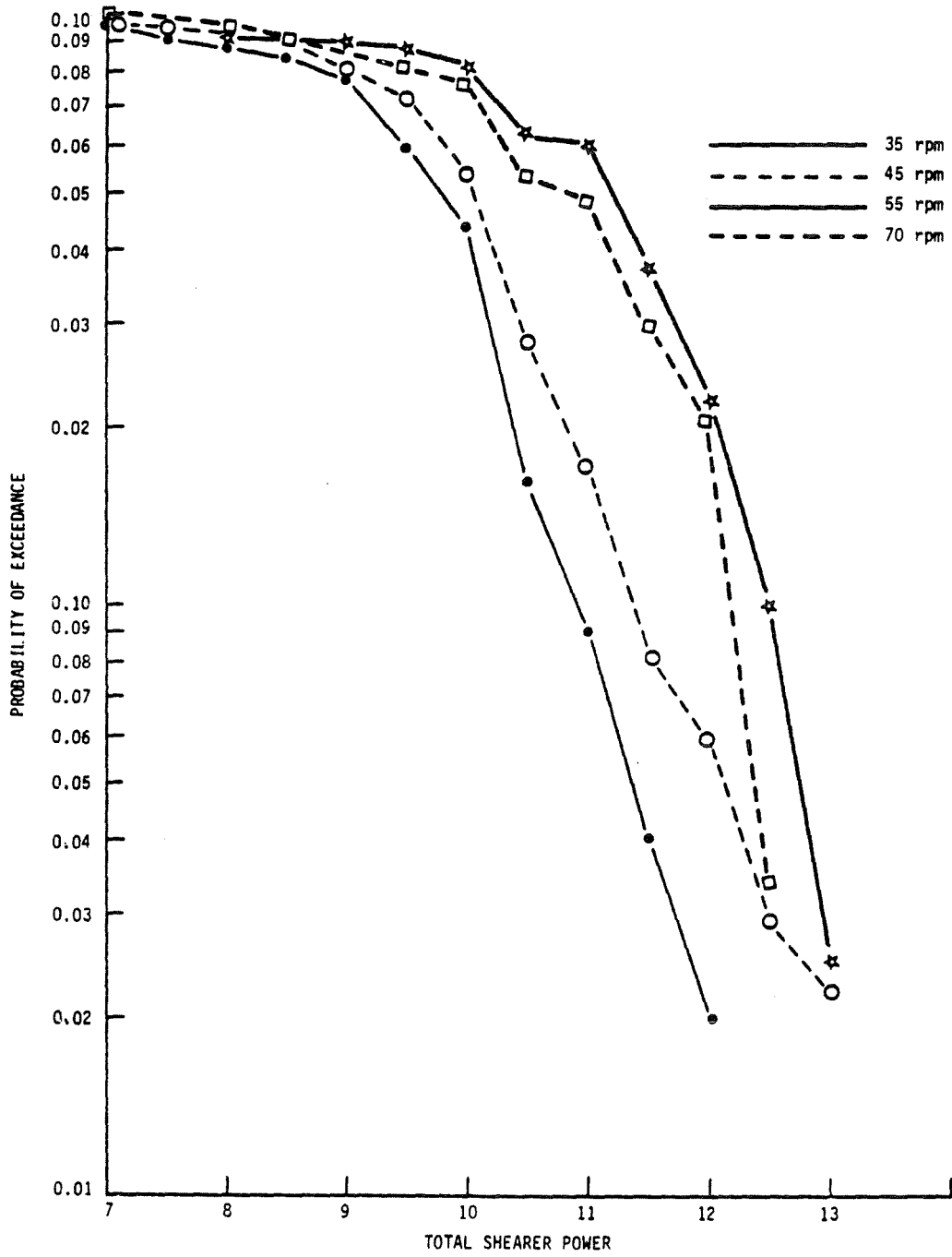


FIGURE 50. - Shearer power distribution at 35, 45, 55 and 70 rpm, two picks per line, new drums.

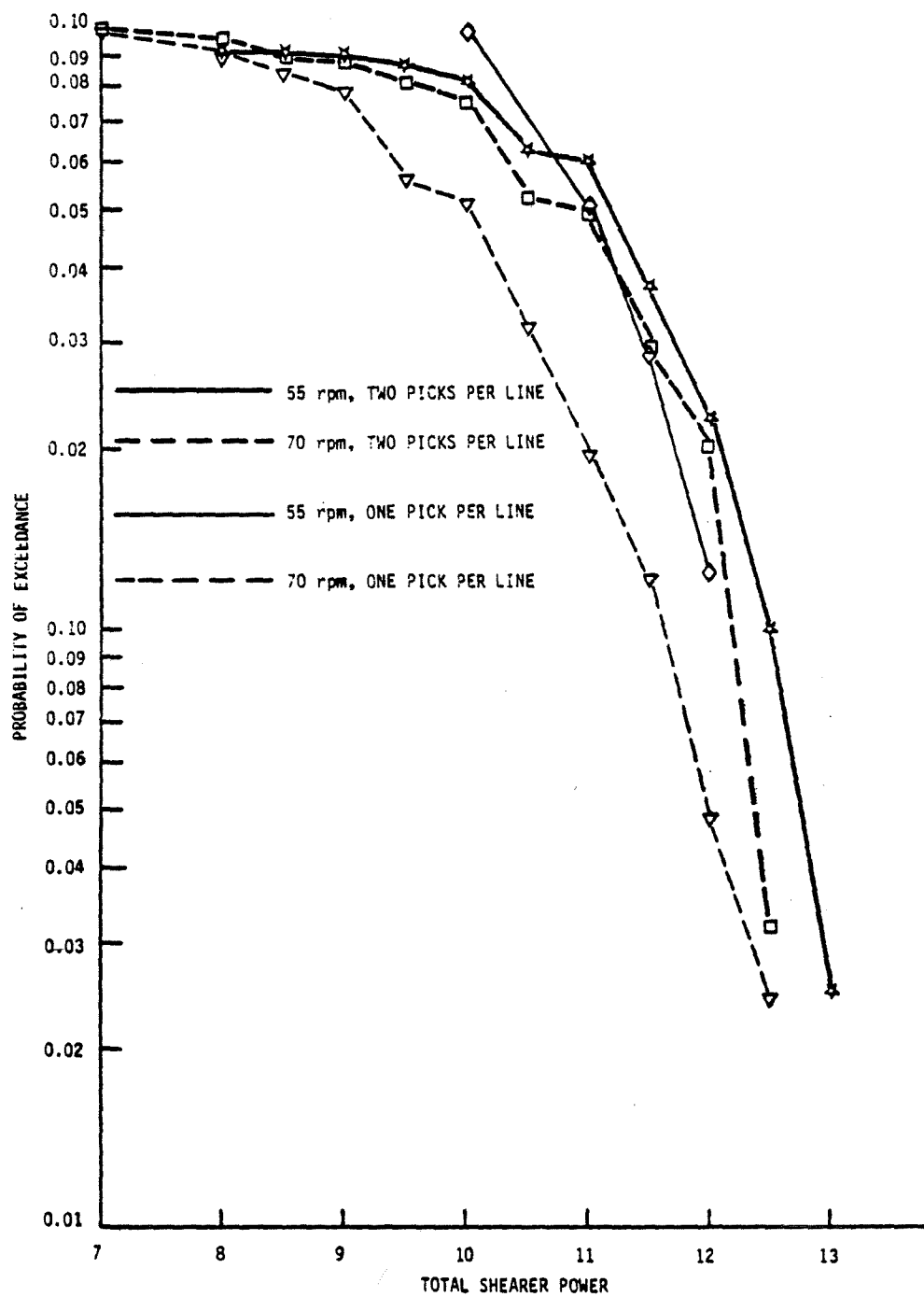


FIGURE 51. - Shearer power distribution, 55 and 70 rpm at one and two picks per line.

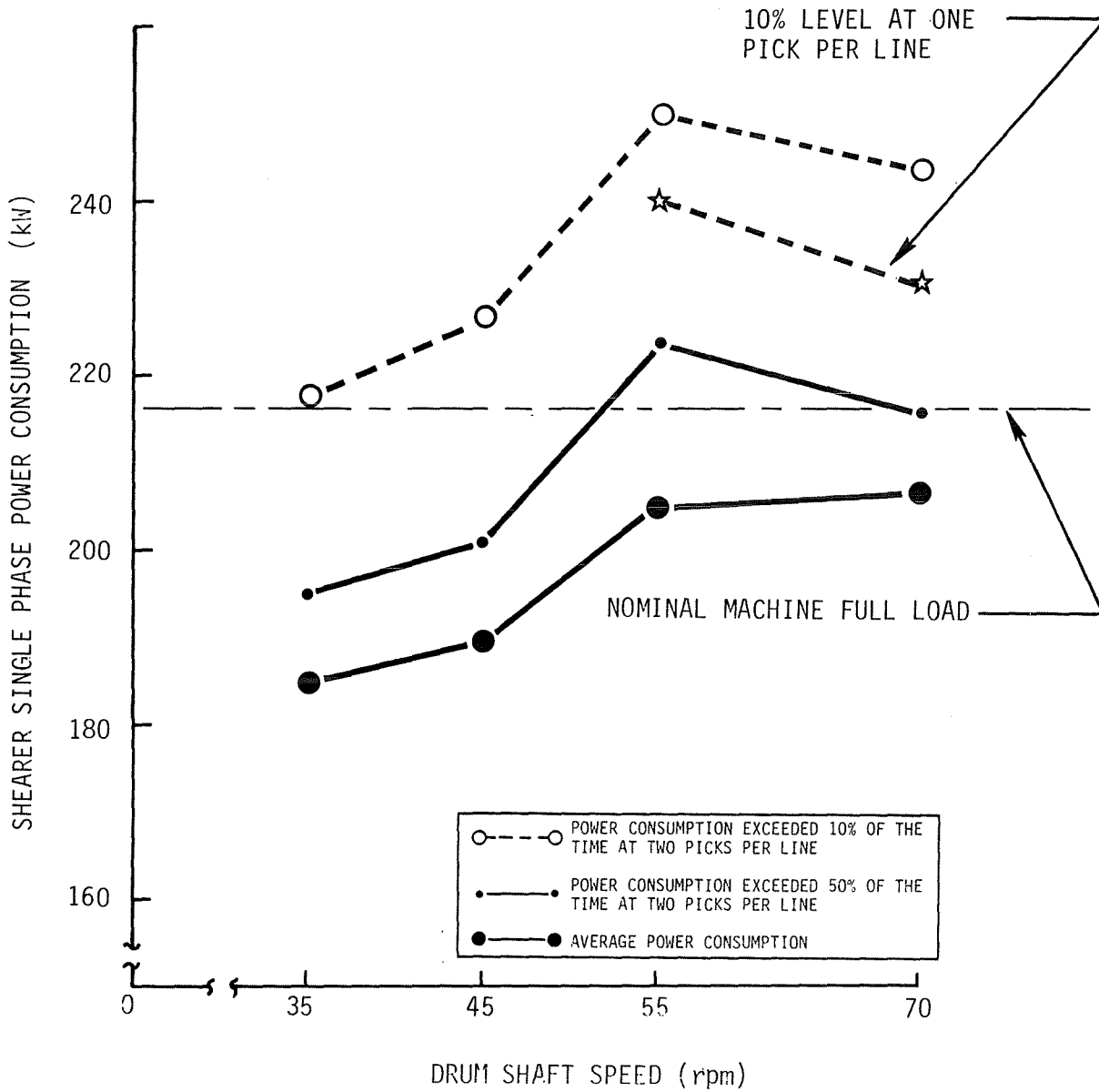


FIGURE 52. - Power consumption as a function of drum speed.

dust level and power consumption. It did not prove possible, however, to maintain the integrity of the shearer haulage speed monitoring package and a consistent data set was not obtained.

Speed data were, however, obtained on all shifts either by means of automatic recording or by observation and timing. These have been analyzed to provide some insight into the effect of drum speed on haulage speed and therefore production rate, and to relate drum speed to actual depth of cut.

The method of analysis was similar to that described above in subsection 9.5.1 in that speed values were selected where the machine was apparently operating in a manner that was unconstrained by special conditions such as slabbing or buildup under the underframe.

The average shearer haulage speeds observed are given in Table 8. It can be seen that the lower drum speeds were generally associated with higher haulage speeds which confirms that at the lower speeds and higher penetrations the shearer was less often constrained by total haulage pressure or overall power consumption considerations. It was also apparent when the penetration depth was increased by the removal of one pick per line, the average speed increased.

This having been said, it should be noted that this is a very imperfect data set which was created from information gathered in an inconsistent manner and selected according to somewhat subjective criteria. The only safe conclusion is merely that average haulage speed decreased as drum speed increased.

TABLE 8. - Shearer drum and haulage speeds

Drum speed (rpm)	35	45	55	70	55	70
Number of picks per line	2	2	2	2	1	1
Average velocity (ft/min)	27.3	27.5	19.8	21.8	24.5	23.0
Penetration (in.)	4.7	3.7	2.2	1.9	5.3	3.9

The information available is certainly not reliable enough to justify the replacement of drum speed with the implied actual penetration depth as the primary independent variable in the analysis of dust level data.

9.6 Summary of Dust Level Analysis

Analysis of the dust level data was conducted to detect association of dust level with drum speed and number of picks per line. Dust levels have been computed in three ways:

- a. Shearer dust make per shield (or 5 ft of face)
- b. Total dust make when cutting from the beginning of the sump at approximately the twentieth shield to the point where the monitor was located
- c. Dust make over whole mining cycles

at two locations - midface, fifty-third shield and tailgate, ninety-first shield.

Ventilation velocity was also measured during each mining cycle.

The extent to which the change of drum speed (or number of picks) caused a change in average dust make was the primary concern for each combination of dust level measurement and measurement location. In order to answer this question, some notice had to be taken of the fact that ventilation velocity varied extensively over the trial period. When these velocities were examined it was found that some particularly low values had been recorded during *some* of the shifts when low drum speeds had been used and that this had not been the case when the higher speeds were used.

This observation required that caution be used in the analysis since it would be possible to mistake the effect of ventilation velocity on dust level for that of drum speed. Since the range of velocity was wide, the dust levels were adjusted for the dilution effect and the resulting levels used to determine whether there was evidence of association between this adjusted dust level and ventilation velocity in the absence of a change in drum speed. (If the adjustment or normalization was correct, there should be no change in normalized dust level when ventilation velocity changes.) It was found that the normalized levels were largely insensitive to changes in ventilation suggesting that the normalization was successful.

The adjusted dust levels were then compared with drum speed to determine whether, other things (such as ventilation velocity) being equal, there was a tendency for higher drum speeds to result in higher dust levels. It was found that this was the case, without exception, at midface where association between dust level and drum speed occurred to such a degree that it would be *very* unlikely to have been erroneously observed. At the tailgate, however, the dust level appeared to be almost independent of drum speed with only one dust measurement, that of total dust make from sump to tailgate showing an association with drum speed that could not have easily occurred by chance. Table 9 summarizes these results.

TABLE 9. - Comparison of the effect of drum speed on dust level over various parts of the mining cycle at midface and tailgate - new drums, two picks per line

Measurement of dust level	Midface (fifty-third shield)	Tailgate (ninety-first shield)
Dust make per shield during normal cutting	Strong. High speed = high dust	Very weak. Drum speed hardly affected dust level
Total dust make during cut to tailgate from sump at approximately twentieth shield	Strong. High speed = high dust	Medium. Drum speed did affect dust level but not as strongly as at midface
Dust make over whole cycle including tram and cutting out at headgate	Strong. High speed = high dust (not as many data points as above so less confidence is result)	Very weak. Drum speed hardly affected dust level

The vibration is a consequence of the higher torque and more variable reaction loads imposed by deep/slow cutting. Its principal consequences are higher duty for picks, pickboxes and shearer transmission, and difficulty in maintaining cutting horizon.

Slabbing (sloughing) was observed when the face was subject to weight on the tailgate side of midface and frequently caused short delays while large lumps passed beneath the shearer underframe. This phenomenon was not, of course, exclusively associated with deep/slow cutting but appeared to the author to occur more frequently under these conditions.

Other conclusions relate to the appropriateness and utility of the methods used to monitor face operations and dust levels. Reliable, continuous measurement of dust levels (for example, sampling at a rate equal to or greater than the time taken for the dust level to change significantly) has only recently become a reality. It has the potential to add considerably to the understanding of the processes associated with the production and transport of ARD. In this study there was no requirement to associate short-term changes in operating conditions with the accompanying change in dust level. It was evident though that investigations of this type were now possible and were likely to be worthwhile.

The distinction between the effects of deep/slow cutting at the tailgate compared to the midface has been ascribed to differences of ventilation regime. The main significance of this is not so much in terms of attenuation of the benefit of deep cutting but of the effect of fixed point sampling in this area.

In conclusion, it can be stated that this trial has achieved its object of defining the nature and extent of the reduction of airborne dust levels that may be achieved by using deep/slow cutting on United States longwalls. In doing so notice has been taken of the practical requirements of operating a longwall. It is, therefore, recommended that wherever possible the United States longwall industry continue to follow the observable tendency towards the application of deep/slow cutting through the specification of machines capable of operating at the lowest practicable drum speed.

11. REFERENCES

1. Evans, I. and C.D. Pomeroy, "Strength, Fracture, and Workability of Coal," Pergamon Press, Oxford, England, 1966.
2. Pomeroy, C.D. and J.H. Brown, "Laboratory Investigations of Cutting Processes Applied to Coal Winning Machines," Journal of Strain Analysis, Vol. 3, No. 3, 1968.
3. Barker, J.S., C.D. Pomeroy, and D. Whittaker, "The MRE Large-Pick Shearer Drum," The Mining Engineer, February 1966.
4. Brooker, C.M., "Design and Underground Trials of a Low Seam NCB Mark II Large Tool Shearer Drum," NCB IR 77/17, 1977.
5. Roepke, W., D. Lindroth, and T. Myren, "Reduction of Dust and Energy during Coal Cutting Using Point Attack Bits," USBM RI 8185, 1976.
6. Strebig, K.C. and H.W. Zeller, "Effect of Depth of Cut and Bit Type on the Generation of Respirable Dust," USBM RI 8042, 1975.
7. Warner, E.M., "Machine and Cutting Element Design," Mining Congress Journal, August 1970.
8. Johnson, B., S. Krepela, and K.C. Strebig, "Field Testing the Microminer-Research Continuous Miner," USBM Technical Progress Report 89, February 1975.
9. Black, S., B. Johnson, R. Schmidt, and B. Banerjee, "Effect of Continuous Miner Parameters on the Generation of Respirable Dust," Mining Congress Journal, April 1978.

APPENDIX A

REAL-TIME AEROSOL MONITOR, MODEL RAM-1 FOR SHORT-TERM AND
CONTINUOUS MEASUREMENT OF DUST, SMOKE, FUMES, AND MISTS
(See Figure A-1)

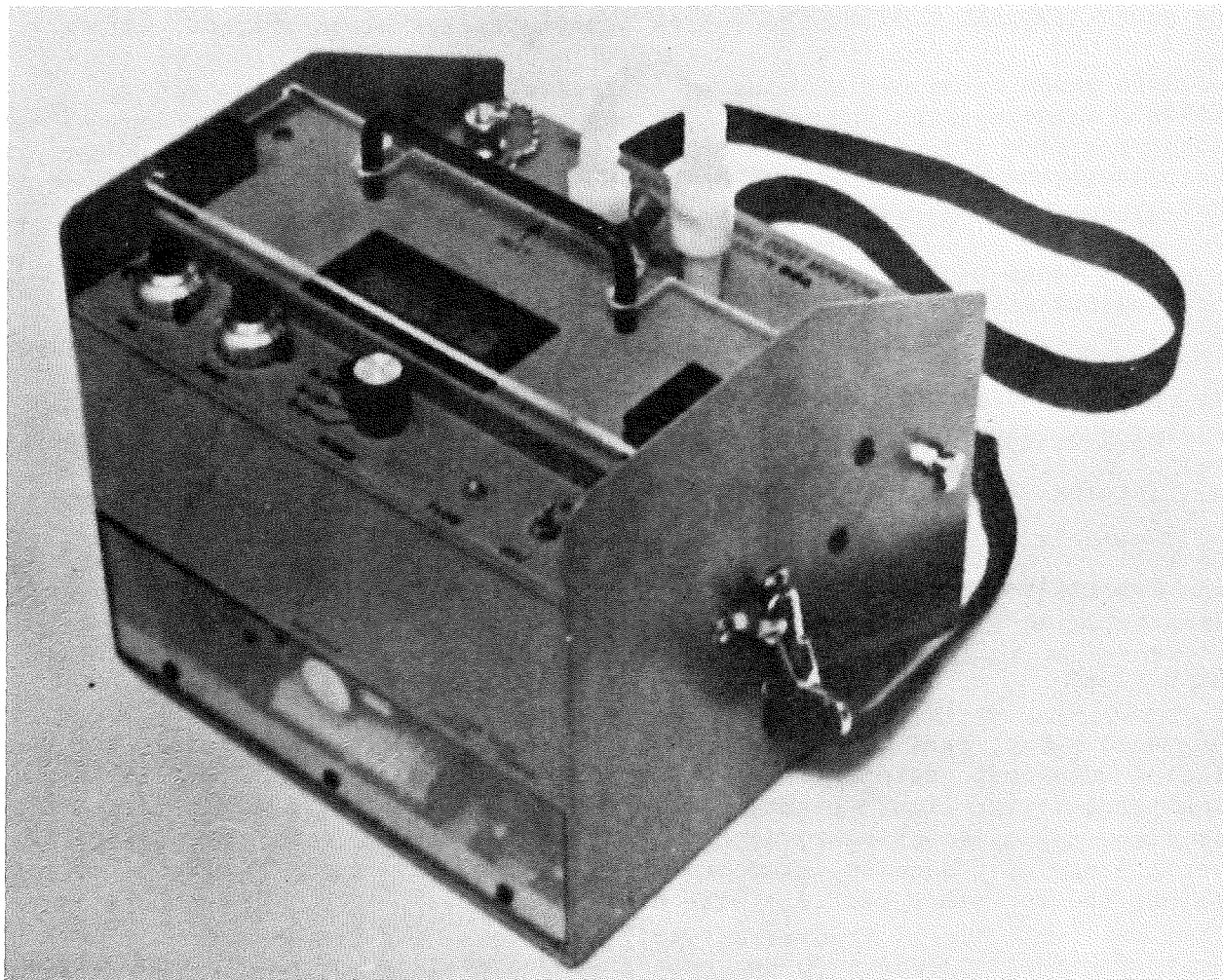


FIGURE A-1. - GCA Respirable Aerosol Monitor RAM-1.

APPLICATIONS

The RAM-1 can be utilized either as a continuous real-time sensor or short-term survey instrument for such diverse aerosol monitoring applications as:

- In-plant or in-mine industrial hygiene surveys.
- In-line monitoring of process, ventilation and air conditioning systems.
- Performing engineering studies on the efficiency of respirators, electrostatic precipitators, fabric filters and other dust control systems.
- Assessing impact of such parameters as process conditions and employee work practices on worker exposure to dust and other aerosols.
- Ambient Particulate Monitoring.
- Monitoring cigarette smoke and other potentially harmful aerosol in homes, offices, restaurants, schools, etc.
- Continuous monitoring of environmental chambers for inhalation and animal exposure studies.
- Visibility measurements.
- Use on airplanes for traversing plumes and mapping aerosol concentrations at different altitudes.

SPECIFICATIONS

- Measurement ranges*: 0 to 2 mg/m³
0 to 20 mg/m³
0 to 200 mg/m³, and
0 to 20 volts (battery voltage).
- Measurement and zero precision and stability: ± 0.1 percent of full scale of ± 0.005 mg/m³, whichever is larger (over a 24-hour period or longer, without adjustments), or better.
- Noise level (2-sigma)*: approximately ± 0.005 mg/m³ at 2-second time constant, and ± 0.001 mg/m³ at 32-second time constant.
- Minimum detectable scattering coefficient (referred to visible light): $4 \times 10^{-6} \text{ m}^{-1}$ (approximately).
- Readout resolution*: 0.001 mg/m³ on 0 to 2 scale
0.01 mg/m³ on 0 to 20 scale
0.1 mg/m³ on 0 to 200 scale, and
0.01 volts d.c. on BAT (battery voltage).
- Measurement time constants (panel selectable): 0.5, 2, 8 and 32 sec
- Display up-date rate: 3 per second.
- Nominal sampling flowrate: 2 liters/minute (adjustable).

*Approximate equivalent respirable mass concentration.

- Nominal clean-air purge flowrate: 0.2 liters/minute (adjustable).
- Nominal battery voltage: 6V.
- Average battery current drain: 300 mA.
- Average battery charging current: 300 mA (approximately 12 hours at full charge).
- Continuous operation on full battery charge: approximately 6 hours (inlet valve in SAMPLE position).
- Operating temperature: 0° to 50° C.
- Outside dimensions: 20 x 20 x 20 cm (approximately).
- Weight: 4kg.
- Recorder output: 10 volts when digital display is at full scale.
Minimum load impedance: 1000 ohms.

INCLUDED ACCESSORIES

- Charger - A.C. line adaptor.
- Charger cable.
- Cyclone precollector (10 mm nylon).
- Inlet flow restrictor.
- Two replaceable filter cartridges.
- Refillable diffusion desiccator cartridge.
- Detachable carrying strap.
- Carrying case for instrument and accessories.
- Instruction Manual.

OPTIONAL ACCESSORIES

- Miniature strip chart recorder.
- Additional battery pack to extend operation beyond that of instrument battery.
- Intrinsic safety modification package.

performed which Quarto in its sole discretion considers a danger or undesirable with respect to the mining operation.

3. Quarto agrees to provide, to the extent required by FMA, the services of a class A Mechanic and an Electrician to install and dismantle the instrumentation required for the study.
4. FMA agrees to reimburse Quarto for the services requested by it under Paragraph 3. Reimbursement will be at the rate of \$118.36 per man shift with premium rates of \$172.54 and \$236.72 per man shift for Saturday and Sunday work, respectively, till March 27, 1980. After March 27, 1980, add \$4.95, \$7.22 and \$9.90 per day respectively to above rates.
5. FMA shall be responsible for any property damage or bodily injury arising out of its performance of the study, and shall release, indemnify, defend and hold harmless its employees and agents from and against any loss, damage, expense, paid claim or paid liability of whatsoever nature in such regard.
6. Since it is anticipated that the data taking will not result in delay or stoppage of the face operations, FMA agrees that the operations will not be required to be altered in any way that will reduce production to accommodate the study.
7. The study will consist of three or more experimental periods of 10 shifts each and during each period a different set of cutting parameters will be applied. The initial period shall consist of normal operations on the test face. During the second and subsequent periods a set of shearer drums

manufactured by Winster Engineering Ltd. and supplied by FMA will be fitted. During these tests the shearer will be operated at both the low and high drum shaft speeds.

At a suitable time during the test Quarto will consider fitting the shearer on the test face with change gears supplied by FMA.

At the conclusion of the tests and subject to approval of the Government, the shearer drums will remain in the possession of Quarto for the remainder of their useful life. During this time Quarto will provide FMA with bit replacement and shearer maintenance rates. At the conclusion of their useful life the disposition of the shearer drums will be at the discretion of FMA.

IN WITNESS WHEREOF the parties have caused this Agreement to be executed as of the day and year first mentioned, by their respective officers duly authorized to do same.

ATTEST:

FOSTER-MILLER ASSOCIATES, INC.

By: _____

Secretary

WITNESS:

By: _____

President

APPENDIX C

FORTRAN PROGRAM FOR TRANSFORMATION OF RAW DUST LEVEL
TO CUMULATIVE EXPOSURE LEVELS

```
get,dustslp
READY.
list,f=dustslp
```

```
81/01/23. 14.32.26.
PROGRAM DUSTSLP
```

```
00100 PROGRAM DUSTSLP(INPUT,OUTPUT,DAT,TAPES=DAT,TAPE6)
00110C DUST PROG WITHCHECK FOR SKIPPED LINES
00120C AND OF THO FAST LINE PRENTER
00130 DIMENSION ID(2,6),T(6),CD(2,6),TEXT(8)
00131 REAL MIN
00140 REWIND 5
00150 CUM1=0.0
00160 CUM2=0.0
00170 N=0
00180C READ ID SAMPLE RATE AND START TIME
00190 READ(5,10) IDENT,(TEXT(I),I=1,8),SRT,ST
00200 10 FORMAT(18/8A8/F12.2/F12.2)
00210C PRINT BACK
00220 PRINT 20,IDENT,(TEXT(I),I=1,8),SRT,ST
00230 WRITE(6,20) IDENT,(TEXT(I),I=1,8),SRT,ST
00240 20 FORMAT(1X,18/8A8/F12.2/F12.2
00250+)
00260 MIN=(ST-AINT(ST))/0.6
00270 ST=AINT(ST)+MIN
00280 DO 400 I=1,4
00290 WRITE(6,80)
00300 80 FORMAT(1X,*B37 JON LUDLOW FOSTERMILLER ASSOC INC
00310+ TO BE COLLECTED *)
00320 400 CONTINUE
00330 99 CONTINUE
00340 N=N+1
00350 SIG=1.0
00360 ATO=AT
00370 READ(5,50)((ID(I,J),I=1,2),J=1,6),IH,IM,IS)
00380 IF (EOF(5))999,1550
00390 1550 CONTINUE
00400 50 FORMAT(2(1X,I5,3(2X,I5)/),1X,I5,3(2X,I5),1X,3I2)
00410 IC=IH+IM+IS
00420 IF(IC.GT.0)GOTO 950
00430 SIG=-1.0
00440 900 AT=ATO+0.1*SRT
00450 GOTO 951
00460 950 CONTINUE
```

```

00470 AT=TH*60.0+IM*1.0+IS/60.0
00480 951 CONTINUE
00490 DO 100 J=1,6
00500 T(J)=A+(J-6)*SRT/60
00510 T(J)=T(J)/60.0
00520 T(J)=ST+T(J)
00521 CPRINT 90,T(J)
00530 MIN=(T(J)-INT(T(J)))*0.6
00540 T(J)=AINT(T(J))+MIN
00550 CPRINT 90 ,MIN
00560 90 FORMAT(1X,F10.4)
00570 IF(T(J).GT.12.0) T(J)=T(J)-12.0
00580 T(J)=T(J)*SIG
00590 100 CONTINUE
00600 C CUMULATION
00610 DO 200 J=1,6
00611 IF(ID(1,J).GT.2000)ID(1,J)=2001
00612 IF(ID(2,J).GT.2000)ID(2,J)=2001
00620 CD(1,J)=CUM1+ID(1,J)*SRT/4000.0
00630 CD(2,J)=CUM2+ID(2,J)*SRT/3000.0
00640 CUM1=CD(1,J)
00650 CUM2=CD(2,J)
00660 WRITE(6,60)ID(1,J),CD(1,J),ID(2,J),CD(2,J),T(J)
00670 60 FORMAT(1X,2(I6,F11.2)F12.3)
00680 200 CONTINUE
00690 GOTO 99
00700 999 CONTINUE
00710 PRINT 70,AT,N
00720 70 FORMAT(1X,*PROG END AT*,F10.2,*MINS AFTER*,I7,* CYCLES
00730 REWIND 6
00740 REWIND 5
00750 END
READY.

```

APPENDIX D

DATA SET FOR STATISTICAL ANALYSIS
DATA ARRANGED AS DESCRIBED IN TABLE 7 ON PAGE 73

81/01/23. 14.24.14.
PROGRAM CDATE

10729452148187045118000000140
10729452204100074081153206000
10729452252083062065127121000
10729452000072000070000142000
10730452138158083080000000000
10730452161136000000000000000
10730452177163057096124154000
10730452131145062094180231000
107313520940000033000000000000
107313521610920580001380 0000
10731352162094057064117115000
10731352109162048077102108000
10801452134121043078000000000
10801452155126047077131125172
10801352122163038089129188000
20804452178133050063000000197
20804452177074050059095099150
20804452129109049063122118153
20804452190105066064122111140
2080535213711804007200 000195
20805352113105033051079099154
20805352081054025048078100130
20805352182085048062133148181
20806452253133068091000000187
20806452216125000000000000213
20807452097112051062000000178
20807452125159074076000000168
20807352000180000081000000240
20807452000148000088000000210
20807452182155053062121161187
2081170238415000000000000177
20811702000157000092000000204
20812552000115000071000000230
20812552000098067064149106180
20812552000098038053181135198
20812552114115047065134116178
20814701264124072065000000211
20814701397000122075000000220
20814701345162092073000000240
20814701298000084000000000197
20815702512207155163000000211
20818702460212109133000000265
20819551179048045042000000187
20819551198102053058000000211
20819551161125050066000000205

20820702000110000046000000230
20820702159130045068000138205
20820'02374145094106167173205
20820'02499205137164000000197
20821702227263091129000000187
20821702269146074095169148210
20821702519145107089169133210
20822552260237092133000000220
20822552362163094109208167245
208225523140000000000000200
2082255237400010100000000200
20822552358000102000185000195
20825701313197128162000000215
20825701269256070144178000187
20825701225206094125208190198
20908452197148064079 00000160
20908452198123043052081070133
20908352126154044083127120179
20908452115141039041090104178
20909352000111000063000000110
2090935200009900000000000104
20909352084118000057000108141
20909452162167058101083124155
20909452264186074109111147134
20910452231201081000108000192
20910452361307085168144211212
2091045216900000000000000191
2091145222500000000000000150
20911352173108047064000000138
20911352141103039053099099129
20911352151109033064104144149
20915452000144000000000000172
20916452194155054098000000166
20916452000155000081000144154
20917452141000054000000000176
2091845200022300000000000175

APPENDIX E
SPSS INSTRUCTION LIST

list,f=SPPROG

81/01/23. 14.31.08.
PROGRAM SPPROGRAM

5. RUN NAME
5.005 PRODD1
10. VARIABLE LIST
10.005 DM,DATE,SP,PKS,CH1,CH2,CH1S,CH2S,CH1C,CH2C,VENT,
12. INPUT FORMAT
12.005 FIXED(F1.0,F4.0,F2.0,F1.0,7F3.0)
15. INPUT MEDIUM
15.005 DISK
20. N OF CASES
20.005 81
30. PRINT FORMATS
30.005 ALL(1)
34. IF
34.005 (VENT LE 1.)VENT=200.
35. COMPUTE
35.005 VCH1=CH1*200./VENT
36. COMPUTE
36.005 VCH1=CH1*200./VENT
45. SELECT IF
45.005 (DM EQ 2)
46. SELECT IF
46.005 (PKS EQ 2)
48. MISSING VALUES
48.005 ALL(0)
50. PEARSON CORR
50.005 CH1,VCH1,SP,VENT
55. PARTIAL CORR
55.005 CH1 WITH SP BY VENT(1)
56. PARTIAL CORR
56.005 VCH1 WITH SP BY VENT(1)
57. PARTIAL CORR
57.005 CH1 WITH VENT BY SP(1)
58. PARTIAL CORR
58.005 VCH1 WITH VENT BY SP(1)
60. REGRESSION
60.005 VARIABLES=CH1,VCH1,SP,VENT
60.500 REGRESSION=CH1 WITH SP(4),VENT(2)/
60.605 REGRESSION=VCH1 WITH SP(4),VENT(2)
61. OPTIONS
61.005 6
70. BREAKDOWN
70.005 TABLES=CH1,VCH1 BY SP
71. STATISTICS
71.005 ALL
80. SCATTERGRAM
80.005 CH1(0,600),VCH1(0,600),VENT WITH SP
81. OPTIONS
81.005 7
82. STATISTICS
82.005 ALL
89. *SELECT IF
89.005 (SP EQ 45 AND VCH1 GE 1.)
90. SCATTERGRAM
90.005 CH1,VCH1 WITH VENT
91. STATISTICS
91.005 ALL
READY.

APPENDIX F

REGRESSION OF DRUM SPEED, NUMBER OF PICKS AND
VENTILATION VELOCITY ON DUST LEVEL DATA

This appendix contains the actual output of SPSS for the following regressions shown in Table F-1.

TABLE F-1. - Regressions

F	Dependent Variable(s)	Independent Variable(s)	Conditions
1	CH1, VCH1	SP, VENT	DM = 2, (new drums) and PKS = 2
2	CH2, VCH2	SP, VENT	DM = 2, (new drums) and PKS = 2
3	CH1S, VCH1S	SP, VENT	DM = 2, (new drums) and PKS = 2
4	CH2S, VCH2S	SP, VENT	DM = 2, (new drums) and PKS = 2
5	CH1C, VCH1C	SP, VENT	DM = 2, (new drums) and PKS = 2
6	CH2C, VCH2C	SP, VENT	DM = 2, (new drums) and PKS = 2
7	CH1	SP, PKS, VENT	DM = 2
8	CH2	SP, PKS, VENT	DM = 2
9	CH1S	SP, PKS, VENT	DM = 2
10	CH2S	SP, PKS, VENT	DM = 2
11	CH1C	SP, PKS, VENT	DM = 2
12	CH2C	SP, PKS, VENT	DM = 2
13	VCH1	SP, VENT	DM = 1 (old drums)

F3

- - - REGRESSION - - -

00051100 DM NEEDED FOR REGRESSION

DEP. VAR... CR16

MEAN RESPONSE 66.27500 STD. DEV. 22.22180

VARIABLE(S) ENTERED ON STEP 1
BP

MULTIPLE R	.7244	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.5247	REGRESSION	1.	17573.274	17573.274	41.952
STD DEV	20.4890	RESIDUAL	39.	15904.101	413.329	SIG. .000
ADJ R SQUARE	.5122	COEFF OF VARIABILITY	30.3607			

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
BP	1.771	.273	41.952	.000	.72437	1.31757
CONSTANT	-21.237	13.983	2.307	.137		

VARIABLE(S) ENTERED ON STEP 2
WENT

MULTIPLE R	.7431	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.5501	REGRESSION	2.	18479.138	9239.569	22.308
STD DEV	20.1254	RESIDUAL	37.	13326.237	405.023	SIG. .000
ADJ R SQUARE	.5279	COEFF OF VARIABILITY	30.1197			

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
BP	1.418	.357	15.777	.000	.57990	1.05473
WENT	.207	.138	2.238	.141	.21279	.36044
CONSTANT	-41.143	19.081	4.350	.038		

ALL VARIABLES ARE IN THE EQUATION.

F3 (continued)

DEP. VAR... VCH16

MEAN RESPONSE 72.94911 STD. DEV. 25.36305

VARIABLE(S) ENTERED ON STEP 1
SP

MULTIPLE R	.3685	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.3231	REGRESSION	1.	8312.817	8312.817	16.142
STD DEV	21.4061	RESIDUAL	38.	17412.333	458.219	SIG. .000
ADJ R SQUARE	.3059	COEFF OF VARIABILITY			29.3PCT	

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	1.219	.286	18.142	.000	.568457	.33109
CONSTANT	12.322	14.631	.702	.405		

* * * * *

VARIABLE(S) ENTERED ON STEP 2
VENT

MULTIPLE R	.3814	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.3487	REGRESSION	2.	8696.300	4348.150	8.849
STD DEV	21.2331	RESIDUAL	37.	16705.348	451.495	SIG. .000
ADJ R SQUARE	.3146	COEFF OF VARIABILITY			29.1PCT	

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	1.324	.377	12.318	.000	.71068	1.08803
VENT	-.179	.148	1.512	.227	-.21335	-.44345
CONSTANT	19.303	20.159	2.142	.152		

ALL VARIABLES ARE IN THE EQUATION.

F4

- - - REGRESSION - - -

00051100 CM NEEDED FOR REGRESSION

DEP. VAR... CR26

MEAN RESPONSE 82.51364 STD. DEV. 32.10609

VARIABLE(S) ENTERED ON STEP 1
SP

MULTIPLE R	.4852	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.2355	REGRESSION	1.	10438.701	10438.701	12.935
STD DEV	28.4051	RESIDUAL	42.	33887.731	806.851	SIG. .001
ADJ R SQUARE	.2173	COEFF OF VARIABILITY		34.4907		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	1.217	.339	12.935	.001	.48524	.73015
CONSTANT	22.092	17.310	1.338	.205		

VARIABLE(S) ENTERED ON STEP 2
VENT

MULTIPLE R	.5244	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.2750	REGRESSION	2.	12121.075	6060.537	7.777
STD DEV	27.9954	RESIDUAL	41.	32133.357	783.740	SIG. .001
ADJ R SQUARE	.2397	COEFF OF VARIABILITY		33.9907		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	.934	.421	3.831	.054	.30044	.30021
VENT	.029	.152	2.338	.142	.25068	.48870
CONSTANT	1.005	22.348	.000	1.000		

ALL VARIABLES ARE IN THE EQUATION.

F4 (continued)

DEP. VAR... VCH2S

MEAN RESPONSE 31.46623 STD. DEV. 30.06025

VARIABLE(S) ENTERED ON STEP 1
SP

MULTIPLE R	.1980	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.0392	REGRESSION	1.	1522.516	1522.516	1.713
STD DEV	29.3145	RESIDUAL	42.	37334.022	888.905	SIG. .198
ADJ R SQUARE	.0163	COEFF OF VARIABILITY		32.6PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	.465	.055	1.713	.199	.19795	.25190
CONSTANT	68.426	18.169	14.193	.001		

VARIABLE(S) ENTERED ON STEP 2
VENT

MULTIPLE R	.3107	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.0866	REGRESSION	2.	3752.037	1876.019	2.181
STD DEV	29.2311	RESIDUAL	41.	35104.300	856.210	SIG. .105
ADJ R SQUARE	.0525	COEFF OF VARIABILITY		32.0PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	.1997	.440	4.124	.048	.38182	-.48600
VENT	-.0556	.159	2.304	.114	-.30202	-.50878
CONSTANT	83.550	20.372	15.817	.000		

ALL VARIABLES ARE IN THE EQUATION.

SEUS USED THIS PROCEDURE.. 1.0889 UNITS

F6

- - - REGRESSION - - -

00051100 CM NEEDED FOR REGRESSION

DEP. VAR... CH2C

MEAN RESPONSE 128.92000 STD. DEV. 30.34101

VARIABLE(S) ENTERED ON STEP 1
SP

MULTIPLE R	.3270	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.1069	REGRESSION	1.	3382.111	3382.111	2.753
STD DEV	29.2900	RESIDUAL	20.	15731.729	786.586	SIG. .111
ADJ R SQUARE	.0681	COEFF OF VARIABILITY		22.7PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	.933	.502	2.753	.111	.32698	.30885
CONSTANT	89.102	24.701	13.012	.001		

VARIABLE(S) ENTERED ON STEP 2
VENT

MULTIPLE R	.6812	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.4641	REGRESSION	2.	10253.719	5126.860	3.526
STD DEV	23.1989	RESIDUAL	22.	11840.121	538.187	SIG. .001
ADJ R SQUARE	.4154	COEFF OF VARIABILITY		18.3PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	-.365	.540	1.087	.308	-.22182	-.20982
VENT	.778	.203	14.883	.001	.81146	1.03563
CONSTANT	22.421	26.190	.734	.401		

ALL VARIABLES ARE IN THE EQUATION.

F6 (continued)

DEP. VAR... VCH20

MEAN RESPONSE 151.05763 STD. DEV. 27.75885

VARIABLE(S) ENTERED ON STEP 1
SP

MULTIPLE R	.2382	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.0588	REGRESSION	1.	1049.343	1049.343	1.384
STD DEV	27.5385	RESIDUAL	23.	17443.745	758.424	SIG. .051
ADJ R SQUARE	.0187	COEFF OF VARIABILITY			18.3PCT	

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	.555	.472	1.384	.251	-.03823	-.17571
CONSTANT	177.600	23.225	59.475	.0		

VARIABLE(S) ENTERED ON STEP 2
VENT

MULTIPLE R	.2382	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.0588	REGRESSION	2.	1049.366	524.683	.282
STD DEV	28.1583	RESIDUAL	22.	17443.821	792.892	SIG. .505
ADJ R SQUARE	.0	COEFF OF VARIABILITY			18.3PCT	

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	-.570	.555	.704	.411	-.03586	-.17398
VENT	-.001	.027	.000	.989	-.00351	-.00348
CONSTANT	177.883	31.788	31.308	.000		

ALL VARIABLES ARE IN THE EQUATION.

SPUS USED THIS PROCEDURE... 1.097 UNITS

F7

--- REGRESSION ---

00053200 CM NEEDED FOR REGRESSION

DEP. VAR... CH1

MEAN RESPONSE 227.51352 STD. DEV. 112.65522

VARIABLE(S) ENTERED ON STEP 1
SP

MULTIPLE R	.7025	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.4935	REGRESSION	1.	331284.338	.33E+06	50.371
STD DEV	90.3402	RESIDUAL	52.	340668.545	6551.518	SIG. .000
ADJ R SQUARE	.4828	COEFF OF VARIABILITY	34.1PCT			

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	5.129	.291	50.671	.000	.70252	1.35235
CONSTANT	-93.333	46.448	3.248	.077		

VARIABLE(S) ENTERED ON STEP 2
PKS

MULTIPLE R	.7483	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.5605	REGRESSION	2.	378977.480	.19E+06	22.514
STD DEV	76.1332	RESIDUAL	51.	295658.001	5797.178	SIG. .000
ADJ R SQUARE	.5432	COEFF OF VARIABILITY	32.1PCT			

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	7.391	.928	63.441	.0	.24711	1.33070
PKS	65.148	30.558	7.755	.007	.29838	.35060
CONSTANT	-304.331	90.438	11.324	.001		

VARIABLE(S) ENTERED ON STEP 3
VENT

MULTIPLE R	.7764	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.6028	REGRESSION	3.	405481.548	.13E+06	25.297
STD DEV	73.0981	RESIDUAL	50.	257151.338	5143.039	SIG. .000
ADJ R SQUARE	.5790	COEFF OF VARIABILITY	30.8PCT			

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	5.952	1.112	27.678	.000	.67076	1.29121
PKS	87.753	29.358	8.935	.004	.30542	.67050
VENT	1.008	.437	5.335	.025	.27408	.78624
CONSTANT	-415.170	99.202	17.515	.000		

ALL VARIABLES ARE IN THE EQUATION.

SBUS USED THIS PROCEDURE.. 1.8501 UNITS

F8

--- REGRESSION ---

00053200 CM NEEDED FOR REGRESSION

DEP. VAR... CH2

MEAN RESPONSE 145.91379 STD. DEV. 30.58822

VARIABLE(S) ENTERED ON STEP 1
SP

MULTIPLE R	.3703	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.1371	REGRESSION	1.	20000.391	20000.391	8.388
STD DEV	47.4101	RESIDUAL	36.	125872.378	3247.721	SIG. .004
ADJ R SQUARE	.1217	COEFF OF VARIABILITY		32.5PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	1.433	.480	8.883	.004	.37028	.30459
CONSTANT	72.287	25.455	8.064	.008		

VARIABLE(S) ENTERED ON STEP 2
PKS

MULTIPLE R	.3848	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.1481	REGRESSION	2.	21602.511	10801.255	4.780
STD DEV	47.5337	RESIDUAL	55.	124270.058	2259.456	SIG. .012
ADJ R SQUARE	.1171	COEFF OF VARIABILITY		32.6PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	1.811	.526	9.383	.003	.41618	.56713
PKS	16.840	19.780	.709	.403	.11442	.21235
CONSTANT	32.176	54.038	.355	.554		

VARIABLE(S) ENTERED ON STEP 3
VENT

MULTIPLE R	.4328	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.1873	REGRESSION	3.	27319.157	9106.385	4.148
STD DEV	46.8555	RESIDUAL	54.	119553.412	2195.434	SIG. .010
ADJ R SQUARE	.1421	COEFF OF VARIABILITY		32.1PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	1.025	.533	2.828	.111	.23492	.36102
PKS	17.523	19.486	.809	.372	.12043	.22362
VENT	.367	.228	2.804	.112	.25068	.46306
CONSTANT	-6.559	59.529	.014	.906		

ALL VARIABLES ARE IN THE EQUATION.

SBUS USED THIS PROCEDURE.. 1.8261 UNITS

F11

DEP. VAR... CHIC

MEAN RESPONSE 132.50000 STD. DEV. 40.18383

VARIABLE(S) ENTERED ON STEP 1
SP

MULTIPLE R	.7681	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.5899	REGRESSION	1.	23813.997	23813.997	34.524
STD DEV	26.2535	RESIDUAL	24.	18554.503	889.771	SIG. .000
ADJ R SQUARE	.5728	COEFF OF VARIABILITY		19.8PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	2.531	.431	34.524	.000	.76808	.94422
CONSTANT	7.381	21.907	.114	.738		

VARIABLE(S) ENTERED ON STEP 2
PKS

MULTIPLE R	.7713	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.5950	REGRESSION	2.	24017.561	12008.780	18.892
STD DEV	26.6829	RESIDUAL	23.	16350.339	710.910	SIG. .000
ADJ R SQUARE	.5597	COEFF OF VARIABILITY		20.1PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	2.387	.504	22.629	.000	.72741	.89424
PKS	-12.100	22.612	.286	.598	-.08183	-.17581
CONSTANT	37.282	80.124	.385	.541		

VARIABLE(S) ENTERED ON STEP 3
VENT

MULTIPLE R	.8874	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.7875	REGRESSION	3.	31789.531	10596.510	27.174
STD DEV	19.7472	RESIDUAL	22.	8578.969	389.953	SIG. .000
ADJ R SQUARE	.7585	COEFF OF VARIABILITY		14.9PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	1.024	.484	4.486	.046	.31080	.38208
PKS	-28.687	17.153	2.793	.109	-.19386	-.41606
VENT	.761	.170	19.931	.000	.57642	1.00731
CONSTANT	3.534	45.166	.006	.938		

ALL VARIABLES ARE IN THE EQUATION.

SBUS USED THIS PROCEDURE.. 1.7781 UNITS

F12

- - - REGRESSION - - -

00053200 CM NEEDED FOR REGRESSION

DEP. VAR... CH2C

MEAN RESPONSE 131.26923 STD. DEV. 32.05088

VARIABLE(S) ENTERED ON STEP 1
SP

MULTIPLE R	.4148	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.1721	REGRESSION	1.	4418.601	4418.601	4.987
STD DEV	29.7647	RESIDUAL	24.	21262.515	885.938	SIG. .035
ADJ R SQUARE	.1376	COEFF OF VARIABILITY		22.7PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	1.067	.478	4.987	.035	.41480	.39564
CONSTANT	79.334	23.977	10.948	.003		

VARIABLE(S) ENTERED ON STEP 2
PKS

MULTIPLE R	.4813	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.2317	REGRESSION	2.	5949.367	2974.683	3.467
STD DEV	29.2800	RESIDUAL	23.	19731.729	857.891	SIG. .048
ADJ R SQUARE	.1648	COEFF OF VARIABILITY		22.3PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	.833	.502	2.753	.111	.32370	.30875
PKS	-42.567	31.881	1.784	.195	-.26059	-.63637
CONSTANT	174.276	74.889	5.415	.029		

VARIABLE(S) ENTERED ON STEP 3
VENT

MULTIPLE R	.7341	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.5390	REGRESSION	3.	13840.994	4613.665	9.573
STD DEV	23.1888	RESIDUAL	22.	11840.121	538.187	SIG. .001
ADJ R SQUARE	.4761	COEFF OF VARIABILITY		17.7PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
SP	-.565	.540	1.097	.306	-.21970	-.20955
PKS	-53.091	25.400	4.369	.048	-.32486	-.79333
VENT	.778	.203	14.563	.001	.76308	1.02312
CONSTANT	128.812	60.502	4.519	.045		

ALL VARIABLES ARE IN THE EQUATION.

SBUS USED THIS PROCEDURE.. 1.7781 UNITS

Statistical Analysis

The data that were examined related to midface measurements of dust exposure per shield. Correlation analysis produced a picture similar to that revealed with the full data set. The most significant result was the relationship between the raw dust level VCH1 and SP ($r = 0.541$, $p = 0.023$). This represents a strong association given that only 14 cycles were available and that the speeds employed were 35 and 45 rpm.

Given that midface ventilation velocity was largely unknown, the calculation of *partial correlation coefficients* was not relevant. Regression of SP on VCH1 yielded the following equation:

$$\text{VCH1} = 4.69 \times \text{SP} - 34.6, \quad p = 0.046$$

(See Appendix F for regression results.)

Table H-1 represents a comparison of the raw dust production rates achieved by the two drums at 35 and 45 rpm. It is perhaps surprising to see that at both speeds the dust make per shield was lower with the old drum than with the newer one which was subjectively the cleaner mining tool both in the view of the author of this report and of the face personnel. In order to reconcile these results it would be necessary to determine the ventilation velocities corresponding to the mining cycles monitored with the new drum. It may be that there was a consistent variation in face airflow between the two conditions which would account for some or all of the observed difference in dust production rate.

TABLE H-1. - Comparison of dust production rates -
new and old drums

Speed (rpm)	Drums	
	Old	New
35	129.6	171.7
45	176.5	225.6