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UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTENTS

ILLUSTRATIONS

TABLES

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

deg	degree	lbf/in^2	pound-force per square inch
ft	foot	mg/m^3	milligram per cubic meter
ft/min	foot per minute	mg/st	milligram per short ton
ft^3/min	cubic foot per minute	pct	percent
ft^3/st	cubic foot per short ton	r/min	revolution per minute
h	hour	st	short ton
in	inch	st/min	short ton per minute
in/rev	inch per revolution	yr	yr
kW	kilowatt		
kW•h/st	kilowatt hour per short ton		

EFFECT OF SHEARER WEB DEPTH ON DUST GENERATION AND METHANE LIBERATION

By J. A. Organiscak,[1] D. M. Doyle-Coombs,[1] and A. B. Cecala[1]

ABSTRACT

The Bureau of Mines recently investigated dust generation and methane liberation during half- and full-web cutting at a double-drum shearer longwall face. This study was conducted to ascertain the health and safety aspects of wider web shearing at longwalls. Results from these underground tests showed that deeper web cutting reduced dust generation and methane liberation per ton of coal mined, while significantly improving shearer production rates. When cutting with the airflow (head-to-tail cut pass) full-web cutting decreased dust generation per ton by 16 pct at the shearer and 6 pct at the tailgate, with an increase in shearer production rate of 72 pct. Methane liberation per short ton also decreased by 36 pct at the shearer and 22 pct at the tailgate. Full-web cutting against the airflow (tail-to-head cut pass) decreased dust generation per ton by 41 pct at the shearer and 37 pct at the tailgate over half-web cutting, with an increase in shearer production rate of 61 pct. Methane liberation per ton also decreased by 35 pct at the shearer and 41 pct at the tailgate. These improvements for full-web cutting are a reflection of improved cutting efficiency (less dust and methane produced from cutting) and less new face area exposed per ton of coal mined (less methane liberated from face per short ton of coal mined).

[1]Mining engineer, Pittsburgh Research Center, Bureau of Mines, Pittsburgh, PA.

INTRODUCTION

Since the introduction of longwall mining in the United States more than 25 yr ago, there has been concern for the health and safety of this highly productive mining method. This concern grew through the 1970's when longwall usage significantly increased and only about one-third of the double-drum shearer sections were in compliance with the 2.0 mg/m^3 respirable dust standard (1).[2] Also, during the late 1970's and early 1980's, the number of recorded longwall face ignitions increased because the high rate of extraction increases methane liberation (2). These events posed a potential conflict between longwall production and worker health and safety.

Bureau of Mines research efforts have produced novel dust and methane control technology to protect the health and safety of workers with negligible impact on production. Dust control developments included numerous water applications, ventilation methods, and machine designs (3). Previous longwall methane studies were conducted to investigate methane emission phenomena and develop ignition prevention technology that included various types of bit flushing and ventilation techniques (2, 4-5). Through these research efforts longwall health and safety has improved and must continue to keep pace with higher longwall production technology under development.

A concept with potential for improving longwall shearer productivity without adversely affecting dust generation is wider web shearing. The British have experimented with increasing shearer drum web depth from 22 to 37 in and have reported a 35-pct increase in productivity, with a reduction in the dust levels (6). Since this experimentation was conducted under considerably different geologic conditions using different longwall equipment than found in the United States, the U.S. Department of Energy investigated the feasibility of wider web shearing using existing U.S. equipment. This study indicated that wider web cutting was technically feasible, but uncertainty remained about its effect on dust generation and methane liberation.

A dust and methane study was conducted by the Bureau at a double-drum longwall shearer section, using 15- and 30-in web depths (referred to as half- and full-web, respectively, through the rest of the paper), to provide insight into the effect of web depth on dust generation and methane liberation. Dust concentrations and methane levels were monitored continuously at the shearer and tailgate. A detailed time record was kept to correlate production rates with dust generation and methane liberation. This report describes the study and presents the findings.

LONGWALL DESCRIPTION

The longwall studied was mining the Pocahontas No. 3 seam, which has an average thickness of 66 in and average depth of cover of 800 ft. A double-drum, chain-haulage, Sagem Sirus 400[3] shearer was employed with 54-in-diam drums rotating at 52 r/min. A total of 40 bits were laced on each 3-start drum. Point attack through-flush bits were used on the drum vanes for dust and methane control; radial attack bits were used on the drum's clearance ring. No external shearer-clearer-type spray system was used, but several external water sprays were directed at the shearer drums and on

[2]Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

[3]Reference to specific products does not imply endorsement by the Bureau of Mines.

the face conveyor. The cutting sequence used was bidirectional shearing. Face length was 525 ft supported by 108 4-legged Joy chock shields, each with a 650-ton yield capacity. Coal was removed from the face on a Westfalia M2-V600, double-inboard face conveyor with over-the-end discharge at the headgate. Air velocity averaged 465 ft/min or 32,500 ft^3/min along the face.

DUST AND METHANE SAMPLING

Respirable dust measurements were made with real-time aerosol monitors (RAM's) located 20 ft on the intake side of the shearer, at the midpoint of the shearer, and on the tailgate end of the face (shield 99). The RAM is a light-scattering instrument that measures the near-infrared light refracted in the forward direction by an aerosol or dust. This instrument has a relative linear response to dust concentrations. Each RAM has a continuous digital display and was equipped with a Metrosonics dl-331 data logger. Two gravimetric samplers were located at the last open crosscut to measure face intake dust concentrations, and two gravimetric samplers were located at the tailgate end next to the RAM-1 to determine the RAM-gravimetric calibration factor. This factor is the ratio of the average gravimetric dust concentration to the average RAM dust concentration measured at the tailgate. Each day's calibration factor was applied to all RAM measurements made at the face to determine absolute (gravimetric) instantaneous concentrations.

Continuous methane measurements were made with remote-sensing CSE 180R methane monitors located at the shearer and tailgate end of face (shield 99). The remote-sensing head uses a catalytic diffusion-type sensor connected by a cable to the monitor. Concentrations are recorded continuously on an internal strip-chart recorder and can be optionally displayed on the monitor. The shearer-mounted monitor was used to determine methane liberated during face cutting at a point on the face side of the shearer body near the tailside drum. The tailgate monitor was used to determine total face methane concentrations, consisting of methane liberated by the shearer during cutting and methane emitted along the face area. Secondary spot methane measurements were made with a handheld monitor on an extender pole to identify any drastic changes in methane levels around the shearer and to verify the other recording methane monitors.

Dust and methane sampling was conducted during four half-web passes (15-in web width) in each cut direction and six full-web passes (30-in web width) in each cut direction. Sampling was conducted only during shearing in the middle 400 ft of the face, omitting cutouts. Data analysis only includes dust and methane concentrations during cutting; the results of the study are shown in table 1.

TABLE 1. - Results of half- and full-web cutting

	Head-to-tail cut pass			Tail-to-head cut pass		
	Half web	Full web	Change, pct	Half web	Full web	Change, pct
Passes	4	6	NAp	4	6	NAp
Av shearer haulage speed...ft/min..	22.3	19.1	-14	21.8	17.5	-20
Max bit penetration........in/rev..	2.57	2.20	-14	2.52	2.02	-20
Face length sampled...........ft..	400	400	0	400	400	0
Production during sampling.....st..	120	240	100	120	240	100
Production rate............st/min..	6.69	11.5	72	6.54	10.5	61
Specific energy[1]..........kW·h/st..	0.75	0.43	-43	0.76	0.48	-37
Av dust conc, mg/m^3:						
Intake	0.67	0.74	10	0.72	0.48	-33
Shearer	2.20	2.95	34	2.12	1.80	-15
Tailgate	2.44	3.58	47	2.96	2.76	-7
Dust generated,[2] mg/st:						
At shearer	210	177	-16	197	116	-41
At tailgate	269	252	-6	349	221	-37
Av methane conc, pct:						
Shearer	0.50	0.55	10	0.43	0.45	5
Tailgate	0.36	0.48	33	0.45	0.43	-4
Av air quantity, ft^3/min:						
Face	32,500	32,500	0	32,500	32,500	0
Tailgate	35,980	35,980	0	35,980	35,980	0
Methane liberated,[3] ft^3/st:						
At shearer	24.3	15.6	-36	21.4	14.0	-35
At tailgate	19.4	15.1	-22	24.4	14.7	-41

NAp Not applicable.
[1]Estimated based on production rates and average shearer input power rating.
[2]Based on $\frac{\text{(dust conc - intake conc) X (air quantity)(0.0283)(face length)}}{\text{(production)(tram speed)}}$.
[3]Based on $\frac{\text{(pct methane)(air quantity)(face length)}}{\text{(production)(tram speed)}}$.

WEB DEPTH VERSUS DUST GENERATION

HEAD-TO-TAIL PASS

Production rate and dust concentrations increased with wider web cutting during the head-to-tail cut pass (see table 1). Full-web cutting reduced the shearer haulage speed by 14 pct but increased the production rate by 72 pct over half-web cutting. This improved production rate for full-web cutting has yielded a 43-pct reduction in the shearer's specific energy consumption (energy consumed to mine 1 st of coal). The notable reduction in specific energy is attributed to the easy to moderate cutting conditions of the Pocahontas No. 3 coal seam. Deeper web cutting improved the shearer's production rate by utilizing its power capability more efficiently.

The dust concentrations along the face also increased with production rate for full-web cutting, but did not increase as much as the production rate. Figure 1 illustrates the average dust concentrations at the face for both web depths. Full-web cutting increased dust concentrations by 34 pct and 47 pct at the shearer midpoint and tailgate end of the face, respectively. Cutting in the same direction as ventilation places the cutting drums in direct contact with the airflow. During full-web cutting, the ventilating airstream passes directly over the trailing drum and around the leading drum, entraining more dust from the additional coal being cut (see figure 2). The increase in dust concentrations at the shearer for full-web cutting with airflow could be remedied with a shearer-clearer or passive barriers (7-8).

Although the production rate and dust concentrations increased for wider web cutting in the head-to-tail direction, the amount of dust generated per unit of production decreased. As mentioned previously, dust concentrations did not increase as much as production rates for

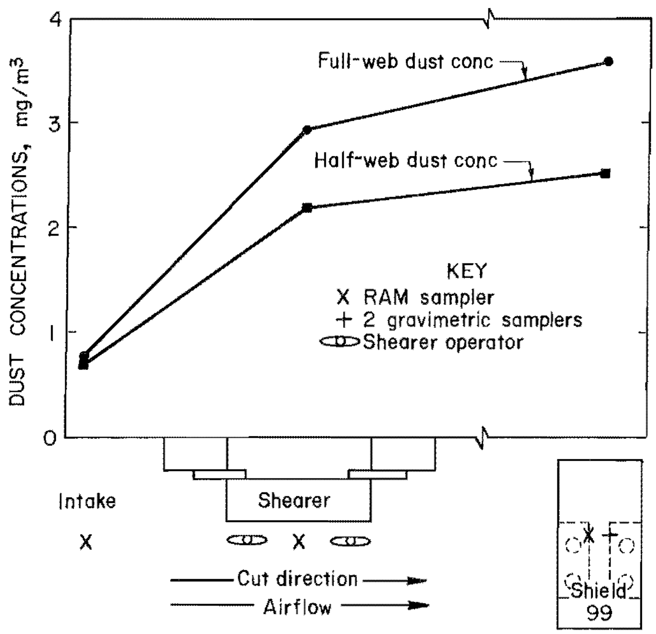

FIGURE 1.–Average dust concentrations at face during the head-to-tail cut pass.

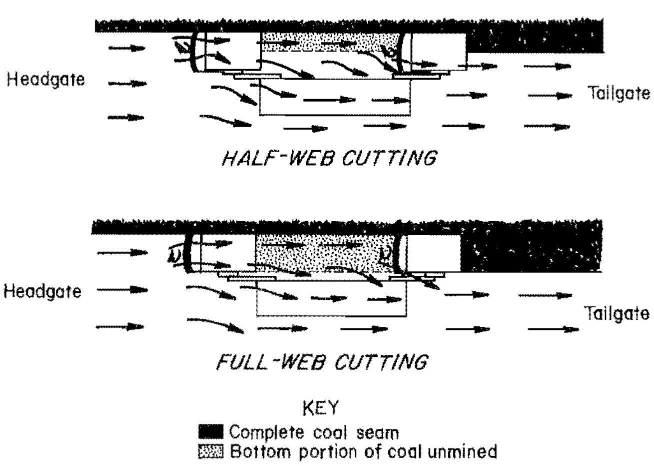

FIGURE 2.–Airflow around shearer while cutting with airflow.

wider web cutting. Dust concentrations are normalized in table 1 for production and ventilation to determine the specific dust generated for half- and full-web cutting. *Dust generated per ton for full-web cutting decreased by 16 pct at the shearer midpoint and 6 pct at the tailgate compared with half-web cutting.* Thus an improvement in the shearer's cutting efficiency is reflected by both the reduction in the shearer's specific energy consumption and dust generation for wider web cutting in the direction of face ventilation.

TAIL-TO-HEAD PASS

During the tail-to-head pass, the production rate increased and dust concentrations decreased with wider web cutting (see table 1). Full-web cutting reduced the shearer haulage speed by 20 pct, but increased production rate by 61 pct over half-web cutting. This amounted to a 37-pct reduction in the shearer's specific energy consumption for full-web cutting. The shearer's improved cutting efficiency was again attributed to easy to moderate cutting conditions of the coal seam.

Dust concentrations decreased along the face despite an increase in production rates with full-web cutting. Figure 3 shows the average dust concentrations measured at the face for both web depths.

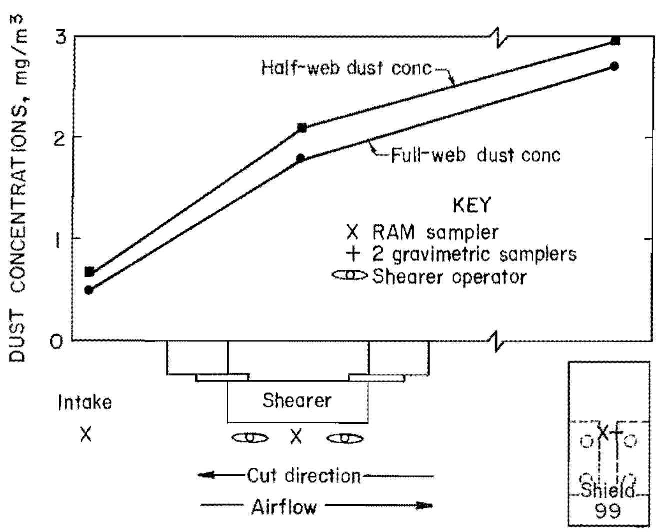

FIGURE 3.–Average dust concentrations at face during tail-to-head cut pass.

Dust concentrations were 15 pct lower at the shearer midpoint and 7 pct lower at the tailgate for full-web cutting. Wider web cutting against ventilation is less dusty because the cutting drums are better shielded from direct face airflow, reducing dust entrainment (see figure 4). The leading drum is shielded from the face airflow, and this confinement improves drum spray dust suppression.

A significant decrease in the dust generated per unit of production for wider web cutting was realized during the tail-to-head pass. This occurred because dust concentrations at the face decreased, while production increased during full-web cutting. Specific dust generated was determined for half- and full-web cutting in table 1 by normalizing dust concentrations for production and ventilation. *Dust generated per short ton for full-web cutting decreased by 41 pct at the shearer midpoint and 37 pct at the tailgate compared with half-web cutting.*

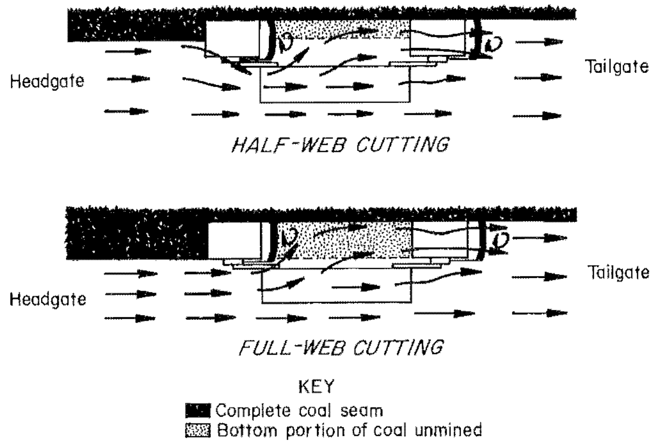

FIGURE 4.—Airflow around shearer while cutting against airflow.

Thus wider web cutting against the direction of face ventilation again shows an improvement in the shearer's cutting efficiency based on the reductions in shearer specific energy consumption and dust generation.

WEB DEPTH VERSUS METHANE LIBERATION

HEAD-TO-TAIL PASS

Methane concentrations increased with production levels for wider web cutting during the head-to-tail cut pass (see table 1). Figure 5 illustrates the average methane concentrations at the face for both web depths. Methane concentrations increased by 10 pct at the shearer and by 33 pct at the tailgate with a 72-pct increase in production rate from full-web cutting. Mining in the direction of ventilation places the cutting drums in the direct path of the airflow (see figure 2). During full-web cutting, the methane liberated from the additional coal cut is quickly dispersed into the airstream moving over the trailing drum and around the lead drum.

Methane liberation patterns at the face indicate that methane was equally liberated by cutting and face drainage. In figure 5, methane levels for both web depths show a slight decline from the shearer to the tailgate, indicating shearer-generated methane is being diluted by ventilation. If most of the methane was produced by cutting, a much greater decline in concentrations from the shearer to the tailgate would be observed (4). If the methane concentration increased from the shearer to the tail end of the face, most of the methane would be liberated from face drainage. Methane spotter measurements around the shearer confirmed that only a slight decrease in methane levels occurred downstream of the shearer and showed that the

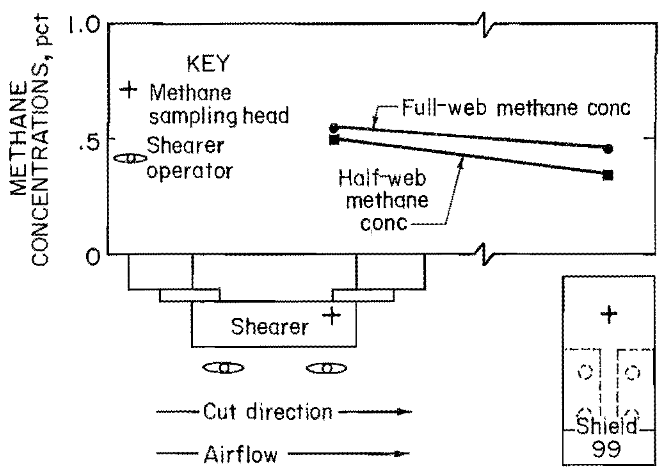

FIGURE 5.—Average methane concentrations at face during head-to-tail cut pass.

highest methane concentrations occurred behind the lead drum at the face. Methane concentrations measured behind the lead drum with the handheld spotter were normally 0.1 to 0.2 pct higher than the continuous sampling monitor on the shearer and sometimes reached 1 pct for either web depth, requiring the shearer to temporarily stop for methane dilution by ventilation. The 1 pct peak methane concentrations usually occurred at the center portion of the face, where the distance between the unmined coal block and developed gate entries of the panel was the greatest.

Although methane concentrations increased with production rate from wider web cutting in the head-to-tail direction, the amount of methane liberated per unit of production decreased. Methane concentrations did not increase as much as production rates did for wider web cutting, so normalizing methane concentrations for production and ventilation (see table 1) shows a decrease in methane liberation with a wider web. *Methane liberated per short ton for full-web cutting decreased by 36 pct at the shearer midpoint and 22 pct at the tailgate compared with half-web cutting.* This reduction in methane liberation for full-web cutting is a reflection of less fines produced (less dust and improved cutting efficiency) and less face area exposed per ton of coal mined (less methane liberated from face per ton of coal mined).

TAIL-TO-HEAD PASS

During the tail-to-head pass, methane concentrations remained essentially the same, while production rates increased with wider web cutting. The average methane concentrations at the face during the tail-to-head pass for both web depths are shown in figure 6. Methane concentrations increased by 5 pct at the shearer and decreased by 4 pct at the tail end of the face, with a 61-pct increase in production rate from full-web cutting. Full-web cutting against the airflow shields the lead drum by the face and any increase in methane liberation

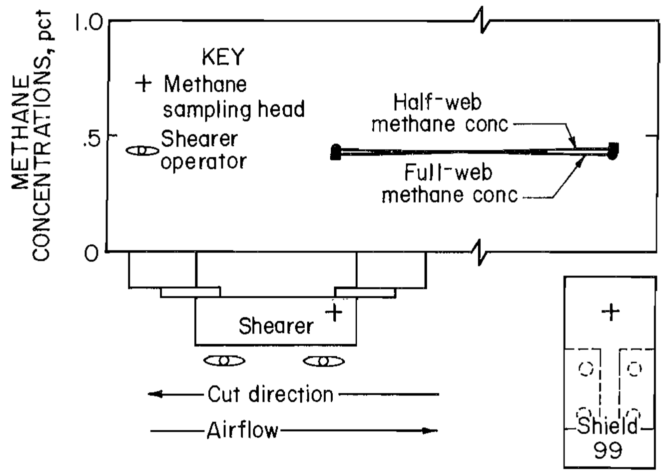

FIGURE 6.–Average methane concentrations at face during tail-to-head cut pass.

from cutting and may not fully disperse into the airstream over the shearer body where it can be measured by the monitor (see appendix A, for shearer tracer gas tests in laboratory). Again, methane spotter measurements behind the lead drum were normally 0.1 to 0.2 pct higher than at the continuous sampling location on the shearer body, so no significant buildup of methane concentrations behind the lead drum was detectable. However, methane spotter measurements behind the lead drum sometimes reached 1 pct at the shearer for either web depth in the center portion of the face, requiring the shearer to stop for dilution.

Methane liberation per unit of production significantly decreased for wider web shearing during the tail-to-head pass because methane concentrations essentially did not change with the significant increase in production rate. Methane concentrations are normalized in table 1 for production and ventilation. *Methane liberation per short ton for full-web cutting decreased by 35 pct at the shearer and 41 pct at the tailgate compared with half-web cutting.* The reduction in methane liberation for wider web cutting against the airflow again reflects an improvement in the shearer's cutting efficiency and less face area exposed per ton mined.

WEB DEPTH DISCUSSION

Results of this study have shown that deeper web cutting produced less dust and methane per short ton of coal mined. Deeper web cutting appears to be more efficient because of its increased production, with less dust fines and methane produced per short ton of mined coal. Inefficient cutting produces more fines (dust) per short ton of coal mined. A look at the cutting parameters involved would provide some insight to theorize about deeper web cutting.

Full-web cutting slowed shearer haulage speeds and reduced the maximum bit penetration by 14 pct for the head-to-tail pass and by 20 pct for the tail-to-head pass over half-web cutting. Slower haulage speeds occurred for deeper web cutting because of the increase in power consumed by the additional bits and loading requirements of the drums. The bits laced on the gobside half of the drum web compose about one-third of the total amount on the drum and cut the same web depth as the other two-thirds of the bits (see figure 7). Although the decrease in bit penetration produces more fines per bit, the lower dust generation and methane liberation per short ton of production for wider web cutting indicates that more fines are produced by the dense bit pattern on the drums clearance rings (9-10). Thus, dust and methane produced from reduced bit penetration at slower shearer haulage speeds seem to be offset by the wider bit spacing on the additional portion of the drum.

Shearer specific energy also experienced a decrease with wider web cutting because production rates increased. Specific energy is the amount of energy consumed by the shearer to mine and load 1 st of coal. Full-web cutting decreased the estimated specific energy by 43 pct for the head-to-tail pass and 37 pct for the tail-to-head pass over half-web cutting. Although power consumption was not directly measured at this section, measurements at another shearer section with varying web depths confirm that specific energy does decrease with an increase in web depth (see figure 8)(11). These data were collected over 12 tail-to-head cut passes from a chain haulage Anderson Mavor 500 (AM 500) shearer. The specific energy changes measured on this shearer were not as significant, but do reflect a decrease in specific energy with respect to increasing web depth. The smaller change measured on the AM 500 shearer is attributed to the harder cutting conditions of the Castle Gate D coal seam mined, which reduced the shearer's haulage speed by 25 pct. Thus higher production rates for a given time period with wider web cutting utilizes the shearer's power more efficiently.

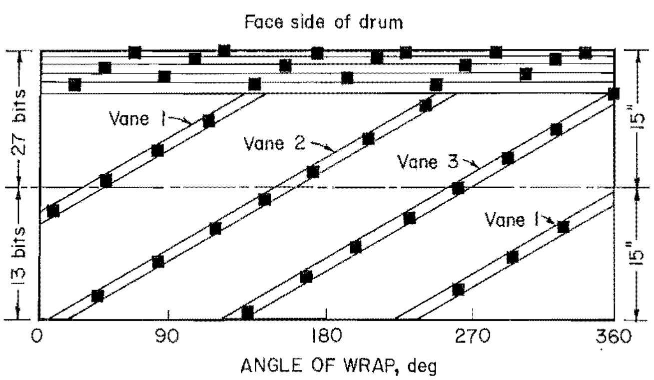

FIGURE 7.—Plan view of three-start longwall shearer drum.

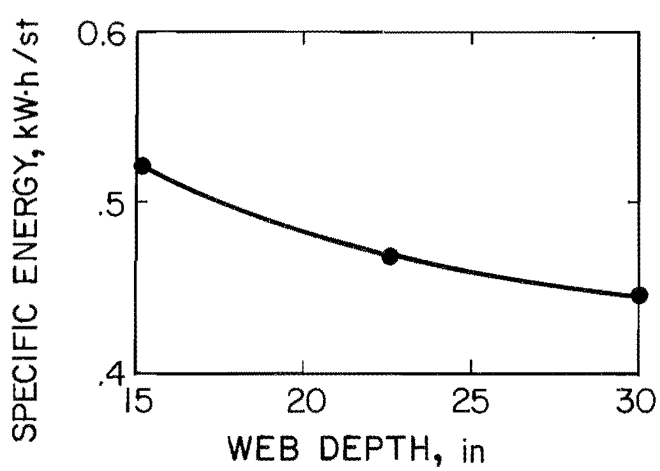

FIGURE 8.—Specific energy consumption versus web depth for longwall shearer.

CONCLUSIONS

The results of this longwall study indicate that wider web cutting provides potential advantages regarding production rate, dust generation, and methane liberation. When the web depth was increased, the production rate increased, and dust and methane production per short ton decreased. This resulted from the wider lateral spacing of fewer bits on the additional portion of the drum. About two-thirds of the drum's bits are on the face half of the drum, including a dense bit pattern on the drum's clearance or face ring, which generates a large portion of fines during mining. Thus, wider web shearing offers potential productivity increases, with improved cutting efficiency.

The extent of web depth advantages in harder cutting conditions and significant wider webs (>40 in) have yet to be studied in the United States. Benefits of wider web cutting may diminish when cutting a significant amount of rock (partings, roof, and floor). Higher bit forces experienced when cutting rock with wider webs may significantly reduce the shearer haulage speed to a point where more fines are produced from reduced bit penetration. Also the impact of ignition potential is uncertain for wider web shearing in gassy coal seams where most of the methane is liberated by cutting, because methane concentrations can build up to explosive levels in dead air zones around the shearer. This study indicates that greater web depth may not increase the ignition potential when a significant amount of methane is liberated from face drainage, because methane continually bleeds over a time period from the face after the shearer passes and may not build up into explosive levels in the dead air zones around the shearer. In any case when significantly increasing web depth in a gassy coal seam, it is recommended that methane be carefully monitored at the shearer and tailgate to reduce the risk of accumulating dangerous levels of methane. *Wider web cutting in nongassy mines with easy to moderate cutting conditions offers the best wider web shearing opportunities for improved productivity with good health and safety.* The increase in dust concentrations for full-web cutting with airflow should easily be remedied with a shearer-clearer or passive barriers (7-8).

Further investigations are required to determine the optimal web depth to maximize shearer production efficiency. The specific energy trend measured on an AM 500 shearer in figure 8 indicates that as web depth increases the specific energy decreases, but at a diminishing rate. It is theorized that a diminishing rate would reflect the additional increase in drum power consumption from the loading of increased production. It is believed that as web depth increases the specific energy reaches a minimum at some point and rises because the drum helix will eventually choke with material, further reducing the shearer's speed. Thus wider web shearer drums, greater than 40 in, will need to be designed for improved cutting and loading to optimize shearer performance.

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APPENDIX.--LABORATORY TRACER GAS TEST OF SHEARER CUTTING AGAINST AIRFLOW

Ventilation tests were conducted in the laboratory to establish airflow patterns around the shearer during the shearer-clearer design and development phases (12).[1] A full-scale longwall test gallery, 7 ft high and 175 ft long, with a full-scale model of the Eickhoff EDW-300-L shearer was used for these tests. The shearer model was equipped with rotating drums, drum sprays, and external sprays. The gallery was ventilated by a 30,000 ft^3/min vaneaxial fan that could be regulated to simulate face air velocities up to 620 ft/min. Water pressure was delivered to the sprays at 100 lbf/in^2. Methane (natural gas) was released in the gallery through manifolds positioned in the face at the cutting drums. The amount of methane release at each drum was proportional to the amount of material that would be cut (70 pct released at the leading drum and 30 pct released at the trailing drum). Gas concentrations were measured at several locations in the gallery, using a Horiba gas analyzer.

[1] Underlined numbers in parentheses refer to items in the list of references preceding this appendix.

A set of baseline tests while cutting against airflow was simulated for a double-drum shearer with typical drum sprays and external cooling water sprays operating. Figure A-1 shows the average results of these tests. The lead drum is shielded from the airflow, creating a dead air zone behind the drum where methane concentrations are the highest. These high methane concentrations start to dilute and diffuse at the shearer's midpoint. Further dilution and diffusion occurs downstream of the trailing drum into the workers' walkway.

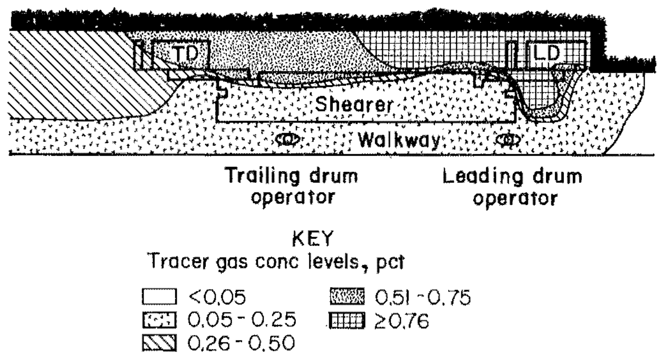

FIGURE A-1.--Laboratory tracer gas test of shearer cutting against airflow.