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Using Barriers To Reduce Dust Exposure of Longwall Face Workers

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UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	mg/m^3	milligram per cubic meter
in	inch	pct	percent

USING BARRIERS TO REDUCE DUST EXPOSURE OF LONGWALL FACE WORKERS

By Robert A. Jankowski[1] and Charles A. Babbitt[2]

ABSTRACT

Through laboratory and underground studies, the Bureau of Mines has evaluated the use of passive barriers (dust shields) to help confine dust generated by longwall shearers to the face area. Laboratory studies focused first on selection of the optimum barrier design, which proved to be a simple, gobside barrier (made of conveyor belting), coupled with a headgate splitter arm, which was found necessary to prevent the dust cloud from entering the walkway at the headgate end of the shearer when cutting tail to head. Further laboratory testing was done to determine whether using passive barriers in combination with different water-spray dust-reduction methods, including the shearer-clearer system developed by the Bureau, would improve dust reduction over that from using the water sprays alone. It was found that the combination of gobside passive barriers plus the full shearer-clearer system was most effective, and surmised that this would be especially useful in thicker seams. However, underground testing revealed that the shearer-clearer system alone was 35 pct more effective in reducing dust contamination than when used with the gobside passive barriers, and far more effective than using passive barriers with a conventional water spray system. For such an effective system as the shearer-clearer, the reduction in available space over the top of the machine actually impeded system performance; this was shown in both eastern and western mines. But when used with comparatively inefficient water spray systems, the passive barriers, used in combination with a headgate splitter arm, provide considerable help in reducing dust levels in the walkway.

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INTRODUCTION

On most longwall faces, shearer-generated dust is the largest contributor to the respirable dust exposure of face personnel (1).[3] Dust concentrations at the shearer operators' locations are generally highest when cutting against the airflow (typically tail-to-head), because the upwind (headgate) drum cuts most of the coal. In addition, the rotation of the headgate drum and its internal water sprays tend to push dust generated by the drum a considerable distance upstream against the airflow, forming an upstream dust "plume." The dust cloud is then captured by the oncoming intake air and pushed out into the walkway over the operators (fig. 1*A*).

One method used to control shearer-generated dust exposure is to confine the dust cloud to the face area, thus keeping it away from face personnel as it travels downstream over the shearer body and beyond. Passive barriers (2), e.g., screens made of conveyor belting, can be used to help achieve this by partitioning the airflow around the shearer into a clean split and a contaminated split (fig. 1*B*).

For years, passive barriers have been used to contain dust or to shield mine personnel from airborne dust. Common underground applications of this technique include:

1. Brattice or belting to shroud conveyor belt transfer points.
2. Hinged belting flaps at the inlet and outlet of stageloader crushers to confine dust within the crusher area.
3. A belting flap covering the throat outlet on continuous miners to prevent dust escape from the underboom region.
4. Brattice cloth used for general face ventilation or for spot applications to help control and direct airflow patterns.

A number of mines have adapted the passive-barrier concept to longwall shearers to help control shearer-generated dust. The Bureau of Mines, through a research contract with Foster-Miller, Inc., conducted a program to investigate the dust control effectiveness of barrier systems used in the field, and to design and evaluate novel barrier systems. This report describes this effort and presents the resulting conclusions.

DETERMINATION OF OPTIMUM BARRIER DESIGN

Preliminary laboratory development focused on the effectiveness of a variety of barrier systems designed to confine contamination to the face area. All testing was conducted in a full-scale longwall test facility, equipped with a full-size mockup of a double-drum shearer with rotating cutting drums sumping into a simulated coal face. The facility cross section reflected both advanced and retracted shields, a walkway area, a spillplate, and a face conveyor. Seam height was 7 ft. Actual mining conditions were simulated, including realistic face airflow quantities and either tail-to-head or head-to-tail cutting geometries. Methane tracer gas was released from both cutting drums at controlled rates to simulate airborne dust, and methane concentrations were measured on a grid pattern throughout the facility (around the shearer, in the walkway, and downstream) to determine gas movement patterns. Comparisons of grid patterns indicated the relative effectiveness of different passive-barrier systems.

BARRIER SYSTEM DESIGNS EVALUATED

Several barrier designs studied during the preliminary tests are shown in figure 2. Configurations A and B represent systems previously used in the field, while configurations C, D, and E represent novel designs developed as testing progressed:

Configuration A.--This is a simple, straight gobside barrier that partitions

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

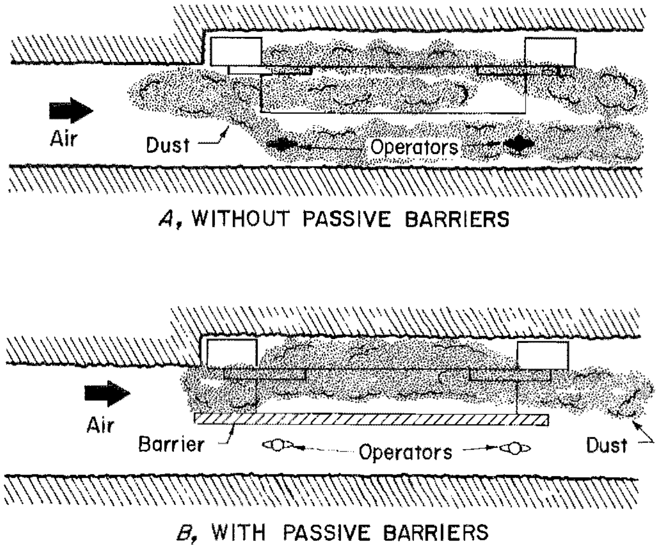

FIGURE 1.—Typical flow of upstream dust plume, with and without passive barriers.

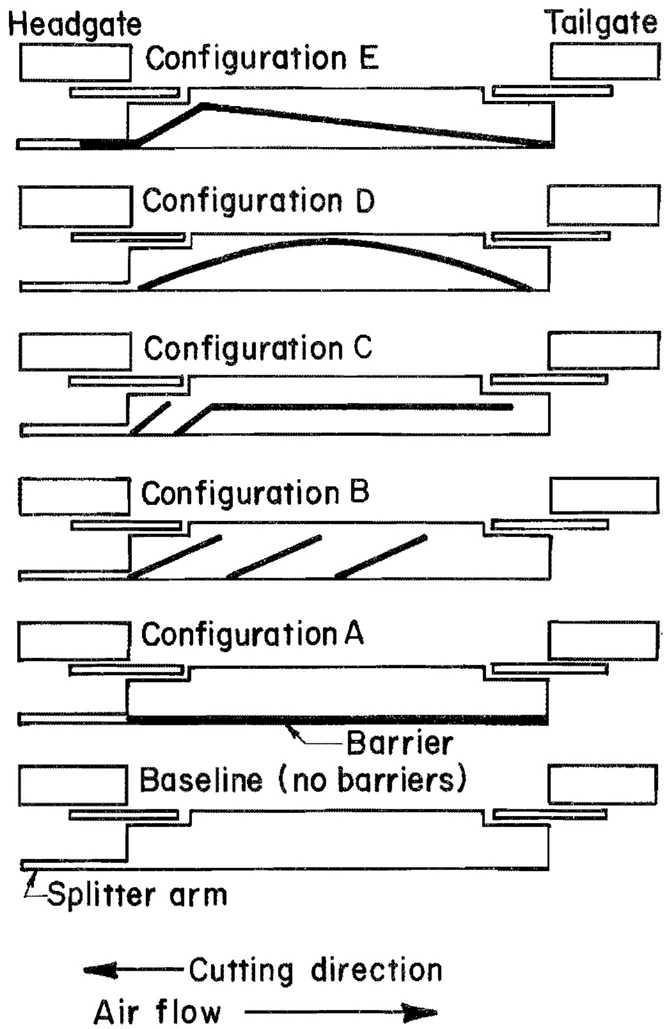

FIGURE 2.—Barrier configurations studied during preliminary laboratory tests.

the airflow between the walkway and face areas.

Configuration B.--This uses angled barriers to channel airflow and dust toward the face; each successive barrier attempts to capture any dust "missed" by the preceding barrier.

Configuration C.--This is a combination of designs A and B; angled barriers channel dust toward the face, followed by a straight barrier to keep the airflows partitioned.

Configuration D.--This uses a venturi effect, which increses the air velocity in the face area and draws dust through the venturi.

Configuration E.--This design is based on fluid-flow theories. The angled barrier at the headgate end of the shearer body channels dust toward the face and provides a slight constriction in the face-side airflow. The constricted airflow, under slight pressure and increased velocity, empties into the expanding void created by the other barrier, which extends to the tailgate end of the shearer. This barrier creates a slight positive air pressure in the walkway and a slight negative pressure in the face area. This results in a tendency for clean walkway air to bleed into the face region, keeping dust out of the walkway.

RESULTS OF INITIAL TESTING

Preliminary testing revealed an important fact: The majority of walkway contamination was introduced at the leading end of the shearer, particularly the headgate end during tail-to-head cutting (against the airflow). When cutting tail-to-head, the upwind dust "plume", created by the action of the headgate drum, encountered the shearer body. Taking the path of least resistance, the dust cloud poured out into the walkway at the headgate end of the shearer. To prevent this and to force the dust cloud up and over the top of the shearer, it proved vital to utilize a headgate

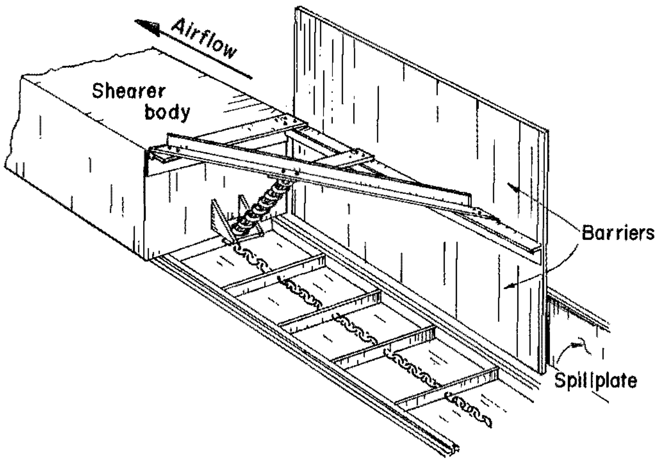

FIGURE 3.—Headgate splitter arm with passive barriers.

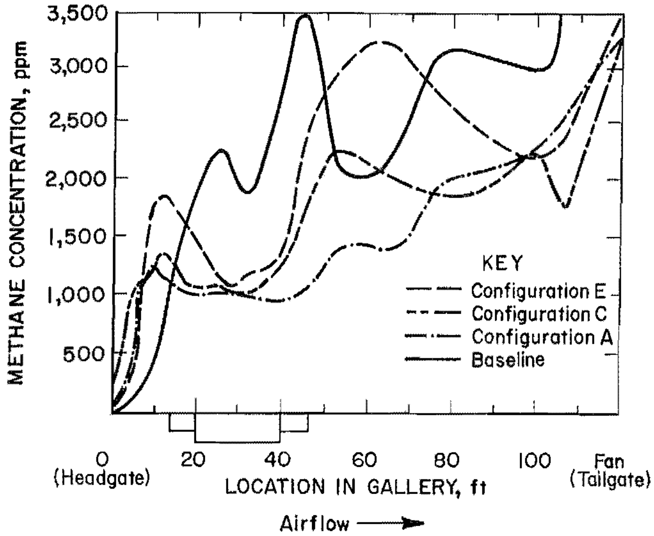

FIGURE 4.—Effects of various passive-barrier configurations on methane concentrations (dust levels) for various locations along the walkway of the gallery.

splitter arm with passive barriers extending downward into the panline and upward toward the roof-support canopies (fig. 3).

Preliminary testing also revealed that the dust cloud, once channeled to the top of the shearer body, tended to remain there as it traveled downstream. Barrier configurations with straight sections parallel, or nearly parallel, to the walkway performed best in maintaining the dust cloud confined to the top of the shearer. (See A, C, and E in figure 2.) Configurations with short, angled barriers (B, fig. 2) and the venturi effect (D, fig. 2) performed poorly.

SIMPLE, GOBSIDE BARRIER SYSTEM

Following the preliminary test series, barrier configurations A, C, and E (fig. 2) were chosen for more detailed analysis. Initial testing focused on the performance of each configuration in reducing methane concentrations, compared with a baseline configuration with no barriers except the headgate splitter arm. No water sprays were added to the barriers during the first test series.

The results confirmed the critical importance of the headgate splitter arm and revealed that a simple, gobside passive barrier system (configuration A) is as effective as more complex designs. This is illustrated in figure 4, which contains plots of methane concentration versus location along the walkway of the test facility. The gobside barrier design (A) resulted in the lowest contaminant concentrations along the walkway, and was considerably more practical than the other designs. Its location along the gob edge of the shearer keeps it as far from the face as possible, minimizing damage from roof falls or coal-cutting activity. The edge location allows for a variety of easy sideboard mounting arrangements and prevents debris from piling up against the operator's side of the barriers. Also, its linear orientation parallel to the direction of airflow permits gaps (or "visibility windows") to be provided for the shearer operators without seriously disrupting the airflow split.

GOBSIDE BARRIERS WITH EXTERNAL WATER-SPRAY SYSTEM

Previous laboratory and underground tests have shown that external spray nozzles, mounted on the shearer body, can have a significant impact on airflow patterns and dust levels around the shearer (3). The Bureau of Mines has conducted extensive evaluations of an external spray system, called the shearer-clearer (4), which contains several water sprays strategically mounted on the headgate splitter arm and along the shearer body. The sprays are oriented so as to divide the airflow around the shearer into clean and contaminated splits. Since the simple, straight, gobside barrier system (A, fig. 2) had proved to be the most practical passive-barrier design, further testing focused on evaluating this system in combination with both conventional and external (shearer-clearer) water spray systems.

It was anticipated that such combination usage of passive barriers and the water-spray air-moving system would be complementary, working together to create the desired air split, particularly under conditions in which either technique alone would be less effective. Both laboratory and underground testing were done using the gobside barriers with both conventional and shearer-clearer water-spray air-moving systems, comparing the performance of each air-moving system with and without the gobside barriers.

LABORATORY TESTING

The combination gobside barrier and shearer-clearer system tested in the laboratory is shown in figure 5. The air-split process begins with the headgate splitter arm, which contains three directional air-moving sprays and a passive barrier extending from the panline upward toward the roof supports. The spray orientation was designed to minimize the upwind plume by increasing the air velocity in the region of dust generation around the cutting drum, while the barrier confines the dust cloud and aids the sprays

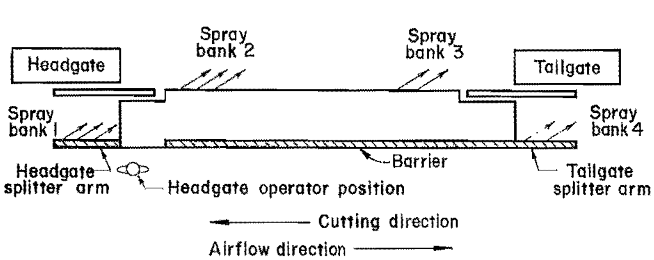

FIGURE 5.—Most effective combination system, consisting of a gobside passive-barrier layout with a full shearer-clearer air-moving system.

in forcing the cloud over the top of the shearer body. The gobside barrier along the shearer body keeps the dust cloud confined as it travels downwind. The two sets of face side sprays (banks 2 and 3) help to maintain the air split by providing spaced velocity boosts to the dust cloud. A short tailgate splitter arm, with two sprays and a barrier extending into the panline, was added to provide a final velocity increase to the dust cloud as it exists the shearer body. This was added in an effort to maintain the air split for a greater distance downwind of the shearer. This system was evaluated against a gobside passive barrier system without external air-moving sprays (configuration A, figure 2), and against baseline conditions without external air-moving sprays and only a headgate splitter arm with a barrier extending into the panline. The internal drum water spray system was operated under all test conditions.

As expected, laboratory testing revealed that the full shearer-clearer air-moving system (shown in figure 5) was much more effective than the conventional system when used with the gobside barriers. The combination barrier-spray system produced a significant reduction in methane tracer gas levels, both in the walkway and at distances of up to 50 ft downstream (fig. 6). Barriers alone reduced methane concentrations in the walkway around the shearer by approximately 50 pct over the baseline condition. The combination barrier-spray system further reduced the concentrations, for a total 95-pct reduction in methane concentrations in the walkway around the shearer, as compared with baseline dust levels.

All laboratory testing in the longwall facility was conducted at a medium seam height of 7 ft, where the gap between the top of the shearer and the underside of the roof-support canopies is relatively small. In these cases, the power of the spray system alone was sufficient to modify the airflow pattern through the "duct" formed by the shearer and roof supports. In thick seams (>9 ft), however, it was surmised that the air-moving capability of the water sprays might not be sufficient to control and modify the

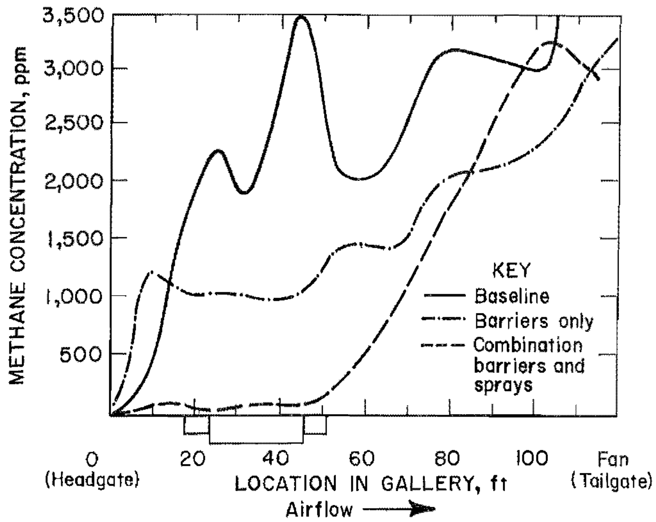

FIGURE 6.—Combination barrier-spray system produced a significant reduction in methane concentrations (dust levels) in the walkway and up to 50 ft downstream of the shearer.

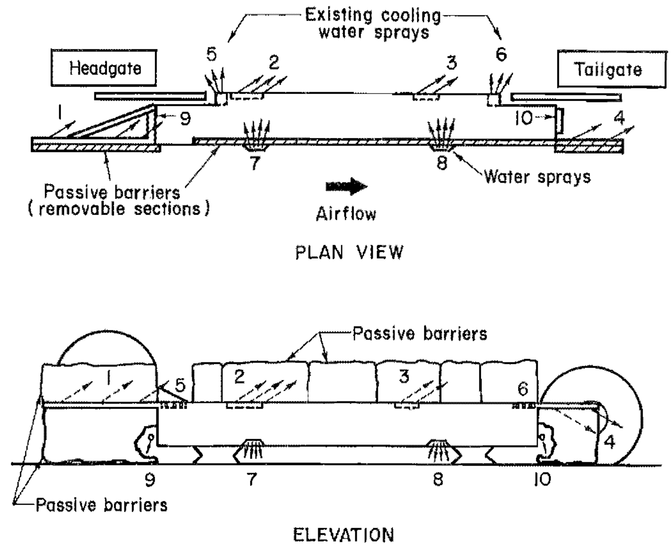

FIGURE 7.—Design of combination passive-barrier, shearer-clearer system tested underground.

airflow through the larger space over the shearer. The importance of the gobside barrier system was expected to be much greater in thicker seams. With this expectation in mind, the underground evaluation was conducted in a high-seam (10-ft) coal mine.

UNDERGROUND EVALUATION

Following the completion of the laboratory tests, the combination gobside-passive-barrier, shearer-clearer spray system was installed and evaluated over 15 operating shifts in a western mine cutting 10 ft of coal. The purpose of the evaluation was to:

1. Compare the new combination system with the mine's existing "conventional" system of drum and cooling water sprays.
2. Evaluate the effectiveness of the gobside passive barrier in furthering dust reductions in the walkway using both the "conventional" and shearer-clearer systems.

For the purpose of the underground evaluation, the shearer was equipped with three basic components (fig. 7):

1. A hinged and spring-loaded headgate splitter arm (see appendix for details of splitter arm design) and a short, rigid-tailgate splitter arm, both equipped with conveyor belting extending downward into the panline. This was used in conjunction with a conventional water-spray system, consisting only of drum sprays plus cooling water sprays discharging from face-side locations (5 and 6 in figure 7). The drum sprays operated at all times during all testing. The cooling water, however, was routed into diversion valves, which ensured that it discharged from locations 5 and 6 only during testing of the conventional system.
2. A modular, removable passive-barrier system (fig. 8), consisting of barriers along the gobside of the shearer body with an additional barrier extending vertically up from the top edge of the headgate splitter arm.
3. A shearer-clearer water-spray system, which consisted of external sprays at locations 1, 2, 3, and 4 plus cooling water sprays rerouted to discharge from locations 7, 8, 9, and 10.

The barrier-spray system combinations were alternated on a pass-by-pass basis while monitoring dust concentrations. Dust levels were measured each 5 ft of shearer advance at the headgate shearer operator's position and at an intake position approximately 30 ft upstream of the headgate drum. Measurements were taken only while the shearer cut and loaded coal. The mine operated according to a modified bidirectional mining

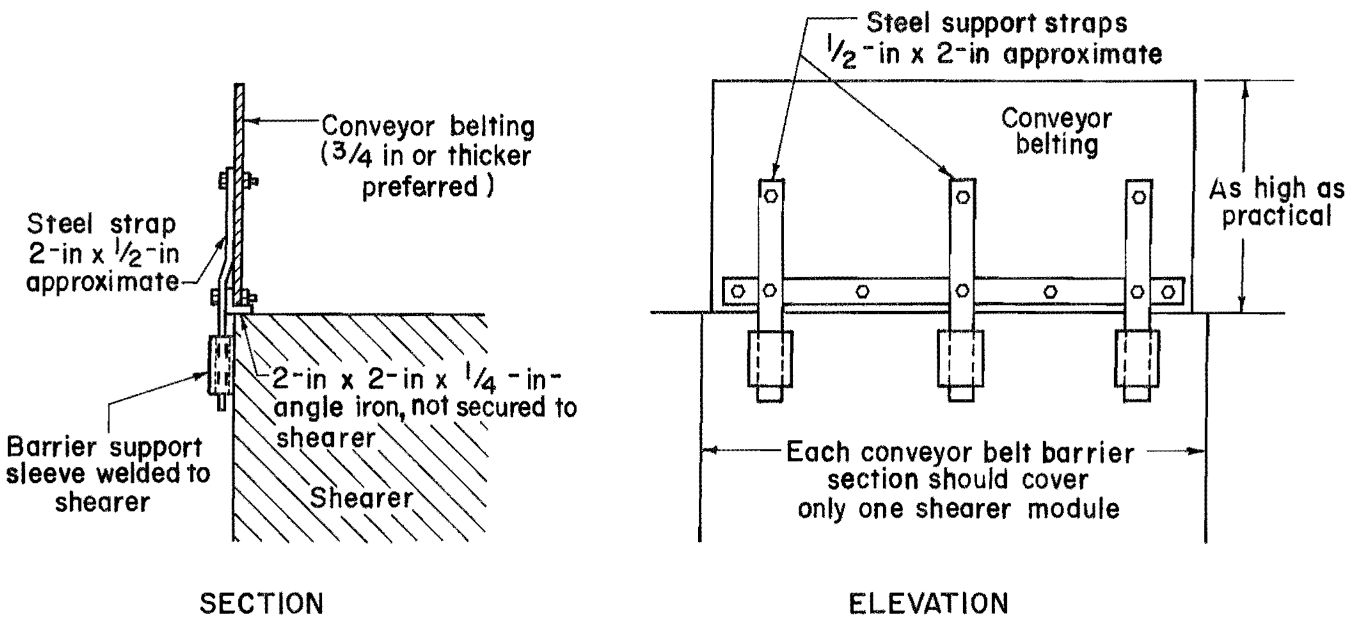

FIGURE 8.—Shearer mounting for gobside passive-barrier system tested during underground evaluation.

sequence that allowed dust monitoring in both directions. However, during head-to-tail cutting, the dust contribution from upstream shield movement so overpowered shearer-generated dust levels that system comparisons were not possible. Consequently, data analysis from the evaluation focused on tail-to-head cutting.

RESULTS AND ANALYSIS

Table 1 contains a synopsis of the average dust concentrations for all tail-to-head cuts. The concentrations were recorded at the headgate shearer operator's position. Intake concentrations, which ranged between 0.73 and 1.25 mg/m^3, have been subtracted from all data in table 1. Hence, the concentrations shown

TABLE 1. - Underground test results

Dust control technique	Dust level, mg/m^3	Pct of conventional
Conventional sprays.....	1.13	100
Conventional sprays with passive barriers.......	.83	73
Shearer-clearer alone...	.53	47
Shearer-clearer with passive barriers.......	.74	65

represent only shearer-generated dust. As shown in table 1, the shearer-clearer alone was more effective than when used with passive barriers:

1. Shearer-generated dust levels decreased by 27 pct when passive barriers were added to the conventional system.
2. With the combination shearer-clearer, passive-barrier system, the levels of shearer-generated dust were 35 pct lower than with the conventional system.
3. With the shearer-clearer system alone, the levels of shearer-generated dust were 53 pct lower than with the conventional system.

It was concluded that a passive-barrier system is most effective when used with an ineffective spray system containing improperly oriented nozzles, which cause dust to boil out into the walkway over the top of the shearer. An effective spray system, using nozzles properly oriented in the direction of the primary airflow, will provide sufficient control of the dust cloud over the shearer body. Such a system will not benefit from a passive barrier on the gobside edge of the shearer. The shearer-clearer system is designed to move large volumes of air over the top of the shearer body, confining the dust to the face area. If insufficient space is available over the top of the machine because this area is confined by a passive barrier, the air-moving capacity of the external sprays causes significant eddying and degrades the efficiency of the system.

Very similar results were obtained during a second underground evaluation of passive barriers in an eastern low-coal mine. The shearer in use in the mine was also equipped with headgate and tailgate splitter arms as well as an external spray air-moving system similar to the shearer-clearer. In addition, a 15-in-high passive barrier of conveyor belting was mounted along the full length of the gobside edge of the shearer body. A series of A-B comparison tests were performed to determine the effectiveness of the barrier at reducing the dust exposures of the shearer operators. A-B testing was performed over six evaluation shifts by removing the barrier for half of each shift. Dust monitoring results showed that use of the passive barrier made no significant difference in dust concentration either at the shearer operator location or at downstream sampling positions.

CONCLUSION

The laboratory tests and underground evaluations demonstrated that passive barriers can be very effective in reducing the respirable dust exposures of longwall face personnel by helping to confine shearer-generated dust to the face.

Of particular importance is the control of dust generated by the headgate drum during tail-to-head cutting. A headgate splitter arm is a vital part of a passive-barrier system, whether or not a spray air-moving system is used on the shearer (5). The splitter arm begins the air-splitting process and provides a supporting framework for the air-moving spray manifolds.

Once the air split is initiated by the headgate splitter arm, a machine-mounted, gobside passive-barrier can help to maintain the split under certain conditions. Typically, the gobside barrier proved very effective when used on shearers that had ineffective external spray systems or were not equipped with external air-moving sprays. The gobside barrier proved to be unnecessary on shearers equipped with effective external air-moving systems, such as the shearer-clearer.

Passive barriers can also be installed over any open spaces between the shearer underframe and the panline to prevent conveyor dust from boiling out into the operator's walkway.

REFERENCES

1. Jankowski, R. A., and J. A. Organiscak. Dust Sources and Controls on the Six U.S. Longwalls Having the Most Difficulty Complying With Dust Standards. BuMines IC 8957, 1983, 19 pp.

2. U.S. Bureau of Mines. Spring-Mounted Screen on Shearer Reduce Operator's Dust Exposure. Tech News No. 121, Dec. 1981.

3. Kissell, F. N., N. I. Jayaraman, C. D. Taylor, and R. A. Jankowski. Reducing Dust at Longwall Shearers by Confining the Dust Cloud to the Face. BuMines TPR 111, 1981, 21 pp.

4. Jayaraman, N. I., R. A. Jankowski, and F. N. Kissell. Improved Shearer-Clearer System for Double-Drum Shearers on Longwall Faces. BuMines RI 8963, 1985, 11 pp.

5. Ruggieri, S. K., and C. A. Babbitt (Foster-Miller, Inc.). Optimizing Water Sprays for Dust Control on Longwall Shearer Faces-Design and Installation Manual (contract J0308019). BuMines OFR 42B-86, 1983, 79 pp; NTIS PB 86-205416.

APPENDIX.--HEADGATE SPLITTER ARM DESIGN

A sturdy and practical splitter-arm design, which proved very successful in several underground field evaluations (5), is shown in figure A-1. The arm is hinged to the shearer and spring-loaded to deflect when large pieces of coal or roof rock strike it. The orientation of the angle-iron members allows spray manifolds to be mounted beneath a leg of the angle for protection.

Two points of caution should be noted. First, the arm must be mounted to a rigid portion of the shearer body that does not rotate with the ranging arm. If not, movement of the arm will cause attached spray manifolds to be improperly oriented. Typically, the splitter arm will be mounted to the upwind gearhead unit; but, on some shearer models, the gearhead rotates along with the ranging arm. Second, in low-clearance conditions, the splitter arm may strike the underside of the roof supports, particularly if the panline "ramps up" onto the stageloader. Although the spring-loaded feature of the arm will allow for some deflection, the arm length may have to be shortened in these cases.

The complete splitter arm assembly shown in figure A-1, consists of four parts:

1. The framework supports the conveyor belting barrier and spray manifolds. It is constructed of 3-in by 3-in by 1/2-in angle iron and lateral steel-support bars welded together. The frame also contains a portion of the hinge assembly, and one of two spring-support studs.

2. The hinge assembly allows the splitter arm to pivot. It is constructed in two halves, each consisting of plate and pipe sections.

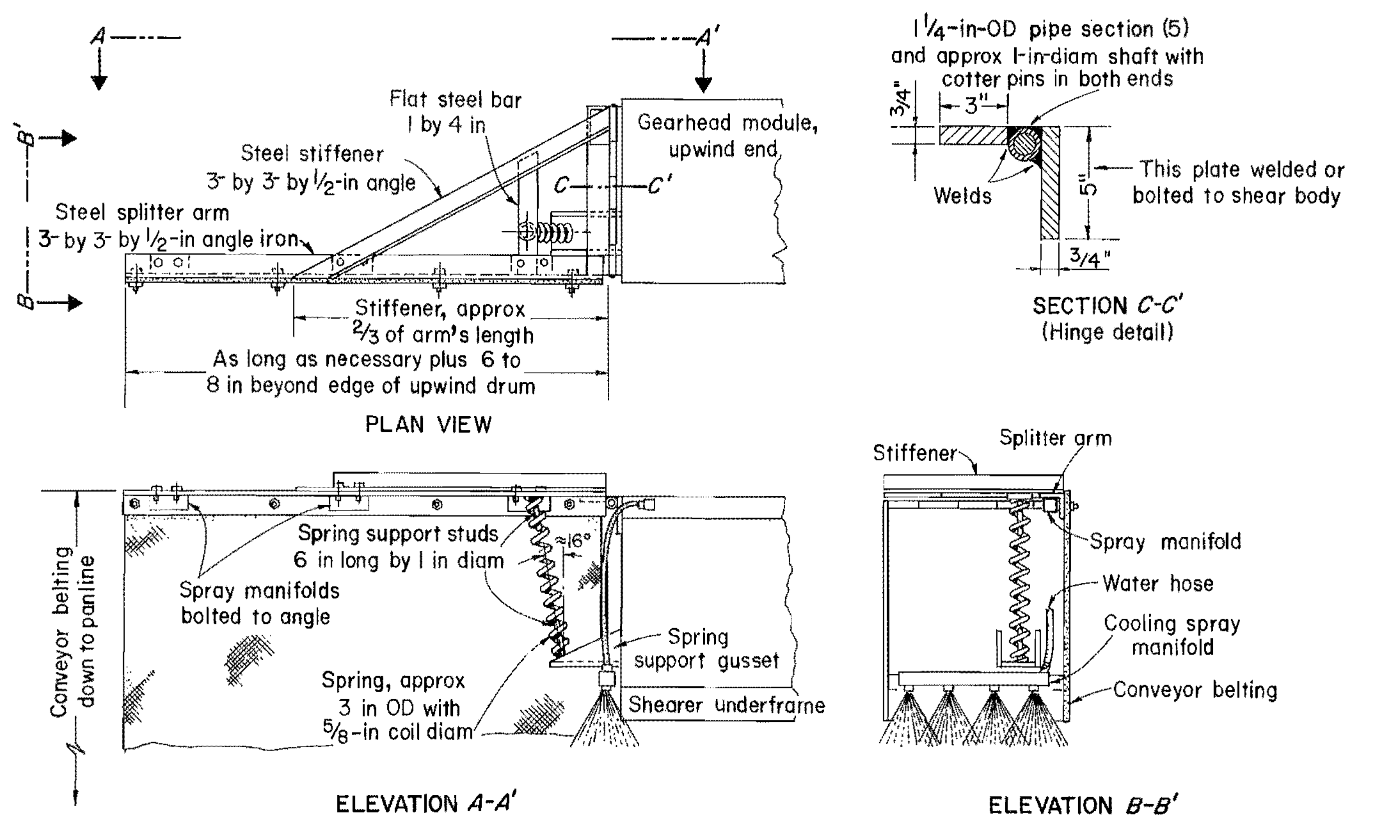

FIGURE A-1.—Successful splitter arm design, used in several underground field evaluations.

3. The bottom spring support bracket guides and supports the spring. It is constructed of a 1-in steel plate, welded to the shearer underframe and strengthened with gusset plates.

4. The spring supports the splitter arm and provides the capability for deflection under load.

The type and size of spring must be considered before fabricating the mounting brackets and support studs to ensure that they are properly located, sized, and fitted. Tail conveyor springs from continuous miners have worked well in this application.

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