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# In-Mine Installation of Passive Water Barriers

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UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

| | | | |
|---|---|---|---|
| °F | degree Fahrenheit | $gal/ft^2$ | gallon per square foot |
| ft | foot | $gal/ft^3$ | gallon per cubic foot |
| $ft^2$ | square foot | in | inch |
| $ft^3$ | cubic foot | $lb\text{-}min^2/ft^4$ | pound-square minute per fourth power of foot |
| ft/min | foot per minute | pct | percent |
| $ft^3/min$ | cubic foot per minute | | |
| ft/s | foot per second | | |

# IN-MINE INSTALLATION OF PASSIVE WATER BARRIERS

By Lung Cheng,[1] Richard Pro,[2] Dennis R. Malcolm,[3] and Aldo L. Furno[4]

## ABSTRACT

The Bureau of Mines has installed passive water explosion barriers in two operating mines to determine their usefulness in U.S. coal mines. The primary objective of this field trial was to determine the effect of the explosion barriers on mining operations. Data were also obtained on the ability of the barriers to withstand the mine environment and on the effect of the barriers on belt operation, ventilation, worker travel, and rock dusting.

Fifty barriers were installed at three separate beltway locations, and periodic inspections were made. A year after installation, no defects of the barriers or support hardware were detected, nor was any complaint as to the presence of the barriers made by the mine personnel. To date, 2-1/2 years after installation, the barriers have had no detrimental effect on rock dusting, belt operation, or ventilation. Costs of material, fabrication, and installation are reported herein.

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## INTRODUCTION

Rock dusting has been the traditional means of controlling dust explosions in U.S. coal mines. However, rock dusting alone is not a completely adequate means of preventing coal dust explosions, especially along conveyor roadways and at transfer points where float dust layering can occur. Barrier systems have been shown to offer additional explosion protection when used as a supplement to rock dusting. Recent research both here and abroad has shown that the passive water barrier is an excellent means of defense against coal dust explosions. Many foreign countries are recommending its use in mines, and in some countries, it has become the principal means of explosion protection.

The Bureau of Mines has conducted research to determine the usefulness of barriers in U.S. coal mines; part of this effort has involved a comprehensive study of passive water barriers such as a conventional German PVC (polyvinyl chloride) trough of 2.9 $ft^3$ capacity (1).[5] Of particular interest were modified barrier designs that are effective against slow-moving dust explosions (2-3). Both the conventional and the modified barriers have been tested in the Bureau's Experimental Mine at Bruceton, PA, and proven to be successful in quenching coal dust explosions. Thus, they are useful as a supplement to rock dusting in providing additional explosion protection. Support frames have been specially designed (3) to accommodate these barriers for U.S. coal mines.

This initial study was conducted along conveyor roadways since previous work had shown such mine areas to be most hazardous (3). The objective was to determine the effect of the explosion barriers on mining operations. For this purpose, 50 barriers were installed in conveyor roadways in 2 operating coal mines. Information was obtained on the cost of material and fabrication of the barriers and on worker-hours for barrier installation. The barriers remained in position for 12 months during which data was recorded on their ability to withstand the mine environment and their effect on belt operation, ventilation, worker travel, rock dusting, and float coal deposition. Information was also obtained on the attitude of the miners, management, and inspectors to the barriers. The field trial of the passive water barriers was a cooperative effort between the Pittsburgh Research Center, Bureau of Mines, and the Rochester & Pittsburgh (R&P) Coal Co., Indiana, PA.

## ACKNOWLEDGMENTS

The authors are thankful to Israel Liebman, who initiated this field trial program, for providing guidances and sharing with us his expertise on the barrier installation; and to J. Kenneth Richmond for his helpful suggestions. Both of them were with Pittsburgh Research Center, Bureau of Mines. We appreciate the collaboration with Rochester & Pittsburgh Coal Company, Indiana, PA, and are grateful for the assistance of the personnel of the Urling No. 1 and No. 3 Mines.

## BARRIER LAYOUT

Based on mine visits and discussions with mine management, two criteria were used to choose the mine entry section to be used in this trial: high-roof entries (>6 ft) and entries where no construction was anticipated during the next 12 months. Three installation sections on three separate beltways were chosen, as shown in figure 1. Installation section A, the main tunnel entrance beltway, is

[5] Underlined numbers in parentheses refer to items in the list of references at the end of this report.

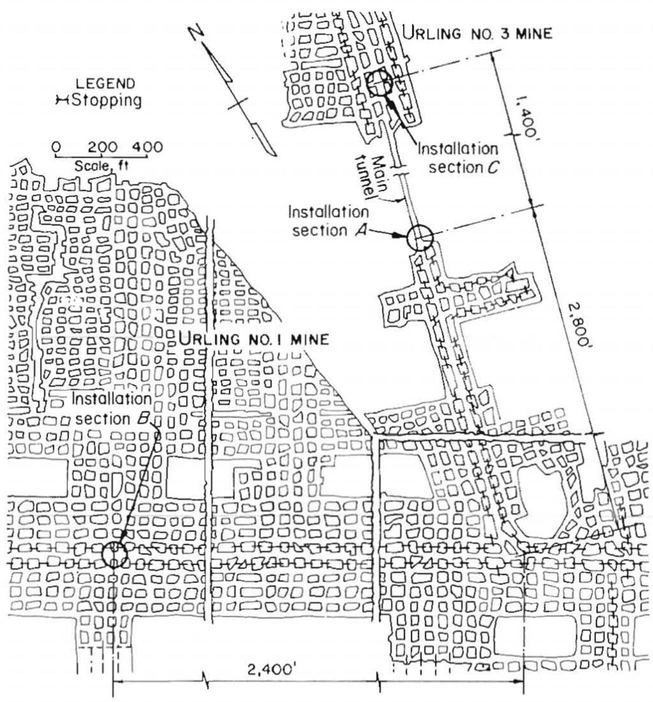


FIGURE 1. - Mine map showing installation sites of passive explosion water barriers.

in Urling No. 1 Mine. The average roof height was 10.5 ft, and the width averaged 17 ft. In section B, the south track of Urling No. 1 Mine, the roof was vaulted from 5 to 9 ft and the average width was 20 ft. In section C, the entrance to the tunnel beltway of Urling No. 3 Mine, the roof was fairly even at a height of 7 ft; the width averaged 20 ft. There was a 3-1/2-ft track at the center of each of these beltway sections, and the roof was bolted in a 4-ft (crosswise) by 5-ft (lengthwise) pattern. In section A, the conveyor belt was suspended from roof at the center of the beltway; in sections B and C, the conveyor belt was installed to one side.

During a dust explosion, the dynamic pressure of wind resulting from the air motion ahead of the propagating flame tilts or shatters the tubs to release and disperse the water, which acts to suppress the oncoming explosion. The conventional German barrier is effective in suppressing moderate-strength dust explosions propagating in excess of 250 ft/s, while the Bureau-modified tub can operate at wind speeds as low as 100 ft/s and therefore has the advantage of being effective against slow-moving dust explosions (4). The modified barrier was made from the conventional one, which was altered by simply removing the lateral lip supports and beveling the front and rear lip supports. Figure 2 shows the conventional and modified barriers.

Currently, guidance for barrier layout design is empirically based on explosion tests of barriers in experimental mines. Three entry parameters are considered: width, cross-section area, and length or volume of the entry covered by the barrier. The present layout for the R&P mines was based on the Bureau's proposal for water barriers on beltways (3). Layout designs are listed in table 1, and layouts are shown in figures 3 and 4. There were three rows of barriers for each section. Approximately half of the barriers were conventional barriers, and the rest were the Bureau's modified version--18 in section A, 17 in section B, and 15 in section C.

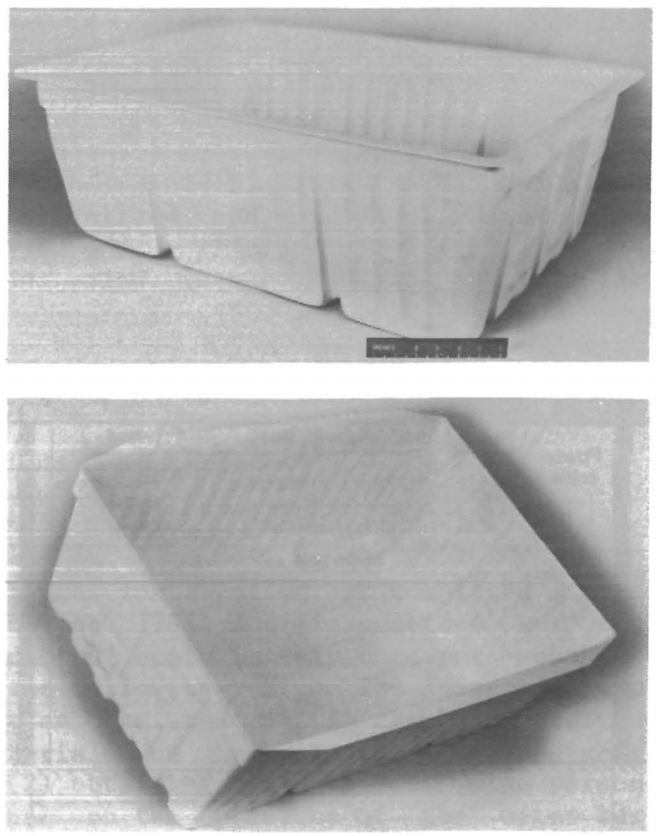

FIGURE 2. - Conventional (top) and modified (bottom) passive explosion water barriers (after Liebman (3)).

TABLE 1. - Summary of layout designs

| Coverage | Section A, | Section B[1] | | Section C, |
|---|---|---|---|---|
| | 178.5 $ft^2$ | 150 $ft^2$ | 176 $ft^2$ | 140 $ft^2$ |
| Width, pct: | | | | |
| Section height/section width............. | 62 | 38 | 44 | 35 |
| Width of barriers/width of section....... | 88 | 62 | 75 | 62 |
| Area, gal/$ft^2$: | | | | |
| Amount of water in one row/area.......... | 0.74 | 0.73 | 0.75 | 0.78 |
| Amount of water in entire barriers/area.. | 2.22 | 2.12 | 2.49 | 2.36 |
| Volume, gal/$ft^3$: Amount of water in one row/space volume[2]........................ | 0.0025 | 0.030 | 0.049 | 0.026 |

[1]The vaulted roof results in several cross-sectional areas; at these 2 chosen areas, rows of barriers are installed.
[2]This is the space volume between 2 adjacent rows of passive barriers.

At present, a conventional barrier imported from Germany costs $14 plus $7 shipping cost. The support frames were made according to the Bureau's design (3). The double-barrier frame costs $80, which is 10 pct more than the cost of a single-barrier frame; these frames are presently made piece by piece. Costs could be greatly reduced by use of U.S. barriers and mass-produced frames.

## INSTALLATION

After the support frames and associated fasteners were made, they were transported to the three sites and installed in accordance with the method outlined by Liebman (3). While installing the barriers on top of the conveyor belt, the conveyor belt was shut off; stepladders were required for working in sections A and B. Figures 5 and 6 show the barrier installations.

Installation of 50 barriers in 27 support frames (4 single barriers and 23 double barriers) required 50 worker-hours. Calculating installation time in worker-hours (w-h) per support frame, it took 2.5 w-h per frame for section A, 1.8 w-h per frame for section B, and 1.2 w-h

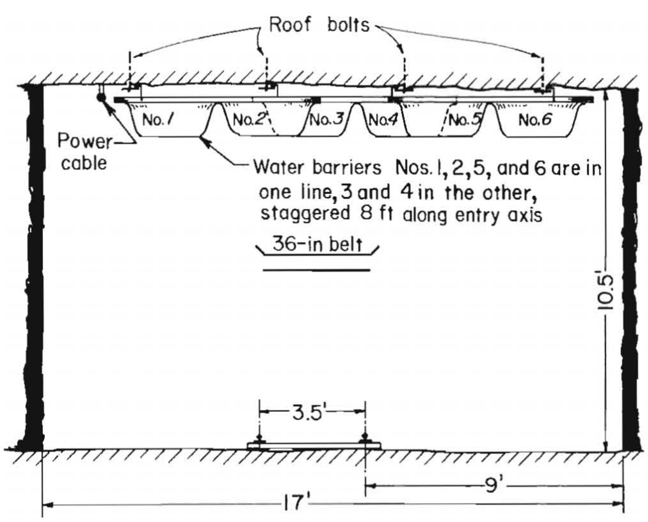


FIGURE 3. - Barrier layout for installation in section A.

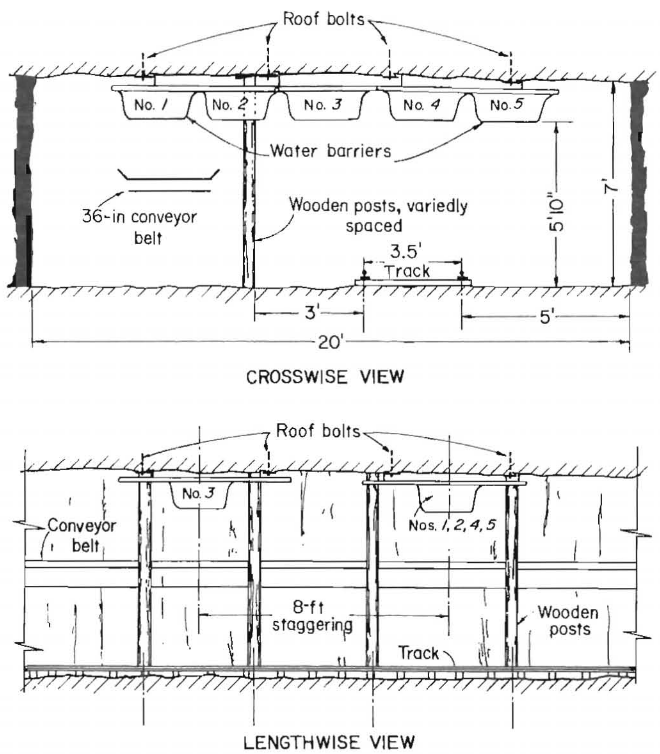


FIGURE 4. - Barrier layout for installation in sections B and C.

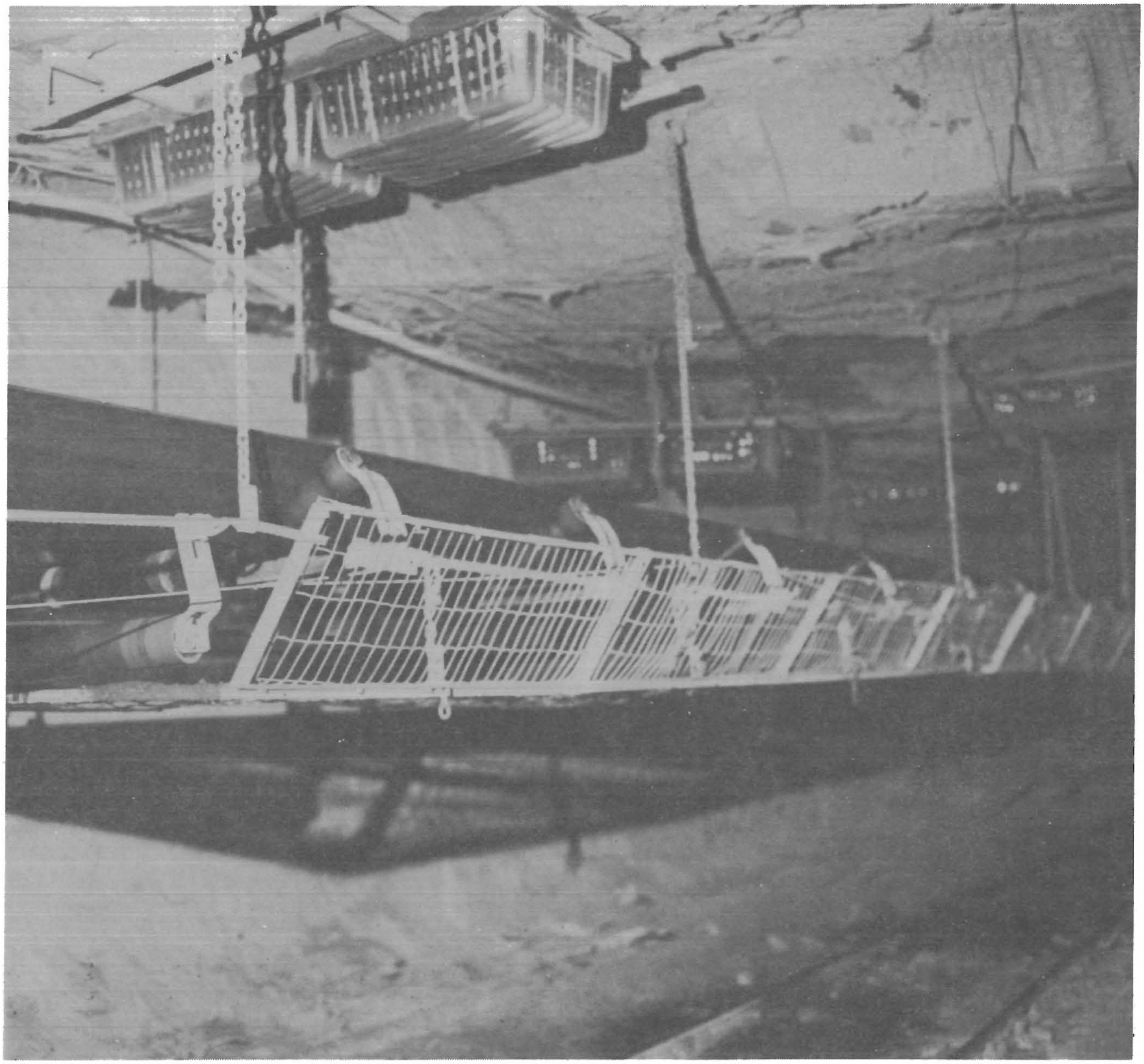

FIGURE 5. - Passive water barriers as seen in section A.

per frame for section C. Thus it appeared that the higher the roof, the more worker-hours are required.

The existing bolts were used for the installation; however, no difficulty was encountered. If the initial roof bolting had been planned for barrier installation, the worker-hours for installation would be 25 pct less than those of the present trial.

## INSPECTIONS

The installation was completed in December 1981, and inspections were conducted approximately once per month for the following year. The inspection program consisted of (1) checking the materials and installations for defects, (2) obtaining comments from mine personnel on the presence of the water barriers, (3) checking the water level in

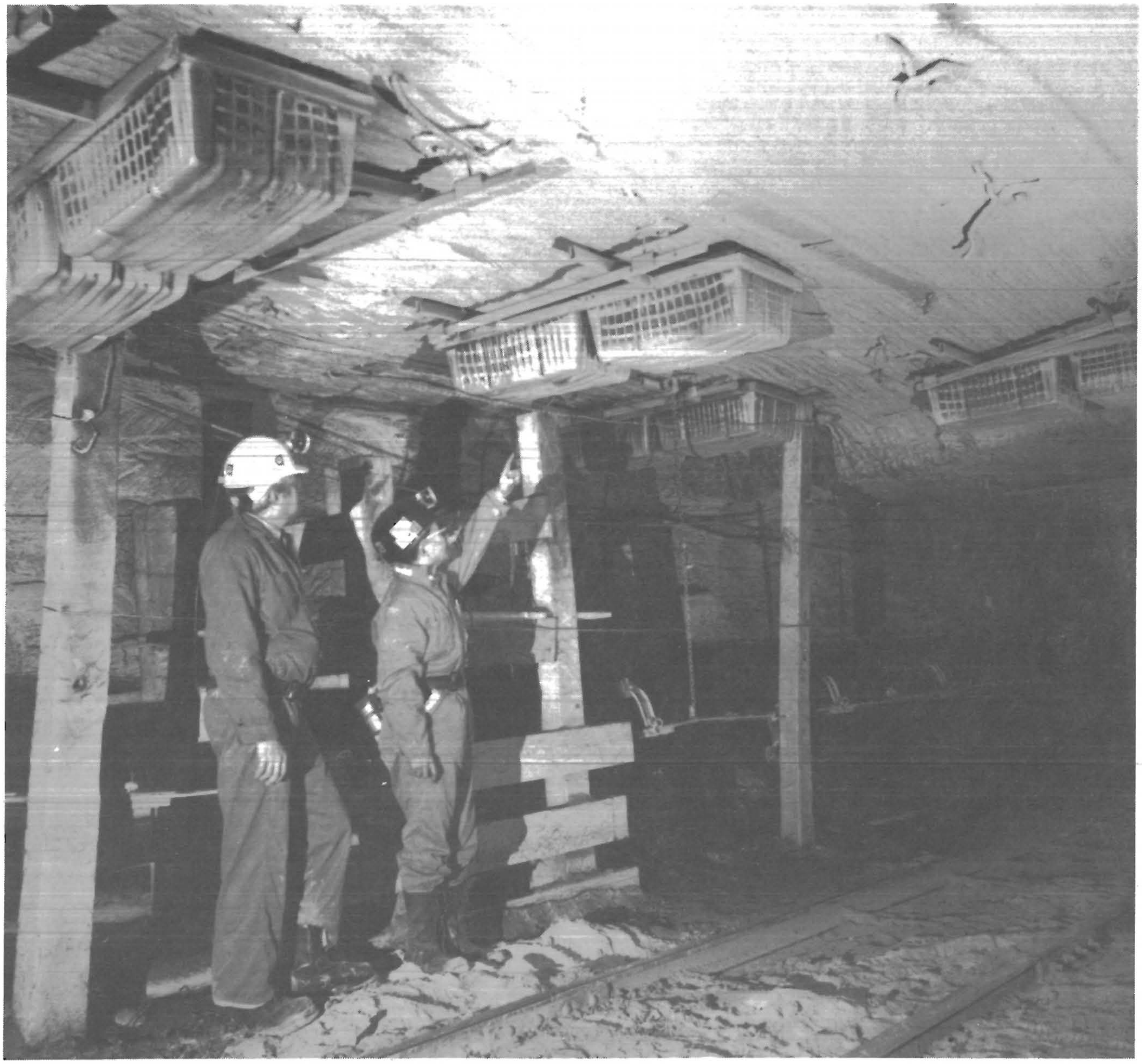

FIGURE 6. - Passive water barriers as seen in section B (also typical of section C).

the barriers, (4) taking float dust samples from barrier surfaces in order to determine the deposition rate and the incombustible percentage of the deposited dust with normal rock dusting practice, and (5) measuring air velocities at installation sites to determine their effect relating to items 3 and 4.

To date (mid-July 1984), no defects of barriers or support hardware have been detected, and there have been no complaints about the presence of the barriers by the mine personnel. It was found that without a cover, the loss of water in the barriers was severe. For example, at an installation site where the temperature was 55° F, the relative humidity 40 pct, and air velocity 280 ft/min, about one-fifth of the water evaporated in 1 month.

To determine the effect of the barriers on mine ventilation requires data on the friction in the airway due to the presence of passive barriers, such as shock-loss factors; such information is not available in the open literature. An estimation of the effect of the barrier was made as described in the following section; measurements of ventilation blockage due to the barriers are planned to verify the calculated prediction, but have not yet been carried out.

## EFFECT OF BARRIERS ON VENTILATION

The equivalent-length method was used to calculate the effect on mine ventilation of the passive barriers. Maintaining the same total head loss of the airflow prior to the barrier installation, the airflow rate is inversely proportional to the square root of the total airway length (5). The reduction of airflow rate is then given by

$$\Delta Q = Q \left(1 - \frac{1}{\sqrt{1 + \alpha}}\right), \qquad (1)$$

where Q is the airflow rate in $ft^3/min$ and $\alpha$ is the ratio of the equivalent length of the passive barriers to the length of the airway wherein ventilation is concerned. From equation 1, the percentage reduction of the airflow rate due to the presence of the passive barriers is

$$\frac{\Delta Q}{Q} = \frac{\sqrt{1 + \alpha} - 1}{\sqrt{1 + \alpha}} \times 100. \qquad (2)$$

To determine the equivalent length of the passive barriers, one must select a friction factor according to the type of airway considered, i.e., $100 \times 10^{-10}$ lb-$min^2/ft^4$ (6); the hydraulic radius of the installation site where the dimensions of the cross sections were measured for barrier layout must also be determined. The blockage of the cross-sectional area of the airway was about 15 pct owing to the presence of the barriers; thus a shock-loss factor was estimated to be 1.5 per row of the barrier. The equivalent lengths were then calculated. The total length of the airways wherein ventilation is concerned was then obtained, and values of $\alpha$ were calculated; calculations of reduction of airflow rate from equation 2 are listed in table 2. Blockage of ventilation based on these calculations is shown to be quite moderate, ranging in reduction from 2 to 5 pct. Therefore, any adjustment of ventilation plan to compensate the reduction of airflow rate is practically not necessary.

Although the method used to calculate the blockage effect is incontestable, the accuracy of the results depends greatly on the accuracy of the estimated value of the shock-loss factor. This would require experimental work either at the Bruceton Experimental Mine or at the Lake Lynn Laboratory (7).

TABLE 2. - Reduction in airflow rates of installation sites

| | Section A | Section B | Section C |
|---|---|---|---|
| Hydraulic radius.......................... | 3.2 | 3.1 | 2.6 |
| Equivalent length of passive barriers per row of barrier (Le)..................ft.. | 155 | 150 | 126 |
| Total length of airway where reduction is concerned (L)[1].......................ft.. | 4,600 | 9,600 | 7,000 |
| Ratio of total equivalent length to total airway length ($\alpha$ = 3Le/L)................. | 0.10 | 0.05 | 0.05 |
| Reduction of airflow rate ($\Delta Q/Q$)......pct.. | 5 | 2 | 2 |

[1]L is the equivalent airway length when the effects of bends, splitting, and area changes are included.

## DISCUSSION

Selection of installation sites for passive barriers should be planned on the basis of two strategic considerations: (1) Coal dust explosions can develop in any section of a roadway containing flammable dust and propagate in either direction, and (2) gas concentrations and other potential ignition sources are more likely to occur at certain points, such as the working face, than at others. Installation of water barriers can be in either a distributed system to meet consideration 1 or a concentrated system to meet consideration 2. Previous research has shown that the barriers' effectiveness is reduced by open crosscuts (3). It has also shown that an explosion can propagate for long distances into adjacent entries through crosscuts (stopping destroyed by the explosion). Although the Bureau research had indicated the use of distributed barriers on beltways (3), in the present field trial concentrated barriers were used because of the predetermined conditions mentioned in the barrier layout. Accordingly, the installation was based rather on the condition that an explosion can develop in any section of a beltway and propagate in either direction. Even so, installations of water barriers on enlarged cross-sectional areas where crosscuts intersect was avoided.

The water requirement for explosion barriers relies on experimental results to achieve an explosion suppression and has received considerable attention by various researchers, as shown in table 3. It should be noted the water requirement based on the entire barrier per cross-sectional area is for concentrated barriers.

TABLE 3. - Comparison of requirements for water barriers

| Coverage | Bureau's proposal (3) | West German regulation (3) | Polish recommendation to Australia (8) |
|---|---|---|---|
| Width (width of barriers/width of section), pct: | | | |
| Section height/section width >20 pct....... | >50 | NAp | |
| Section height/section width <20 pct....... | >67 | NAp | |
| Cross-sectional area <108 $ft^2$.............. | NAp | >35 | NS |
| Cross-sectional area 108-162 $ft^2$........... | NAp | >50 | |
| Cross-sectional area >165 $ft^2$.............. | NAp | >65 | |
| Area, $gal/ft^2$: | | | |
| Amount of water in one row/area............ | 0.65 | NS | >0.19-0.25 |
| Amount of water in entire barriers/area.... | ([1]) | >4.5 | 4.9 (nongassy)<br>9.8 (gassy) |
| Volume, $gal/ft^3$: Amount of water in one row/space volume[2]............................. | >0.008 | >0.032 | >0.008 |

NAp Not applicable. NS Not specified.

[1]As many rows as practical.

[2]Space volume between 2 adjacent rows of passive barriers.

## CONCLUSIONS

Based on observations of passive water barriers installed at the R&P mines in December 1981, the following remarks can be made:

1. Through appropriate layout design, the barriers are adaptable to the size and shape of existing cross sections of beltways in U.S. coal mines where the height is 7 ft or more.

2. Using steel support frames that can be adapted to both the conventional barrier and the Bureau's modified version, in-mine installation can be carried out easily, using existing roof bolts.

3. As of July 1984, no defects of barriers or support hardware had been detected, nor had any complaint on the presence of the barriers been made by mine personnel at the R&P mines.

4. No effect of the barriers on rock dusting practices and belt operation (the minimum clearance between the barrier and belt was 18 in) was observed, and the effect on ventilation appeared insignificant in the R&P installation.

Monitoring of dust deposition on barrier surfaces is continuing, and comments from others than the mine personnel are still sought. Measurements of ventilation blockage due to the presence of passive barriers to verify calculated values are planned.

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