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15. Supplementary Notes			
<p>16. Abstract</p> <p>Literature review and extensive field survey of line and check curtain materials and practices showed:</p> <ul style="list-style-type: none"> ● Miners, in general, know how to set tight curtains, and do so when needed. ● The tradeoff is economic; tight ventilation is labor-intensive. <p>Line and check curtain techniques found are catalogued and evaluated.</p> <p>A fieldworthy 10 ft extensible brattice to maintain a 10 ft setback was found in use in two mines on continuous miner faces. This technique was evaluated in the laboratory for leakage and methane control at the face. Significant results include: 1) Air leakage through a gap in the extensible curtain depends upon the ratio of the cross-sectional areas between entry and return as well as gap area; 2) Gap shape has no significant effect on methane concentrations at the face - increasing gap <i>area</i> diminishes ventilation effectiveness; and 3) Substantial reductions of CH₄ concentrations at the face were accomplished by brattice extensions with gaps of up to 5 ft² in area.</p> <p>An "inby hook," inserted in the roof automatically to make possible the deployment of a longer (20 ft) brattice extension in the context of a remotely controlled miner, was tested in various roof types. Insertion of this design succeeded only in coal.</p>			
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FOREWORD

This report was prepared by Foster-Miller, Inc., of Waltham, Massachusetts, under U.S. Bureau of Mines (USBM) Contract No. JO100075. It was administered under the technical direction of the Pittsburgh Research Center (PRC). The technical project officers were Mr. Edward Divers and Mr. Jon Volkwein. Mr. Alan G. Young was the contracting officer for the USBM. This report is the result of work performed during the period July 1980 to July 1982.

The technical effort was conducted by Foster-Miller's Mining Division under the direction of Mr. David A. Monaghan.

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1. INTRODUCTION

This document is the Final Technical Report in USBM Contract No. JO100075, "Improving Check Curtains, Line Curtains, and Extensible Face Ventilation Systems," summarizing the effort expended and the results obtained. This report presents the details of an evaluation of presently used check curtains, line curtains, and extensible face ventilation systems; a laboratory evaluation of extensible face ventilation systems; and a field test of a hook insertion device conceived for installing and maintaining extensible face ventilation systems.

1.1 Background

Face ventilation in the working sections of coal mines is generally accomplished by directing mine air with check curtains and line curtains. This method is the mainstay of face ventilation because it is simple and employs common materials and equipment. Present systems, however, suffer from substantial leakage. This means that a significant fraction of air entering the section short circuits into the return airway before reaching the working face. Eliminating or significantly reducing check and line curtain leakage could make more air available for ventilating the working face.

The air available for ventilating the working face is used most effectively when the end of the line curtain is kept within 10 ft of the face. Maintaining a maximum 10 ft setback is required under CFR, Title 30, Part 75. Unfortunately, advancing the line curtain usually requires that mining be stopped, temporary support be set, the curtain be advanced, and then mining be resumed. This procedure interferes with production, and exposes miners to roof which is not permanently supported while advancing the curtain. These negative aspects could be eliminated with an effective extensible face ventilation system. Realizing this, the Bureau of Mines in 1974 let a contract entitled, "Extensible Face Ventilation Systems Duct and Brattice," NTIS: PB 265-067/AS. The contractor found approximately 20 unusual extensible ventilation systems that had been proposed or tried in various locations across the United States. In addition, the contractor designed, built and did some preliminary testing of two new extensible face ventilation systems. Careful evaluation of the 20 previously tried systems and testing of the two new systems revealed nothing that appeared attractive except under a particular set of underground conditions.

Contract JO100075, the subject of this report, was awarded to evaluate and improve the performance of presently used line and check curtains and to develop an extensible face ventilation system acceptable to the industry.

1.2 Objectives

The broad objective of this program was to assist the coal industry in getting more air to the face by developing techniques to reduce check and line curtain leakage and developing an extensible face ventilation system acceptable to the industry.

Specific contractual objectives included the following:

- a. Evaluate present check curtains, line curtains, and extensible face ventilation systems for cost, practicality and air sealing ability.
- b. Investigate ways to improve upon currently used check curtains, line curtains and extensible face ventilation systems, and design new and improved systems.
- c. Select the best check curtains, line curtains, and extensible face ventilation systems and test them at the working sections of coal mines.

1.3 Scope of Effort

The original program was to be completed in three phases:

- a. Phase I - Evaluation of check curtains, line curtains, and extensible ventilation systems now in use.
- b. Phase II - Evaluate ways to improve and develop new check curtain, line curtain, and extensible ventilation systems.
- c. Phase III - Analyze all of the check curtains, line curtains, and extensible systems and test the optimum designs at the working sections of coal.

The Phase I effort included the following tasks:

- a. Conduct a literature and patent search from 1974 to 1980 and reviewing the search in subsection 3.2 of the Bureau of Mines Final Report, "Extensible Face Ventilation Systems Duct and Brattices," NTIS: PB 265-067/AS.

- b. Contact five major suppliers of ventilation equipment to learn what products they are selling and what recommendations they have for improving working section ventilation.
- c. Contact professional ventilation personnel from ten operating underground coal mines which have high methane content to learn how they believe present working section ventilation systems can be improved.
- d. Visit the ten mines identified above to evaluate the characteristics and performance of check curtains, line curtains, and extensible face ventilation systems.

The Phase I effort and results, which were presented in a Phase I Report and orally to USBM personnel, are summarized in Section 2 of this report.

Phase I results showed that the materials and technology needed to improve line and check curtain performance are already available, however, good curtains are costly due to increased labor costs for installation and maintenance.

There is still need for lightweight, extremely simple, inexpensive, and effective extensible curtain systems. Two such systems were observed during mine visits. Both were lightweight, simple, and inexpensive cantilevered curtains. The effectiveness of such systems, however, had not been determined.

Discussions with the mining industry also showed that trends toward remote control mining will increase the need for extensible ventilation systems with extension ranges between 20 and 40 ft if the production potential of remote control mining is to be realized. These results led to a redirection of program effort.

Phase III in-mine testing was deleted from the contract. Phase II effort was modified to include:

- a. Laboratory testing to establish design specifications for extensible brattice systems.
- b. Gallery test two extensible brattice systems.
- c. Design and fabricate a mine roof hook insertion fixture for an improved extensible curtain system.
- d. Mine test of hook insertion device to determine the feasibility of the concept.
- e. Prepare the Final Report.

The results of the laboratory evaluation of extensible brattice systems are presented in Section 3 of this report. The design, fabrication, and testing of a mine roof hook insertion device are presented in Section 4.

Major results, findings, and conclusions of the program are summarized in the following subsection.

1.4 Summary of Key Findings and Results

The literature survey and patent search uncovered no curtain concepts worthy of development. The vast majority of published face ventilation work deals with problems occurring while standard exhaust brattice is already set at 10 ft, which is the legal requirement. Where setbacks of greater than 10 ft are discussed, it is in context with auxiliary systems which ventilate the face adequately.

The survey of ventilation equipment suppliers revealed the general opinion that materials and equipment are available to achieve improved ventilation, and mine personnel know how to do it. The chief reason why it is not done is economic - the problem being labor costs, rather than material costs.

Professional ventilation personnel added the following comments:

- a. Miners know how to get more air when the need exists.
- b. No incentive exists for mine officials to improve curtains.
- c. Economics and high absenteeism preclude assigning (and training) men whose major duty is curtain installation and maintenance.
- d. Requiring present face crews to improve and maintain curtain installations would probably reduce their productivity.

Mine survey visits generally substantiated these comments. Curtain technology and maintenance was in each case adequate to the particular ventilation situation, although construction ranged from crude and simple to elaborate, and maintenance from careless to precise.

For line curtains surveyed:

- a. A significant number were used like regulators, by-passing air not needed at the face.
- b. The complexity of construction of elaborate systems (fly boards, etc.) raised costs (principally through increased labor), but also increased air at the face.
- c. The clearest indicator of leakage rate appears to be the ratio between the cross-sectional areas of the entry and the return. The higher the velocity, the greater the leakage.

Similar findings were reported for check curtains (except that they are not used as regulators).

Two extensible brattice systems were found in use to advance ventilation in order to reduce interruption of continuous miner operations. Each involved a piece of brattice cloth suspended from a cantilevered pole. The effect on face ventilation of leakage past this extended curtain was subjected to laboratory evaluation.

Cantilevered extensible brattice systems with 10 and 20 ft extensions were tested at various airflows in 4 and 6 ft coal. The following were key results:

- a. Air leakage through gaps at the top of the curtain increased with gap area, and were relatively insensitive to the shape of the gap.
- b. Increase with area was percentage-wise more rapid in 4 ft coal than 6 ft coal.
- c. This effect is strongest when the miner is making the sump cut.
- d. Measured leakage through the gap is much greater than the corresponding reduction in face methane dilution.

A 5 ft² gap which produces nearly 90 percent "leakage" in 4 ft coal increases methane concentrations at the face by only 30 percent. In other words, the *crudest* extensible brattice is vastly better than no brattice at all. A good extensible brattice (with a gap area of less than 2 ft²) allows *less than 10 percent increase* in face concentration over a tight brattice of equal length.

This testing* validated the effectiveness of the simple extensible brattices already in use in the field.

A useful application of these results would be in extensible systems of 20 ft length to use in combination with remotely controlled continuous miners. This combination could achieve safely sump depths of 30 ft plus which would increase production by reducing place changes.

A system was devised based upon a hook inserted in the roof by a remotely actuated ram. This hook was tested in several types of roof, failing everywhere except in coal. More development for the inby roof attachment is required.

*The forces required to hold the extended brattice in place were found to be small with ventilation at 6,000 cfm. A two-by-four laid on the brattice slack proved sufficient restraint.

2. CURRENT FACE VENTILATION SYSTEMS AND PRACTICES

Check curtains, line curtains, and extensible ventilation systems currently in use were evaluated. This evaluation included a literature and patent search, discussions with ventilation equipment suppliers and professional mine ventilation personnel, and visits to ten underground coal mines to measure curtain performance.

The following subsections present the results of this evaluation.

2.1 Literature and Patent Search

A literature search was conducted for the period 1974 to 1980 to update and document any advances in underground coal mine face ventilation. Information sources included:

- a. MSHA mine ventilation reports
- b. Mining journals
- c. Health and safety magazines
- d. Mining Engineering Handbook
- e. USBM publications:
 1. Reports on Investigations
 2. Informational Circulars
 3. Technical Progress Reports
 4. Bulletins
- f. MESA Informational Reports
- g. National Safety Council publications and presentations
- h. Engineering Index.

A bibliography of all literature reviewed is included as Appendix A.

The majority of information on mine ventilation available in the United States literature deals with two areas:

- a. Overall mine ventilation
- b. Methane and/or dust control at the face with auxiliary systems such as:
 1. Diffuser fans
 2. Sprayfans
 3. Flooded bed scrubber.

General mine ventilation literature was reviewed and found to be of no significant value to this program.

The goal of auxiliary control systems is to improve methane and dust control at faces already using "typical" brattice installations. A "typical" brattice is an exhaust curtain with a 10-ft setback. Some reference is made to cases where combination systems are as effective with brattice setbacks between 10 and 20 ft as standard exhaust brattice set at 10 ft. Auxiliary systems, such as the diffuser fan, are installed when standard brattice systems do not adequately control gas or dust at the face.

The literature search did not uncover any new documentation specifically related to the construction of or improvement of standard line curtains and check curtains. Several documents which impact the use of extensible face ventilation systems were uncovered. These are abstracted below:

Wallhagen, R.E., "Development of Optimal Diffuser and Sprayfan Systems for Coal Mine Face Ventilation," USBM Contract No. HO230023, November 1977.

The results indicate that diffuser fan and sprayfan systems that were designed to augment the natural airflow pattern in the entry could provide a factor of 3 to 5 reduction in average methane concentration at the face, compared to a mining machine with conventional water sprays alone. The properly designed diffuser and sprayfan systems also significantly reduced the total methane present in the entry. A properly designed dust scrubber discharge can reduce face methane levels by a factor of 2.

The sprayfan was originally installed to supplement standard brattice; however, its high face ventilation efficiency has resulted in a combination system which is more effective with the brattice at 20 ft than a standard water spray system with a 10-ft brattice.

Moynihan, D.J., J.A.L. Campbell, W.D. Roper, L.A. Williams, R.A. Gothard, and L.R. Finley, "Peabody Controls Continuous Miner Dust Emissions and Minimizes Methane Control Problems," Fourth Institute on Coal Mine Health and Safety, Colorado School of Mines, Golden, CO, 1 December 1978.

A high-efficiency flooded bed respirable dust scrubbing system, developed, tested, and placed into production by Peabody, controls dust emissions from continuous miners. The scrubber is totally automated and does not require any actions from the continuous miner operator to be utilized. Respirable dust levels at the miner, shuttle car or in the immediate return meet the MSHA 2 mg/m³ requirement. The flooded bed scrubber is operated with a blowing face ventilation system with a 20-ft brattice setback.

Krisko, W.J., "Evaluation of the Use of Air Curtains to Improve Face Ventilation," USBM Contract No. H0357097, Final Report dated March 1977.

An air curtain is created along one side of a mining machine by blowing air at the roof from a slot in a pipe laying on the machine. The pipe has the same orientation as the line curtain. When operated such that the air curtain overlaps the line curtain, the air curtains function as an extension of the line curtain. This system has been demonstrated underground, where it showed a 30 percent improvement in dust control.

Divers, E.F., J.C. LaScola, and F.N. Kissel, "Sideboard Devices for Improved Face Ventilation in Coal Mines," USBM-TRP 108, dated August 1979.

A rigid sideboard attached to the side of a continuous mining machine is used as an extension of the line curtain. The major problem with previous

sideboard concepts, the seal between the sideboard and the brattice, is overcome by the use of sprays mounted at the outby end of the sideboard. The sprays form a seal which prevents intake air from short-circuiting between the curtain and the sideboard.

The Engineering Index for 1974 to 1980 was also reviewed for foreign literature pertinent to improved face ventilation. Articles from both England and Germany deal with ventilation of faces mined by roadheaders. The ventilation systems used are analogous to tubing systems used in the United States; however, the advance rate of a roadheader is typically about 3m/shift, or an order of magnitude less than that of a continuous mining machine. The tubing systems for roadheaders do not appear suitable for the rapid advance rates typical in the United States. The Engineering Index review did not uncover significant literature from other foreign sources.

The patent search included the United States Patent Class 98-50 "Ventilation, Mines" (primary classification and sub-classification) for the years 1974 through 1980. Three patents relevant to the contract objectives were found and are abstracted below:

Ventilation System for Automated Mining Machines, No. 4,200,036, Joseph E. Matta and Fred N. Kissell, 1980.

A machine-mounted blower is utilized to ventilate a heading by blowing contaminated air through collapsible tubing to a desired discharge point. In the event of a failure of the machine-mounted blower, an auxiliary blower outby the working place automatically starts and reverses the flow of air in the collapsible duct supplying fresh air to the mining machine. This maintains ventilation in the heading at all times.

Mine Face Ventilation System, No. 4,235,163, Edward F. Divers, 1980.

A trough added to the end of a blowing tubing system increases the quantity of air reaching the face by retarding the decay of the jet stream discharged from the end of the tubing.

Mine Ventilation System and Elements Thereof, No. 4,175, 481, James V. Burgess, Jr., 1979.

A mine curtain is stabilized by the addition of vertical pockets which are filled with a fluid or extraneous material such as refuse. The stabilized curtain will hang uniformly and sustain greater differential pressures without moving.

2.2 Survey of Ventilation Equipment Suppliers

Five major suppliers of mine ventilation equipment were surveyed to identify the materials commonly available for face ventilation and to obtain their recommendations for procedures which would improve face ventilation. These companies and contacts included:

<u>Company</u>	<u>Contact</u>
Environmental Control Systems	Ira Estrich
Johnson-Morehouse-Dickey Company	Herb Forse
Mine Ventilation Systems, Inc.	James Burgess
National Mine Service Company	Jay Raies
Peabody ABC Corporation	Robert Stevenson

2.2.1 Face Ventilation Materials and Accessories

The standard materials and accessories for face ventilation are discussed below. Details related to the available sizes, grades and prices of commercial brattice materials are presented in Table 1.

Cloth Brattice

Jute and canvas have been used to control and direct air in mines since the late 1880s. The practice first began in British mines using sail cloth and then jute sacks (like those used to bale cotton and ship potatoes). Jute became the more popular because the fibers were readily imported from India, which was then part of the British Empire, whereas cotton had to be purchased from non-British sources.

TABLE 1. - Commercial brattice materials

Material Brattice cloth	Parameters			
	Grade (oz)	Width (in.)	Roll length (ft)	Cost range per yd ² * (\$)
Jute cloth	15, 20, 22	36, 42, 48, 54, 60 72, 84, 96, 108, 120	25, 50 75, 100	0.66 to 1.04
Cotton cloth	15	36, 48, 60, 72, 84 96, 108, 120	25, 50 100	1.05
Plastic	6, 15	36, 42, 48, 54, 60 72, 84, 96	25, 50 100	0.44 to 0.86
Reinforced plastic	10 to 12, 12 to 15 48**	36, 54, 84 54	25, 50 25	1.08 to 1.30 3.38
Jute plastic	22	36, 42, 48, 54, 60 72, 84, 96, 108, 120	25, 50 75, 100	1.22

*1981 list prices, subject to quantity discount.
**Check panels - special feature, eyelets, velcro strip.

Jute proved to be an excellent material. Of all types of brattice materials, it is the lowest in cost. In high-humidity mine atmospheres, it absorbs moisture which causes the fibers to swell, tending to make the cloth more airtight. Jute is also relatively easy to make flame-resistant by using low-cost calcium chloride.

Cotton duck cloth is a closely woven, smooth surface canvas. It is often used for haulageway curtains and where air leakage through jute may be excessive. Its double-warp construction, with a 76 yarn count in the warp direction, results in a material having a relatively high tensile strength and resistance to abrasion. Permeability of cotton cloth is approximately an order of magnitude less than jute; however, in-mine studies show most air losses occur around frames or at the edges. Permeability is not the controlling factor.

Plastic Brattice

Plastic brattice is finding increased use for temporary stoppings and check panels. The popularity of plastics comes mainly from their acid and oil resistance, low moisture absorbance, mildew resistance and low permeability. Antimony trioxide is the most frequently employed flame-resistant agent.

One type of plastic brattice is made by laminating low-cost 10 to 12 oz jute cloth with polyvinyl chloride (PVC). Most jute-plastics have the PVC on one side only.

Supported plastic is PVC-impregnated nylon mesh. A transparent or translucent product is frequently used for check curtains because of the greater chance of seeing light on the other side. A bright yellow-colored PVC is frequently used where high visibility is desired.

Unsupported plastic sheet is made from PVC. It does not have the resistance to tearing of the supported plastic. Also, to be an effective line curtain, it requires better framing than do the other types of brattice.

Brattice Supports

"Pogo" sticks are used for rapid installation on line and check curtains. When used properly with brattice that is wider than the height of the seam mined, pogo sticks permit rapid

installation of reasonably tight curtains and minimize the need for framing. Because they permit "nailess" installation, brattices supported by pogo sticks have greater potential for reuse.

A pogo stick consists of two telescoping tubes. A spring, attached to the inner tube, rides on a pin in the outer tube. Pins projecting axially from the ends of the stick reduce its chance of sliding on the floor or roof. Pogo sticks are light in weight and easy to carry and store. They are available in sizes ranging from 30 to 144 in. at prices from \$12 to \$17.

Tubing

Tubing is utilized as part of an auxiliary face ventilation system which can be operated in either an exhaust or blowing mode. Details related to the available sizes, accessories and prices are presented in Table 2. Four types of tubing are used in the mines:

- a. Metal
- b. Rigid fiberglass
- c. Wire-reinforced plastic
- d. Collapsible plastic.

Rigid tubing (types a and b above) is more resistant to tearing and puncture than the soft tubing (types c and d). In addition, the rigid tubing also has a lower frictional resistance. Metal tubing is normally constructed from aluminum or steel. The fiberglass is glass fiber, reinforced with polyester.

Metal and fiber-reinforced tubing sections which are installed in short segments can be repaired more easily than collapsible tubing when damaged by machinery or a fall of roof or rib. The metal, however, is more likely to be adversely affected in such cases; even small dents decrease air-carrying capacity. Metal tubing also is the most adversely affected by strongly acidic or alkaline water. Rigid fiberglass tends to become brittle if exposed to cold temperatures. In general there is a strong industry trend toward the use of rigid fiberglass tubing.

PVC tubing, with and without reinforcement (types c and d above), is collapsible. These, therefore, require far less

TABLE 2. - Commercial tubing and tubing accessories

Item	Diameter (in.)	Length (ft)	Horsepower	Typical capacity ranges** (ft ³ /min)	Cost range* (\$)
<u>Tubing</u>					
Collapsible	12 to 36, 2-in. increments	25, 50, 100	-	-	34.80 to 84.40
Wire-reinforced	12, 14, 16, 18, 20, 24	10, 20	-	-	0.16 to 6.00
Rigid fiberglass	12, 14, 16, 18, 20, 24, 30	10	-	-	5.80 to 16.26
<u>Fiberglass Fittings</u>					
Elbow - <90 deg		-	-	-	47.08 to 119.00
Elbow - 90 deg		-	-	-	67.00 to 163.00
Cap	12, 14, 16, 18, 20, 24, 30	-	-	-	18.85 to 66.50
Tee		-	-	-	48.15 to 131.00
Y		-	-	-	56.00 to 147.00
<u>Fans</u>					
	16	-	20 50	3,400 to 9,700 6,300 to 14,500	6,000 to 15,000
	18	-	20 50	5,500 to 13,000 9,800 to 15,600	

*1981 list prices, subject to quantity discount.

**Capacity is a function of the amount of attached tubing.

effort to transport and store than rigid tubes. PVC tubing is also lighter in weight and thus is the easiest type to install. The nonreinforced collapsible tubing is suitable for blowing systems only.

Fans

Permissible fans 16 to 18 in. in diameter are most frequently used for auxiliary face ventilation tubing systems. The fans normally range between 20 and 50 hp. The capacity ranges listed in Table 2 reflect the volumes obtainable with typical system restrictions produced by frictional losses in the tubing.

The ventilation material suppliers provided the following comments and recommendations for improving face ventilation:

- a. The mining companies know how to achieve the ventilation they require.
- b. The materials are available to do the job.
- c. The efficiency of the systems in use is proportional to the care taken during installation and the maintenance given the curtains.
- d. Face ventilation can be improved with currently available techniques and materials, however, improvements are costly due to increased labor requirements.

In addition, ventilation equipment suppliers emphasized the need for:

- a. Educating supervisors in the values of good face ventilation
- b. Training persons who install and maintain brattice and tubing
- c. Using brattice at least 8 in. wider than height of seam mined
- d. Using brattice boards (framework)
- e. Early replacement or repair of damaged curtains and checks.

2.3 Survey of Professional Ventilation Personnel

Discussions were also held with mine officials, company ventilation engineers, USBM personnel, MSHA and state inspectors to determine their opinions on ways to improve face ventilation or why more emphasis is not placed on improving face ventilation systems. A list of people contacted is presented in Table 3.

A compilation of their varied thoughts and opinions is listed below:

- a. Increase the pressure differential between the intake and return entries inby the last permanent stoppings.
- b. Use brattice that is at least 8 in. wider than the height of seam mined.
- c. Redirect the attitudes of section foreman and face crews.
- d. Increase bratticemen and mason wage rates to a grade between one (their present and lowest grade) and two.
- e. Miners know well their need for good air and how to "get more when the need exists."
- f. No incentive exists for mine officials to improve curtains.
- g. Current systems meet or can be made to satisfy legal requirements so there is no incentive to improve current systems.
- h. Resolution of other problems is a higher priority.
- i. Economics and high absenteeism rates preclude assigning persons whose major duty would be to install and maintain curtains.
- j. Dependence on present face crews to improve and maintain curtain installations probably would reduce productivity.

TABLE 3. - Professional ventilation personnel

Company/Agency/Group	Contact	Title
Consolidated Coal Westmoreland Coal Island Creek Coal U.S. Steel Rochester and Pittsburgh Bethlehem Steel Freeman United Coal North American Coal Jim Walter Resources Peabody Coal Pittston Coal USBM personnel	William Parisi Hershel Hayden John Kalasky James Girod Edward Onuscheck Thomas Korbrick Paul Budzak George Radomsky Jack Stevenson James Clem Munroe West Edward Divers Fred Kissel Robert Vinson	Director of Safety Vice President, Engineering/Production Ventilation Engineer Chief Inspector Assistant to President/Safety Director Safety and Workman's Compensation Manager Safety Director Safety Manager - Eastern Division Chief Ventilation Engineer Vice President, Safety Director of Safety - Jewell Ridge Division
MSHA	Robert Dalzell Robert Haney Ralph Foster	
United Mine Workers	Martin Connors Everett Accord D. Davidson	Director of Safety
Pennsylvania Department of Mines	Walter Vincinelly Paul Hyatt	Commissioner of Deep Mine Safety Director of Bureau of Bituminous Deep Mine Safety
West Virginia University	E. Lemont Dr. Syd Peng	

- k. Curtains should be made to overlap at the roof and to reach the floor.
- l. Brattice framework should be installed.
- m. Narrow panels of brattice material, strips of belt conveyor or extra layers of brattice should be secured to the curtain at shuttle-car run-through places.

2.4 Mine Investigations

The face ventilation procedures utilized at 10 underground coal mines were examined to define current practices and the performance obtained using line curtain, check curtain and extensible face ventilation systems. A total of 20 sections were evaluated in mines located in Pennsylvania, Virginia and West Virginia.

The selected mines encompassed the ranges of underground conditions listed in Table 4.

In this subsection we present a discussion of the construction techniques employed for line curtains, check curtains and extensible brattice devices observed during the mine visits. Also presented are summaries of the data collected and an analysis of that data. Data collection procedures are included in Appendix B.

2.4.1 Line Curtains

Line Curtain Construction

The in-mine studies revealed four basic line curtain constructions, which have been classified as Types A through D for consistency throughout this report:

- a. *Type A* (Figure 1) is the simplest construction. The curtains are hung from roof bolt plates on 4- to 5-ft centers. This construction results in gaps at the roof between the bolts. The size of the gaps varies with the care taken during installation. The curtain is prone to close on the rib with high flow rates because the bottom simply lays on the floor.

TABLE 4. - Ranges of conditions encountered in the mine investigations

Parameter	Ranges
Seam height	2.5 to 7.2 ft
Entry widths	16.5 to 20.5 ft
Ventilation systems	1 and 2 splits
Intake air quantities	6,600 to 29,000 ft ³ /min
Air quantities at last open crosscut	7,000 to 29,000 ft ³ /min
Face air quantities	1,500 to 12,000 ft ³ /min
Face velocities	80 to 500 ft/min
Curtain lengths	21 to 124 ft
Brattice-rib clearance	2.2 to 6.3 ft
Curtain setbacks	5.5 to 15 ft
Line curtain leakage	0 to 24,000 ft ³ /min
Line curtain pressure drop	0.0 to 0.25 in. WG
Check curtain leakage	0 to 16,400 ft ³ /min
Check curtain pressure drop	0.0 to 0.14 in. WG
Curtain leakage per foot	0 to 500 ft ³ /min
Mine CH ₄ liberation	0.1 to 2.0 million ft ³ /day ft ³ /min/day
CH ₄ behind line curtain	0.0 to 0.8 percent

- b. *Type B* (Figure 2) is designed to minimize the major problems of Type A curtains. It is spadded to the roof on approximately 12-in. centers, minimizing the gaps between the roof and the curtain. It is attached to one or two two-by-fours on the bottom to stabilize it and to prevent closing on the rib with high ventilation flow rates.
- c. *Type C* (Figure 3) utilizes props for vertical support. The top of the curtain is generally attached to each prop and spadded to the roof between the props. A two-by-four stabilizes the curtain on the floor at the base of the props.
- d. *Type D* (Figure 4) also utilizes props for vertical support. In addition, horizontal brattice boards are attached between the props. Typically, the curtain is spadded to the roof on about 12-in. centers and the bottom of the curtain is stabilized by a two-by-four.

Line Curtain Performance

A total of 77 line curtains were evaluated during the in-mine studies to determine the performance currently being achieved. All curtains observed were exhaust curtains. Data collected included:

- a. Curtain dimensions
- b. Curtain location relative to face and ribs
- c. Airflows associated with the curtain
- d. Pressure drops associated with the curtain.

The raw data collected are presented in detail in Appendix C. Section maps corresponding to the data are presented in Appendix D.

An extremely wide variation exists in the data collected. This is attributable to the variation in the quality of curtain construction and curtain maintenance. Differences in quality were observed in attachment of the outby end of the curtain, spadding centerlines and linear tautness of the curtain. Primary maintenance problems were holes and rips in the curtain. These marginal installations and maintenance practices did not create operational problems at the mine section level because the mines were achieving the target airflow across the faces.

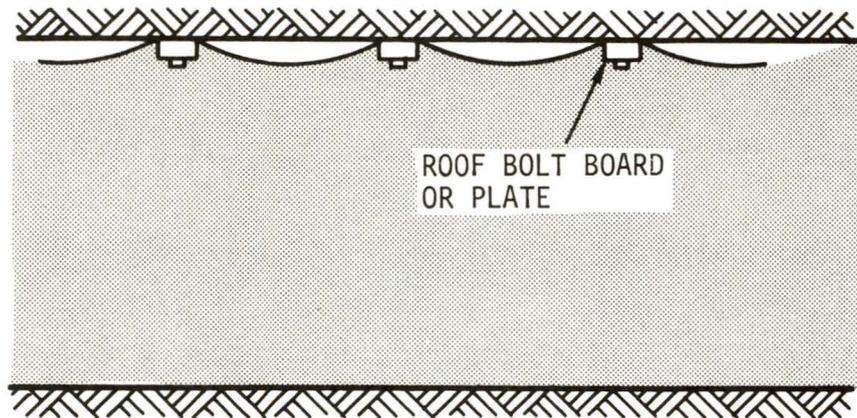


FIGURE 1. - Type A line curtain - curtains hung from roof bolt plates.

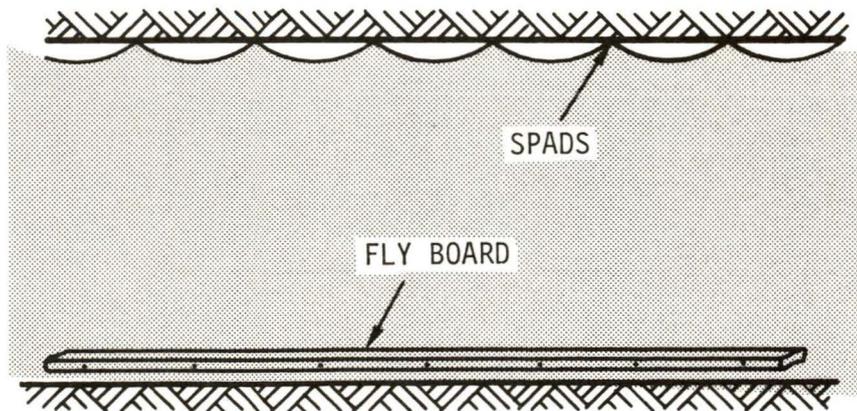


FIGURE 2. - Type B line curtain - curtain spadded to roof, with fly boards as support on bottom.

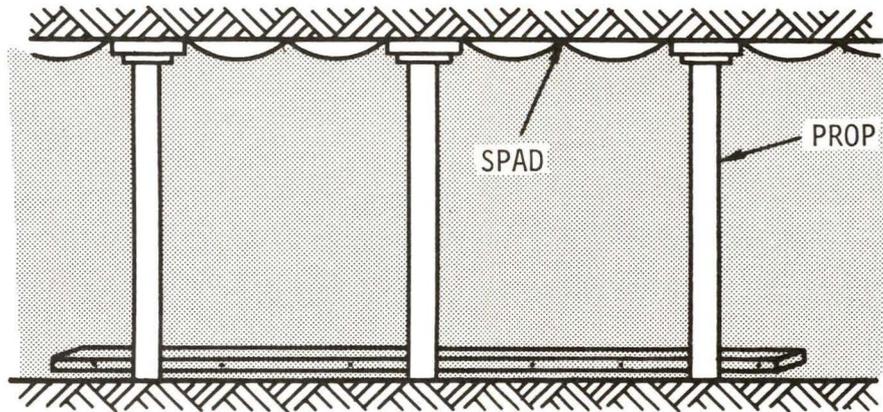


FIGURE 3. - Type C line curtain - curtains nailed to props, spadded between props with boards as support on the bottom.

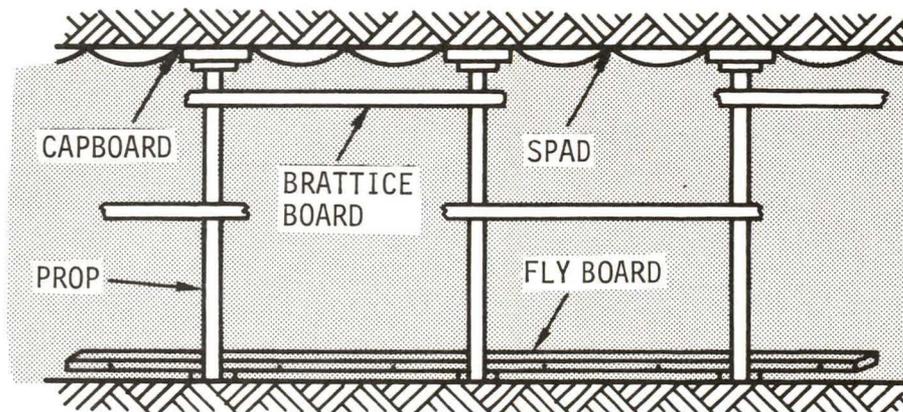


FIGURE 4. - Type D line curtain - curtain nailed to props, spadded between props, boards near top and at bottom.

Table 5 presents a data summary of average values for curtain parameters for each mine. Mine sites are coded to indicate the states in which they are located. Curtain "efficiency" is defined as the volume of air reaching the face divided by the volume of air entering the outby end of the curtain.

Average values for curtain efficiencies at the 10 mines ranged from 18 to 79 percent. The 18 percent value for mine PA1 was low because the curtain was too narrow and hung 1 ft above the floor. The 19 percent value for WV1 is low because the outby ends of the curtains were used as regulators and only a portion of the air at each inlet was directed toward the face. With the exception of mine PA2 and a few isolated faces, it was common practice to bypass air at the outby end of the curtain. Curtains used in this bypass mode were adjusted to achieve the desired volume of air at the face, with the remaining air permitted by bypass.

Highest efficiencies were observed in situations where pressure drop across the curtain was low. Mines V1 and V2, with efficiencies of 79 and 77 percent, respectively, pass relatively small volumes of air through relatively large returns behind the curtains.

Efficiencies are most accurately determined for those installations where the curtain was installed to carry *all* the air to the face with no bypass at the outby end. For the curtains of this type tested by Foster-Miller, efficiencies ranged from 43 to 79 percent.

Table 6 presents the line curtain evaluation results averaged by curtain type. The installed costs per 100 ft of curtain ranged from \$60 for the simple Type A curtain to over \$550 for the most complex Type D curtain. The quoted installed costs include both material and labor costs and are based on mine supplied data. The average efficiency for Types A, B, and C curtains, without bypass air, ranged from 70 to 80 percent. The average pressure drops measured for these three curtain types were extremely low, which tends to explain the unexpectedly high efficiencies measured for even the simple curtain types.

TABLE 5. - Line curtain data summary by mine

Parameter	Mine code									
	PA1***	V1	V2	V3	V4	WV1*	WV2*	WV3**	WV4	PA2
Curtain type	B	A	B	A	C	B	A	A	A	D
Number of curtains	1	9	9	13	11	10	8	6	5	5
Average air to face, ft ³ /min	4,641	4,532	4,481	4,267	5,824	3,633	6,845	3,521	3,570	5,809
Average leakage, ft ³ /min	21,000	2,152	3,204	2,216	3,701	15,452	10,758	6,850	4,250	12,051
Average length, ft	46	98	81	81	55	83	77	77	72	104
Average leakage, ft ³ /min/ft	456	25	43	31	71	172	142	90	75	112
Average efficiency, percent	18	79	63	77	68	19	43	43	46	43
Average pressure drop, in., WG	0	0.04	0	0	0	0	0.04	0.02	0.02	0.10
Average return area, ft ²	17.0	20.8	29.3	23.4	23.7	28.4	12.7	20.7	26.7	17.3
<p>* Air bypassed at outby end ** Heavy bypass on two curtains *** Curtain was 1 ft off the floor</p>										

TABLE 6. - Line curtain data summary

Parameter	Curtain type							
	A		B ¹		C		D	
	Total curtains	Curtains without bypass	Total curtains	Curtains without bypass	Total curtains	Curtains without bypass	Total curtains	Curtains without bypass
Average curtain length, ft	81	83	86	72	55	54	104	110
Average air to face, cfm	4,658	3,890	3,786	5,050	5,824	5,846	5,809	6,589
Average leakage, cfm	4,863	2,253	9,653	1,415	3,701	2,671	12,051	12,787
Average leakage, cfm/ft	65	27	110	20	71	49	112	116
Average efficiency, percent	63	73	40	80	68	71	43	34
Average pressure drop, in W.G.	0.02	0.02	<0.01	0	<0.01	0	0.1	0.07
Number of curtains	41	24	19	4	11	10	5	2
Average cross-sectional area behind curtain, ft ²	20.1	23.2	28	30.7	23.6	24.3	17.3	17.1
Installed cost ² , \$/100 ft	60		199		440		560	
Brattice material	Cotton duck, supported plastic		Jute, cotton duck, supported plastic		Cotton duck		Supported plastic	
Typical section dust ³ , mg/m ³	1.5		1.3		1.5		0.8	
<p>¹Curtain 1 ft off floor not included.</p> <p>²1981 prices.</p> <p>³Data from mine personnel; not measured by Foster-Miller.</p>								

The type of curtain construction also correlates with quantity of air reaching the face. As air quantity increases so does the complexity of the curtain construction required to bring a given percentage to the face.

The Type D curtain, the most expensive and most complex, showed the lowest measured efficiency. This unexpected result was due to operating conditions on the one section where this curtain type was evaluated. On this section, entries were driven only 16 ft wide. There was little room for the line curtain. In addition, the mine was very gassy requiring higher air volumes at the last open crosscut. The higher air volumes coupled with the restricted area behind the curtains resulted in higher pressure drop across the curtain, high leakage, and lower than expected efficiency.

Line Curtain Conclusions

The following conclusions can be drawn from the in-mine evaluations of line curtains:

- a. A significant number of line curtains have gaps on the outby end to bypass air and to allow passage of men and materials.
- b. For those faces where air is not intentionally bypassed, the quantity of air required at the face appears to correlate with the complexity of the line curtain construction.
- c. The costs of installed line curtains is a function of the amount of labor required to install them. Type D curtains require significantly more labor for installation, than the simple Type A curtains.
- d. The leakage rate across typical line curtains is dependent upon the pressure drop across the curtain, which depends upon the ratio of area behind the curtain to entry area, rather than the type of curtain construction.

2.4.2 Check Curtains

Check Curtain Construction

The in-mine studies evaluated five basic check curtain constructions. They are:

- a. *Type A check curtain* - Figure 5 depicts the Type A check curtain which is constructed by nailing a piece of brattice cloth to the roof bolt boards or a board running across the entry. The top is frequently nailed or spadded to the roof between the roof bolt center-line. The sides of the curtain are nailed to the ribs.
- b. *Type B check curtain* - The Type B check curtain of Figure 6 is constructed in the same manner as the Type A, with the addition of a "fly" board attached to the bottom of the curtain to prevent the bottom of the curtain from blowing off the floor.

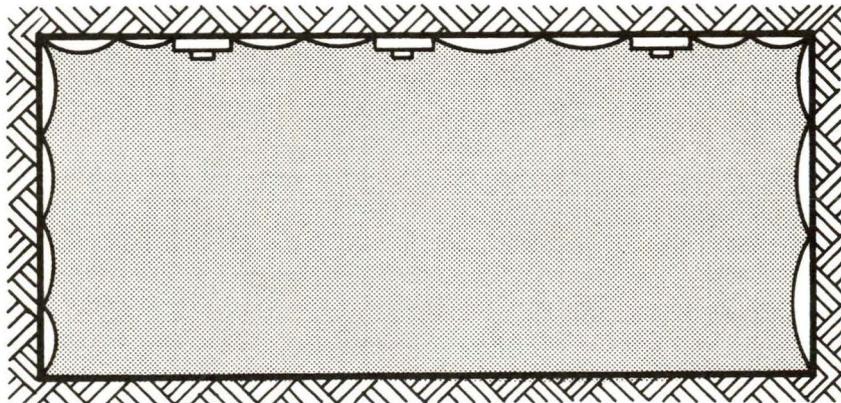


FIGURE 5. - Type A check curtain - curtain nailed to boards or roof bolt plates and ribs.

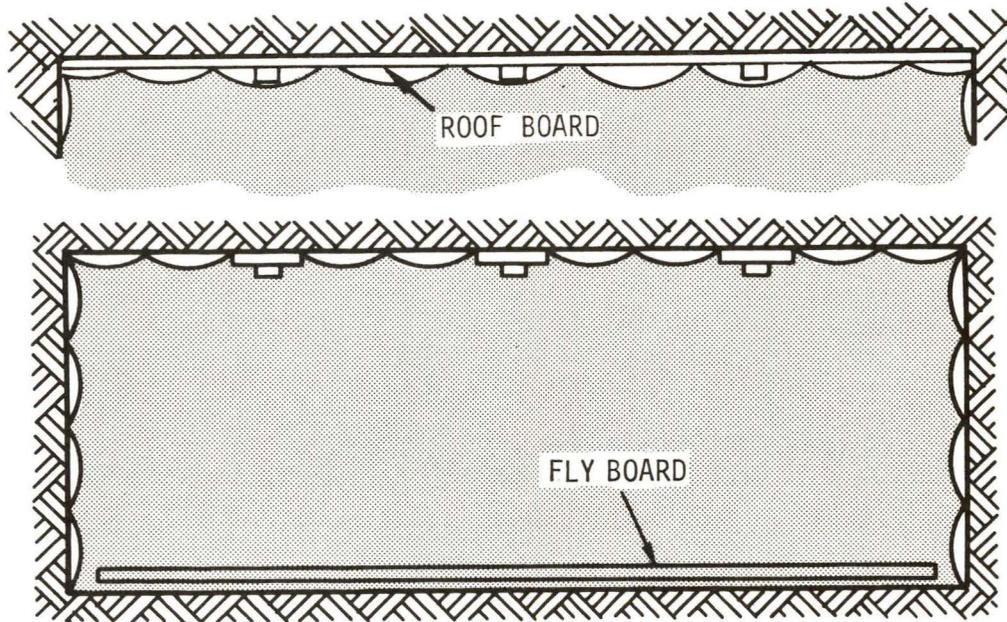


FIGURE 6. - Type B check curtain - curtain nailed to roof board or roof bolt plates with an additional "fly" board at bottom.

- c. *Type C check curtain* - The Type C check curtain of Figure 7 has the basic construction of the Type A curtain, the bottom fly board of the Type B curtain and an additional wooden framework to prevent the center of the curtain from ballooning.
- d. *Type RT (run-through) check curtain* - The Type RT check curtain, Figure 8, is utilized to permit movement of men and machinery without significant disruption of the ventilation system. The RT curtains observed were constructed of two, three or four pieces of brattice material which overlap by a few inches. Typically, these strips of material are nailed to a board which has been attached to the roof. Translucent material is often used to permit personnel to see approaching lights on the other side of the curtain.

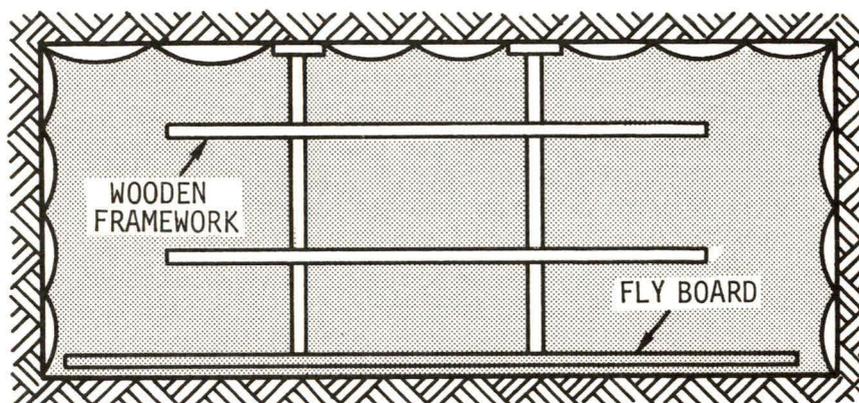


FIGURE 7. - Type C check curtain - curtain nailed to roof board or roof bolt plates with boards at bottom and additional framework.

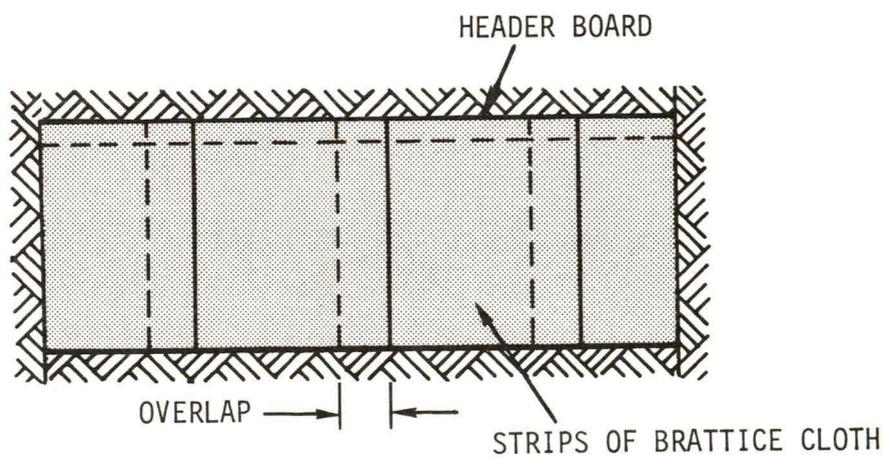


FIGURE 8. - Type RT (run-through) check curtain.

- e. *Type RU (roll-up) check curtain* - The Type RU curtain of Figure 9 is utilized on sections with large pressure drops across the curtains and where it is necessary to allow vehicular passage while ensuring good check seals. Typically, it is installed in an entry over the end of a crosscut. It overlaps the pillars on either side of the crosscut by about 2 ft. When access through the curtain is required, the curtain is rolled up from the bottom and tied against the roof. The RU curtain is constructed by nailing a piece of brattice material to a board attached to the roof. Tie ropes are nailed over the board and one end hangs on each side. The bottom of the curtain is stabilized with a fly board.

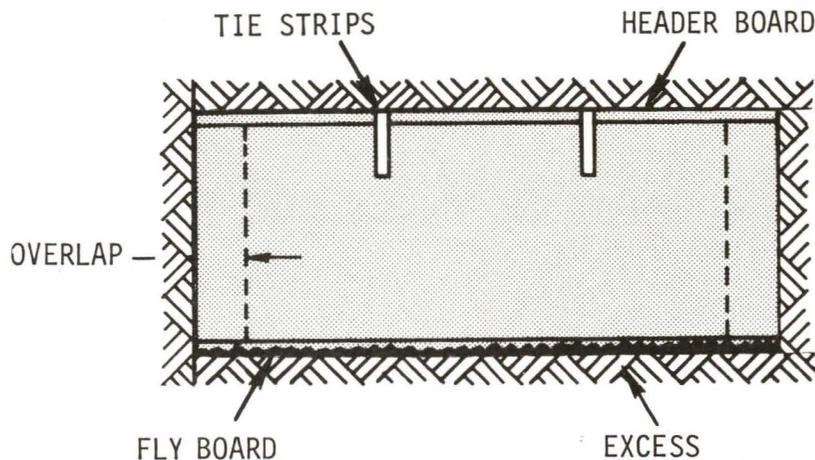


FIGURE 9. - Type RU (roll-up) check curtain.

Check Curtain Performance

During the in-mine studies of check curtains, the following data were collected for 118 curtains:

- a. Curtain dimensions
- b. Pressure drop across the curtains
- c. Curtain location on the section relative to the faces and other curtains.

Detailed data on each check curtain are listed in Appendix E. The location of the curtains is depicted on the mine section maps in Appendix D.

Check curtain leakage was determined by performing airflow material balances. Direct measurement of leakage volume was not possible due to the curtain locations relative to crosscuts.

The check curtains studied during the in-mine investigation fall into two basic categories - fixed and movable. Types A, B, and C are fixed or semi-permanent curtains while Types RT (Run Through) and RU (Roll Up) are movable. They can be rolled up or pushed aside to facilitate movement of men and equipment.

Check curtain results for each mine are presented in Table 7. Eight of the 10 mines visited used Type A curtains, one mine Type B, and one mine Type C. The average measured leakage varied from practically 0 for mine PA2 using Type C curtains to 5582 ft³/min for mine WV2 using Type A curtains.

The average measured leakage for these mines using Type A curtains ranged by an order of magnitude from 530 to 5580 ft³/min. The lowest measured leakage, 530 ft³/min was in mine V2; the highest, 5580 ft³/min, in mine WV2. Closer analysis of these results showed that mine V2 had over twice the area behind their line curtains (29.3 ft²) as mine WV2 (12.7 ft²). Test results from all 10 mines, plotted in Figure 10, show an apparent correlation between check curtain losses and the area behind the line curtain. As the area behind the line curtain increases the leakage across the Type A curtains decreases.

The movable curtain results are also summarized in Table 8 on a mine-by-mine basis. The average leakage ranges from 1800 to 9365 ft³/min. *The highest leakage occurred at Mine WV2 which had the higher fixed check curtain leakage and the smallest area behind the line curtains.* The remaining movable check curtain

TABLE 7. - Check curtain summary by mine

Parameter	Mine Code									
	PA1	V1	V2	V3	V4	WV1	WV2	WV3	WV4	PA2
<u>Fixed curtains</u>										
Curtain type	A and B	A	A	A	B	A	A	A	A	C
Number of curtains	3.0	8.0	3.0	5.0	5.0	10.0	16.0	4.0	5.0	8.0
Height, ft	7.3	5.2	6.9	5.3	5.2	6.5	3.8	6.3	6.0	6.8
Width, ft	16.0	17.5	18.5	17.5	18.4	19.7	20.1	17.2	19.2	16.0
Average leakage, cfm	4216.0	4393.0	530.0	3336.0	269.0	2170.0	5582.0	3892.0	1444.0	*
Average leakage/foot, cfm/ft	263.0	286.0	27.0	187.0	15.0	110.0	267.0	227.0	76.0	*
Pressure drop, in. WG	0.00	0.01	0.00	0.00	0.00	0.01	0.02	0.01	0.02	0.08
Area behind line curtains, ft ²	17.0	20.8	29.3	23.4	23.7	28.4	12.7	20.7	26.7	17.3
<u>Movable curtains</u>										
Curtain type	-	RT	RU							
Number of curtains	0.0	9.0	9.0	8.0	10.0	0.0	7.0	3.0	1.0	4.0
Height, ft	-	5.2	6.8	5.5	4.9	-	3.8	6.5	6.3	6.8
Width, ft	-	17.5	18.3	18.5	18.5	-	20.2	17.2	20.0	16.0
Average leakage, cfm	-	3624.0	4876.0	1801.0	2261.0	-	9365.0	3444.0	0.0	*
Average leakage/foot, cfm/ft	-	208.0	207.0	91.0	124.0	-	336.0	201.0	0.0	*
Pressure, drop, in. WG	-	0.01	0.00	0.00	0.00	-	0.01	0.02	0.00	0.02
Area behind line curtains, ft ²	-	20.8	29.3	23.4	23.7	-	12.7	20.7	26.7	17.3
*Leakage is essentially zero from material balance.										

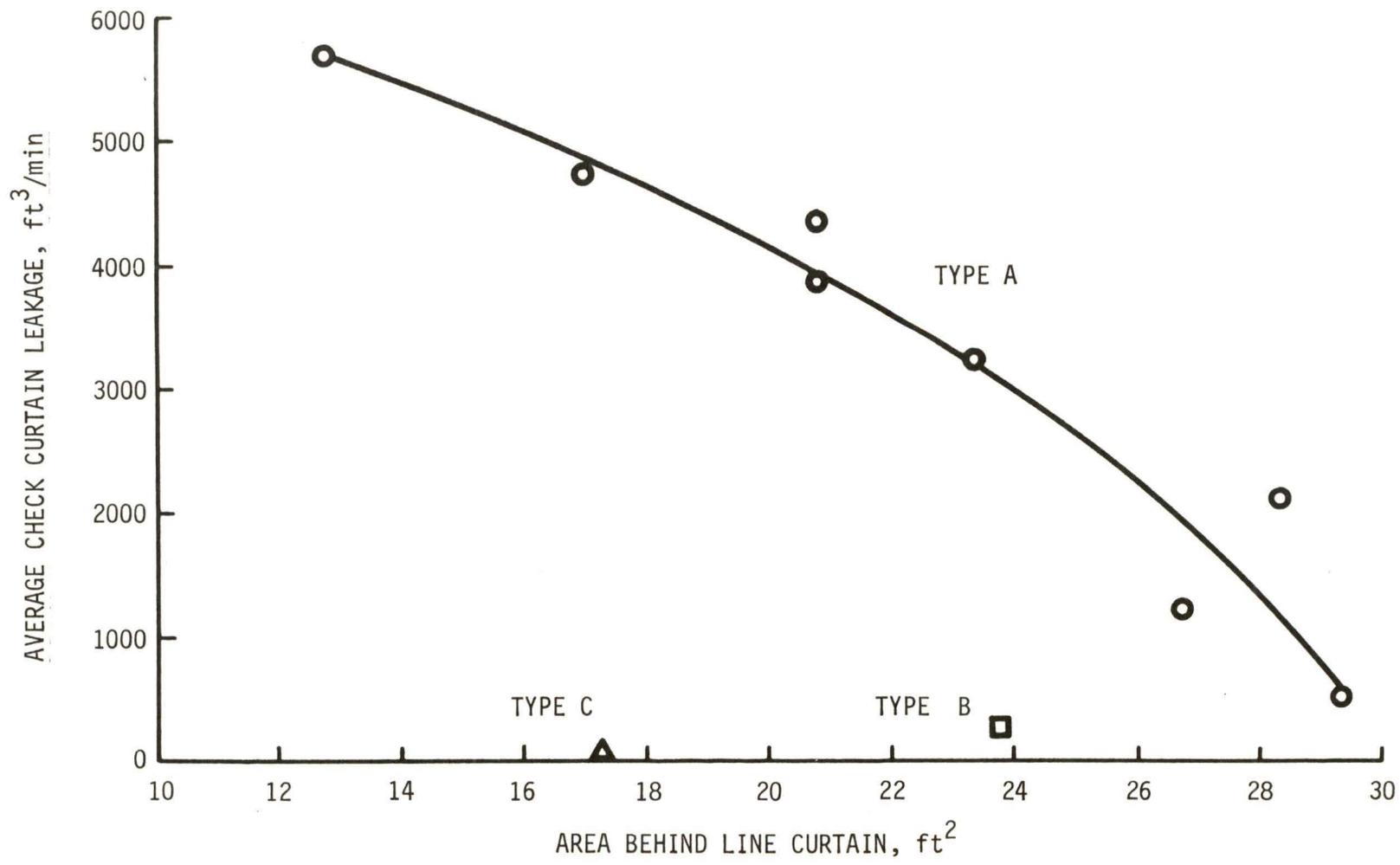


FIGURE 10. - Fixed check curtain leakage versus area behind the line curtain.

leakages fall in a range which varies by a factor of about two. No significant effect between mines is evident.

Analysis by Curtain Type

Table 8 summarizes the check curtain results based on curtain type. The Types C and RU were the most effective with essentially no measurable leakage. These were also the most labor intensive and therefore the most costly. The Type B curtains were significantly more effective than the Type A with only a moderate increase in cost. The Type A and RT were the least expensive and least effective.

The effectiveness of the fixed check curtains by type was depicted in Figure 10 where their leakage was shown to correlate with cross-sectional area behind the line curtain. For an equal cross-sectional area, the Type B curtains appear to be an order of magnitude more effective than Type A. The Type C has a greater effectiveness ratio even though these curtains were used in conjunction with small line curtain return areas. The superior effectiveness found during this study for the Types B and C curtains would be expected based on engineering principles. The magnitude of improvement associated with each is an approximation because only six Type B and eight Type C curtains were evaluated. The Type B curtain, which is essentially a Type A curtain with a fly board on the bottom produces a more effective check curtain at a nominal increase in operating cost.

The Type C curtains are extremely effective; however, their cost is not warranted unless mining conditions dictate use of line curtains in such a way that high pressure drop across the working section is produced.

Check Curtain Conclusions

The following conclusions can be drawn based on the check curtain analysis:

- a. Check curtain losses are a function of the face area pressure differential, that is, losses increase as the ΔP increases across the face area.
- b. The cross-sectional area behind the line curtains appears to be a reasonable indicator of the pressure drop between the intake and return entries and therefore an indicator of check curtain losses.

TABLE 8. - Check curtain summary by curtain type

Parameter	Units	Curtain Type				
		A	B	C	RT	RU
Number of curtains		52.0	6.0	8.0	48.0	4.0
Average height	ft	5.3	5.5	6.8	5.4	6.8
Average width	ft	18.6	17.9	16.0	20.7	16.0
Average leakage	ft ³ /min	3948.0	758.0	Note 1	3930.0	Note 1
Average leakage per foot	cfm/ft	208.0	46.0	Note 1	188	Note 1
Pressure drop	in., WG	0.02	0.00	0.08	0.00	0.02
Cost	\$	10.0	40.0	100.0	30.0	40.0

Notes: 1. Leakage is essentially zero from material balance.

- c. The effectiveness of the check curtains studied corresponds to the effort and cost of constructing them.
- d. Type B curtains generally warrant the additional effort involved in their construction

2.4.3 Extensible Curtain Systems

The need for a system to maintain a brattice or tubing within 10 ft of the face during mining has been partially offset by the development and wide spread implementation of the "Sprayfan" system in eastern mines using exhaust ventilation systems. In midwestern mines, development, and widespread use of the "Flooded Bed Scrubber" with blowing ventilation systems has had a similar effect.

In many mines, including those in this study, the line brattice still must be maintained within 10 ft of the face. This is done in one of two ways. In most cases, production is halted, temporary support is set, the permanent line curtain is extended, and mining is resumed. In two of the mines visited during this study, the brattice was extended using simple extensible curtain systems. The two systems are illustrated in Figures 11 and 12.

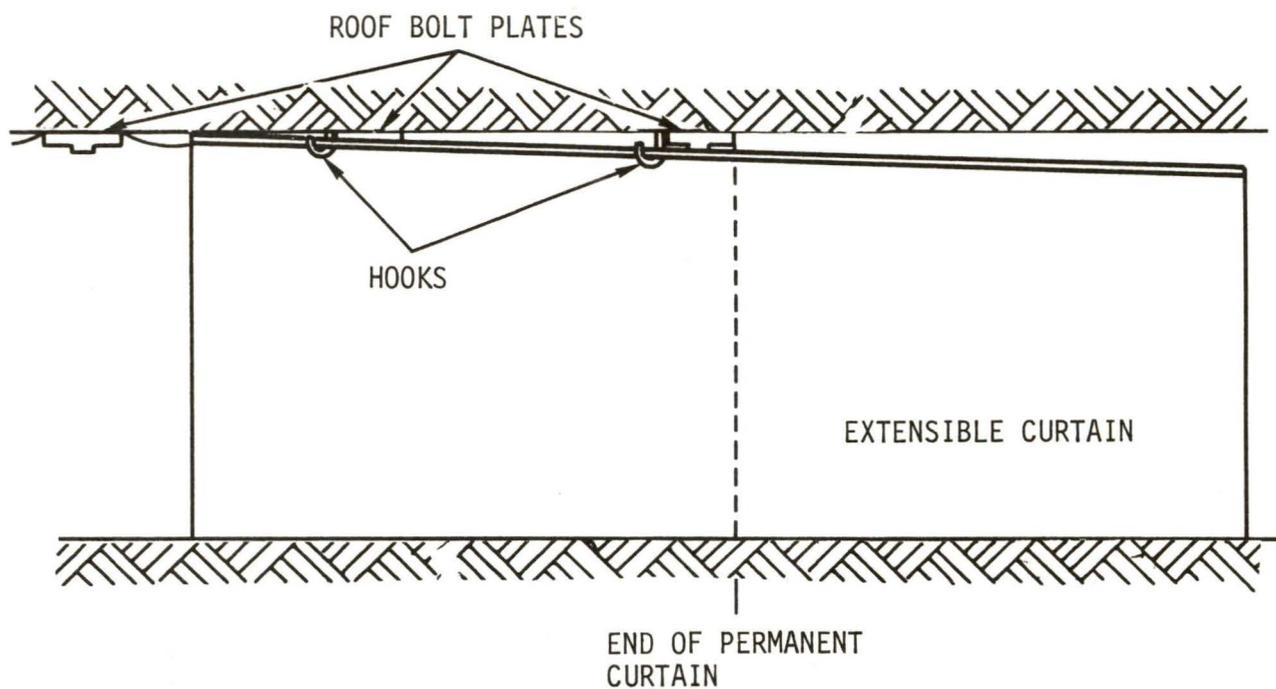
The first system (Figure 11) consists of the following:

- a. Two adjustable J-hook assemblies
- b. 20 ft of 1/2 in. diam pipe
- c. 20 ft of brattice cloth.

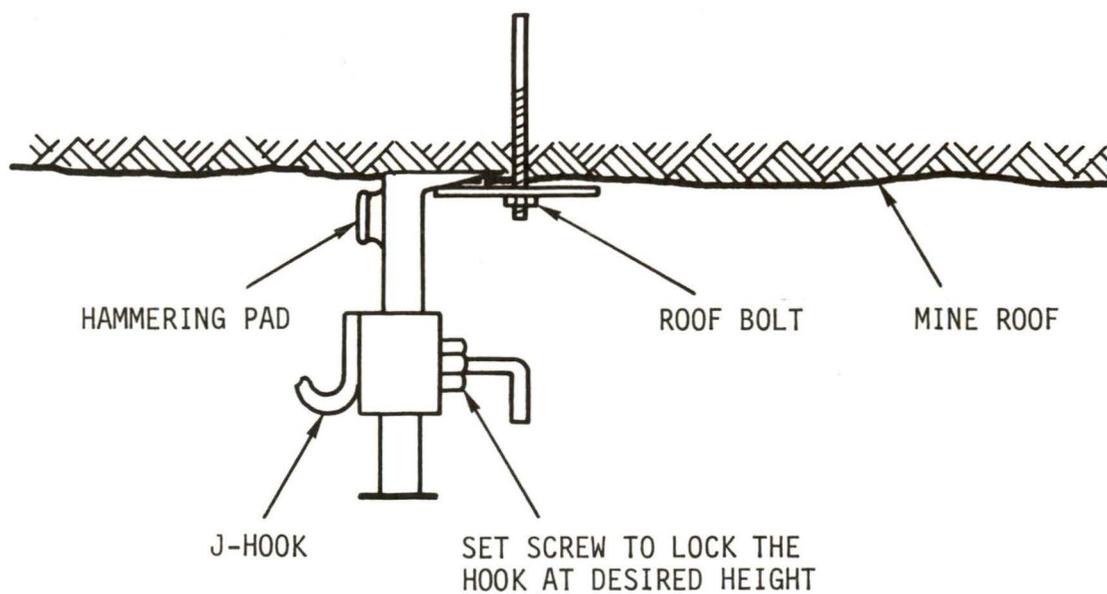
The two J-hooks are installed on the last two roof bolts next to the rib. The pipe, with the brattice cloth attached is suspended on the hooks. As the continuous miner advances, the pipe and brattice are pushed forward.

The second system (Figure 12) consists of the following:

- a. Two "pogo" sticks
- b. 16 ft 2 × 4
- c. 15 ft of brattice cloth.



a) EXTENSIBLE BRATTICE ASSEMBLY USING J-HOOKS



b) ADJUSTABLE ROOF HOOK

FIGURE 11. - J-hook extensible curtain system.

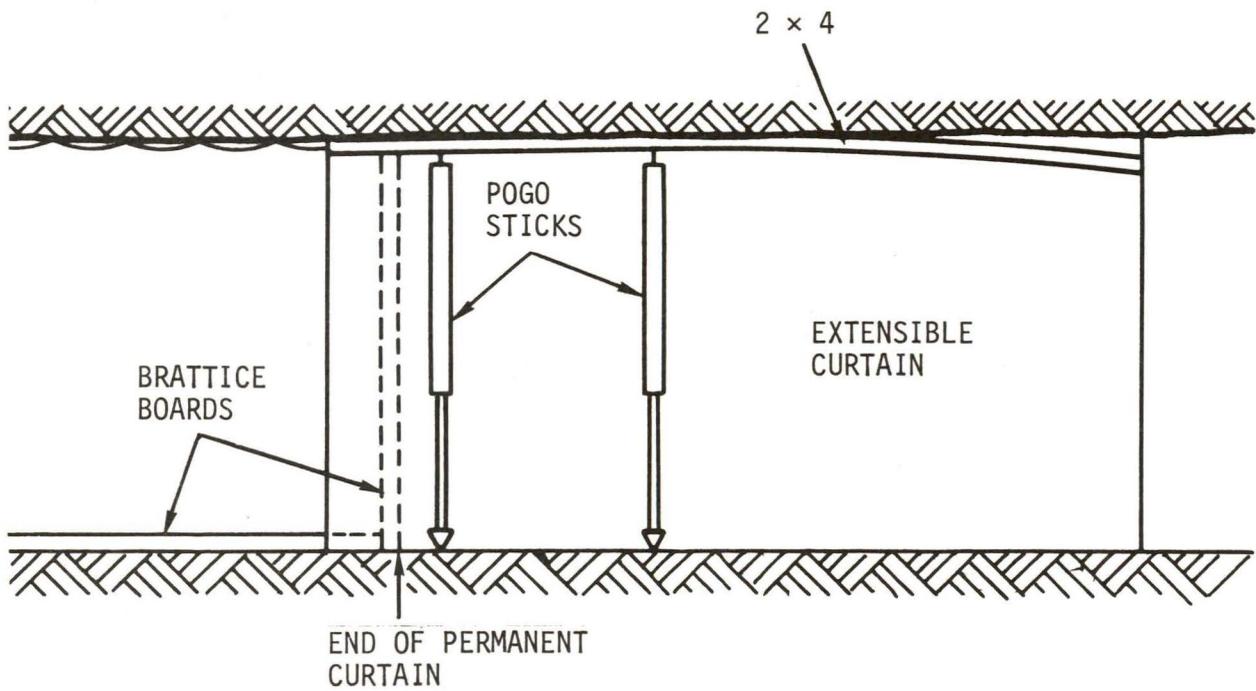


FIGURE 12. - Pogo stick extensible curtain system.

As the continuous miner advances, the 2 × 4 with the brattice attached is lifted to the roof. One pogo stick is installed even with the last row of bolts, the second is installed 3 to 4 ft outby the last row of bolts.

Both of these systems are lightweight, extremely simple, and inexpensive. They can be installed by personnel working under permanently supported roof, thus eliminating the need to stop mining and set temporary supports to advance the line curtain. *The performance of these systems in comparison to curtains installed as advances of the permanent curtain, however, was suspect and could not be determined in the field.* There are significant gaps between the roof and curtain caused by either sagging of the support pipe board or by irregularities in the roof surfaces. One would expect these gaps to allow leakage of intake air to the return, minimizing line curtain effectiveness in controlling methane concentrations at the face.

2.5 Summary and Conclusions

The major results and conclusions from the evaluation of current face ventilation systems and practices can be summarized as follows:

- a. A review of the literature from 1974 to 1980 did not identify any major developments in line curtains, check curtains, or extensible face ventilation systems which have gained industry acceptance. The review did indicate a diminished need for extensible systems with a 10 ft reach. The diminished need results from variance granted on the requirement to maintain the end of the line curtain within 10 ft of the face. These variances have been granted where sprayfan systems and flooded bed scrubber systems have been implemented and shown to provide effective face ventilation.
- b. A need still exists for 10 ft extensible systems especially in mines which cannot tolerate the water requirements of the sprayfan or the space requirements of the flooded bed scrubber.
- c. The patent search for the period 1974 to 1980 did not uncover any new developments which warranted further evaluation on this program.

- d. The materials and technology needed to produce good face ventilation with line and check curtains are available. However, this good ventilation is costly due to the substantial labor required for installation and maintenance.
- e. Data from the in-mine study of line curtain shows line curtains of simple construction are effective when the cross-section behind the curtain is large.
- f. The leakage across check curtains correlates with both the quality of curtain construction and maintenance and the pressure differential between intake and return. The ratio between entry cross-sectional area and area behind the line curtain is an indicator of the pressure differential across a section and therefore also an indicator of check curtain losses.
- g. For an extensible ventilation system to be accepted by the industry it must be simple, inexpensive, low weight, and effective. Two such systems were observed. The effectiveness of these systems, however, was questionable due to gaps between the curtains and the mine roof. Effectiveness needed to be determined and design specifications for 10 ft extensible systems developed.
- h. The trend in the coal mining industry appears to be toward remote control of continuous miners. Remote control will increase productivity if the miner can advance more than 20 ft without changing places by minimizing changeout time. In some cases this could be achieved by a 20 ft long extensible brattice which maintains adequate face ventilation.

3. LABORATORY EVALUATION TO ESTABLISH DESIGN SPECIFICATIONS FOR EXTENSIBLE CURTAIN SYSTEMS

Mining personnel, in general, agree that good extensible face ventilation systems would improve safety and enhance production. However, their specifications for a good system are usually qualitative. Typical specifications include:

- a. Effective
- b. Inexpensive
- c. Low weight
- d. No interference with the mining cycle.

Effectiveness, of course, is most critical, but effectiveness must be balanced against the other specifications for systems to be used. The two systems described in Section 2 are used because they are inexpensive, low weight, and relatively easy to advance. As pointed out, however, these two systems both use a cantilevered beam to support the curtain. This results in gaps over the curtain due to irregular roof and/or sag caused by the weight of the curtain. The effects of this gap over the curtain, and other parameters of curtain performance were not known.

The performance of extensible ventilation systems, and the effects of some installation and operating parameters were measured in a full-scale simulation of a continuous miner face. Overall results are shown in Figure 13 for a miner at the end of a 20 ft box cut in 6 ft coal.

Results show the improvement in methane dilution at the face with a 10 ft extensible brattice over a brattice setback of 20 ft with no extension, as a function of area of gap in the brattice. There is substantial improvement in face methane concentrations even with significant gaps over the curtain extension.

These tests show the value of even the crudest brattice extension for control of methane at the face.

In the following subsections, the continuous miner gallery is briefly described, the testing methods are detailed, and results are given and analyzed.

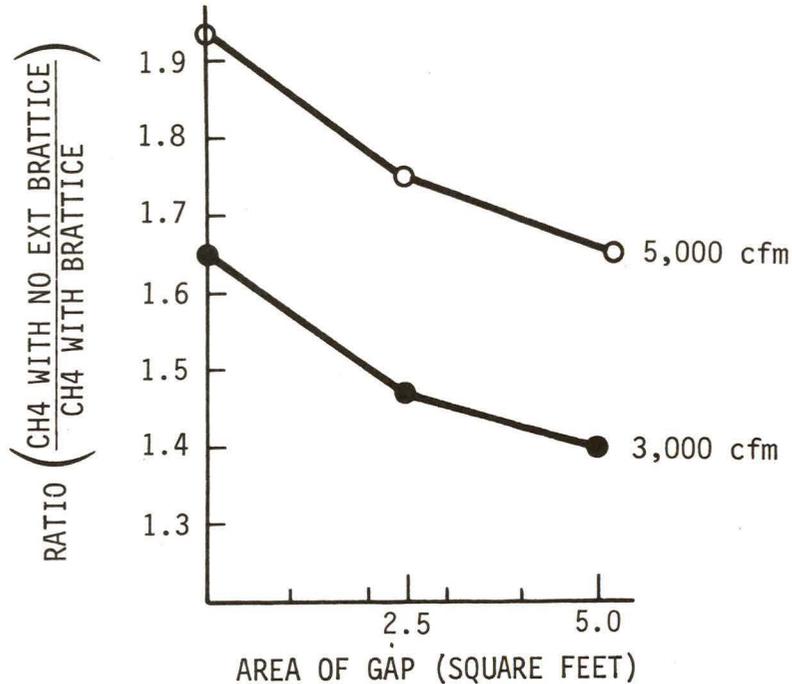


FIGURE 13. - Improvement in face CH₄ average extensible brattice over no brattice 6 ft coal - 20 ft slab - miner at the end of the box cut.

3.1 Continuous Miner Test Gallery

The continuous miner test gallery at Foster-Miller was built under USBM Contract No. HO199070, "Development of Optimal Water Sprays for Dust/Methane Control in Underground Coal Mines." The overall dimensions and layout are shown in Figure 14.

Geometrical Variation

The gallery is designed to model all stages in the conventional two-step mining cycle. The plan shape of the "entry" is changed by inserting floor-to-roof panels - for example, to simulate a "slab" of any depth. (These panels can also release tracer gas if desired - such as when simulating the beginning of the slab cut). The roof is free inside the walls, and can be raised or lowered to simulate either a 4 ft or 6 ft seam height.

FIGURE 14. - Isometric view of gallery with dimensions.

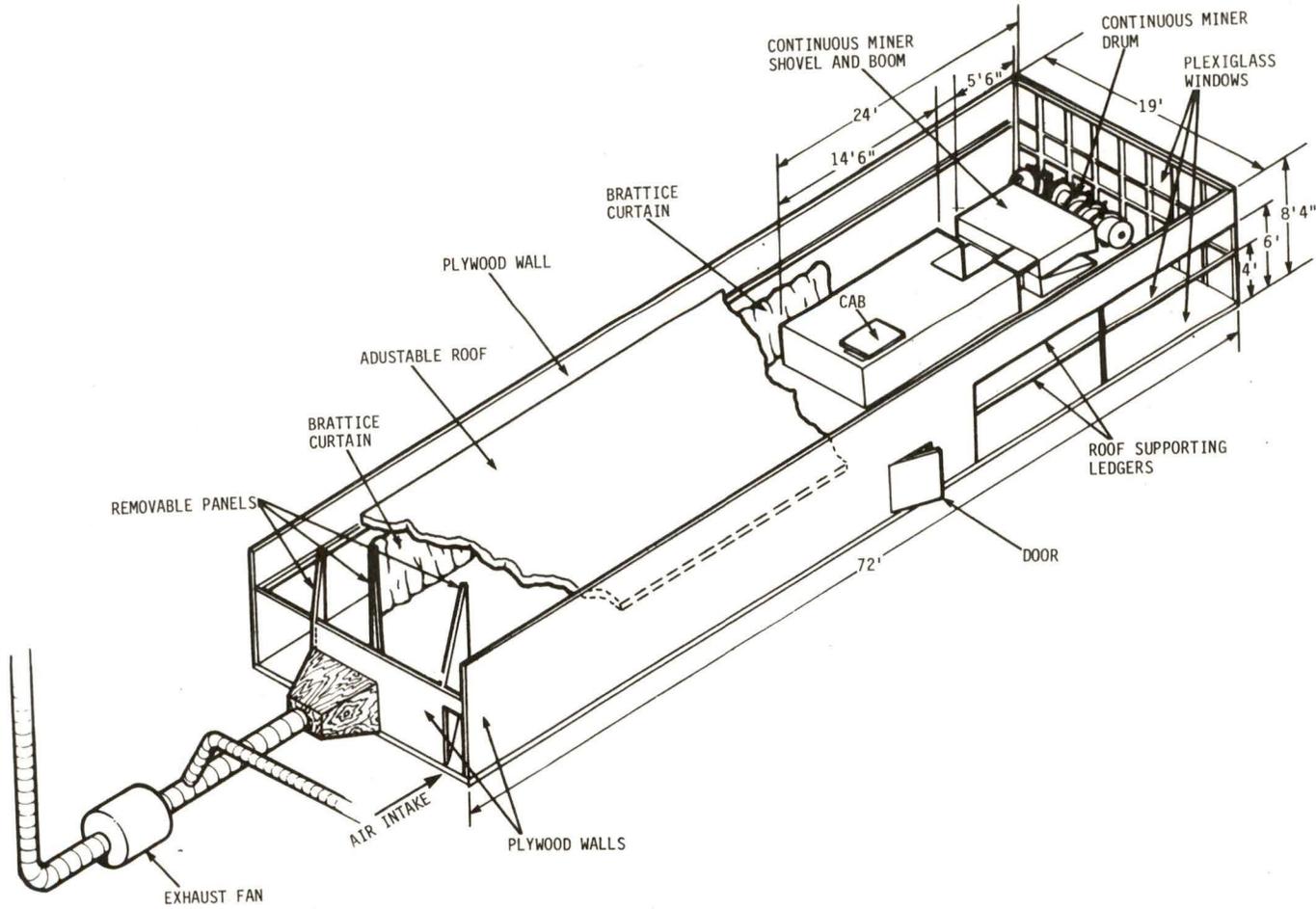


FIGURE 14. - Isometric view of gallery with dimensions.

Ventilation

Primary ventilation is provided by a 30 hp vane-axial fan. Flow is controlled by a choke. This permits flow variation from 3000 cfm to nearly 20,000 cfm. The fan transition from the gallery includes a swinging gate which allows air to be drawn from either side of the gallery. This makes possible ventilation on both sides of the entry to simulate blowing and exhausting ventilation using either brattice or tubing.

Miner Model

The full-size miner model (see Figure 15) is a composite of models for high and low coal offered by the major mining equipment manufacturers. The cutting drum rotates, and the boom raises and lowers. The model can quickly be moved from place to place in the gallery to simulate the various positions in the cutting cycle.

Water Sprays

For this study a type of conventional dust suppression spray arrangement was used (see Figure 16). Sixteen sprays were mounted on a spray bar above the boom in the conventional position. These sprays were Spraying System BD 3-2's and they were aimed directly at the face, about 15° up from horizontal - when the boom was down. Side sprays were mounted on both sides. These were also BD3-2's, angled 15° to the side. Mounting and spacing of these side sprays was also conventional, but they were about 2-1/2 ft closer to the face than the usual manufacturer's specifications. System flow at 60 psi was about 11.5 gal/min.

Gas Injection

The wall of the gallery which represents the working face is divided into 20 regions, ten 4 ft high - making up the low coal face, and ten 2 ft high panels above them (see Figure 17). Street gas (CH₄) is metered into any or all of these panels, and released through small holes over the surface. For this study, gas was released over the face directly in front of the miner, at a uniform rate per unit face area (see Figure 18).



FIGURE 15. - Model miner in gallery.

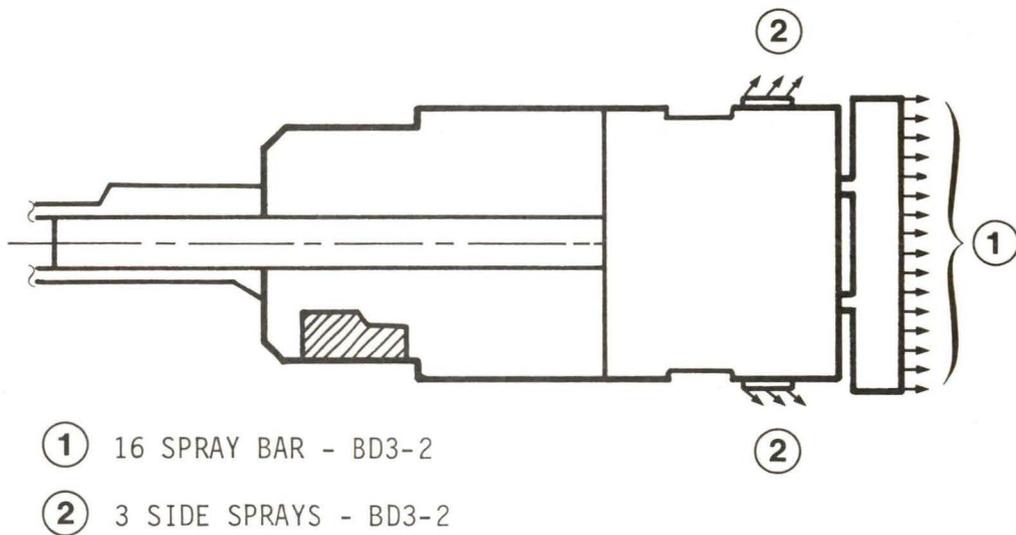


FIGURE 16. - Water spray system used in face CH_4 evaluation.

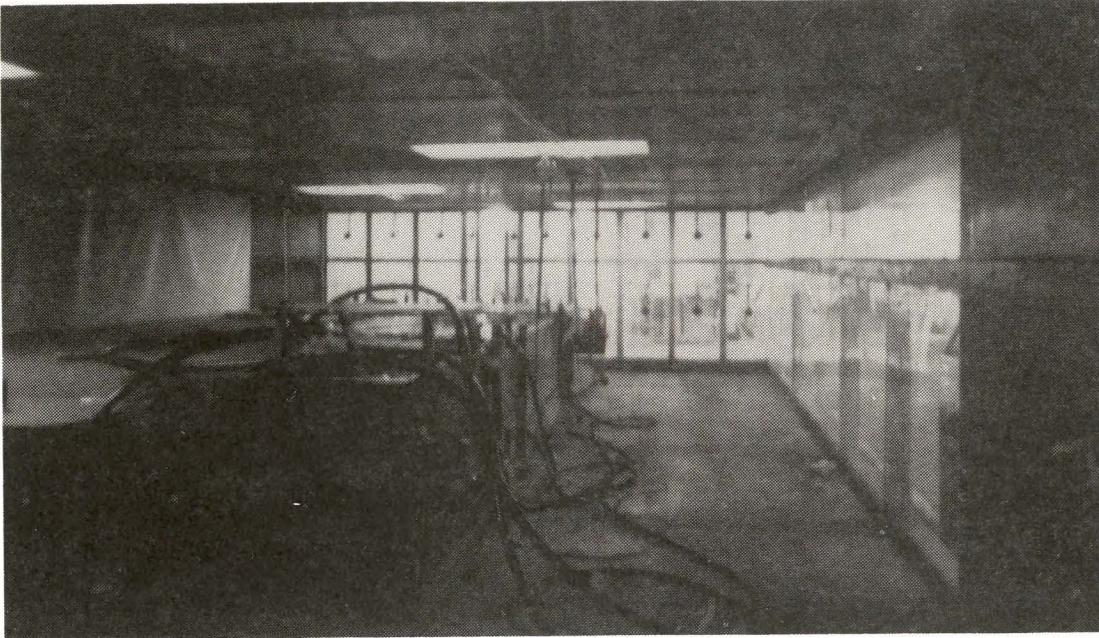


FIGURE 17. - Interior of gallery showing individual gas release panels.



FIGURE 18. - End of gallery showing gas distribution system.

Gas Sampling

Sampling in the gallery is controlled by a microcomputer, which integrates data from an infrared absorption analyzer over time (Figure 19). The computer controls a tube sampling system, switching solenoids automatically as each sample interval is completed.

For this program, sampling was done with the miner at the end of a 20 ft sump cut, in 4 ft and 6 ft "coal". The next subsection describes test methods utilized.

3.2 Test Methods

Measurement of Leakage

Leakage was measured by determining the airflow passing through the gap area. This was measured by dividing the gap into small subareas and measuring a central velocity in each subarea. Total leakage was taken as the sum of flows through subareas (see Figure 20).

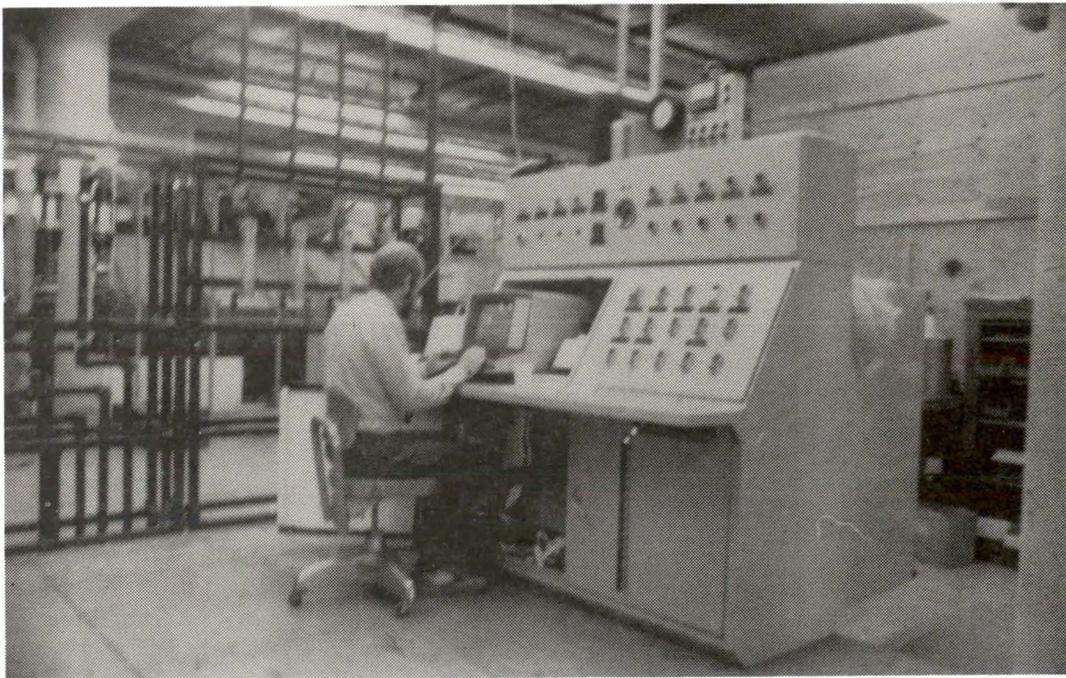


FIGURE 19. - Control console and flow measurement station.

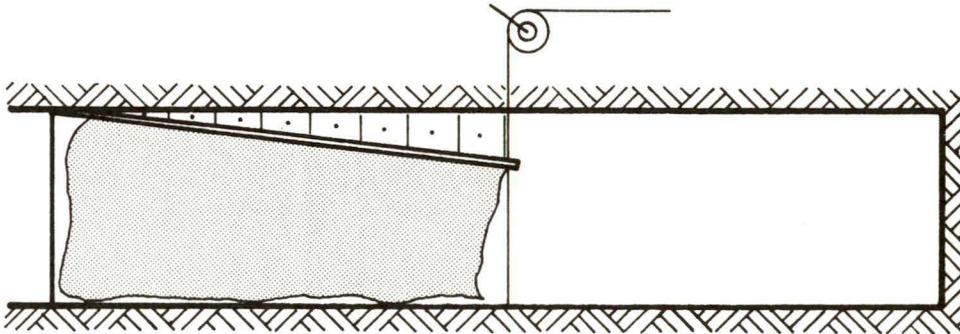


FIGURE 20. - Division of gap area into subareas for leakage measurement.

This method was not expected to be precise, as there appeared to be no obvious way to compensate for edge effects, or the difficulty of evaluating velocity in a turning airstream. In fact, leakage measurements gave reasonably good (± 5 percent) material balances when combined with a similar measurement taken over the plane perpendicular to the return at the inby end of the brattice.

All velocity measurements were made with a Hastings-Raydist[®] hot-wire anemometer.

Determination of Average Methane at the Face

Gas sampling was done through sample lines inserted into the gallery at the roof (see Figure 21). Previous work has shown that, in the presence of water sprays or similar auxiliary ventilation, vertical stratification in the entry is not significant. The selected gas sample is drawn by a vacuum pump into an infrared absorption gas analyzer. The signal from the gas analyzer is integrated over about 40 seconds to damp out signal fluctuation which occurs with this type of ventilation. With

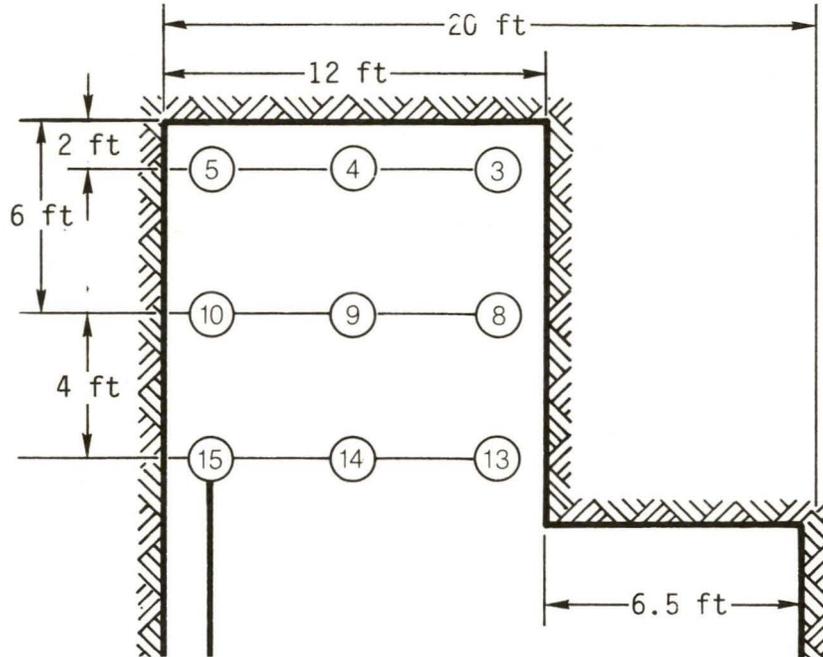


FIGURE 21. - Sample point locations used in face methane evaluation.

watersprays operating, however, instantaneous peaks in the face area are usually less than 5 percent higher than the average value obtained by integration.

Extensive use was made of methane maps in the analysis (see subsection 3.3). The face average reported is in every case the simple average of the front three sample points (5, 4, and 3). These are 2 ft from the face, and give an accurate relative evaluation of conditions at the face.

Extensible Brattice Designs

Three design factors were varied in the testing:

- a. A 10 ft and a 20 ft extension were used
- b. Gap geometry was varied
- c. Gap area was varied.

Two gap geometries were used (see Figure 22), a rectangular gap at the top, simulating the space allowed by some types of attachment devices; and a triangular gap with the base in by, simulating the inevitable sag of a cantilevered system.

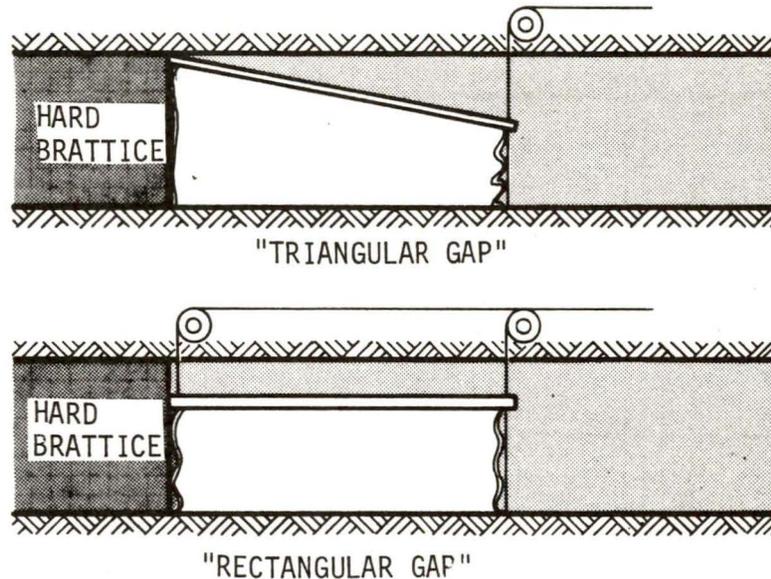


FIGURE 22. - Extensible brattice test arrangements.

3.3 Test Results

All tests discussed in this section were run with the continuous miner at the end of a box cut and with the boom down. The critical test variables and ranges considered are:

- a. Primary ventilation (3,000, 6,000 and 9,000 cfm)
- b. Box depth (20 and 30 ft).

In these tests brattice is brought to within 10 ft of the sump face *in every case* unless specifically noted. Although gaps are classified by area, only results from triangular gap tests are introduced unless noted. Two extensible brattice arrangements are tested, one 10 ft long - used with a firm brattice 20 ft from the face, and the other 20 ft long used with a firm brattice set 30 ft from the face.

The discussion is divided into four parts:

- a. Air leakage through gaps in the extensible curtain
- b. Effect of curtain gaps on methane concentrations in the face area

- c. Evaluation of forces acting on the curtain
- d. The effect on ventilation of sump rib depth.

3.3.1 Effects of Curtain Gaps and Mining Parameters on Airflow Leakage

For the purpose of this test, leakage is defined as the measured flow passing through the gap area. These values are not taken as absolute values for leakage, but only as relative measurements of ventilation effectiveness.

As expected, measured leakage varies with gap area, increasing as area increases. Test results shown in Figure 23 show leakage increasing smoothly with gap area independent of gap geometry. (Slight differences in airflow between the rectangular and triangular gap stem from errors in measurement in the narrow part of the triangle).

Leakage percentage increases as seam height decreases in Figure 24. The increase in depth over the miner between 4 ft to 6 ft coal is more than twofold (20 in. to 48 in.). For this reason velocities approaching the gap are considerably higher, and the gap is a significantly larger fraction of the effective brattice wall in 4 ft coal.

Tests run with similar curtain configurations but with the miner elsewhere (beginning the slab cut) show a slightly lower leakage rate for comparable conditions.

In summary:

- a. The shape of the gap has no significant effect on measured leakage.
- b. Leakage percentage increases with gap area. This increase is roughly linear in 6 ft coal, but more rapid in 4 ft coal.
- c. The effect is strongest when the miner is making the sump cut.

All leakage data was obtained without dust suppression sprays of any kind in use. In regard to the size of measured leakage, consider:

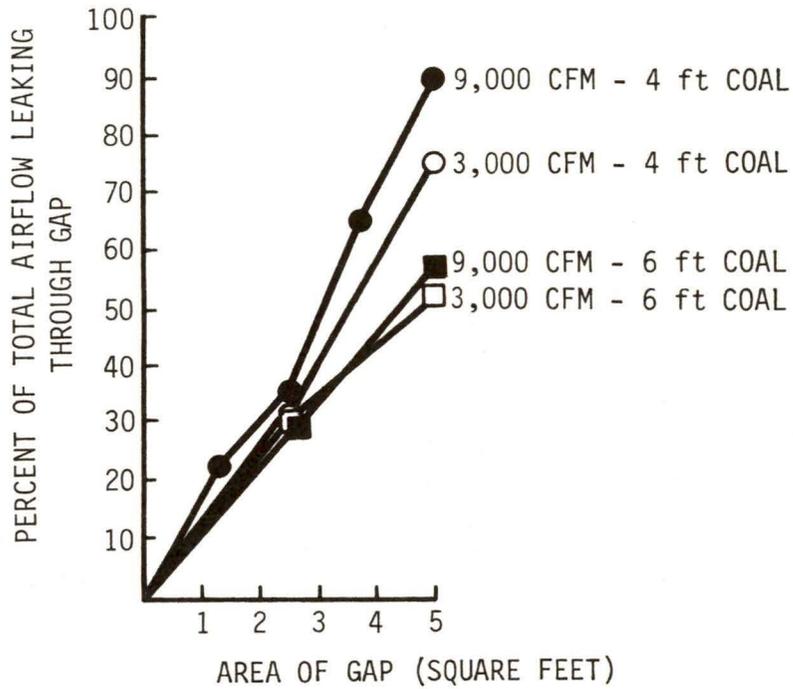


FIGURE 23. - Curtain leakage versus gap geometry - 4 ft coal.

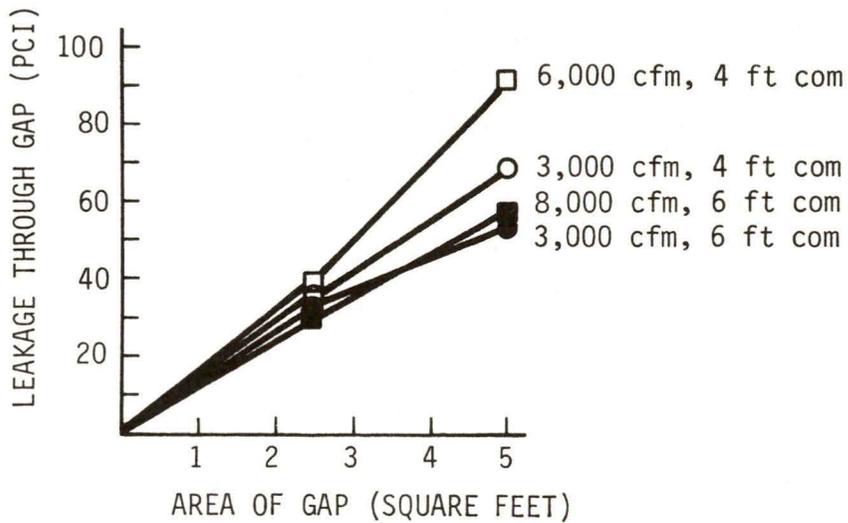


FIGURE 24. - Curtain leakage and seam height.

- a. Fifty percent leakage would *not* imply a 50 percent loss in ventilation capability. The leakage flow passes into the return distributed over the entire length of the gap. Some air gets almost as close to the face as with no gap.
- b. In any case the amount of entering air reaching the face is only a fraction of total primary airflow. The size of this fraction is determined by the airflow pattern in the entry. Changing the orifice characteristics of the brattice affects this pattern. To judge whether this is significant, methane measurements at the face must be compared.

In the next section, the effect of gaps in the extended brattice on dilution of methane at the face is evaluated.

3.3.2 Effects of Curtain and Mining Parameters on Face Methane Concentrations

This discussion is in two parts. The first gives a qualitative idea of how the extensible brattice works. The second gives overall results.

How the Extensible Brattice Works

As a gap in the extensible curtain enlarges, the airflow pattern over the miner changes. This is shown in Figure 25 by using methane profiles - groups of three samples spread across the entry. (Sample location is shown in the key).

Reading vertically down, we see methane concentration profiles 2, 6, and 10 ft from the face for different triangular gap. Results for 3,000 cfm are on the left, 6,000 cfm on the right.

At 3,000 cfm, small gaps have insignificant effect at the face. Even the 5 ft² gap does not change the distribution at the face, although concentrations increase. Moving back from the face, the increased gap over the curtain becomes important directly in front of the return. At a gap of 5 ft² methane concentrations are almost double those of the tight curtain at sample point 10. Moving across the entry towards the slab rib shows gap area again having little effect.

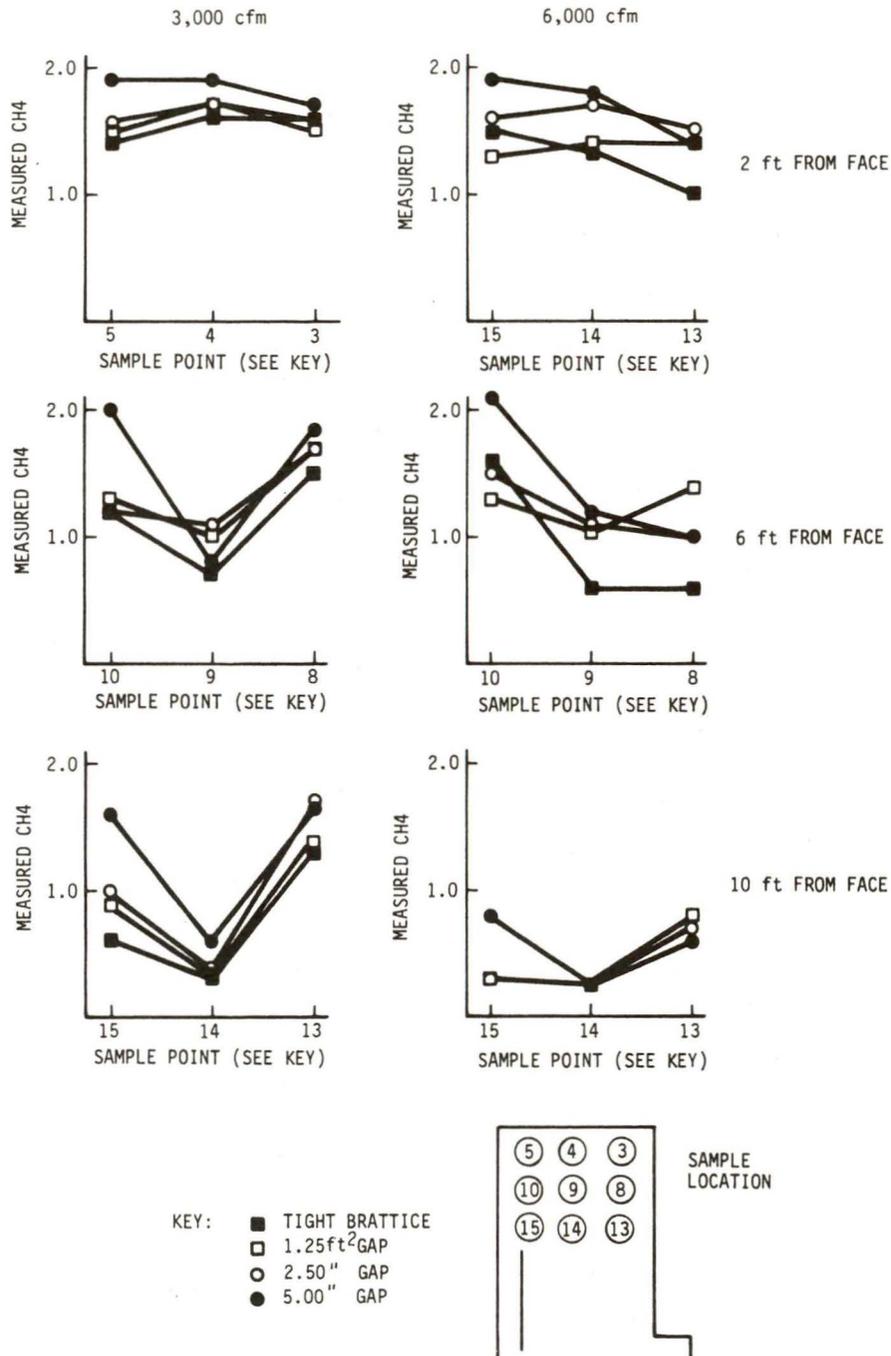


FIGURE 25. - Dilution of face methane by entering air - 4 ft coal, 10 ft setback.

At 6,000 cfm primary airflow, entering air penetrates all the way to the face, and ventilation is due to the combined effect of primary air and mixing due to water sprays. The increasing gap has almost no effect 10 ft from the face. The difference in patterns is due to the increased momentum of entering air.

At 6,000 cfm the additional momentum of the primary airflow causes effective penetration to the 10 ft plane and inby, so that there is very little significant effect as the gap increases. Moving further inby, a 10 ft *tight* brattice appears to project a jet of diluting air up to within 2 ft of the face, clinging to the slab wall. Concentrations on the slab rib side of the entry are significantly lower. As the gap opens, concentrations across the entry become more uniform. The *percentage* of increased CH₄ with an opening gap at the face is more significant at 6,000 cfm than 3,000 cfm.

The establishment of a jet would be made difficult by the transition from full to half-entry width at the slab face. A stagnant area, caused by flow separation, is always found just inby the slab face next to the slab rib. A good demonstration of this effect is found when results with different sump depths are compared (subsection 3.3.4).

Overall Test Results

The effects discussed in the previous paragraph can be seen again in Figure 26 which shows the increase in average CH₄ at the face as a function of gap area for different primary airflows.

Gap geometry has no significant effect on CH₄ at the face. These results are plotted in Figure 27.

Overall results for 20 ft sump are given in Table 9. This table includes "Face Gradients" which are ratios between the average CH₄ at 2 ft and at 6 ft. We see that in general they are higher for 6,000 and 9,000 cfm, indicating the penetration of entering air to the 6 ft mark, but that this effect diminishes with a large gap. When a pronounced gradient exists between 2 and 6 ft, it is due to penetration of entering air to the face. When no gradient exists, ventilation is due to mixing induced by the dust suppression sprays.

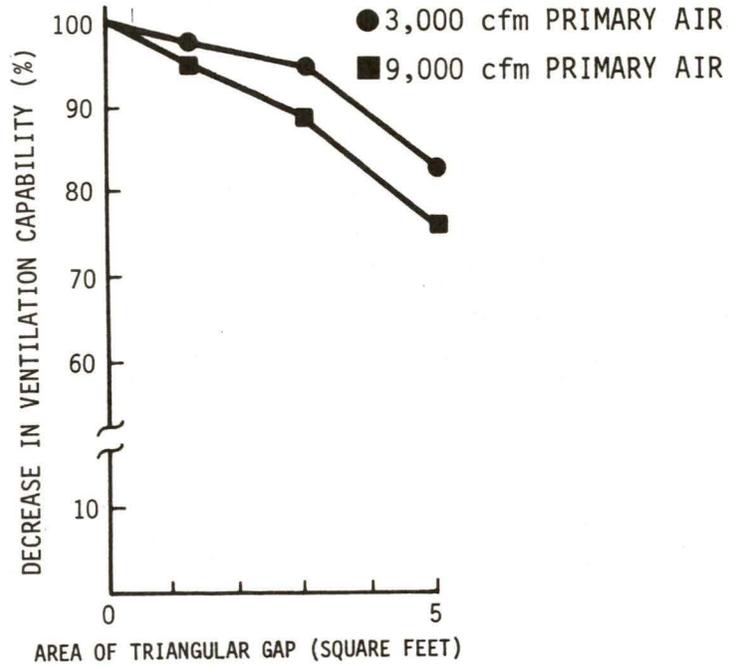


FIGURE 26. - Decrease in ventilation capacity with gap area 4 ft coal - 10 ft brattice setback.

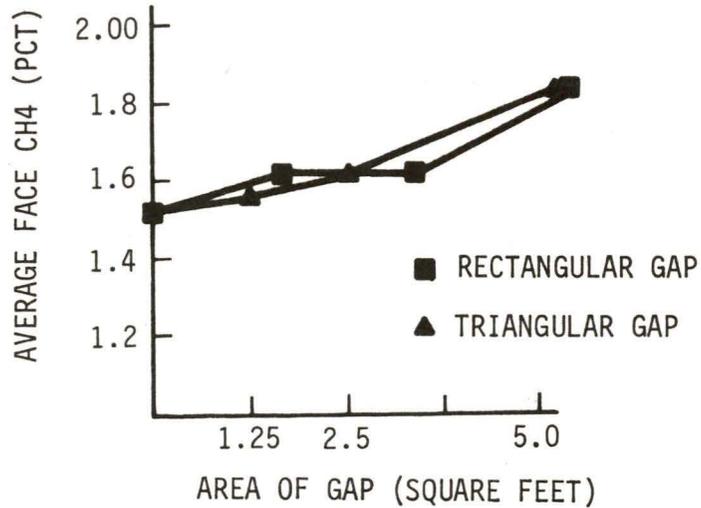


FIGURE 27. - Impact of gap geometry 4 ft coal - 3,000 cfm ventilation.

TABLE 9. - 20-ft slab methane data

Gap area	2 ft From Face			6 ft From Face			Face Gradients		
	4 ft coal	6 ft coal	4 ft coal/ 6 ft coal	4 ft coal	6 ft coal	4 ft coal/ 6 ft coal	4 ft coal/ 4 ft coal	6 ft coal/ 6 ft coal	
0	1.30	1.02	1.27	0.93	0.76	1.23	1.30	1.34	6,000 and 9,000 cfm
1.25	1.37	-	-	1.26	-	-	1.09	-	
2.5	1.60	1.13	1.41	1.23	0.86	1.44	1.30	1.31	
5.0	1.70	1.20	1.42	1.43	1.07	1.34	1.19	1.12	
0	1.53	1.33	1.15	1.13	1.22	0.93	1.35	1.09	3,000 cfm
1.25	1.57	-	-	1.33	-	-	1.18	-	
2.5	1.62	1.49	1.09	1.33	1.36	0.98	1.22	0.80	
5.0	1.83	1.58	1.16	1.55	1.42	1.09	1.18	1.45	

Summary

Although the deterioration of CH₄ averages at the face measured in these tests appear to be roughly linear with gap area, these concentrations are also strongly dependent on the depth of the sump. The maintenance of a minimal gap (apparently on the order of 3 ft² or less) is necessary for maintenance of the attached jet - one of the two important components of face ventilation in this position. Therefore:

- a. A minimum roof gap area of ~2-3 ft² should be maintained
- b. This minimum becomes more important as air quantities increase
- c. These results certainly justify use of almost any curtain of this sort as an aid to face ventilation.

3.3.3 Evaluation of Forces Acting on the Curtain

As pointed out in Section 2, the two observed problems with currently used extensible systems are that they sag and that they collapse against the rib due to Δp across the curtain and the lack of lateral support in the curtain. The previous two subsections have discussed the impact of sag on curtain performance. These tests, however, maintained the curtain the same distance away from the rib as the permanent curtain. If the curtain had been allowed to collapse, performance would have deteriorated.

The maximum Δp across the curtain occurs when the curtain is tight against the roof and sealed against the permanent brattice which forces all return air behind the extensible curtain. With these conditions set, the force required to maintain curtain to rib spacing was measured.

Forces were measured with a spring scale attached to the inby bottom corner of the curtain as shown in Figure 28. Both the forces required to hold the curtain in a fully opened position, and the forces required to reopen the curtain after collapse were measured.

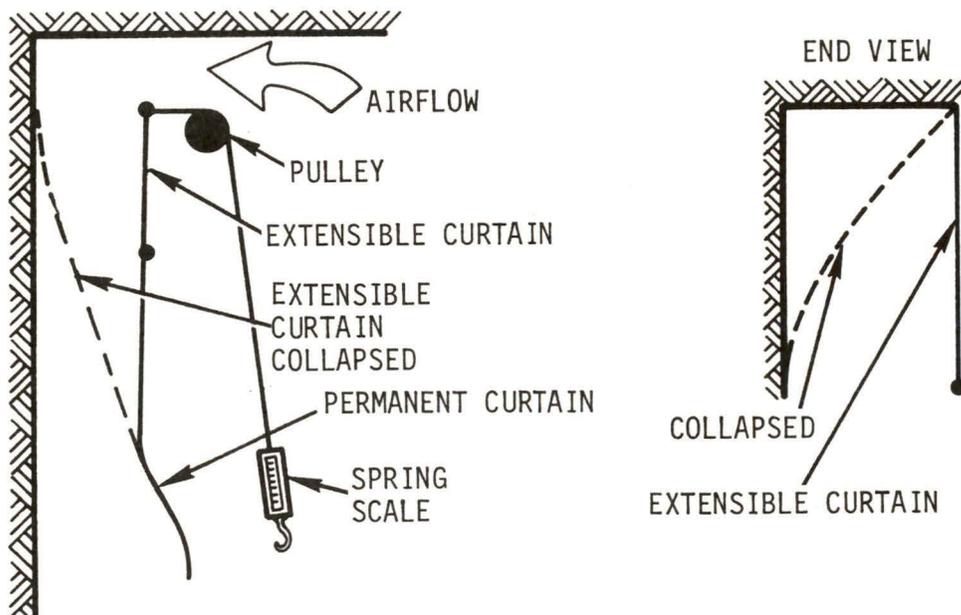


FIGURE 28. - Test set up to measure force required to prevent extensible curtain collapse.

Test results showed that with a 3,000 cfm intake airflow the weight of the curtain itself was adequate to prevent curtain collapse. With a face airflow of 6,000 cfm, 13 lb was required to keep the curtain open; 24 lb was required to reopen the curtain after collapse. Additional testing at 6,000 showed that a 2 × 4, the length of the extensible curtain attached to the bottom of the curtain, was adequate to maintain the curtain in place.

3.3.4 The Effect of Sump Depth on Face Ventilation

During data analysis of the 10 and 20 ft extensions, face ventilation with *no gap* was found to be better with a 30 ft deep sump than a 20 ft deep sump. This effect is discussed here because:

- a. It illustrates the possible importance of jet penetration in ventilating the face area.
- b. It would be important in remote-controlled mining operations where the miner may advance more than 20 ft in a place.

The effect is summed up in Figure 29. The ratio of face methane averages for two different sump depths is plotted against gap area. This data demonstrates that depth of sump is a factor in face ventilation.

Two components are in play. Entering air is forced forward by the brattice. With no gap penetration is more effective, and appears to be enhanced by the longer slab rib. Improvement due to the slab rib alone is correspondingly more dramatic (50 percent) with higher air volume. As the gap opens, this effect is diffused.

Note, however, that face ventilation is significantly better in all cases with the longer slab rib. The figure shows once again that the gap nullifies some of the penetrating effect of higher airflow.

This analysis suggests the following:

- a. The extensible curtain with gap will be relatively more effective (show less ventilation loss) at lower primary airflows.

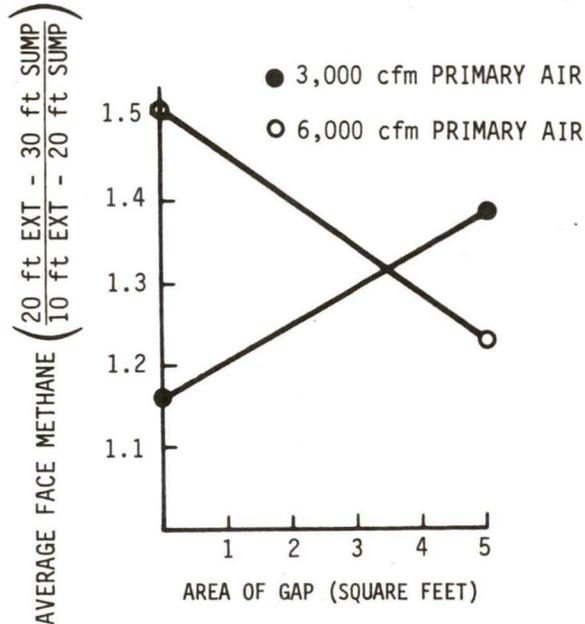


FIGURE 29. - Ratio of average face methane
10 ft brattice setback - 4 ft coal.

- b. Factors affecting primary air penetration to the face need more study. It is strongly affected by gaps in the extensible curtain.

Figure 30 compares the 20 ft slab results with the 30 ft slab results. Although the effect of the gap is more detrimental (in terms of percentage) with the 30 ft slab, it must be remembered that ventilation of the face under these conditions *without* a brattice extension would be extremely difficult. In the next section, a system appropriate for remote controlled miners which would provide a 20 ft extension with negligible gap is tested and discussed.

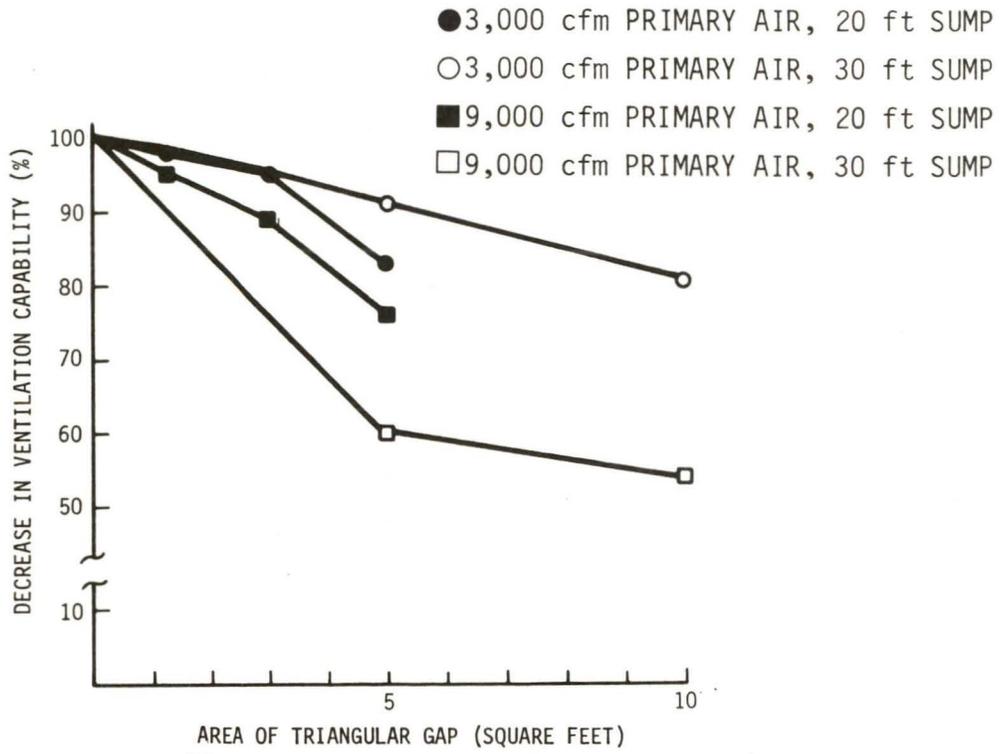


FIGURE 30. - Decrease in ventilation capacity with gap area 4 ft coal - 10 ft brattice setback.

4. EXTENSIBLE CURTAIN CONCEPT USING AN INBY HOOK

Currently used continuous haulage systems and remotely controlled continuous miners are being ventilated with standard line and check curtain systems. Maintenance of the line curtain to within 10 ft of the face is done by the traditional methods described in Section 2. As a result, total advance is limited to 20 ft or less.

Mining personnel believe that greater use of remote control mining would be possible if a better extensible face ventilation system was developed. If a system could be developed that would allow curtain advances of 20 or 25 ft with personnel remaining under permanently supported roof, mining advances could be increased to 30 or 40 ft. Increased advance distance would significantly improve production by minimizing place change-out times.

A 20 to 25 ft extension of the line curtain, however, is not feasible using crude cantilevered systems. The increase in length of the cantilevered portion of the system would increase the weight significantly. In addition, a 20-ft cantilevered system would sag much more than a 10-ft system because of the added curtain weight. This additional sag and resulting increase in gap area would, as shown in the laboratory testing, significantly reduce the effectiveness of such a system.

For a 20 to 25 ft extensible system to be effective it will require support in the inby end of the curtain and will require features to make installation easier for the miner installing it. The system, however, still has to be simple, inexpensive, and not interfere with continuous miner.

A concept for one such system utilizing a hook installed in the mine by a device mounted on the continuous miner was generated during this program. The following subsections present the concept and the results of preliminary testing to determine the feasibility of the concept.

4.1 Inby Hook Extensible Curtain Concept

The inby hook extensible curtain concept is illustrated in Figure 31. The system basically includes a device mounted on the continuous miner to install a hook or eye bolt in the mine roof at the inby end of the extensible curtain, a rope fed through the hook with one end attached to the curtain extension, and the curtain.

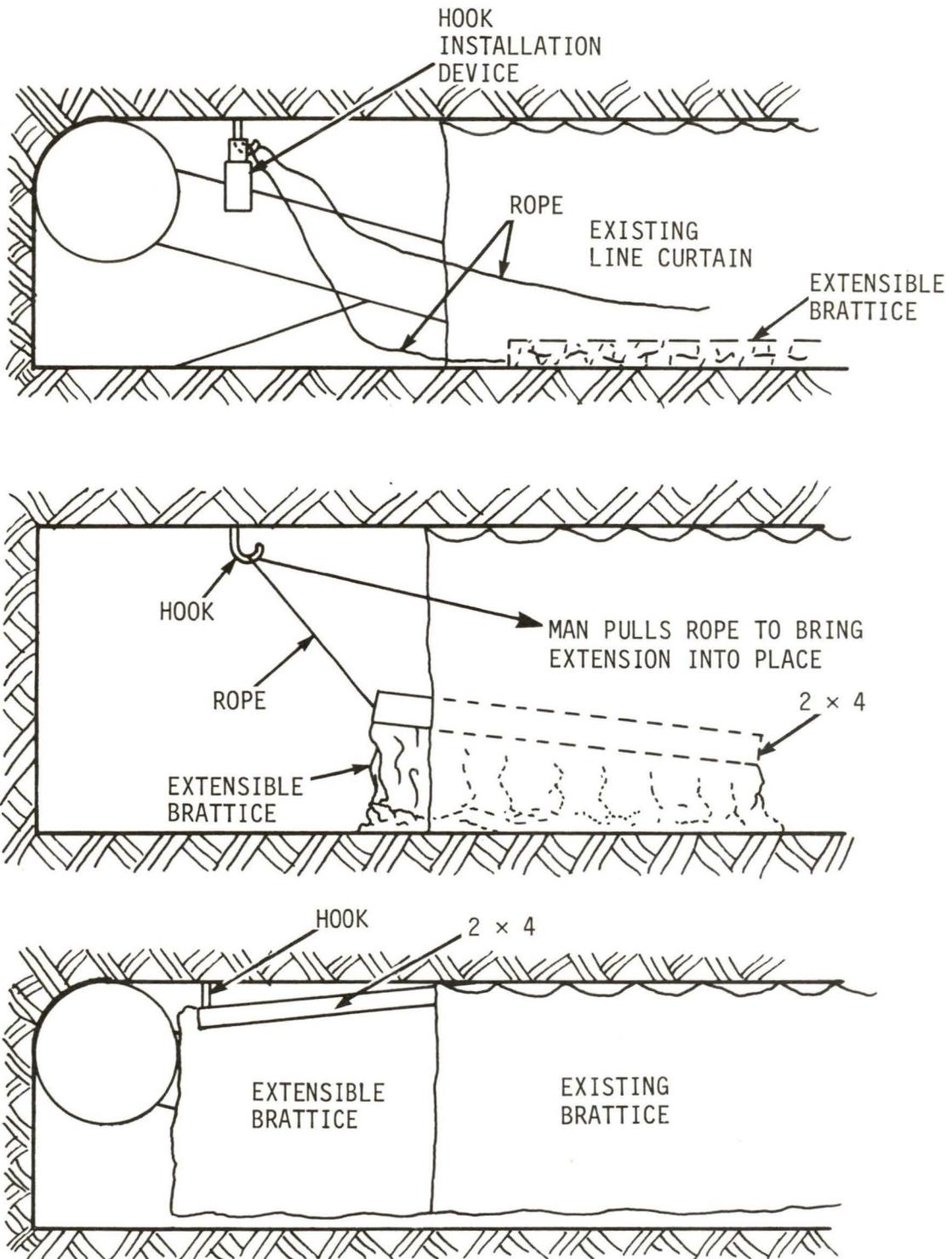


FIGURE 31. - Extensible curtain concept.

When the miner prepares to start mining the sump cut, the hook with attached rope would be mounted in the device on the miner. As the miner advances, the rope would be played out by the miner helper. When the miner advances to where the curtain needs to be extended, the continuous miner operator would activate the hook insertion device. Once the hook is installed, the miner helper using the rope would pull the inby end of the curtain into place and secure the outby end of the rope. The outby end of the curtain extension could then be lifted to the roof and tied to a roof bolt plate or supported with a post.

The advantages of this proposed concept include:

- a. The curtain can be supported at both ends.
- b. The rope allows the curtain to be extended from under permanently supported roof.
- c. The rope makes advancing and raising the curtain extension much easier which overcomes the weight limitations imposed by simple cantilevered systems.
- d. The inby curtain support will not interfere with continuous miner retreat from the sump.
- e. Curtain advanced of up to 30 ft could be realized.

The actual use of such a system, however, depends on the feasibility and practicality of the hook insertion device. Several concepts for such a device were considered. These included:

- a. A device to drill and insert a hook with an expansion shell-type anchor
- b. A device to drive the hook into the roof using impact forces
- c. A device to simply push the hook into the roof.

Of these three, the third was considered to be the most feasible and practical from a device design standpoint. Previous studies had shown that up to 1-in. diam roof bolts could be forced 24 to 30 in. into mine roof using a ram. It was felt that the inby hook would only require a 3/8 to 1/2 in. anchor pushed only a few inches into the roof to provide sufficient anchorage to support the curtain. Although the forces required to push the

anchor in would vary with the type of roof material, it was felt that these forces could be obtained with a simple hydraulic cylinder mounted on the boom of the miner or by the boom itself.

The actual forces required to insert the hook and the resulting holding strength needed to be determined.

4.2 Testing of the Hook Insertion Concept

4.2.1 Design and Fabrication of the Hook Insertion Test Fixture

The forces required to install the inby hook had to be determined by actually inserting pins into typical mine roof and measuring the forces required. To do this a test fixture was designed and fabricated. The device, shown in Figure 32, included the following basic components:

- a. Hydraulic cylinder, pump, and force gauge - manufactured by Everpac, Model 1010, 10-1/8 in. stroke, 20,000 lb capacity
- b. Base including a jack post assembly adjustable from 4 to 7 ft, 10-ton capacity
- c. Adaptor, removal bracked and miscellaneous fittings.

All components were designed for quick assembly and disassembly.

4.2.2 Preliminary Laboratory Testing

Preliminary testing of the hook insertion concept was conducted in the laboratory using a 3000-psi concrete test block. Tests were conducted using hex head and socket cap bolts of various lengths, diameters, and hardness. Bolt tips were ground into spad shapes or bullet shapes.

Test results showed that the mild steel bolts bent with little effective penetration of the block. Tests using 1/2-in. diam hardened steel bolts showed that the spad shaped tip required less force for penetration and provided significantly higher pull-out force than the bolts with bullet-shaped tips.

Based on these results, tests were conducted in underground mines.

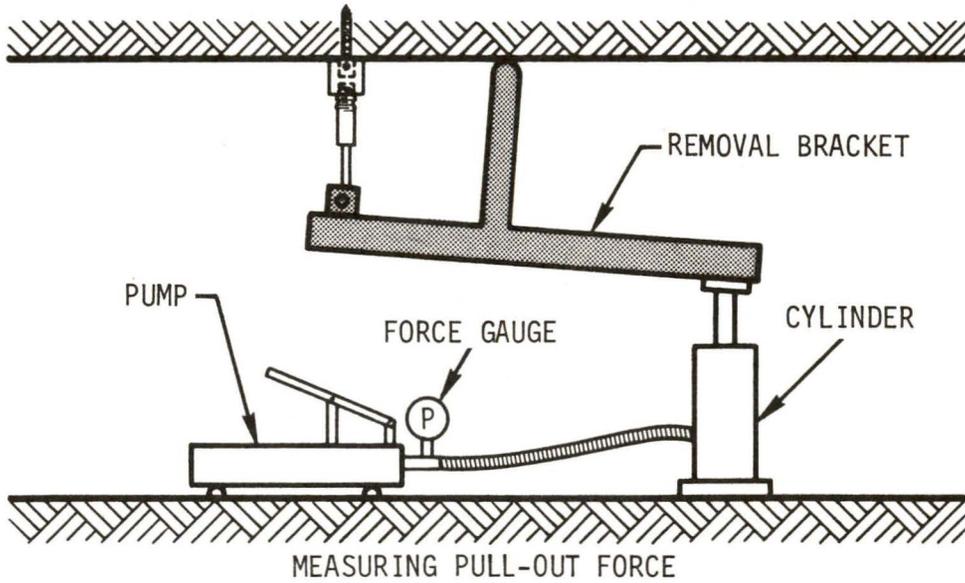
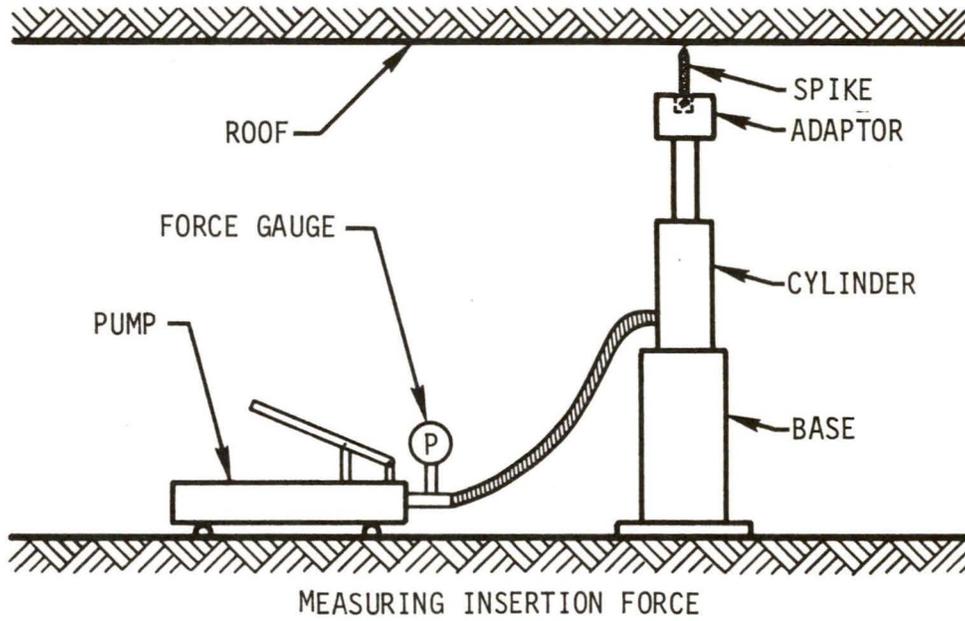


FIGURE 32. - Measuring pull-out force portable insertion/pull-out test device.

4.2.3 Underground Mine Testing

The objective of the underground mine tests was to determine the forces required to insert and pull out hook configurations in typical mine roof. Tests were conducted in mine areas with roof coal, limestone, sandstone, and shale. Tests were conducted using both 3/8 and 1/2 in. hardened steel bolts which were ground to spad shaped tips.

Results for the roof coal tests showed that bolts with spad shaped tips could be successfully inserted into roof coal. Insertion forces ranged from 1,400 to 8,000 lb. Results, however, also showed that sufficient pullout force could only be obtained with penetration depths of at least 4 in. With shorter bolts, spalling of the coal around the bolt reduced pullout forces.

Tests in the limestone, sandstone, and shale roofs failed. During all tests, the bolt either bent at the tip or at the shank or failed to penetrate the roof at forces up to 20,000 lb. Analysis of the bolts indicated that the bending may have been caused by the weakening effects introduced by the tip grinding.

An additional series of tests were conducted with hardened steel pitons used for rock climbing. Test results were similar. Piton tips bent before penetration.

Based on these results the concept of inserting the hook into the roof using only applied force does not appear feasible.

4.3 Summary and Conclusions

Productivity and increased use of remotely controlled continuous miners could be improved if the extensible ventilation system capable of 20 to 30 ft advances could be developed. A concept for one such system utilizing a hook installed in the mine roof by a device mounted on the continuous miner was generated during this program.

Several concepts for the hook insertion device were considered. The simplest and most practical appeared to be a hydraulic cylinder mounted on the boom to push the hook into the roof. Tests of the concept, using a hydraulic cylinder test

fixture and various sizes and shapes of bolts, however, showed that effective penetration could only be achieved in roof coal. Attempts to install the bolts in limestone, sandstone, or shale were unsuccessful.

Tests of other hook insertion concepts could not be evaluated within the funds available on this contract. It is strongly felt, however, that the concept of using an inby hook for an extensible ventilation system is promising. The concept is relatively cheap, simple, and most importantly can achieve certain advances of 20 to 30 ft. The successful application of this concept only depends upon the design of an effective reliable hook insertion device. Such a device warrants further development.

APPENDIX A

LITERATURE SEARCH

1. Bielicki, R.J. and F.N. Kissell, "Statistical Analysis of Methane Concentration Fluctuations Produced by Incomplete Mixing of Methane and Air at a Model Coal Mine Working Face," USBM R.I. 7987, 1974, 21 pages.
2. Bielicki, R.H., et al., "Replacing Brattice Cloth at Coal Faces with Air Curtains and Diffuser Fans, A Preliminary Study," USBM R.I. 8052, 1975, 8 pages.
3. Croome, D.J., "Environmental Engineering Aspects of Coal Mines," BSE, Vol. 45, January 1978, pp. 176-183.
4. Dalzell, R.W. and J.W. Stevenson, "Solving Common Ventilation Problems," MSHA Presentation at 64th National Safety Congress and Exposition, Chicago, IL, 18-21 October 1976, 8 pages.
5. Divers, E.F., et al., "Sideboard Device for Improved Face Ventilation in Coal Mines," USBM Technical Progress Report, August 1979, 10 pages.
6. Frycz, A. and J. Suikowski, "Calculation of the Reliability of the Mine Ventilation System or Subsystem," Second International Mine Ventilation Congress, Session IV, Ventilation Systems Analysis, November 1979, pp. 30-37.
7. Goddard, B., "A Review of the Prevention and Control of Dust in British Coal Mines," The Mining Engineer, July 1977, pp. 579-590.
8. Goddard, B. and K. Bower, "Some Practical Aspects of Dust Control in Coal Mining," National Coal Board, July 1977, pp. 553-564.
9. Hadden, J.D., Jr., and S.M. Hoover, "Face Ventilation Study, No. 50 Mine, U.S. Steel Corporation, Pineville, Wyoming County, WV," MSHA Investigative Report No. P110-V26, 5-9 November 1974, and 21-23 January 1975, 10 pages.
10. Hadden, J.D., Jr., et al., "Ventilation Survey Report, Lancashire No. 25 Mine, Barnes and Tucker Company, Barnesboro, Cambria County, PA," MSHA Investigative Report No. P150-V57, 11-20 September 1978, 5 pages.

11. Hagood, D.W., "A High-Capacity Face Ventilation System," Second International Mine Ventilation Congress, Session XVI, Face Ventilation, November 1979, pp. 19-31.
12. Hamilton, R.J., et al., "Developments in Dust Control in Coal Mines," The Mining Engineer, March 1976, pp. 317-326.
13. Hamilton, R.J. and A.G. French, "Research and Development in Dust Control in Coal Mines," National Coal Board Mining Research and Development Establishment, March 1976, pp. 565-577.
14. Haney, R.A., "Preliminary Report on Improved Face Ventilation Systems Low Coal Tests," MSHA Presentation at 69th Mine Inspectors' Institute of America, Columbus, OH, 17-20 June 1979, 13 pages.
15. Haney, R.A., et al., "Face Ventilation Study, Renton Mine, Pittsburgh Coal Company, Division of Consolidation Coal Company, Renton, Allegheny County, PA," MSHA Investigative Report No. P100-V20, 23-27 September 1974, 6 pages.
16. Haney, R.A., et al., "Face Ventilation Study, Parts I and II, Wabash Mine, Amax Coal Company, Keensburg, Wabash County, IL," MSHA Investigative Reports No. P103-V22 and P105-V23, 7-10 October 1974 and 5-8 November 1974, 17 pages.
17. Haney, R.A. and S.M. Hoover, "Ventilation Survey, Cargill Salt Mine, Cargill Incorporated, South Lansing, Tomkins County, NY," MSHA Investigative Report No. P130-V38, 11-13 May 1976, 11 pages.
18. Haney, R.A., et al., "Face Ventilation Study, No. 3 Mine, U.S. Pipe and Foundry, Adger, Jefferson County, AL," MSHA Investigative Report No. P114-V31, 14-17 January, 4-8 March, and 9-15 April 1975, 18 pages.
19. Haney, R.A., et al., "Ventilation Tubing Airflow Tests, Jones and Laughlin Steel Corporation, Clarksville, Green County, PA," MSHA Investigative Report No. P95-V16, 24-25 June 1974, 3 pages.
20. Harrison, S.P., "Ventilation Surveys and Their Use in Mine Planning," Second International Mine Ventilation Congress, Session XVII, Case Studies, November 1974, pp. 1-14.

21. Hoelter, Heinz, "Underground Use of Dust Scrubbers," Mining Congress Journal, March 1978, pp. 46-49.
22. Hoover, S.M., "Ventilation Survey Report, Solar Fuel No. 9 Mine, Solar Fuel Company, Somerset, Somerset County, PA," MSHA Investigative Report No. P137-V44, 7 pages.
23. Hoover, S.M., et al., "Face Ventilation Survey, Old Ben No. 21 Mine, Old Ben Coal Corporation, Sesser, Franklin County, IL," MSHA Investigative Report No. P86-V10, 11-14 February 1974, 6 pages.
24. Hoover, S.M., et al., "Ventilation Survey Report, Inland Mine, Inland Steel Corporation, Sesser, Franklin County, IL," MSHA Investigative Report No. P98-V18, 10-18 June 1974, 5 pages.
25. Khan, M.A., "Ventilation Aspects of Dust Control," Colliery Guardian, March 1976, pp. 88-91.
26. Kissell, F.N., et al., "Peak Methane Concentrations During Coal Mining, An Analysis," USBM R.I. 7885, 1974, 16 pages.
27. Kissell, F.N. and R.J. Bielicki, "Methane Buildup Hazards Caused by Dust Scrubber Recirculation at Coal Mine Working Faces, A Preliminary Estimate," USBM R.I. 8015, 1975, 24 pages.
28. Krisko, W.S., "Evaluation of the Use of Air Curtains to Improve Face Ventilation," Donaldson Company, Inc., USBM Contract No. HO357097, March, 1977.
29. Lough, H., et al., "Face Ventilation Survey, Part II, Alexander Mine, The Valley Camp Coal Company, Moundsville, Marshall County, WV," MSHA Investigative Report No. P87-V11, 21-25 January 1974, 5 pages.
30. Luxbacher, G., "Ventilation Survey, Bell Mine, Bellefonte Mining Co.," 12-19 November 1976, 24 pages.
31. MSHA, "Integral Machine-Mounted Dust Collectors," for Presentation at the Fifth Annual Institute on Coal Mining Health, Safety and Research, Blacksburg, VA, 27-29 August 1974, 39 pages.
32. Mathias, P., et al., "A Straight Blowing Auxiliary Ventilation System for a 7500 ft (2285M) Single Heading Exploration Drive," Second International Mine Ventilation Congress, Session XVII, Case Studies, November 1979, pp. 15-19.

33. McLendon, C.R., "Exhaust Manifold Face Ventilation in Room-and-Pillar Mining," Second International Mine Ventilation Congress, Session XVI, Face Ventilation, November 1979, pp. 17-18.
34. Miller, E.J., et al., "Ventilation Survey Report, Peabody No. 10 Mine, Peabody Coal Company, Pawnee, Christian County, IL," MSHA Investigative Report No. P99-V19, 30 July to 1 August 1974, 6 pages.
35. Moynihan, D.J., J.A.L. Campbell, W.D. Roper, L.A. Williams, R.A. Gothard and L.R. Finley, "Peabody Controls Continuous Miner Dust Emissions and Minimizes Methane Control Problems," Fourth Institute on Coal Mine Health and Safety, Colorado School of Mines, Golden, CO, 1 December 1978.
36. Mundell, R.L., "Blowing Versus Exhausting Face Ventilation for Respirable Dust Control on Continuous Mining Sections," MSHA I.R. 1059, 1977, 11 pages.
37. Pickering, A.J. and R. Aldred, "Controlled Recirculation of Ventilation - A Means of Dust Control in Face Advance Headings," The Mining Engineer, March 1977, pp. 329-345.
38. Press, D.C. and J. Johnstone, "Ventilation at Craigmont Mines," CIM Bulletin, January 1976, pp. 75-84.
39. Rochester and Pittsburgh Coal Company, "Face Ventilation Plans, Urling No. 1 Mine," Revised, 9 October 1978, 20 pages.
40. Smales, T.E., "Dust Control and Planned Layout in the Ten Feet Seam at Holditch," The Mining Engineer, August/September 1976, pp. 669-681.
41. Smith, R.L., et al., "Ventilation Survey, Monterey No. 1 Mine, Monterey Coal Company, Carlinville, Macoupin County, IL," MSHA Investigative Report No. P108-V25, 7-14 January 1975, 7 pages.
42. Stachulak, J., "Computer Network Calculation of Creighton Mine Mass Flow and Natural Ventilation," Second International Mine Ventilation Congress, Session XVII, Case Studies, November 1979, pp. 20-30.

43. Stevenson, J.W. and D.M. Hoover, "Face Ventilation Study, No. 50 Mine, U.S. Steel Corporation, Pineville, Wyoming County, WV," MSHA Investigative Report No. P123-V34, 15 October 1975, 2 pages.
44. Tien, J.C.J., "Pros and Cons of Underground Ventilation Systems," Coal Mining and Processing, June 1978, pp 110-112, and pp. 132-134.
45. Wallhagen, R.E., "Development of Optimal Diffuser and Spray-fan Systems for Coal Mine Face Ventilation," USBM Contract No. H0230023, November 1977.

APPENDIX B

IN-MINE DATA COLLECTION PROCEDURES

A total of 20 sections in operating coal mines was surveyed to generate data on existing curtain practices. The specific procedures utilized are detailed in the following discussion.

Airflow Quantities

At each station where an air quantity measurement was required, the minimum information obtained consisted of:

- a. Entry dimensions
- b. Air velocity measurements
- c. Methane concentration
- d. Direction of air flow.

Entry dimensions were determined by measuring three heights, three widths, and obstructions (posts, cribs, excessive sloughing) that could affect velocity. Figure B-1 illustrates the approximate locations where the entry height and width measurements were taken.

Anemometers were used to measure velocities of 150 ft/min or more. Smoke was used for lower velocities. Measurements were made near the downwind end of pillars, preferably where ribs and roof were relatively straight and uniform.

When an anemometer was used, the velocity of the airstream was measured by traversing two equal halves of the entry cross-section. Each half was traversed for 1 min using the traverse profiles illustrated in Figure B-2. A 24-in. wand was used to keep the measurer's body out of the airstream. At least two measurements were made. Each had to agree within 20 ft/min after correction. Measurements that did not match were repeated.

To determine velocities with chemical smoke, cloud travel was timed along a pre-established distance. The length of travel was based on how well the smoke cloud held together and how well it could be seen. Generally, it was 10 ft, though lengths of 5 to 25 ft were used when appropriate. For these measurements, the

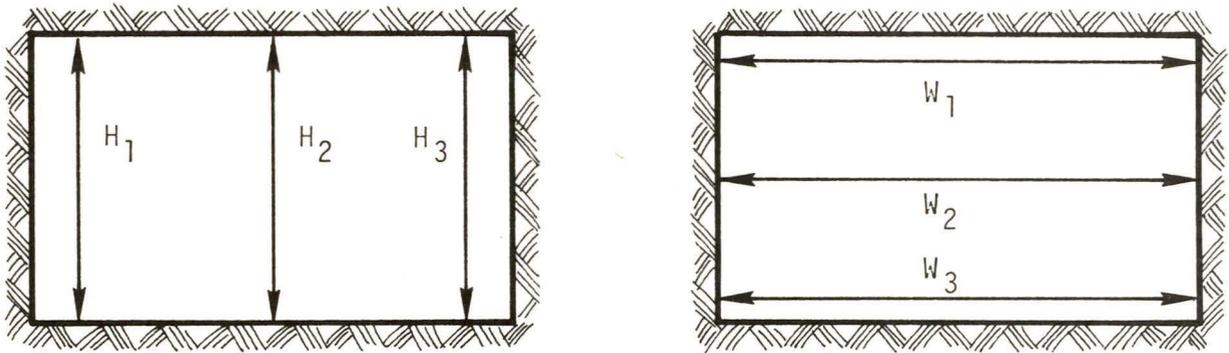


FIGURE B-1. - Approximate location of entry height and width measurement.

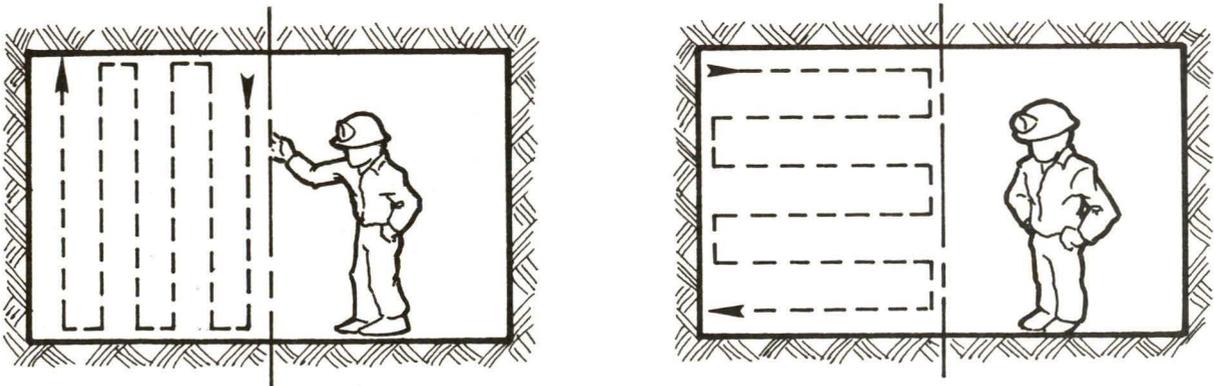


FIGURE B-2. - Anemometer traverse profiles.

smoke-generator person stood at the upstream point another person with a stopwatch at the downstream point. Three measurements were made at each of the nine points in the cross-section, as shown in Figure B-3.

Typical locations where air velocity measurements were obtained included:

- a. Section intake inby permanent stopping
- b. At end of line brattice
- c. In crosscuts between faces
- d. Section return (last open crosscut) inby permanent stoppings.

These locations are depicted and illustrated by number in Figure B-4.

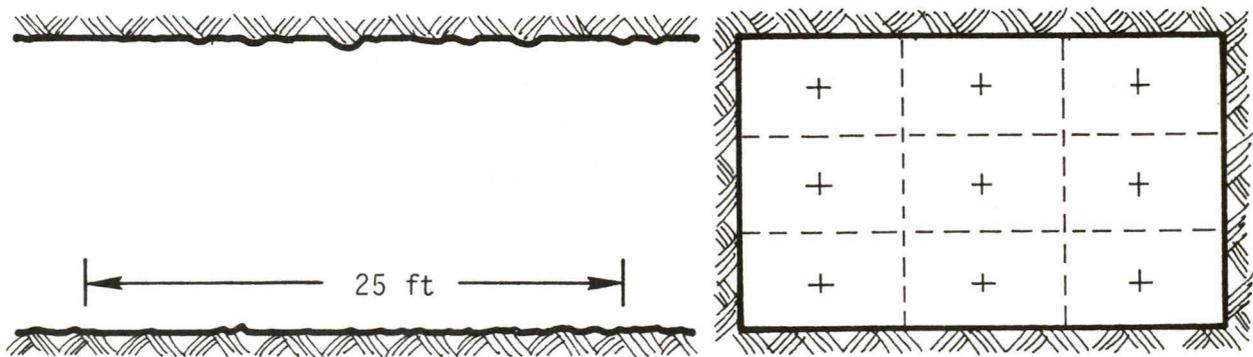


FIGURE B-3. -Approximate entry locations for smoke tube velocity measurements.

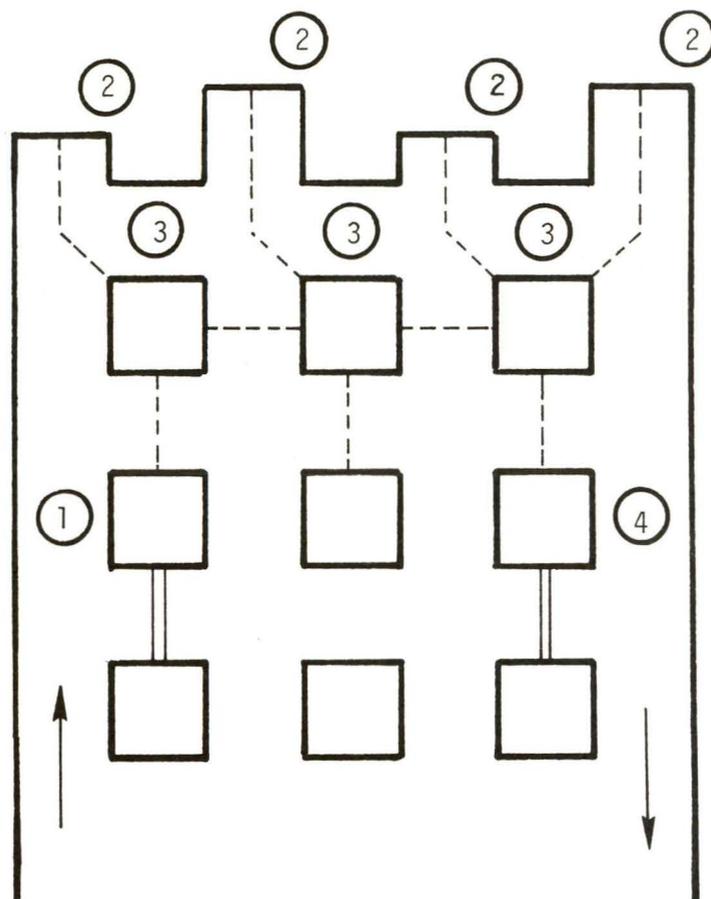


FIGURE B-4. - Typical locations for velocity measurements at a working coal mine section.

Pressure Drops

Pressure differentials across line, check and extensible units were measured using Magnehelic pressure gauges capable of reading 0.01 in. WG. By extending rubber tubing from the Magnehelic into the high pressure side of the line and check curtains a direct pressure drop could be read. Pressure drops across line curtains were measured in 5-ft intervals up to the mouth of the curtain. When pressure readings changed, smaller increments were obtained to define an area of "high pressure loss." Check curtain readings were measured in 5-ft increments as well.

Curtain lengths were measured to determine whether air leakage was a function of curtain length.

Methane Measurements

Methane concentrations were measured at each face, behind the line curtains and in the return with a hand-held methanometer. Smoke airflow patterns were used to locate dead air spaces, recirculation paths and general flow of air. Curtain setback from the faces were also measured.

General overall impressions were obtained by observing and recording:

- a. Cutting cycle
- b. Gas and roof test cycle
- c. Curtain advances
- d. Curtain construction and repair.

APPENDIX C

LINE CURTAIN DATA

The reduced data on each line curtain evaluated during the mine visits are listed in Table C-1. The line curtain numbers, which run from 1 to 77, correspond to the same numbers on the mine section maps in Appendix D.

TABLE C-1. - Line curtain data

Curtain number	Mine name	Section identification	Seam height (ft)	Entry width (ft)	Curtain length (ft)	Leakage through curtain (ft ³ /min)	Leakage/ft (ft ³ /min/ft)	ΔP (in.) (WG)	Brattice to rib distance (ft)	Area (ft ²)	Face velocity (ft/min)	Face quantity (ft ³ /min)	Curtain setback from face (ft)	CH ₄ at face (%)	Section intake quantity (ft ³ /min)	Return quantity (ft ³ /min)	CH ₄ return	Respirable dust for face miners	Curtain type
1	PA1	A	7.3	16.0	46.0	21,000	456	0	2.30	17.0	273.0	4,641	9.0	0	-	-	-	1.4	B
2	V1	A	5.2	18.0	101.0	0	0	0	4.10	21.0	134.0	2,814	8.0	0.10	13,374	11,200	0	1.7	A
3	V1	A	5.3	18.0	99.0	0	0	0	4.20	22.4	123.0	2,755	9.0	0.20	13,374	11,200	0	1.7	A
4	V1	A	5.1	17.0	118.0	0	0	0	4.30	22.0	127.0	2,794	12.0	0.30	13,374	11,200	0	1.7	A
5	V1	A	5.4	17.0	86.0	0	0	0	4.00	22.0	137.0	3,014	10.0	0.20	13,374	11,200	0	1.7	A
6	V1	A	4.6	18.5	108.0	8,400	78	0	4.50	21.0	144.0	3,024	8.0	0.30	13,374	11,200	0	1.7	A
7	V1	A	5.1	18.3	126.0	1,500	12	0.025	4.00	20.4	583.0	11,900	-	-	13,374	11,200	0	1.7	A
8	V1	B	5.1	17.0	82.0	2,000	24	0	3.40	17.3	219.0	3,789	12.0	0.30	14,030	11,508	0.2	1.7	A
9	V1	B	5.3	16.0	76.0	200	3	0.100	3.80	20.0	287.0	5,740	11.0	0.10	14,030	11,508	0.2	1.7	A
10	V1	B	5.8	17.0	84.0	9,067	108	0.250	3.70	21.3	233.0	4,963	8.0	0.10	14,030	11,508	0.2	1.7	A
11	V2	A	6.3	18.0	112.0	3,500	31	0	4.00	25.2	144.0	3,640	-	-	10,533	7,140	0.2	0.8	B
12	V2	A	6.4	17.0	76.0	2,382	31	0	6.30	40.3	118.0	4,758	9.0	0.20	10,533	7,140	0.2	0.8	B
13	V2	A	6.5	19.0	104.0	600	6	0	5.10	33.2	197.0	6,540	12.0	0.30	10,533	7,140	0.2	0.8	B
14	V2	A	7.3	19.0	42.0	500	12	0	5.00	36.5	154.8	5,649	10.0	0.30	10,533	7,140	0.2	0.8	B
15	V2	A	6.8	17.0	101.0	4,060	40	0	4.50	30.6	100.7	3,081	10.0	0.30	10,533	7,140	0.2	0.8	B
16	V2	A	6.8	17.0	115.0	6,534	57	0	4.20	29.0	138.0	3,989	7.0	0.20	10,533	7,140	0.2	0.8	B
17	V2	B	6.9	20.0	83.0	2,300	28	0	3.50	24.2	128.0	3,100	-	-	26,760	29,960	-	0.8	B
18	V2	B	7.0	20.2	42.0	500	12	0	3.20	22.4	220.0	4,928	6.2	0.20	26,760	29,960	-	0.8	B
19	V2	B	6.8	19.6	50.0	8,460	169	0	3.30	22.4	207.0	4,645	10.1	0.10	26,760	29,960	-	0.8	B
20	V3	A	5.4	17.1	70.0	900	13	0	4.00	21.6	130.0	2,800	9.0	0	6,666	14,946	0	1.1	A
21	V3	A	5.3	17.6	81.0	0	0	0	4.50	24.0	154.0	3,700	10.0	0	6,666	14,946	0	1.1	A
22	V3	A	5.2	17.2	84.0	1,192	14	0	4.20	22.0	164.0	3,600	-	-	6,666	14,946	0	1.1	A
23	V3	A	5.1	17.0	52.0	1,192	23	0	4.70	24.0	150.0	3,600	7.0	0	6,666	14,946	0	1.1	A
24	V3	A	5.3	17.5	96.0	1,100	11	0	4.90	26.0	142.0	3,692	6.0	0	6,666	14,946	0	1.1	A
25	V3	B	4.8	18.1	72.0	4,800	67	0	3.20	15.4	390.0	6,000	-	0	15,300	15,228	0	1.1	A
26	V3	B	5.2	17.9	93.0	5,400	58	0	4.10	21.3	253.0	5,400	-	0	15,300	15,228	0	1.1	A

TABLE C-1. - Line curtain data (Continued)

Curtain number	Mine name	Section identification	Seam height (ft)	Entry width (ft)	Curtain length (ft)	Leakage through curtain (ft ³ /min)	Leakage/ft (ft ³ /min/ft)	ΔP (in.) (WG)	Brattice to rib distance (ft)	Area (ft ²)	Face velocity (ft/min)	Face quantity (ft ³ /min)	Curtain setback from face (ft)	CH ₄ at face (%)	Section intake quantity (ft ³ /min)	Return quantity (ft ³ /min)	CH ₄ return	Respirable dust for face miners	Curtain type
27	V3	B	5.7	17.0	69.0	5,000	72	0	4.00	22.8	254.0	5,800	-	-	15,300	15,228	0	1.1	A
28	V3	B	5.3	18.4	89.0	5,800	65	0	3.80	20.1	248.0	5,000	-	0	15,300	15,228	0	1.1	A
29	V3	B	5.4	17.8	64.0	4,400	69	0	3.30	17.8	360.0	6,400	-	-	15,300	15,228	0	1.1	A
30	V3	C	5.8	20.0	93.0	20	5	0	4.90	28.4	92.0	2,600	-	-	15,933	14,000	0	1.1	A
31	V3	C	5.7	19.9	89.0	0	0	0	4.60	26.2	100.0	2,620	7.0	0	15,933	14,000	0	1.1	A
32	V3	C	6.0	20.0	107.0	0	0	0	5.80	34.8	123.0	4,280	13.0	0	15,933	14,000	0	1.1	A
33	V4	A	4.2	18.4	67.0	4,146	62	0	4.50	18.9	106.0	2,000	-	-	21,300	19,600	0.1	1.5	C
34	V4	A	4.6	18.0	60.0	2,146	36	0	4.40	20.2	198.0	4,000	-	-	21,300	19,600	0.1	1.5	C
35	V4	A	4.9	18.0	63.0	1,146	18	0	4.20	20.6	242.0	5,000	-	-	21,300	19,600	0.1	1.5	C
36	V4	A	4.0	18.0	65.0	14,000	215	0	4.20	16.8	333.0	5,600	-	0.20	21,300	19,600	0.1	1.5	C
37	V4	A	4.1	18.0	39.0	4,050	104	0	4.50	18.5	324.0	6,000	-	-	21,300	19,600	0.1	1.5	C
38	V4	B	4.7	19.1	24.0	0	0	0	4.80	22.6	297.0	6,712	5.0	0.10	16,300	16,288	0.1	1.5	C
39	V4	B	6.2	19.2	98.0	0	0	0	5.90	33.5	198.0	7,247	7.0	0.10	16,300	16,288	0.1	1.5	C
40	V4	B	4.6	18.4	52.0	978	19	0	3.60	16.6	487.0	8,084	8.0	0.10	16,300	16,288	0.1	1.5	C
41	V4	B	6.0	19.0	30.0	2,000	67	0	5.50	33.0	214.0	7,062	6.0	0.10	16,300	16,288	0.1	1.5	C
42	V4	B	4.9	18.3	42.0	8,300	198	0	4.70	23.0	-	4,000	-	-	16,300	16,288	0.1	1.5	C
43	V4	B	6.3	18.0	64.0	3,941	62	0	5.80	36.5	229.0	8,359	8.0	0.10	16,300	16,288	0.1	1.5	C
44	WV1	A	5.2	20.0	100.0	13,100	131	0	4.00	21.0	150.0	3,150	7.5	0	18,886	19,300	0	1.8	B
45	WV1	A	5.2	19.9	81.0	11,800	146	0	4.00	20.8	153.0	3,182	7.5	0	18,886	19,300	0	1.8	B
46	WV1	A	5.2	18.2	79.0	12,300	156	0	3.10	16.1	166.0	2,672	8.5	0	18,886	19,300	0	1.8	B
47	WV1	A	10.8	18.6	80.0	12,300	154	0.020	5.80	61.0	127.0	7,747	5.0	0	18,886	19,300	0	1.8	B
48	WV1	A	5.0	18.5	101.0	12,800	127	0.020	3.20	16.0	135.0	2,160	8.0	0	18,886	19,300	0	1.8	B
49	WV1	B	5.7	20.5	77.0	24,400	317	0	3.90	22.2	133.0	2,953	12.0	0	28,882	22,933	0	1.8	B
50	WV1	B	6.9	19.9	97.0	20,800	214	0	4.10	28.3	121.0	3,424	6.0	0	28,882	22,933	0	1.8	B
51	WV1	B	6.8	20.2	89.0	15,222	171	0	4.00	27.2	165.0	4,488	15.0	0	28,882	22,933	0	1.8	B
52	WV1	B	7.0	20.9	101.0	16,145	160	0	4.20	29.1	105.0	3,055	10.0	0	28,882	22,933	0	1.8	B

TABLE C-1. - Line curtain data (Concluded)

Curtain number	Mine name	Section identification	Seam height (ft)	Entry width (ft)	Curtain length (ft)	Leakage through curtain (ft ³ /min)	Leakage per foot (ft ³ /min/ft)	ΔP (in.) (WG)	Brattice to rib distance (ft)	Area (ft ²)	Face velocity (ft/min)	Face quantity (ft ³ /min)	Curtain setback from face (ft)	CH ₄ at face (%)	Section intake quantity (ft ³ /min)	Return quantity (ft ³ /min)	CH ₄ return	Respirable dust for face miners	Curtain type
53	WV1	B	7.0	20.0	113.0	15,701	139	0	6.00	42.0	83.0	3,499	13.0	0	28,882	22,933	0	1.8	B
54	WV2	A	5.6	20.3	21.0	4,668	222	0.020	3.30	18.5	413.0	7,640	12.0	0.80	23,500	23,000	0.2	1.5	A
55	WV2	A	3.0	19.7	86.0	9,500	110	0.070	3.00	9.0	313.0	2,813	8.0	0.15	23,500	23,000	0.2	1.5	A
56	WV2	A	2.5	20.1	103.8	21,550	207	0.070	3.60	9.0	321.5	2,894	8.0	0.10	23,500	23,000	0.2	1.5	A
57	WV2	A	4.0	20.4	76.0	2,950	39	0.040	4.50	18.0	334.0	6,012	8.0	0.00	23,500	23,000	0.2	1.5	A
58	WV2	B	3.8	20.5	89.0	24,000	270	0.070	3.00	11.4	631.0	7,200	10.0	0.30	23,500	23,150	0.2	1.5	A
59	WV2	B	3.8	20.5	84.0	11,200	133	0.050	3.00	11.4	1000.0	12,000	10.0	0.20	23,500	23,150	0.2	1.5	A
60	WV2	B	3.8	20.5	86.0	8,200	95	0.020	2.50	9.5	950.0	9,000	9.0	0.20	23,500	23,150	0.2	1.5	A
61	WV2	B	3.8	20.0	70.0	4,000	57	0.010	3.90	14.8	486.0	7,200	8.0	0.60	23,500	23,150	0.2	1.5	A
62	WV3	A	6.2	17.6	90.0	13,090	145	0.020	4.30	27.0	57.0	1,540	8.0	0	15,625	14,670	0	1.7	A
63	WV3	A	6.3	17.1	124.0	11,525	93	0.030	2.80	17.6	171.0	3,105	7.0	0	15,625	14,670	0	1.7	A
64	WV3	A	7.1	17.4	68.0	8,348	123	0.010	3.00	21.3	218.0	4,652	10.0	0	15,625	14,670	0	1.7	A
65	WV3	B	6.2	17.0	102.0	1,390	14	0.030	3.20	19.8	212.0	4,220	8.0	0	15,941	25,124	0	1.7	A
66	WV3	B	6.0	17.4	56.0	4,751	85	0.020	3.10	18.6	194.0	3,608	8.0	0	15,941	25,124	0	1.8	A
67	WV3	B	6.0	17.1	24.0	2,000	83	0.010	3.30	19.8	202.0	4,000	8.0	0	15,941	25,124	0	1.8	A
68	WV4	A	6.2	19.0	103.5	3,358	32	0.020	4.00	25.0	120.0	3,000	10.0	0	11,242	10,790	0	1.8	A
69	WV4	A	5.9	19.0	82.0	3,358	41	0.020	4.20	25.0	120.0	3,000	10.0	0	11,242	10,790	0	1.8	A
70	WV4	A	6.1	19.5	91.0	5,693	63	0.030	3.90	24.0	126.0	3,000	8.0	0	11,242	10,790	0	1.8	A
71	WV4	B	6.0	19.0	52.0	4,190	80	0	5.10	30.6	150.0	4,500	-	0	9,000	9,000	-	1.8	A
72	WV4	B	6.3	19.2	29.0	4,650	160	0	4.60	29.0	150.0	4,350	-	0	9,000	9,000	-	1.8	A
73	PA2	A	7.2	17.3	119.0	13,600	114	0.100	2.20	15.8	409.0	6,462	8.0	0	26,858	20,900	0	0.8	D
74	PA2	A	7.3	16.0	122.0	13,700	112	0.220	2.17	15.8	399.0	6,304	8.0	0	26,858	20,900	0	0.8	D
75	PA2	B	6.8	15.6	101.0	11,973	118	0.030	2.70	18.4	365.0	6,716	7.2	0	23,800	22,971	0	0.8	D
76	PA2	B	6.8	16.5	81.0	0	0	0.080	2.90	19.7	260.0	5,127	5.5	0	23,800	22,971	0	0.8	D
77	PA2	B	6.8	15.9	96.0	20,980	218	0.050	2.50	17.0	216.0	4,437	9.2	0.30	23,800	22,971	0	0.8	D

APPENDIX D

MINE SECTION MAPS

The sketches of mine section maps contained in Appendix C (Figures D-1 through D-20) illustrate the locations of the line and check curtains studied during the mine visits. Curtains numbered 1 to 77 are line curtains. Detail data on each numbered line curtain are listed in Appendix C. The check curtains are numbered from 100 to 217. Detail data on each numbered check curtain are listed in Appendix E.

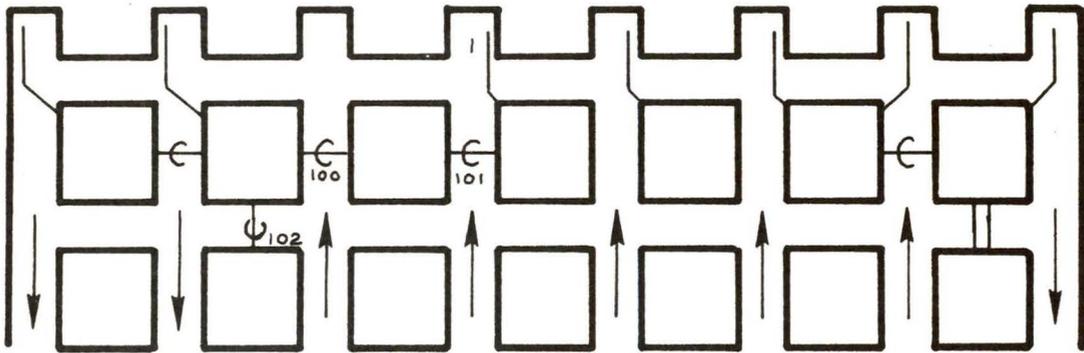


FIGURE D-1. - Pennsylvania mine No. 1, section A.

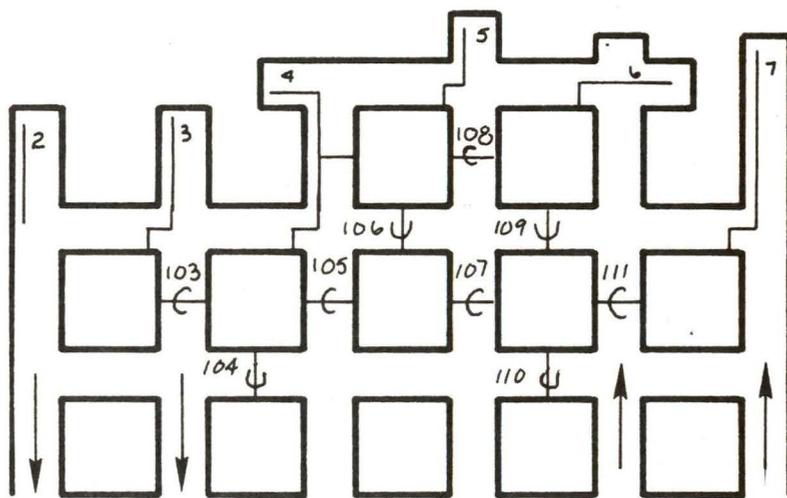


FIGURE D-2. - Virginia mine No. 1, section A.

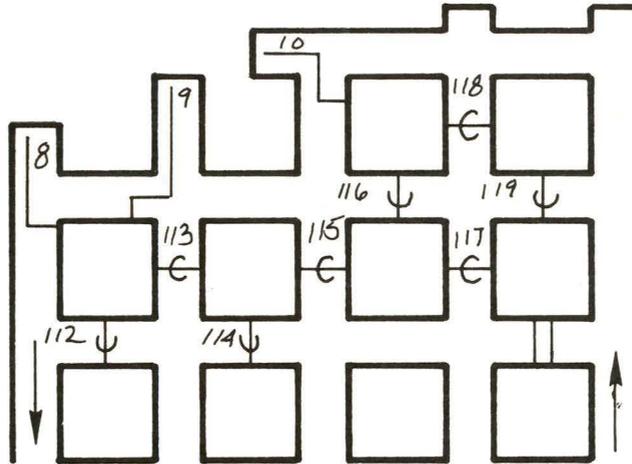


FIGURE D-3. - Virginia mine No. 2, section B

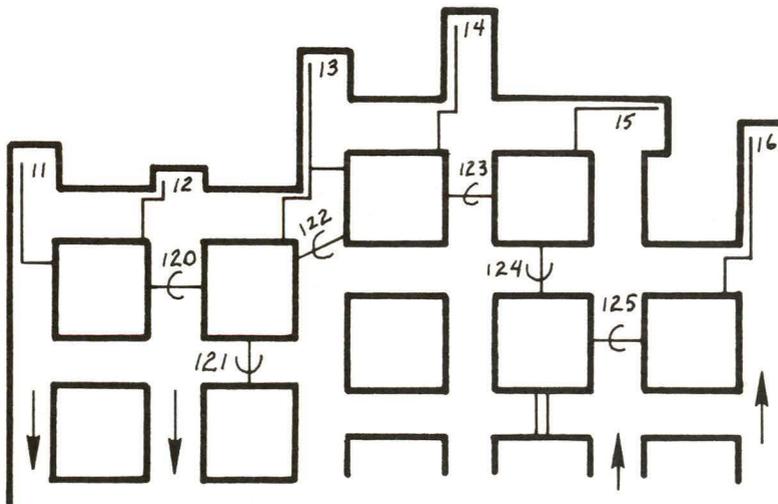


FIGURE D-4. - Virginia mine No. 2, section A

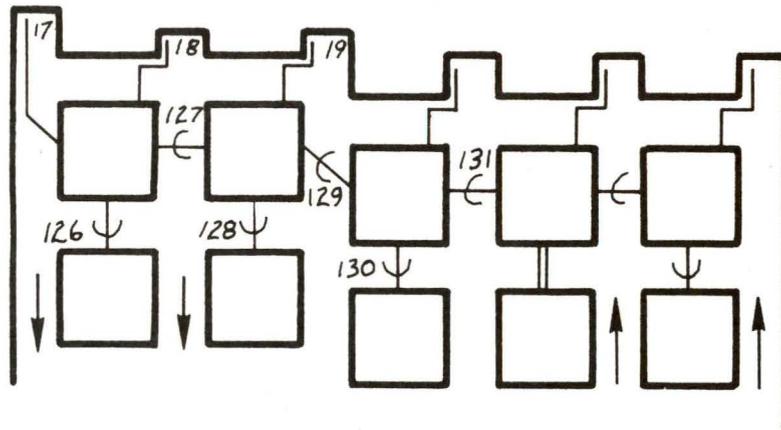


FIGURE D-5. - Virginia mine No. 2, section B

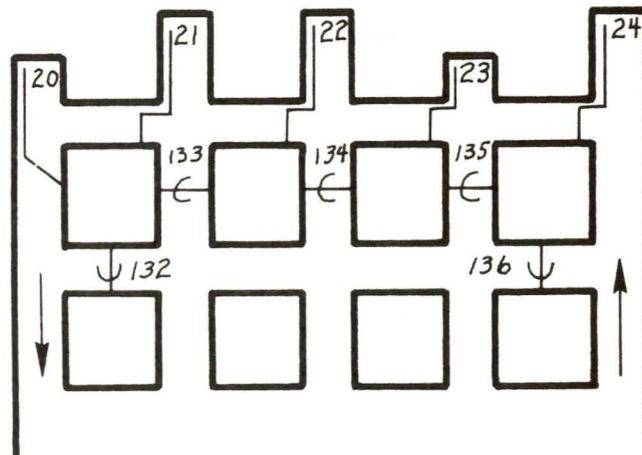


FIGURE D-6. - Virginia mine No. 3, section A

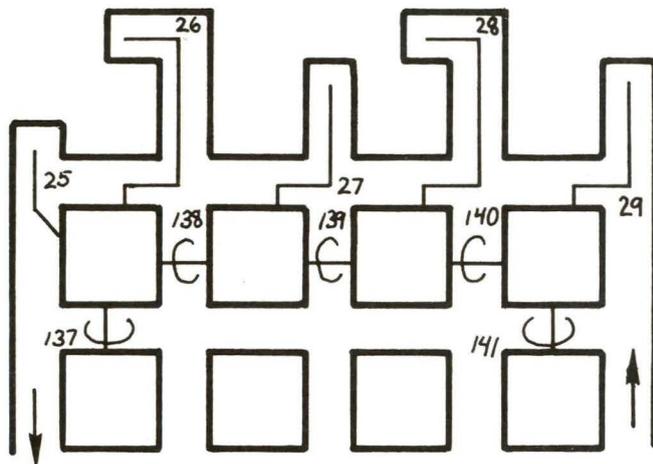


FIGURE D-7. - Virginia mine No. 3, section B

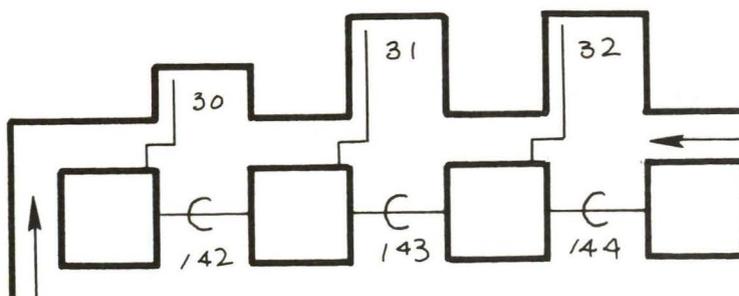


FIGURE D-8. - Virginia mine No. 3, section C

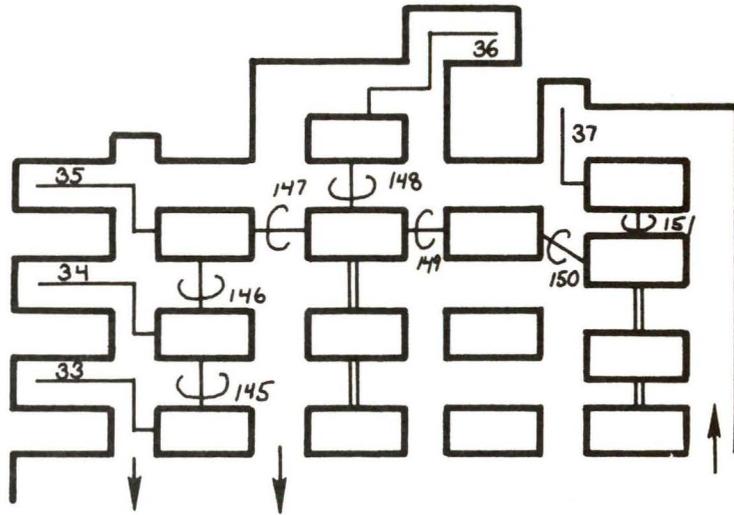


FIGURE D-9. - Virginia mine No. 4, section A

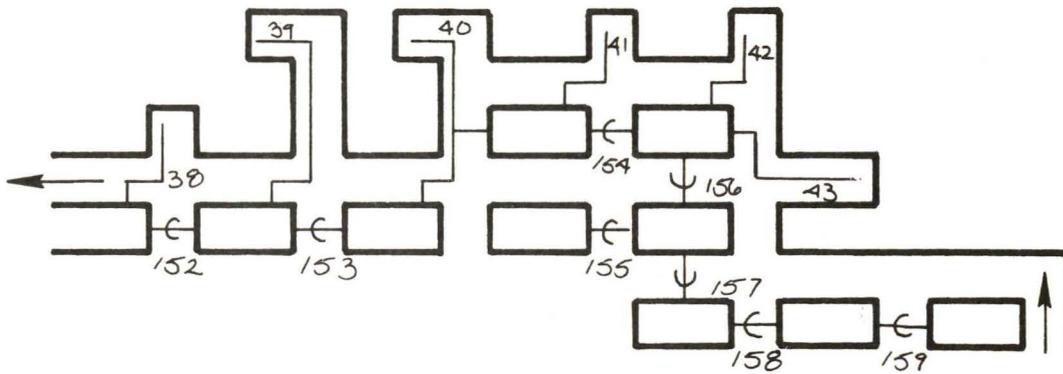


FIGURE D-10. - Virginia mine No. 4, section B

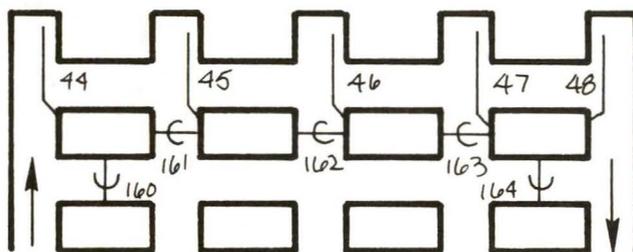


FIGURE D-11. - West Virginia mine No. 1,
section A.

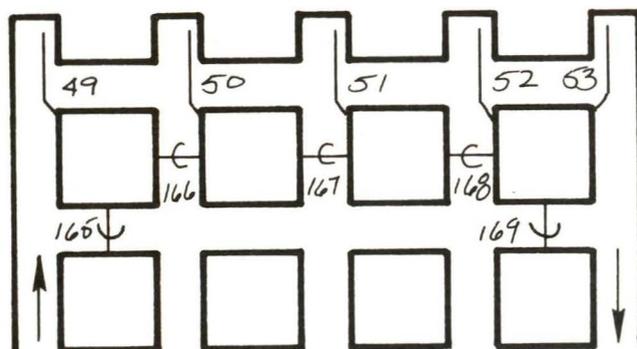


FIGURE D-12. - West Virginia mine No. 2,
section B.

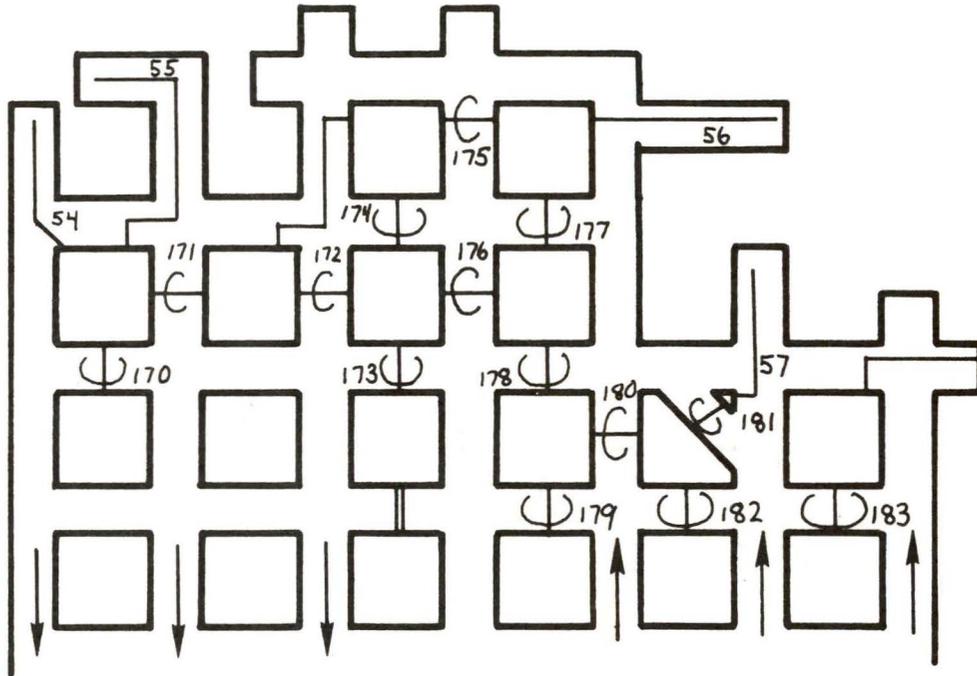


FIGURE D-13.- West Virginia mine No. 2, section A.

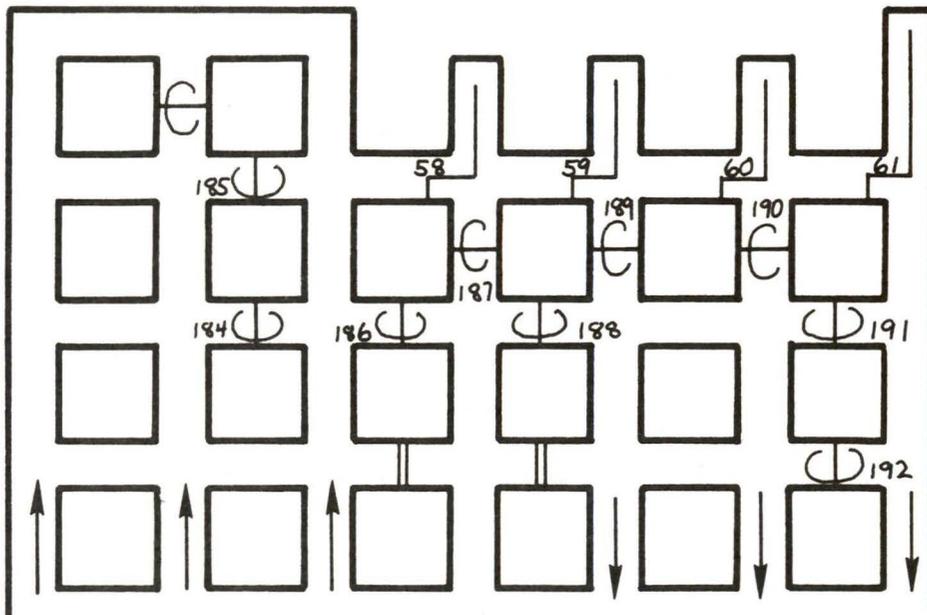


FIGURE D-14. - West Virginia mine No. 2, section B.

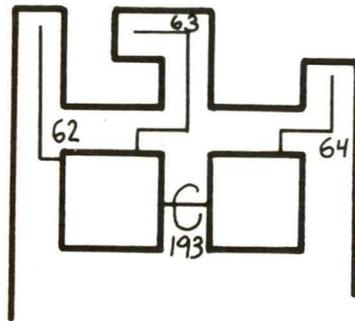


FIGURE D-15. - West Virginia mine No. 3,
section A.

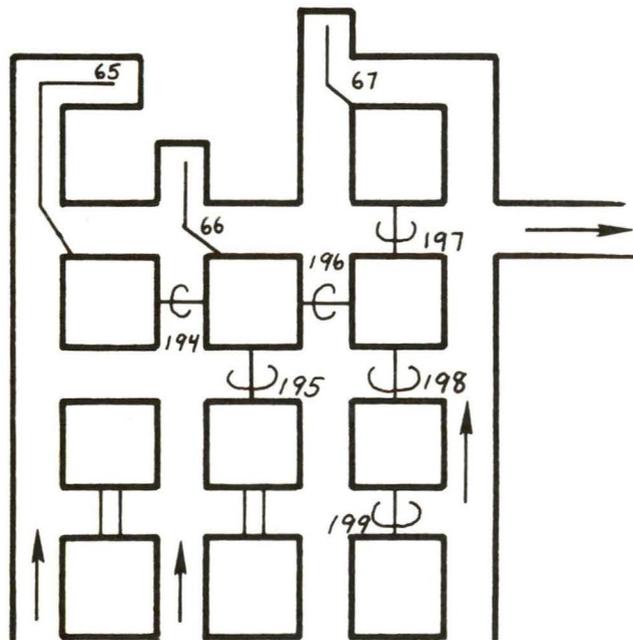


FIGURE D-16. - West Virginia mine No. 3,
section B.

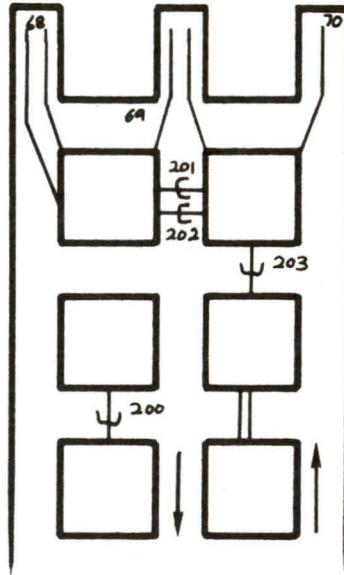


FIGURE D-17.- West Virginia mine No. 4, section A.

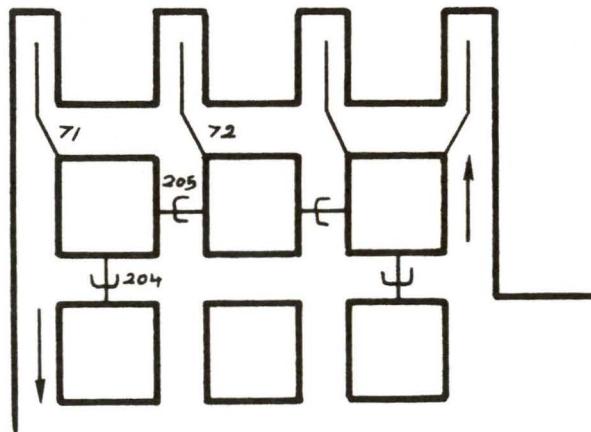


FIGURE D-18.- West Virginia mine No. 4, section B.

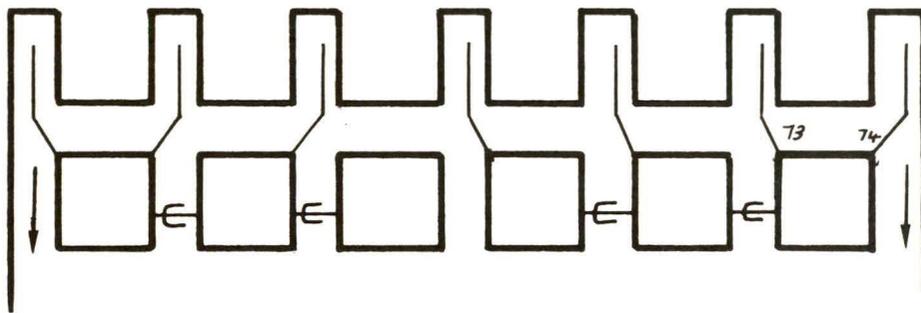


FIGURE D-19. - Pennsylvania mine No. 2,
section A.

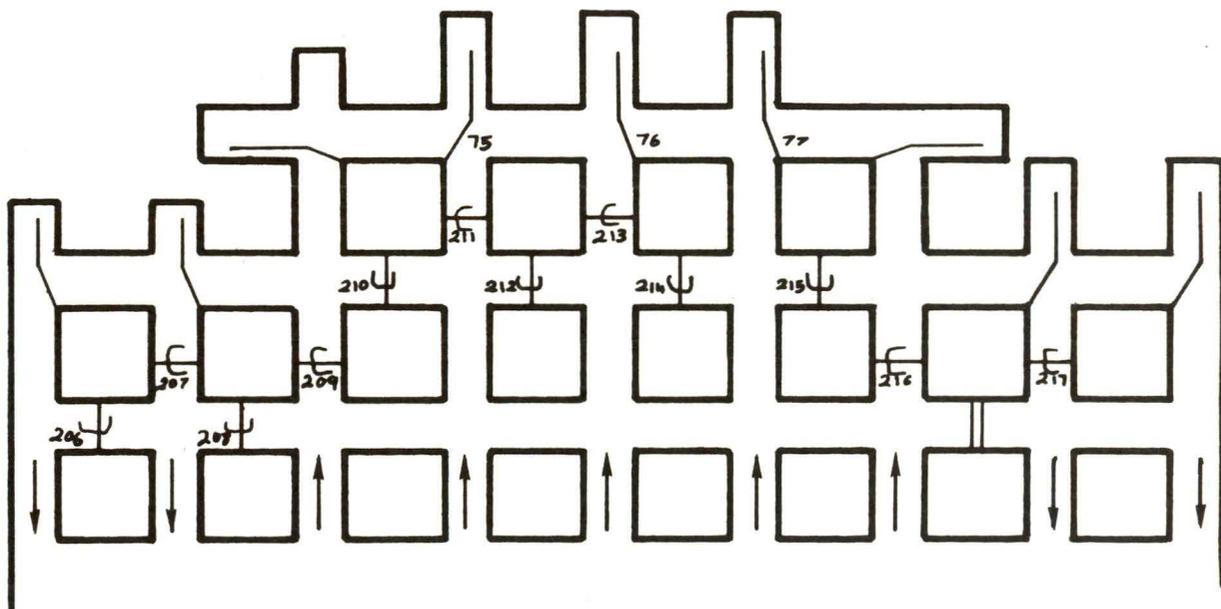


FIGURE D-20. - Pennsylvania mine No. 2,
section B.

APPENDIX E

CHECK CURTAIN DATA

The reduced data on each check curtain evaluated during the mine visits are listed in Table E-1. The check curtain numbers, which run from 100 to 217, correspond to the same number on the mine section maps in Appendix D.

TABLE E-1. - Check curtain data.

Check curtain number	Mine name	Section identification	Seam height (ft)	Entry width (ft)	Leakage (ft ³ /min)	Leakage per foot (ft ³ /min)	ΔP check curtains	Curtain type
100	PA1	A	7.3	16.0	3,200	200	0	B
101	PA1	A	7.3	16.0	3,200	200	0	A
102	PA1	A	7.3	16.0	6,250	390	0	A
103	V1	A	5.2	18.0	6,400	356	0	RT
104	V1	A	5.3	18.0	2,000	111	0	RT
105	V1	A	5.1	17.0	1,200	71	0.010	RT
106	V1	A	5.4	17.0	7,600	447	0.010	A
107	V1	A	4.6	18.5	2,800	151	0.010	RT
108	V1	A	5.1	18.3	3,400	186	0	A
109	V1	A	5.0	18.0	2,000	111	0.040	A
110	V1	A	4.9	18.1	4,600	254	0	RT
111	V1	A	5.3	18.0	0	0	0	RT
112	V1	B	5.1	17.5	5,766	329	0	A
113	V1	B	5.3	16.9	200	11.8	0	RT
114	V1	B	5.8	17.1	8,999	526	0	A
115	V1	B	5.1	17.0	12,214	718	0	RT
116	V1	B	5.3	16.9	4,286	254	0	A
117	V1	B	5.8	16.4	3,200	195	0.020	RT
118	V1	B	5.2	17.1	0	0	0	A
119	V1	B	5.4	17.2	7,486	435	0.005	A

TABLE E-1. - Check curtain data (Continued)

Check curtain number	Mine name	Section identification	Seam height (ft)	Entry width (ft)	Leakage (ft ³ /min)	Leakage per foot (ft ³ /min)	ΔP check curtains	Curtain type
120	V2	A	6.3	18.0	0	0	0	RT
121	V2	A	6.4	17.0	2,783	164	0	RT
122	V2	A	6.5	19.0	0	0	0	RT
123	V2	A	7.3	17.0	0	0	0	RT
124	V2	A	6.8	17.0	3,383	199	0	RT
125	V2	A	6.8	19.0	0	0	0	A
126	V2	B	6.9	17.0	0	0	0	A
127	V2	B	7.0	17.0	8,200	482	0	RT
128	V2	B	6.8	20.0	16,360	818	0	RT
129	V2	B	6.9	20.2	13,160	651	0	RT
130	V2	B	7.0	19.6	1,600	82	0	A
131	V2	B	7.0	19.8	0	0	0	RT
132	V3	A	5.4	17.6	11,246	639	0	A
133	V3	A	5.3	17.2	1,092	63	0	RT
134	V3	A	5.2	17.0	0	0	0	A
135	V3	A	5.1	17.5	0	0	0	RT
136	V3	A	5.3	18.1	937	52	0	A
137	V3	B	5.4	17.8	4,500	252	0	A
138	V3	B	5.3	18.4	0	0	0	RT
139	V3	B	5.7	17.0	0	0	0	RT

TABLE E-1. - Check curtain data (Continued)

Check curtain number	Mine name	Section identification	Seam height (ft)	Entry width (ft)	Leakage (ft ³ /min)	Leakage per foot (ft ³ /min)	ΔP check curtains	Curtain type
140	V3	B	4.8	18.1	0	0	0	RT
141	V3	B	5.2	17.9	0	0	0	A
142	V3	C	5.8	20.0	0	0	0	RT
143	V3	C	5.9	20.0	1,660	83	0	RT
144	V3	C	5.9	20.1	11,653	580	0	RT
145	V4	A	4.2	18.0	0	0	0	RT
146	V4	A	4.6	18.0	0	0	0	RT
147	V4	A	4.9	18.0	14,000	778	0	RT
148	V4	A	4.0	18.0	546	30	0	B
149	V4	A	4.1	18.4	0	0	0	RT
150	V4	A	4.6	18.0	0	0	0	RT
151	V4	A	4.5	18.0	0	0	0	B
152	V4	B	4.7	19.0	535	28	0	RT
153	V4	B	6.2	19.1	837	44	0	RT
154	V4	B	4.6	19.1	3,238	170	0	RT
155	V4	B	6.0	19.2	0	0	0	RT
156	V4	B	4.9	18.4	4,000	217	0	RT
157	V4	B	4.9	19.0	0	0	0	B
158	V4	B	6.3	18.3	800	44	0	B
159	V4	B	6.2	18.0	0	0	0	B

TABLE E-1. - Check curtain data (Continued)

Check curtain number	Mine name	Section identification	Seam height (ft)	Entry width (ft)	Leakage (ft ³ /min)	Leakage per foot (ft ³ /min)	ΔP check curtains	Curtain type
160	WV1	A	5.2	20.0	2,700	135	0.040	A
161	WV1	A	5.2	19.9	1,300	65	0	A
162	WV1	A	5.2	18.2	0	0	0	A
163	WV1	A	5.0	18.6	0	0	0	A
164	WV1	A	10.8	18.5	4,300	232	0.030	A
165	WV1	B	5.7	20.5	1,529	75	0	A
166	WV1	B	6.9	19.9	3,131	157	0	A
167	WV1	B	6.8	20.2	4,512	224	0	A
168	WV1	B	7.0	20.9	490	23	0	A
169	WV1	B	7.0	20.0	3,733	187	0.020	A
170	WV2	A	5.6	20.3	0	0	0.020	A
171	WV2	A	3.0	19.7	1,220	62	0.010	A
172	WV2	A	2.5	20.1	10,950	545	0.010	A
173	WV2	A	4.0	20.4	1,000	49	0.010	RT
174	WV2	A	4.2	20.5	0	0	0	A
175	WV2	A	4.1	21.0	0	0	0	A
176	WV2	A	3.8	21.6	0	0	0.020	RT
177	WV2	A	3.7	21.0	0	0	0.100	A
178	WV2	A	4.0	20.0	5,000	250	0.010	RT
179	WV2	A	4.5	19.8	17,550	886	0.030	RT

TABLE E-1. - Check curtain data (Continued)

Check curtain number	Mine name	Section identification	Seam height (ft)	Entry width (ft)	Leakage (ft ³ /min)	Leakage per foot (ft ³ /min)	ΔP check curtains	Curtain type
180	WV2	A	4.6	19.6	17,000	867	0.120	A
181	WV2	A	4.0	19.4	3,500	180	0.050	A
182	WV2	A	3.8	19.0	26,000	1,368	0.030	A
183	WV2	A	3.9	21.0	6,645	316	0.010	A
184	WV2	B	3.8	20.5	0	0	0.010	A
185	WV2	B	3.0	20.0	0	0	0.010	A
186	WV2	B	2.5	20.5	8,000	390	0	RT
187	WV2	B	4.0	19.0	8,000	421	0.010	RT
188	WV2	B	3.8	19.9	26,000	1,306	0.020	RT
189	WV2	B	3.8	19.8	6,000	303	0.010	A
190	WV2	B	3.8	20.0	6,000	30	0.010	A
191	WV2	B	3.8	20.1	12,000	597	0.010	A
192	WV2	B	3.8	20.3	0	0	0.080	A
193	WV3	A	7.0	17.0	1,630	96	0.010	A
194	WV3	B	6.2	17.1	2,749	161	0	RT
195	WV3	B	6.3	17.4	7,582	443	0.040	RT
196	WV3	B	7.1	17.0	0	0	0.030	RT
197	WV3	B	6.2	17.4	2,359	136	0	A
198	WV3	B	6.0	17.1	11,582	677	0.030	A
199	WV3	B	6.2	17.0	0	0	0	A

TABLE E-1. - Check curtain data (Concluded)

Check curtain number	Mine name	Section identification	Seam height (ft)	Entry width (ft)	Leakage (ft ³ /min)	Leakage per foot (ft ³ /min)	ΔP check curtains	Curtain type
200	WV4	A	5.9	20.0	0	0	0	A
201	WV4	A	6.0	19.0	2,335	123	0.020	A
202	WV4	A	6.0	19.0	2,335	123	0.040	A
203	WV4	A	6.0	19.0	2,549	134	0.020	A
204	WV4	B	6.2	19.0	0	0	0	A
205	WV4	B	6.3	20.0	0	0	0	RT
206	PA2	B	6.8	15.6	-	-	0.120	C
207	PA2	B	6.8	16.0	-	-	0.080	C
208	PA2	B	6.8	16.0	-	-	0.140	C
209	PA2	B	6.8	16.5	-	-	0.080	C
210	PA2	B	6.8	15.9	-	-	0.020	RU
211	PA2	B	6.8	16.0	-	-	0	RU
212	PA2	B	6.8	16.0	-	-	0.040	RU
213	PA2	B	6.8	16.0	-	-	0.020	RU
214	PA2	B	6.8	16.0	-	-	0.040	C
215	PA2	B	6.8	16.1	-	-	0.060	C
216	PA2	B	6.8	15.8	-	-	0.070	C
217	PA2	B	6.8	16.0	-	-	0.080	C