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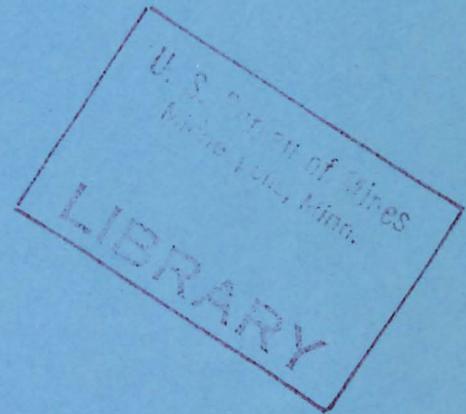


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USBM H0232067

# DEVELOP AND TEST CANOPY AIR CURTAIN DEVICES

by  
William J. Krisko



United States  
Department of the Interior  
Bureau of Mines

USBM CONTRACT REPORT H0232067

June 1975

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DONALDSON COMPANY, INC.

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## FOREWORD

This report was prepared by Donaldson Company, Inc., Corad Division, Minneapolis, Minnesota, under USBM Contract No. HO232067. The contract was initiated under the Federal Coal Mine Health and Safety Research Program. It was administered under the technical direction of the Pittsburgh Mining and Safety Research Center with Mr. Edward F. Divers acting as the Technical Project Officer. Mr. Alan Granruth was the contract administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period July 1973 to June 1975. This report was submitted by the author on 6 June 1975.

## DIGEST

This report covers the entire period of the contract, summarizing the development effort of the canopy air curtain device. Phase I included design, fabrication and laboratory testing of air curtain devices. Phase II consisted of design and fabrication of a refined canopy air curtain, laboratory and underground tests of the device and the build-up of a demonstration model. Instructions for operating, maintenance cost and reliability, recommended changes to production models, estimated costs of these production models and final engineering drawings are also included in this report.

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## INTRODUCTION AND SUMMARY

This contract final report summarizes the design, fabrication and testing of canopy air curtain devices under Bureau of Mines Contract HO232067. The canopy air curtain device is designed to reduce the level of respirable dust exposure to a continuous mining machine operator while having a minimum effect on operator safety, mobility and comfort and being compatible with mining equipment.

This contract was devoted to the development of a device which utilizes an invisible curtain of air to envelope a mining machine operator's breathing zone with filtered air to provide respiratory protection. Various concepts were evaluated by means of laboratory tests. One concept was selected and was tested on various mining machines at underground sites by means of MSA personal samplers. The canopy air curtain was found to be effective. The percent reductions over the ambient dust concentrations were about 30 to 75 percent depending on the amount of time the operator spent under the air curtain. At one test site, the device enabled the mining machine to operate within compliance. Donaldson Company is presently working on the commercial production of the device.

Performance of this contract began on 21 June 1973. The development effort was divided into two phases. Phase I consisted of fifteen tasks covering activities of evaluating prototype air curtain concepts and establishing interface requirements on continuous mining machines and other mining machinery. Phase II covered the fabrication of one each of the most promising concepts selected, laboratory testing, and field testing of these units in underground coal mines.

A brief background of the respirable dust problem and importance of a canopy air curtain device to help solve this problem is presented in Section 2 of this report. Section 3 outlines the contract objective and requirements and overall program plan and Section 4 defines the test procedures. Section 5 contains a summary of the work done under Phase I and Section 6 covers work done under Phase II. Instructions for operation of the canopy air curtain are presented in Section 7 and maintenance cost and reliability in Section 8. Section 9 contains recommended changes to production models and the estimated costs of such models. The subject list of inventions is contained in Section 10. The final engineering drawings can be found in the Appendix.

The Federal Coal Mine Health and Safety Act of 1969, set allowable exposure to respirable coal dust by miners to be 2 mg/cubic meter when averaged over an 8-hr shift. During the past several years, much effort has been expended to reduce the respirable dust concentration in underground coal mines. These efforts include increased use of ventilation air, dust collectors, improved dust suppression using water sprays, wetting agents and foams, and improvements in machine bit design. While considerable progress has been and is continuing to be made, certain work stations in underground mines still have high dust exposure. One such work station is the operator's cab of the continuous miner.

To protect personnel at these high dust exposure work stations, development of individual protection equipment continues. While protectors such as face mask respirators have been in use for a number of years, they are not a solution to the problem but simply an interim expedient. The miner's objections to face mask respirators are primarily associated with physical discomfort. These objections result in compromising the protection afforded by the dust respirator. Efforts to eliminate the miner's objections have included powering the respirator, using enclosure helmets and redesigning the mask for comfort. Aligned with these, is the program that was carried on by Donaldson Company for the development of an air curtain respiratory protective device under Contract HO122087. This air curtain device is an individual respiratory protector that is part of the miner's hat. The major advantages of this device are no physical contact with the miner's face, no breathing resistance from wearing it, and no impairment of speech or expectoration. However, a hose is required to connect the miner to the machine and it is only natural that the wearer is aware of its existence and that some discomfort will occur.

Federal legislation, effective in 1974, required all underground mining machines to be equipped with canopies over the operator's station. Donaldson Company believes that by incorporating an air curtain device into the canopies of the underground machines, effective respiratory protection can be afforded the operator, eliminating the physical interface that exists with the helmet air curtain device.

### 3 CONTRACT DEFINITION

#### 3.1 Contract Objective

The objective of Contract HO232067 was to design, develop, fabricate and test prototype air curtain devices. These devices are intended to protect an operator from the hazards of respirable coal dust with minimum restraint on operator safety, and mobility and with minimum cost.

#### 3.2 Design Requirements

As stated in the contract, the general design requirements for the canopy air curtain device were as follows:

- The device shall be designed for minimum size, maintenance and cost
- The device shall be capable of mounting on a continuous miner and not mechanically connected to the machine operator
- The device shall be readily adaptable to most continuous mining machines
- The device shall be adaptable to other underground mining machinery, as shuttle cars and longwall machinery
- The device shall be adjustable by the operator if needed for his maximum comfort and effectiveness
- The device shall be designed for minimum noise levels
- The device shall have a minimum possibility of recirculation (the specific volumetric rate values and layout of components which may lead to the possibility of recirculation problems are subject to approval by the Bureau of Mines).

#### 3.3 Design Concepts

Design concepts considered, as defined in the contract, included but were not limited to:

- A filtered air curtain and filtered air core
- A mine ambient (dusty) air curtain and filtered air core

- A low velocity, low volume filtered air jet directed toward the operator's breathing zone
- Partial mechanical enclosures near operator that block undesirable airflow patterns

### 3.4 Program Plan

To attain the contract objective, Donaldson Company, in accordance with the contract, was responsible for the overall design, development and test effort. The program was carried out in two phases, as follows: Phase I - Design, fabrication and laboratory testing of prototype air curtain concepts, Phase II - Fabrication of unit (s) of each concept selected and underground field testing of unit (s). A brief discussion of the effort carried out during Phase I and Phase II is provided in the following paragraphs.

#### 3.4.1 Phase I

Phase I was scheduled as a 12-month effort starting on 21 June 1973. Initially, the first air curtain model was designed and fabricated and the following concepts were investigated:

- Low velocity air curtain
- Non-continuous high velocity jet
- Low velocity core requirements
- "Dirty" outside peripheral jet with "clean" core
- Use of shield at rear of canopy
- Low velocity, low volume breathing zone air curtain
- Use of a receiver, below canopy

A second prototype model was then designed and fabricated with the size and configuration intended to be more compatible with a mining machine canopy. The following studies were then conducted:

- Optimize open areas and airflows
- Effects of air curtain attitude and height
- Effects of operator position under canopy
- Interface of canopy air curtain to field demonstration machines

A Phase I Final Report summarizing the work done thus far and including recommendations for Phase II completed the Phase I effort.

### 3.4.2 Phase II

Phase II was scheduled to last seven months starting in June 1974. Prior to Phase II air curtain design, further refinement of the Phase I air curtain was accomplished and air mover and filter element performance tests were run.

After design and fabrication of the Phase II air curtain, laboratory tests were run prior to the installation of the units in the field machines. After installation, tests were run in the underground coal mines and a demonstration model was built.

This contract final report which summarizes the work accomplished under the contract and includes instructions for operation, maintenance cost and reliability and recommendations and estimated cost for production models will complete the Phase II effort.

The following subsections define the test procedures used throughout this contract and referred to in Sections 5 and 6 of this report.

#### 4.1 Full Scale Chamber Tests

The procedure used to calibrate the full-scale chamber for dust feed rate was the following:

- a. An interference jet diffuser was designed and fabricated in order to obtain a relatively even velocity of air directed at the canopy air curtain.
- b. The interference jet airflow was adjusted until about 100 ft/min was measured at the front edge of the air curtain prototype model. This velocity does vary and did increase to 150 ft/min at times.
- c. The airflow required to obtain the velocity of 100 ft/min was 106.6 cfm.
- d. The GCA Dust Monitor was placed in the same location as that for the taking of velocity measurement. The GCA was set up to read respirable concentrations.
- e. Full-spectrum coal dust was fed to the interference jet airflow while the GCA was used to sample the chamber concentration.<sup>3</sup> The dust feed rate was adjusted until readings of about 5 mg/m<sup>3</sup> respirable coal dust were obtained.
- f. The resulting feed rate of full-spectrum coal dust was 47.39 gms per hour per 106.6 cfm, or the dust feed concentration of full-spectrum coal dust was 262 mg/m<sup>3</sup> to obtain 5 mg/m<sup>3</sup> respirable coal dust concentration inside the chamber.
- g. Concentration measurements were taken by two methods: GCA Dust Monitor and gravimetric samples. The gravimetric samples were taken by drawing 1.50 cfm of air through the mannequin's nose and mouth and routing this air through a 47 mm Nuclepore membrane. These membranes were weighed before and after dust deposition on a Cahn gram electrobalance. The weights of the clean membranes vary from 20,000 mg to 23,000 mg. The amount of dust collected varied from 0.2000 mg to 2.0000 mg.

- h. The GCA samples were drawn from the mannequin lung line and were taken concurrently during the 1-hour gravimetric sampling. This gave us better correlation between the gravimetric samples and the GCA samples than did the GCA readings taken outside the lung line.

Refer to Figure 4-1 for a schematic of the test setup. Refer to Figure 4-2 for a schematic showing the location of the samples taken for chamber calibration.

When tests were run with an interference jet velocity of 300 ft/min rather than 100 ft/min, a change had to be made to the interference jet airflow and feed concentration. The same calibration procedure was used. Table 4-1 presents the interference jet velocity, feed concentration, and chamber concentration for both 100 ft/min and 300 ft/min.

Table 4-1. Full-Scale Chamber Concentration

Interference Jet Velocity	Feed Concentration (mg/m <sup>3</sup> )	Chamber Concentration (mg/m <sup>3</sup> )	
		Total	Respirable
100	262	65.76	-
100	262	66.58	-
100	262	51.38	5.32
100	262	45.00	-
300	299	38.26	5.26
300	299	37.27	4.31

#### 4.2 Procedure for the Determination of the Respirable Fraction

The method used to calculate the respirable concentration from the gravimetric samples, taken on the Nuclepore membranes, is described below. In the coal mining industry, respirable dust concentration in the mines has been defined as that mass fraction of material which penetrates the 10 mm reverse-flow cyclone separator tube used in the individual dust samplers. The design goal for protection afforded by this canopy air curtain was 0.5 mg of respirable dust per cubic meter of air when the ambient

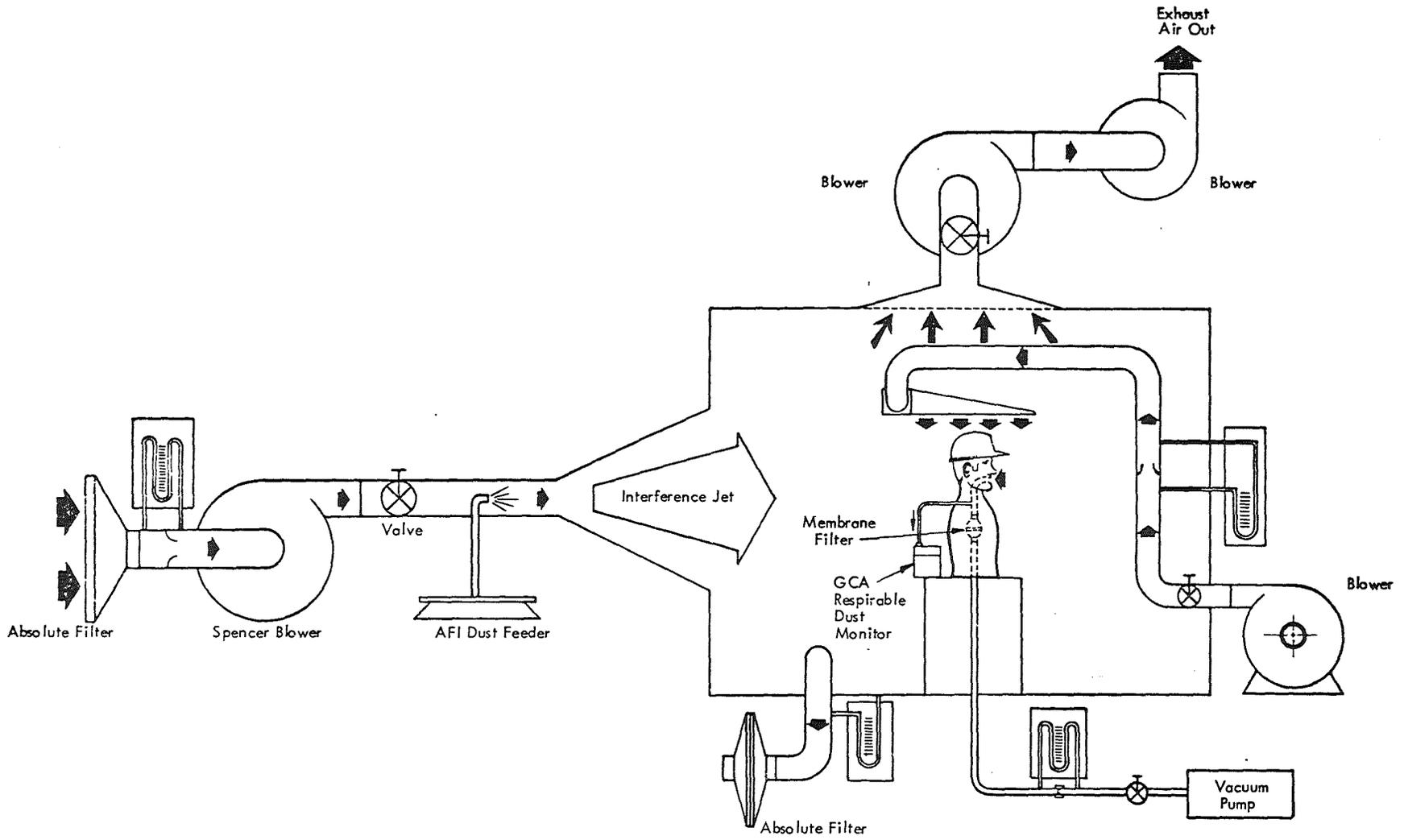


Figure 4-1 . Schematic of Canopy Air Curtain Test Set-Up

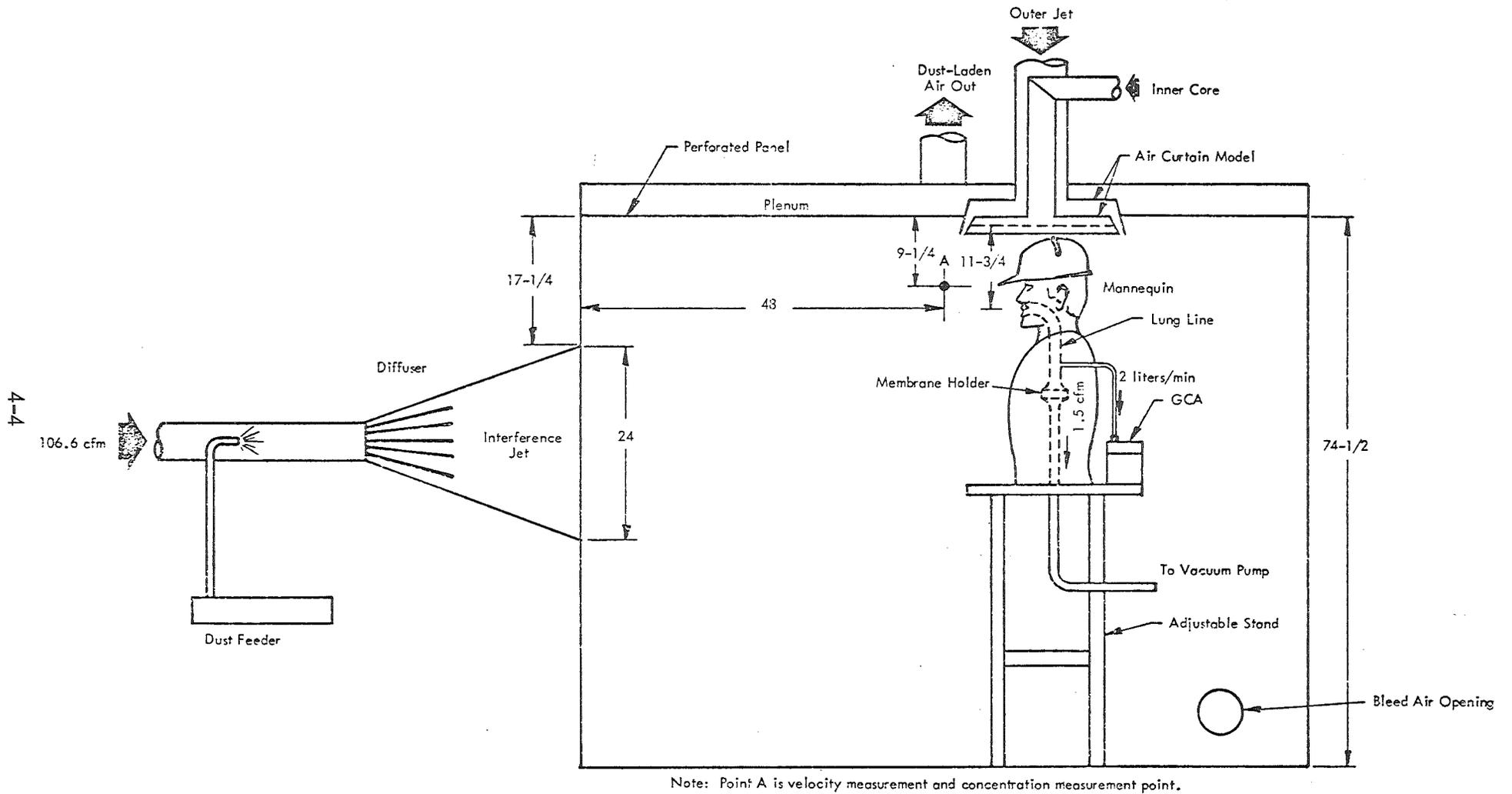


Figure 4-2. Full-Scale Chamber Calibration

concentration of respirable is  $5.0 \text{ mg/m}^3$ . For comparison purposes, it seemed logical that the same definition of respirable dust be used in each application.

The dust was collected on non-hygroscopic Nuclepore membrane filters. The mass of material on the membrane was obtained by weighing the membranes before and immediately after test. From this data on total mass collected, a total concentration was calculated.

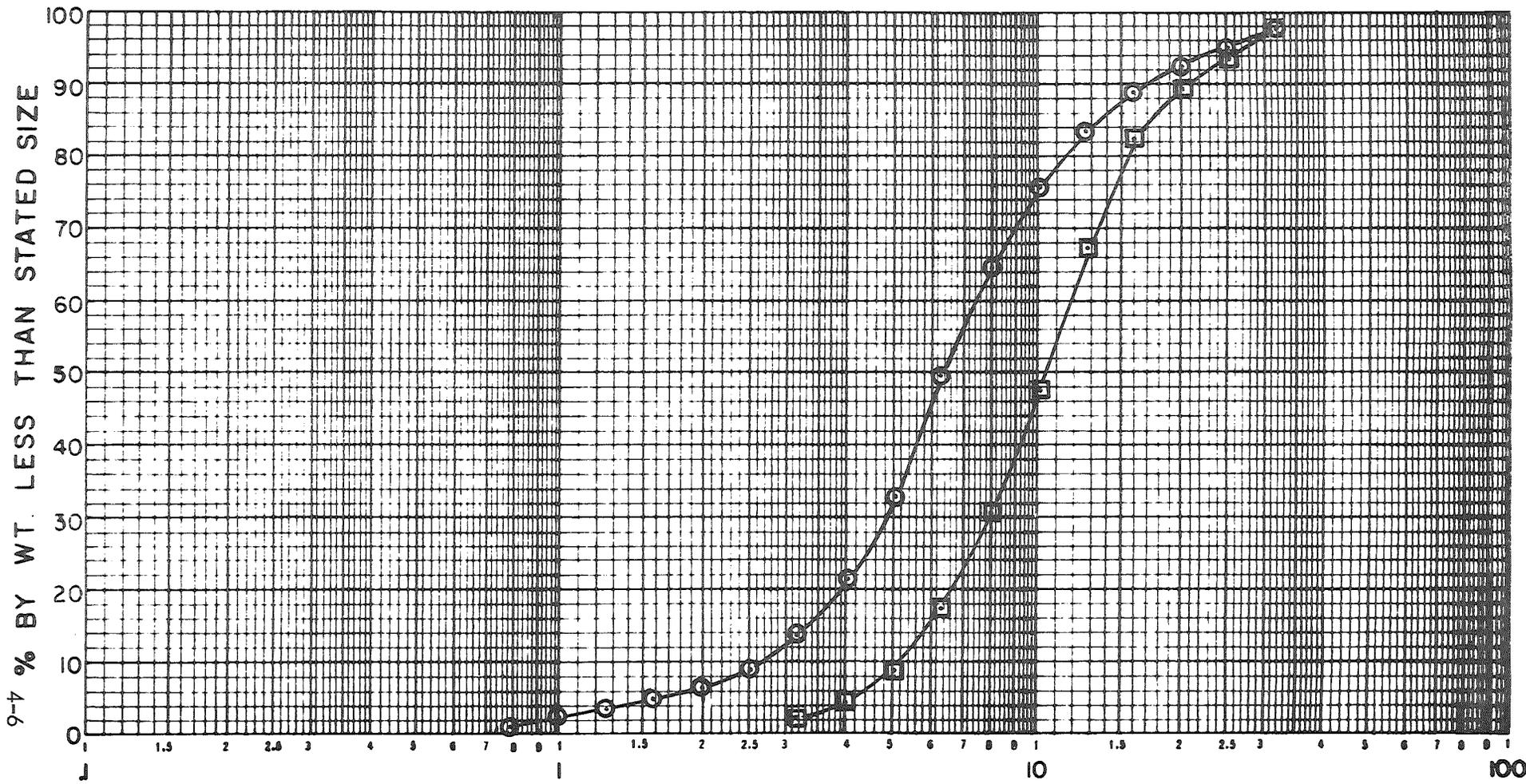
Following the weighing procedure, the coal dust was washed from the membrane and a Coulter Counter analysis was conducted to determine the particle-size distribution of the sample.

Knowing both the mass of total material collected from the inhaled air, and the particle size distribution of the material, we calculated a respirable concentration with the AEC definition of respirable dust. In 1961, the AEC established a definition of respirable dust as that portion of the inhaled dust which penetrates to the non-ciliated portions of the lung. This was defined as:

- 100 percent of dust at and below 2 microns
- 75 percent of dust at  $2\frac{1}{2}$  microns
- 50 percent of dust at  $3\frac{1}{2}$  microns
- 25 percent of dust at 5 microns
- 0 percent of dust at 10 microns

These percentages were the design parameters that were used to design the 10 mm reverse-flow cyclone tube used in the individual dust sampler.

Using the definition of respirable dust, we calculated the respirable dust concentration in the following manner: From the particle size spectrum for sampler number 171 (the mannequin lung sample), Figure 4-3, the following data was obtained:



Coal Dust
Full Spectrum Coal Dust (5 mg/m <sup>3</sup> respirable)
○ #171, Nuclepore Sample
□ #83, Nuclepore Sample
△
◇

PARTICLE DIAMETER, MICRONS

- ANALYSIS BY
- COULTER COUNTER
  - MSA ANALYZER
  - MICROSCOPE
  - SIEVE  \_\_\_\_\_

DONALDSON CO. INC
CORAD DIVISION
DATE 9-24-73 BY RMN
FILE NO. _____
DRWG. NO. 9121 F-2425

Figure 4-3. Particle Size Spectrum Curve

For Sample No. 171  
Particle Spectrum Data

Percent less than particle size		Percent Difference	Average Penetration per Band AEC Curve
	0 micron	6.5	100
6.5	2.0 microns	2.5	87.5
9.0	2.5 microns	7.2	62.5
16.2	3.5 microns	16.8	37.5
33.0	5.0 microns	42.8	12.5
5.8	10.0 microns	-	-

Since we had already calculated a total inspired concentration ( $0.4704 \text{ mg/m}^3$ ), we used it, instead of the mass of material, in the following calculation:

$$\begin{aligned} \text{Respirable Concentration} &= \\ &(\text{percent difference})(\text{total concentration})(\text{average penetration per band}) \\ &= (.065)(.4704)(1.00) + (.025)(.4704)(.875) + \text{etc.} \end{aligned}$$

The following computer program was used to perform the calculations:

```
00010 INPUT A,B,C,D,E,W
00020 F=1.00 x A x W
00030 G=.875 x (B-A) x W
00040 H=.625 x (C-B) x W
00050 I=.375 x (D-C) x W
00060 J=.125 x (E-D) x W
00070 M=F + G + H + I + J
00080 PRINT USING 90,M
00090 RESPIRABLE DUST CONCENTRATION = #.#### MG/M3
00100 END
```

A respirable concentration of  $.1168 \text{ mg/m}^3$  was determined for sample No. 171. All gravimetric samples were determined in the same manner.

Work in Phase I consisted of the design, fabrication and testing of two prototype air curtain devices as well as a low profile model. The concept recommended for underground tests and the test sites and procedures were also defined during this phase.

### 5.1

#### First Prototype Model

The first prototype model was designed so that airflow could be routed separately to an outer jet and also to an inner core of lower velocity airflow. The higher velocity outer jet was anticipated for deflection of mine ventilation air velocities impinging against it. The low velocity inner core provides the breathing volume and also helps to deflect the outer jet outward. The feature of having separate airflow suppliers for the outer jet and inner core permits variation of the airflows separately and determination of the ratio of airflow between the inner core and outer jet. The outer jet was later eliminated from the design because the airflow required was too high to warrant the slight increase in efficiency. Since this model was used to determine optimum open area of the inner core, optimum slot width of the outer jet and optimum slot angles of the outer jet, it was designed such that these parameters could be easily varied and tested (see Figures 5-1 and 5-2). The first model was also used to simulate the concepts and configurations as requested by the contract.

The first model was aimed at selection of the most efficient concept. The best concept was found to be the non-continuous inner core only concept. This concept provides operator protection with the least airflow.

The concepts that were designed and tested are illustrated on the following pages.

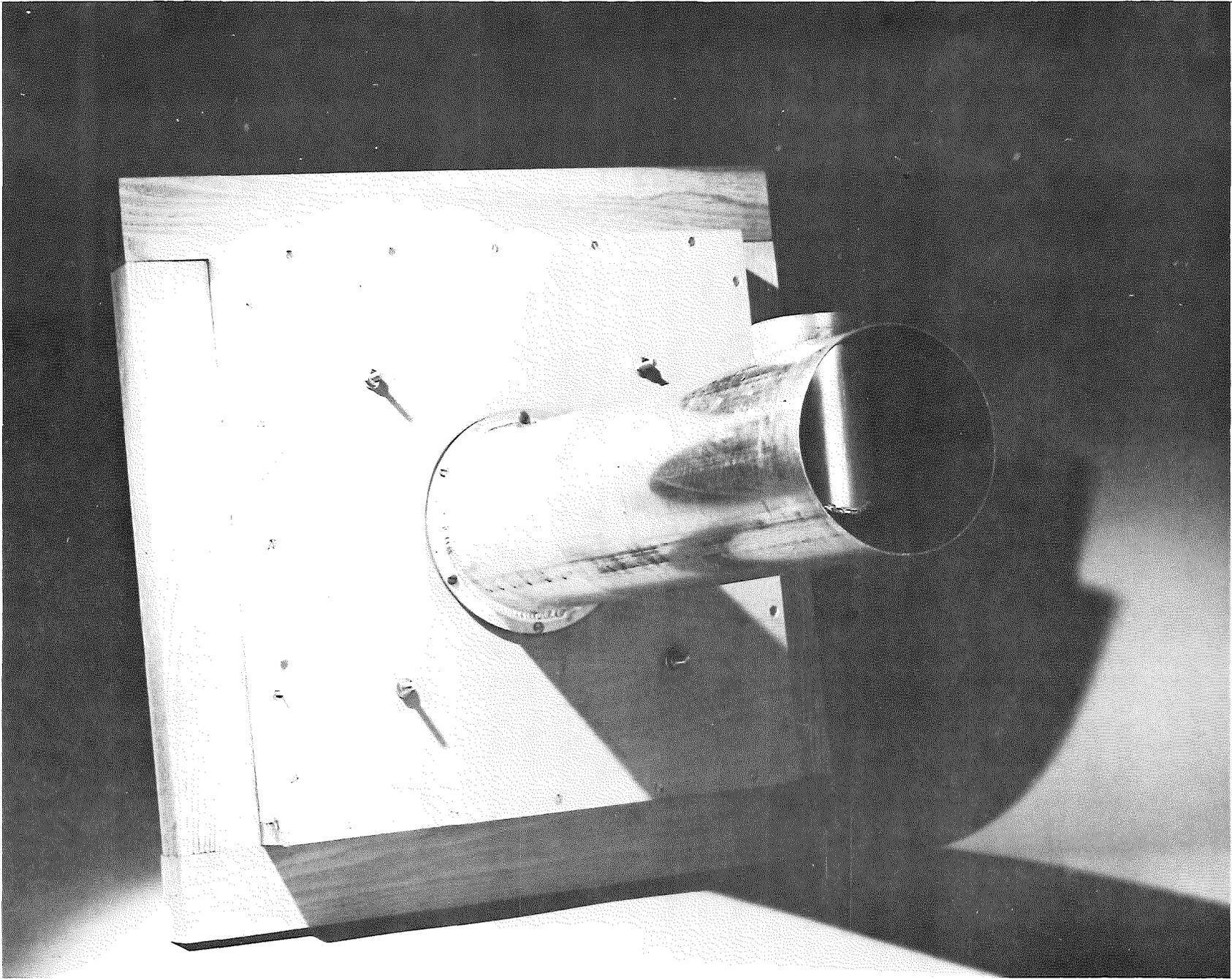


Figure 5-1. First Prototype Model -  
Top View

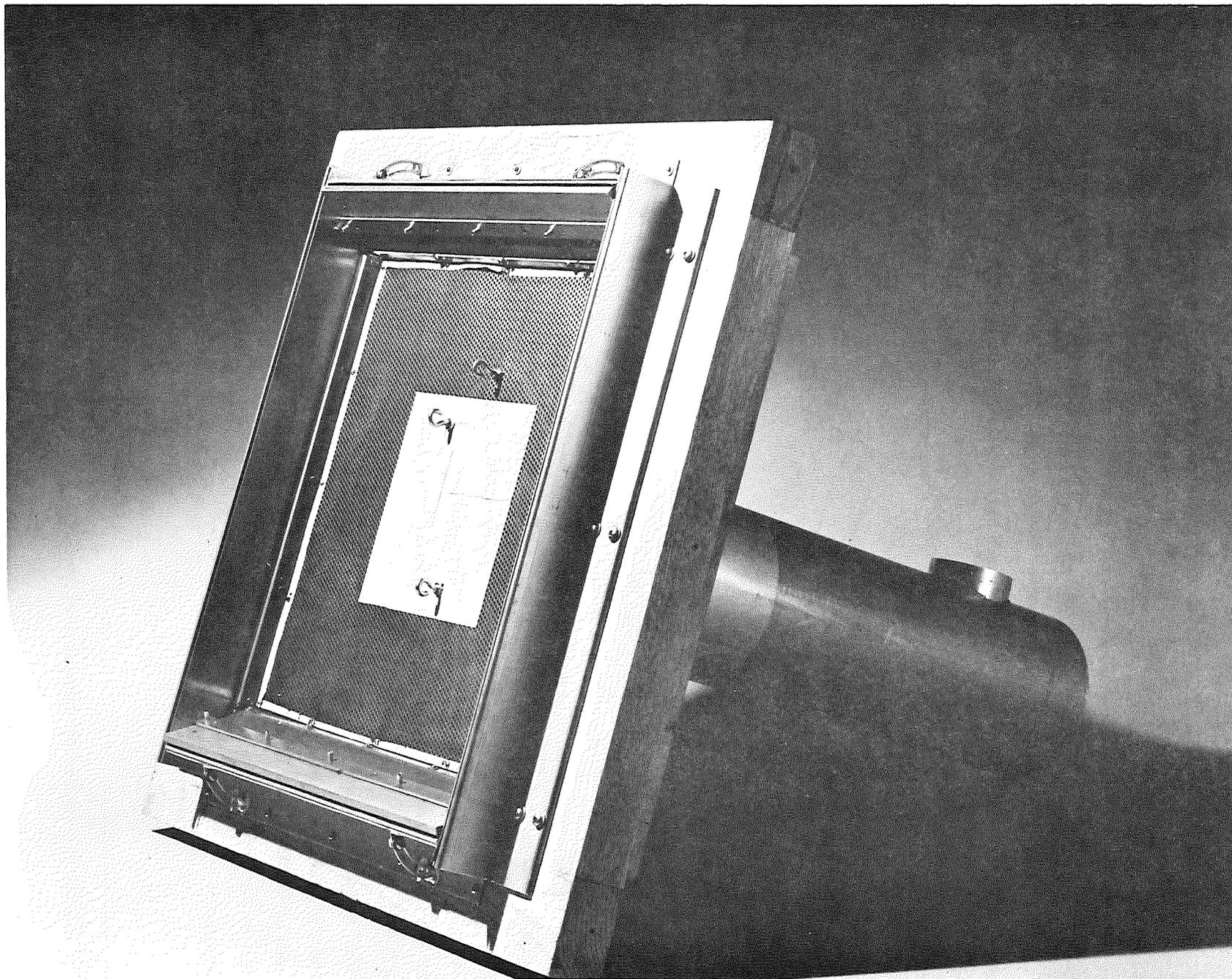


Figure 5-2. First Prototype Model -  
Bottom View

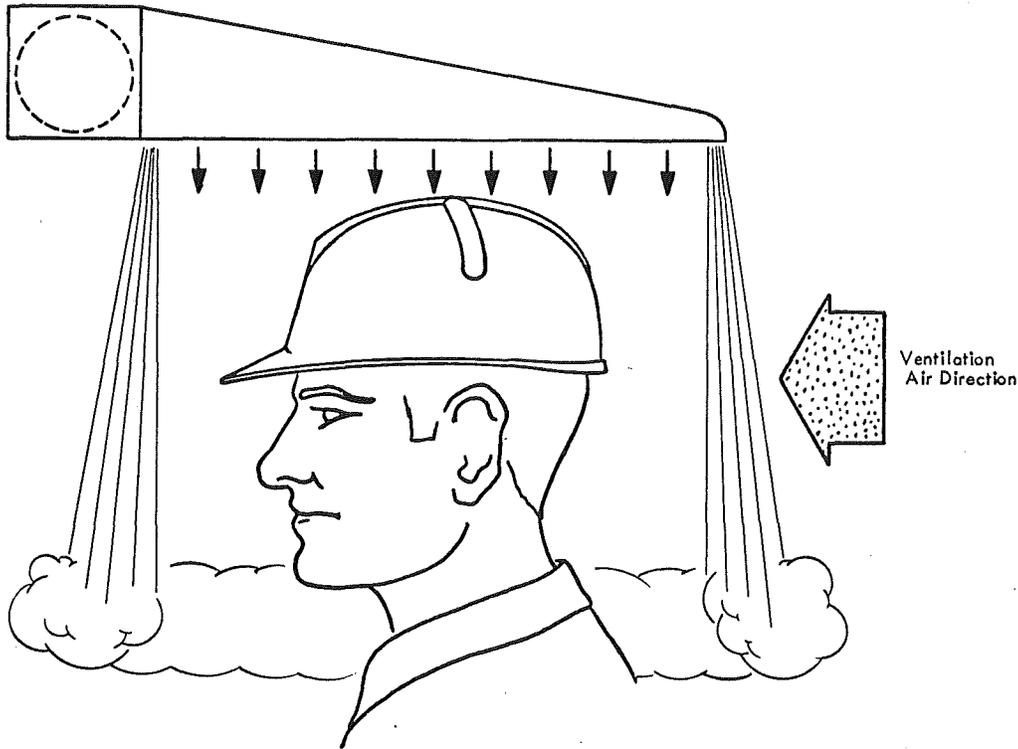


Figure 5-3. Continuous Outer Jet with Continuous Inner Core

Continuous Outer Jet with Continuous Inner Core - This concept used a "continuous" (four-sided) high velocity outer jet around the outside periphery of the inner core. The inner core consisted of a panel of perforated metal backed with a spun-bonded material to provide a low velocity column of breathing air. The inner core on this concept was "continuous". In other words, no central area of the perforated metal was blocked off. The tests on this concept resulted in the following determinations for this particular configuration: best ratio of inner core airflow to outer jet airflow is 3 to 1, the best inner core open area was found to be 32 percent open area perforated metal backed with 14 mil CEREX<sup>®</sup>, the best outer jet slot width was 0.125 in., and the best outer jet angle outward from the vertical was 30 degrees. Good results were obtained with this concept using as little as 419 cfm. However, further reduction in the airflow requirement was attained with other concepts so this concept was dropped.

<sup>®</sup> CEREX is a registered trademark of Monsanto

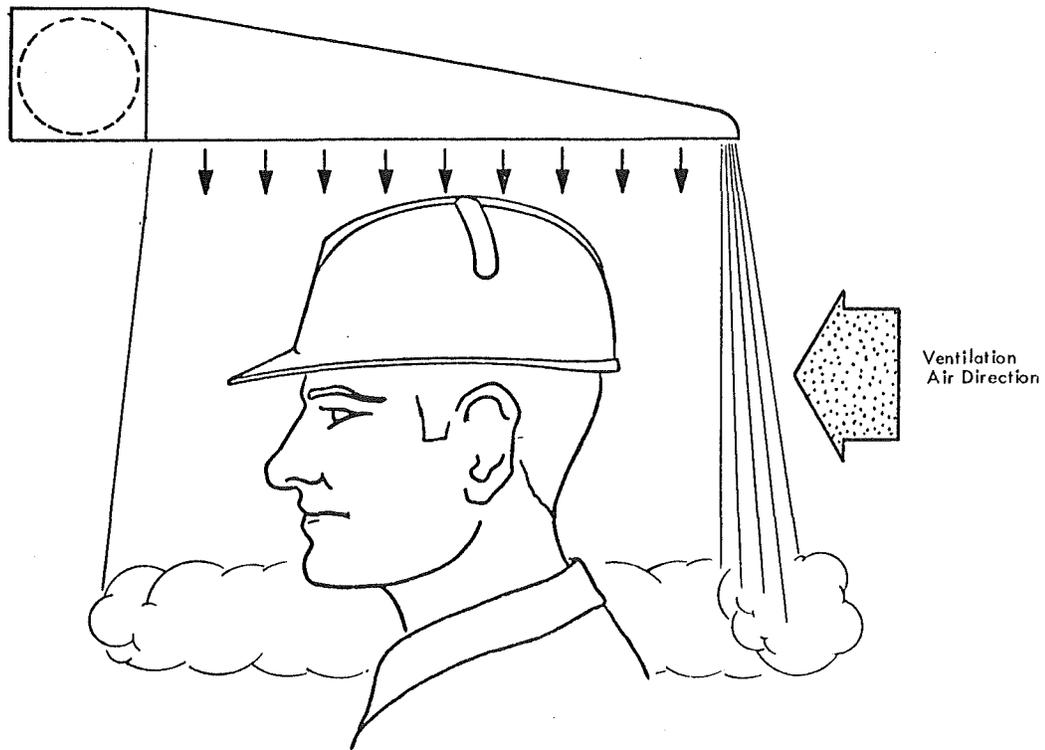


Figure 5-4. Non-Continuous Outer Jet with Continuous Inner Core

Non-Continuous Outer Jet with Continuous Inner Core - Based on the tests on the Continuous Outer Jet with Continuous Inner Core concept described above, we felt we could reduce the airflow requirements by blocking off one side of the outer jet on the side opposite the interference jet. Consequently, the term "non-continuous outer jet" was created. The perforated metal used was 32 percent open area with 14 mil CEREX. The outer jet used a slot width of 0.125 in. at a 30 degree angle. The ratio of inner core airflow to outer jet airflow was increased to 4 to 1 due to the reduced airflow in the outer jet. This concept performed well down to 295 cfm; however, the inner core only concept performed as well with a lower airflow.

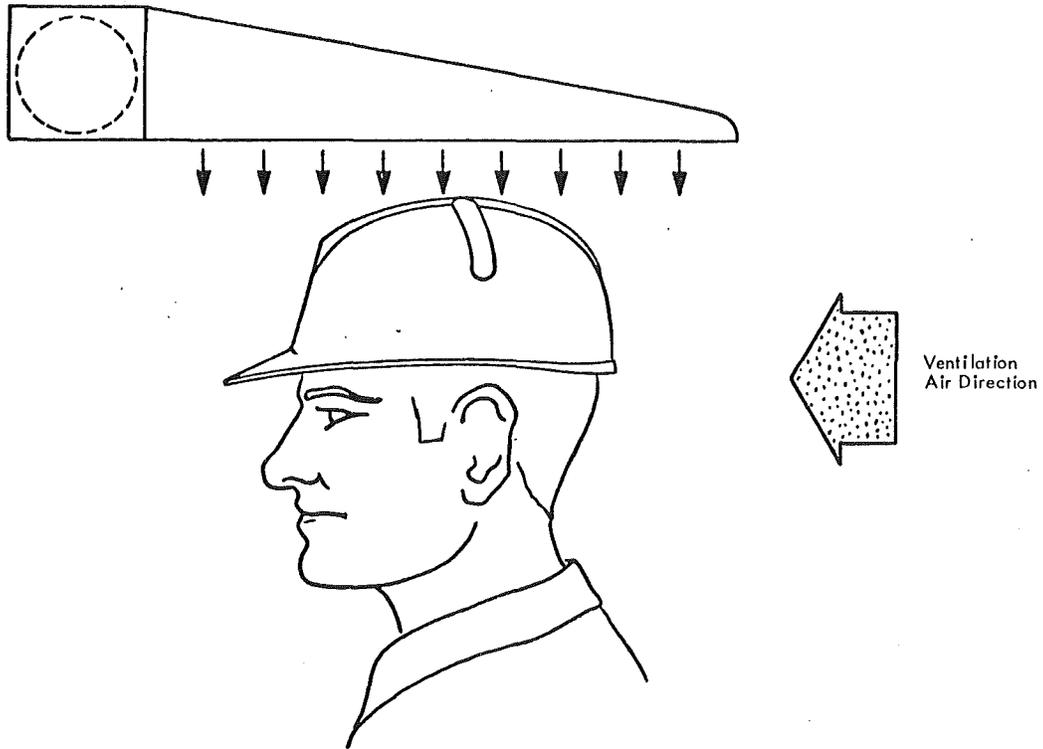


Figure 5-5. Inner Core Only

Inner Core Only - Further reduction in the airflow required to attain protection was achieved by completely eliminating the outer jet. At the low interference jet velocities (mine ventilation air velocity) found in coal mines of approximately 100 ft/min, it was felt that the outer jet would not be needed to deflect the coal dust. It was found from tests that as little as 172 cfm can be used with the first model using the inner core only configuration to provide protection within the contract requirement.

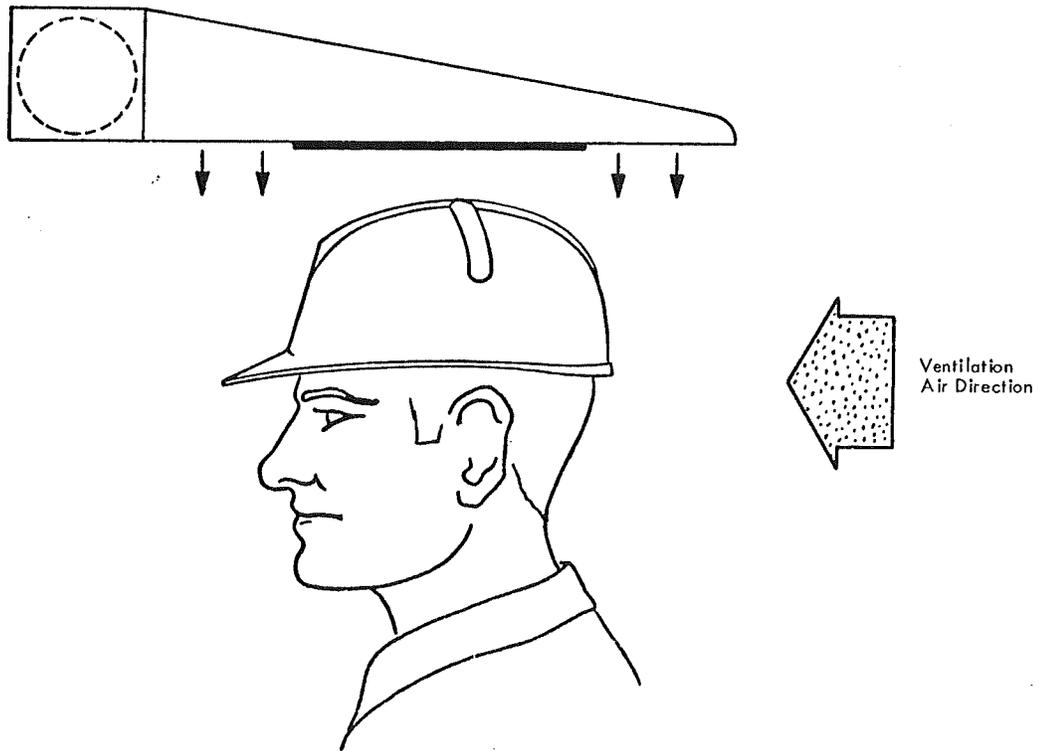


Figure 5-6. Non-Continuous Inner Core Only

Non-Continuous Inner Core Only - As a result of the favorable results on the inner core only concept, it was felt that a center portion of the inner core could be blocked off and would consequently reduce the airflow required. A 6-7/8 in. x 6-7/8 in. area was then blocked off and the concept was tested. Better results were obtained with this configuration at 157 cfm than the inner core only concept at 172 cfm. This concept was ultimately found to be the most efficient of any tested and is the unit selected for Phase II testing.

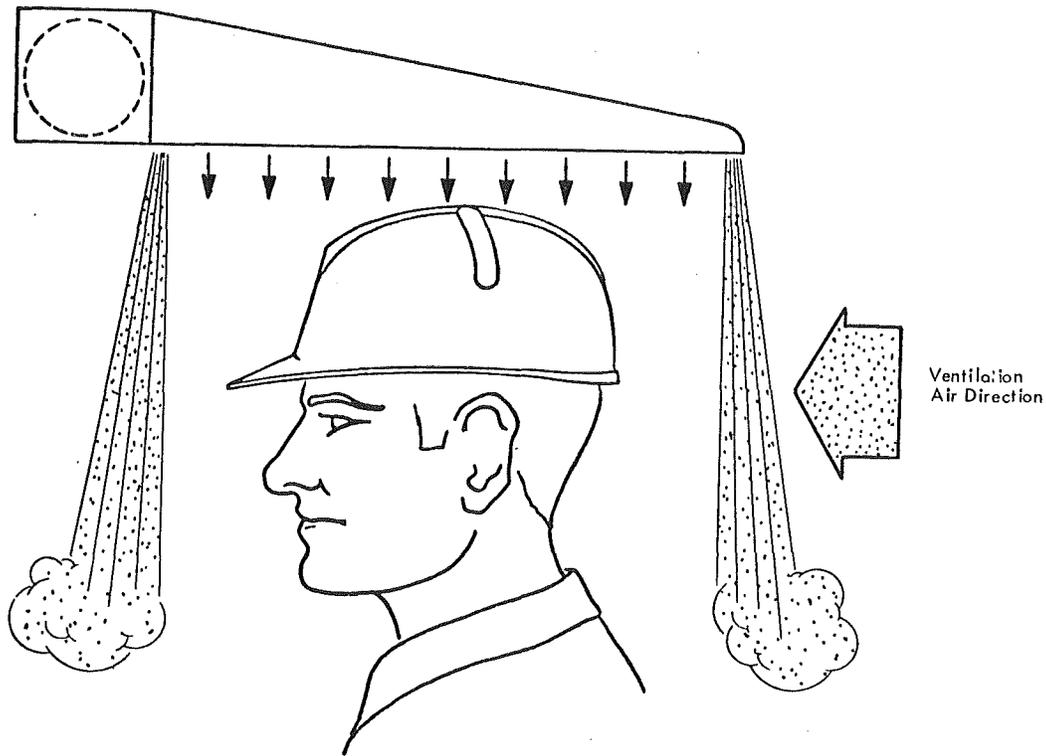


Figure 5-7. Dirty Outer Jet

Dirty Outer Jet - This concept is the same as the continuous outer jet with continuous inner core concept described above except the outer jet airflow is "dirty". In other words, full-spectrum coal dust was fed to the outer jet at a total concentration of  $100 \text{ mg/m}^3$ . The purpose for studying this concept was to determine if power requirements could be reduced by filtering only the inner core airflow. The test results indicated an increase in the penetrating dust concentration of approximately  $0.60 \text{ mg/m}^3$  over the penetrating dust concentration for a clean outer jet at a total air curtain airflow of 524 cfm. Consequently, this concept was dropped from further consideration.

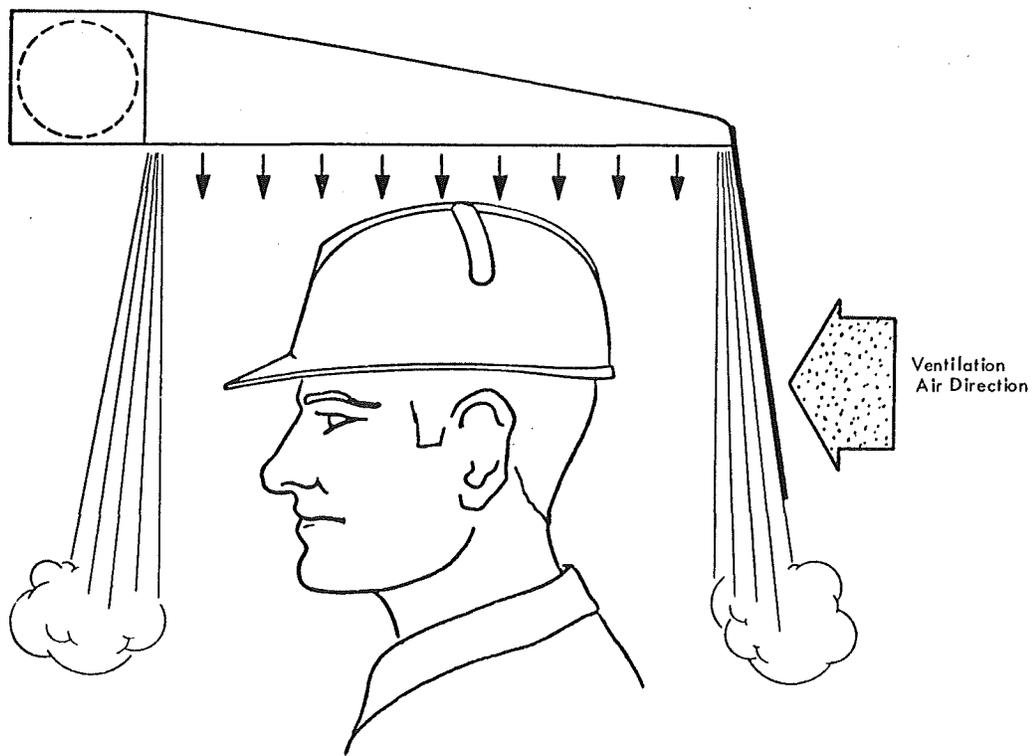


Figure 5-8. Use of Shield

Use of Shield - The shield concept consists of placing a physical barrier between the interference jet (mine ventilation air direction) and the operator. The shield was placed on only one side of the air curtain. The shield was tested with it located both on the outside of the outer jet and also on the inside leading edge of the outer jet. The shield had dimensions of 20-1/2 in. x 12 in. The configuration of the outer jet and the inner core were the same as the continuous outer jet with continuous inner core concept (0.125 in. wide slot, 30 degree slot angle, 32 percent open perforated metal with 14 mil CEREX backing). The tests indicated that the shield does not improve the air curtain performance. Since the shield interferes with the operator's backward movement, has no apparent advantage, and requires a high airflow, no further development of this concept was attempted. However, this concept could prove effective when the ambient velocities are higher such as above ground applications.

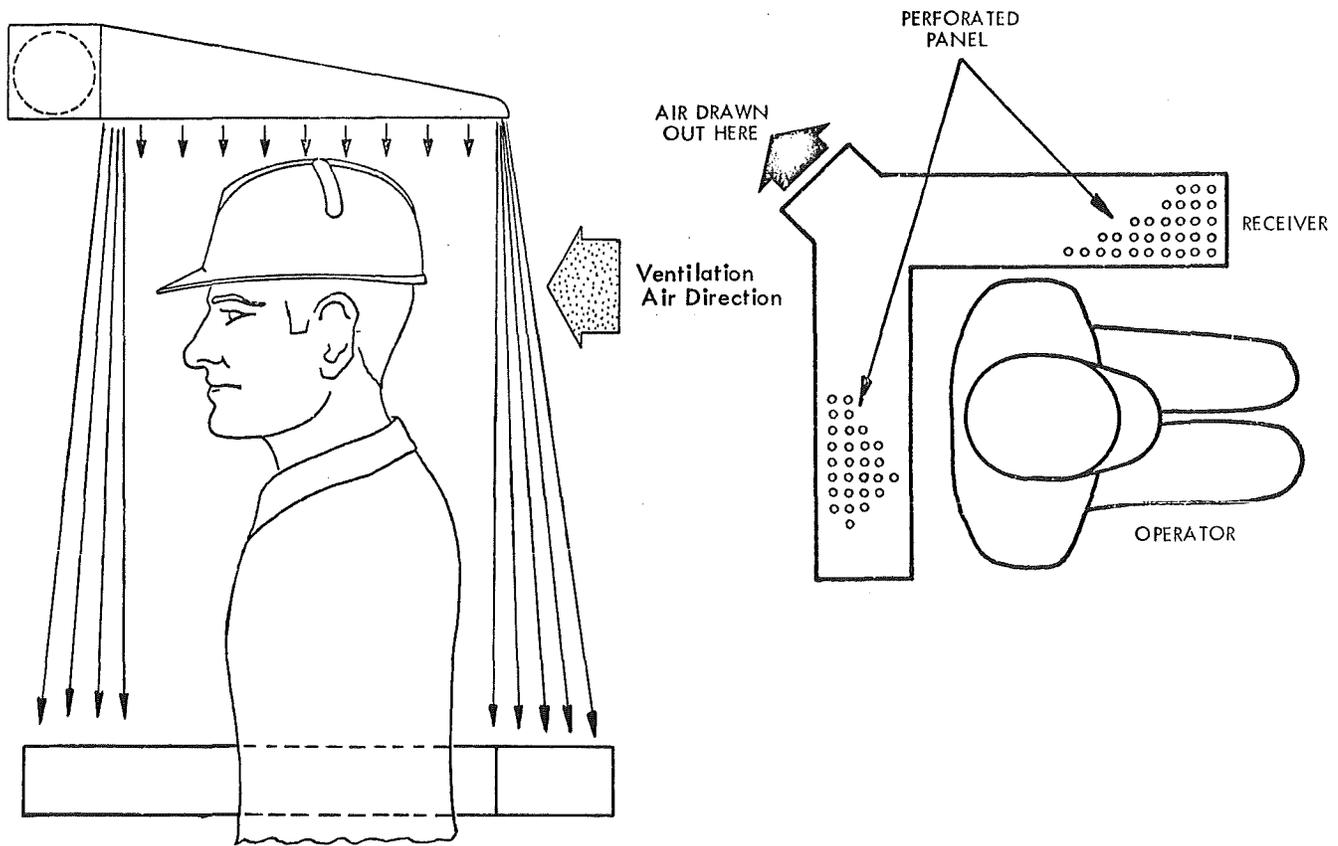


Figure 5-9. Use of a Receiver

Use of a Receiver - This concept consists of an L-shaped plenum located in the vicinity of the operator's waist. This was tested in conjunction with both the non-continuous outer jet and inner core only concepts. The intention of this concept is to provide better extension downward of the air curtain by drawing air through the plenum near the operator's waist. No distinct advantages were found for this concept, but several disadvantages are evident. The total airflow required is higher, additional hardware is required, and the location of the receiver could hinder movement of the operator of the mining machine. This concept was dropped from consideration.

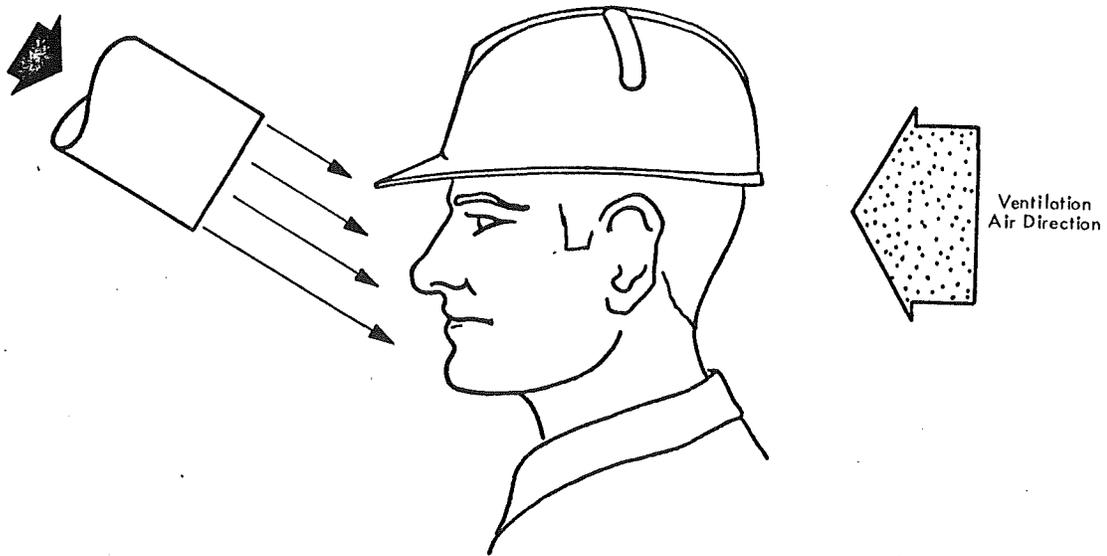


Figure 5-10. Breathing Zone (Straight 4 in. Pipe)

Breathing Zone (Straight 4 in. Pipe) - Four different "breathing zone" concepts were tested. The purpose was to reduce airflow required. This concept consisted of directing filtered air from a 4 in. diameter duct at the operator's breathing zone. The results were very poor even at airflows up to 200 cfm. Consequently, this concept was rejected.

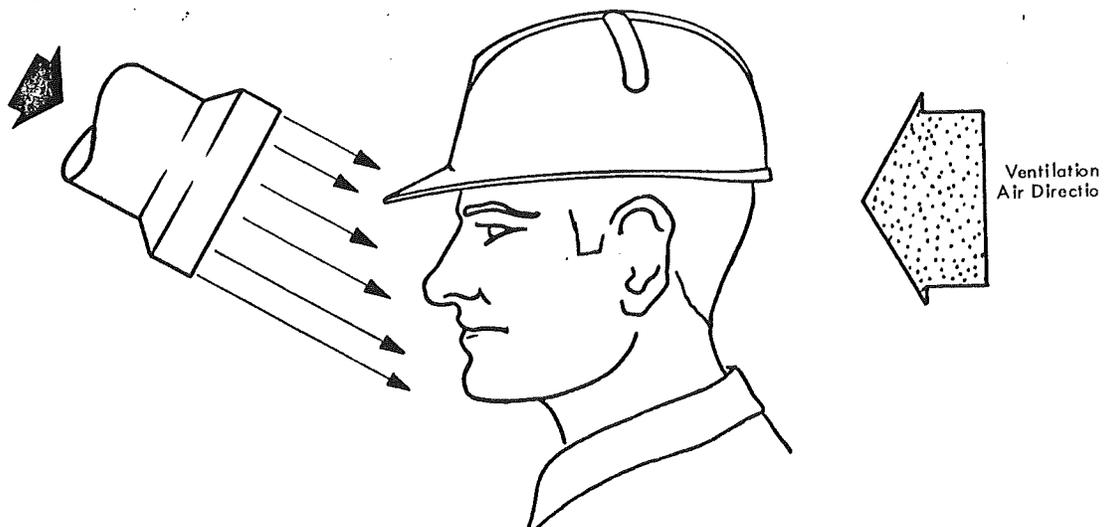


Figure 5-11. Breathing Zone (4 in. to 5-1/2 in. Adapter)

Breathing Zone (4 in. to 5-1/2 in. Adapter) - This concept was essentially the same as the breathing zone (straight 4 in. pipe) concept above except a 4 in. to 5-1/2 in. adapter was used to "spread" the airflow somewhat. This concept had the best performance of the four breathing zone concepts. However, even at 100 cfm the total penetrating concentration was  $2.46 \text{ mg/m}^3$ . This concept was dropped from further consideration.



Figure 5-12. Breathing Zone (4 in. Pipe with 3 in. Cone)

Breathing Zone (4 in. Pipe with 3 in. Cone) - This concept consisted of a 4 in. diameter duct with a 3 in. diameter cone 3-3/4 in. high fitted inside the outlet. Again, the intention was to "spread" the airflow over a larger area and also to provide a higher velocity. This concept was also rejected because of poor test results.

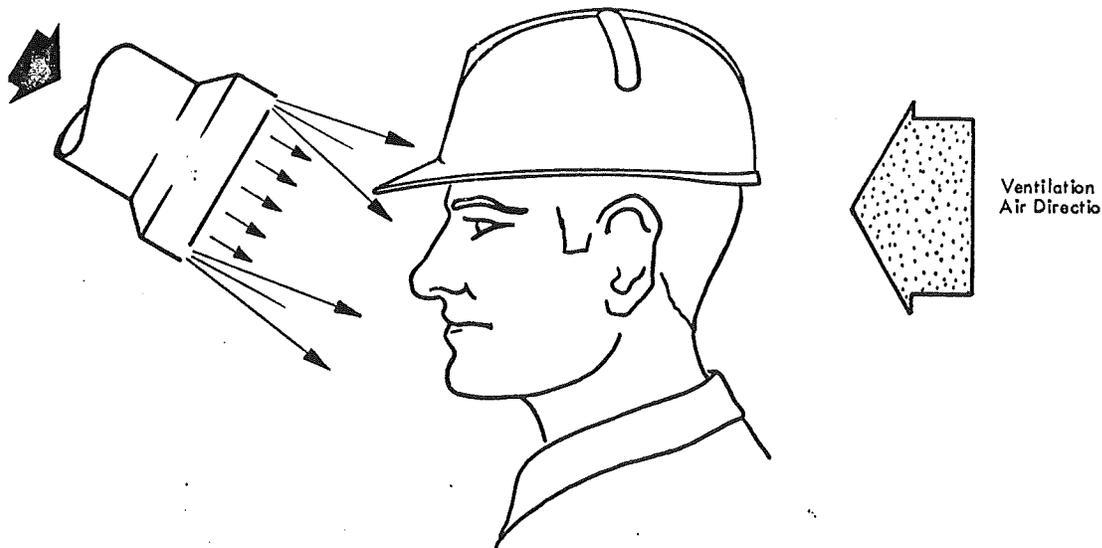


Figure 5-13. Breathing Zone (Adapter with Perforated Baffle)

Breathing Zone (Adapter with Perforated Baffle) - This concept consisted of a 4 in. to 5-1/2 in. adapter fitted with a circular perforated baffle having an open area of 13 percent. The diameter of the baffle was such that there was a 1/4 in. wide open slot around the periphery of the adapter. Here we tried to create a miniature continuous outer jet with continuous inner core concept. This concept was the poorest of the breathing zone concepts tested.

The concepts described on the previous pages can be compared by a numerical number which is the ratio of total airflow required to obtain a penetrating concentration of  $0.35 \text{ mg/m}^3$ . These values are listed below. A low ratio is desirable. Extrapolation from test data was used for some of the concepts.

<u>Concept</u>	<u>Ratio</u>
Continuous Outer Jet with Continuous Inner Core -	524
Non-Continuous Outer Jet with Continuous Inner Core -	344
Inner Core Only	268
Non-Continuous Inner Core Only	157
Dirty Outer Jet	1497
Use of Shield	726
Use of Receiver	206
Breathing Zone (Straight 4 in. Pipe)	1743
Breathing Zone (4 in. to $5\frac{1}{2}$ in. Adapter)	703
Breathing Zone (4 in. Pipe with 3 in. Core)	1412
Breathing Zone (Adapter with Perforated Baffle)	2457

Note that the receiver concept has a fairly low ratio (206). However, other features such as hinderance to the machine operator and complexity definitely detract from this concept. The non-continuous inner core concept had the lowest ratio and was chosen for the final design.

The second prototype model design was based on information gained from the first model. The first model was intended to prove feasibility of the various concepts, optimize open areas, and provide a model that was easily converted into different configurations. When the first model was designed, it was necessary to locate the inlet in the top of the unit. However, this does not lend itself to mounting on a mining machine canopy because of interference with the mine roof. Consequently, the second model was designed with a side inlet. A side inlet requires a shaded plenum to maintain an even airflow out of the diffuser. The second model was also made slightly larger to allow for more operator mobility. The second prototype inner core open area is 16.5 in. x 16.0 versus 14.5 in. x 14.5 in. for the first model. See Figures 5-14, 5-15 and 5-16 for the photographs of the second prototype model.

Tests on the second prototype model were aimed at determining optimum open areas, effects of canopy height and attitude, and effects of operator position. Most of the tests on the second prototype were performed with the unit in the non-continuous inner core configuration. However, this model also has an outer jet designed into it should higher ambient velocities be encountered. For the non-continuous inner core tests, this slot was simply blocked off as was a central portion of the inner core.

Tests were also performed to determine the effects of the inlet location relative to the ventilation air direction. The unit was tested with the inlet at the rear, at the front and at the side. The purpose was to give us supporting data should we find it necessary to orient the device in the canopy to improve visibility for the operator or simplify installation.

Additional tests performed were to determine the effects of a 300 ft/min interference jet versus 100 ft/min, effects of using a full-brim hat versus a bill-type hat, and airflow resistance of the second prototype. Test configurations and results are described below.

Effects of Inner Core Open Area - This test configuration was used to determine the best open area for the second prototype. Three different blocked-off areas of the 32 percent

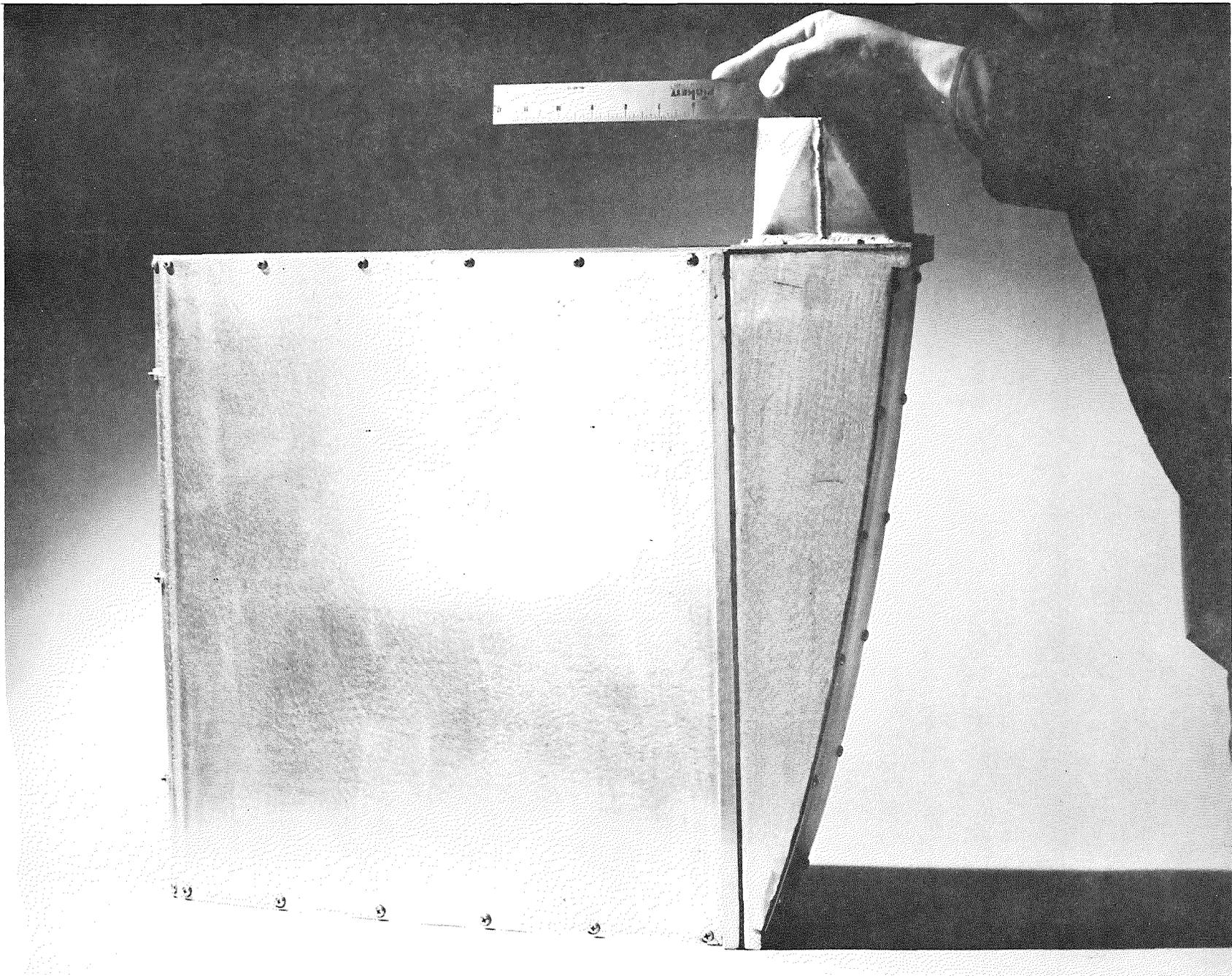


Figure 5-14. Second Prototype Model - Top View

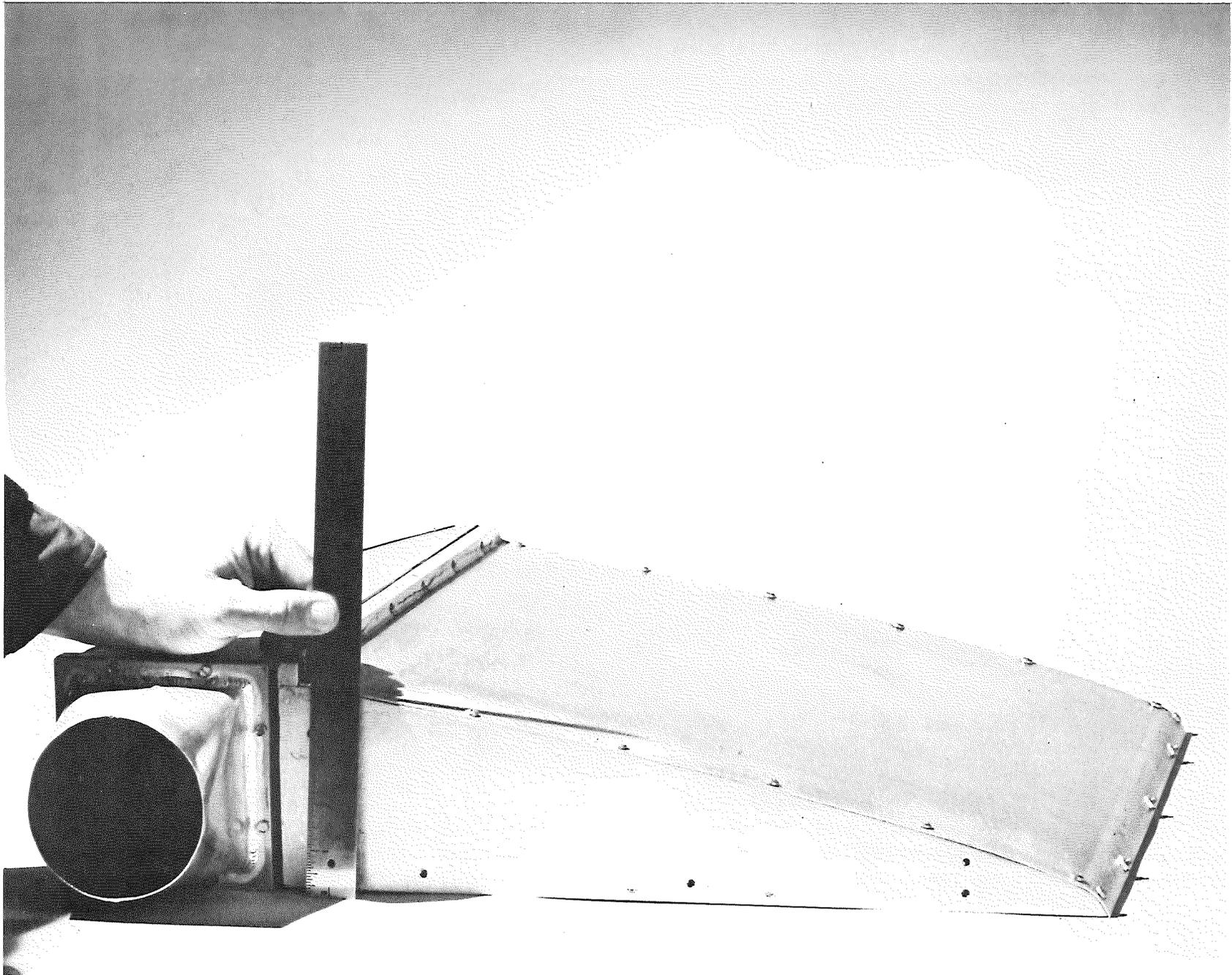


Figure 5-15. Second Prototype Model  
Side View

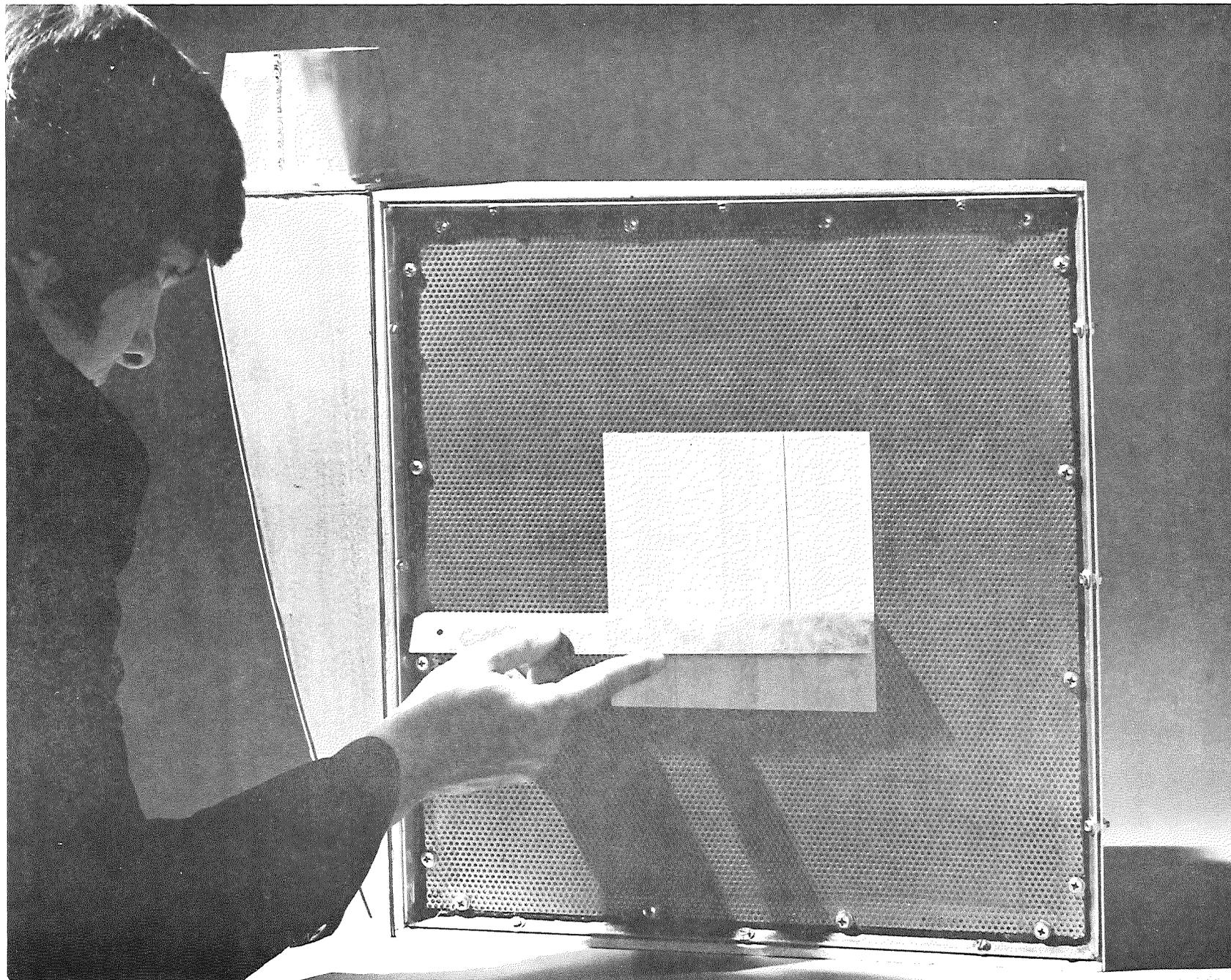


Figure 5-16. Second Prototype Model - Bottom View

open area perforated metal were tested (x and y). These were 9-7/8 in. x 10-1/4 in., 9-1/8 in. x 9-13/32 in., and 6-7/8 in. x 6-7/8 in. The best of the three was found to be 6-7/8 in. x 6-7/8 in. In addition, three different densities of spun-bonded backing material for the 32 percent perforated metal were tested - 14 mil, 20 mil and 25 mil CEREX. The best results were obtained using 25 mil CEREX. Finally, tests were performed to see if we could eliminate the CEREX backing by using a perforated metal with a lower percentage open area. We tested a 5 percent open area which has almost the same airflow resistance as the 32 percent perforated metal with 25 mil CEREX. However, this did not perform as well.

Effects of Direction Operator Facing - This test configuration was used to determine the effects of direction the operator is facing or the direction of the mine ventilation air. Tests have shown that when the operator is facing away from the interference jet there is less penetration of coal dust into the lungs. Facing the interference jet results in about 2-1/2 times as much respirable dust penetration as facing away from the interference jet. However, the effectiveness is still within the requirement of 0.5 mg/m<sup>3</sup> respirable penetration.

Effects of Air Curtain Angles - Tests were conducted on the device at a 13-degree angle. We decided to put the air curtain into the canopy at this angle in order to gain head clearance. Also, on canopies which have adjustable jacks, the canopy can be positioned at such an angle. The test results indicate a slight degrading effect on the performance because of the angle. A curtain angle of 0° results in a total coal dust penetration concentration of 0.10 mg/m<sup>3</sup> average. For an angle of 13°, the results were 0.17 mg/m<sup>3</sup> average.

Effects of Hat Brim Distance - When the air curtain angle is 13°, the operator is facing away from the interference jet and the vertical distance from the mouth to the perforated metal is about 24 in. The best location of hat brim distance is 6 in. All hat brim distances were measured using an MSA COMFO<sup>®</sup> Cap, unless otherwise specified. The hat brim distance is the horizontal distance between the outside edge of the perforated metal and the edge of the bill on the hat. However, when one compares the respirable dust penetration data, there is no significant difference in penetration between a hat brim

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<sup>®</sup> COMFO-Cap is a registered trademark of MSA.

distance of 4 in. and 8-1/2 in. ( $0.38 \text{ mg/m}^3$ ).

Effects of Distance Below Air Curtain - The vertical distance between the surface of the perforated metal and the mouth of the operator was varied from 11-3/4 in. down to 24 in. The distance of 11-3/4 in. provides a hat clearance of 2 in. and 24 in. provides about 14 in. However, studies of canopies at Old Ben, Freeman and Peabody mines indicated even less hat clearance than 2 in. The effects of hat distance were determined for both a 0-degree air curtain angle and a 13-degree angle. The test data shows that when the hat clearance is about 3 in., 189 cfm is the minimum airflow required. At least 236 cfm is needed to meet the required  $0.5 \text{ mg/m}^3$  respirable dust penetrating concentration at the "worst case" conditions of 13 degree canopy angle and distance to mouth of 24 in.

Comparison of Second Prototype to First Model When Used in the Non-Continuous Outer Jet Configuration - These tests were conducted to determine the best open areas for the second prototype when used in the non-continuous outer jet configuration. They also give a comparison of effectiveness to the first model. It was found that the second prototype did not work as well as the first model but still meets the contract requirement of  $0.5 \text{ mg/m}^3$  respirable dust penetration when 295 cfm is used and the ambient velocity is 100 ft/min or less. An airflow of 295 cfm was used because that was the least airflow used with success on the first model. The best performance for the second prototype was without any area blocked off on the inner core and the slot width at 0.050 in. The respirable dust penetration for the first model was  $0.19 \text{ mg/m}^3$  and the second was  $0.48 \text{ mg/m}^3$ .

Effects of 13° Angle Direction Relative to Ventilation Air Direction - Test position with the device tilted back was tested because it affords better visibility than with the device tilted forward. The test results indicate that when the device tilted back is used at 189 cfm, the performance is degraded. However, when 236 cfm is used, the performance is better than with the device tilted forward. These tests were conducted using both the second prototype and the low profile model. The low profile model did not work as well as the second prototype, however. Hat brim distances were also varied for the device tilted back. The best results were for a hat brim distance of 2-1/8 in. The requirement of  $0.5 \text{ mg/m}^3$  respirable dust penetration can be met using either 189 cfm or 236 cfm for

the device tilted back. However, the penetrating concentration is cut in half by using 236 cfm for the low profile model and by much more for the second prototype.

Effect of 13° Angle and Inlet on Operator's Left Side - This orientation was tested because certain applications may require this for duct routing, visibility, or simply ability to fit the particular canopy. In addition, it was noted at Old Ben mine (Goodman boring machine) that the operator often leans out of the cab to his right side. This orientation would help to protect the operator when he is leaning out because the airflow is directed in the same direction he is leaning. Tests indicated that 236 cfm is needed for this orientation. Also, it was found that better results are achieved when the distance to the center of the hat shown above is shifted 2-7/8 in. to the right of the air curtain center rather than right on center.

Effects of Full-Brim Miner's Hat - An MSA 454712 TOPGARD® full-brim hat was used for these tests. All other tests were conducted using an MSA 82769 COMFO-Cap which is a bill-type hat. The second prototype was used for these tests. For purposes of comparison, the operator's mouth was in the same position for both hat types. The performance of the air curtain was degraded considerably because of the full-brim hat. Tests indicated average total dust penetrations of 2.3 mg/m<sup>3</sup> to 6.3 mg/m<sup>3</sup> depending on the hat brim distance. This is well above the performance of the bill-type hat which results in concentrations below 0.5 mg/m<sup>3</sup> for total spectrum penetrating concentrations.

Effect of 300 ft/min Interference Jet - Three air curtain concepts were tested using a contaminant interference jet velocity of 300 ft/min: Non-continuous inner core only, inner core only, and the non-continuous outer jet. The non-continuous outer jet concept worked the best. The other two were very poor. The best results for this concept when using 295 cfm was a respirable dust penetration of 0.75 mg/m<sup>3</sup>. This does not meet the 0.5 mg/m<sup>3</sup> goal. With airflows above 295 cfm, the device should meet the goal when using a 300 ft/min ambient velocity. All other tests were performed with a 100 ft/min interference jet.

Airflow Resistance Tests - Airflow resistance tests were conducted on both the second prototype and the low profile model. At the airflow we are going to use in underground tests (up to 250 cfm), the airflow resistance is well within the capacity of the Cincinnati PB-9

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blower we have selected for Phase II hardware. The airflow resistance for the second prototype with one 90° elbow included is 1.16 in. wg at 200 cfm and 1.56 in. wg at 250 cfm, (see Figure 5-17). When a total of two 90° elbows, one 45° bend, and 5 feet of 4 in. dia hose are included into the restriction, the resistance is 1.97 in. wg at 200 cfm and 2.80 in. wg at 250 cfm. These elbows, bends and hose are anticipated for the Goodman boring machine interface. The restriction of the low profile model was somewhat higher. With a straight 3 in. pipe into the inlet, the restriction was 1.50 in. wg at 200 cfm and 1.95 in. wg at 250 cfm. (See Figure 5-18)

### 5.3 Low Profile Model

Following the interface studies made at Old Ben, Freeman and Peabody mines, it was determined that head clearance and visibility is a problem. Consequently, a low profile model was fabricated and tested in the non-continuous inner core configuration. The open area of the inner core was the same as for the second prototype. However, the plenum depth was reduced from 4 in. for the second prototype to 3 in. for the low profile model. Tests were performed to compare the effectiveness of the two models. The low profile model did not perform as well as the second prototype; however, it is still within the requirement of 0.5 mg/m<sup>3</sup> respirable penetration. Both models utilized the same inner core open areas and dimensions. Results for the second prototype were as low as 0.08 mg/m<sup>3</sup> total penetrating concentration, but for the low profile the lowest was 0.63 mg/m<sup>3</sup> when using 236 cfm.

### 5.4 Underground Test Sites and Interface Information

Agreement for underground tests was obtained from three different coal mines in Phase I. Visits were made to Old Ben, Freeman and Peabody Coal Mines in order to obtain interface information on the mining machines to be tested during Phase II.

At Old Ben Mine #21 information was obtained on the Goodman boring machine. A mock-up of the Cincinnati PB-9 blower with hydraulic motor and filter was brought into the mine as an aid in determining a suitable mounting location. Measurements were taken of the canopy and the area behind the boring motor. The hydraulic hookup was

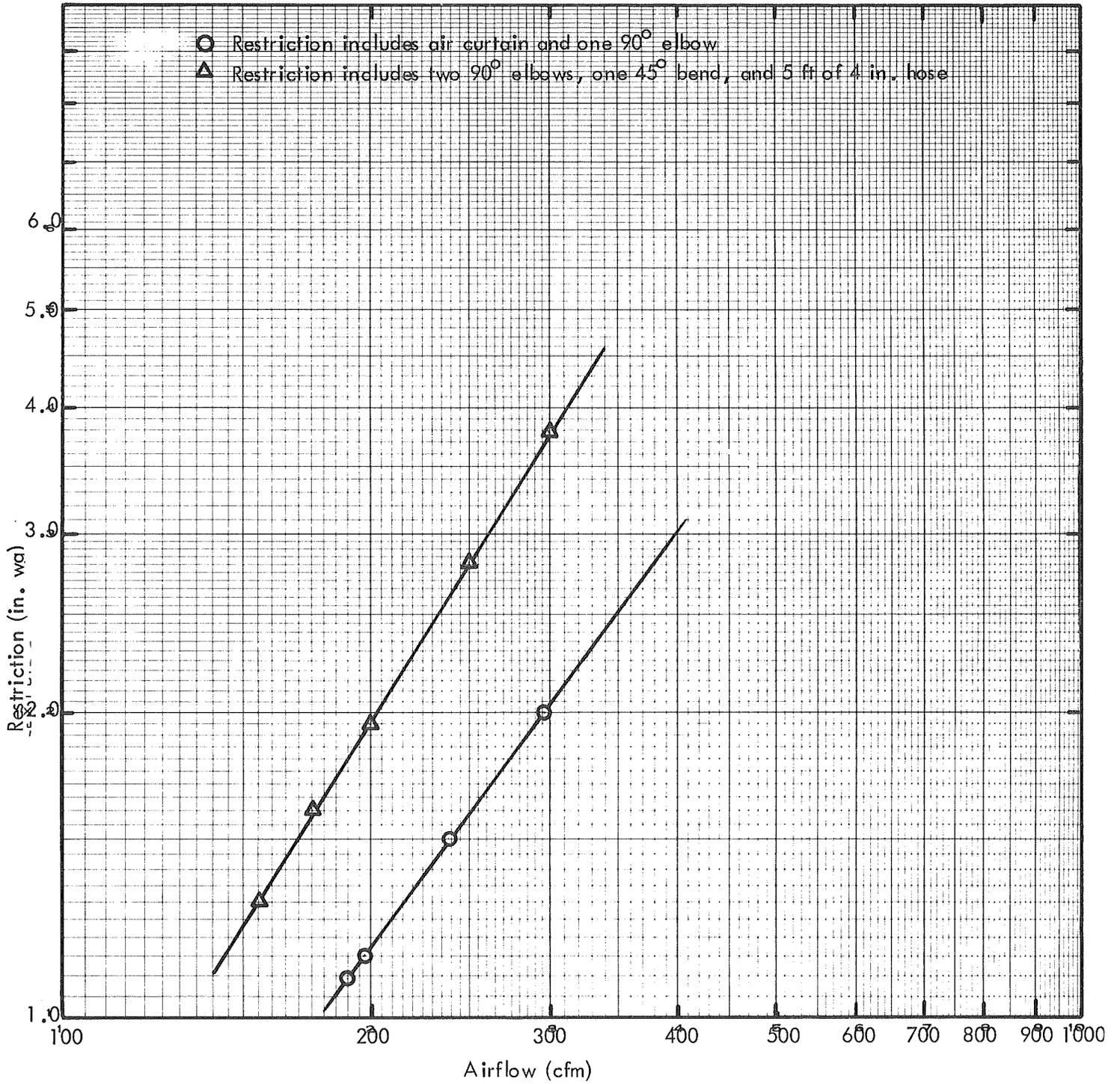


Figure 5-17. Restriction of Second Prototype (Non-Continuous Inner Core)

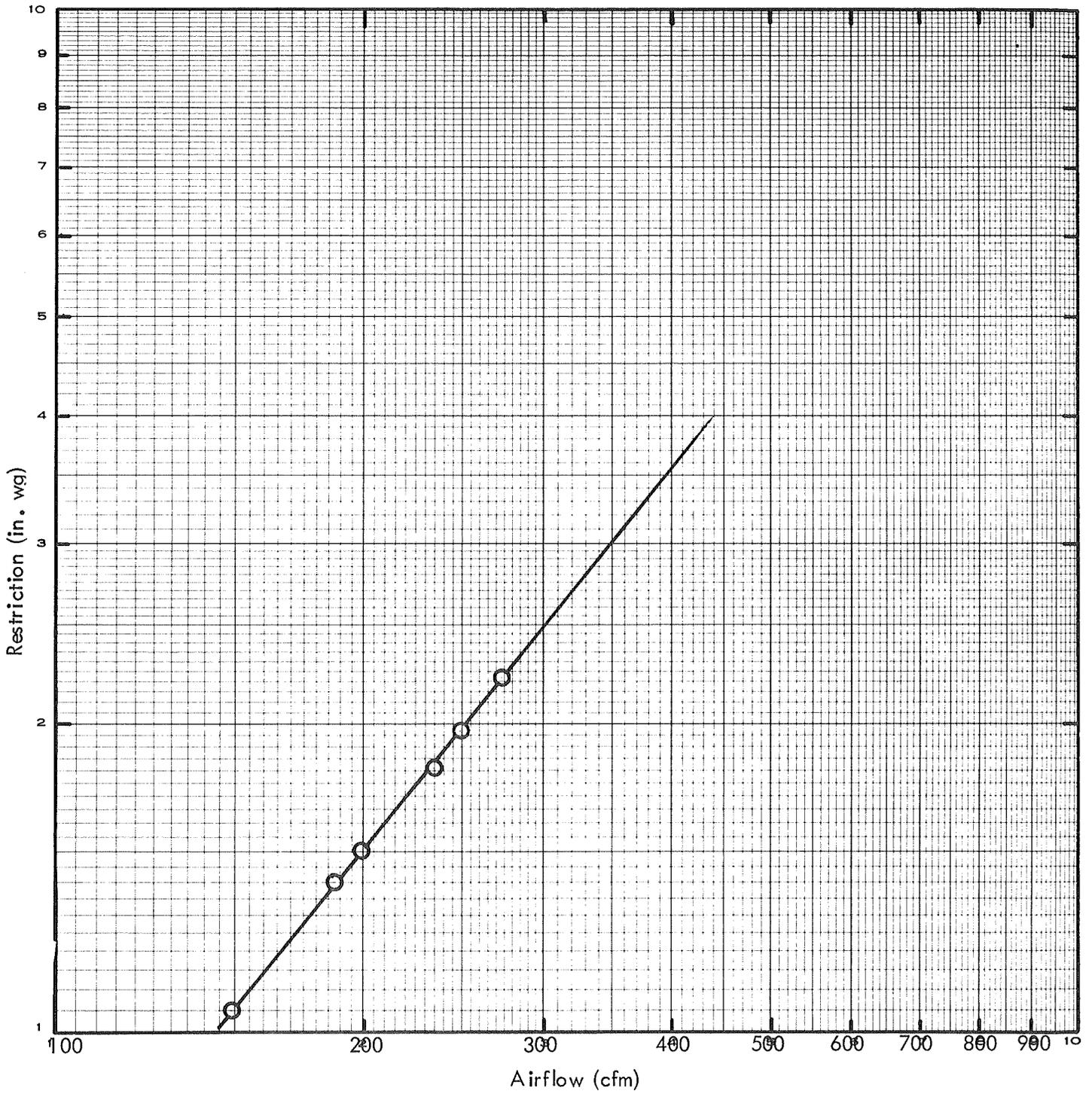


Figure 5-18. Restriction of Low Profile Model (Non-Continuous Inner Core)

also determined. The head clearance on this machine from the top of the miner's cap to the inside of the canopy is about 3-1/2 in. This is a fixed canopy so there is no problem with adjustment. The depth of the canopy is 3 in. The air curtain device will have to be mounted in the canopy at a 13° angle with the inlet at the back of the inlet at the left side. If the inlet is as the front, then the operator has visibility problems. The hydraulic power can be taken from a pump which actuates the automatic greaser. This pump has a capacity of 7 gpm at 1900 psi. Our requirements will be about 2 or 3 gpm at 600 to 700 psi. The blower package will be mounted just behind the boring motor. This location affords some protection from rock falls.

The machine to be used for test at Freeman mine (Orient #3) is the Jeffrey Heliminer. Due to lack of available space, the blower package will have to be placed on top of the machine in front of the operator. The blower will require a protective cover. Head clearance was also a problem. We can possibly lower the seat to improve this. The canopy has twin adjustable jacks; however, they are usually kept at the lowest position.

Measurements were taken and hydraulic power determined. Hydraulic power can be taken from a pump which actuates the auger extension and the canopy jacks. This pump puts out 3.7 gpm at 500-3000 psi.

The machine at Peabody #10 was the Joy 12 CM Continuous Miner. Measurements were taken and a drawing of the canopy was obtained. The canopy is adjustable in that it has a series of holes in the corner posts for pins. However, they keep the canopy as low as possible. The head clearance is minimal. A mock-up of the blower was used to determine a location for the blower. The only place for the blower package is in front of the operator's station, just ahead of a protective cover for the controls. It also would fit under the seat, but this is not desirable because of a need for accessibility to other various items under the seat. The hydraulic power can be taken from the pump for the scrubber. This pump puts out about 38 gpm at 1500 psi.

The hydraulic circuit for the blower is shown on Figure 5-19. This sketch includes the blower, hydraulic motor, pressure relief valve and the flow control. This arrangement will be used on all three applications described above.

5-27

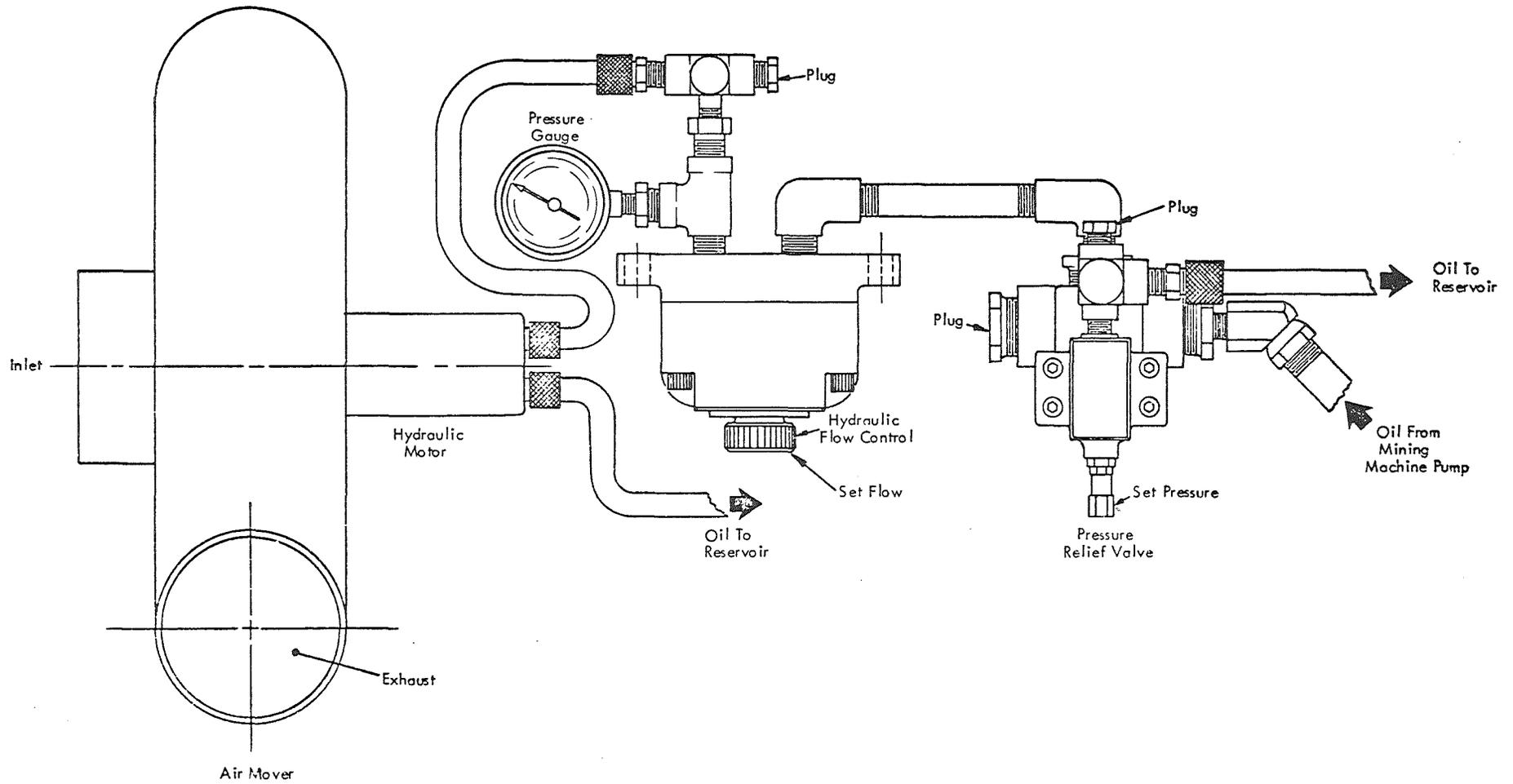


Figure 5-19. Hydraulic Circuit for Blower Package

5.5

Air Mover/Filter Package

The air mover and filter package selection was based on size, power requirements and noise operation. Two different blowers can be used for the underground tests - a Cincinnati PB-8 and PB-9. A tabulated comparison of those two blowers is shown below. The PB-8 is the smaller of the two. However, note that we can run at a lower rpm, can probably reduce noise, reduce hydraulic flow required and will need less horsepower.

Table 5-1. Cincinnati Blower

Blower No.	Airflow (cfm)	Static Pressure (in. wg)	RPM	BPH	Height (in.)	Width (in.)	Depth (in.)
PB-8	200	6	4337	0.509	11.00	10.00	3.50
PB-9	200	6	3753	0.385	14.25	13.25	3.75

The hydraulic motor will be a Stanley Hydraulic Tools hydraulic motor, 300,000 series. This motor requires about 2.3 gpm at 4000 rpm and 500 psi. It develops about 0.4 horsepower at 4000 rpm and 500 psi.

The filter element will be a standard Donaldson Company washable filter (No. P11-8340). The filter medium, a standard commercial filter paper, is the same as we used on Contract No. HO122087, Air Curtain Respiratory Protective Device. The clean restriction of this element at 200 cfm is about 0.15 in. wg. This filter has a restriction rise of 4 in. wg in about 10 mine shifts if the full-spectrum coal dust concentration is 33 mg/m<sup>3</sup>. The filter can be changed or washed.

Under Contract HO122087, this media showed a 99.74 percent efficiency on respirable dust and a 99.99 percent efficiency on full-spectrum dust. The tests conducted to determine the efficiency used a coal dust concentration of 33 mg/m<sup>3</sup>. The particle size distribution ranged up to 70 microns with 5 mg/m<sup>3</sup> being respirable dust. The efficiency of this medium is well within the allowable limits required to maintain the respirable dust concentration at a level far below the contract requirement of 0.5 mg/m<sup>3</sup>. Figure 5-20 shows the air mover/filter package using the PB-8 blower.

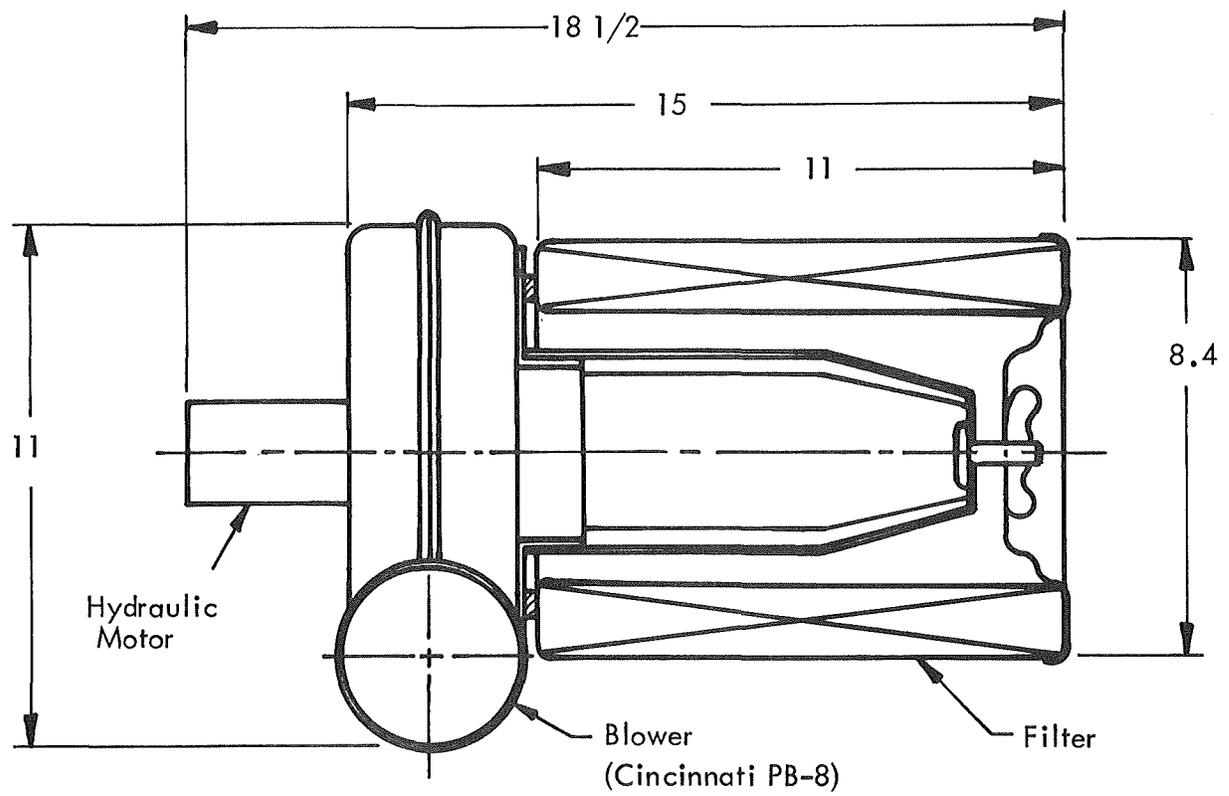


Figure 5-20. Air Mover/Filter Package

Work in Phase II consisted of further refinement of the Phase I air curtain, air mover and filter element performance tests, design and fabrication of the Phase II air curtain, laboratory and underground tests on the Phase II device and build-up of a demonstration model. The following pages describe the work involved in each of these tasks.

### 6.1 Tests on Phase I Air Curtains

Before design and fabrication of the Phase II air curtain, more tests were run with the second prototype and low profile model fabricated in Phase I. These tests, as reported below, resulted in further refinement of the Phase I air curtain.

#### 6.1.1 Low Profile Model

The spun-bonded CEREX material used to back the perforated metal on the Phase I air curtains was determined to be undesirable from a maintenance standpoint. It was anticipated that coal dust could easily plug this material and impair the air curtain efficiency. Consequently, testing was performed on various perforated panel configurations to eliminate the CEREX backing material prior to design of the Phase II air curtain. The inner core of the low profile model was fitted with 5 percent open area perforated metal without CEREX backing (1/16 in. dia holes on 1/4 in. centers, staggered pattern). The data, as shown on Table 6-1, indicated poor results (not within the goal of 0.5 mg/m<sup>3</sup> respirable dust penetration).

Table 6-1. Low Profile Model with 5 Percent Perforated Metal  
(1/16 in. dia holes, 1/4 in. centers, staggered pattern)

Airflow (cfm)	Test Position	Curtain Angle	Hat Brim Distance (in.)	Distance to Mouth (in.)	Penetrating Concentration (mg/m <sup>3</sup> )	
					GCA	Gravimetric
236	facing away	13° left	2-7/8 rt center	12-15/16	off scale	10.59 tot, 1.54 resp
236	facing away	13° left	2-7/8 rt center	12-15/16	off scale	10.17 tot
236	facing away	13° left	2-7/8 rt center	12-15/16	off scale	10.65 tot

### 6.1.2

### Second Prototype Model

Tests were subsequently continued with the second prototype model in order to find a substitute for the CEREX backing material and to optimize the configuration prior to Phase II hardware design. The following parameters were varied on the first set of tests:

- Percent open area of the perforated metal
- Use of 80 mesh screen as replacement for CEREX backing material
- Use of no backing material
- Alignment of staggered hole pattern of the perforated metal relative to the interference jet direction
- Orientation of the face of the perforated metal

The orientation of the face of the perforated metal was varied to determine the effect of the perforated metal hole shape on efficiency. Because the perforated metal is punched from sheet metal, one side of each individual hole has a bell shape and the opposite side has a burr from the die breakout. Figure 6-1 shows the location of the bell shape relative to the airflow direction. The "bell-up" configuration resulted in better efficiency by a factor of approximately 2.

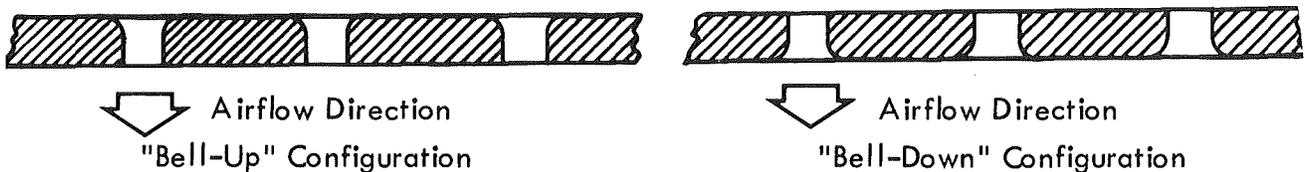


Figure 6-1. Effects of Airflow Direction Through Perforated Metal

Figure 6-2 illustrates alignment of the staggered hole pattern relative to the interference jet direction. When the holes are aligned "perpendicular" to the interference jet direction, efficiency is better than when "parallel" by a factor of approximately 1.5. As illustrated in Figure 6-2, when the holes are aligned perpendicularly, the path between the holes decreases. The closer spacing apparently presents a better barrier to the dirty interference jet.

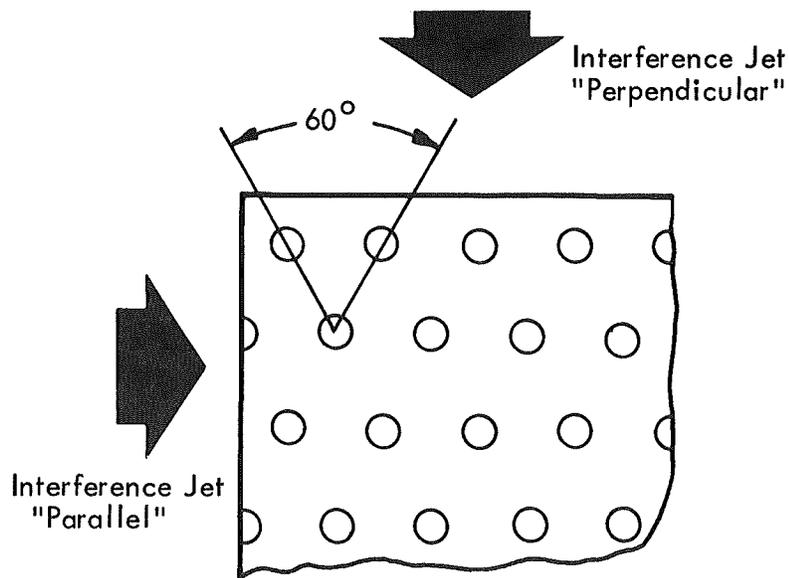


Figure 6-2. Effects of Hole Pattern Orientation

The following percent open area perforated metal panels were tested:

- 5 percent open without backing  
(1/16 in. diagonal holes, 1/4 in. centers)
- 32 percent open with 80 mesh screen  
(3/32 in. staggered holes, 5/32 in. centers)
- 22-1/2 percent open with 80 mesh screen  
(1/16 in. staggered holes, 1/8 in. centers)
- 13 percent open with 80 mesh screen  
(3/32 in. staggered holes, 1/4 in. centers)
- 13 percent open without backing  
(3/32 in. staggered holes, 1/4 in. centers)

The best results were with 13 percent open perforated metal backed with 80 mesh screen. The 80 mesh screen has a particle retention or opening width of 0.007 in. (180 microns). The plugging problems noted when using CEREX backing material should not occur with this screen.

Table 6-2 presents data which indicates the following diffuser configuration to be the best of these tested: 13 percent open perforated metal backed with 80 mesh screen, the bell side up, and the hole pattern located perpendicular to the interference jet direction. All the tests were with the mannequin facing away, the curtain angle at 0°, a hat brim distance of 4 in. and the distance to the mouth at 11-3/4 in. In addition, a 6-7/8 in. x 6-7/8 in. area in the middle of the inner core was blocked.

A second set of tests were performed to determine if 100 mesh screen would perform better than 80 mesh and if 22-1/2 percent perforated metal in the inlet plenum would work better than 32 percent. Table 6-3 presents this set of data. If Test No.'s 1 and 2 are compared with 3 and 4, it can be seen that 80 mesh screen is better than 100 mesh. A comparison of Test No.'s 3 and 4 with 5 and 6 shows that 32 percent perforated metal in the inlet plenum is better than 22-1/2 percent. Finally, a comparison of Test No.'s 7 and 8 with 9 indicates that when using 32 percent perforated metal backed with 80 mesh screen, the "bell down" orientation of the diffuser is better than the "bell-up". This is just the opposite when 13 percent perforated metal is used.

### 6.1.3 Full-Scale Chamber Concentration

A calibration check of the full-scale chamber ambient concentration was performed again during Phase II as was done in Phase I. The results indicated concentrations close to the required 5.0 mg/m<sup>3</sup> respirable concentration. Table 6-4 presents these results.

Table 6-4. Full-Scale Chamber Concentration

Interference Jet Velocity (ft/min)	Feed Concentration (mg/m <sup>3</sup> )	Chamber Concentration (mg/m <sup>3</sup> )	
		Total	Respirable
* 100	262	51.38	5.32
* 100	262	45.00	—
100	262	65.76	4.82
100	262	66.58	7.63

Table 6-2. Non-Continuous Inner Core (Second Prototype)

Test No.	Airflow (cfm)	Perforated Metal	Screen	Bell Direction	Hole Direction	Penetrating Concentration (mg/m <sup>3</sup> )	
						GCA	Gravimetric
1	236	5%	none	bell up	not applicable	1.58 tot	10.44 tot, 1.53 resp
2	236	5%	none	bell up	not applicable	2.16 tot	9.69 tot
3	236	32%	80 mesh	bell down	parallel	0.24 tot	0.54 tot, 0.12 resp
4	236	32%	80 mesh	bell down	parallel	0.19 tot	0.48 tot
5	189	32%	80 mesh	bell down	parallel	1.23 tot	2.84 tot, 0.53 resp
6	189	22-1/2%	80 mesh	bell down	perpendicular	1.20 tot	3.42 tot, 0.63 resp
7	189	22-1/2%	80 mesh	bell down	perpendicular	1.25 tot	3.10 tot
8	236	22-1/2%	80 mesh	bell down	perpendicular	1.18 tot	3.56 tot, 0.66 resp
9	236	22-1/2%	80 mesh	bell down	perpendicular	1.05 tot	3.39 tot
10	236	13%	80 mesh	bell up	perpendicular	0.09 tot	0.40 tot, 0.09 resp
11	236	13%	80 mesh	bell up	perpendicular	0.09 tot	0.39 tot
12	189	13%	80 mesh	bell up	perpendicular	0.12 tot	0.55 tot, 0.10 resp
13	189	13%	80 mesh	bell up	perpendicular	0.17 tot	0.55 tot
14	189	13%	none	bell up	perpendicular	2.54 tot	15.22 tot, 2.22 resp
15	189	13%	none	bell up	perpendicular	2.40 tot	14.40 tot
16	189	13%	80 mesh	bell up	parallel	0.10 tot	0.91 tot, 0.17 resp
17	189	13%	80 mesh	bell up	parallel	0.12 tot	0.91 tot
18	189	13%	80 mesh	bell down	perpendicular	0.28 tot	1.12 tot
19	189	13%	80 mesh	bell down	perpendicular	0.31 tot	1.17 tot, 0.20 resp
20	236	13%	80 mesh	bell down	perpendicular	0.32 tot	0.96 tot, 0.20 resp
21	236	13%	80 mesh	bell down	perpendicular	0.38 tot	0.95 tot
22	189	13%	none	bell down	perpendicular	2.63 tot	13.99 tot, 2.44 resp
23	189	13%	none	bell down	perpendicular	2.45 tot	12.78 tot

6-5

To see the effect of the 80 mesh screen, compare test no's 12 and 13 to 14 and 15. The effects of hole pattern orientation relative to the interference jet are shown by comparing test no's 12 and 13 to 16 and 17. Finally, the effects of the bell direction are shown by comparing test no's 12 and 13 to 18 and 19.

Table 6-3. Non-Continuous Inner Core (Second Prototype)

Test No.	Airflow (cfm)	Perforated Metal (Diffuser)	Perforated Metal (Inlet)	Screen	Bell Direction	Hole Direction	Penetrating Concentration(mg/m <sup>3</sup> )	
							GCA	Gravimetric
1	189	13 percent	32 percent	100 mesh	bell up	perpendicular	0.28 tot	0.81 tot
2	189	13 percent	32 percent	100 mesh	bell up	perpendicular	0.33 tot	0.78 tot
* 3	189	13 percent	32 percent	80 mesh	bell up	perpendicular	0.12 tot	0.55 tot, 0.10 resp
* 4	189	13 percent	32 percent	80 mesh	bell up	perpendicular	0.17 tot	0.55 tot
5	189	13 percent	22-1/2 percent	80 mesh	bell up	perpendicular	0.09 tot	0.58 tot
6	189	13 percent	22-1/2 percent	80 mesh	bell up	perpendicular	0.28 tot	0.59 tot
7	189	32 percent	32 percent	80 mesh	bell up	perpendicular	1.21 tot	3.21 tot
8	189	32 percent	32 percent	80 mesh	bell up	perpendicular	1.15 tot	3.59 tot
* 9	189	32 percent	32 percent	80 mesh	bell down	parallel	1.23 tot	2.84 tot, 0.53 resp

\* Reported on Table 6-2

The Cincinnati PB-9 blower with the Stanley Hydraulic Tools hydraulic motor was tested. The purpose of these tests was to determine filter element clean restriction, the hydraulic oil flow, pressure and blower rpm needed when the filter element is clean and when the restriction has risen by 4.0 in. wg, and how many hydraulic flow adjustments would be needed during underground tests to account for 4.0 in. wg restriction of the filter element.

The filter element, Donaldson element P11-8340, has a clean restriction at 250 cfm of 0.3 in. wg. Table 6-5 shows the oil flow, hydraulic pressure and rpm needed to start at 254 cfm and drop to 189 cfm with a filter restriction rise of 4.0 in. wg. Higher filter restriction can be accommodated by running the hydraulic motor at higher speeds; however, noise levels and hydraulic oil flow requirements would also increase.

Table 6-5. Oil Flow, Hydraulic Pressure and rpm Determination

Airflow (cfm)	Filter Restriction (in. wg)	Blower Speed (rpm)	Oil Flow (gpm)	Hydraulic Pressure (psi)
189	4.2 (dirty)	4100	1.72	375-450
254	0.3 (clean)	3550	1.50	350-450

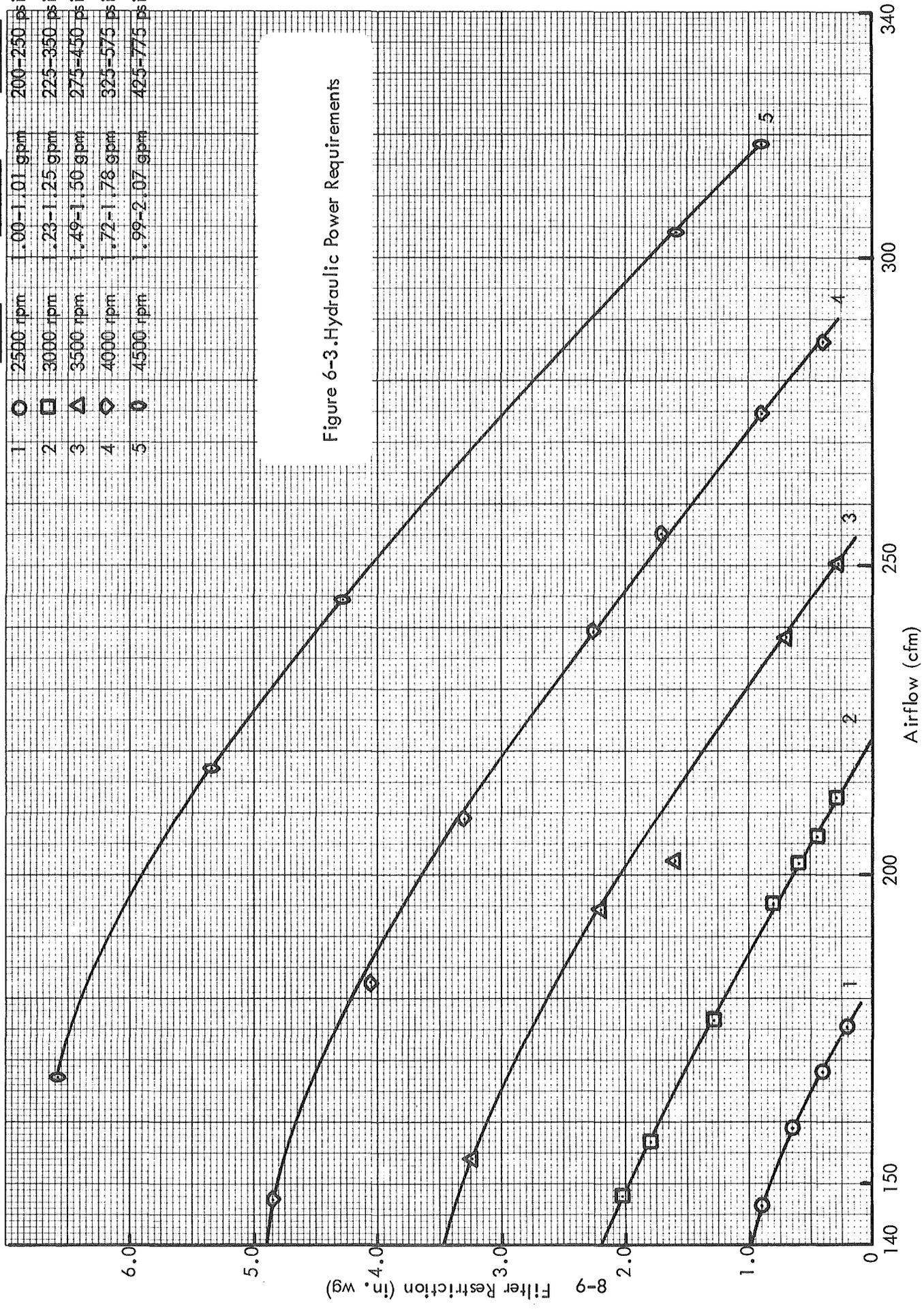
The hydraulic pressure on Table 6-5 is the pressure needed at the motor. The hydraulic flow control valve requires an additional 200 psi, or a total of about 650 psi, from the mining machine. This is well within the capacity of the mining machines we are going to use for underground tests. The oil flow is also well within the capacity of these machines.

Figure 6-3 presents the data taken for filter restriction rise versus blower airflow for blower speeds from 2500 rpm to 4500 rpm. The flow control valve maintains the motor speed by maintaining the oil flow. Curve number 3, for a blower speed of 3500 rpm indicates that if we start out at about 250 cfm with a clean filter, we can account for about 2.1 in. wg of restriction rise without adjusting the flow control valve. Beyond this, the airflow will drop below 190 cfm and the air curtain efficiency will drop below acceptable levels. Consequently, one adjustment in the flow control would be necessary before the filter is changed.

An alternative to the above would be to start the blower at about 4000 rpm and 287 cfm when the filter is clean and let it follow curve number 4 on Figure 6-3. This would

	Speed	Oil Flow	Pressure
1	2500 rpm	.00-1.01 gpm	200-250 psi
2	3000 rpm	.23-1.25 gpm	225-350 psi
3	3500 rpm	.49-1.50 gpm	275-450 psi
4	4000 rpm	.72-1.78 gpm	325-575 psi
5	4500 rpm	.99-2.07 gpm	425-775 psi

Figure 6-3. Hydraulic Power Requirements



eliminate the need to adjust the flow control; however, the higher airflow would load the filter element more quickly and necessitate more frequent element replacement.

Figure 6-4 is a schematic of the test setup for these tests. This schematic shows that a valve was used downstream of the PB-9 blower to simulate the Phase II air curtain restriction. The restriction was set at 2.0 in. wg at 189 cfm. This restriction is close to the second prototype model with two 90° elbows, one 45° bend and five feet of 4 in. hose.

The filter restriction was also simulated by progressively closing off a portion of the element with tape. The pressure tap was installed in the end of the element to monitor the restriction. Each element used for underground tests had a pressure tap so that we could monitor restriction rise versus operation time.

### 6.3 Filter Element Tests

Dust loading tests were performed on the filter element design to be used in the underground tests. Full spectrum coal dust was fed to the element at a concentration of 100 mg/m<sup>3</sup>. Two different airflows were used -- 200 cfm and 250 cfm. This range of airflows is anticipated during the underground tests as the filter element restriction versus time for 200 cfm and 250 cfm are shown on Figure 6-5. At 250 cfm it takes about 13.3 hours to get a restriction rise of 4.0 in. wg. These times can be multiplied by 3 if the dust concentration encountered in the underground tests are 33 mg/m<sup>3</sup> rather than 100 mg/m<sup>3</sup>. The collection efficiency of the filter element was found to be 99.92 percent at 200 cfm on full spectrum coal dust. Consequently, this medium is well within the allowable limits required to maintain the respirable dust concentration at a level far below the contract requirement of 0.5 mg/m<sup>3</sup>.

### 6.4 Phase II Air Curtain Laboratory Tests

Four Phase II air curtains were fabricated for tests. One was used for laboratory tests and three were used in underground testing. The laboratory tests will be described in this section. These tests consisted of airflow resistance tests, noise tests, and dust deflection tests. Figures 6-6 and 6-7 depict the Phase II air curtain and the blower/filter combination. The filter element is a Donaldson P11-8340, the blower is a Cincinnati PB-9 centrifugal,

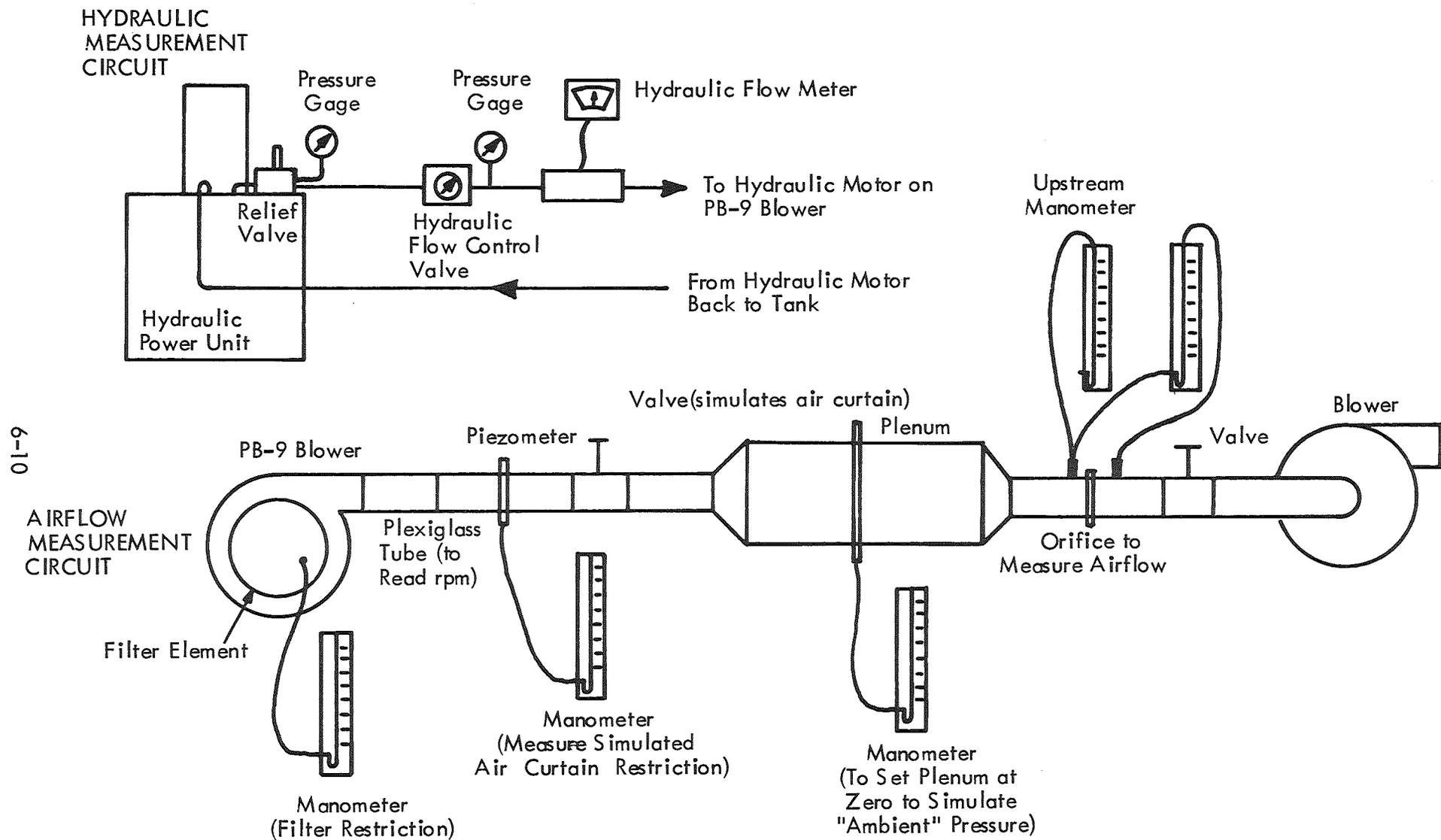


Figure 6-4. Schematic - Air Mover/Hydraulic Motor Tests

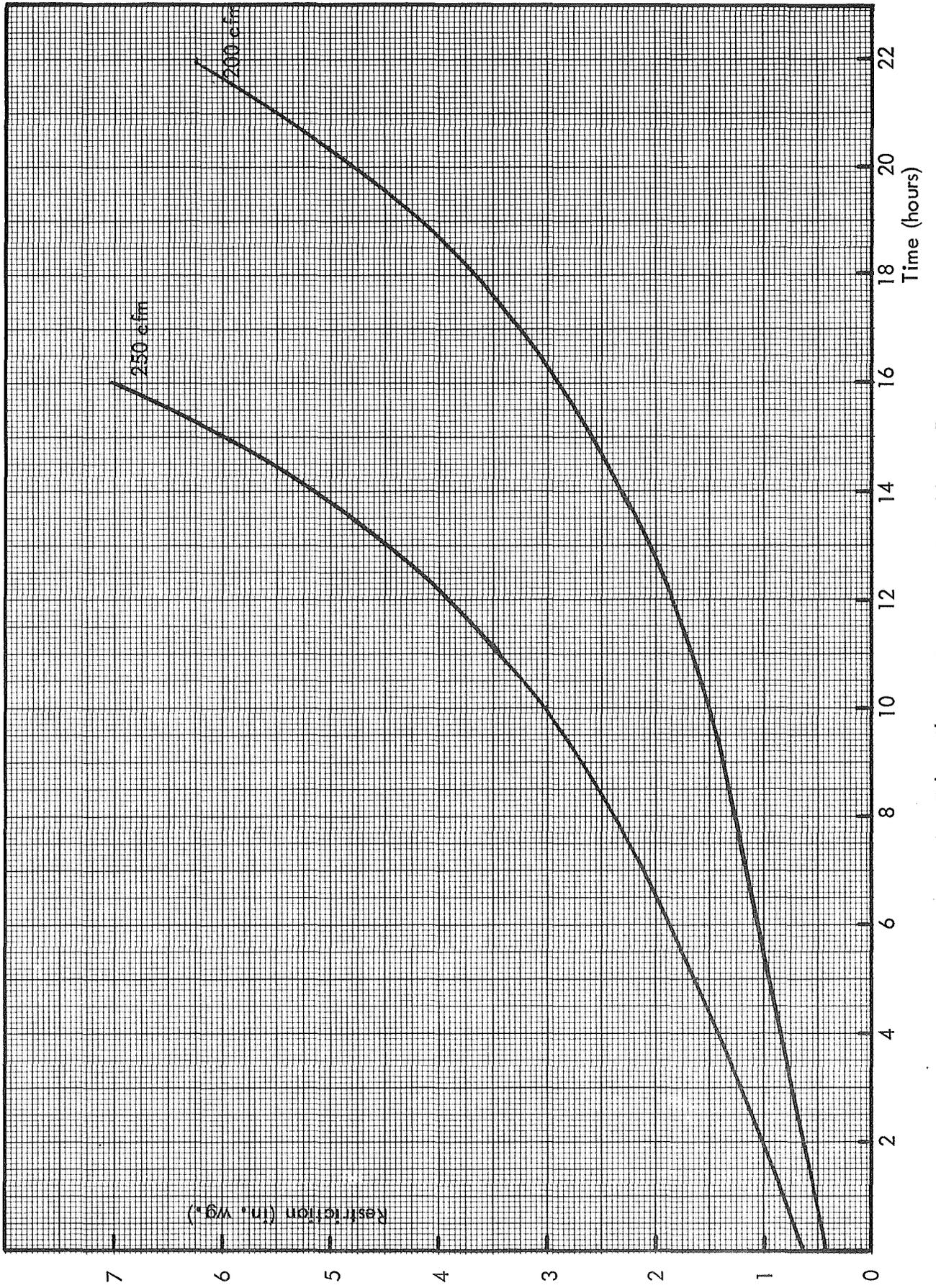


Figure 6-5. Filter Element Restriction Rise Versus Time



Figure 6-6. Phase II Air Curtain - View I

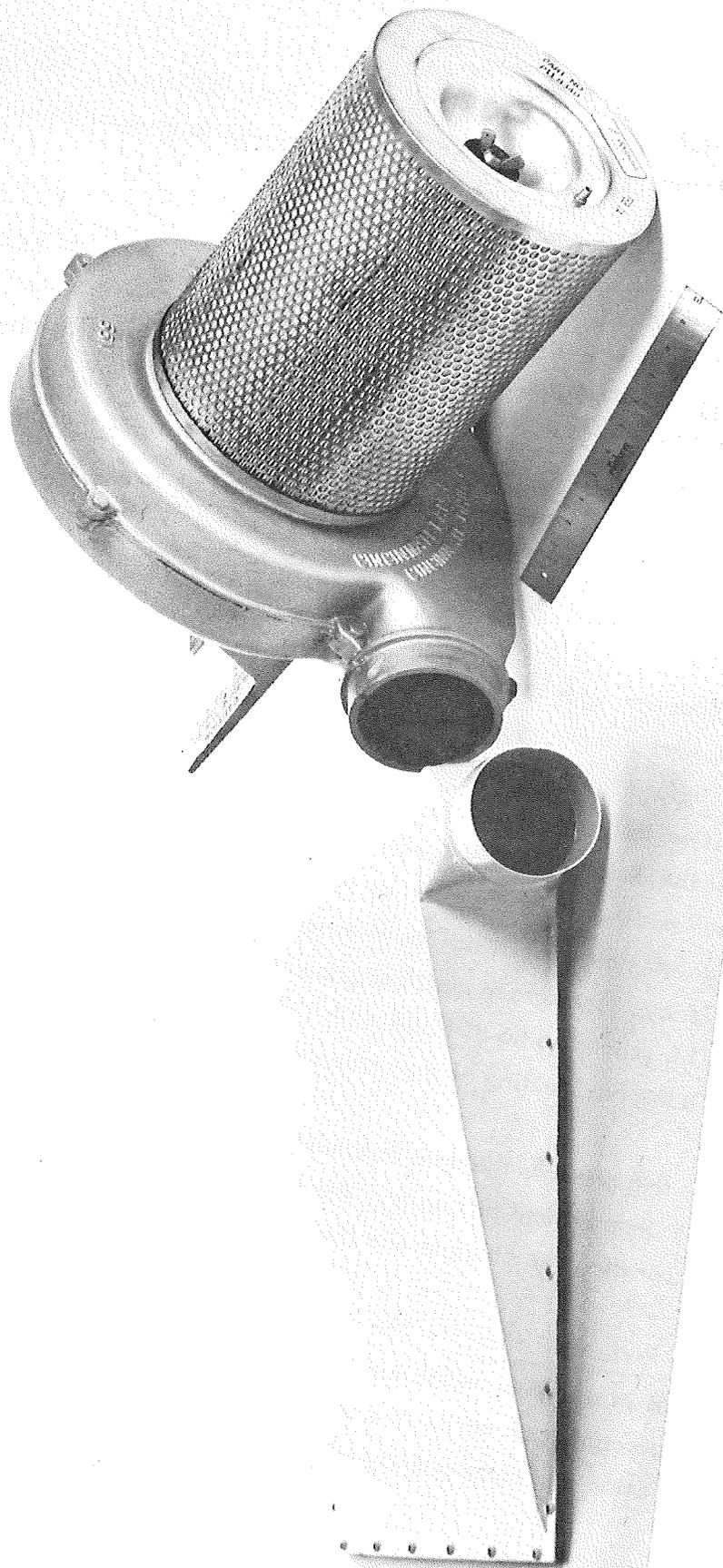


Figure 6-7. Phase II Air Curtain - View 2

and the hydraulic motor is a Stanley Hydraulic Tools 300 series. The blower/filter units used for underground tests utilized protective covers to protect the unit from rock fall damage.

The profile height of the Phase II air curtain was designed to be  $3\frac{1}{2}$  inches. This is between the second prototype of 4 inches and the low profile model of 3 inches. The profile height is an important parameter when one considers the minimal head room on mining machines. However, as one makes the air curtain thinner, it became increasingly difficult to obtain even airflow distribution on a side inlet plenum. Consequently, the compromise on profile height was made.

#### 6.4.1 Dust Deflection Tests

Dust deflection tests were performed on the Phase II air curtain laboratory model and also the three underground test units. Some modifications had to be made to the original design before the unit functioned successfully. After numerous modifications and dust deflection tests, the laboratory model proved effective; however, upon the build-up and test of the underground test units, it was found that the results could not be repeated. Further modifications proved that the spacing between the 80 mesh screen and the perforated metal is critical for even airflow distribution and, thus, good dust deflection efficiency. The screen must be spaced away from the perforated metal without touching it. This proved to be difficult with  $1/16$  in. spacing; however,  $3/16$  in. spacing along with adhesive bonding of the screen to the spacer proved successful.

Table 6-6 presents the data obtained on the laboratory test model prior to the build-up of the underground test units. The following paragraphs describe the Phase II air curtain incorporating the changes and the reasons for the change.

Inlet Perforated Metal – The use of 32 percent open perforated metal with 80 mesh screen results in a higher restriction but provides a much more even airflow into the plenum. A  $22\frac{1}{2}$  percent open perforated metal with 80 mesh screen was tested but created too much restriction and consequently more burden on the air mover.

Table 6-6 Phase II Air Curtain Dust Deflection Tests

Test No.	Airflow (cfm)	Test Position	Curtain Angle	Hat Brim Dist (in)	Distance to Mouth (in)	Inner Core Blocked Area	Hat Type	Penetrating Concentration (mg/m <sup>3</sup> )	
								GCA	Gravimetric
1	189	facing away	12°	4	13-7/8	6-7/8 in x 6-7/8 in	bill	-	12.26 tot, 1.56 resp
2	189	" "	"	4	"	" "	"	-	12.76 tot, 2.02 resp
3	236	" "	"	4	"	" "	"	-	11.56 tot, 1.80 resp
4	189	" "	"	2-1/8	"	" "	"	-	3.26 tot, 0.54 resp
5	189	" "	"	4	"	" "	"	-	13.95 tot, 2.06 resp
6	189	" "	"	4	"	" "	"	-	4.22 tot, 0.68 resp
7	189	" "	"	2-1/8	14-1/4	" "	"	-	1.04 tot, 0.16 resp
8	189	" "	"	"	"	" "	"	-	0.99 tot
9	189	" "	"	"	"	" "	"	-	1.02 tot, 0.17 resp
10	189	" "	"	"	"	" "	"	-	0.99 tot
11	236	" "	"	4	13-7/8	" "	"	-	1.61 tot
12	236	" "	"	"	"	" "	"	-	1.86 tot, 0.29 resp
13	189	" "	"	"	"	" "	"	-	2.56 tot
14	189	" "	"	"	"	" "	"	-	2.72 tot, 0.41 resp
15	236	" "	"	2-1/8	14-1/4	" "	"	-	0.75 tot
16	236	" "	"	"	"	" "	"	-	0.82 tot, 0.12 resp
17	189	" "	"	"	11-5/8	" "	"	-	0.56 tot, 0.07 resp
18	189	" "	"	"	"	" "	"	-	0.49 tot
19	236	" "	"	"	"	" "	"	-	0.27 tot
20	236	" "	"	"	"	" "	"	-	0.35 tot, 0.05 resp

6-15

Diffuser Panel - 13 percent open perforated metal backed with 80 mesh screen proved effective; however, the screen must be spaced away from the perforated metal by 1/16 inch. This was accomplished by adding a gasket between the perforated metal and the screen around the periphery of the mounting flange. Also, a 1/16 inch spacer was bonded to the 6-7/8 inch x 6-7/8 inch blocked off area in the middle of the diffuser. It was found that this spacer aided in providing a more uniform airflow than bonding the screen directly to the perforated metal. Finally, a 3/8 inch wide by 1/2 inch high gasket was bonded around the outside periphery of the diffuser. This resulted in improved efficiency because it acted as a barrier to the contaminated interference jet very near to the surface of the perforated metal. This gasket also provides protection from the sharp edges of the mounting screws and does not decrease head clearance. This barrier could be made of metal to provide stiffening to the perforated panel if deemed necessary. Figure 6-8 illustrates the above described configuration of the Phase II air curtain.

Table 6-6 presents the data taken for various configurations tested during this reporting period. The following list describes the configurations tested according to test number shown on Table 6-6.

- |                |   |
|----------------|---|
| 1 -            | 13% open perf. metal with 80 mesh screen backing on diffuser.<br>32% open perf. metal for inlet diffuser.                                   |
| 2, 3, 4 -      | 13% open perf. metal with 80 mesh screen bonded to diffuser.<br>22½% open perf. metal with 80 mesh screen bonded to inlet diffuser.         |
| 5 -            | Same as 2, 3, 4 except outside diffuser dimensions reduced to 14 in. x 15¼ in.  |
| 6, 7, 8 -      | 13% open perf. metal with 80 mesh screen spaced 1/16 in. on diffuser.<br>32% open perf. metal with 80 mesh screen bonded to inlet diffuser. |
| 9 through 20 - | Same as 6, 7, 8 except 3/8 in. x 1/2 in. gasket around periphery of diffuser.   |

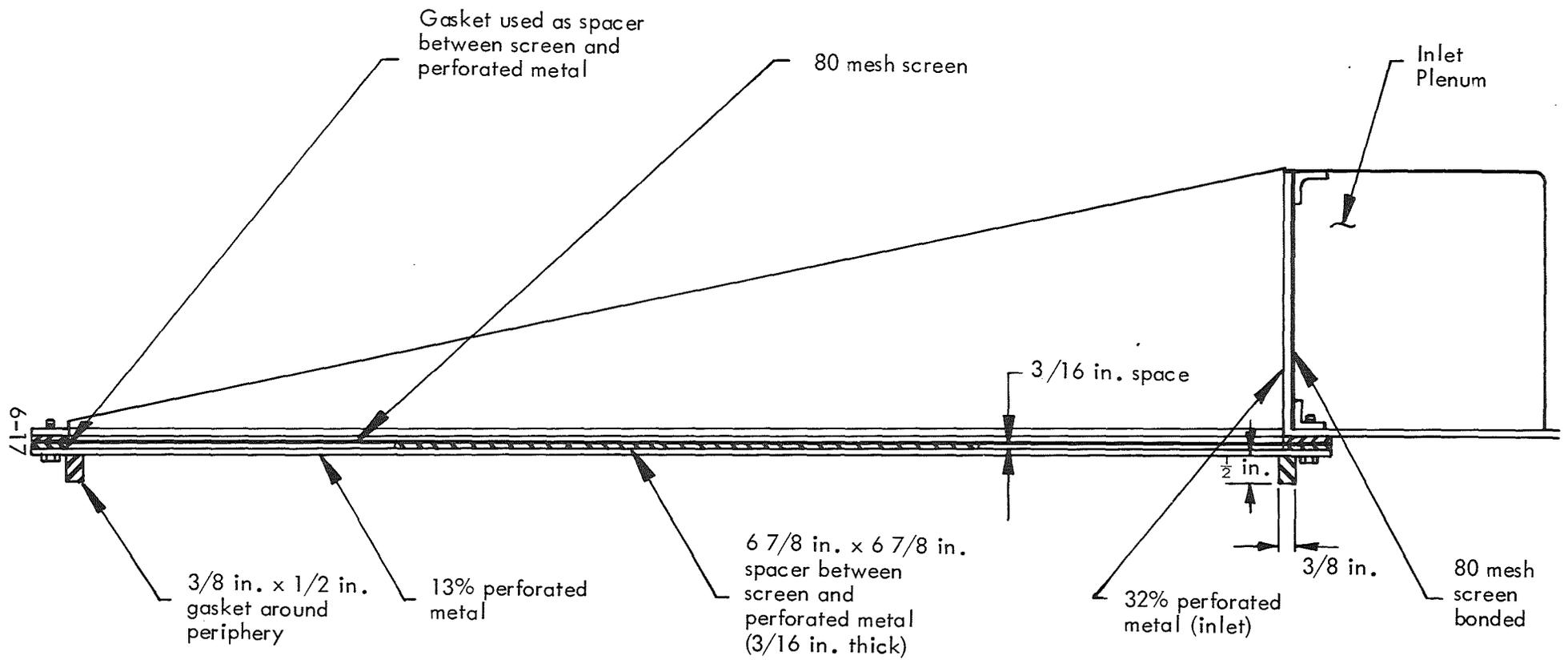


Figure 6-8. Phase II Air Curtain Final Configuration

The data for this configuration (test numbers 9 through 20) indicates that the air curtain meets the requirements of  $0.5 \text{ mg/m}^3$  respirable penetrating concentration at airflow down to 189 cfm. Test numbers 17 through 20 show the effects of positioning the mannequin such that the hat is touching the diffuser. The position is more typical of what will be encountered during underground tests. Head clearance will be minimal. As was expected, the efficiency improved by placing the mannequin closer to the diffuser.

Following the tests described on Table 6-6 on the laboratory model of the Phase II air curtain, the Phase II air curtains destined for underground tests were assembled in the same manner as the laboratory model. Dust deflection tests were started to verify the performance. The initial results were poor ( $3.34 \text{ mg/m}^3$  to  $4.59 \text{ mg/m}^3$  total penetrating concentration). Upon closer inspection, it was determined that we could not uniformly maintain the  $1/16$  inch spacing between the 80 mesh screen and the perforated metal. A slight bulge in the screen resulted in the screen touching the perforated metal. This created an uneven airflow and subsequently poor performance. Consequently, two items were changed: 1) The  $1/16$  inch spacing was increased to  $3/16$  inch and 2) the screen was bonded to both the center blocked-off area and the  $3/16$  inch spacer around the periphery of the perforated metal. This apparently solved the problem on the two air curtains; however, the other unit was also changed and tested before underground tests were begun. The test data is shown on Table 6-7.

Test No.'s 1 and 2 are identical tests using 189 cfm. This unit was configured similarly to the laboratory mode; however, the penetrating concentration for the laboratory model was about  $1.0 \text{ mg/in.}^3$  and the underground test model resulted in penetrating concentrations of  $3.46 \text{ mg/m}^3$  and  $3.34 \text{ mg/m}^3$ .

Test No. 3 is the same unit as test No.'s 1 and 2 except that the sealant around the inlet perforated metal was removed. It was felt at the time that the sealant may have been causing bad results due to blockage of holes. This was not the case. In fact, the change only resulted in poorer performance ( $4.59 \text{ mg/m}^3$ ).

Test No. 4 was the same as No. 3 except that the spacing between the 80 mesh screen and the perforated metal was increased from  $1/16$  inch to  $3/16$  inch. This change improved the performance ( $1.42 \text{ mg/m}^3$ ).

Table 6-7. Tests on Underground Test Air Curtains

DCI Serial No.	Test No.	Air-flow (cfm)	Test Position	Curtain Angle	Hat Brim Dist. (in)	Distance to Mouth (in)	Inner Core Blocked Area	Hat Type	Penetrating Concentration (mg/m <sup>3</sup> )	
									GCA	Gravimetric
1931	1	189	facing away	12°	2-1/8	14-1/4	6-7/8 in x 6-7/8 in	bill	-	3.46 tot, 0.63 resp.
1931	2	189	"	"	"	"	" "	"	-	3.34 tot
1931	3	189	"	"	"	"	" "	"	-	4.59 tot, 0.74 resp.
1931	4	189	"	"	"	"	" "	"	-	1.42 tot, 0.20 resp.
1932	5	189	"	"	"	"	" "	"	-	1.11 tot, 0.15 resp.
1933	6	189	"	"	"	"	" "	"	-	1.55 tot, 0.25 resp.
1933	7	236	"	"	"	"	" "	"	-	0.95 tot, 0.15 resp.

61-9

Test No. 5 was run on another underground test unit with the inlet perforated metal sealed and the 3/16 inch screen spacing. This test indicated even better performance (1.11 mg/m<sup>3</sup>) than previously.

Test No.'s 6 & 7 - these tests were the same as 4 and 5. These tests completed the checkout of the underground test units. The results indicated approximately the same efficiency as the other two air curtains.

Table 6-8 defines where each air curtain was tested underground according to serial number.

Table 6-8. Serial No. of Air Curtain vs. Mine Site Location

DCI Serial No.	Mine Site Location	Test Machine
1931	Freeman (Orient #3)	Jeffrey 120H Heliminer
1931	Old Ben (Mine #21)	Joy 12 CM (hydraulic canopy)
1932	Peabody (Mine #10)	Joy 12 CM (fixed canopy)
1933	Old Ben (Mine #21)	Goodman Boring Machine

#### 6.4.2 Airflow Restriction Tests

The airflow resistance of the Phase II air curtain was determined for the final configuration. Figure 6-9 presents graphically the data for this unit, the Phase I second prototype, and the low profile model. The low profile model had a straight pipe into the inlet rather than a 90° elbow. The Phase II air curtain is still within the head capacity of the blower to be used.

#### 6.4.3 Noise Tests

Noise tests were conducted on the Phase II air curtain with the Cincinnati PB-9 blower and hydraulic motor used to supply the airflow. A microphone was fitted in the ear of the mannequin and the mannequin was placed under the air curtain. The microphone

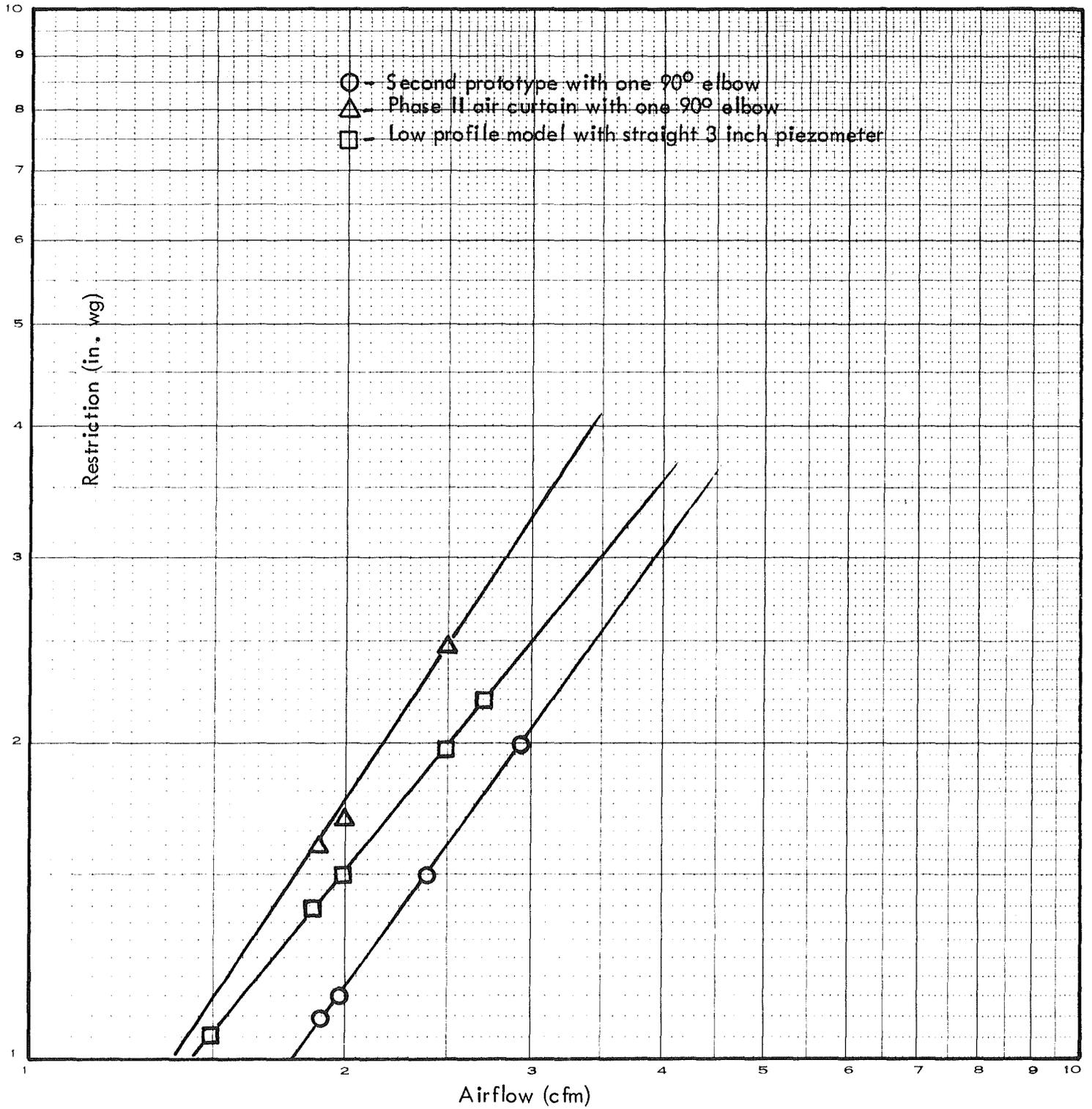


Figure 6-9. Restriction of Phase II Air Curtain Compared to Phase I Second Prototype Model & Low Profile Model

was connected to a B & K sound level meter. Noise level readings were taken at two different airflows -- 200 cfm and 250 cfm. Readings were also taken three feet from the blower at various points and at six inches from the outlet of the blower. These tests show that the noise is primarily airborne and is transmitted by the ducting to the air curtain. For example, at distances of three feet, the noise levels were 70 to 74 dbA at 250 cfm; whereas, the noise level at the mannequin's ear at 250 cfm was 85.5 dbA. The noise level six inches from the blower outlet was about 100 dbA at 250 cfm. Also, the data shows no significant difference in noise levels when the mannequin's ear was 9 feet or 5.5 feet from the blower. Test data is presented in Table 6-9.

There was some effect on noise level by moving the mannequin closer to the air curtain diffuser panel. At a mouth distance of 14 inches and an airflow of 250 cfm, the noise level was 85.5 dbA. However, when the mannequin was moved up to a mouth distance of 10-3/4 inches, the noise level increased to 86.5 dbA.

The noise levels at a lower airflow of 200 cfm decreased to 80 dbA because of decreased blower speed and some effects from air noise through the perforated metal.

A muffler was installed into the ducting to determine possible noise level reduction. A muffler with six inch inlet and outlet, eight-inch diameter and thirteen inches long, was used. At 250 cfm, the noise level dropped from 85.5 dbA to 80 dbA. At 200 cfm it dropped from 80 dbA to 75.5 dbA.

Because the noise levels are below the permissible eight hour day noise exposure of 90 dbA, it is felt that the muffler will not be needed. A muffler would consume valuable space on a mining machine and would be subject to damage.

## 6.5                      Underground Tests

Three air curtains were fabricated for the underground tests. These air curtains were installed on five different machines underground. One of the sites, the Harris longwall site in West Virginia, proved to be infeasible due to high ventilation air velocities. Consequently, dust deflection efficiency tests were performed on four of the five machines.

Table 6-9. Noise Levels of Phase II Air Curtain

Airflow (cfm)	Distance to Mouth	Distance From Blower to Ear	Use of Muffler	Sound Level (dbA)
200	14 in	9 ft	No	80.0
250	"	" "	No	85.5
200	"	11 ft	Yes	75.5
250	"	"	Yes	80.0
250	14 in	5.5	No	85.5
250	12-1/8	"	No	87
250	11-3/4	"	No	87
250	11-1/4	"	No	87
250	10-3/4	"	No	86.5
200	NA	6 in. from outlet	Yes	90
250	NA	"	Yes	102
200	NA	"	No	94
250	NA	"	No	99

A temporary installation was made at the Harris mine on a Sagem double drum shearer and smoke tests were performed. These tests proved the installation infeasible. A list of the installations is given below on Table 6-10.

Table 6-10. Underground Test Sites

Mine	Location	Machine
Peabody #10	Pawnee, Illinois	Joy 12 CM (with fixed canopy)
Old Ben #21	Sesser, Illinois	#405 Goodman Boring Machine
Freeman Orient #3	Waltonville, Illinois	Jeffrey 120 H Heliminer
Old Ben #21	Sesser, Illinois	Joy 12 CM (with hydraulic canopy)
Harris Mine	Bald Knob, W. Va.	Sagem Double Drum Shearer

Dust concentrations were determined by using MSA personal samplers and cassettes to collect gravimetric respirable dust samples. The total sampling times or sampler on time was recorded and used to determine the average concentration during the shift.

#### 6.5.1 Underground Tests at Peabody No. 10 (Joy 12 CM)

The canopy air curtain was installed and tested on a Joy 12 CM miner at Peabody Mine #10 during January 1975. Personal samplers were used to monitor the ambient respirable dust concentrations at three locations outside the air curtain and one location on the operator (see Figure 6-10 for sampler locations). The air mover filter restriction rise was also monitored. The clean restriction of the filter is 0.15 in. wg. The airflow to the air curtain was set at 215 cfm for each test shift. This was the maximum flow attainable because of the limits of the scrubber hydraulic pump which was used for the hydraulic flow to the air curtain air mover. Photographs which were taken of this installation are shown on Figure 6-11 and 6-12. The test conditions and results are shown on Table 6-11.

The location of the personal samplers are shown on Figure 6-10. The samplers were placed in the same locations for each test. The personal sampler pumps used were MSA and the cassettes were UNICO. The sampling time per shift was usually close to six hours and 15 minutes.

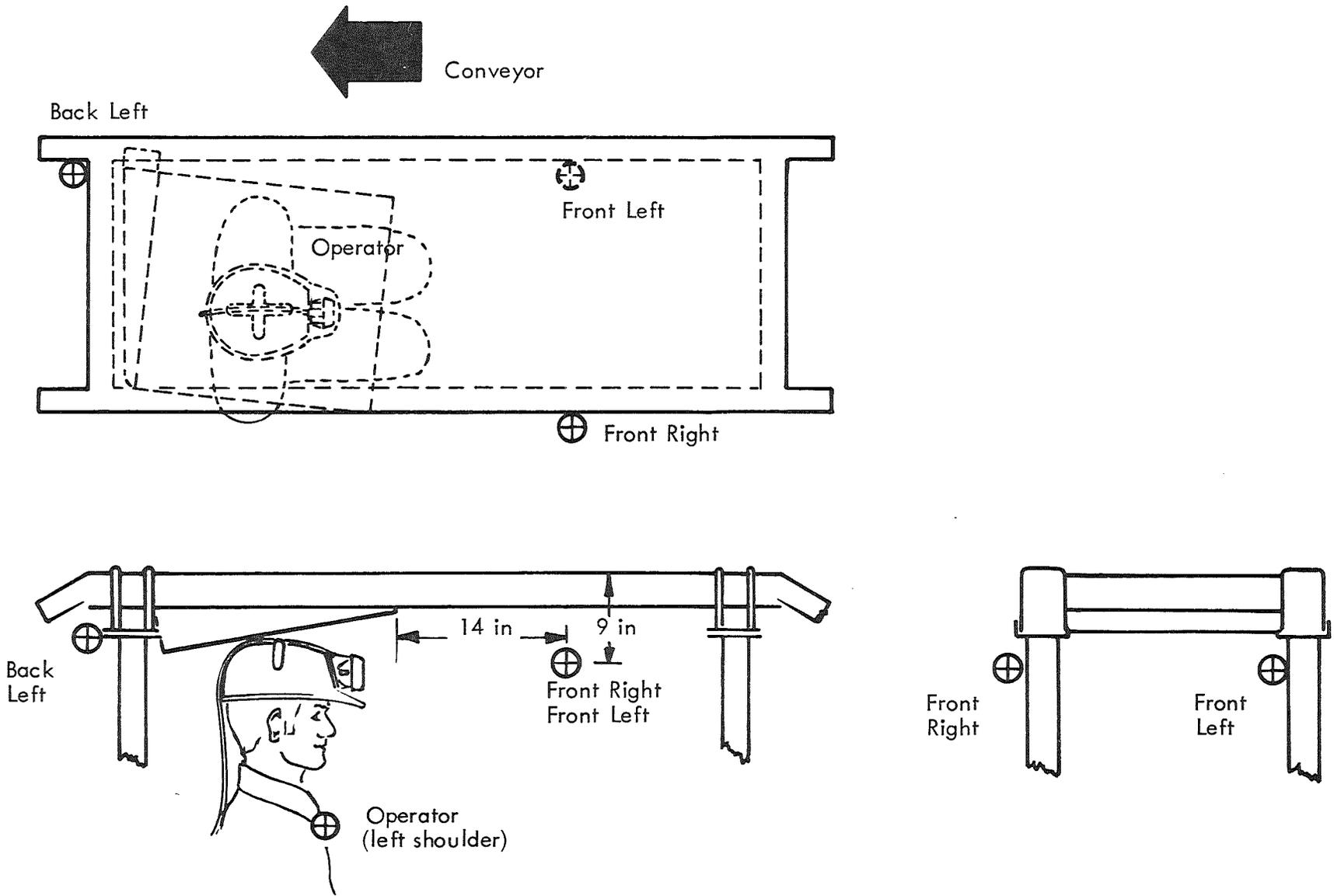


Figure 6-10. Personal Sampler Locations - Peabody Test Site

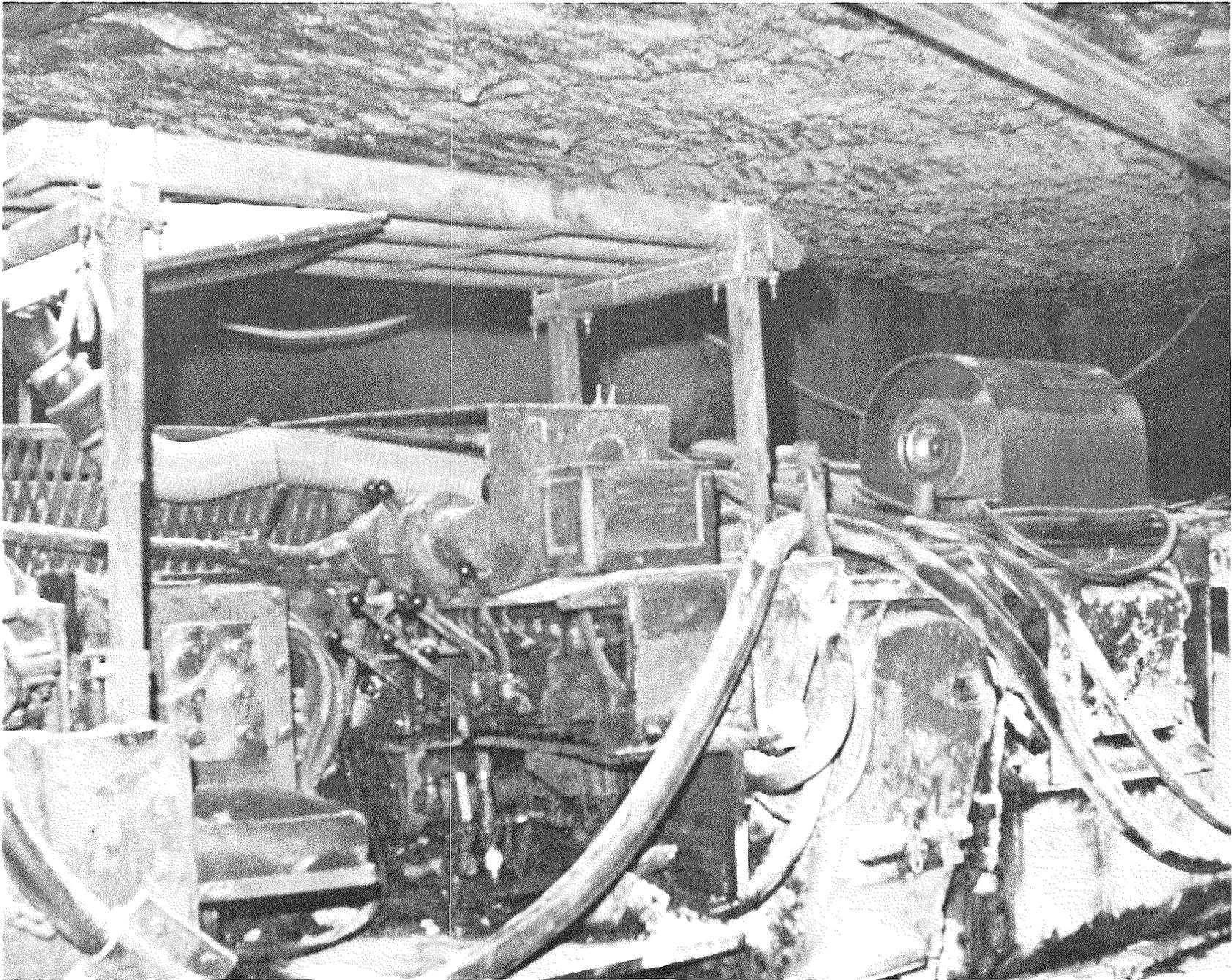


Figure 6-11. Installation of Canopy  
Air Curtain (View 1)



Figure 6-12. Installation of Canopy  
Air Curtain (View 2)

The week of 6 January, the air curtain was installed and was tested for one shift. These tests were invalid due to inaccurate preweights on the filter. Subsequent cassettes were weighed at the mine to insure accurate preweights.

The week of 13 January, tests were conducted for four shifts (see Table 6-11). Note the poor results for Tuesday. This is not consistent with the cleaner appearance of the filter on the operator. The other three sets of tests showed an improvement for the operator. Averaging the "outside" concentrations, one finds that the percent reductions are 34 percent for Wednesday, 60 percent for Thursday, and 42 percent for Friday.

The air mover filter restriction was measured during these tests. The restriction rise per shift was found to be about 0.4 in. wg to 1.0 in. wg. This indicates that the blower head can easily account for about 10 shifts of operation time before the element needs replacement or cleaning. Table 6-12 presents the restriction rise per shift.

Table 6-12. Filter Restriction Data

Running Time	Total Restriction Rise	Restriction Rise per shift
Tues. thru Wed. (2 shifts)	0.75 in. wg	0.38 in. wg
Tues. thru Thurs. (4 shifts)	1.40 in. wg	0.35 in. wg
Thurs. thru Fri. (1 shift)	1.00 in. wg	1.00 in. wg

Four different machine operators used the air curtain while cutting coal. These men were interviewed and the following comments and observations were compiled:

- One man objected to the "cooling effect" of the airflow
- There was no objection to noise
- Almost all operators objected to the lack of head room
- All operators tended to lean out from under the canopy, not because of the air curtain, but because of the lack of visibility associated with the canopy itself

Table 6-11. Underground Test Results - Peabody No. 10

Test site - Peabody No. 10

Section - 3rd West, 1st South, 5½ West

Type of Machine - Joy 12 CM with Schroeder Universal Canopy Kit No. 3358

Type of Ventilation - Blowing Brattice

Air Curtain Airflow - 215 cfm

Tuesday, 14 January 9:00 a.m., to 3:15 p.m., coal tonnage - 715 tons

Cassette location - back left - 2.6 mg/m<sup>3</sup> respirable

- front right - 1.2

- operator - 2.8

% reduction - 0%

Wednesday, 15 January 4:55 p.m., to 11:15 p.m., coal tonnage - 830 tons

Cassette location - back left - 1.3 mg/m<sup>3</sup> respirable

- front right - 2.2

- front left - 2.4

- operator - 1.3

% reduction - 34%

Thursday, 16 January 4:50 p.m., to 11:15 p.m., coal tonnage - 850 tons

Cassette location - back left - 3.7 mg/m<sup>3</sup> respirable

- front right - 4.7

- front left - 4.3

- operator - 1.7

% reduction - 60%

Friday, 17 January 4:50 p.m., to 8:05 p.m., coal tonnage - 812 tons

Cassette location - back left - 3.9 mg/m<sup>3</sup> respirable

- front right - 2.1

- front left - 4.8

- operator - 2.1

% reduction - 42%

- There was some objection to the air mover location from a visibility standpoint. One man said the end of the filter element reflected light.
- Hydraulic motor was subject to damage and needs a better shield

In order to allow for more operator movement under the canopy (such as leaning to the right) and provide more head room. The air could be mounted vertically on the operator's left hand side. The air would then blow across the operator from left to right rather than downward. However, this location might cause a visibility problem for the operator when looking across the top of the conveyor. The canopy on this machine was a fixed-type which does not lend itself to operator head room like a hydraulically-actuated canopy.

The cooling effect from the air curtain airflow could be reduced or eliminated by using the warm water that is used to cool the electric motors on the machine. A small heat exchanger could be placed in-line in the ducting to the air curtain.

The Contract Project Officer visited the site on Tuesday, 14 January to observe the operation of the device.

#### 6.5.2 Underground Tests at Old Ben - Goodman Boring Machine

During the month of February, the canopy air curtain was installed and tested at Old Ben #21 on the 405 Goodman boring machine. Personal samplers were used to monitor the ambient respirable dust concentrations at three locations outside the air curtain, one under the air curtain, and one on the operator. The air mover restriction rise was also monitored and found to be 1.4 in. wg per shift. The airflow to the air curtain was set at 265 cfm with a clean filter element. The operator time under the canopy was also monitored with a stop watch. Figure 6-13 illustrates the type of canopy on this machine-fixed. A fixed canopy doesn't lend itself to providing operator head room.

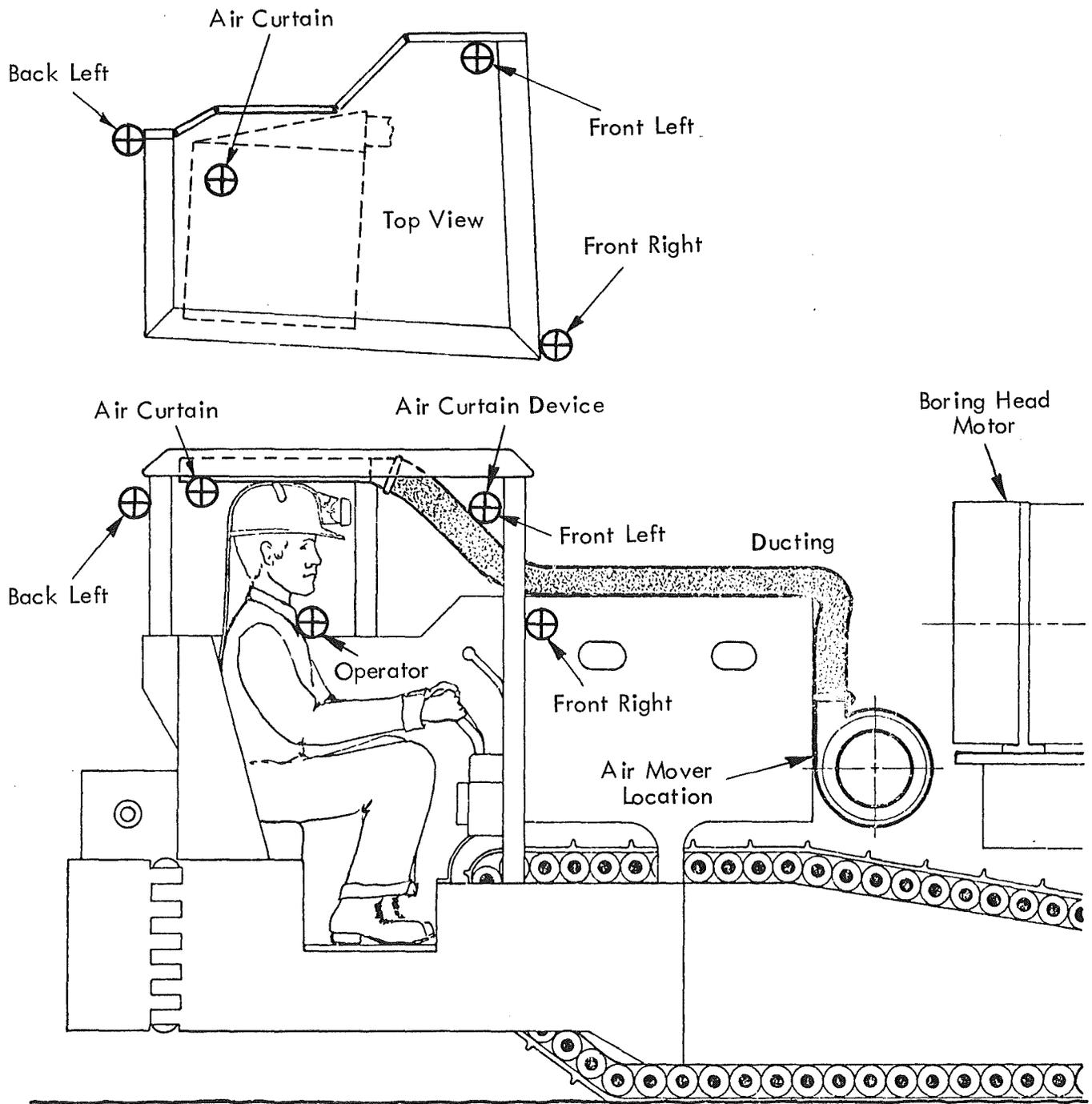


Figure 6-13. Personal Sampler Locations - Old Ben Test Site

The location of the personal samplers are also shown in Figure 6-13. The samplers were placed in the same location for each test. The personal sampler pumps and the cassettes used were MSA. Table 6-13 presents the underground test results.

The following day, the hydraulic motor mounting on the blower loosened and ruined the seal on the motor. Another blower and motor were modified (using locking screws) and this unit replaced the damaged unit. The tests were continued to the week of 17 February 1975. Three days of tests were completed before the motor again loosened and ruined the motor seal. The device was removed. A new motor mounting design was then completed and the parts were fabricated. This new arrangement was used at the next test site.

The data shown on Table 6-13 indicates poor results at the operator position. This is because the operators spend little time under the air curtain, normally controlling the boring machine from a standing position next to the machine. Also, when the operators do sit on the seat, they lean out from under the canopy. A stop watch was used to determine the amount of time the operator is sitting on the seat. Table 6-13 presents these times. Note that the operators spend about 20 to 25 percent of their time on the seat under the air curtain.

A sampler was also placed under the air curtain, with the inlet of the 10 mm cyclone tube 3 in. down from the perforated panel. This sampler indicated about a 50 percent reduction from the ambient concentration. This reading would be better, except the air curtain shuts down and the sampler pump continues sampling during these down times. Six different machine operators used the air curtain while cutting coal. The following comments were compiled:

- There was no objection to noise
- All operators objected to lack of headroom
- The operators didn't object to the airflow, but a union inspector thought it might be too warm

Table 6-13. Underground Test Results - Old Ben No. 21

Test site - Old Ben No. 21

Coal seam - Illinois #6 (Herrin Seam)

Section - 9th through 24th East South Mains

Type of Machine - Goodman Boring Machine #405 with canopy design by Old Ben Coal

Type of Ventilation - Blowing Tubing (14 in. dia)

Air Curtain Airflow - 265 cfm (clean filter)

Tuesday, 4 February 9:00 a.m., to 3:00 p.m.

coal tonnage - 240 tons

operator time under air curtain - 1 hr 48 min

Cassette location - back left - 10.2 mg/m<sup>3</sup> respirable  
- front right - 8.8  
- front left - 8.8  
- operator - 8.4  
- air curtain - not taken  
% reduction - 9%

Tuesday, 18 February 8:45 a.m., to 2:30 p.m.

coal tonnage - 200 tons

operator time under air curtain - 1 hr 18 min

Cassette location - back left - 8.9 mg/m<sup>3</sup> respirable  
- front right - bad sampler pump  
- front left - 8.9  
- operator - 8.2  
- air curtain - 4.4  
% reduction - 8%

Wednesday, 19 February 10:30 a.m., to 2:50 p.m.

coal tonnage - 180 tons

operator time under air curtain - 1 hr 6 min

Cassette location - back left - 2.5 mg/m<sup>3</sup> respirable  
- front right - void  
- front left - 3.0  
- operator - 2.7  
- air curtain - 1.5  
% reduction - 0%

Table 6-13. Underground Test Results (continued)

Thursday, 20 February 8:45 a.m., to 1:00 p.m.

coal tonnage - 84 tons

operator time under air curtain - 46 min

Cassette location - back left - 0.9 mg/m<sup>3</sup> respirable

- front right - 1.3

- front left - 1.1

- operator - 1.1

- air curtain - 0.9

% reduction - 0%

Bureau of Mines' personnel were present at this test. The Bureau of Mines' personnel took three sets of dust measurements using the SRI dust monitor both inside and outside the air curtain. These measured values were the following:

<u>Outside Air Curtain</u> <u>(mg/m<sup>3</sup>) Respirable Dust</u>	<u>Inside Air Curtain</u> <u>(mg/m<sup>3</sup>) Respirable Dust</u>
80	15
25	2
10	2

### 6.5.3                      Underground Tests at Freeman Orient #3 (Jeffrey 120 H Heliminer)

The installation and test of the air curtain at Freeman Orient #3 on a Jeffrey 120 H Heliminer was conducted during March and April 1975.

Personal samplers were used to monitor the ambient respirable dust concentrations at three locations outside the air curtain, one under the air curtain, and one on the operator. The filter element restriction rise was also monitored and was found to be 4.0 in. wg to 5.0 in. wg per shift. The airflow to the air curtain was set at 235 cfm with a clean filter element. The operator time under the canopy was also monitored with a stop watch and is presented on Table 6-14. The canopy on this machine was a hydraulically-actuated type which allows the operator to adjust the head room (see Figure 6-14). This tends to increase the amount of time the operator spends under the canopy.

The sampler locations were left front, right front, back left, under the air curtain, and on the operator himself. The locations were the same for all four tests. MSA personal sampler pumps and cassettes were used during these tests. The sampler pump airflows were checked and adjusted periodically throughout the tests. The data is presented on Table 6-14. The operator samples indicated reductions over the average of the ambient concentrations of 34 percent to 70 percent. Note that the highest reduction of 70 percent was obtained during the shift in which the operator spent the most time under the air curtain.

Table 6-14. Underground Test Results - Freeman Orient No. 3

Test Site	-	Freeman Orient #3
Coal Seam	-	Illinois #6 (Herrin Seam)
Type of Machine	-	Jeffrey 120 H Heliminer
Type of Ventilation	-	Blowing Brattice
Air Curtain Airflow	-	235 cfm (clean filter)

Wednesday, 2 April 1975

Coal Tonnage - 328

Operator Time under Air Curtain - 2 hrs 10 min

Total Sample Time - 6 hrs 40 min

Cassette Location	- back left	-	0.64 mg/m <sup>3</sup>
	- front right	-	1.84
	- front left	-	0.96
	- operator	-	0.56
	- air curtain	-	0.32
			% reduction - 51%

Friday, 4 April 1975

Coal Tonnage - 229

Operator Time under Air Curtain - 2 hrs 7 min

Total Sample Time - 4 hrs 12 min

Cassette Location	- back left	-	1.71 mg/m <sup>3</sup>
	- front right	-	1.81
	- front left	-	1.26
	- operator	-	1.06
	- air curtain	-	1.16
			% reduction - 34%

Table 6-14. Underground Test Results - Freeman Orient No. 3 (continued)

Wednesday, 9 April 1975

Coal Tonnage - 406

Operator Time Under Air Curtain - 2 hrs 46 min

Total Sample Time - 6 hrs 21 min

Cassette Location	- back left	-	3.43	mg/m <sup>3</sup>
	- front right	-	4.19	
	- front left	-	3.28	
	- operator	-	1.37	
	- air curtain	-	2.27	
	% reduction - 62%			

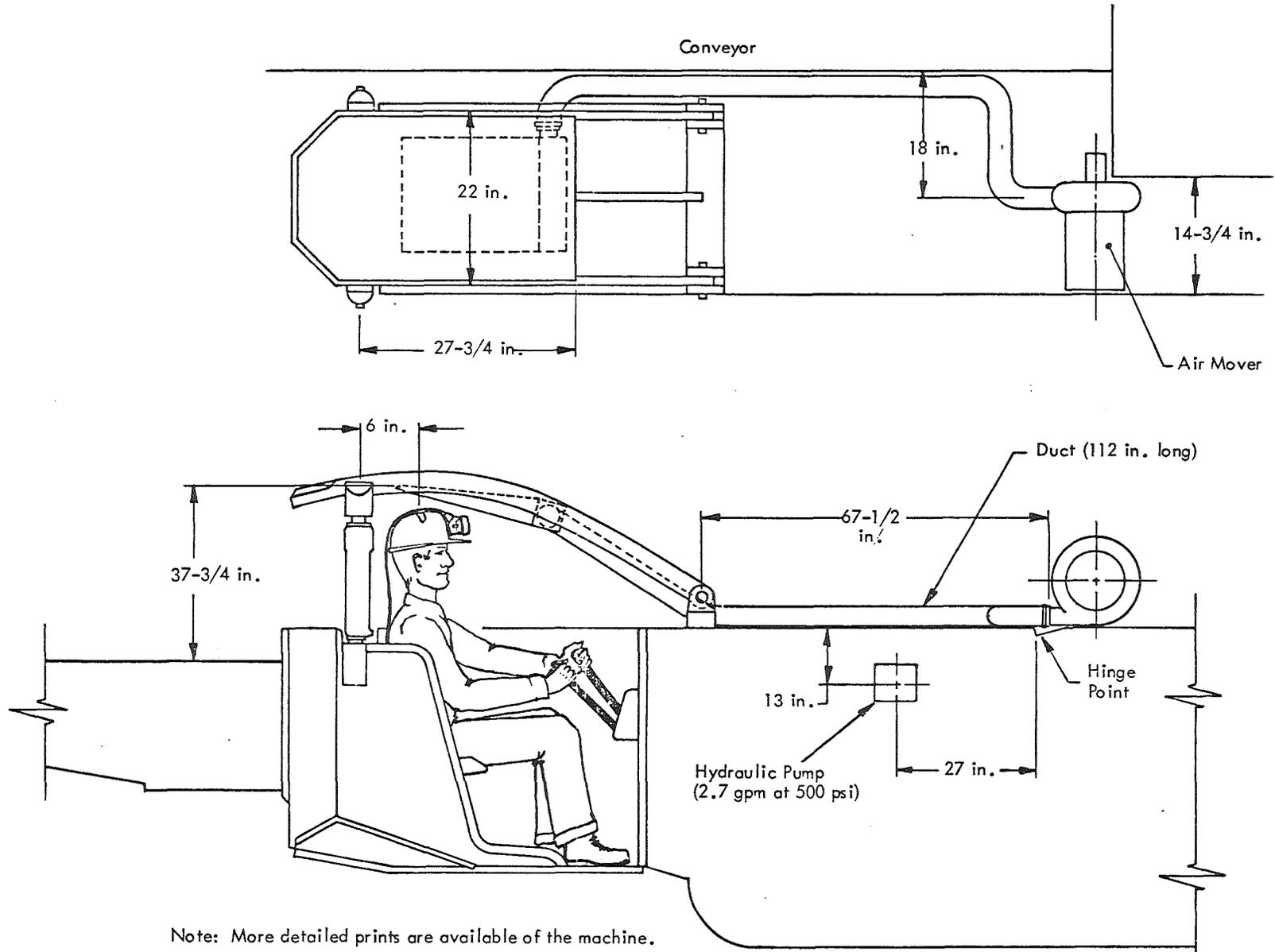
Thursday, 10 April 1975

Coal Tonnage - 532

Operator Time Under Air Curtain - 3 hrs 48 min

Total Sample Time - 6 hrs 32 min

Cassette Location	- back left	-	1.65	mg/m <sup>3</sup>
	- front right	-	2.98	
	- front left	-	2.35	
	- operator	-	0.71	
	- air curtain	-	0.94	
	% reduction - 70%			



Note: More detailed prints are available of the machine.

Figure 6-14. Interface to Jeffrey 121H Heliminer

#### 6.5.4

#### Underground Tests at Harris Mine (Sagem Longwall Shearer)

The air curtain was temporarily installed on the Sagem longwall double drum shearer. Smoke tests were then conducted to determine if the air curtain could defeat the ventilation air velocity. It was determined that the air curtain would not be effective in any orientation relative to the ventilation air direction. For example, when the air curtain was oriented directly against the ventilation air and smoke was induced into the ventilation air upstream, the smoke would penetrate to within one inch of the perforated panel of the air curtain. The airflow to the curtain was set higher than normal (290 cfm vs. 250 cfm) which did not help.

The only practical method of powering the blower was high pressure water. High pressure water was used to power a Stanley 600 series hydraulic motor. We used 200-250 psi water and obtained sufficient speed on the blower to get 290 cfm of airflow. The motor uses about 5 to 6 gpm of water at operating speed. This water was dumped on the face after passing through the motor. The equipment was subsequently removed and returned to Donaldson Company.

#### 6.5.5

#### Old Ben Tests - Joy 12 CM Machine

Tests were conducted again at Old Ben No. 21 but on a Joy 12 CM rather than a Goodman boring machine. This Joy 12 CM was fitted with a hydraulically actuated canopy which allows the operator to adjust his head room. With increased head room, the operator tends to stay under the canopy. The percent reductions for the operator over the average of the ambient concentrations ranged from 23 percent to 72 percent reduction. Note that the lowest reduction of 23 percent (for 19 May 1975) was during a shift where the air curtain fell down to 133 cfm. This was due to a damaged gear pump being used to power the hydraulic motor on the air curtain air mover. Table 6-15 presents the data taken at Old Ben on the Joy 12 CM machine.

Table 6-15. Tests at Old Ben No. 21 - Joy 12 CM

Test Site - Old Ben No. 21  
 Coal Seam - Illinois #6 (Herrin Seam)  
 Type of Machine - Joy 12 CM  
 Type of Ventilation - Blowing Tubing

Tuesday, 6 May 1975

Air Curtain Airflow - 180 cfm

Coal Tonnage - 581

Operator Time under Air Curtain - 3 hrs, 22 min

Total Sampling Time - 7 hrs

Cassette Location	- back	-	4.88 mg/m <sup>3</sup> respirable
	- front right	-	4.17
	- front left	-	3.57
	- operator	-	1.40
	- air curtain	-	4.88
	% reduction - 60%		

Thursday, 8 May 1975

Air Curtain Airflow - 180 cfm

Coal Tonnage - 756

Operator Time under Air Curtain - 5 hrs, 18 min

Total Sampling Time - 7 hrs

Cassette Location	- back	-	4.56 mg/m <sup>3</sup> respirable
	- front right	-	4.56
	- front left	-	4.44
	- operator	-	1.78
	- air curtain	-	0.78
	% reduction - 56%		

Table 6-15. Tests at Old Ben No. 21 - Joy 12 CM (continued)

Friday, 9 May 1975

Air Curtain Airflow - 180 cfm

Coal Tonnage - 70

Operator Time under Air Curtain - 56 min

Total Sampling Time - 2 hrs

Cassette Location	- back	-	3.33 mg/m <sup>3</sup> respirable
	- front right	-	3.33
	- front left	-	4.58
	- operator	-	2.08
	- air curtain	-	1.67
	% reduction		- 44%

Monday, 19 May 1975

Air Curtain Airflow - 133 cfm (hydraulic gear pump on machine going out)

Coal Tonnage - 728

Operator Time under Air Curtain - 3 hrs, 12 min

Total Sampling Time - 6 hrs

Cassette Location	- back	-	bad test, hose leaked
	- front right	-	13.89 mg/m <sup>3</sup> respirable
	- front left	-	19.03
	- operator	-	12.64
	- air curtain	-	9.86
	% reduction		- 23%

Tuesday, 20 May 1975

Air Curtain Airflow - 180 cfm

Coal Tonnage - 777

Operator Time under Air Curtain - 4 hrs, 13 min

Total Sampling Time - 5 hrs

Cassette Location	- back	-	9.67 mg/m <sup>3</sup> respirable
	- front right	-	12.33
	- front left	-	11.50
	- operator	-	4.67
	- air curtain	-	3.83
	% reduction		- 72%

Table 6-15. Tests at Old Ben No. 21 - Joy 12 CM (continued)

Wednesday, 21 May 1975

Air Curtain Airflow - 240 cfm

Coal Tonnage - 42

Operator Time under Air Curtain - 17 min

Total Sampling Time - 60 min (conveyor breakdown)

Cassette Location	- back	-	1.67 mg/m <sup>3</sup> respirable
	- front right	-	1.67
	- front left	-	4.17
	- operator	-	5.00
	- air curtain	-	2.50
	% reduction - invalid tests		

Friday, 23 May 1975

Air Curtain Airflow - 240 cfm

Coal Tonnage - 613

Operator Time under Air Curtain - 4 hrs, 12 min

Total Sampling Time - 6 hrs, 30 min

Cassette Location	- back	-	4.23 mg/m <sup>3</sup> respirable
	- front right	-	4.36
	- front left	-	11.28
	- operator	-	3.46
	- air curtain	-	3.72
	% reduction - 48%		

## INSTRUCTIONS FOR OPERATION

The operation of the canopy air curtain device requires only two considerations: 1) The initial set-up of the airflow to the air curtain, and 2) change of dirty filter elements.

The airflow to the canopy air curtain is determined in the field by measuring the restriction of the air curtain. An inlet pressure tap is provided which permits connection to a water manometer or appropriate pressure gauge. This pressure should correspond to either 2.2 in. wg or 1.95 in. wg for an initial airflow of 250 cfm, as shown on Figure 7-1. As the filter element loads with dust, the airflow is allowed to degrade to about 190 cfm before the filter element is changed. Figure 7-2 presents two configurations - one for the air curtain fitted with a 4 in. to 3½ in. connector to a 90° elbow and one of a 4 in. to 3½ in. connector straight into the air curtain. These two configurations allow orientation of the air curtain best lending itself to the particular installation.

The airflow to the air curtain can be adjusted by changing the speed of the blower. This is accomplished by adjusting the hydraulic flow control valve shown on Figure 5-10 until the pressure tap reading is correct. The hydraulic oil pressure can be monitored by the pressure gauge shown on Figure 5-10. This reading should be approximately 500-600 psi depending on the amount of line loss from the flow control valve to the hydraulic motor. This pressure can be adjusted with the pressure relief valve shown.

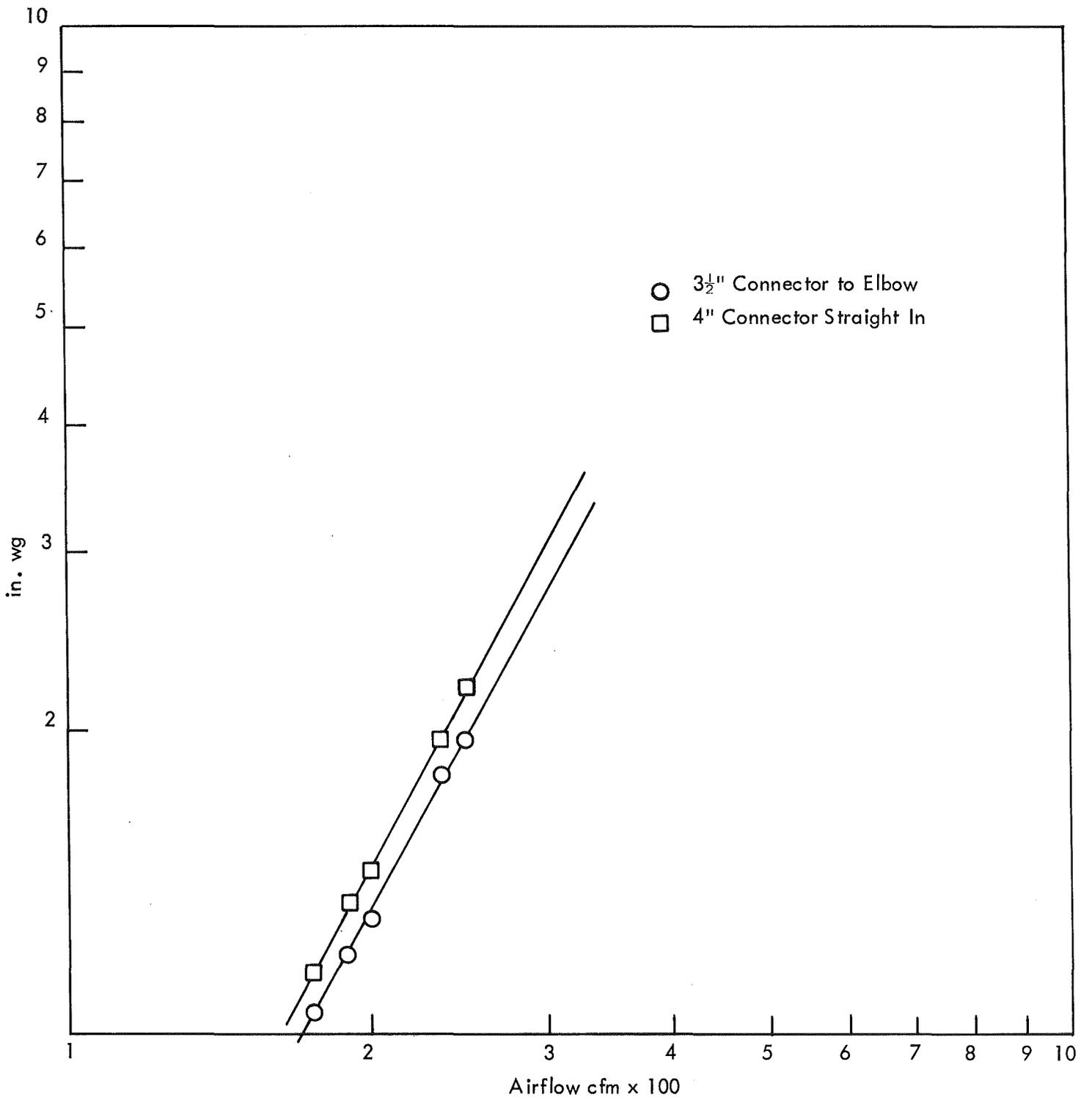


Figure 7-1. Phase II Canopy Air Curtain Restriction Curves

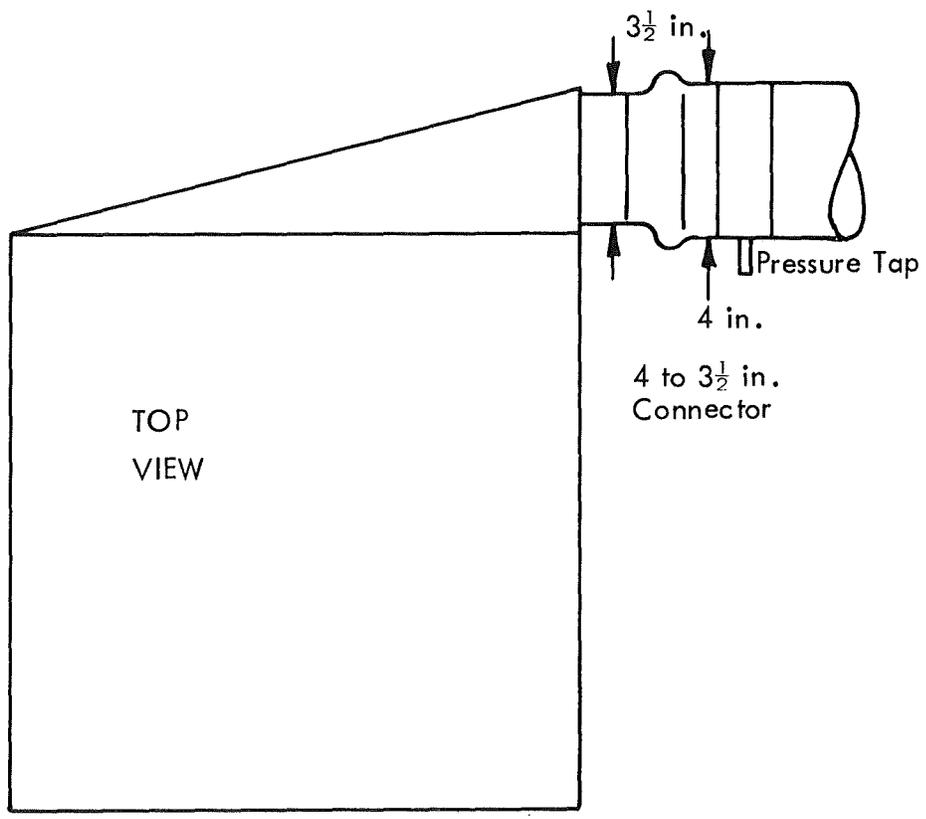
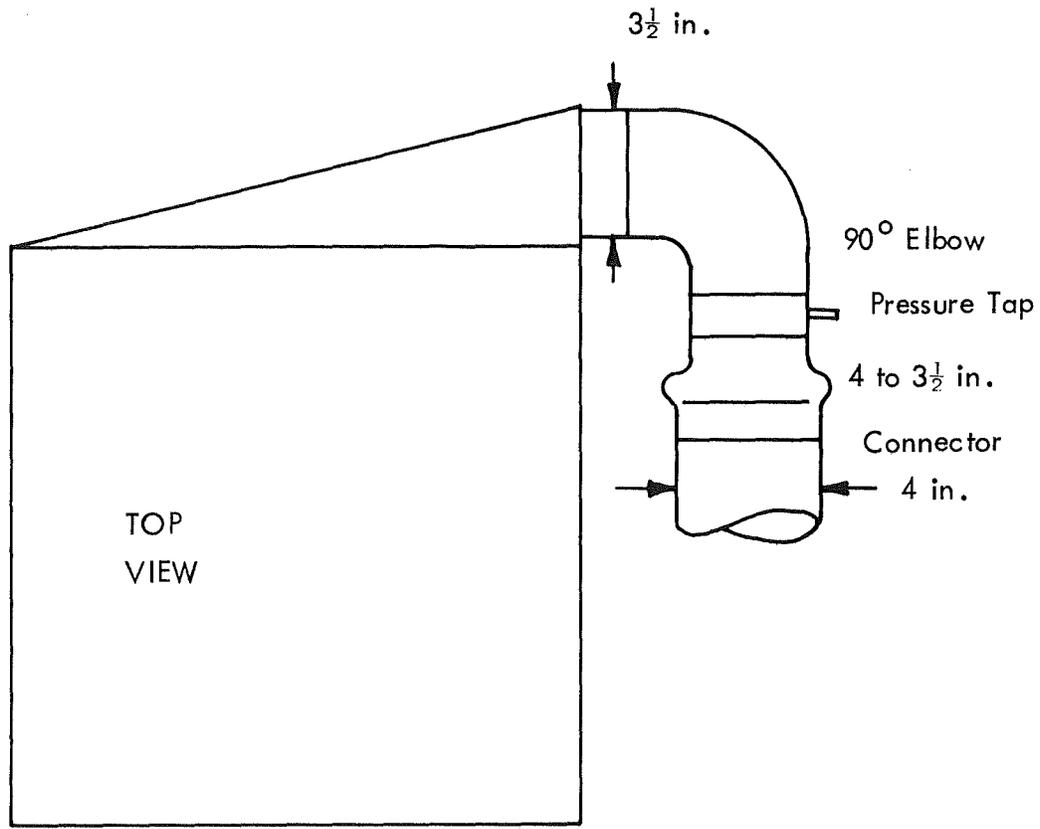


Figure 7-2. Inlet Configurations

The canopy air curtain device requires very little maintenance since the only moving parts are the blower and the hydraulic motor. The only item requiring regular maintenance is the filter element which can be reused after cleaning with water and detergent or back flushing with compressed air. The element can be cleaned in this manner and reused approximately six times.

The hydraulic motor and blower reliability depends on how well it is protected from rock falls. A protective cover is usually necessary. The hydraulic motor life or wear index is dependent on the amount of particles present in the hydraulic oil. The manufacturer recommends a 20 micron hydraulic filter upstream of the motor.

The following recommendations can be considered for future production models:

- Air curtain housing constructed of vacuum-formed plastic or fiberglass to reduce cost
- Perforated panel fabricated with center already blocked off and gasket surface blocked to reduce costs and improve appearance
- Use of rivets to hold perforated panel to housing of air curtain to reduce costs and assembly time
- Investigation of use of a cheaper hydraulic motor, flow control and relief valve to reduce cost
- Investigation of use of permissible electric motor to power the blower in order to facilitate installation and also increase running time (when using hydraulic motor, the air curtain shuts down with machine shut-down.)
- Investigation of building air curtain into canopies so that unit allows more headroom
- Investigation of using smaller blower package to facilitate installation, improve operator visibility and present lower profile which would be easier to protect
- Investigation of method to control temperature of air curtain air in mines where it is considered cool or warm. The air could be warmed by using the cooling water on the machine and running it through a heat exchanger in the ducting to the air curtain.
- Investigation of improving filter element life by using a pre-cleaner, a lower airflow or simply a larger element
- Investigation of putting a "Change Filter" indicator on the air curtain to give the operator a visible warning

## 9.2

### Estimated Production Selling Price

The estimated selling price of the canopy air curtain to a user would be \$1541.00. This is for quantities of 10 units or less and includes the following items:

- Air curtain generator
- Hydraulic flow control
- Hydraulic relief valve
- Hydraulic motor
- Blower
- Brackets for filter and blower
- Air duct
- Adaptors, clamps
- Filter element

The only periodic maintenance to be performed is to change or clean the filter element. The user cost of the filter element is \$8.40.

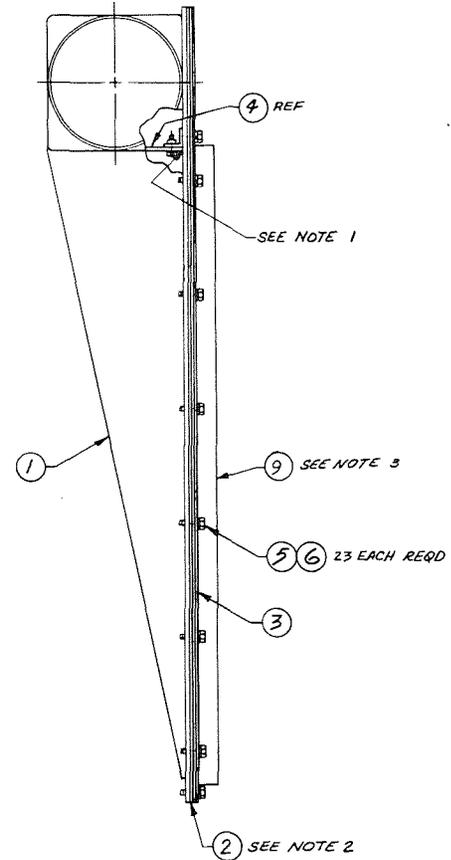
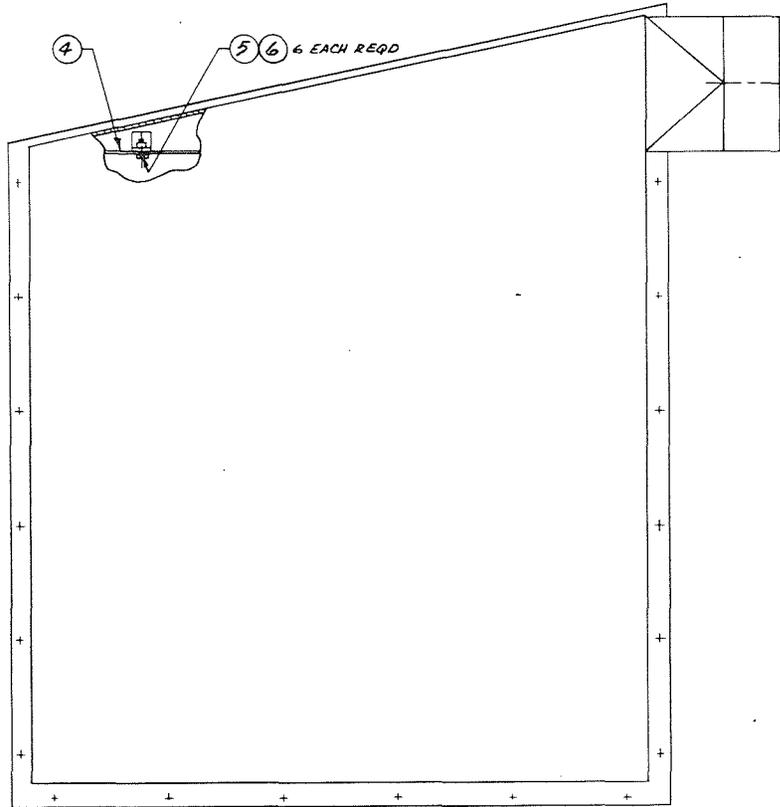
Section 10

SUBJECT LIST OF INVENTIONS

An Invention Disclosure, Form DI-1217, was filed with the Department of the Interior, 26 June 1974. A prior art patent search on "Canopy Air Curtain Device for Respiratory Protection of Mining Machine Operators", Case No. MIN-2384 was conducted by Thomas Zack, patent attorney with the Department of Interior, Division of General Law. The Government subsequently concluded that there is insufficient novelty to warrant a patent application.

# APPENDIX

## FINAL ENGINEERING DRAWINGS



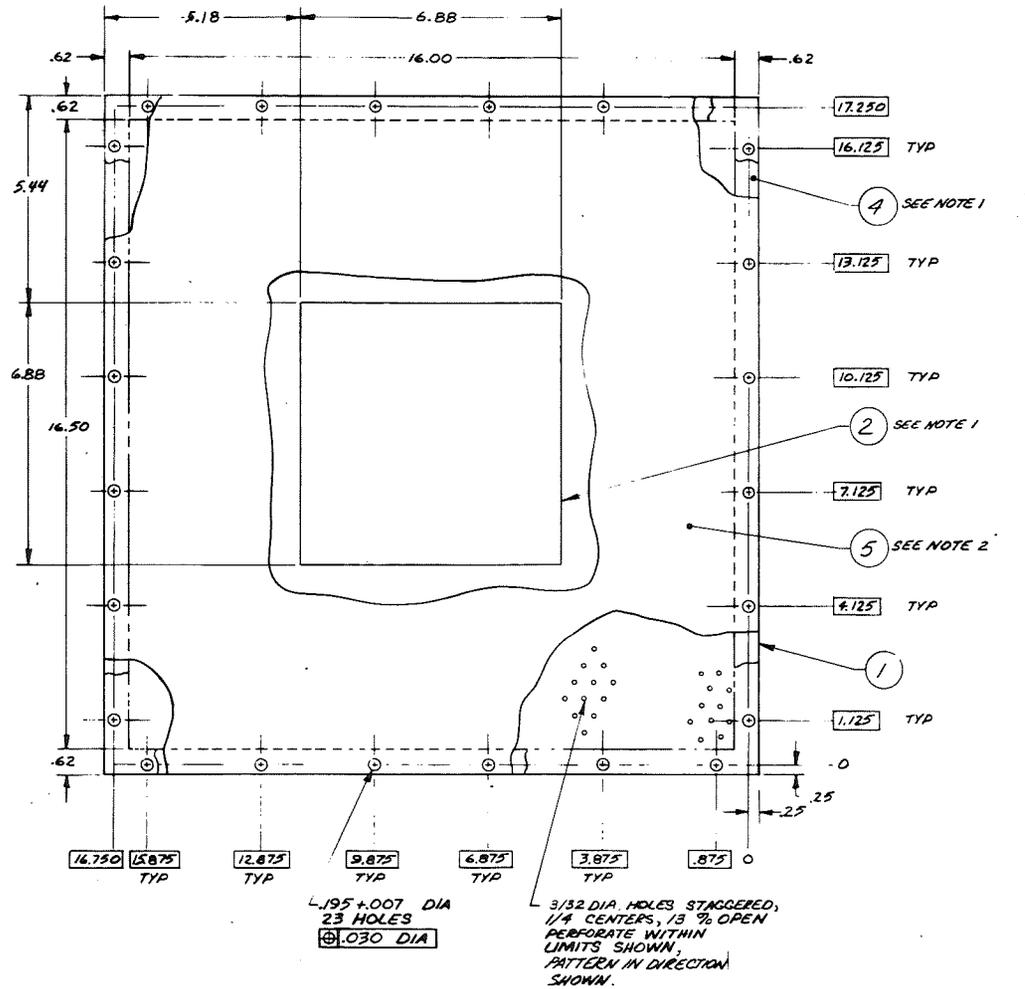
ITEM	QTY	NOMENCLATURE
1	1	E9700W29 - CANOPY
2	1	C9700W30 - GASKET
3	1	C9700W31 - PANEL, PERFORATED
4	1	B9700W32 - PANEL, PERFORATED
5	29	SCREW - NO. 8-32UNC X 1/2 LG
6	29	WASHER, LOCK, NO. 8
7	---	ADHESIVE - SPEC MMM-A-121
8	---	RTV
9	1	C9700W48 - GASKET

NOTES:

1. SEAL ALL AROUND ITEM 4 USING ITEM 8.
2. SECURE ITEM 2 TO ITEM 1 USING ITEM 7.

3. SECURE ITEM 9 TO ITEM 3 USING ITEM 6.

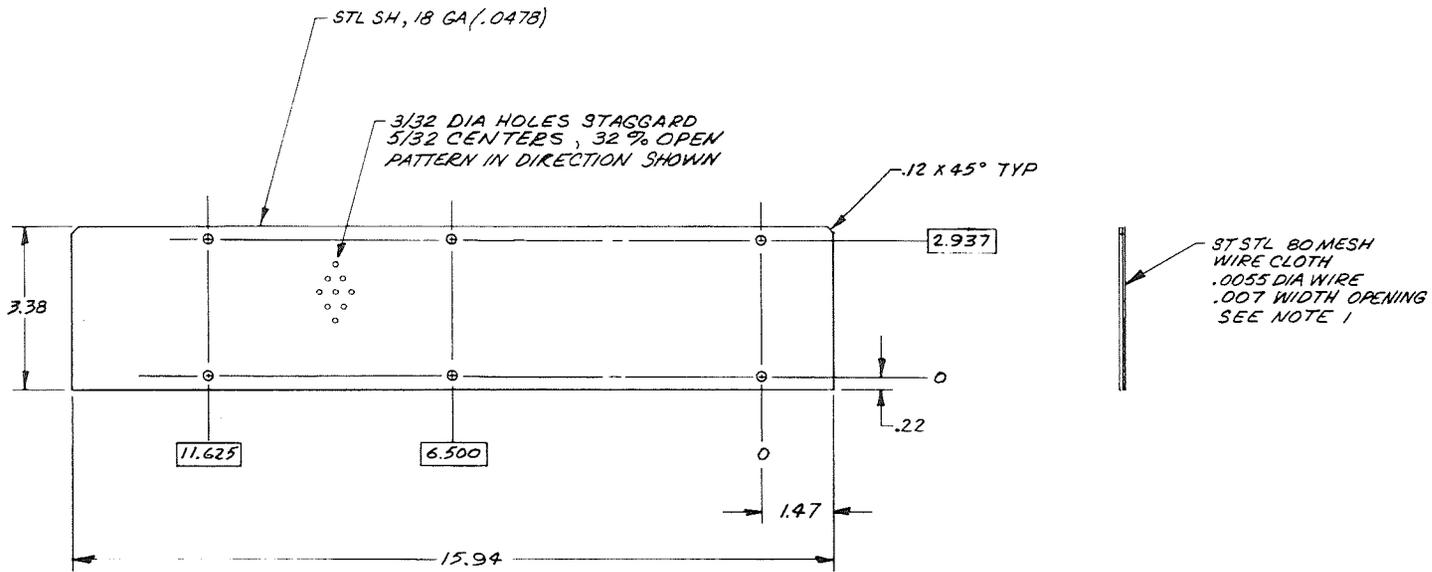
DRAWING MADE IN THIRD ANGLE PROJECTION		EXP	All rights to manufacture, copy, reproduce, or dispose of this drawing or its contents are reserved unless otherwise specified in writing by Dowdickson Company, Inc.		
		PROD.	TITLE	CANOPY AIR CURTAIN	
MATERIAL		CANC			
		JOB REQ			
		DR	29-MAT-74	DWG NO.	C9700W33
		CHK		REV	1
APP	WJK 20-JUNE-74	APP			
REFERENCES		TOLERANCES UNLESS OTHERWISE SPECIFIED	SCALE 1/2	SHEET OF	SIZE
CODE IDENT. NO. 18285		2 PL DEC =	SECTIONAL <input type="checkbox"/>	OUTLINE <input type="checkbox"/>	YES <input type="checkbox"/>
		3 PL DEC =	OUTLINE <input type="checkbox"/>	DRAWN <input type="checkbox"/>	NO <input type="checkbox"/>
		ANGLES =	CLASS CODE		<b>C</b>
<b>DO NOT SCALE DRAWING</b>					



ITEM	QTY	NOMENCLATURE
1	1	STL SH, 20GA (.035)
2	1	RUBBLE SH, 18B NOM STK THK, GRADE SC-915B/G, MK-R-3065
3	---	ADHESIVE, 1257, 3M CO.
4	1	C9700W62, GASKET
5	1	WIRE CLOTH, 80 MESH, STL ST .0035 DIA WIRE, .007 WIDTH OPENING
6	---	ADHESIVE, 3M 77

NOTE  
 1. ITEMS 2 AND 4 TO BE SECURED TO ITEM 1 (PUNCHED SIDE) USING ITEM 3.  
 2. ITEM 5 TO BE SECURED TO ITEMS 3 AND 4 USING ITEM 6.

DRAWING MADE BY THIRD ANGLE PROJECTION	EXP	All rights to manufacture, copy, reproduce, or dispose of this drawing or its contents are reserved unless otherwise specified in writing by Donaldson Company, Inc.		
	PROD.	CANC	TITLE PANEL, PERFORATED	
	JOB REQ	DR	C.C.M.	19-MAY-74
	CHK	APP	WJK	20-JUNE-74
MATERIAL	APP	DWG NO.	C9700W31	REV 2
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DO NOT SCALE DRAWING	1 PL DEC =	OUTLINE	<input type="checkbox"/>	DRAWN
	ANGLES =	CLASS. CODE		

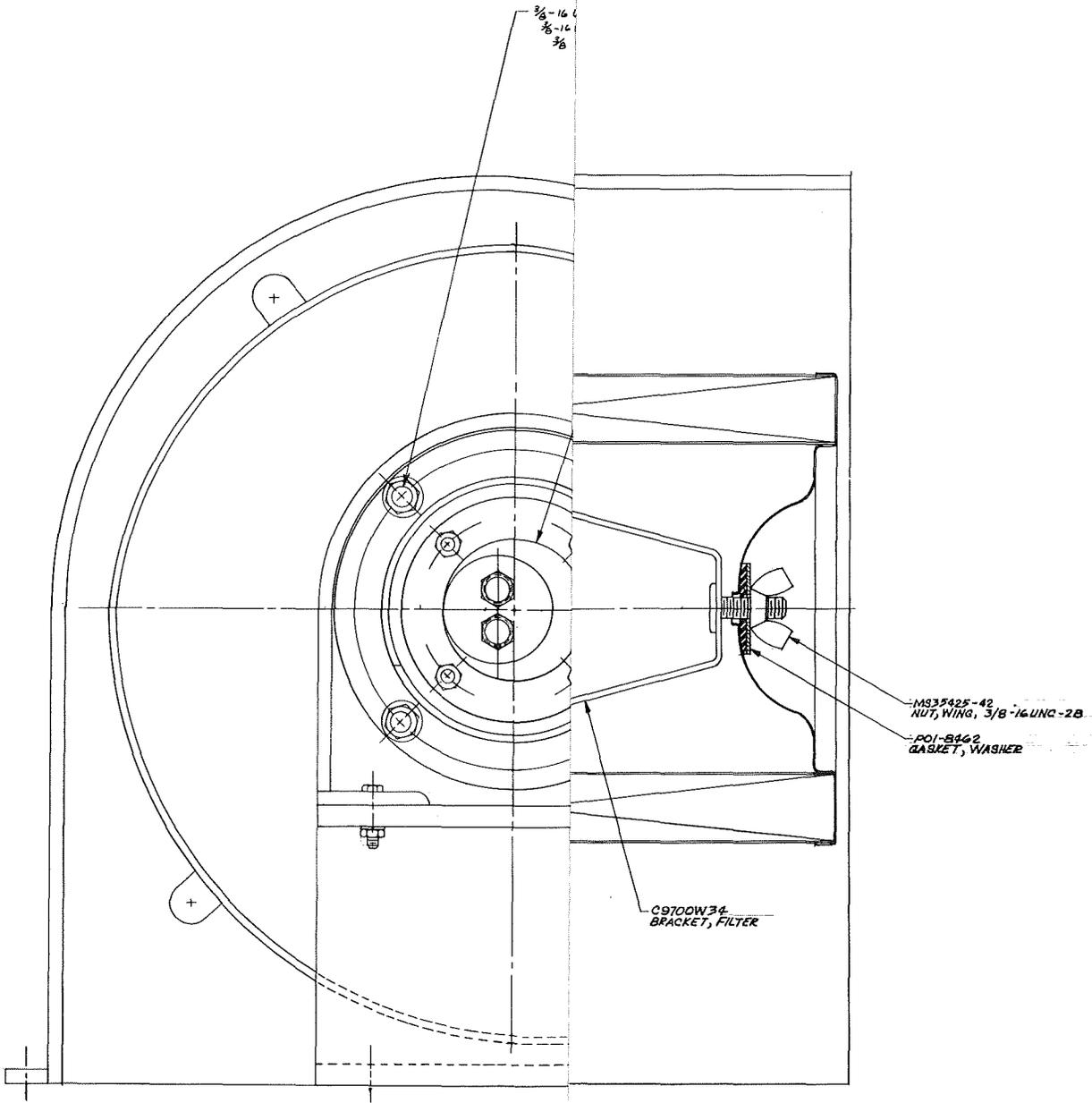


NOTE :  
1. WIRE MESH TO BE SECURED TO  
PERFORATED SHEET (BURR SIDE)  
USING SPRAY ADHESIVE 3M 77.

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	JOB REQ	DWG NO.	REV
	DR C.C.M. 29-MAY-74	B9700W32	1
	CHK		
	APP WJK 20-JUNE-74		
REFERENCES	TOLERANCES UNLESS OTHERWISE SPECIFIED	SCALE 1/2	SHEET OF
CODE IDENT. NO. 18265	2 PL DEC ± .03	SECTIONAL <input type="checkbox"/>	OUTLINE <input type="checkbox"/> YES
	3 PL DEC ±	OUTLINE <input type="checkbox"/>	DRAWN <input type="checkbox"/> NO
	ANGLES ±	CLASS. CODE	
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CHK		REV	
APP vjk, 20-3-74		1	
APP		R	
TOLERANCES UNLESS OTHERWISE SPECIFIED		SCALE 1 / 1	
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3 PL DEC =		SECTIONAL <input type="checkbox"/> OUTLINE <input type="checkbox"/>	
ANGLES =		DRAWN <input type="checkbox"/> YES <input type="checkbox"/>	
		NO <input type="checkbox"/>	
		CLASS. CODE	



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