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AUGUST 1987

IMPROVED CANOPY AIR CURTAIN SYSTEMS

Contract J0318014
Donaldson Company, Inc.

**BUREAU OF MINES
UNITED STATES DEPARTMENT OF THE INTERIOR**



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<p>The objectives of this contract were to develop an improved canopy air curtain system for mining use. The canopy air curtain concept offers an inexpensive solution to dust protection of an individual worker while not interfering with the production process. The purpose of this contract was to apply canopy air curtain concepts to a wider variety of mining equipment and operations.</p> <p>The work was conducted in three phases: In Phase I canopy air curtains currently used in the mining industry were studied and concepts for mine mill air curtains were designed. During Phase II, canopy air curtains for retrofit on underground mining machines and enclosed cabs on surface mines were designed. The possibility of a gas purification module for protection from diesel contaminants was investigated. The air curtain for mine mill application was tested in the laboratory. During Phase III, the canopy air curtain for retrofit on underground mining equipment and the air-conditioned, partially enclosed cab were fabricated and laboratory tested. Results showed an 89 percent reduction in respirable dust under the canopy air curtain. Three mine mill systems were field demonstrated and showed dust reductions of 82.8 to 98.4 percent. In addition, field maintenance and mine worthiness of the systems were excellent. During Phase IV, the air-conditioned, partially enclosed cab system was field tested. Poor heat distribution and inadequate heating precluded dust testing of this unit in severe winter conditions. The retrofit canopy air curtain and the heat only partially enclosed cab systems were constructed and shipped to their respective field test sites for USBM evaluation. A cost and use study on cab air filtration systems used in the mining industry was also conducted.</p>			
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FOREWORD

This report was prepared by Donaldson Company, Inc., Minneapolis, Minnesota under U.S. Bureau of Mines Contract No. J0318014. This contract was initiated under Public Law 91-173 (83 Stat. 799) as amended by Public Law 95-164 (91 Stat. 1320). It was administered under the technical direction of PRC, with Mr. J.C. Volkwein acting as the Technical Project Officer. Mr. Joseph A. Gilchrist was the Contracting Officer for the Bureau of Mines. This report is a summary of the work recently completed as part of this contract during the period June 1981 through April 1987. This report was submitted by the authors in May 1987.

No subject inventions were conceived during the course of this contract.

EXECUTIVE SUMMARY

This report summarizes the activities and conclusions of work performed during contract J0318014, issued by the United States Department of the Interior, Bureau of Mines, Washington, DC. This four-task program's objective was to improve the canopy air curtain system efficiency and user acceptance, apply the canopy air curtain concept to a greater variety of mine uses and investigate the feasibility and design of a gas purification module for use on canopy air curtain systems when applied to dieselized equipment in underground mines.

During Phase I, Donaldson Company studied canopy air curtain devices previously used in the mining industry. Major problem areas with these devices were identified as insufficient airflow, hydraulic problems, temperature of delivered airflow, excessive noise under the air generator, inadequate generator size and short element life.

Air Curtain devices for use at mine mill work stations were also evaluated. The work station air curtain designs were fully investigated and it was concluded that a system that provided a clean air zone 4 feet square (16 sq ft) with about 6400 cfm of airflow would be appropriate for most work stations.

During Phase II, improved canopy air curtain systems for retrofit on various underground mining machines and partially enclosed cabs in surface mines were designed. A design and evaluation of a gas purification module was started.

Mine mill air curtain concepts were evaluated and laboratory testing was started. The evaluation and tests resulted in a self-contained design consisting of panel filters to clean and disperse the airflow, a fan, and an airflow damper to provide for operator control. This design provided a clean air zone of 4 feet square (16 sq ft).

During Phase III, the improved canopy air curtain system for retrofit on various underground mining machines was fabricated and tested. Testing showed an average dust reduction efficiency of 89%.

This system consisted of an air curtain generator with improved airflow distribution, an electrically driven high-speed blower with greater airflow and static capabilities, and an air cleaner with low initial restriction and longer element life.

The design of a single system to include all design parameters of the partially enclosed cab was deemed impractical. Therefore, the partially enclosed cab was designed as two systems, one with heating/air conditioning and one with heating only.

The heating/air conditioning system consisted of commercially available heating/air conditioning components, a self-cleaning filter system, the air generator, fan, and complete operator controls. It was all packaged in a housing designed to be installed on a vehicle cab roof.

The heat only partially enclosed cab canopy air curtain system was designed and components were purchased, but the unit was not fabricated or tested at this time because an installation site was not located.

The design and evaluation of a gas purification module designed for use with the canopy air curtain system in dieselized mines was completed.

Because the gas purification module would be large, expensive and marginally effective, further development was not pursued. The contract was modified to eliminate further gas filtration effort.

Three mine mill canopy air curtain systems were fabricated and field demonstrations completed.

The first field test unit was a self-contained design with panel filters to clean and disperse the airflow. Test results showed the operator's exposure level reduced an average of 96.6 percent and dust levels in the plant reduced an average of 34 percent. A major problem was encountered, however, with heavy dust loading of the panel filters. This caused unacceptably short filter life and high maintenance. As a result, a second unit was designed and fabricated.

The second unit contained a pulse cleaning filter system, a redesigned air generator, and a modified blower/motor package. This unit was modular in design, rather than being self-contained.

Test results of this second unit showed the operator's exposure level reduced an average of 98.4 percent. This second unit was very large, however, because of its modular construction.

Consequently, a third unit was designed as a self-contained system which resulted in a lighter and smaller unit. Test results of this unit showed the operator's exposure level reduced an average of 82.81 percent and dust levels in the plant reduced an average of 12.38 percent.

During Phase IV, the air conditioned partially-enclosed cab canopy air curtain system field demonstration was completed.

This system was removed from operation, however, before dust reduction testing was conducted because of excessive fan noise and insufficient heating capacity.

The underground retrofit canopy air curtain system and the modified heat only partially enclosed cab canopy air curtain system were fabricated and shipped to their respective field test sites for subsequent evaluation by the Bureau of Mines.

Due to a contract modification, the heat only partially enclosed cab canopy air curtain was redesigned specifically for an underground application. Heating capability was omitted from this redesigned system.

The study of cab air filtration systems was also completed.

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1.0 BACKGROUND/STATEMENT OF THE PROBLEM

The Federal Coal Mine Health and Safety Act of 1969 set allowable exposure of miners to respirable coal dust of 2 mg/m^3 , when averaged over an 8-hr shift. During the past several years, much effort was expended to reduce the respirable dust concentration in underground coal mines. These efforts included 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 was and is continuing to be made, certain work stations in underground mines still have high dust exposure.

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 miners' objections to face-mask respirators are primarily associated with physical discomfort. These objections compromise the protection afforded by the dust respirator. Efforts to eliminate the miners' objections have included powering the respirator, using enclosure helmets, and redesigning the mask for comfort.

Aligned with these efforts, was the program carried on by Donaldson Company for the development of an air curtain respiratory protective device under Contract H0122087. 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
- No impairment of speech or expectoration

However, a hose is required to connect the miner to the machine and it is only natural that some discomfort occurs.

Federal legislation, effective in 1974, required all underground mining machines to be equipped with canopies over the operator's station. Donaldson

Company recommended the incorporation of an air curtain device into the canopies of the underground machines to provide effective respiratory protection to the operator, and to eliminate the physical interface of the helmet air curtain device.

In June 1973, Donaldson Company received a contract to design, fabricate, and test canopy air curtain devices compatible with mining equipment. This contract enabled the development of a device which utilizes an invisible curtain of air. This curtain envelops the mining machine operator's breathing zone with filtered air to provide respiratory protection. Various design concepts were evaluated in laboratory tests. The concept selected 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 percentage reductions over the ambient dust concentrations were 30 to 75 percent, depending on the amount of time the operator spent under the curtain. At one test site, the device enabled the mining machine to operate within compliance of the 2 mg/m^3 standard.

Recognizing both these problems and the potential of air curtains to provide mine workers with a clean breathing zone, the Bureau of Mines issued Contract J0318014 to Donaldson Company to develop an improved canopy air curtain system for mining use, to investigate its feasibility and to develop a method and hardware to remove gaseous contaminants and particulates from the mine air delivered by the canopy air curtain. In addition, applying the air curtain to a greater variety of mining equipment and mine mill operations was investigated.

A contract modification eliminated the development of the gaseous removal contaminant hardware from the contract.

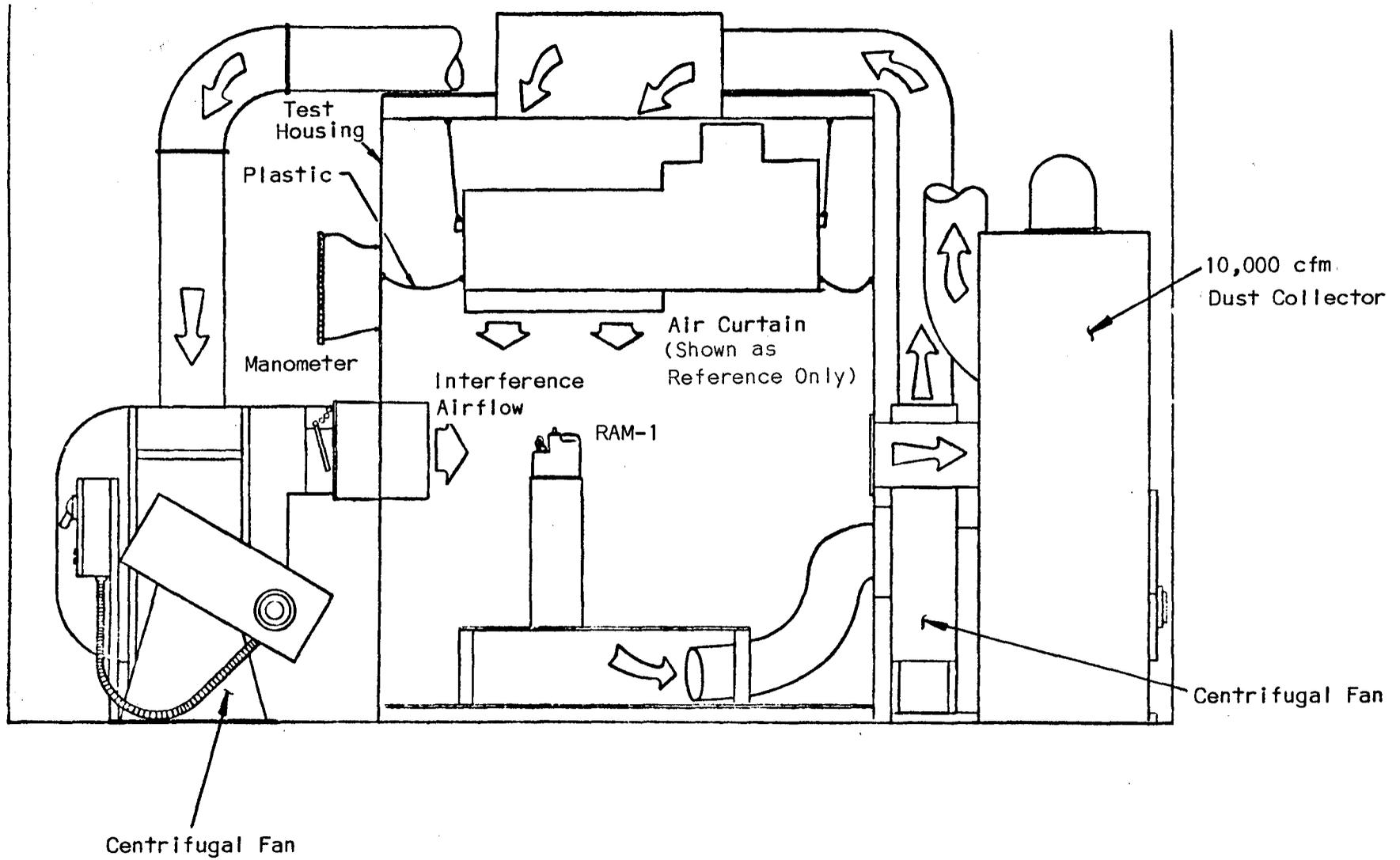
2.0 Test Facility

A facility designed specifically for testing the various CAC concepts was assembled (figure 1). The major components of the facility include test chamber, ducts, air movers, air cleaners, dust feeders, and power outlets. The test chamber is a 12 feet high by 12 feet wide by 10 feet deep structure; it is made of plywood and 2 by 4 studs. The chamber provides a controlled environment that consists of recirculated filtered air, interference air (used to determine the effect of side drafts on the air curtain's dust protection system), and mounting platforms for instrumentation. Specifications on all the major components of the test facility and instrumentation can be found in table 1.

Table 1. Test Facility Components and Instrumentation

Component	Model
Recirculation Fan	Aerovent 1000B Centrifugal, 50 hp Motor at 1,400 rpm
Interference Fan	Aerovent 1000B Centrifugal, 50 hp Motor at 1,400 rpm
Dust Feeder	Donaldson Automatic Dust Feeder
Aerosol Monitor	GCA RAM-1 Real Time
Strip Chart Recorder	Soltec VP-6723S 2 Pen Portable
Thermometer	0 to 250°F Mercury
Manometer	Dwyer Slack Tube
Hot Wire	TSI Model 1610 Velocity Transducer and
Anemometer	TSI Model 67 Linearizer
Velometer	Alnor Instrument Company, Type 3002
DB Meter	Bruel and Kjaer Impulse Precision Sound Level Meter Type 2204

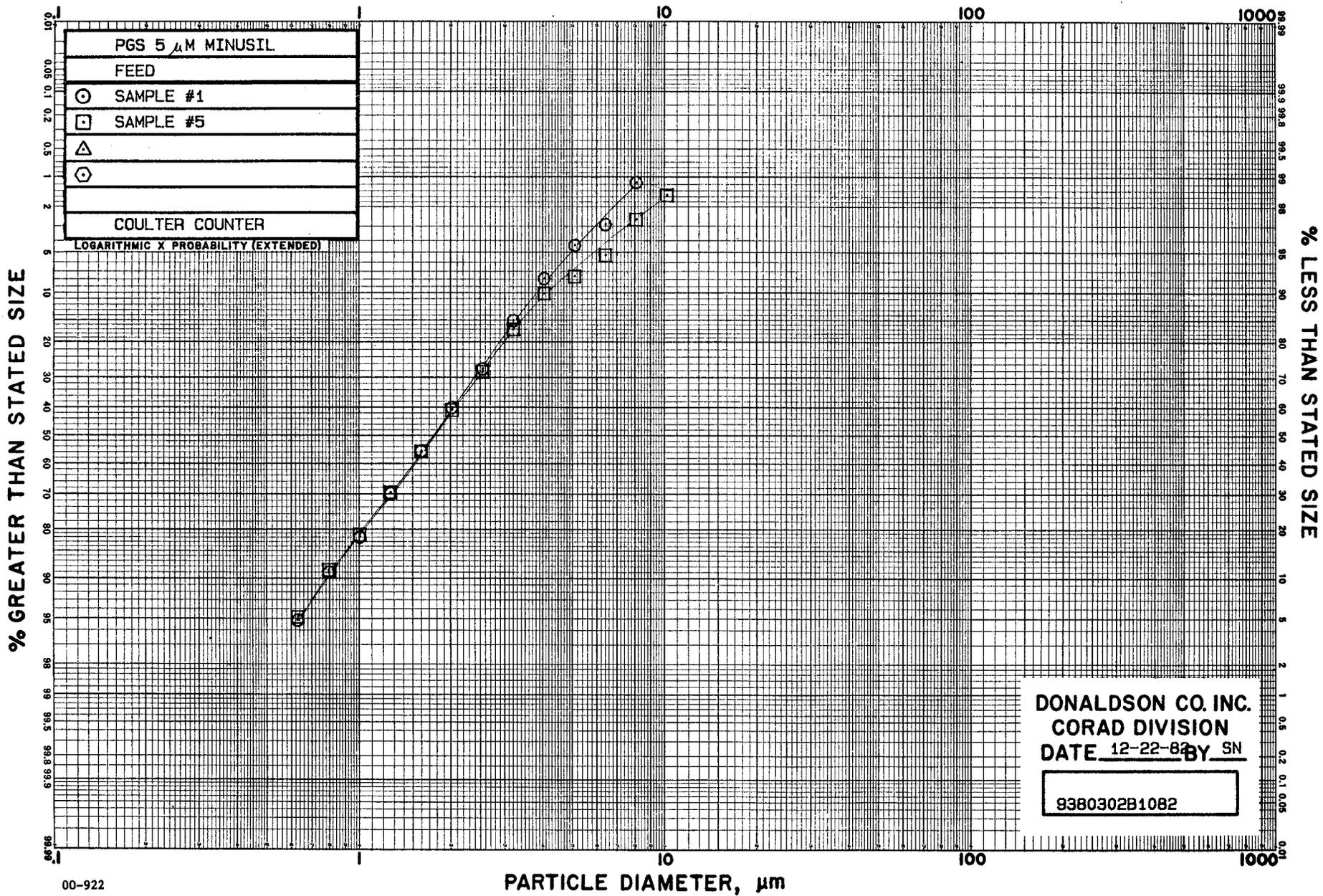
Figure 1. Schematic of Air Curtain Test Facility



2.1 Test Dust

The test dust, tradenamed MIN-U-SIL, was from Pennsylvania Glass and Sand Company. The mean particle diameter was 5 microns; the content was 99 percent silica.

Refer to figure 2 for a graph of the particle size analysis of the test dust.



00-922

Figure 2. Five Micron MIN-U-SIL

3.0 MINE MILL CANOPY AIR CURTAIN

Potential applications for the air curtain included a picking table or a shaker table at a coal preparation plant. The operator in this application is in a small enclosed building which has no ventilation airflow. Generally, in the winter this operation is out of compliance. When this occurs, workmen move to another environment for half of the day to keep within the 2 mg/m^3 respirable dust exposure level. In addition, the silica flour packing station is well suited for an air curtain device. This operation varies from plant to plant. Generally, the equipment operates in compliance. Occasional malfunctions, however, place the operation extremely out of compliance. The primary means of keeping the workmen in compliance are using respirators and transferring the worker to another area. The position that NIOSH has published is "that respirators should not be used as a primary means of reducing worker exposure to silica flour."* This lends further support for the adaptation of air curtain devices for use at mine mill work stations.

3.1 Evaluation of Mine Mill Operations

To determine the design parameters of the work station air curtain, several silica processing facilities were visited. In addition, two other facilities were contacted that declined to permit a visit of any kind. The operators were willing to discuss the use of an air curtain and answer questions about their work stations and the dust generated.

A summary of guidelines for a protective air curtain for a work station is found in table 2. The work stations that Donaldson Company has observed could generally be protected by a device that would provide a clean air zone of 4-ft square. The height of a protective air zone device is not critical, if the side closest to the loading bin is minimized to facilitate installation and optimize personnel protection.

*Mine Safety & Health Report, Vol. 3, No. 4, p. 62, July 15, 1981

Table 2. Guidelines For Work Station Air Curtain

Guideline	Criteria
Capital Investment	Lowest Cost
Maintenance Cost	Lowest Cost
Maintenance Cycle	Longest Cycle
Maintenance Accessibility	Easiest Access
Simplicity/Flexibility of Installation	Most Flexible to Install for Variety of Applications
Noise	Noise for Operator Acceptable
Size and Profile	Minimize to Provide for Flexibility

During the field evaluation of work stations, dust levels were monitored using both gravimetrics and instantaneous techniques. Mine Safety Appliance personal samples were used for gravimetric sampling. GCA Corporation Real-Time Aerosol Monitors Model RAM-1 were used for instantaneous monitoring. The real-time measurements were also recorded on strip charts for a permanent record.

The strip charts indicate relative measurements of dust concentrations during the work cycle at silica packing work stations. Background measurements were found to be approximately 0.2 mg/m³. The average measurements during the work cycle were recorded from 0.4 to 0.5 mg/m³. For short durations occasional readings exceeded 20 mg/m³.

Dust concentrations computed from the samples collected with the personal samplers averaged 0.5 mg/m³. These were measurements of total dust as collected without the cyclone preseparator.

An analysis of this dust using the Coulter Counter indicated that 87 percent of the dust collected is in the smaller than 10 μm range. The curves of the Coulter analysis are shown in figure 3.

Evaluation of mine mill operations studied, indicates that dust collection at the specific operation dust source alone will not protect the operator adequately. Upon occasion, background dust measurements bordered on the standard for silica. A source for providing clean makeup air is clearly needed.

3.2 Design of Mine Mill Air Curtain Systems

From the summarization of design parameters, the concepts for eight basic workstation air curtain systems were formulated. These designs are depicted in figures 4 through 11. All of the designs are based on providing a zone of coverage 4-ft square.

Figure 4 shows the traditional concept of an air curtain generator with a remote blower/air cleaner package. An option of this configuration would be a receiver to provide a completely balanced, closed-loop system.

Figure 5 shows a self-contained air curtain system. With this configuration, the heat exchanger is the primary means of distributing the air from the fan. Figure 6, while similar to the concept presented in figure 5, permits 25 percent additional area for air filtration, thus reducing system restriction.

The concepts presented in figures 7 through 11 utilize filter media to disperse the air. In these concepts, the filter media is located directly between the fan and the air curtain. The concept presented in figure 7 depicts a self-contained system for use when height is limited and/or when the intake should be protected from falling dirt and other objects. The concept presented in figure 8 offers additional space for filter media and a different orientation for the fan, while maintaining a minimum height. The concepts in figures 7 and 8 could also be combined to further increase the filter media while minimizing height.

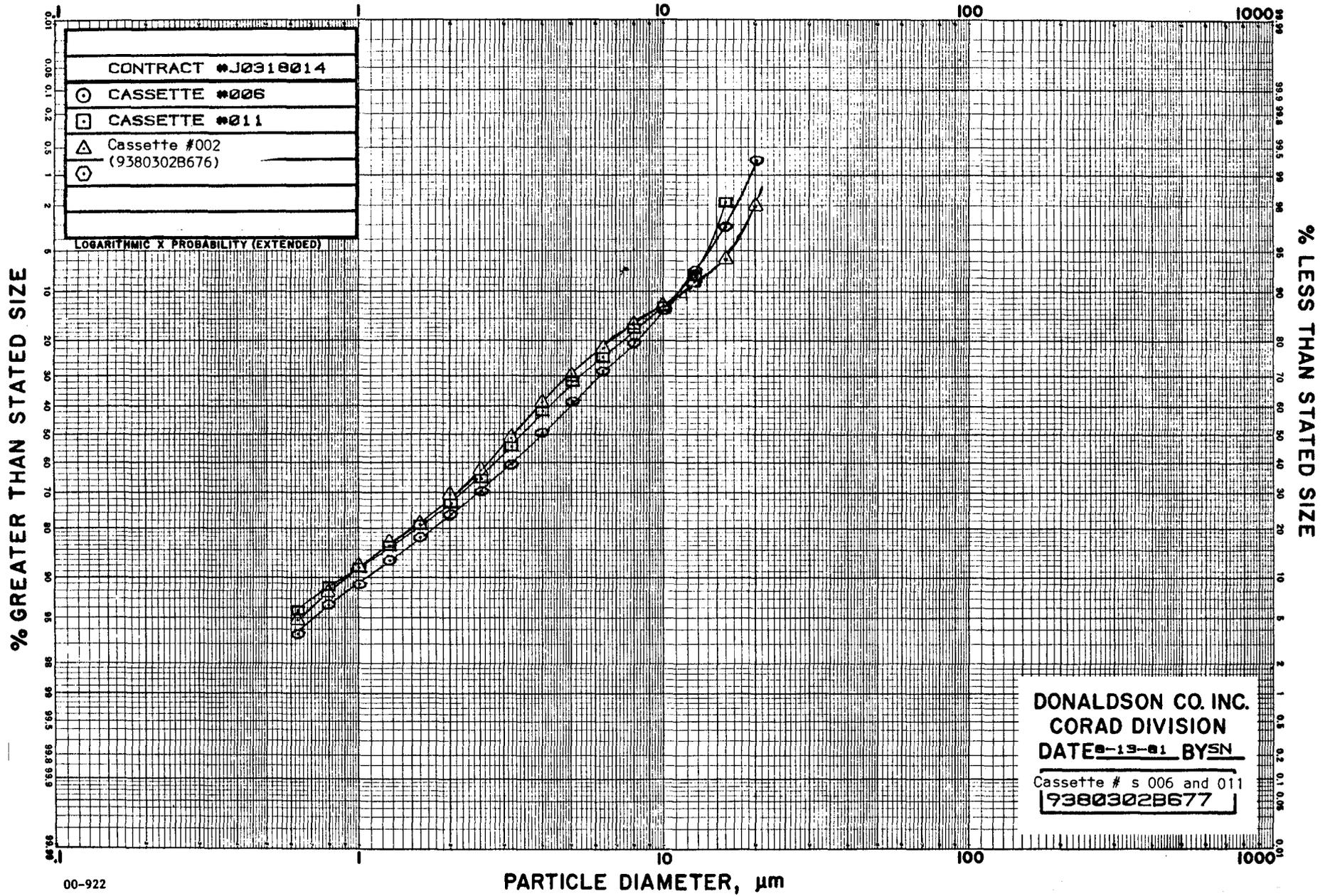


Figure 3. Particle Dust Analysis

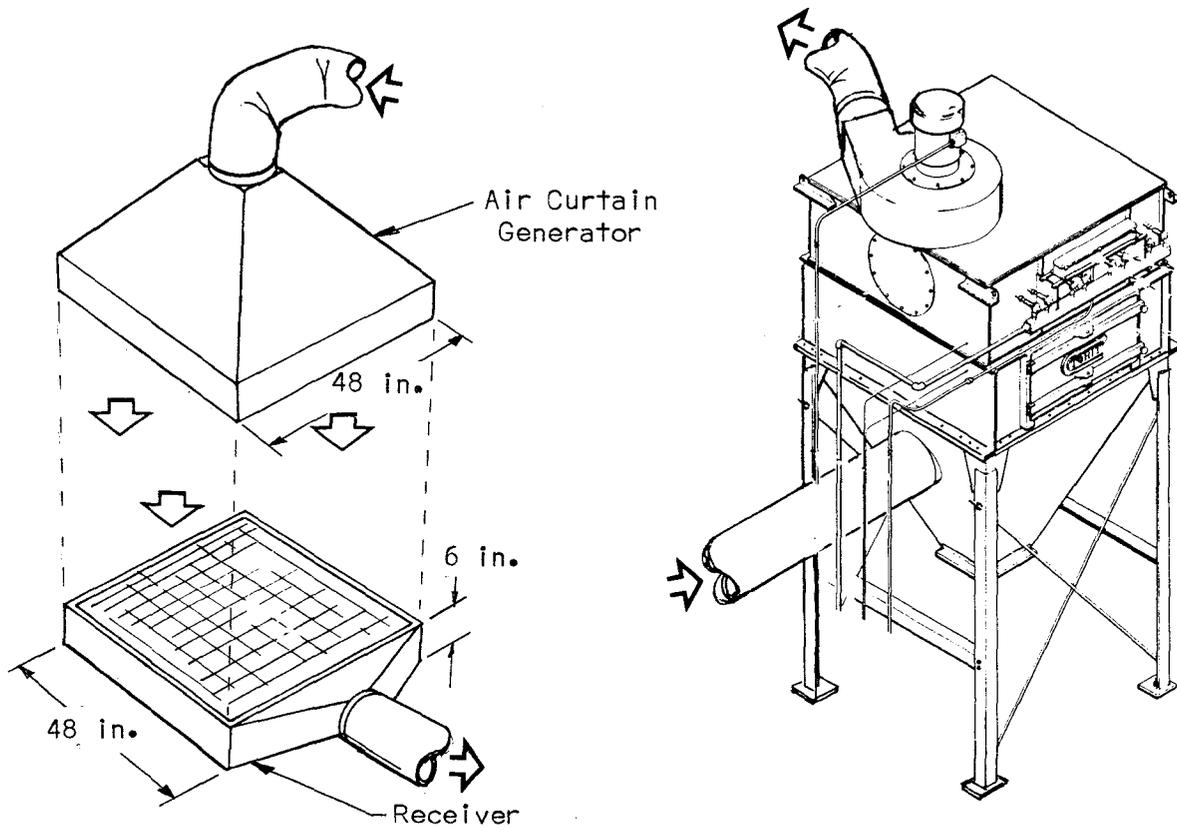


Figure 4. Air Curtain System With Remote Air Cleaner/Blower Package and Optional Receiver

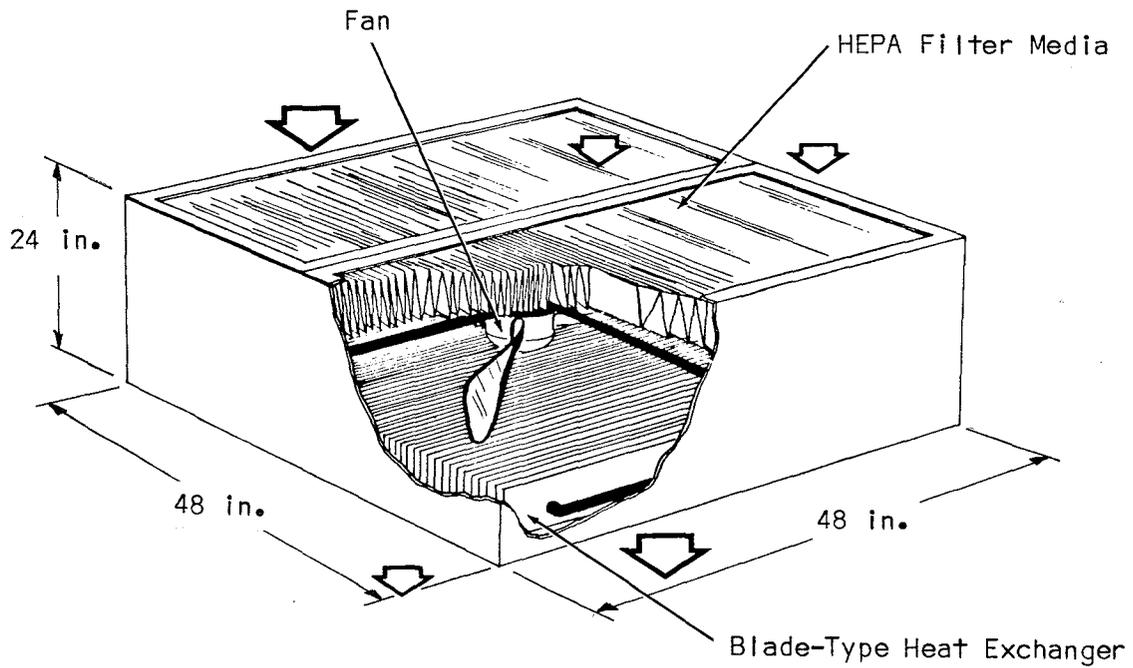


Figure 5. Self-Contained Air Curtain System With Minimal Profile

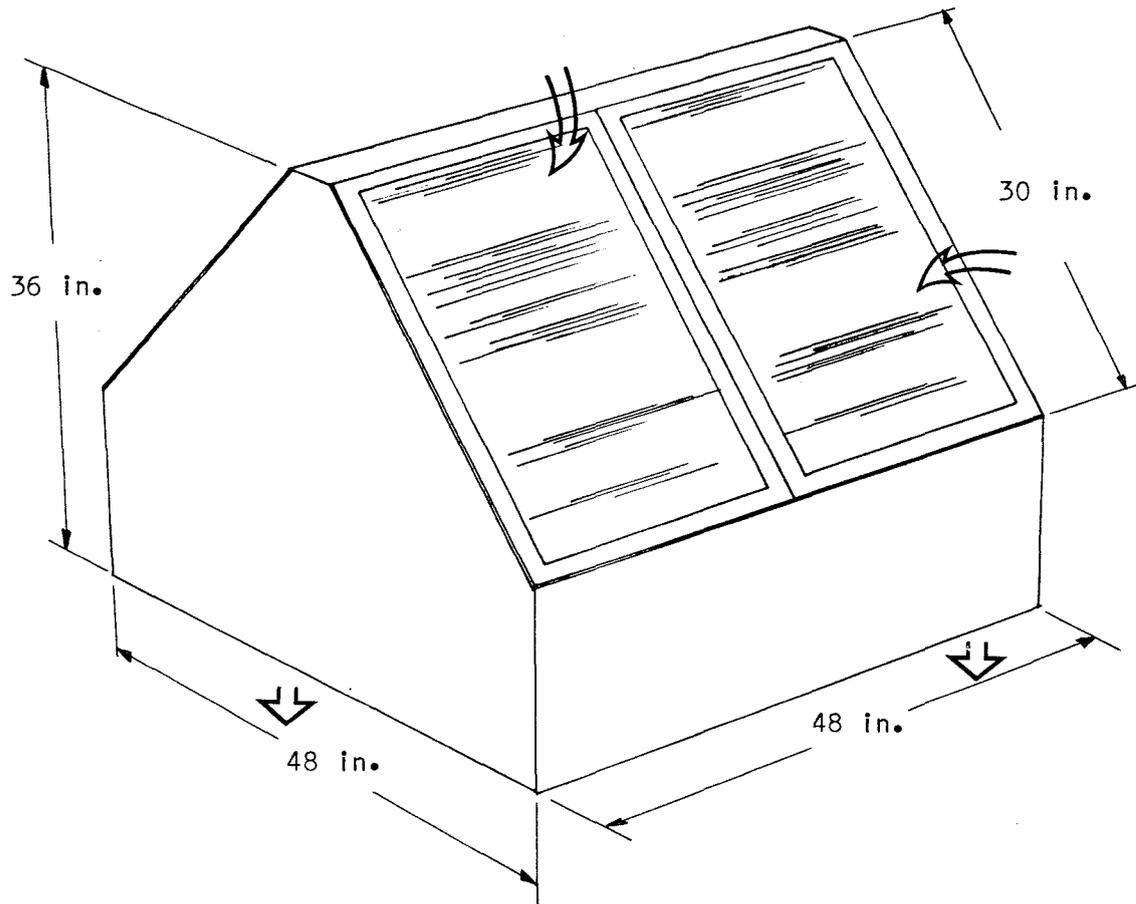


Figure 6. Self-Contained Air Curtain System With Increased Height for Additional Filtration Media

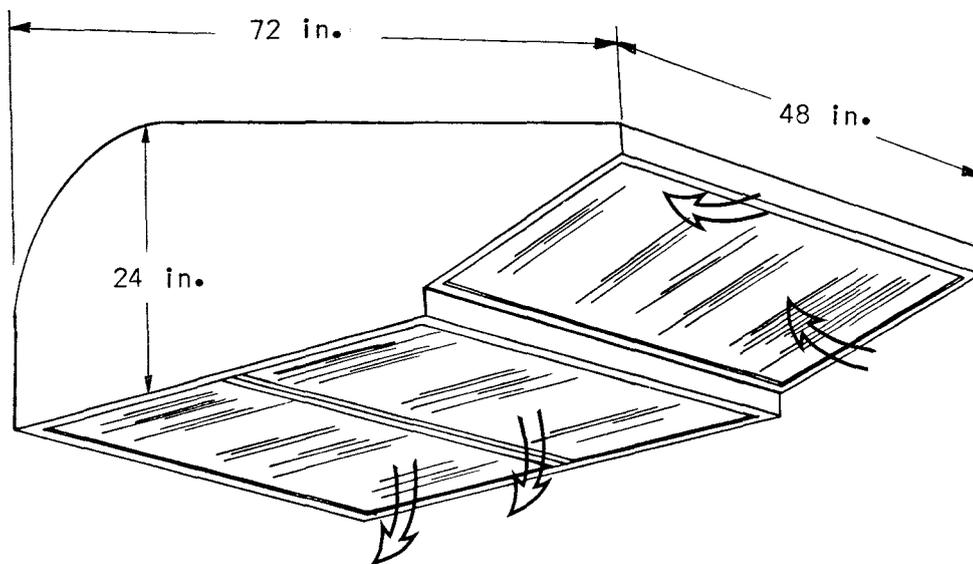


Figure 7. Self-Contained Air Curtain System for Applications With Overhead inlet Obstructions

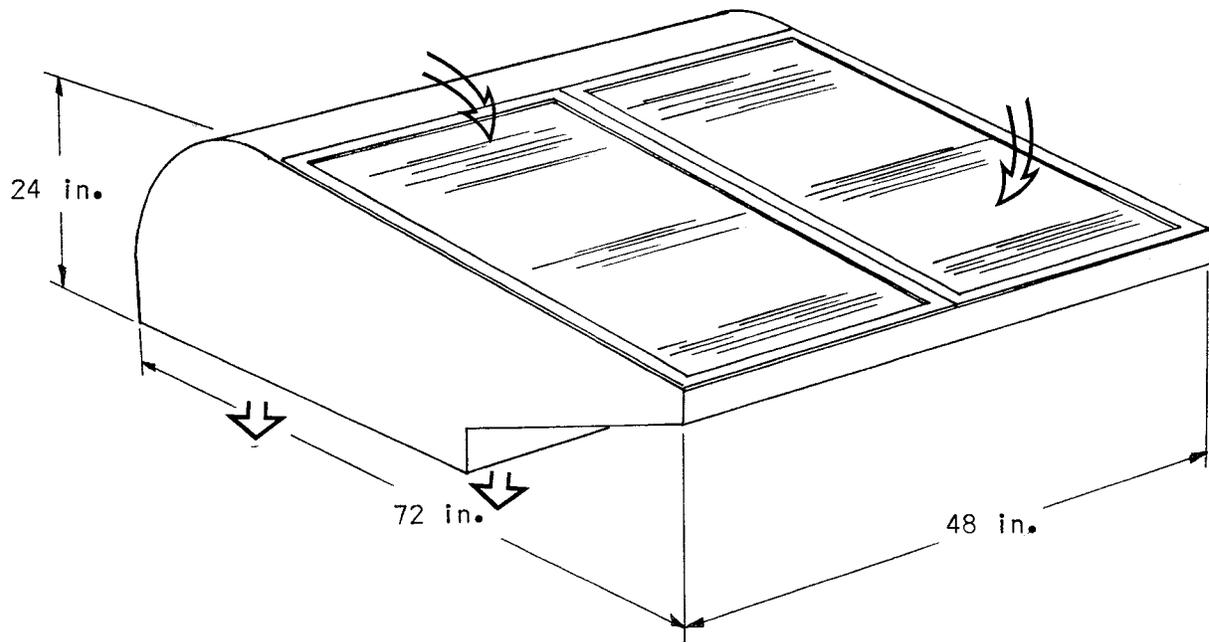


Figure 8. Self-Contained Air Curtain System, Minimal Profile With Increased Filtration Media

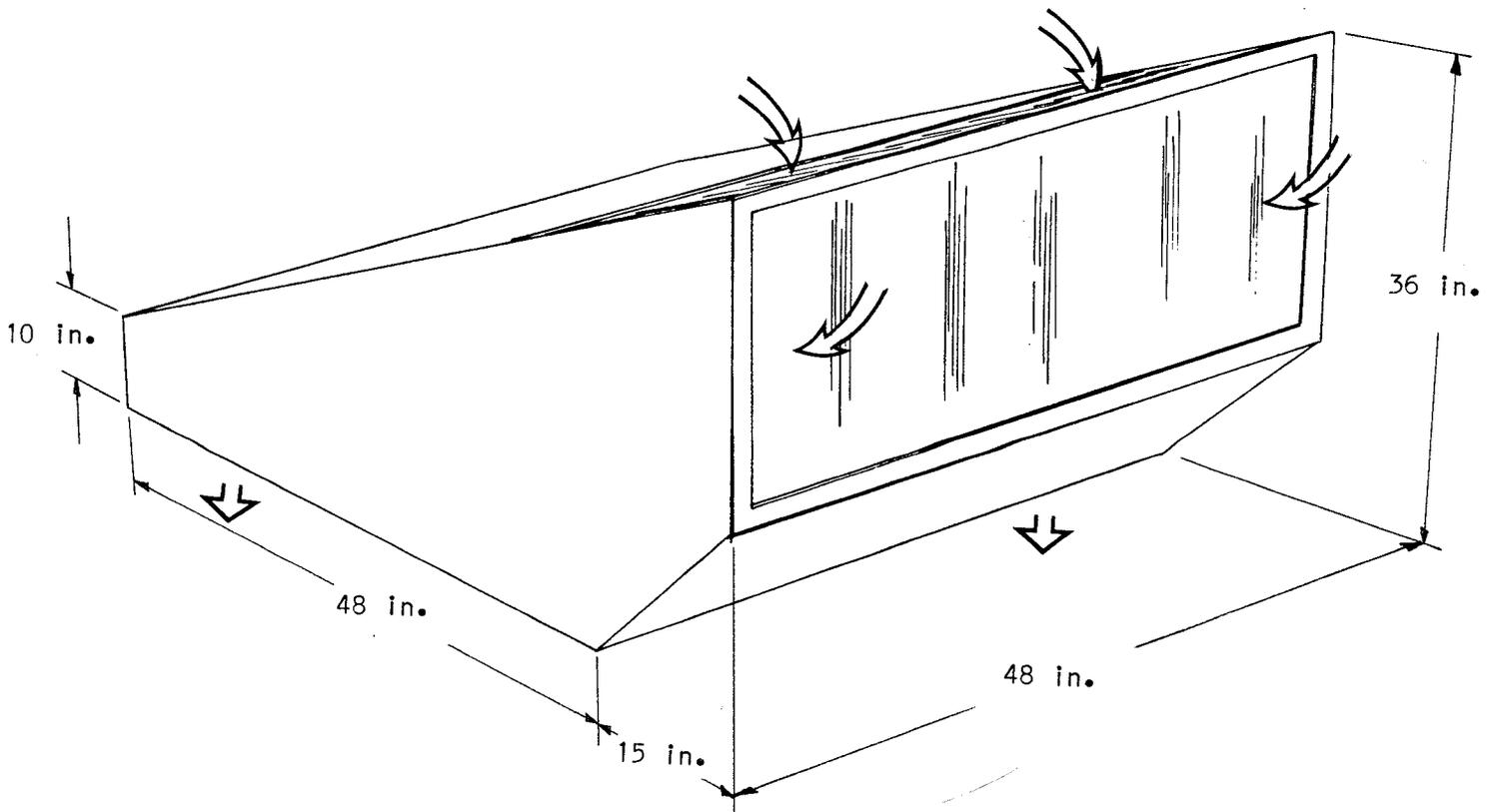


Figure 9. Self-Contained Air Curtain System with Minimal Leading Edge

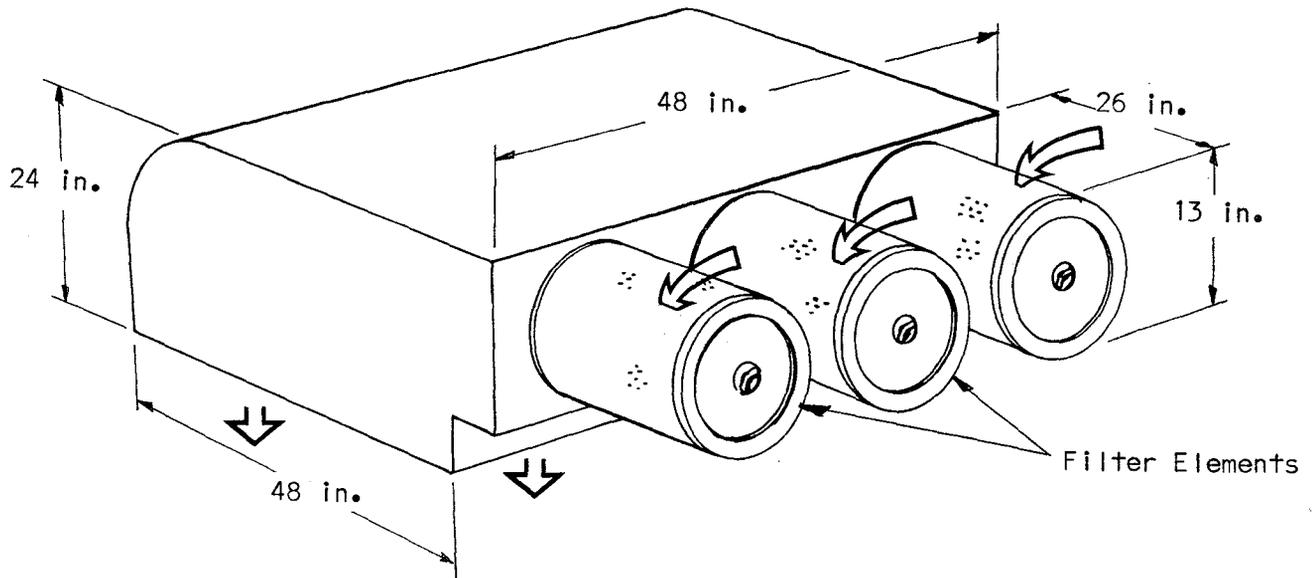


Figure 10. Self-Contained Air Curtain System With Standard Cylindrical Filter Elements

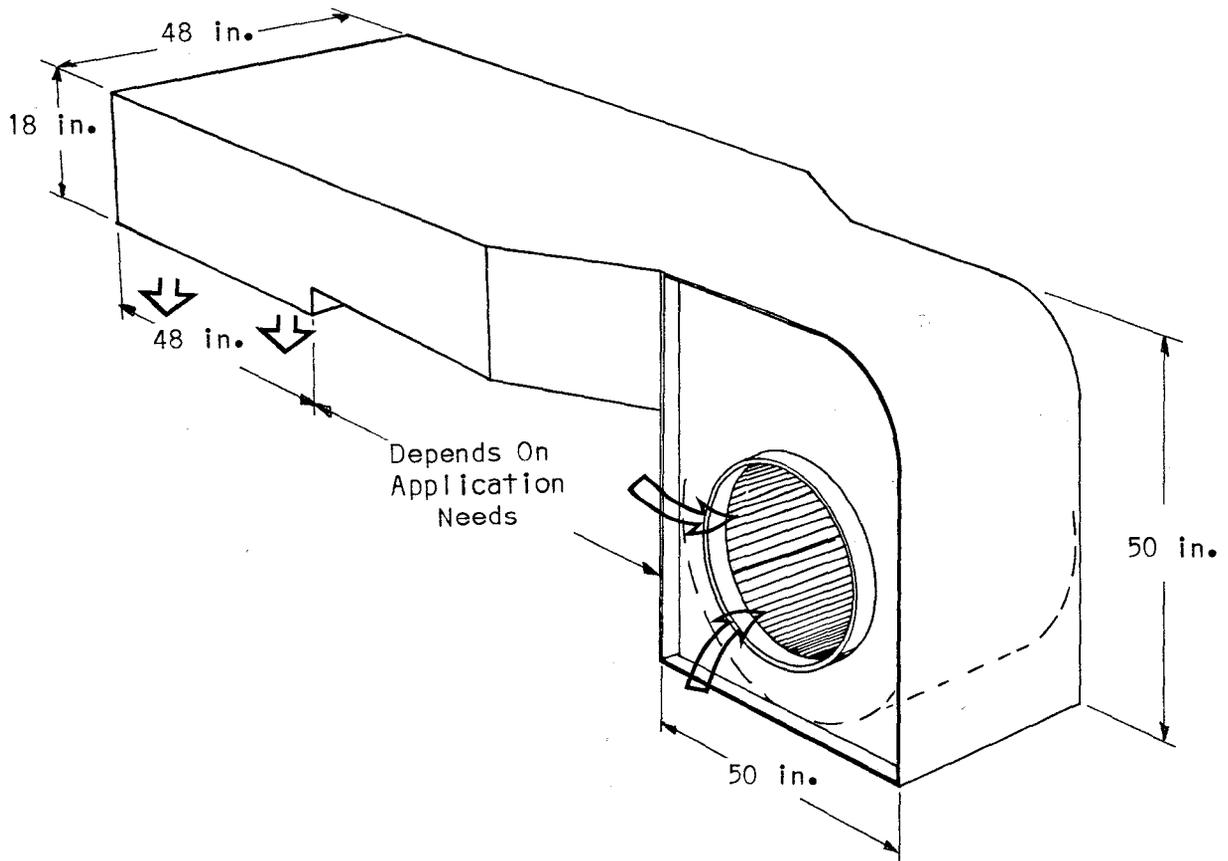


Figure 11. Air Curtain System With Externally/Remote Mounted Fan

The concept presented in figure 9 is a self-contained system that provides substantial area for filtration, excellent fan orientation, and minimal height on the leading edge. This configuration could be particularly useful in applications such as packing, where a loading bin may angle over the operator's position.

The concept presented in figure 10 is a self-contained system that utilizes cylindrical filter elements. Minimum height and simplicity of maintenance are this concept's advantages. In this instance, the cylindrical filter elements remove the contaminants while the filter media panels only disperse the airflow to create the clean air zone or curtain.

The concept presented in figure 11 is a work station air curtain system with a remote-mounted fan or an externally mounted fan. While this configuration is bulky, various methods of silencing the fan package are readily adaptable to this system.

3.2.1 Air Curtain System Installation Sketches

During the evaluation of mine mill operations, slides of the various work stations were taken. From prints of these different potential applications, a composite pseudo-perspective drawing was prepared. The worker is depicted at a packing station for silica products with four different air curtain systems shown in appropriate installation configurations. These drawings are shown as figures 12 through 15.

3.2.2 Conclusions and Recommendations

From the evaluation of the data collected during the study of mine mill applications for air curtains, Donaldson Company concluded that a system that provides a clean air zone of 4-ft square would be appropriate for most work stations. System airflow was recommended at about 6400 ft³/min. For the

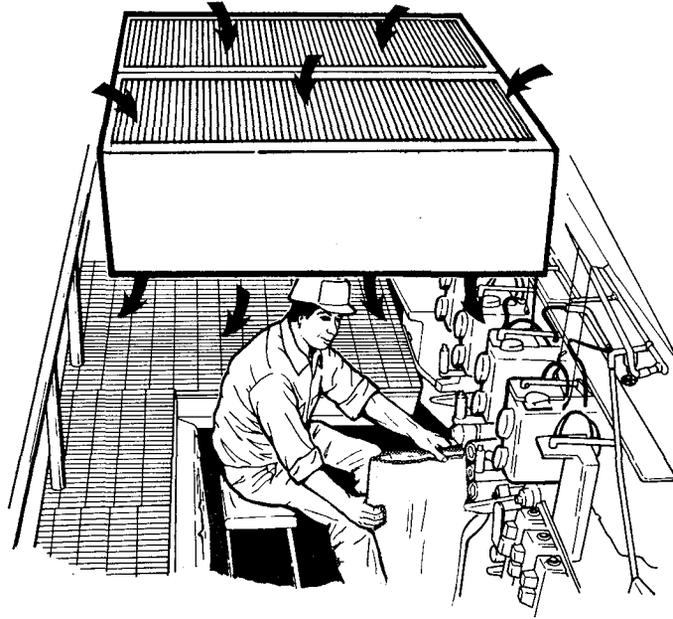


Figure 12. Installation Drawing of Self-Contained Air Curtain System With Minimal Profile

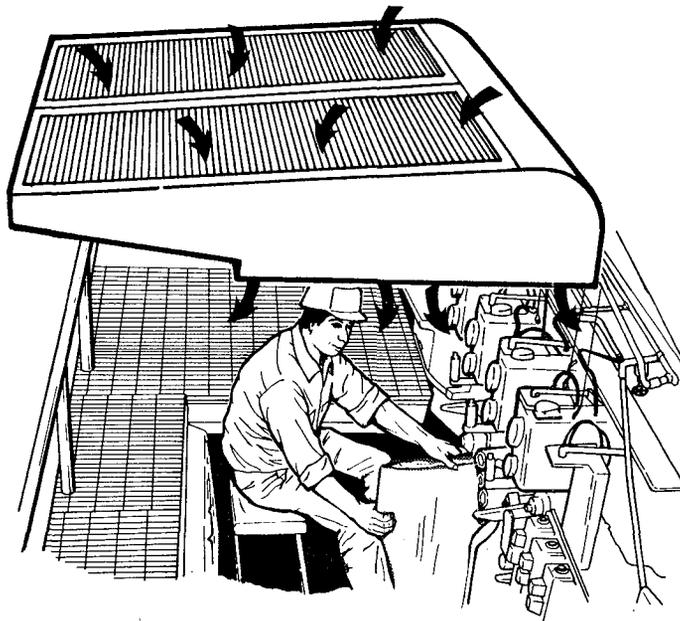


Figure 13. Installation Drawing of Self-Contained Air Curtain System, Minimal Profile With Increased Filtration Media

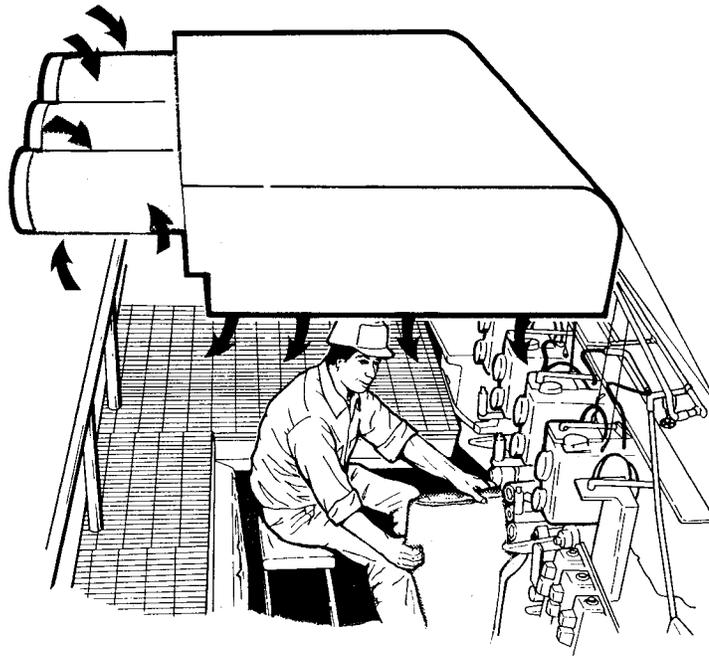


Figure 14. Installation Drawing of Self-Contained Air Curtain System With Standard Cylindrical Filter Elements

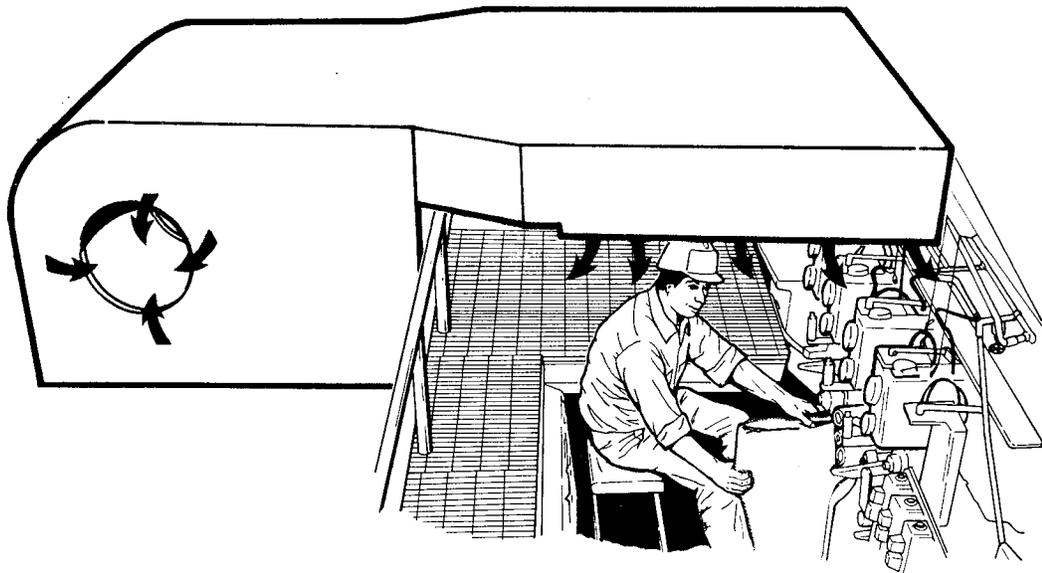


Figure 15. Installation Drawing of Air Curtain System With External/Remote Mounted Fan

laboratory tests, Donaldson Company recommended that full-scale plywood models be used. This would facilitate the greatest flexibility for modifications at the lowest cost. Table 3 shows the work station air curtain trade-off analysis.

Donaldson Company recommended laboratory testing of the following concepts:

- (1) Self-contained air curtain system with minimal profile (figures 5 and 12)
- (2) Self-contained air curtain system, minimal profile with increased filtration media (figures 8 and 13)
- (3) Self-contained air curtain system with standard cylindrical filter elements (figures 10 and 14)
- (4) Air curtain system with externally/remote mounted fan (figures 11 and 15).

Investigation of silencer and penetration barrier requirements should continue during the laboratory testing. In addition Donaldson Company recommended that operator control for temperature and airflow be provided in the final design.

Table 3. Work Station Air Curtain Trade-Off Analysis

Concept Figure Number	Capital Investment	Maintenance Cost	Maintenance Cycle	Maintenance Accessibility	Simplicity/Flexibility of Installation	Noise	Size and Profile	Total Rating	Selected For Testing
2	5	1	1	3	3	1	3	17	
3	2	2	3	2	1	2	1	13	*
4	3	2	2	2	5	2	5	21	
5	3	3	4	2	2	2	2	18	
6	3	2	3	2	2	2	2	16	*
7	3	2	3	2	4	2	4	20	
8	4	2	3	1	2	2	2	16	*
9	1	2	3	3	3	1	3	16	*

Rating Scale	High		Average		Low
	1	2	3	4	5

3.3 Mine Mill Work Station Air Curtain Concepts

Recommendations were made to laboratory test the following concepts, using 6,400 cfm of air dispersed over 4 foot square (16 square feet) area:

- Self-contained air curtain system with minimal profile (figure 5)
- Self-contained air curtain system, minimal profile with increased filtration media (figure 8)
- Self-contained air curtain system with standard cylindrical filter elements (figure 10)
- Externally/remote mounted air curtain system (figure 11)

The air distribution methods recommended were:

- Dispersion of airflow through use of filter media
- Dispersion of airflow through use of a finned heat exchanger
- Dispersion of airflow through use of perforated sheet metal (similar to that in the underground CAC)

3.3.1 Concept Evaluations

The combinations of the proposed air curtain concepts and dispersion methods were evaluated in these areas:

- Type of fan and its capabilities
- Configuration of the unit and its capacities
- Static pressure changes as filtration and dispersion method varies

It was concluded that the minimum profile system with the required propeller type fan could not maintain design airflow for this system's static pressure range. Maximum static pressure rise for this fan is .75 in. wg, whereas the estimated range needed is 1.5 to 6 in. wg. The finned heat exchanger could not provide an adequate pressure drop to evenly distribute the airflow. The concepts which remained were:

- a. Self-contained air curtain system with filtration media to disperse airflow
- b. Air curtain system with externally/remote mounted fan, filter media to disperse airflow
- c. Perforated sheet metal

3.4 Mine Mill Work Station Testing

Initial testing involved the use of filter media as a flow dispersant. An air generator mockup was designed and built of plywood (figure 16). Filters were selected that could easily cover the 4 foot square area and provide an initial pressure drop of about 1 inch (figure 17). This 23.5 by 23.5 inch panel filter, part number P13-5930, is presently manufactured by Donaldson Company. Four of the filters cover 15.3 of the 16 square feet. To keep a low initial pressure drop across these elements, the amount of media was increased from 112 to 223 square feet.

These filters were placed in a frame and attached to the mockup. Airflow for this test was supplied by a centrifugal fan outside the test facility. Air velocity measurements were taken 32 inches below the mockup with a hot wire anemometer (figure 18).

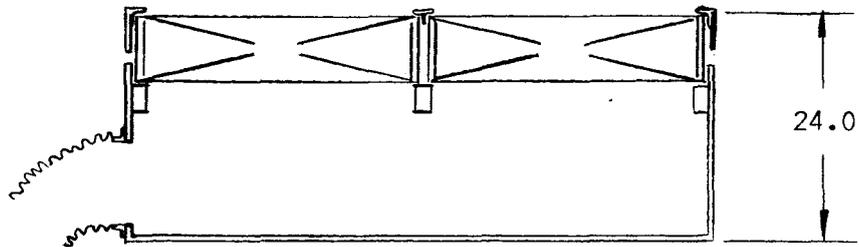
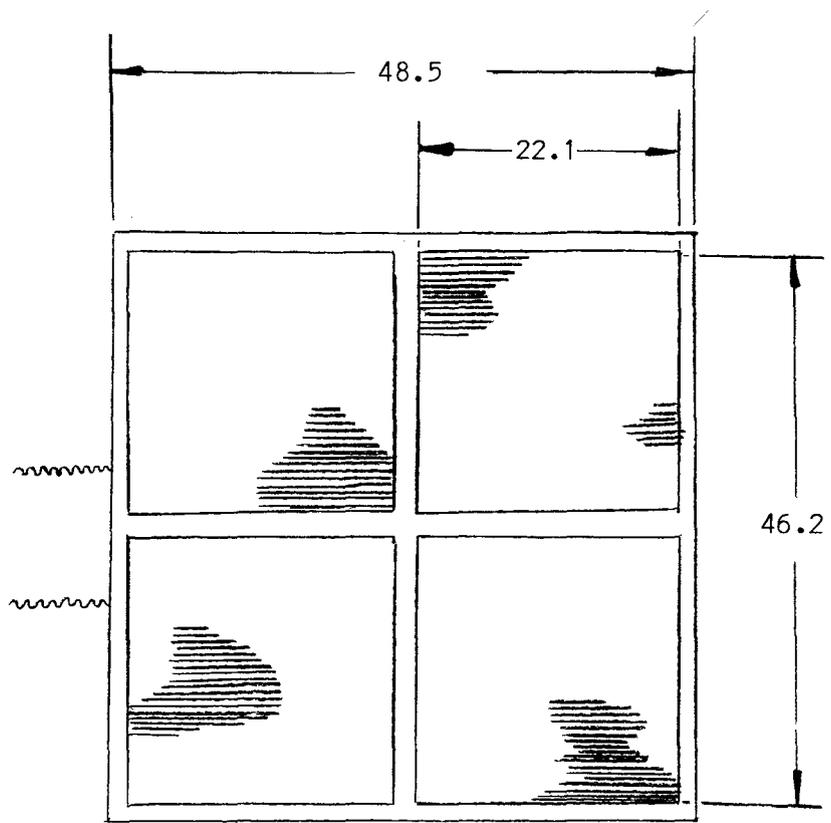


Figure 16. Air Generator Mock-Up

Note:

1. Total Pleats of modified filter media are 275 versus 138 standard filter media.

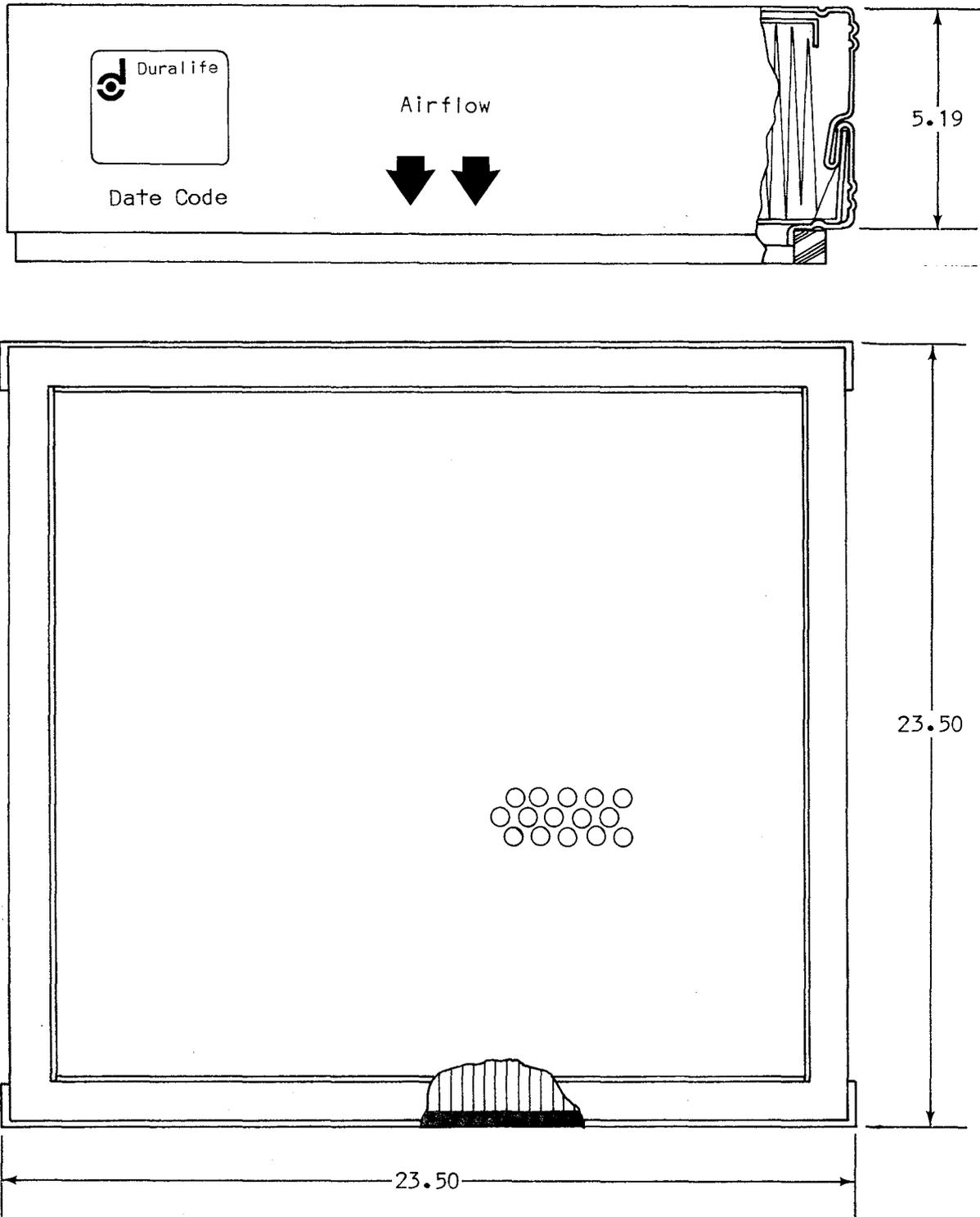
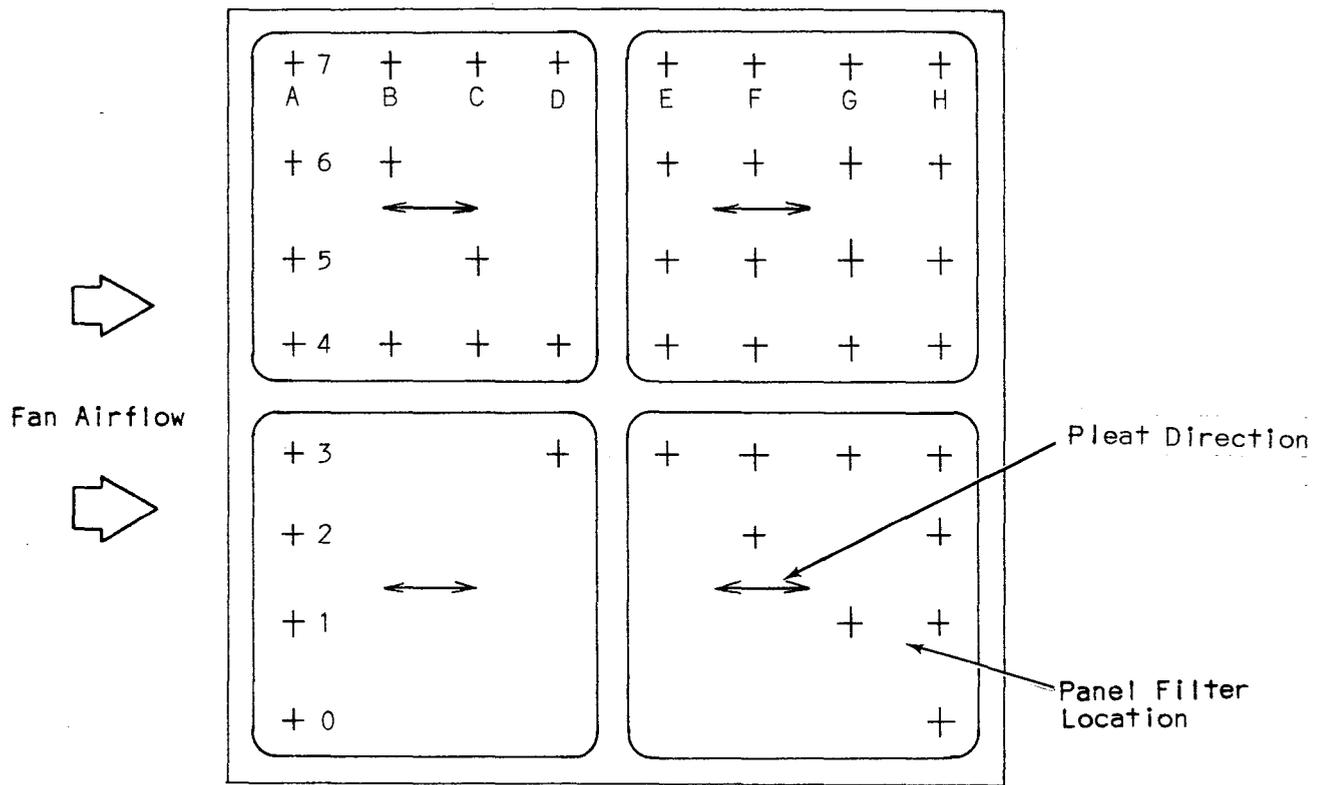


Figure 17. Filter Assembly, Panel STD. Modified (P13-5930)



NOTE: Airflow = 3,920 cfm

- Figures represent airflow velocity in feet/minute, taken 32 inches below panel filters. Generator concept with modified P13-5930 panel filters. Air supplied by 10,000 cfm centrifugal fan.

	A	B	C	D	E	F	G	H
7	168	72	156	210	228	312	363	291
6	192	84			192	318	432	555
5	204		135		114	185	354	429
4	243			123	138	219	510	288
3	246			102	138	219	390	186
2	258					177		210
1	223						489	336
0	132							309

Figure 18. Mine Mill Air Curtain Airflow Distribution Pattern

A search was made to locate a fan to provide approximately 6,400 cfm at .50-inch static pressure. A centrifugal fan with a backward curved impeller (figure 19) was purchased, with catalog rated performance at 3,400 rpm as follows:

Airflow (cfm)	Static Pressure (inches of H ₂ O)
5,300	2.5
5,050	3.0
4,700	3.5
4,400	4.0
4,100	4.5
3,800	5.0
3,500	5.5
3,200	6.0

The plywood mockup of the self-contained unit was designed. Provisions were made to accommodate modifications such as prefiltering, motor and drive modifications, and heat exchangers.

The completed self-contained plywood mockup was 86 by 50 by 31 inches with an air generator 48.5 by 48.5 by 6 inches and four modified P13-5930 panel filters (figure 20).

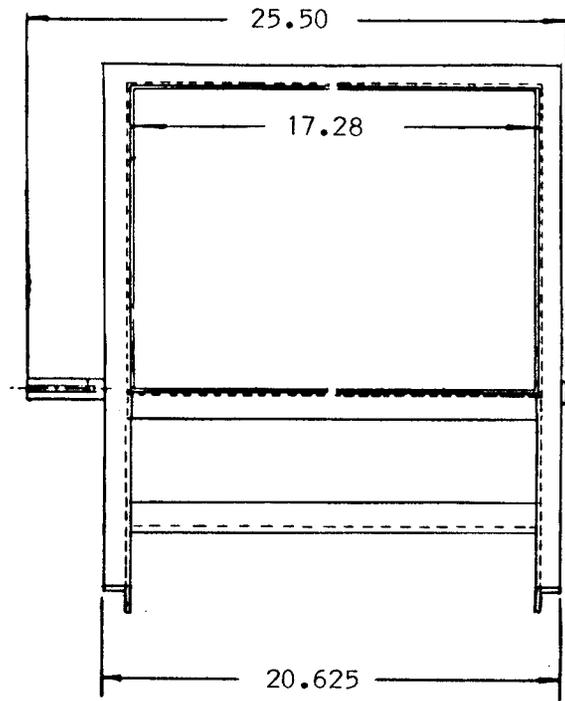
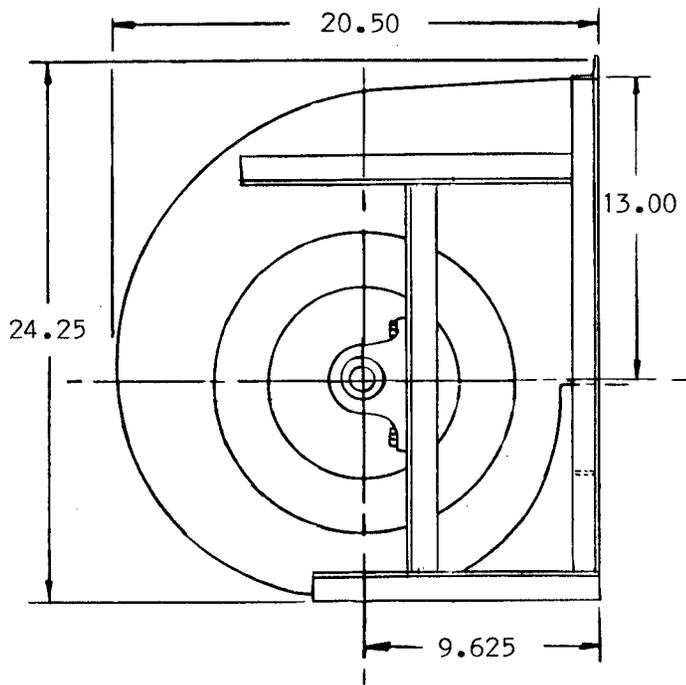


Figure 19. Mine Mill Canopy Air Curtain Fan

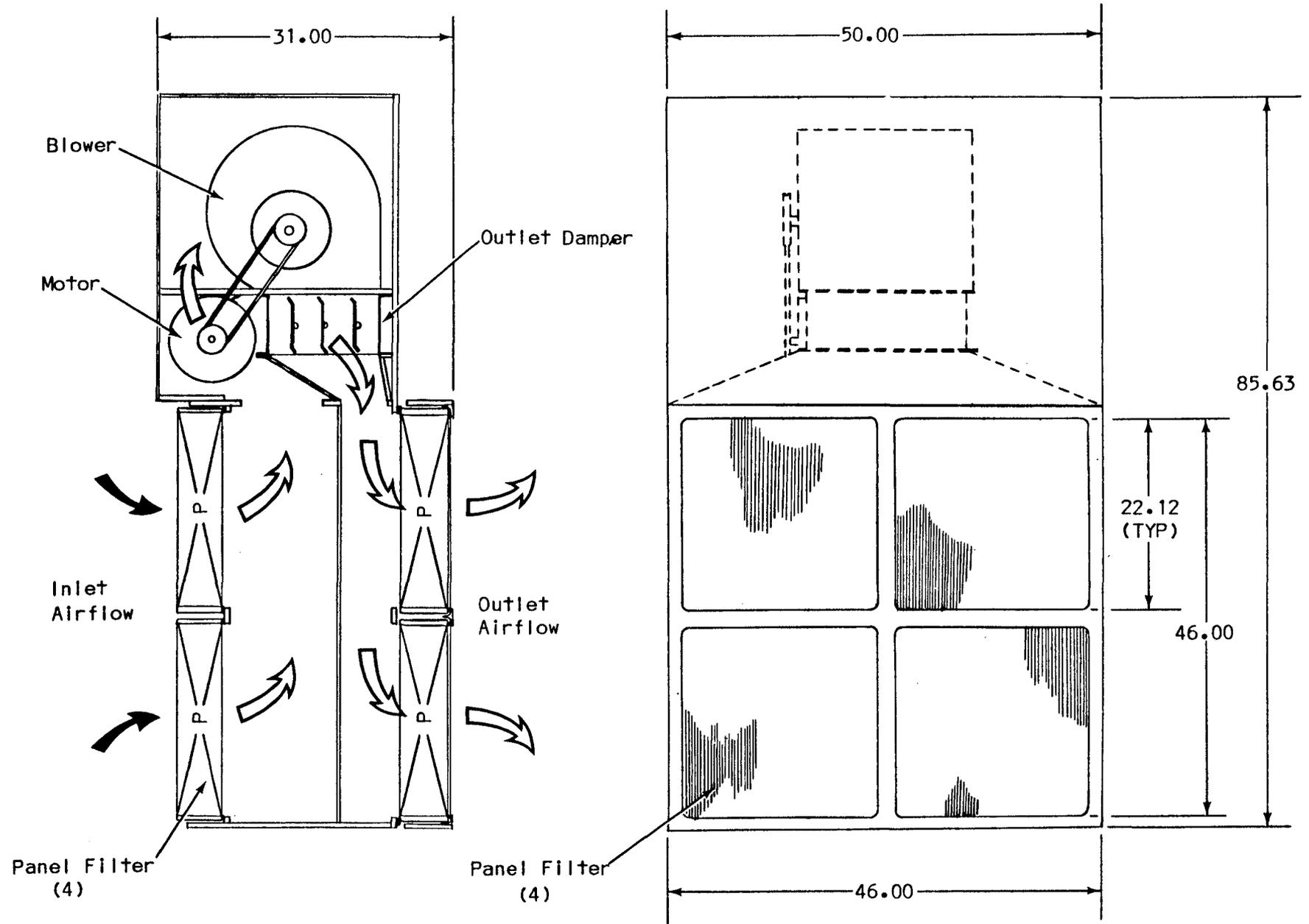


Figure 20. Mock-Up of Self-Contained Mine Mill Air Curtain

Before placing the fan into the mockup, it was tested to establish performance curves and manometer tap locations for final testing in the mockup (figures 21 and 22). The tests were done using 5 and 10 hp motors running at 3,224 and 4,209 rpm respectively. The fan was tested with and without a parallel blade damper mounted on the exhaust outlet.

Once the initial tests were completed, the fan and the 5 and 10 hp motors were mounted in the canopy air curtain plywood mockup. The mockup was then installed in the test chamber.

In dispersion testing of the mockup, a velometer was used to measure air velocities at predetermined locations under the CAC. The tests were run to determine the effects on the airflow distribution of the following parameters (figures 23 through 29):

- Prefiltering
- Pleat orientation in panel filter to direction of airflow
- Standard panel versus one with increased media
- Beaded versus nonbeaded media in panel filters
- Damping of air on fan outlet

Prefiltering, pleat orientation, and various types of panel filters had no negative effect on the airflow distribution. Placing the damper on the fan outlet did have a negative effect on the airflow distribution.

The test chamber was prepared for feeding dust to the CAC mockup. A Donaldson Company dust feeder was set up to feed approximately 1 gram per minute of dust into the chamber through two feeder locations (figure 30). A RAM-1 and strip chart recorder monitored the dust levels in the chamber. Seven locations around the chamber were monitored for 5 minutes for each test (table 4). All RAM-1 locations were kept a vertical distance of 32 inches below the bottom plane of the CAC generator panel filters. This 32 inch distance represents the breathing zone of a worker stationed 24 inches under the CAC generator panel filters.

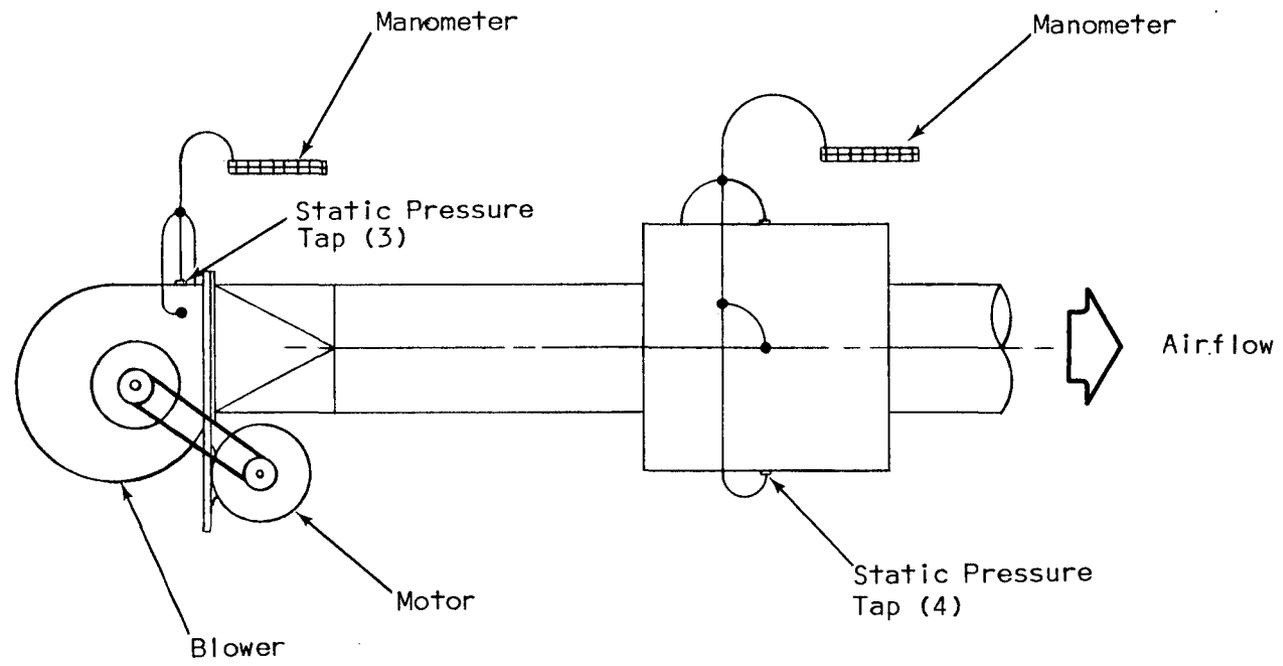
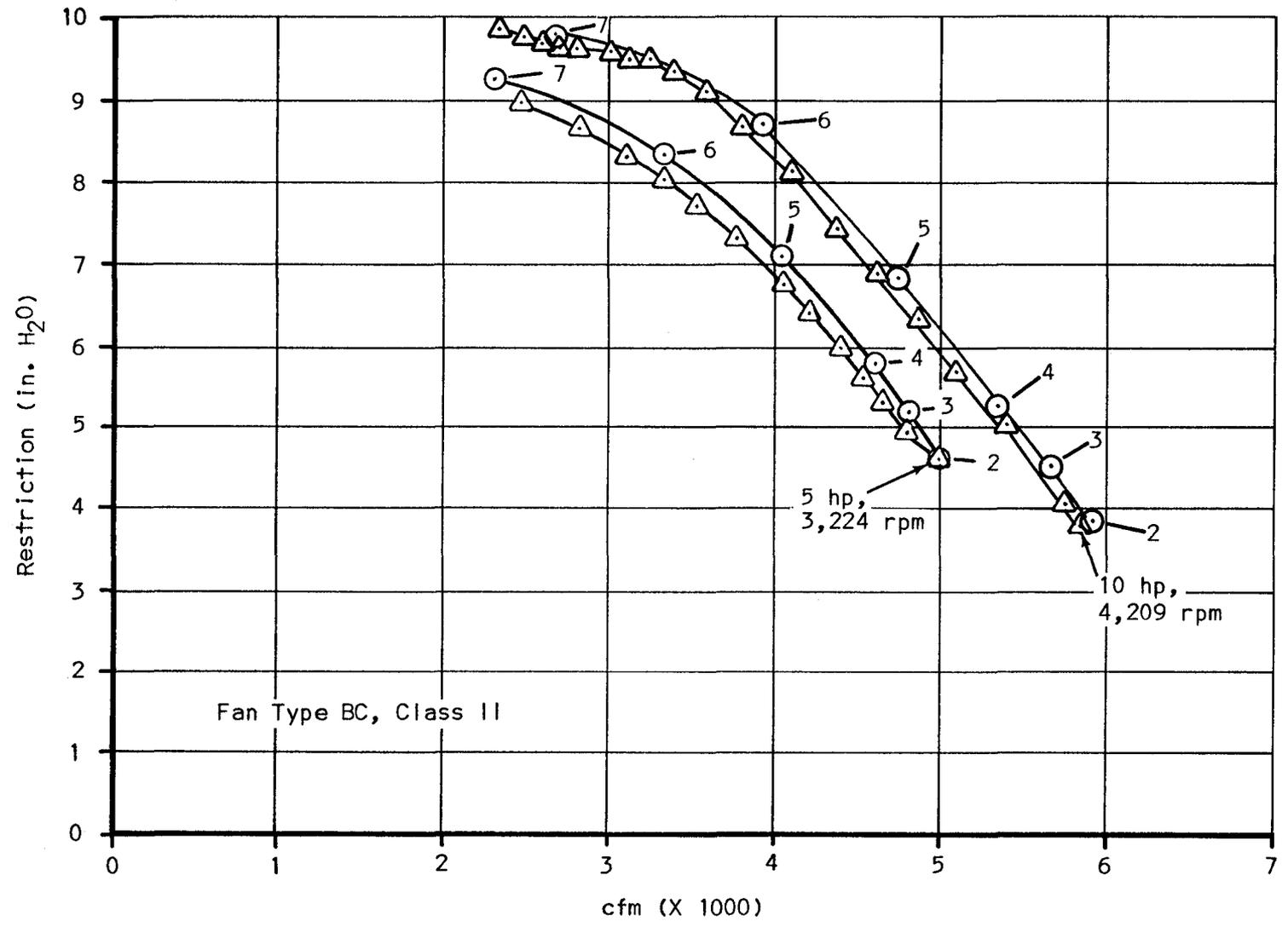


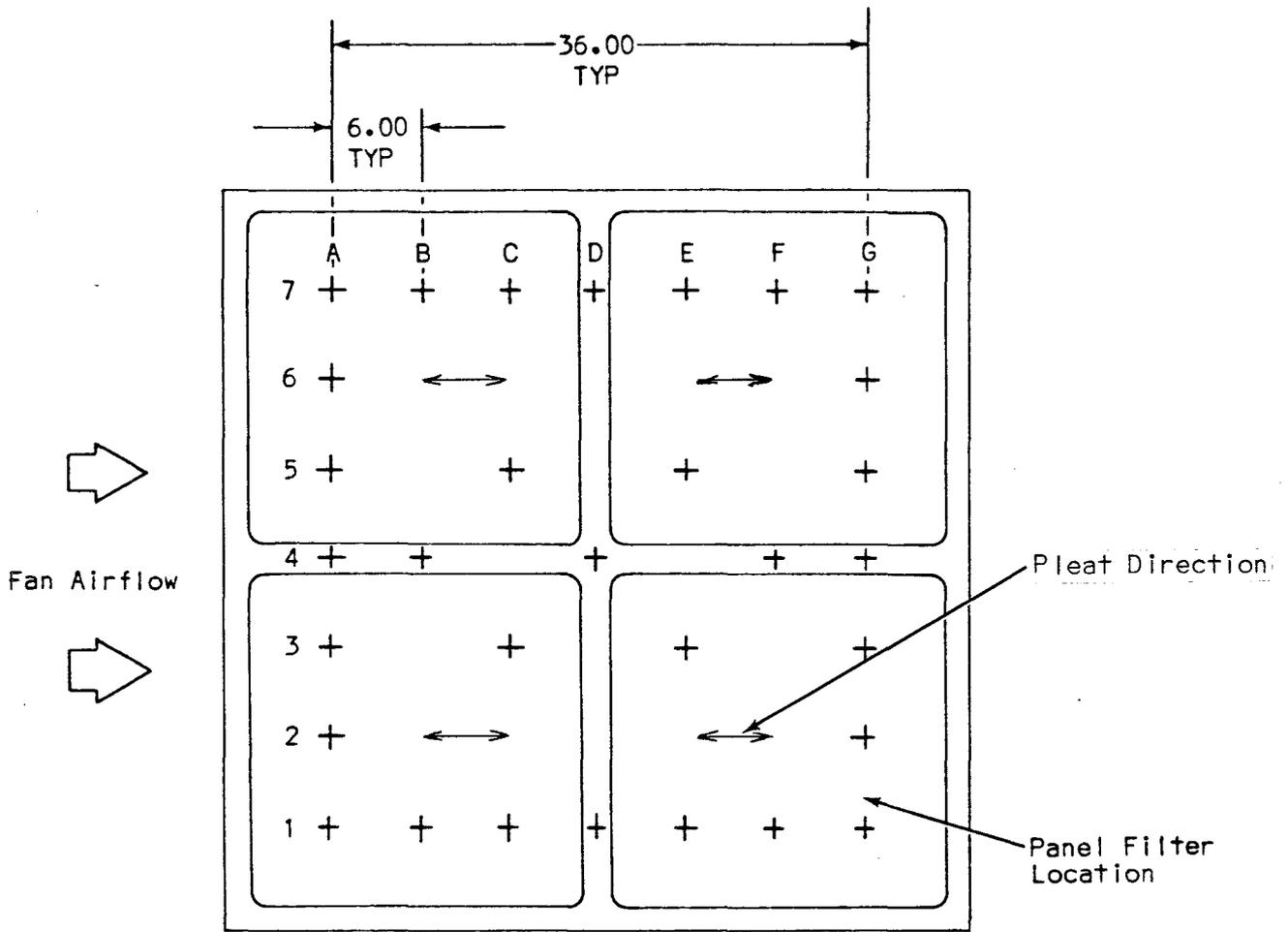
Figure 21. Static Pressure Tap Locations, Blower Airflow Tests

Figure 22. Airflow Versus Static Pressure Air Curtain Blower with Outlet Damper

KEY:

- △ - Tested With Damper Open
- - Tested With Damper in Positions 1-7
(2 = Open Position, 7 = Closed Position)



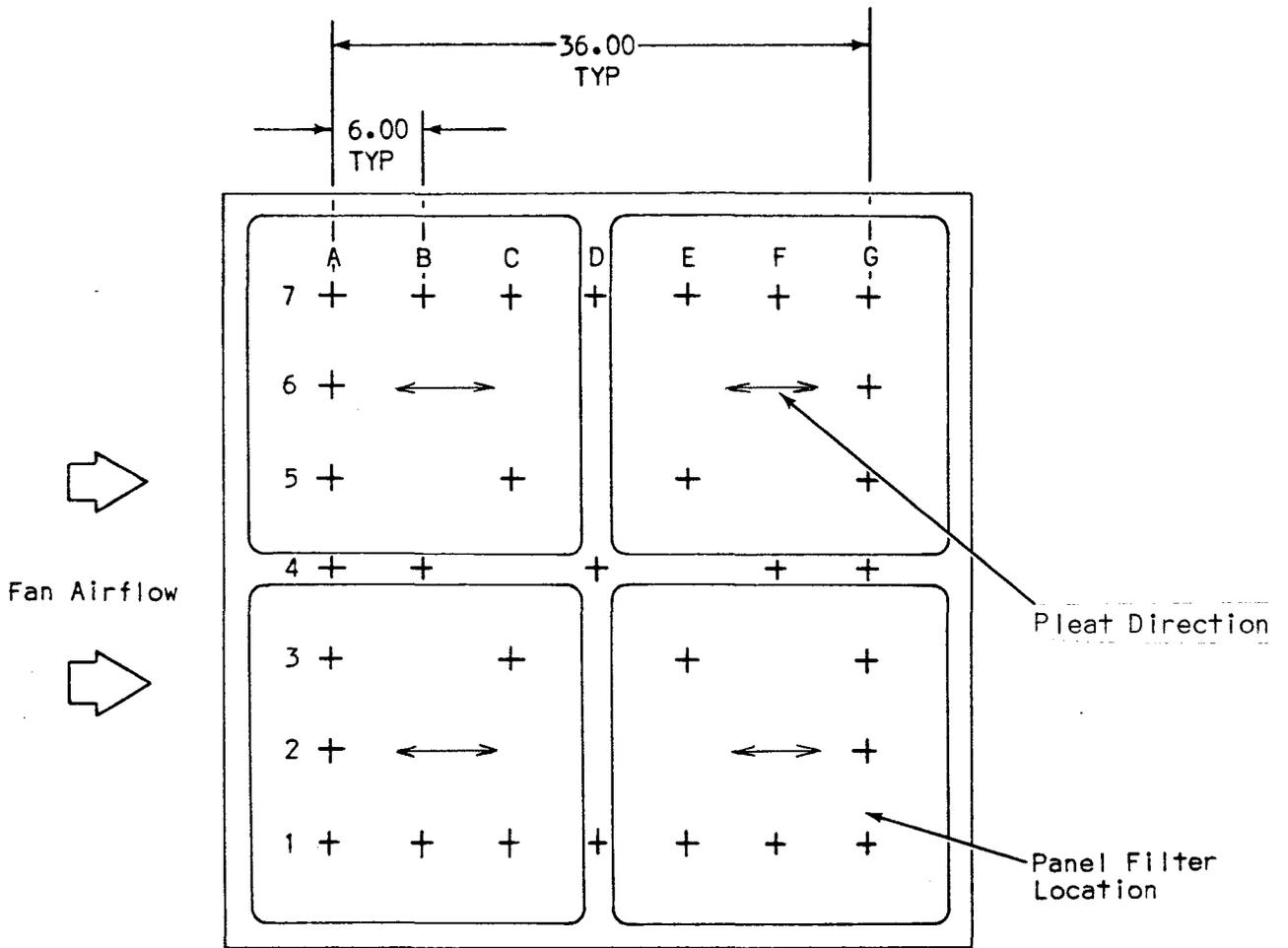


NOTE:

1. Figures represent airflow velocity in feet/minute, taken 32 inches below panel filters, using blower with 10 hp motor. Dampned to 4,400 cfm.

	A	B	C	D	E	F	G
7	0	100	120	100	150	275	300
6	0	100		100		280	275
5	-100		50		175		300
4	-100	-100		-25		190	290
3	- 75		50		140		325
2	25	75		50		275	350
1	25	100	100	100	175	250	250

Figure 23. Mine Mill Air Curtain Airflow Distribution Pattern

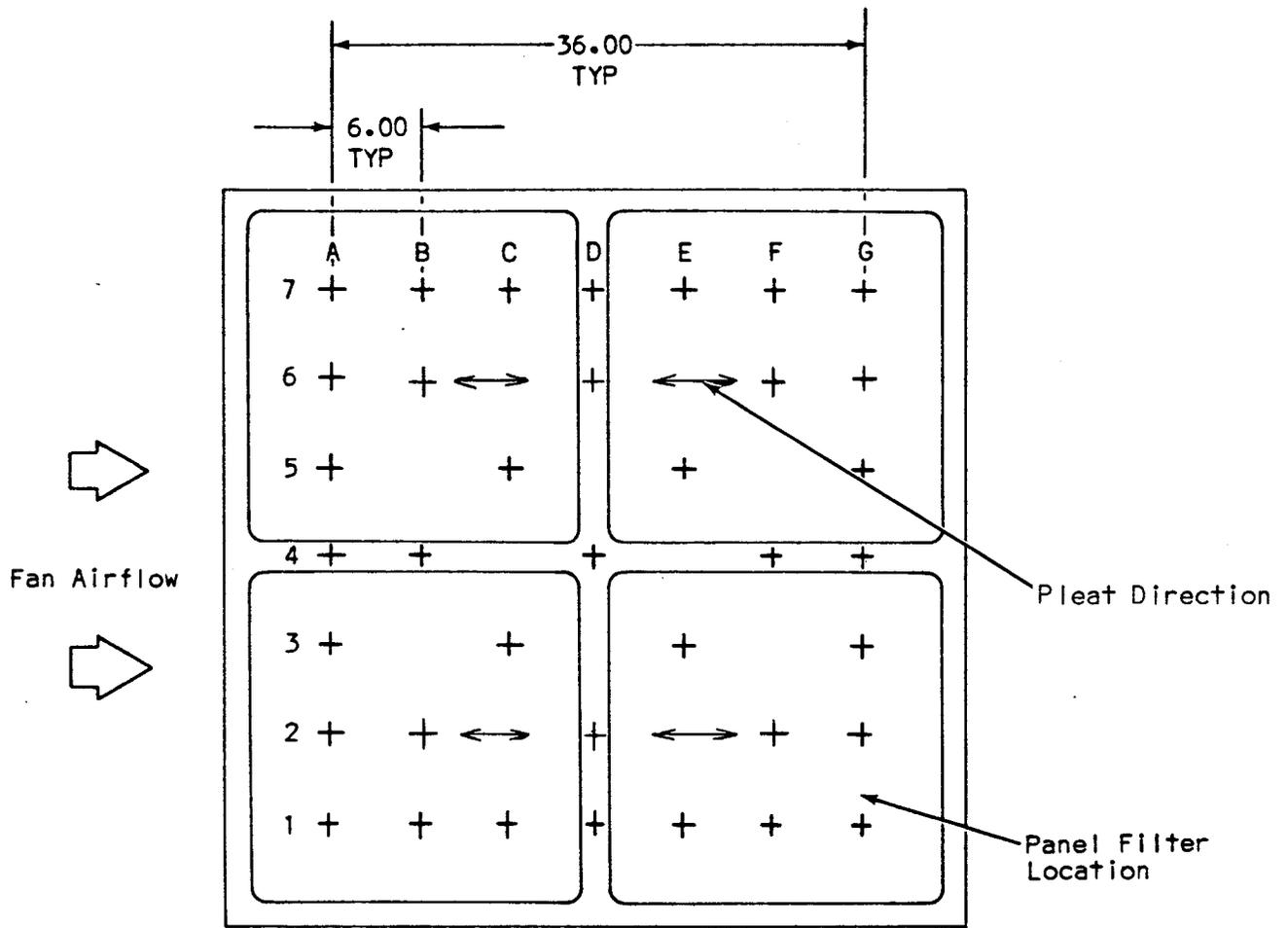


NOTE:

1. Figures represent airflow velocity in feet/minute, taken 32 inches below panel filters, using blower with 5 hp motor. Off-the-shelf P13-5930 panel filters.

	A	B	C	D	E	F	G
7	75	60	75	125	175	255	300
6	135	175		145		300	300
5	245		260		300		300
4	260	300		210		300	300
3	260		300		225		300
2	275	280		290		225	275
1	295	300	265		170	25	50

Figure 24. Mine Mill Air Curtain Airflow Distribution Pattern

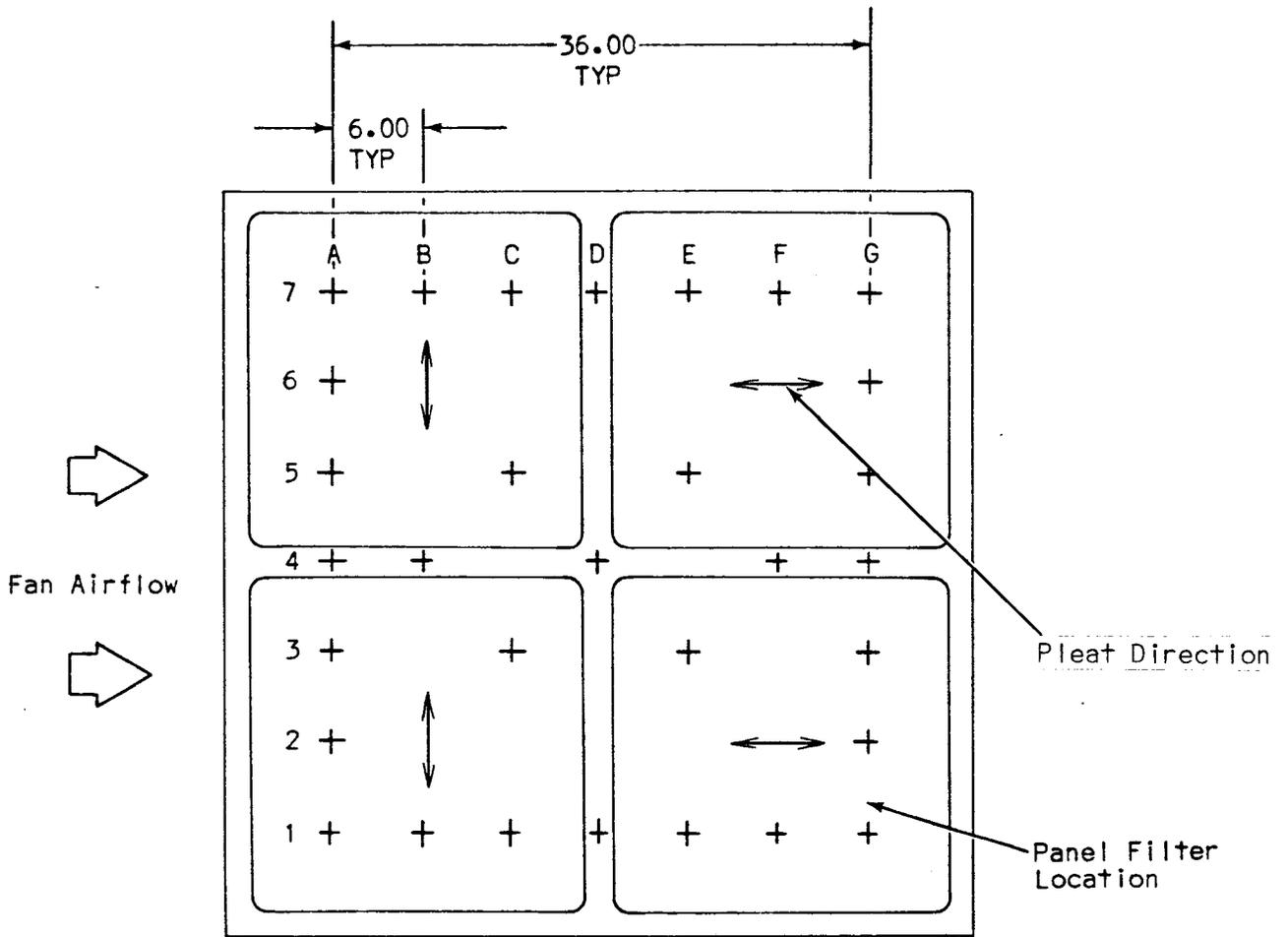


NOTE:

- Figures represent airflow velocity in feet/minute, taken 32 inches below panel filters, using blower with 10 hp motor. Standard P13-5930 panel filters.

	A	B	C	D	E	F	G
7	100	160	160	250	350	530	580
6	100	300		340		+560	+580
5	300		320		520		660
4	400	400		260		590	550
3	420		400		300		530
2	360	400		340		340	250
1	420	400	420	320	180	50	0

Figure 25. Mine Mill Air Curtain Airflow Distribution Pattern

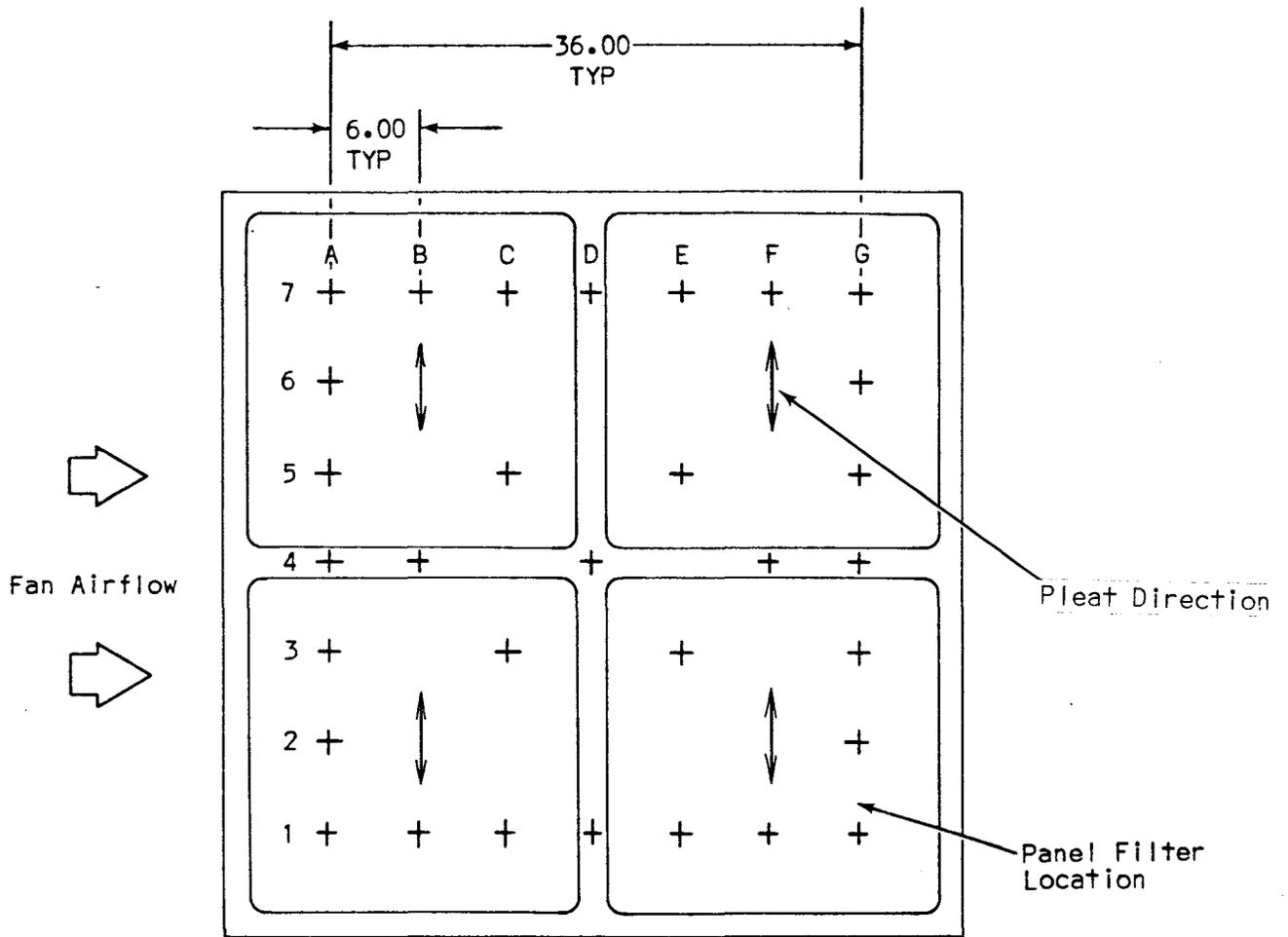


NOTE:

1. Figures represent airflow velocity in feet/minute, taken 32 inches below panel filters, using blower with 5 hp motor. P13-5930, no prefiltering.

	A	B	C	D	E	F	G
7							
6							
5							
4	75	200		255		190	205
3	75		160		300		300
2	100	192		130		300	300
1	300	300	300	250	290	300	300

Figure 26. Mine Mill Air Curtain Airflow Distribution Pattern

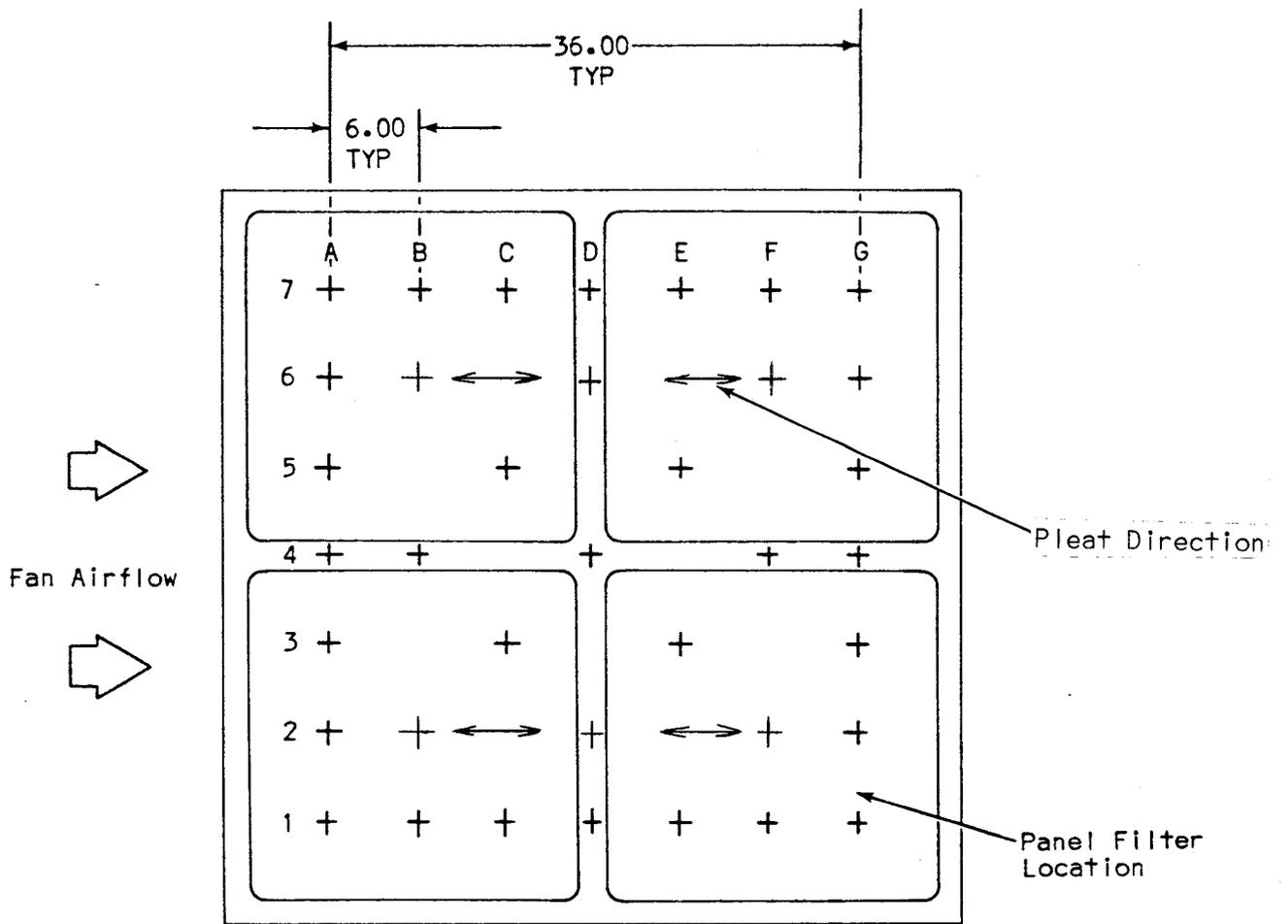


NOTE:

- Figures represent airflow velocity in feet/minute, taken 32 inches below panel filters, using blower with 5 hp motor. P13-5930 modified with no prefilters.

	A	B	C	D	E	F	G
7	300	300	280	230	215	275	300
6	260	280		260		280	295
5	240		275		240		275
4	160	160		--		175	215
3	150		155		180		160
2	230	290		300		230	260
1	300	300	300	300	300	300	300

Figure 27. Mine Mill Air Curtain Airflow Distribution Pattern

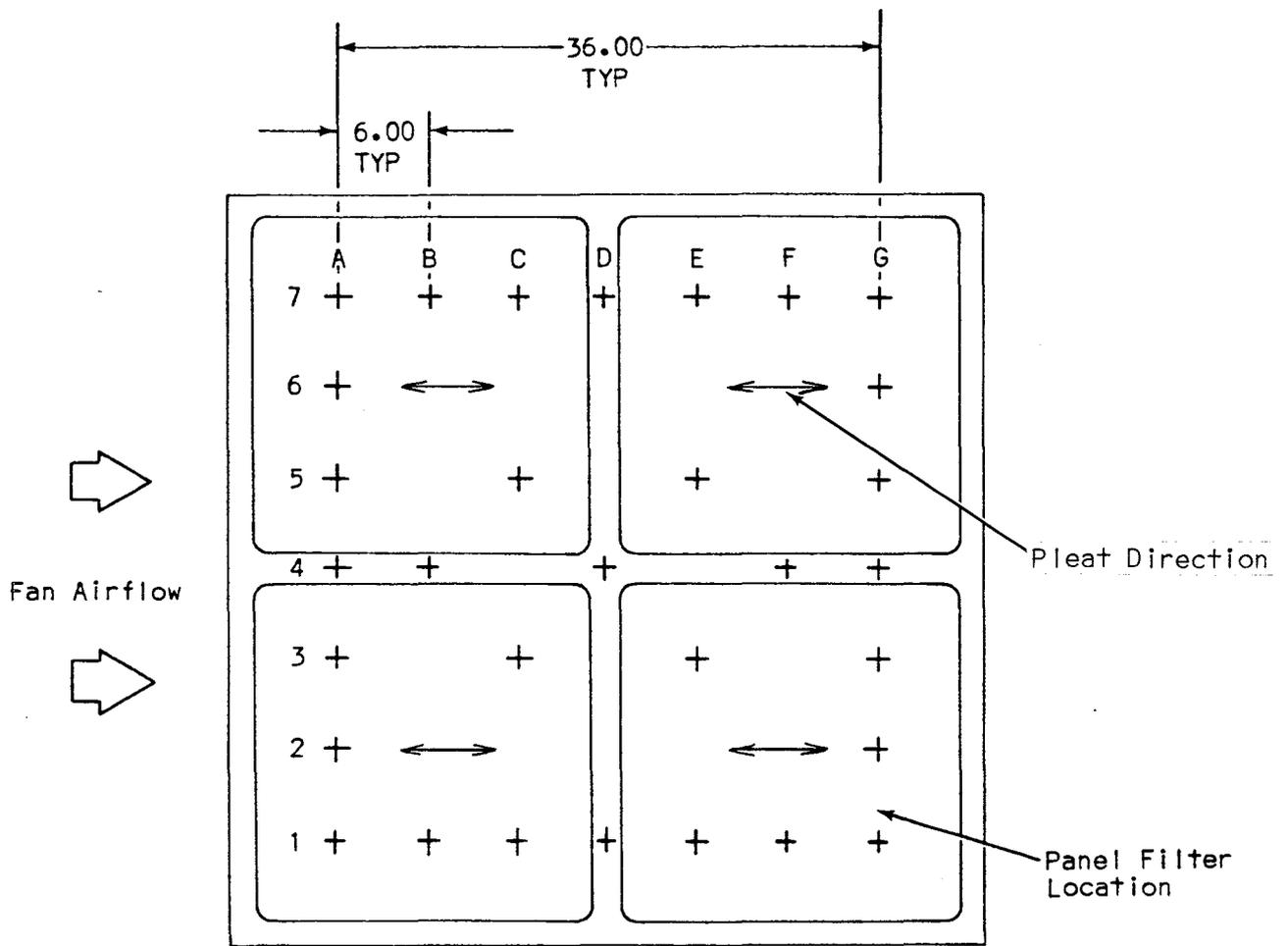


NOTE:

1. Figures represent airflow velocity in feet/minute, taken 32 inches below panel filters, using blower with 5 hp motor and modified P13-5930 panel filters.

	A	B	C	D	E	F	G
7	275	270	225	200	150	250	+300
6	275	240		165		+300	+300
5	165		200		210		+300
4	160	150		165		+300	+300
3	275		210		215		+300
2	+300	260		200		+300	+300
1	290	230	220	120	215	240	+300

Figure 28. Mine Mill Air Curtain Airflow Distribution Pattern



NOTE:

1. Figures represent airflow velocity in feet/minute, taken 32 inches below panel filters, using blower with 5 hp motor. Standard P13-5930 without beading.

	A	B	C	D	E	F	G
7	170	245	180	235	230	300	300
6	180	220		190		300	300
5	185		215		235		300
4	90	160		220		300	275
3	125		225		250		300
2	250	255		195		300	300
1	215	265	220	180	205	275	295

Figure 29. Mine Mill Air Curtain Airflow Distribution Pattern

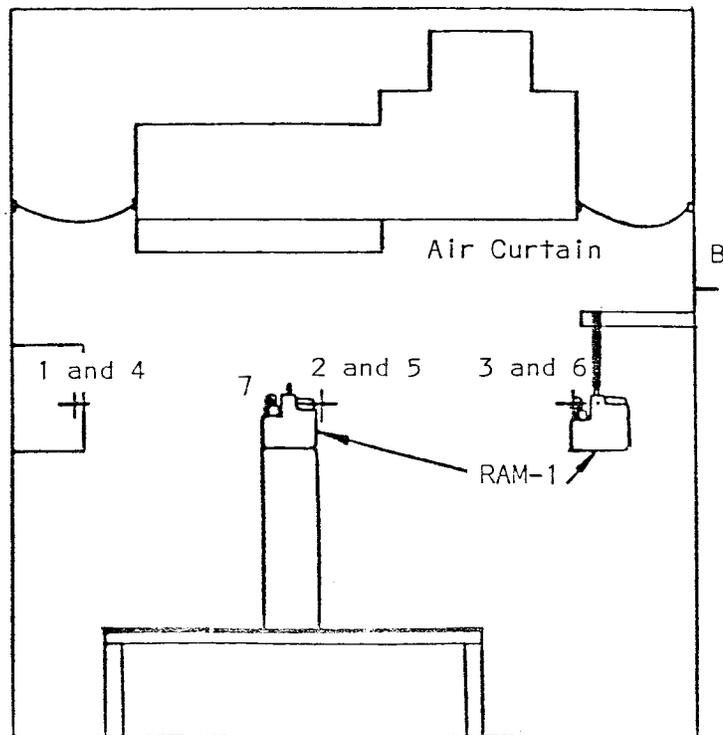
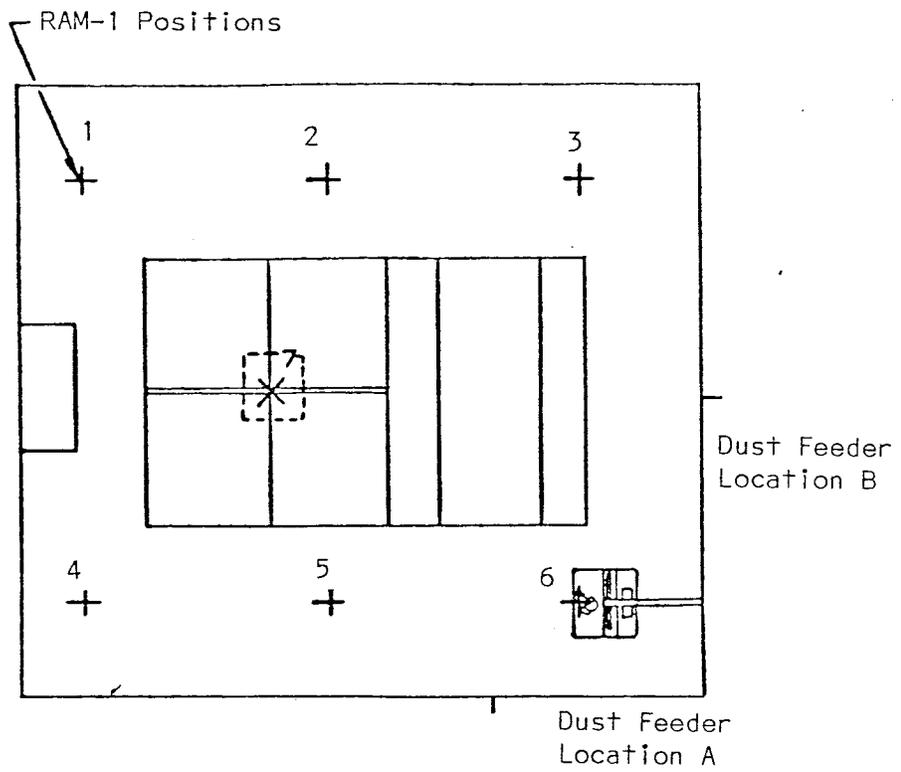


Figure 30. RAM-1 Locations for Dust Feed Tests

At dust feeder location A, the dust concentration ranged from 3.2 to 9.2 mg/m³ (respirable) outside of the CAC protected zone. Under the protected zone, the concentration was 0.52 to 0.74 mg/m³ (respirable). At feeder location B, dust concentration outside the CAC ranged from 1.2 to 7.8 mg/m³ (respirable), under the CAC the concentration was .44 to .53 mg/m³ (respirable). The concentrations outside of the CAC are several times higher than the field measurements (average of .4 to .5 mg/m³). For such low concentrations a more sensitive dust feeder is required and was used in the final testing of the work station CAC.

Table 4. Dust Concentrations During Laboratory Test of CAC
(Reference figure 30 for locations)

Dust Feed Location	A	B
RAM-1 Locations	mg/m ³	mg/m ³
1	3.2 - 5.6	1.4 - 2.0
2	4.8 - 6.4	1.6 - 2.4
3	6.4 - 9.2	3.2 - 4.2
4	3.2 - 5.0	1.2 - 1.6
5	---	5.0 - 7.8
6	9.2 - 12.0	5.6 - 6.8
7	0.52 - 0.74	0.44 - 0.52
(under CAC)		

The following noise level measurements were taken from a location 32 inches under the CAC generator center:

Scale	dB
Linear	97.5
dB(A)	94.5
63 cps	84.0
125	89.0
250	90.0
500	90.0
1,000	90.5
2,000	89.0
4,000	82.5
8,000	73.0

The significant measurement is the 94.5 dB(A), which is above the 90 dB(A) maximum exposure level for an 8 hour period (code of Federal Regulations, Title 29, Chapter XVIII, part 1926).

The following methods were evaluated to bring the noise level into compliance:

- Shock mount the motor and fan
- Insulate the fan enclosure with sound absorbtive material
- Place a silencer between the fan and generator
- Slow the tip speed of the fan impeller (a new fan is required for this)

3.4.1 Conclusions and Recommendations

Based on the previous tests, the following conclusions and recommendations were made:

3.4.1.1 Conclusions

- Evaluation of the CAC concepts recommended in Phase I resulted in a final choice of the self-contained air curtain system, minimum profile with increased filtration media (figure 8) for prototype build and testing
- The prototype CAC requires a larger fan to reduce the noise level to less than 90 dB(A)
- Shock mounting and acoustic padding will further reduce the noise level
- Dust tests used a dust feeder that maintained a dust concentration of 1.2 to 9.2 mg/m³
- A more sensitive dust feeder is required for closer simulation of field conditions (.4 to .5 mg/m³)
- The use of pleated paper panel filters in the CAC sufficiently distributes the air to provide a protective zone around the operator
- Prefiltering does not upset the airflow distribution of the CAC
- Flow control damper on the fan outlet upsets airflow distribution

3.4.1.2 Recommendations

The following items should be used in future evaluations.

- A larger fan in CAC prototype sound and airflow evaluation
- Shock mounting and acoustic padding in CAC prototype sound evaluation
- A more sensitive dust feeder in any dust tests
- Flow control damper on the fan inlet

3.5 MINE MILL WORK STATION AIR CURTAIN FIELD EVALUATION

3.5.1 Field Evaluation Site One

Prior to fabricating the first mine mill work station air curtain, several additional testing and design tasks were performed as recommended in section 3.4.1.2. With the completion of these additional tasks, final designs and drawings were submitted for approval and fabrication was started. A name for the canopy air curtain was also established and will, from this point on, be referred to as an Overhead Air Supply Island (O.A.S.IS.). Concurrent to fabrication of the first system, a suitable field site was investigated and field evaluation procedures were established.

A detailed description of the first field installation and evaluation, along with the above mentioned items, is provided in the following paragraphs.

3.5.1.1 O.A.S.IS. Generation One

The final design for the first O.A.S.IS. system included all the recommendations from section 3.4.1.2.

Prior to fabricating any new prototype, additional testing was performed. This testing was done to evaluate O.A.S.IS. effectiveness when subjected to cross drafts/interference airflows which may be present in actual field operation. Three tests were performed at two O.A.S.IS. airflows (5,600 cfm and 5,280 cfm) and five different interference airflow velocities (333 ft/min, 448 ft/min, 510 ft/min, 619 ft/min, and 734 ft/min). Interference airflow was provided through a duct 18 inches high by 30 inches wide at a position 20 inches from the edge of the O.A.S.IS. air canopy. The center of this duct was level with the breathing zone of the mannequin positioned in the clean air zone. (Refer to figure 31 for a sketch of the test setup.) Profiles of the interference airflow at the canopy edge were obtained; an average of these velocities was used for analysis. Respirable dust concentrations were measured using RAM-1s. The RAM-1s were located at the center of the interference airflow ducting and at two positions in the clean air zone. Two tests were

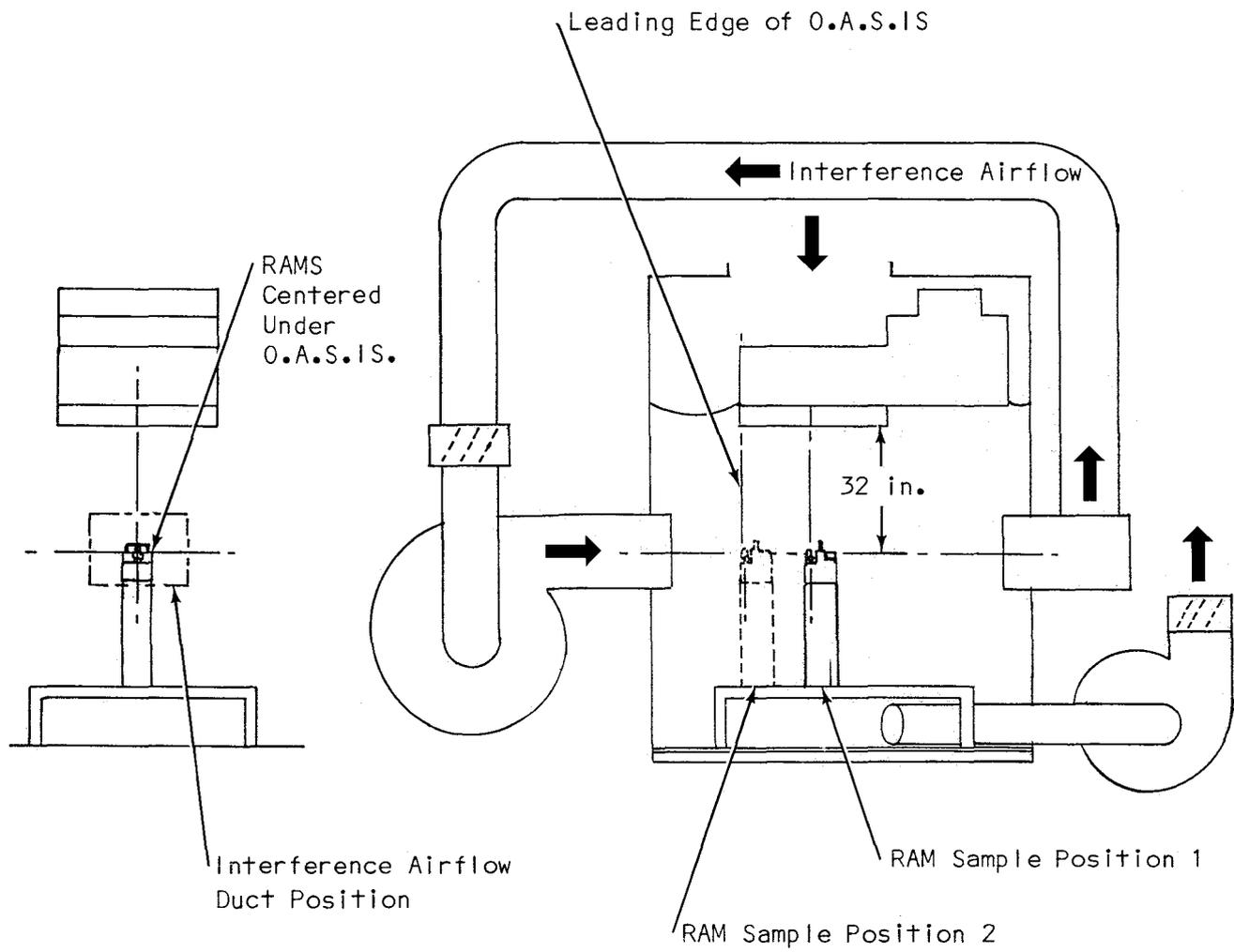


Figure 31. Test Equipment Setup For Interference Airflow Dust Testing

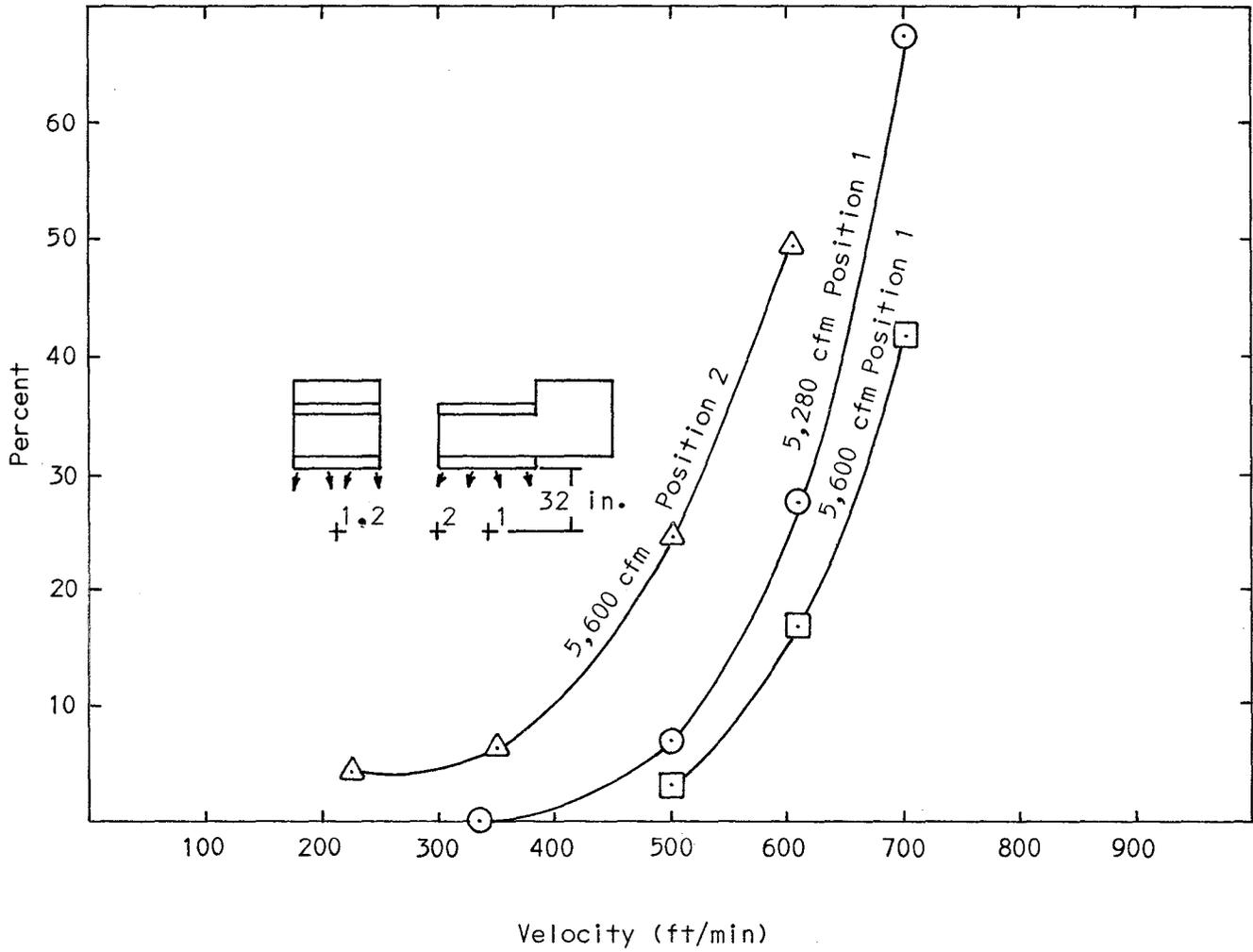
run with a RAM-1 centered 32 inches below the clean air zone and one test with the RAM-1 centered 32 inches below the leading edge of the clean air zone nearest to the interference airflow. The results (figure 32) were expressed as a percentage of the original amount of dust able to penetrate into the clean air of the O.A.S.I.S. plotted against the velocity of the interference airflow.

Results showed that only 2.97 percent and 6.70 percent of the dust contained in the interference airflow could penetrate to the sampling locations at velocities well above the average discharge velocity provided by the O.A.S.I.S. These results may be partially explained due to the skewed airflow distribution of the O.A.S.I.S. (figure 33). The average velocity of airflow 32 inches below the O.A.S.I.S. discharge was 375 ft/min. The average velocity of the airflow for the first half of the O.A.S.I.S. canopy, also at 32 inches below the discharge, was 419 ft/min. The penetration of the dust into the clean air zone was reduced due to the higher protection velocities present in the first half of the air canopy. Further testing to evaluate the degree of protection provided at different interference airflow attack directions was not possible because of the size of the O.A.S.I.S. However, testing did indicate adequate protection was provided at an O.A.S.I.S. discharge velocity of 375 ft/min.

With the conclusion of these tests, a larger fan was laboratory tested (figure 34) and installed in a prototype for further dust efficiency and noise testing. The larger fan was tested based on recommendations for noise reduction. Sound tests of this system showed that it could operate within the 90dba standard.

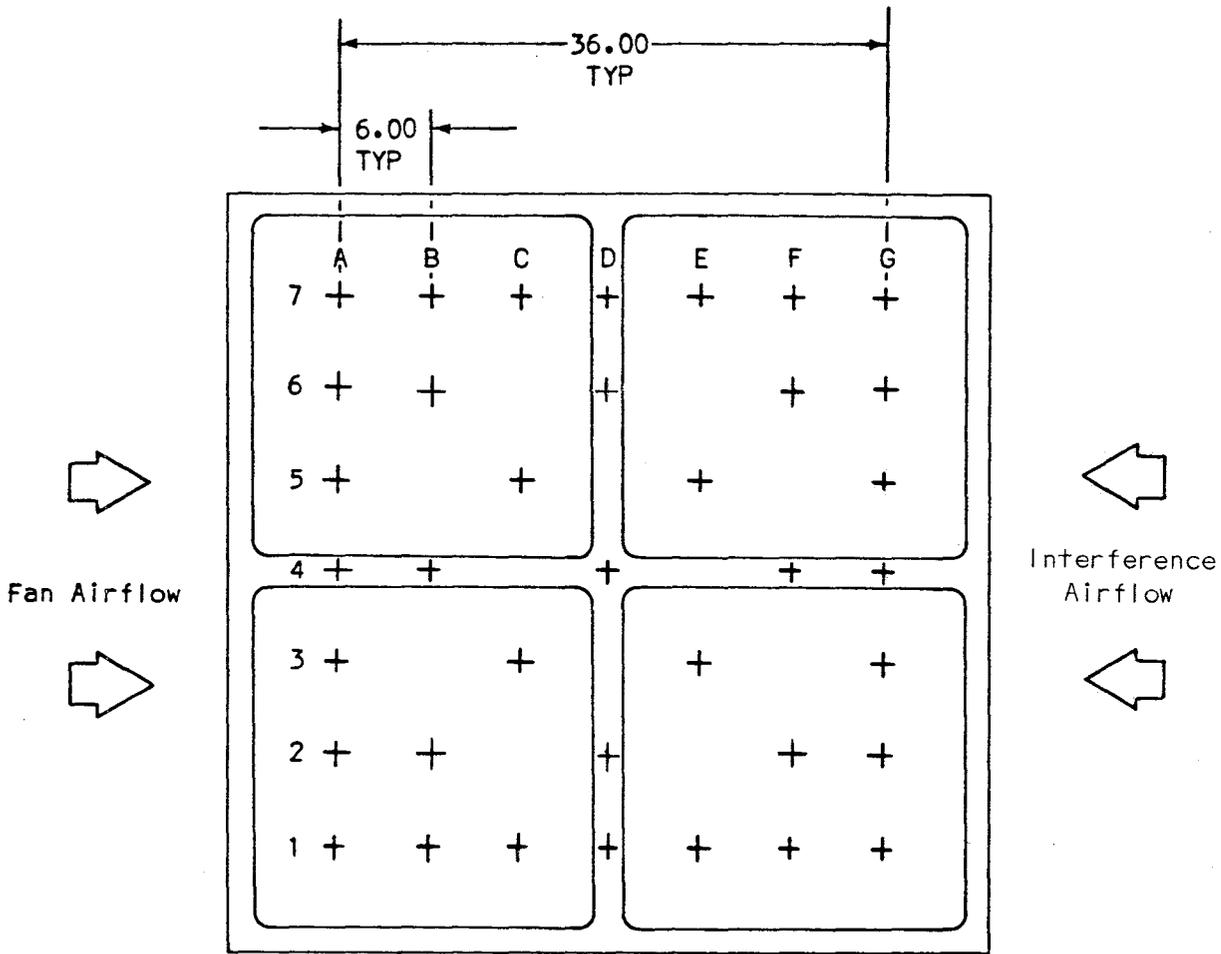
Two 8 hour tests were run in the test chamber to determine filter efficiencies. Gravimetric samplers and RAM-1 aerosol monitors were used at two positions. The first position was located at the mannequin's lapel centered 32 inches under the air canopy. The second was in the surrounding environment of the test chamber. (See figure 35 for an accurate layout of the test equipment.) Test results are given in table 5.

Percent Penetration* Versus Interference Airflow Velocity



*Assuming Air Curtain Supplying Perfectly Clean Air

Figure 32. Interference Airflow Dust Testing Results



NOTE:

- Figures represent airflow velocity in feet/minute, taken 32 inches below panel filters, using blower with 10 hp motor. Standard P13-5930 panel filters.

	A	B	C	D	E	F	G
7	100	160	160	250	350	530	580
6	100	300		340		+560	+580
5	300		320		520		660
4	400	400		260		590	550
3	420		400		300		530
2	360	400		340		340	250
1	420	400	420	320	180	50	0

 Higher Velocity Region

 Sample Location

Figure 33. O.A.S.I.S. Airflow Distribution

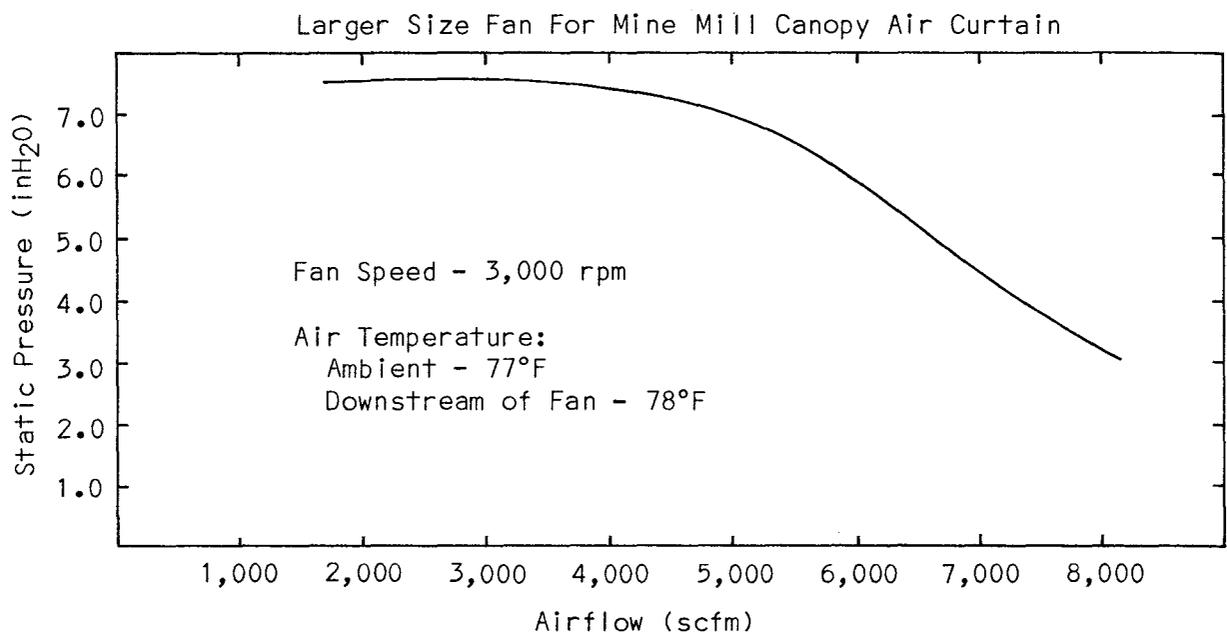


Figure 34. Fan Performance

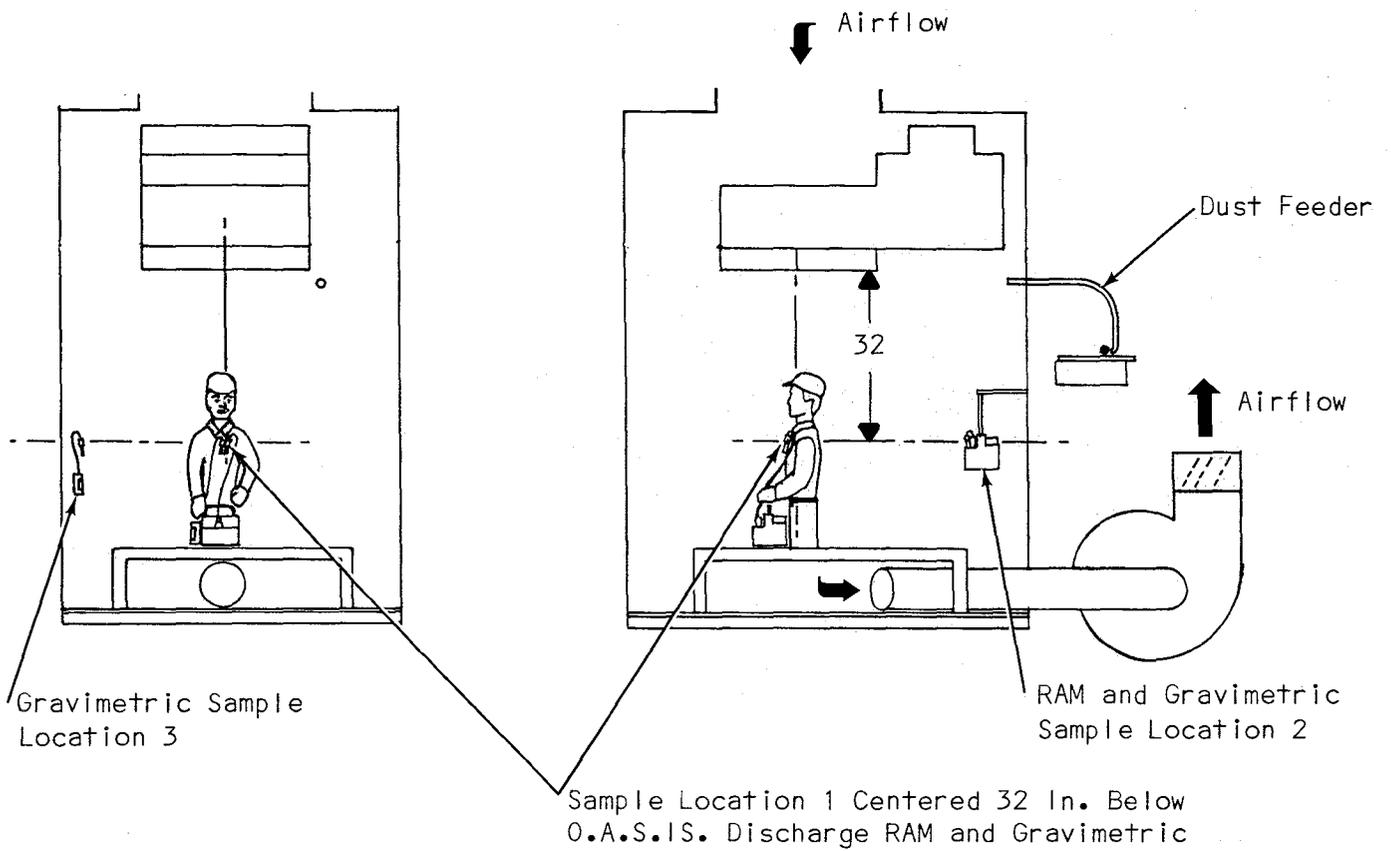


Figure 35. 8-hour Dust Testing Facility Layout

Table 5. Dust Test Results

Reference Test Chamber Drawing (Figure 1) for Sampler Locations	Test 1 (8 hours)	Test 2 (8 hours)
Location 2 RAM-1 Average Concentration Range Total Dust (Planimeter)	.531 mg/m ³ .15 to .95 mg/m ³ .510 mg	.521 mg/m ³ .15 to 1.5 mg/m ³ .500 mg
Location 2 Gravimetric Average Concentration Weight Gain	.111 mg/m ³ .107 mg	0.282 mg/m ³ 0.271 mg/m ³
Location 3 Gravimetric Average Concentration Weight Gain	No data Pump malfunction	0.072 mg/m ³ 0.069 mg
Location 1 RAM-1 Average Concentration Range Total Dust (Planimeter)	0.0888 mg/m ³ <.01 to .3 mg/m ³ 0.084 mg	0.024 mg/m ³ <.01 to .08 mg/m ³ 0.023 mg
Location 1 Gravimetric Average Concentration Weight Gain	-0.007 mg*	-0.006 mg*
CAC Efficiency on Dust Fed (From RAM-1 Data)	83.4 percent	95.4 percent

*Amount of dust collected not sufficient enough to be accurately weighed.

Room temperature increased from 76°F to 84°F over a 16 hour period. The 84°F temperature was obtained 8 hours into the testing.

The dust efficiency improved from 83.4 percent in the first 8 hour test to 95.4 percent in the second 8 hour test. This is normal and can be expected to rise to more than 99 percent after the initial buildup of a fine cake of dust on the filters. Once this buildup occurs, the maximum efficiency is obtained and remains for the service life of the filter elements. This initial efficiency is experienced by all standard types of filter media.

With this information, additional testing of the panel filter elements was performed to estimate filter life and determine fractional efficiencies at different points in the life of the filter. Testing consisted of feeding dust to the elements at 2.5 grams/minute until a 1/2 inH₂O rise in the pressure drop across the filter was achieved. At the 1/2" H₂O intervals, the fractional efficiency data was obtained. Airflow through the filter was maintained at a constant 1,875 cfm. The test apparatus schematic is shown in figure 36. Testing showed that the Donaldson Company panel filter reached 4 inH₂O restriction when 550 grams of AC Fine dust was loaded onto the filter surface (figure 37). Filter field life calculations can be estimated from this testing.

Filter life and fractional efficiency tests were also performed on a Donaldson Company panel filter, containing a media with known higher initial efficiencies. Only two tests for determination of fractional efficiencies could be performed on this filter because it loaded with dust too quickly. This panel filter reached 10.0" H₂O restriction after only feeding 110 grams of AC fine test dust (see Figure 38).

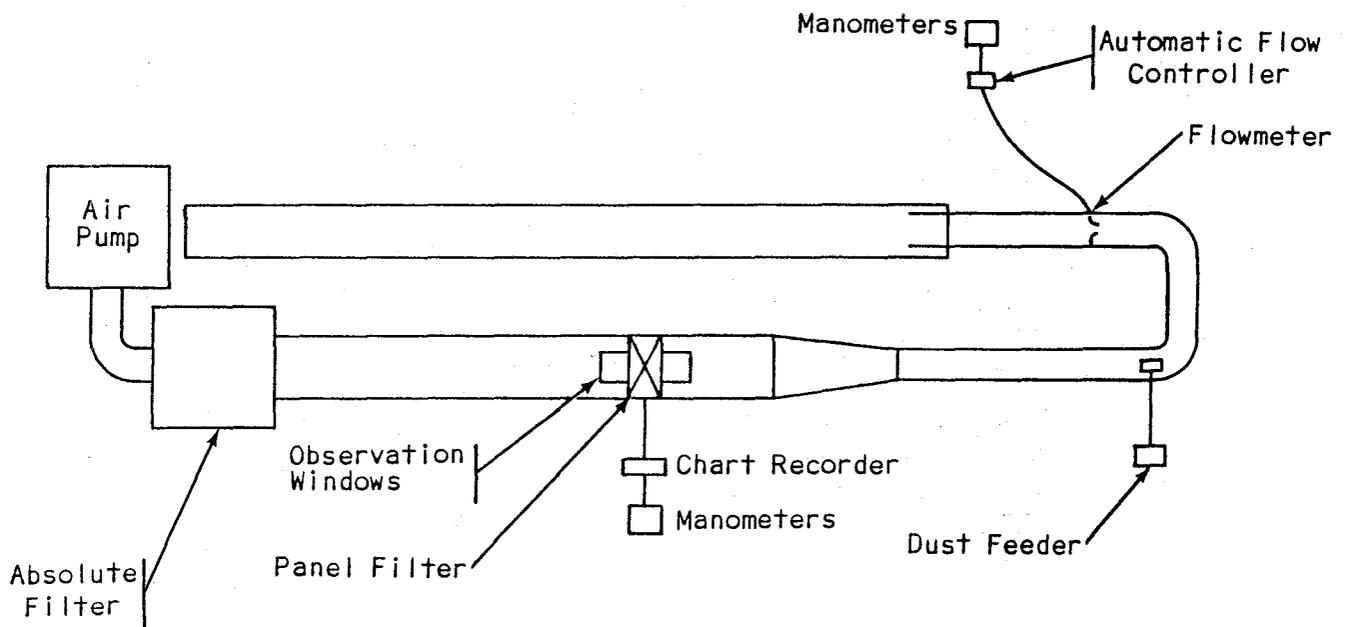


Figure 36. Panel Filter Efficiency Test Apparatus

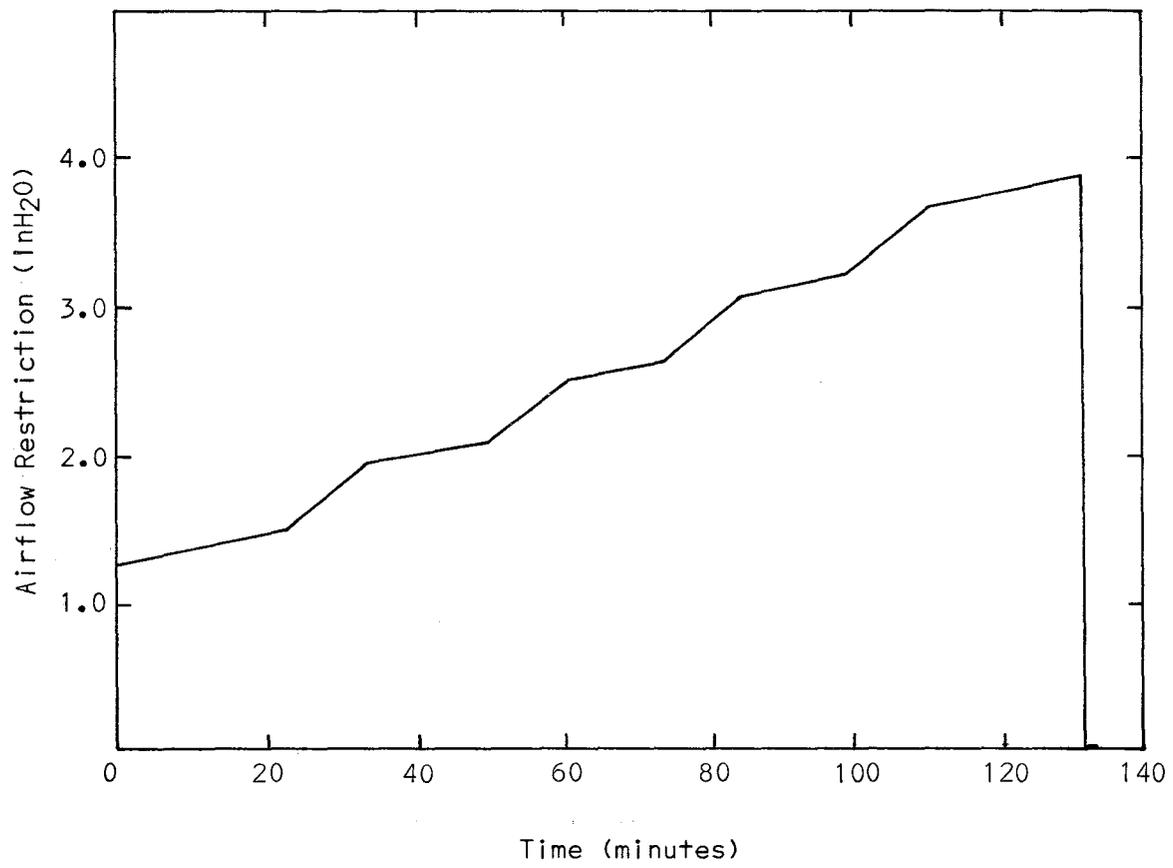


Figure 37. Loading Curve For Standard Panel Filter

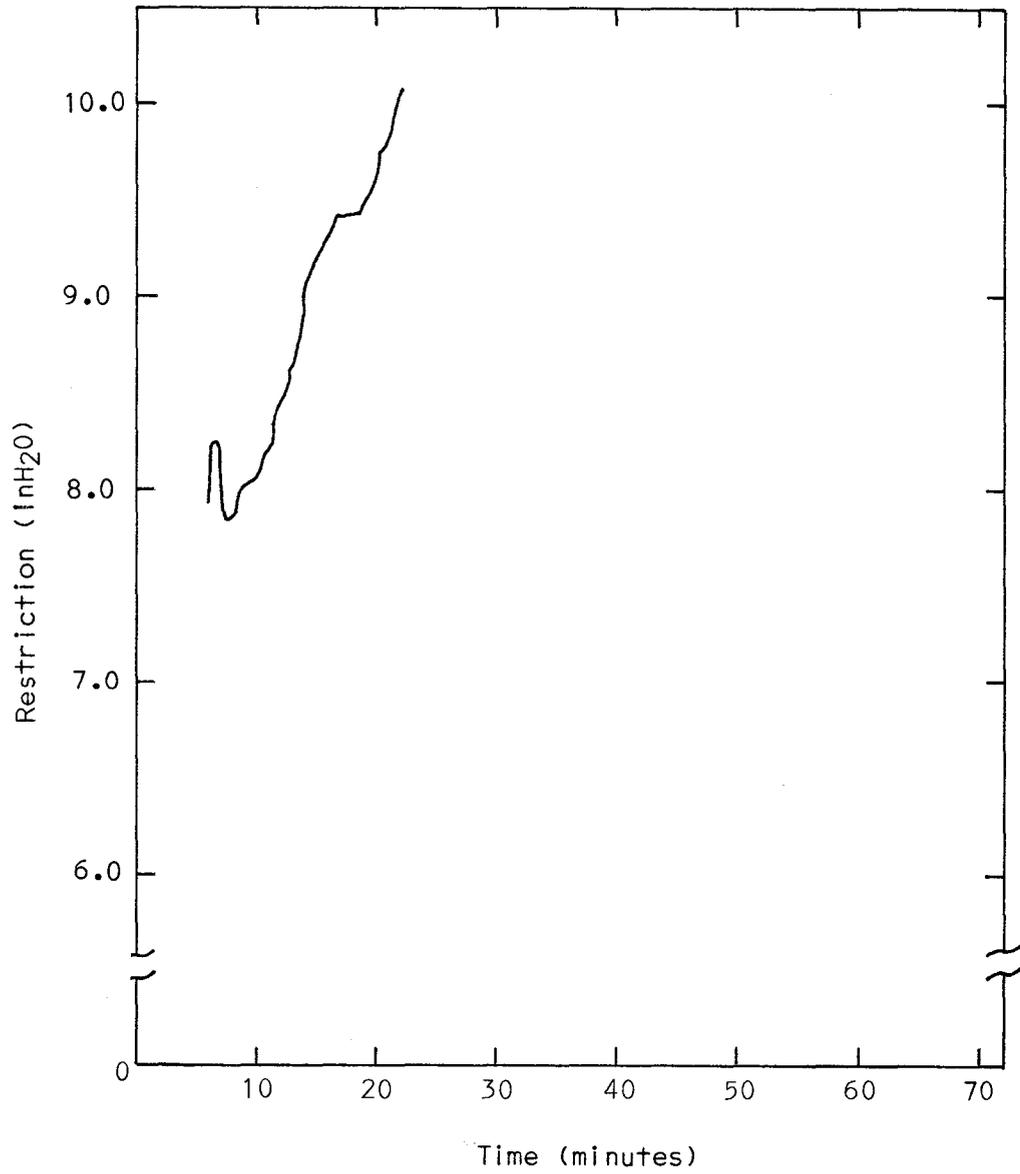


Figure 38. Loading Curve For Modified Panel Filter

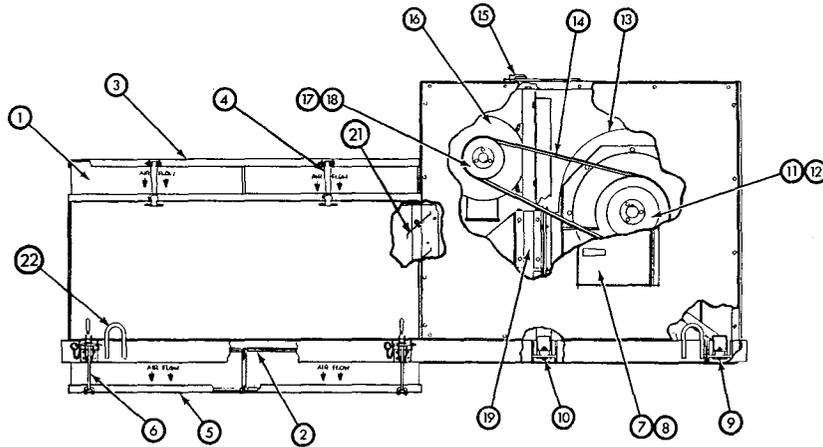
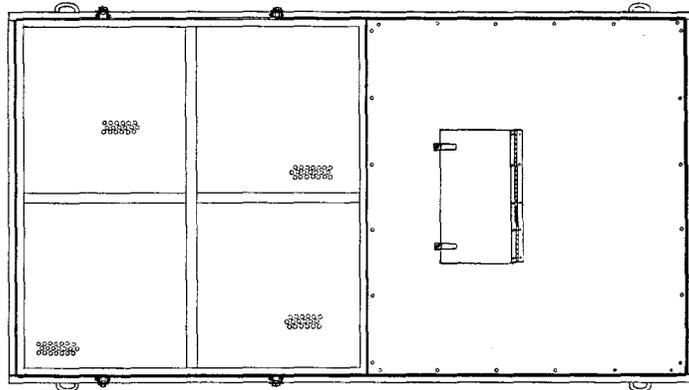
Results showed that the standard media filter had initial efficiencies of 88.04 percent by number and 97.08 percent by volume on particles less than 8.000 micron in diameter. This efficiency improved to 99.956 percent by number and 99.940 percent by volume. The filter containing nonstandard media had initial efficiencies of 99.076 percent by number and 99.822 percent by volume. These efficiencies increased to 99.364 percent and 99.887 percent, respectively, when the test ended. Fractional efficiencies for particle size ranges for all of the tests can be found in appendix A. Based on the dust efficiency and filter life tests, the panel filter containing the standard media was chosen to be used with the O.A.S.I.S.

Fabrication and assembly of the first system was completed in August 1983 (figure 39). Following testing and modifications, including the addition of a heater and shroud, installation manuals were written and preparations made for shipment to the first field site.

A heater was purchased to provide for operator comfort while operating in a cold environment. A 55 kW electrical open coil duct heater was specified to provide a maximum 30°F temperature rise. Since placing the heater inside the O.A.S.I.S. was not practical, a shroud was designed to enclose it. The shroud containing the heater was designed to be removable to maintain primary panel filters access, as it was positioned directly above them (figure 40).

3.5.1.2 Field Test Site One

Several companies were contacted that had expressed an interest in installing and maintaining the O.A.S.I.S. for field testing. Jesse S. Morie Company, a producer of industrial sands, has a bagging operation at their Mauricetown, New Jersey, plant suitable for installation. They agreed to install, maintain, and assist in testing the system.



REPLACEMENT PARTS LIST

Item	Part No.	Description	Item	Part No.	Description
1	P13-5930	PANEL FILTER	12	9760A161	BUSHING
2	9760A156	GASKET KIT (SEE NOTE 1)	13	9760A120	BLOWER
3	9760A89	FRAME ASSEMBLY	14	9760A116	V-BELT (2)
4	KYX00-4599	LATCH KIT	15	9760A118	LATCH
5	9760A90	FRAME ASSEMBLY	16	9760A119	MOTOR
6	9760A117	CLAMP	17	9760A162	SHEAVE
7	9760A123	INSPECTION DOOR	18	9760A163	BUSHING
8	9760A157	GASKET KIT	19	9760A104	SLEEVE
9	9760A159	VIBRATION MOUNT	20	9760A164	GAUGE
10	9760A158	VIBRATION MOUNT	21	9760A74	AIRFLOW DAMPER ASSEMBLY
11	9760A160	SHEAVE	22	9760A91	LIFTING LUGS

NOTE:

1. Gasket kit replaces one panel filter section only.

Figure 39. O.A.S.I.S. Generation One

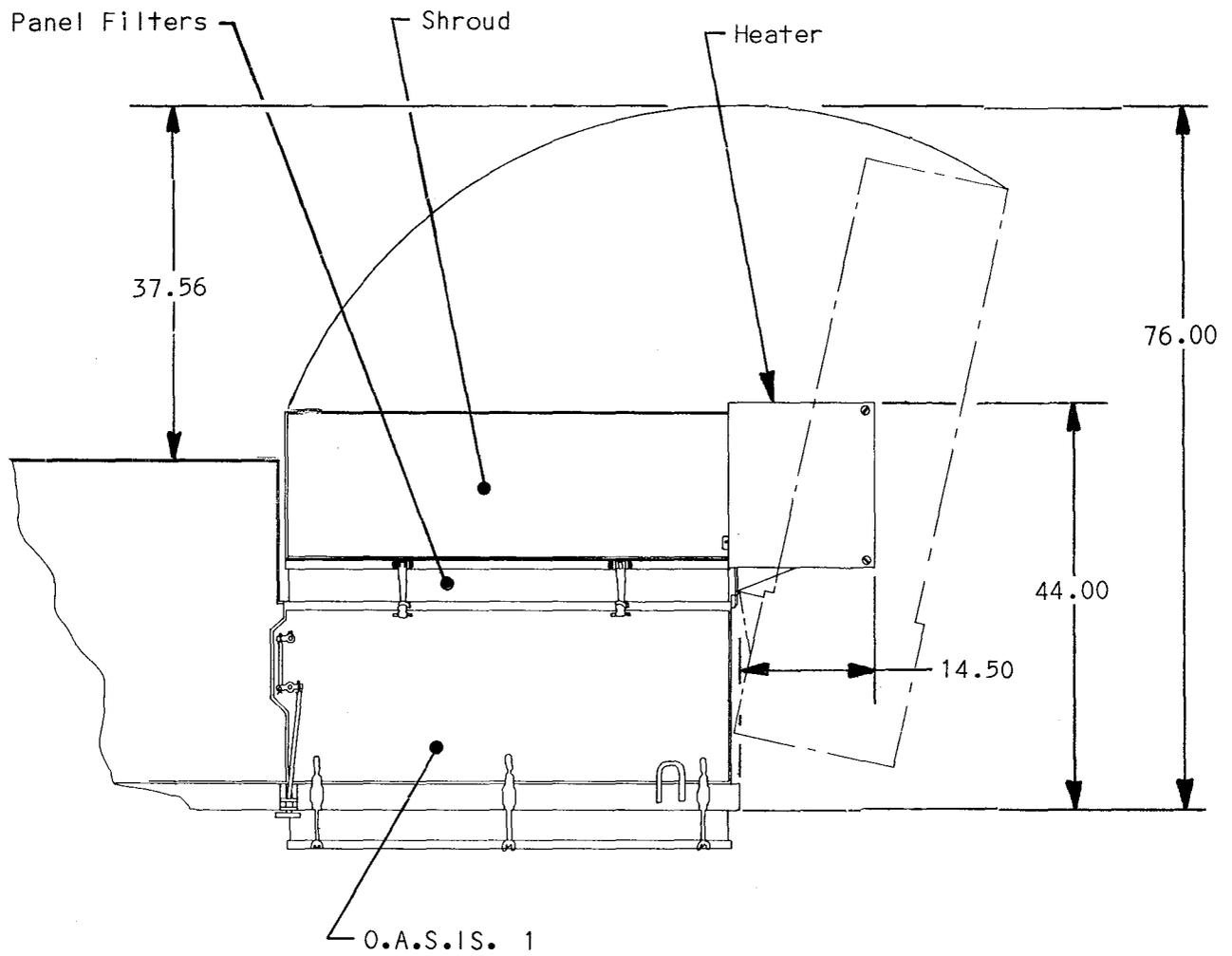


Figure 40. Heating Unit and Shroud

The first system was installed on a four spout bag packing machine. Typical operation consisted of an operator stationed in front of the machine placing bags on the spouts. The bags were filled by forcing sand through the spouts and into the bags with pressurized air. The full bags were dropped onto a conveyor for transport away from the packing machine. When the bag dropped away, another was placed over the spout to start the cycle over. Dust generation develops from several sources:

- Material being expelled from the bag as it is being filled
- Material leaking from nozzle
- Air and material being expelled from bag will pick up additional dust which has settled on surrounding structures
- The filled bags dropping onto the conveyor

Because several other workers are in the plant during the bagging operation, assurance was required that the installation and operation of the O.A.S.I.S. would not deteriorate air quality in the plant. Installation took place during the week ending 10 December 1983.

The O.A.S.I.S. air discharge was located 54 inches above the center of the work area of the bagging machine and 19 inches above the head of the machine operator. This operator was stationed on a platform approximately 7 feet above the floor. The inlet to the O.A.S.I.S. heater shroud was approximately 13-1/2 feet above the floor and directly adjacent to the bagging machine (figures 41 and 42).

3.5.1.3 Testing and Evaluation

The O.A.S.I.S. installed at Jesse S. Morie and Son, Inc, was tested to evaluate field performance. Initial testing began after 111 hours of operation following the installation in December 1983. Field evaluation involved using

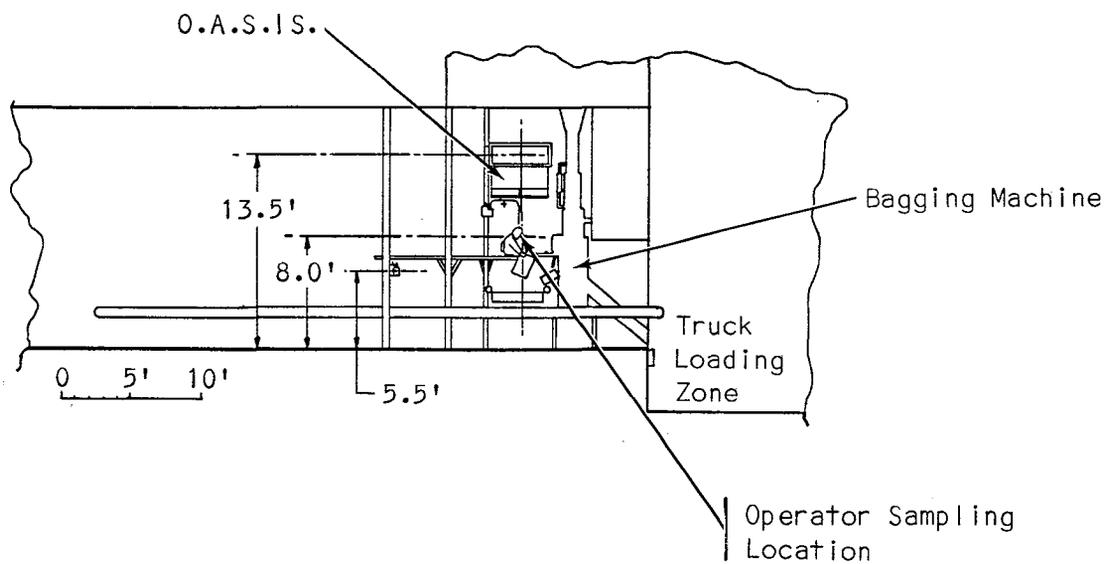
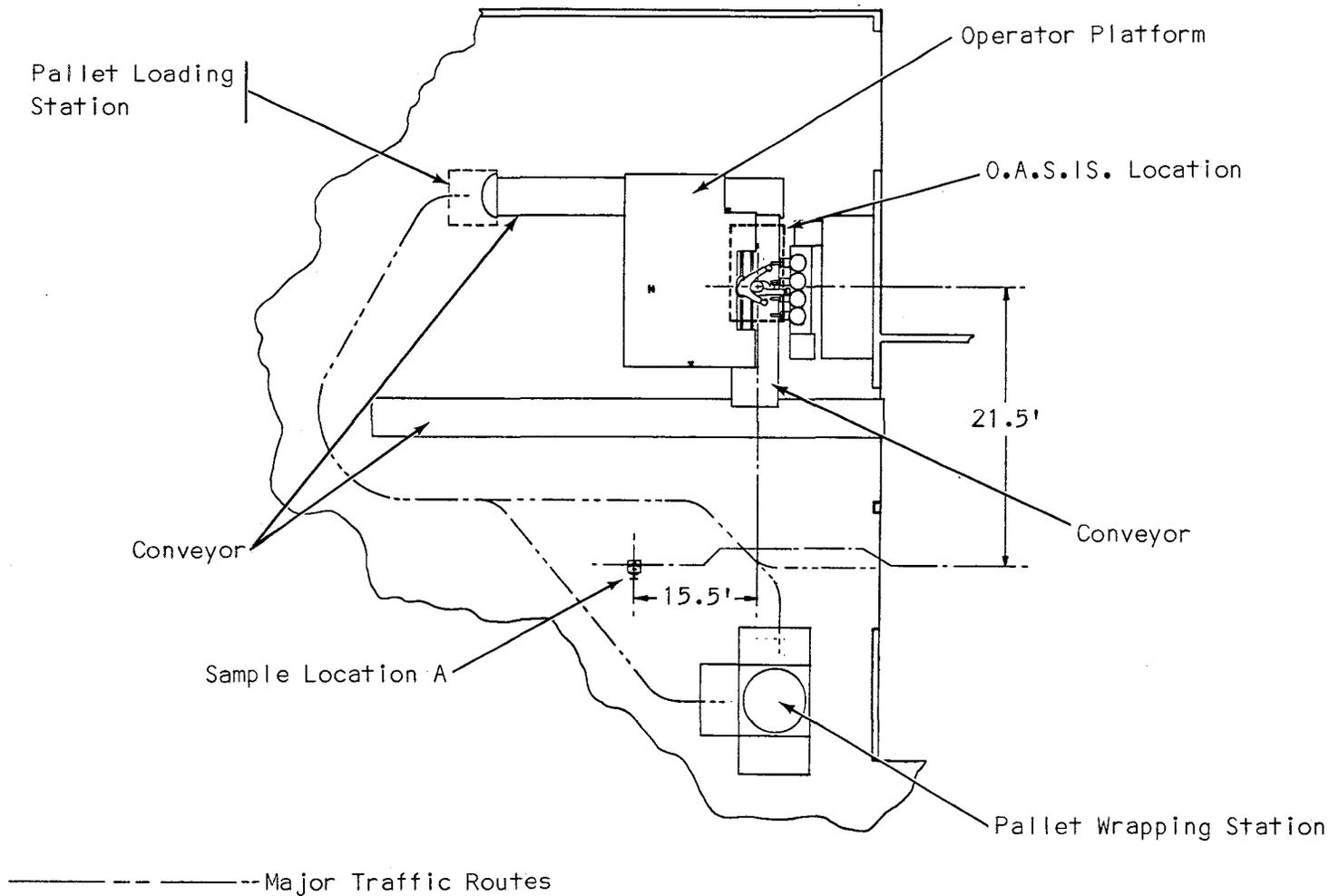
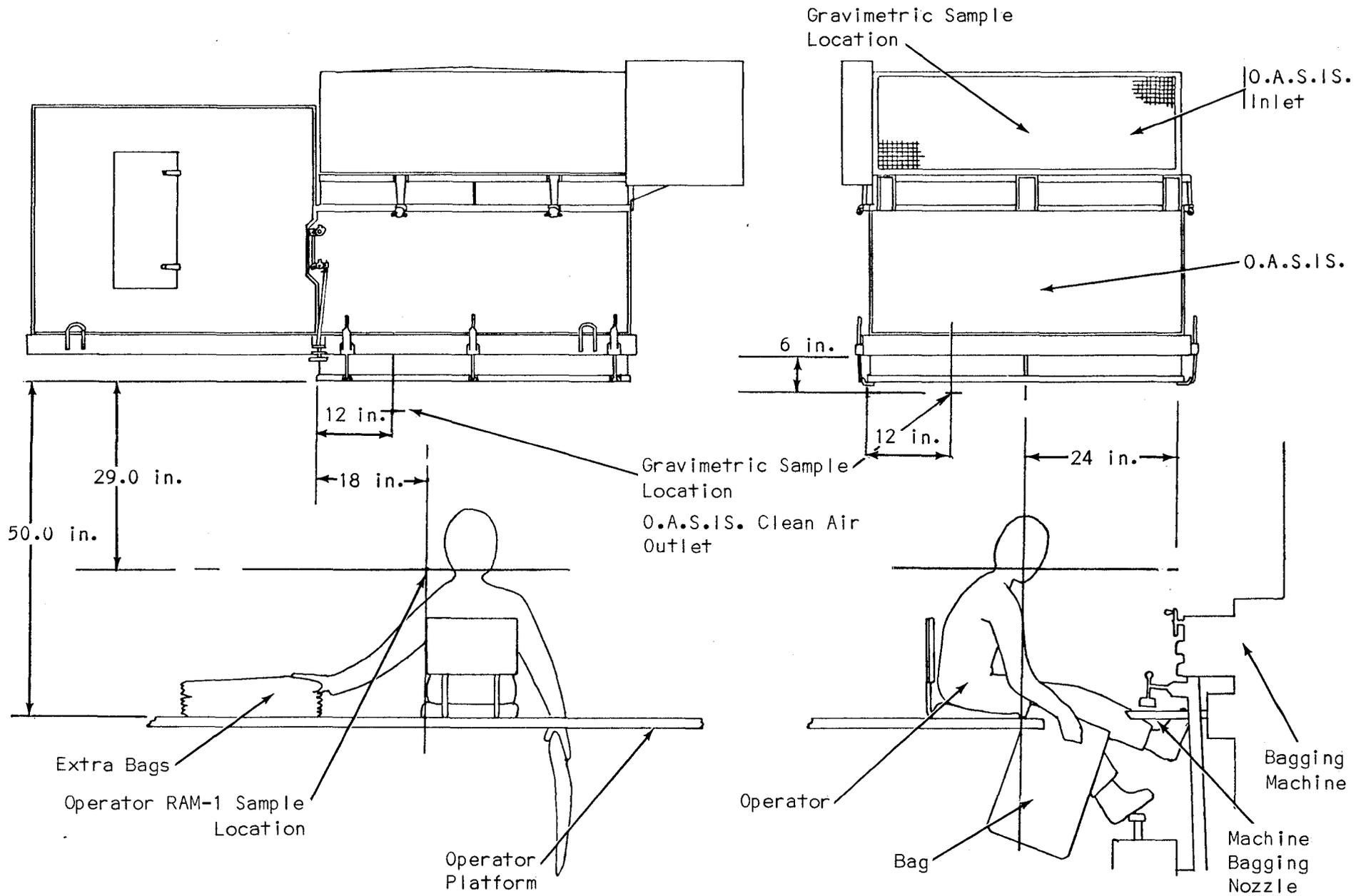


Figure 41. O.A.S.I.S. Installation at Bagging Operation Showing Aerosol Monitoring Locations

Figure 42. Aerosol Monitoring Locations at Bagging Operation



gravimetric samplers and RAM-1 aerosol monitors. This equipment was located in four places both under and outside the air curtain (figures 41 and 42).

Gravimetric samplers were used in all four locations to determine the following:

- Dust removal efficiency of the O.A.S.I.S.
- Effectiveness of the O.A.S.I.S.
- Effect of the O.A.S.I.S. on respirable dust levels in the plant

RAM-1 aerosol monitors, calibrated to silica dust, were located in two positions and were used to determine the following:

- Effectiveness of the O.A.S.I.S. at operator's station
- Effect of O.A.S.I.S. operation on respirable dust levels in the plant

The analog output signal from the RAM-1 was then recorded by two instruments. A Metrosonics dL331 Data Logger digitally stored the analog signal on a RAM (random access memory). A Metrosoft software program for use on an IBM PC was then used to retrieve and analyze the stored data. A representative printout of analyzed data from this program is shown on figures 43 and 44. A two pen strip chart recorder was also used as backup for a permanent data record.

To determine O.A.S.I.S. effectiveness, both RAM and gravimetric samplers were used. Normally, gravimetric samplers are used to obtain shift averages to evaluate respirable dust levels. However, this leads to comparison of respirable dust levels obtained over long periods of time and varying environmental conditions. Evaluation of performance using data obtained in this manner does not reflect the affect of O.A.S.I.S. operation on respirable dust levels in the plant. For field evaluation, data was acquired in shorter time periods, with the O.A.S.I.S. on and then off. The length of these time periods was set at 15 minutes. This allowed time to obtain sufficient data, yet remained short enough to maintain similar operating conditions under which to collect data.

*DATE - 03/20/85

METROSONICS INC.

331/11

TIME - 0:00:00

SAMPLE LOCATION - OPERATOR

SAMPLE NUMBER - 10-13

RAM SERIAL NO. - OFF 1377

ON/OFF DATA -

S/N: 1425 RANGE= 2.00 PERIOD = 0:00:10

CUMM. AVG. = 0.26 STANDARD DEV. = 0.20

VALUE	STEL (5 MIN.)	STEL (10 MIN.)	STEL (15 MIN.)
TIME	0:33:30	0:17:40	0:23:30

PEAK = 2.34 TIME OF PEAK = 1:01:22

RUN TIME= 1:16:20 STANDBY TIME = 1:44:34

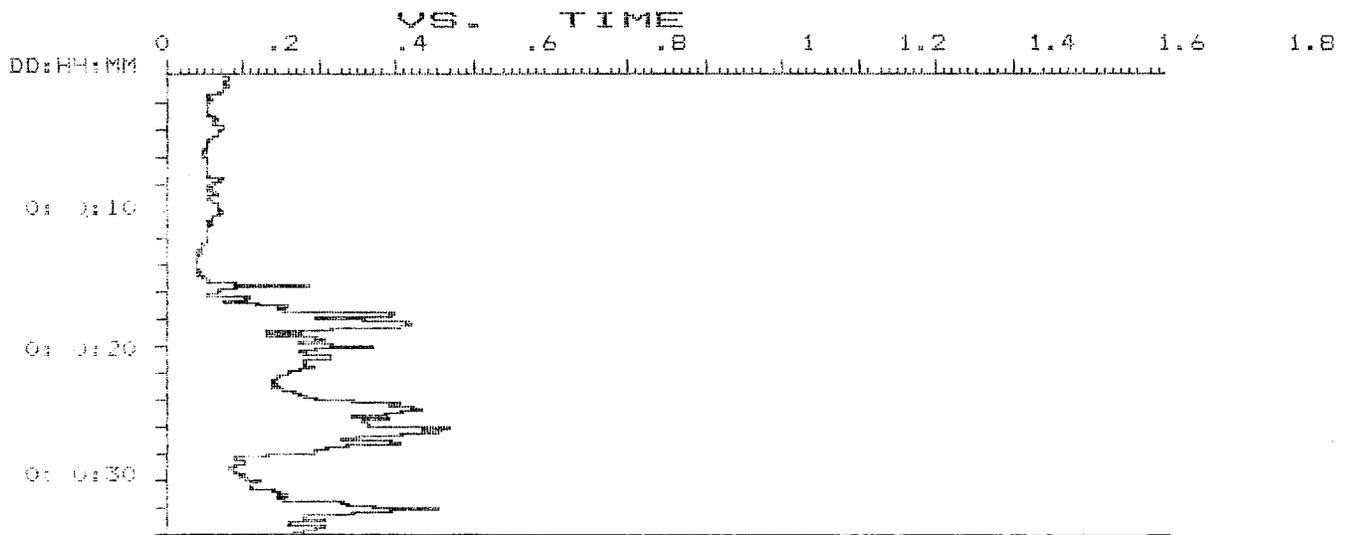


Figure 43. Sample Data Graphic Printout

DATE - 03/20/85
 TIME - 0:00:00
 SAMPLE LOCATION - OPERATOR
 SAMPLE NUMBER - 10-13
 RAM SERIAL NO. - OFF 1377
 ON/OFF DATA -

METROSONICS INC.

331/11

S/N: 1425 RANGE= 2.00 PERIOD = 0:00:10

CUMM. AVG. = 0.26 STANDARD DEV. = 0.20

	STEL (5 MIN.)	STEL (10 MIN.)	STEL (15 MIN.)
VALUE	0.56	0.45	0.46
TIME	0:33:30	0:17:40	0:23:30

PEAK = 2.34 TIME OF PEAK = 1:01:22

RUN TIME= 1:16:20 STANDBY TIME = 1:44:34

DD:HH:MM:SS	0:00:00	0:00:10	0:00:20	0:00:30	0:00:40	0:00:50
0:00:00	0.150	0.160	0.160	0.150	0.140	0.160
0:01:00	0.150	0.140	0.130	0.110	0.110	0.120
0:02:00	0.110	0.100	0.110	0.100	0.100	0.110
0:03:00	0.110	0.120	0.130	0.120	0.120	0.140
0:04:00	0.140	0.130	0.130	0.130	0.120	0.110
0:05:00	0.100	0.100	0.100	0.090	0.100	0.090
0:06:00	0.090	0.100	0.100	0.100	0.100	0.100
0:07:00	0.100	0.100	0.100	0.110	0.140	0.130
0:08:00	0.120	0.110	0.120	0.110	0.120	0.130
0:09:00	0.110	0.110	0.120	0.130	0.130	0.130
0:10:00	0.130	0.140	0.130	0.120	0.120	0.110
0:11:00	0.120	0.110	0.110	0.100	0.100	0.100
0:12:00	0.100	0.100	0.100	0.090	0.090	0.090
0:13:00	0.080	0.090	0.080	0.080	0.080	0.080
0:14:00	0.080	0.080	0.080	0.080	0.090	0.080
0:15:00	0.090	0.100	0.110	0.170	0.370	0.170
0:16:00	0.130	0.130	0.100	0.220	0.200	0.150
0:17:00	0.230	0.310	0.290	0.300	0.600	0.580
0:18:00	0.380	0.510	0.620	0.640	0.610	0.430
0:19:00	0.260	0.340	0.260	0.390	0.410	0.340
0:20:00	0.420	0.540	0.390	0.340	0.360	0.420
0:21:00	0.430	0.360	0.350	0.350	0.380	0.340
0:22:00	0.320	0.310	0.290	0.290	0.270	0.270
0:23:00	0.290	0.270	0.300	0.330	0.340	0.360
0:24:00	0.390	0.480	0.610	0.580	0.640	0.670
0:25:00	0.610	0.560	0.480	0.580	0.510	0.530
0:26:00	0.520	0.740	0.670	0.710	0.610	0.500
0:27:00	0.450	0.580	0.610	0.470	0.410	0.390
0:28:00	0.390	0.260	0.170	0.170	0.200	0.200
0:29:00	0.180	0.160	0.170	0.170	0.200	0.190
0:30:00	0.200	0.250	0.220	0.220	0.210	0.270
0:31:00	0.290	0.320	0.290	0.300	0.450	0.470
0:32:00	0.540	0.700	0.580	0.480	0.360	0.350
0:33:00	0.410	0.320	0.320	0.410	0.380	0.350

Figure 44. Sample Raw Data Tabular Printout

To determine O.A.S.I.S. dust removal efficiency, gravimetric samplers were positioned at the inlet of the O.A.S.I.S. and directly below the air discharge. The samples were weighed and efficiency determined by the weight gain differences on the cassette sampler media.

Testing was divided into two 15 minute cycles, and equipment was dedicated to collect data or samples during its assigned cycle only. Data was collected for conditions when the O.A.S.I.S. was on and off for determination of effectiveness. Thirteen on and fourteen off periods were completed for a total of 195 minutes of data. The on and off samples were then compared to determine O.A.S.I.S. effectiveness.

Data analysis showed that the O.A.S.I.S. reduced the operator's exposure level an average of 96.6 percent (figure 45). Respirable dust levels in the plant were reduced an average of 34 percent when the O.A.S.I.S. was on (figure 46).

Problems were encountered with the test procedures and their effects on the gravimetric samples. One gravimetric cassette for each sampler was used to ensure sufficient weight gain during testing. However, because only 195 minutes of total sample time were completed, no weight gain could be measured. The 15 minute time periods did not allow sufficient time to collect a measurable weight gain on the cassette filter. Evaluation of the test procedures showed that future use of the gravimetric samplers would be impractical, and should therefore be eliminated.

A second difficulty involved the dust loading on the four panel filter pre-filters of the O.A.S.I.S. The initial maintenance performed on the system required removing and cleaning the prefilters; this occurred after only 117 hours of operation. The O.A.S.I.S. was set for an airflow range from 7,000 cfm to 4,500 cfm. This airflow range was determined by observing a magnehelic gage having green markings to indicate adequate airflow and red markings to warn of inadequate airflow (figure 47). When operation of the O.A.S.I.S. reached the red zone on the magnehelic gage (low airflow of 4,500 cfm), maintenance on the prefilters would occur. If cleaning the prefilters did not return airflow to the green range, as observed on the gage, maintenance was

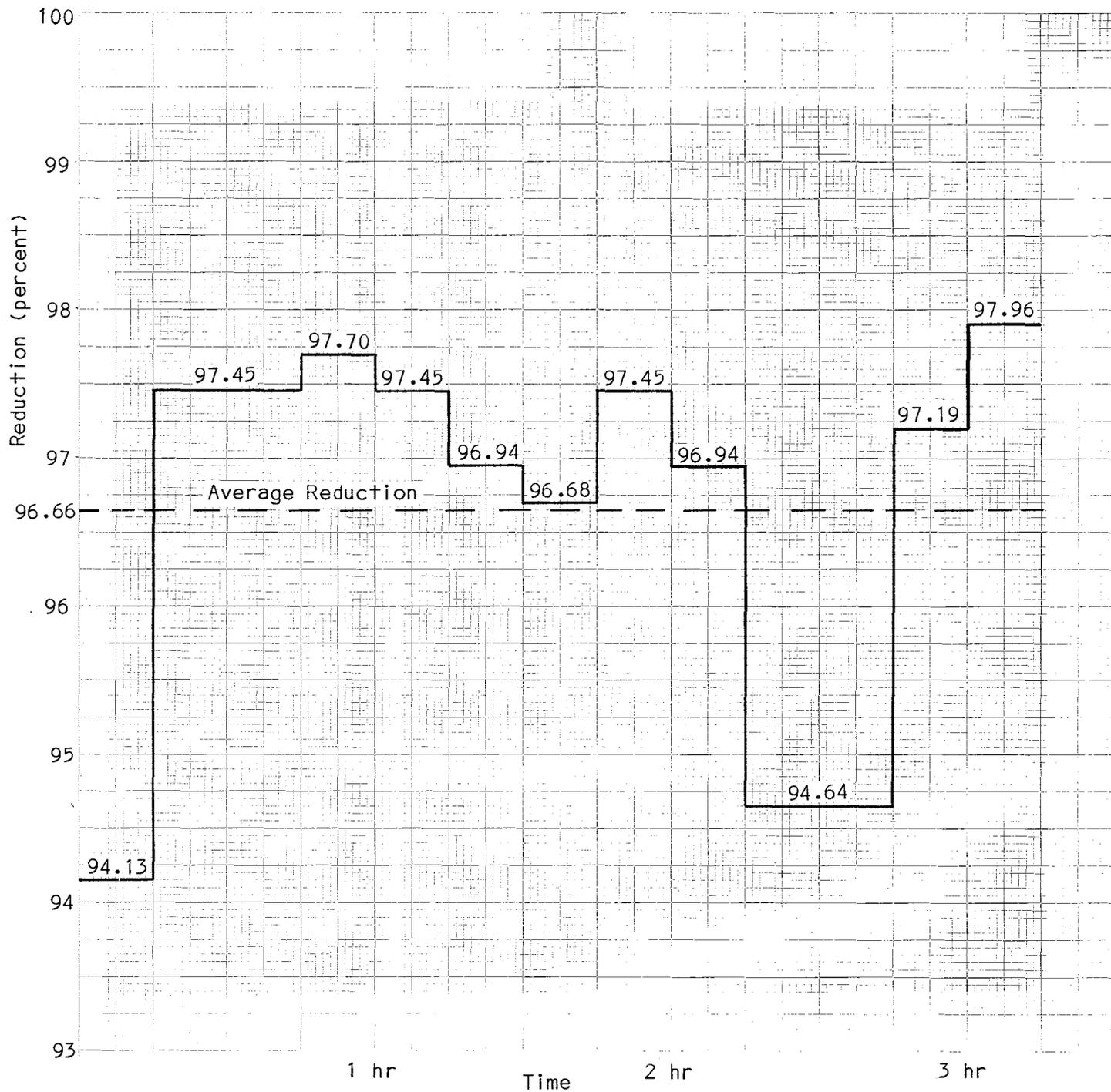


Figure 45. Bagging Operator's Reduction to Respirable Dust During O.A.S.I.S. Operation

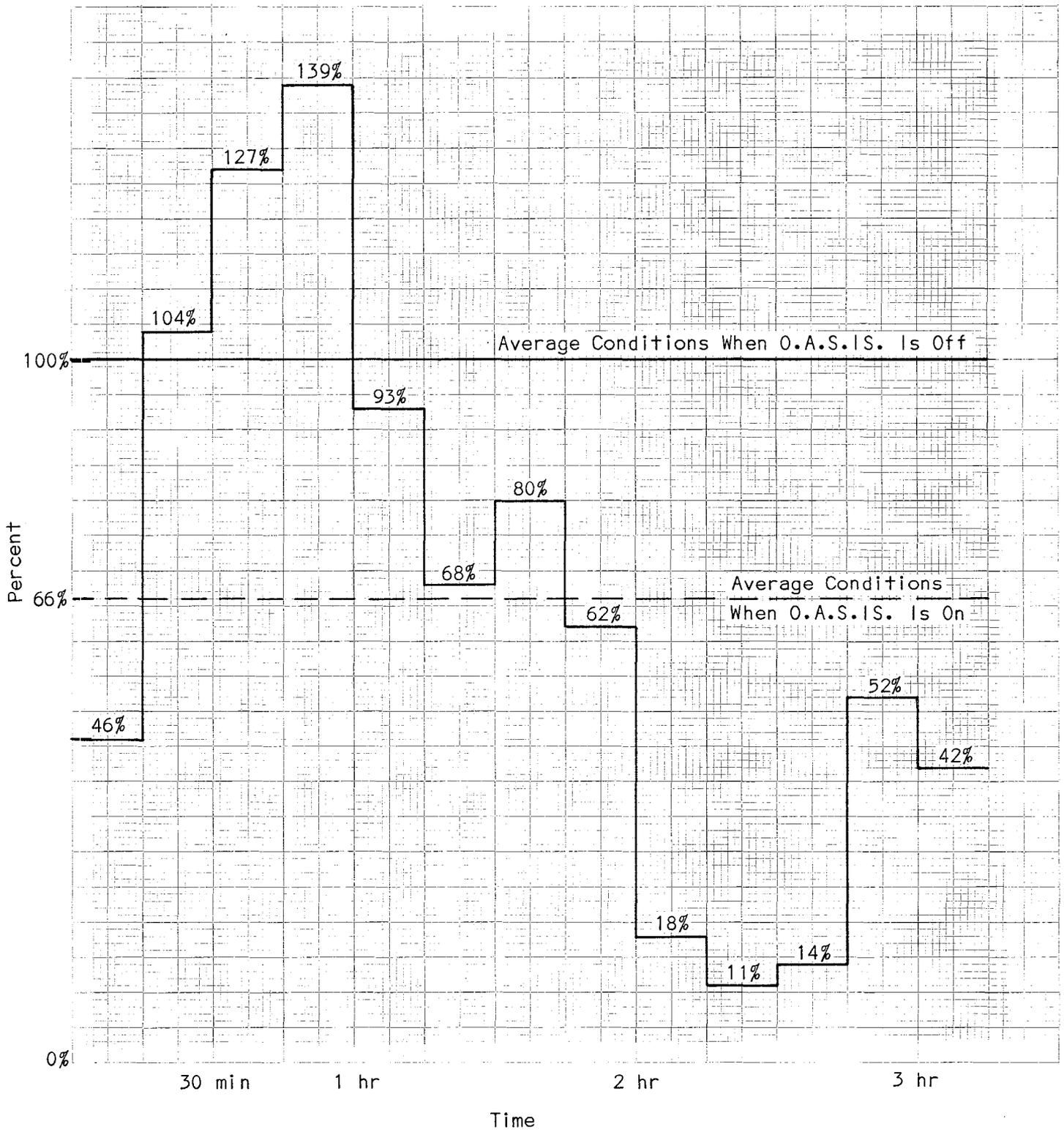


Figure 46. Reduction in Room Level Respirable Dust During O.A.S.I.S. Operation

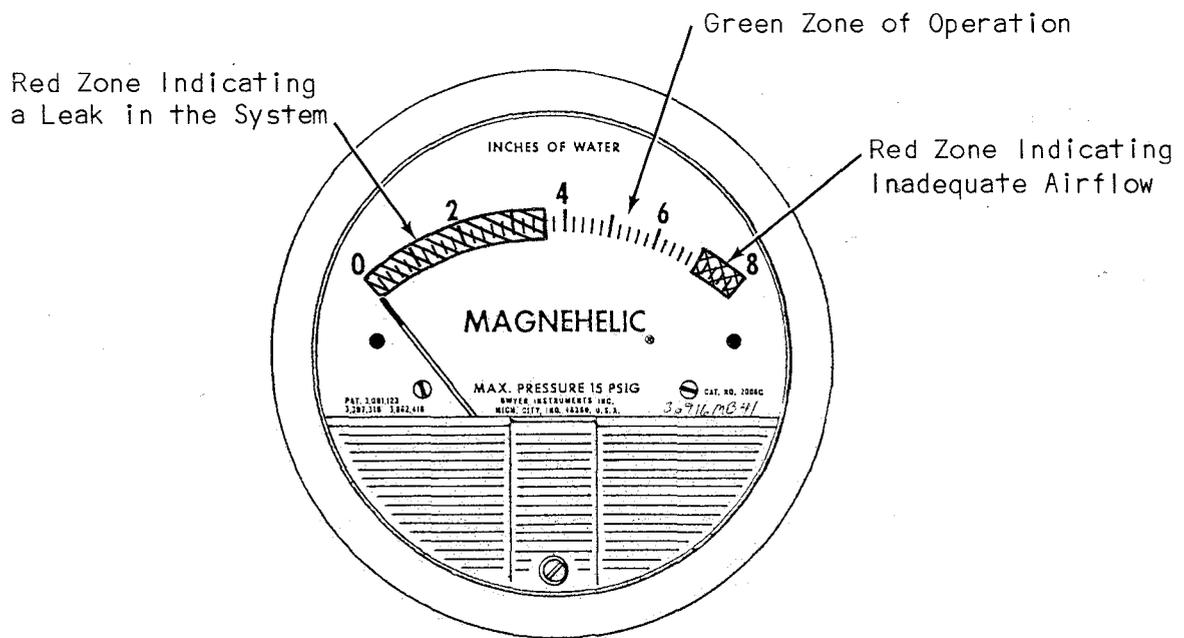


Figure 47. Magnehelic Gage

performed on the four safety filters. During one sample period of time at the field site, 158.8 pounds of dust were collected in 413 hours. (A particle size analysis of this dust can be found in figure 48.) A record of the required maintenance performed on the O.A.S.I.S. is contained in table 6. A review of this maintenance information prompted an investigation into the use of precleaners for use on the O.A.S.I.S. inlet.

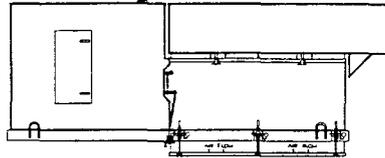
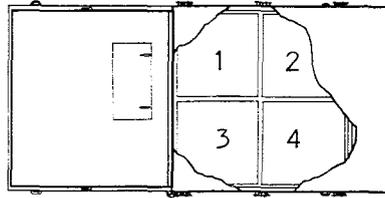
Two precleaner systems were investigated and one was tested. The first system proposed incorporated a Donaldson Company STRATA®* panel with a 600 cfm, 10 percent scavenge (figure 49). The STRATA would remove approximately 85 percent of the dust particles above 2 micron in diameter. This would effectively reduce loading on the prefilters and extended the maintenance schedule. The drawback to this system was that the scavenge airflow required yet a second air cleaner prior to discharging to atmosphere.

The second system investigated used fine screen mesh to reduce loading on the prefilters. A precleaner constructed from 400 mesh screen was tested and evaluated. Tests were conducted to determine pressure drop, efficiency, and dust loading characteristics of the screen. The precleaner was fabricated from 400 mesh wire cloth, type 304 stainless steel, .0010 inch diameter wire, .015 inch opening, twill weave, 36 percent open area. Both sides of the screen panel were supported with a .25 inch by .25 inch mesh screen, .015 inch diameter wire, 88 percent open area. A 9 inch diameter disk assembly containing the precleaner components was sandwiched between duct sections to facilitate testing.

The test assembly was scaled to represent conditions encountered at the Jesse S. Morie Company field test site. Testing determined that a practical size O.A.S.I.S. precleaner would provide 10.64 square feet of filtering area. The test assembly contained .389 square feet of filtering area and was evaluated at a constant airflow of 274 cfm. Air velocity through the test assembly was 705 ft/min.

*A registered trademark of Donaldson Company, Inc.

Table 6. O.A.S.I.S. Maintenance Record



Date	No.	Schedule		Filter Weight Gain					Comments
		Total Hours	Operating Hours	1	2	3	4	Total	
01/12/84	1	117	117	--	--	--	--	--	
01/17/84	2	159	42	24	15-1/4	7-3/4	7-1/4	54-1/2	
--	3	186	186	1/2	1/2	1/2	1/2	2	First cleaning of safeties
01/27/84	4	230	71	26-1/4	16	12-1/2	14-1/2	69-1/4	
02/10/84	5	303	73	6-1/2	6	5-1/2	4	22	
02/29/84	6	390	87	5-1/2	5	3-3/4	3	17-1/2	
02/29/84	7	390	204	1/2	1/2	1/2	1/2	2	Second cleaning of safeties
03/13/84	8	490	100	6	8-1/2	7	5	26-1/2	
03/27/84	9	572	82	6-1/2	9-12	7	5-1/2	28-1/2	
05/03/84	10	708	136	3-1/2	7-1/2	4-1/2	3-1/2	19	New prefilters
06/ /84	11	1,006	298	7-1/2	8	6	5-1/2	27	
06/ /84	12	1,178	172	4-1/2	4-1/2	3-1/4	4-3/4	17	
07/19/84	13	1,467	289	6-1/2	7-1/2	6-1/4	6-1/2	26-3/4	
07/27/84	14	1,566	99	3-1/2	3	2-1/2	2	11	Placed used safeties in primary
08/08/84	15	1,694	128	4	4	3-1/2	3	14-1/2	Replaced safetyies
08/23/84	16	1,858	164	5	5	4-1/2	4-1/2	19	
08/31/84	17	1,985	127	4	3-1/2	3	3	13-1/2	New prefilters
09/13/84	18	2,113	128	4-1/2	5	4	5	18-1/2	
09/21/84	19	2,202	89	3-1/2	4	3-1/2	3-1/2	14-1/2	New prefilters
10/05/84	20	2,352	150	5	6	5-1/2	5	21-1/2	
10/18/84	21	2,493	141	4	4	3-1/2	3	14-1/2	Prefilters washed
10/31/84	22	2,581	88	3-1/2	3-1/2	2	2-1/2	11-1/2	
01/13/85	23	2,689	108	--	--	--	--	--	
Totals		2,689		133-3/4	125-3/4	95-1/2	91	446	
Averages			116.9	7	6-1/2	5	4-3/4	23-1/2	

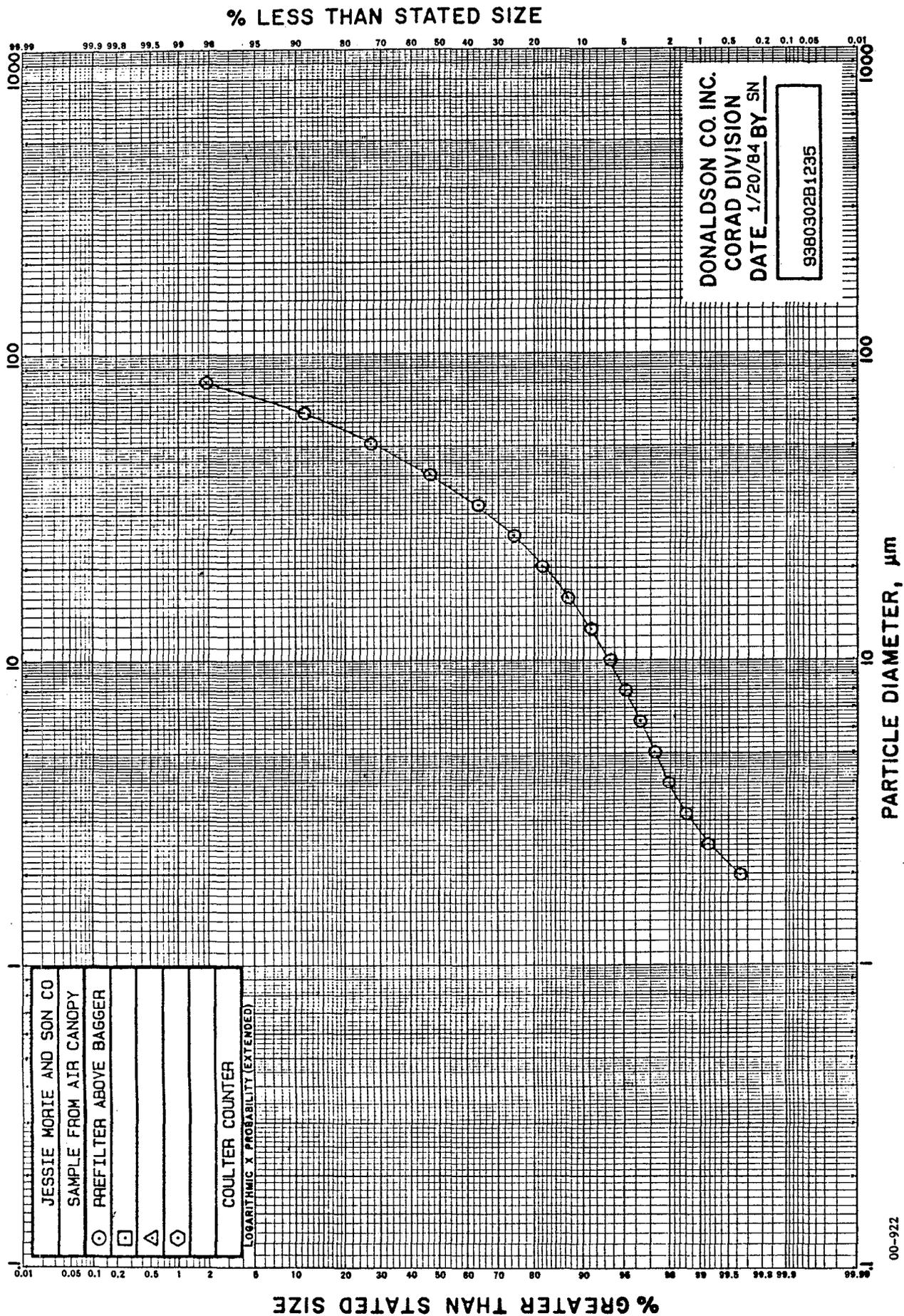


Figure 48. Particle Size Analysis of Dust Collected on the Prefilters at First Field Test Site

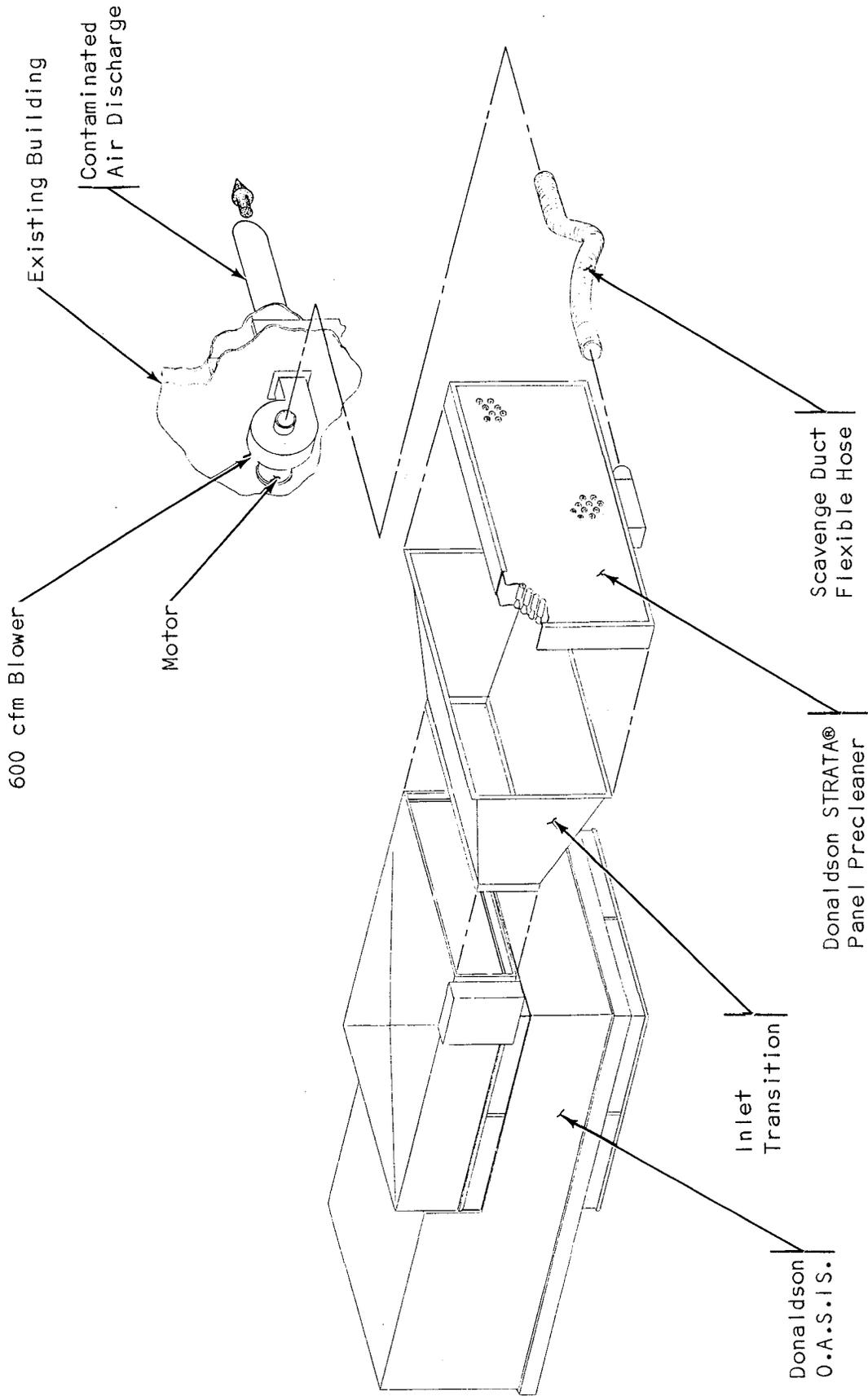


Figure 49. O.A.S.I.S. Precleaner Proposal

Course test dust with a 30 micron mean particle diameter size was metered to the test assembly at .13 grams per minute. This dust feed rate was consistent with the field conditions previously mentioned. Particle size information for the test dust is displayed in figure 50. Restriction of the 400 mesh screen is shown in figure 51. Restriction for the screen mesh assembly was .55 inH₂O, which was slightly higher than the manufacturer's data because of the support grid assembly on both sides of the screen.

The test apparatus is illustrated in figure 52. A high efficiency filter was placed downstream of the assembly to capture dust that passed through the screen. Efficiency was determined by weighing the screen assembly before and after feeding dust and dividing this weight gain by the total amount of dust fed. The screen was 71 percent efficient. A test was conducted to simulate field conditions and determine precleaner life. After feeding dust at .13 grams per minute for 30 minutes, the screen restriction climbed to 2.5 inH₂O, and after 53 minutes, restriction climbed to 13.0 inH₂O.

3.5.1.4 Conclusions

- Filter life insufficient
- Precleaner impractical
- Respiratory protection against interference airflow excellent
- Bagging operator's exposure to respirable dust significantly reduced
- Respirable dust levels in the plant lowered

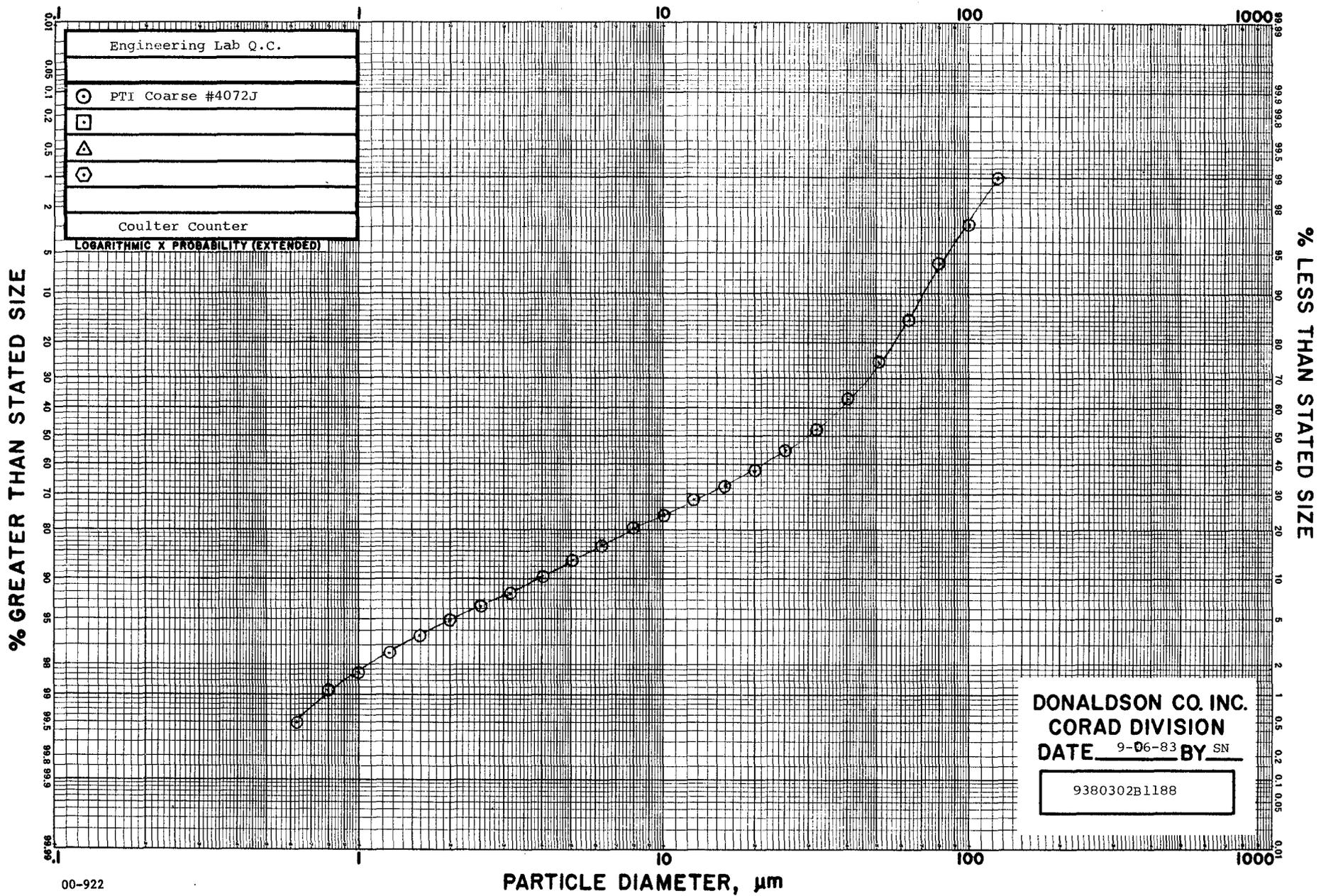


Figure 50. Test Dust Particle Size Analysis

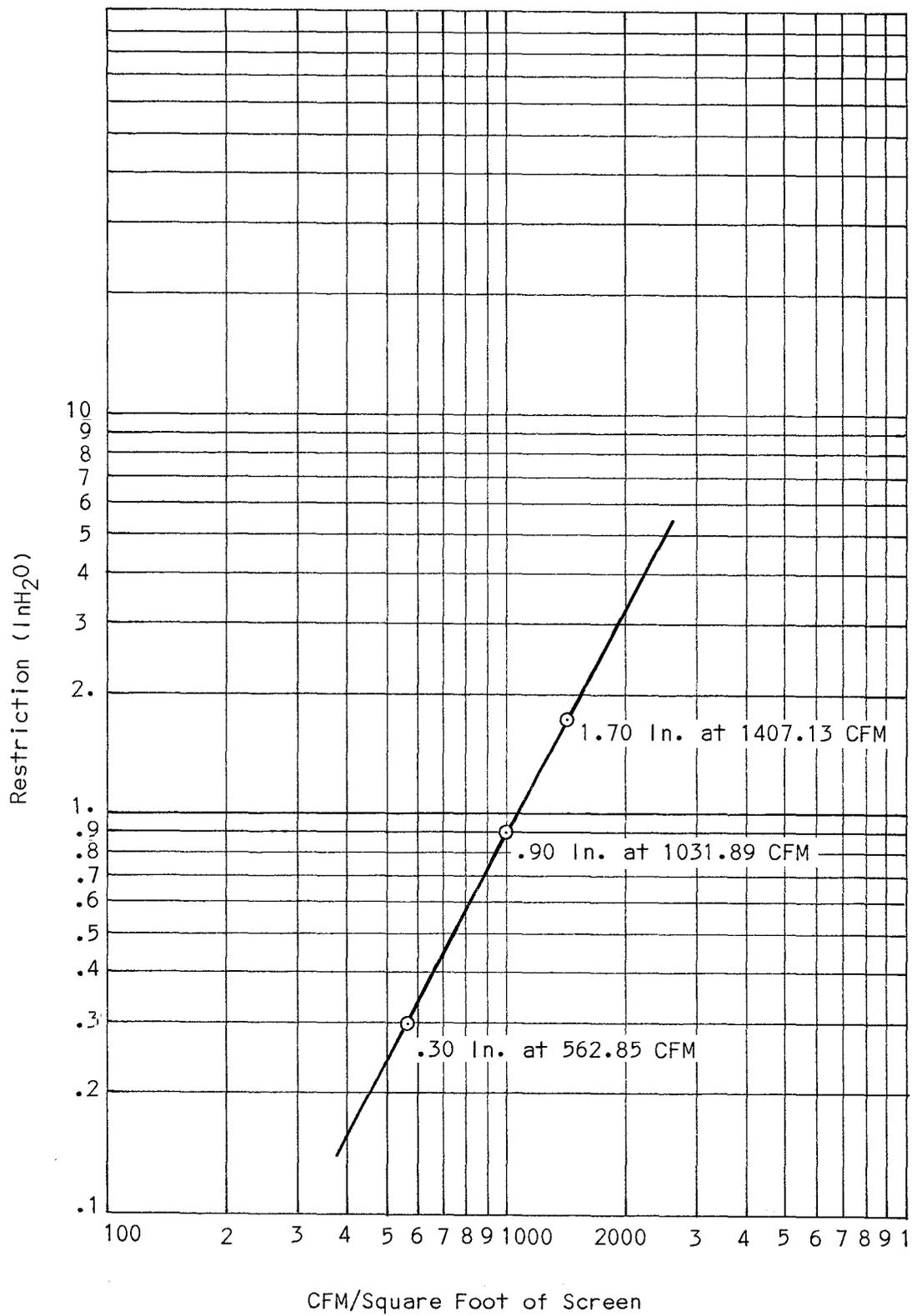
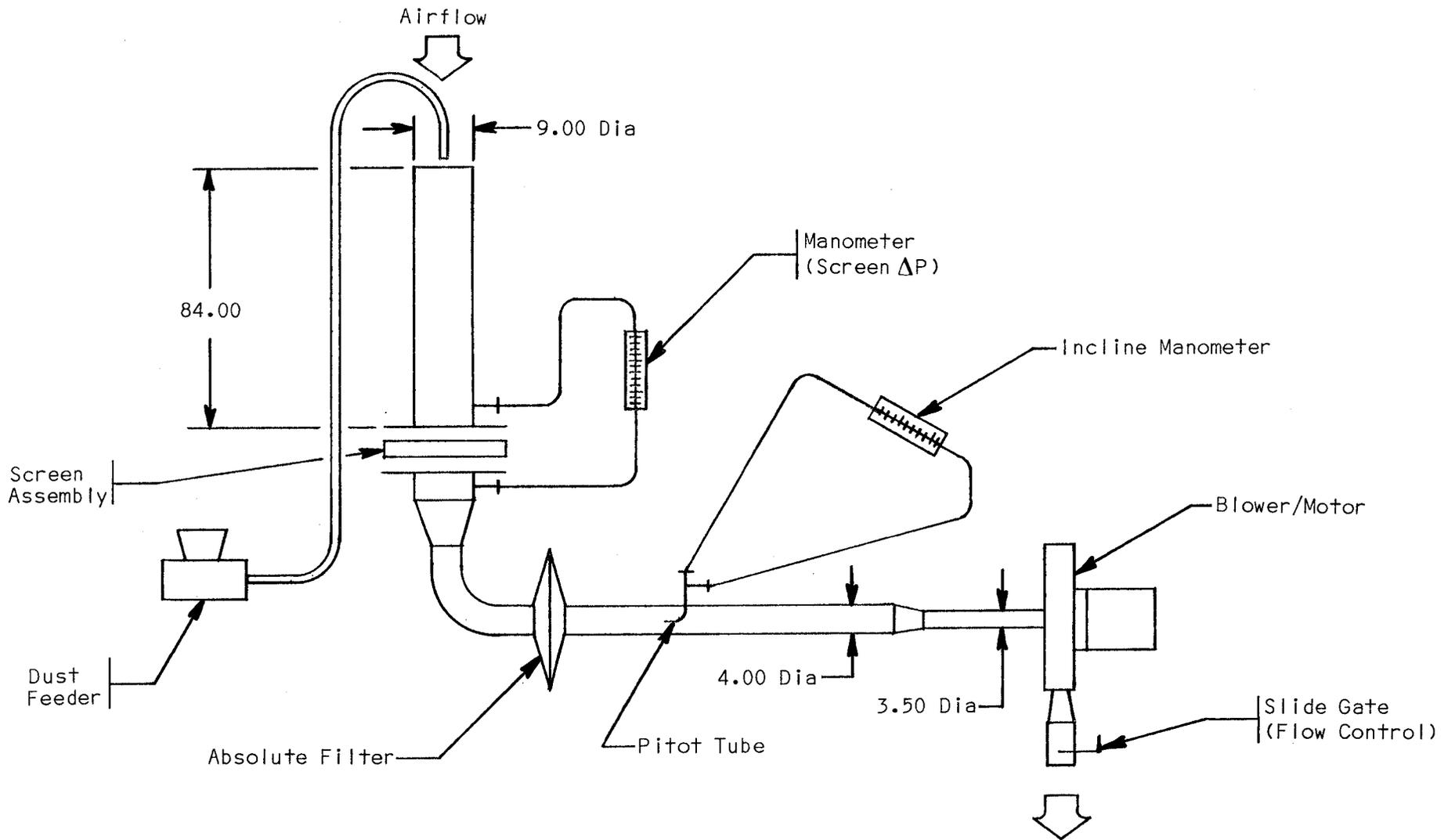


Figure 51. Airflow Restriction for 400 Mesh Screen

Figure 52. Test Apparatus



3.5.1.5 Recommendations

Based on the conclusions resulting from the first field evaluation, a design review meeting was held to discuss the direction of the O.A.S.I.S. mine mill work station air curtain. The following recommendations were made:

- Maintain airflow at 6,400 cfm
- Use self-cleaning primary filters to reduce maintenance
- Keep secondary filters the same
- Install second O.A.S.I.S. at first field site for evaluation under heavy dust loading conditions

3.5.2 Field Evaluation Site Two

The second field test O.A.S.I.S. was installed at the same bagging station at Jesse S. Morie Company, replacing the first O.A.S.I.S. unit. This was done because of the recommendations listed in section 3.5.1.5. Arrangements were made with Jesse S. Morie Company for removal of the first system and placement of the redesigned O.A.S.I.S. After 2,689.8 hours of operation, the original O.A.S.I.S. was removed and shipped to Donaldson Company. Installation of the new system took place during December 1984 and January 1985.

3.5.2.1 O.A.S.I.S. Generation Two

The O.A.S.I.S. was redesigned based on recommendations from the design review meeting. The resulting new design involved replacement of some components and redesign of many major components. The new O.A.S.I.S. contained an improved filtration system, a redesigned air generator, a modified motor and blower package, and a modular construction. A discussion of each change is provided in the following paragraphs.

The major problem encountered at the first field site was the maintenance intensive primary filter section. The redesign replaced the four panel filters from the primary filter section with an industrial dust collector capable of handling the amount of dust that was being collected. The Environmental Air Cleaner (EAC), a standard Donaldson Company product, was chosen (figure 53).

The EAC is a reverse pulse jet cleaning filter designed for 3,200 cfm. The design airflow of 6,400 cfm for the O.A.S.I.S. is maintained by using two adjacent units with a common clean air chamber. Each of the collectors contains four cylindrical pleated paper high efficiency filter elements. Pulse cleaning of the filters is accomplished by blowing compressed air, released by a solenoid operated valve for a short duration, back through the filter elements. This effectively dislodges the dust loaded on the filter, thereby lowering the pressure drop across the element. This cleaning sequence is programmed to occur when the machine is shut down for the day.

A second major change in the redesigned O.A.S.I.S. was the modular construction. Concurrent to the first field test and the redesign effort, a search for additional field test sites was performed. The search pointed to major installation problems at many locations due to the extreme height of the air generator, 50 inches in the original O.A.S.I.S. A minimal profile for the air generator (necessary to accommodate numerous installation possibilities) and the increased size of the dust collector necessitated a modular construction.

A benefit of the modular construction was the ability to install the heater into a clean air duct. This also improved the flow characteristics across the face of the heater effectively reducing hot spots which shortened the heater life. For the second field test site, the heater was placed in a duct between the primary filter section and the motor and blower enclosure.

The final modifications to the original design were to the motor and blower enclosure and the air generator. The motor and blower remained the same as that used in the first O.A.S.I.S. unit. The difference was that they were placed in a separate enclosure capable of being assembled at the field test

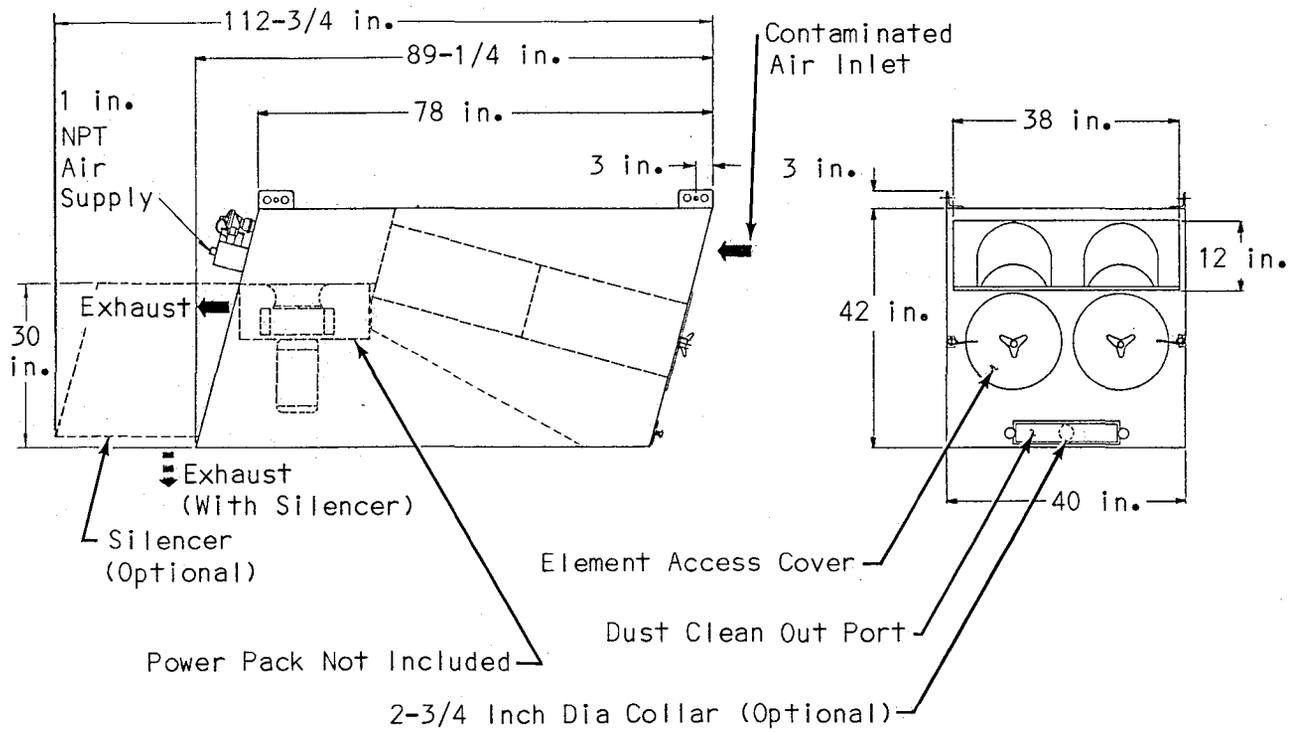


Figure 53. EAC

site in any of four outlet directions (figure 54). The outlet of the enclosure was bolted to the air generator, which had a redesigned profile providing even air distribution over the 4 foot by 4 foot area.

The redesigned air generator profile is based on a technical report published by National Advisory Committee For Aeronautics.* The report discusses a method for predicting wall shape to obtain a uniform discharge through a porous resistance (figure 55). The porous resistance is the panel filters for the O.A.S.IS. By obtaining even airflow, greater protection and comfort may be achieved.

3.5.2.2 Testing and Evaluation

Installation was completed on 19 January 1985, and the system was operated for 140 hours prior to testing. Testing was done at the field site to determine the following:

- Effectiveness of the O.A.S.IS. in reducing operator exposure levels
- Effect of the O.A.S.IS. on respirable dust levels in the plant
- Effect of the new primary filter section on maintenance intervals

Initial field evaluation of this second installation occurred during the week ending 8 February 1985. Evaluation involved using RAM-1 aerosol monitors that were calibrated to silica dust, Metrosonics dL331 Data Loggers, and a two pen strip chart recorder. The monitors were placed in two locations so plant dust concentrations could be monitored while simultaneously monitoring respirable dust concentrations at the operator.

Testing, set up similar to the first O.A.S.IS. field evaluation, was divided into two cycles. Each cycle was dedicated to collect data at one of two sampling locations (figure 56) for either on or off operation of the O.A.S.IS.

*National Advisory Committee for Aeronautics, "Turbulent Flow Through Porous Resistances Slightly Inclined to the Flow Direction", Technical Note 4221, Albert L. Loeffler, Jr, and Morris Parlmutter.

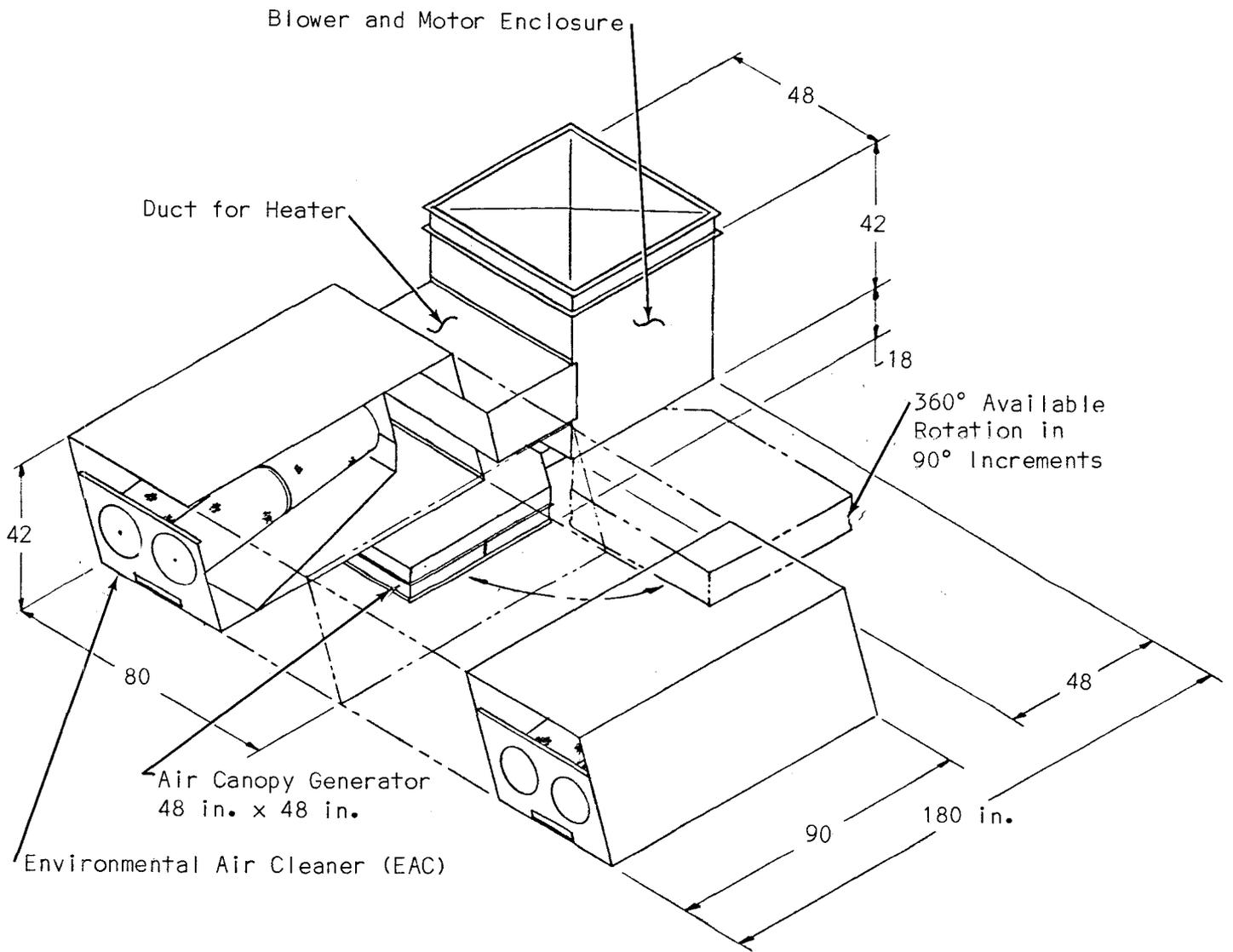
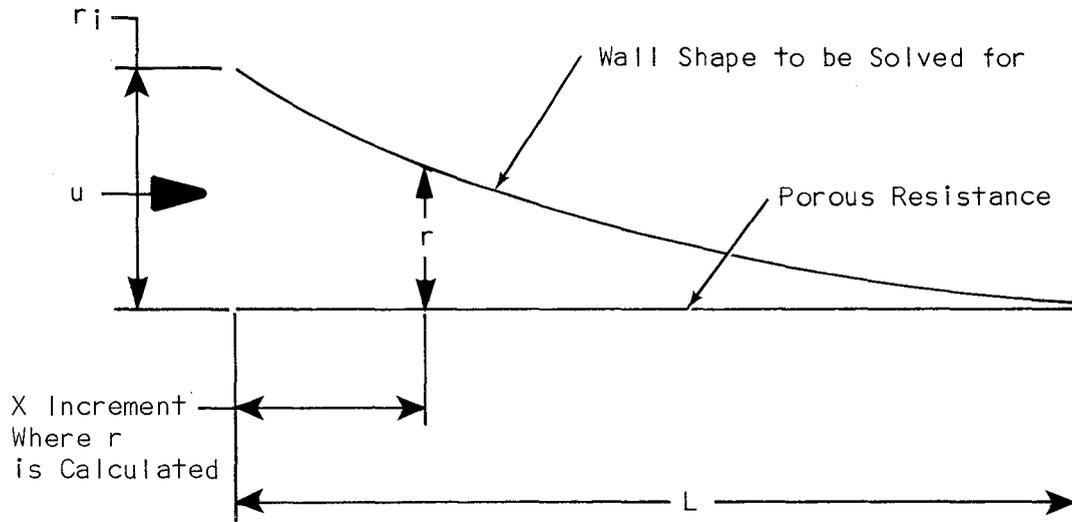


Figure 54. O.A.S.I.S. System Design With Modular Construction



$$r/r_i = (1 - X/L)^{1+\beta} + \frac{.0685}{\beta + 1/4} \frac{L}{r_i} \frac{1}{(Re)^{1/4}} \left[(1 - X/L)^{3/4} - (1 - X/L)^{1+\beta} \right]$$

Where:

r = Desired channel height at X

r_i = Channel height

X = Distance measured along porous resistance in axial direction from upstream end where channel height is desired

L = Length of porous resistance in X direction

β = Fraction of original X - momentum transferred to the fluid remaining in the channel to the fluid entering the porous resistance

u = Mean velocity of fluid entering the channel in X direction (ft/sec)

Re = $2 ru/v$

Figure 55. Wall Shape Calculation

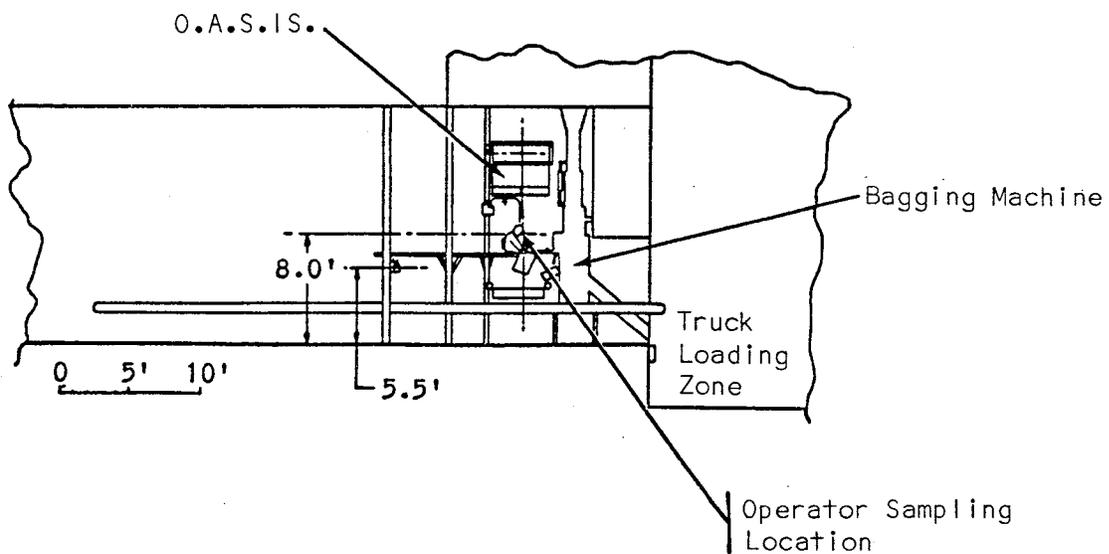
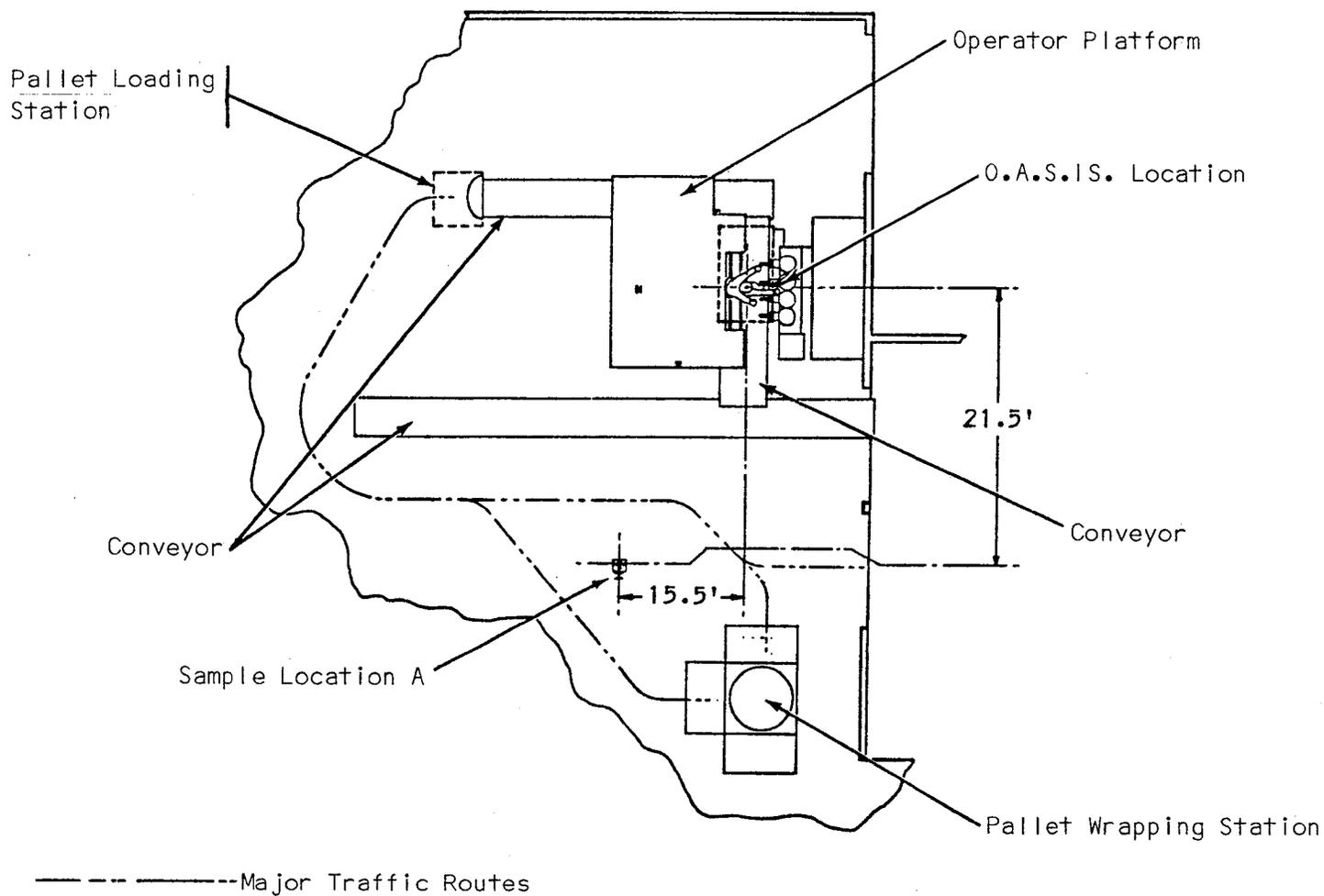


Figure 56. Aerosol Monitoring Locations at Bagging Operation

Sampling periods from the previous tests were determined to be too long to maintain, for comparison, similar plant and production conditions. Cycle sampling lengths were allowed to vary from 2 minutes to 15 minutes, depending on the production schedule; however, each pair of cycles to be compared were of the same length. A total of 21 on and off cycles were completed. Analysis of the data showed that the O.A.S.I.S. reduced the operator's respirable dust exposure level an average of 98.4 percent (figure 57). This represented an improvement in the protection over the first O.A.S.I.S.

3.5.2.3 Conclusions

- The generation two system works better by reducing maintenance
- Operator protection was improved
- O.A.S.I.S. system size will limit installation possibilities

3.5.2.4 Recommendations

- Reduce O.A.S.I.S. system size by utilizing standard EAC blowers and eliminating blower enclosure
- Provide complete electrical controls

3.5.3 Field Evaluation Site Three

The third field test installation was located at Illinois Minerals Company in Elco, Illinois. They produce silica flour and have several material bagging locations in the plant suitable for an O.A.S.I.S. application. A two spout silica flour bagging machine with one operator was selected.

Prior to fabrication of this final unit, some changes in the O.A.S.I.S. design were performed. A discussion of these changes, the installation, testing, and evaluation follows.

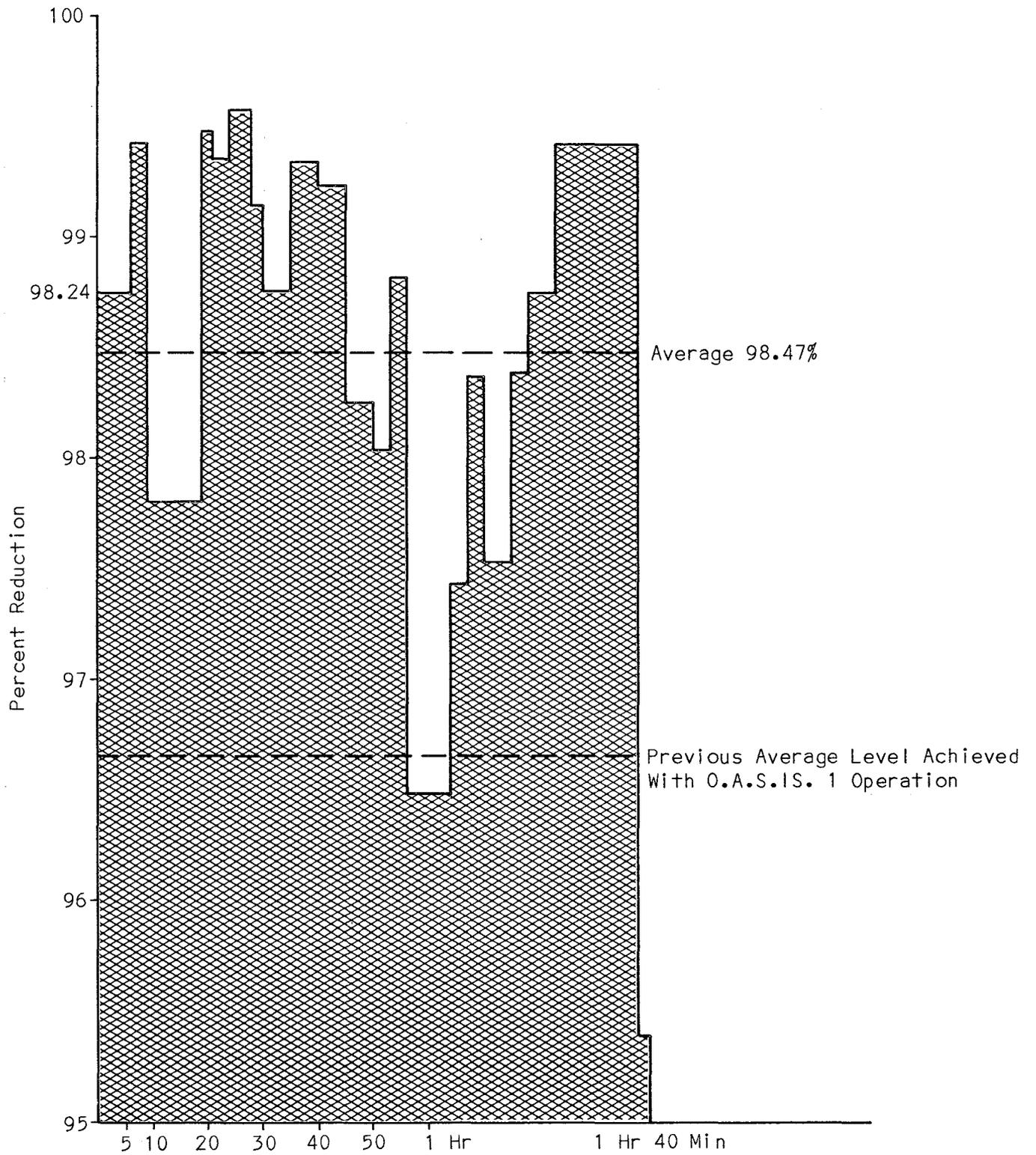


Figure 57. Bagging Operator's Reduction to Respirable Dust During O.A.S.I.S. Operation

3.5.3.1 O.A.S.I.S. Generation Three

Two changes in the design of the O.A.S.I.S. were performed based on the conclusions and recommendations from sections 3.5.2.3 and 3.5.2.4. The first change was to shorten the overall system length which, at the Jesse S. Morie Company site, was approximately 24 feet long. The second change, which also affected the length, concerned the concept of a self-contained system which the second design had departed from.

First, the motor and blower enclosure was eliminated in favor of using the standard EAC power pack. The power pack comes standard at two different airflows (3,000 cfm and 2,000 cfm). Using a 3,000 cfm power pack, two EACs could be joined, obtaining an airflow near the originally designed 6,400 cfm. Based on manufacturer supplied data, the estimated performance of the two fans operating in parallel could deliver a maximum of 6,000 cfm with the addition of the air generator and heater downstream (figure 58). By removing the previous motor and blower enclosure, 8 feet of ducting was eliminated (figure 59).

The second consideration was to return to the self-contained concept. By using the EAC dust collector blowers and positioning the air canopy generator closer to the collector, a more uniform single package system was re-established. This third design of the O.A.S.I.S. now contained a proven dust collector, was 8 feet shorter, had an improved airflow path, weighed 500 pounds to 700 pounds less, and finally, it closely approximated the original concept of a self-contained system.

3.5.3.2 Testing and Evaluation

The O.A.S.I.S. installed at Illinois Minerals Company in Elco, Illinois, was tested to evaluate field performance. The installation was at a two spout silica flour bagging machine. Testing, completed during the week of 18 to 22 March 1985, evaluated the degree of protection provided to the bagging machine operator and the effect of O.A.S.I.S. operation on respirable dust levels in the plant.

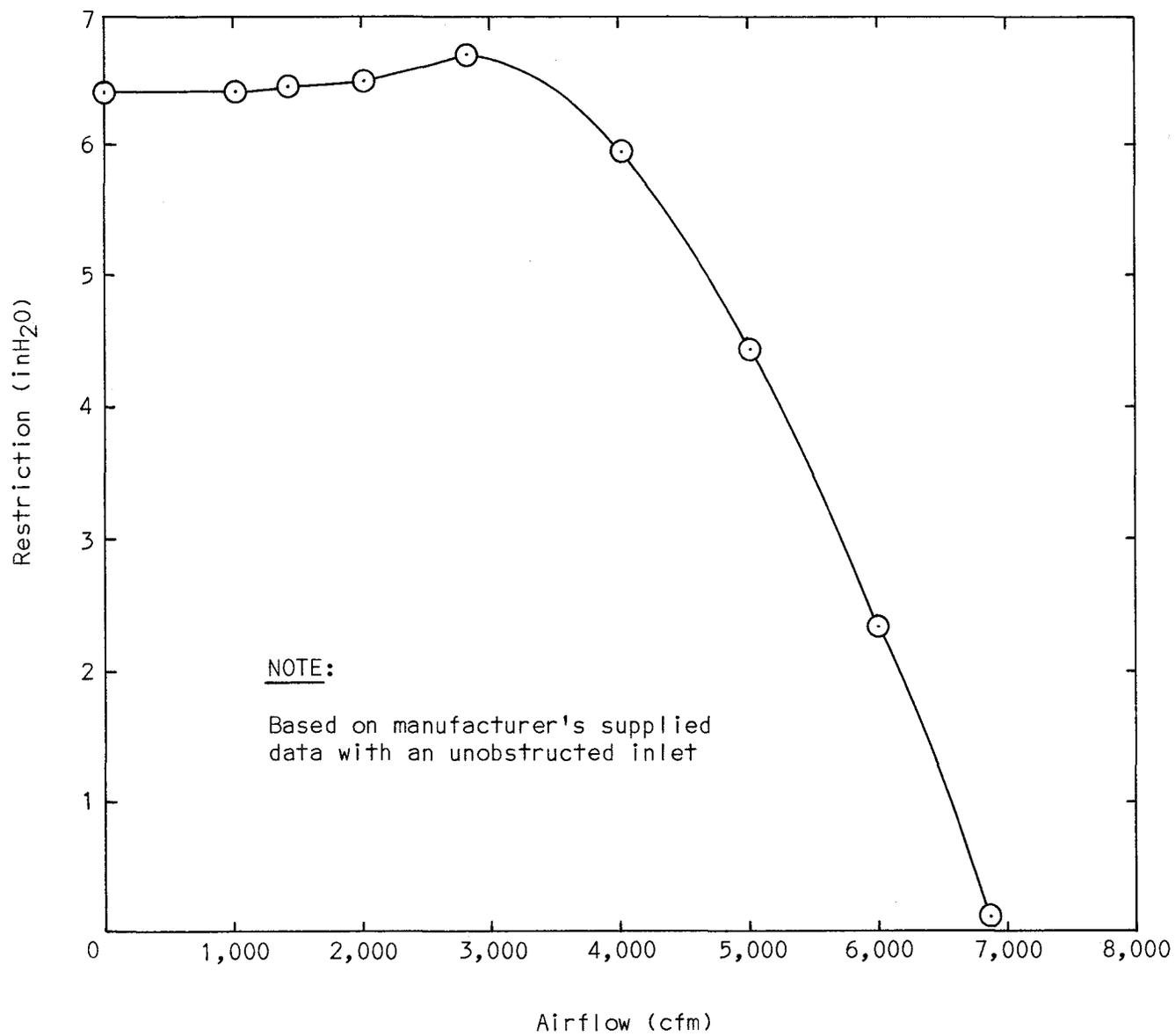


Figure 58. O.A.S.I.S. System III Fan Performance Curve

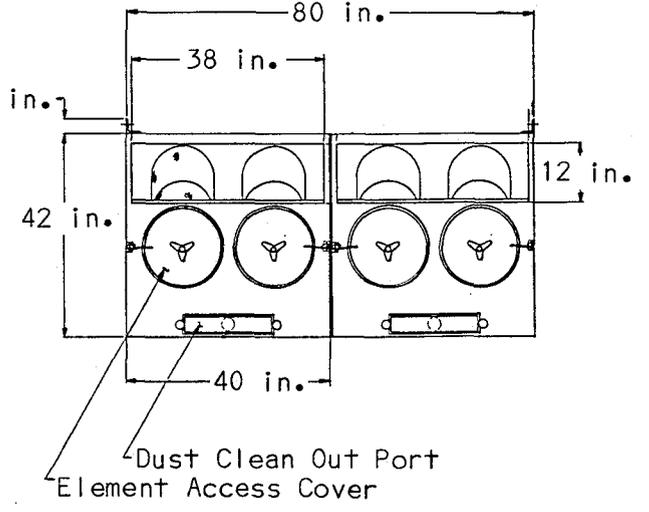
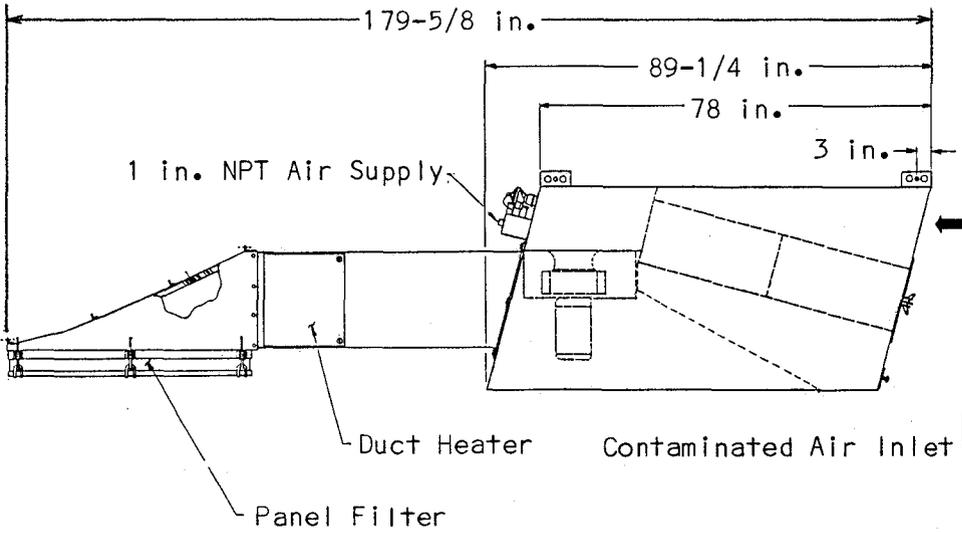
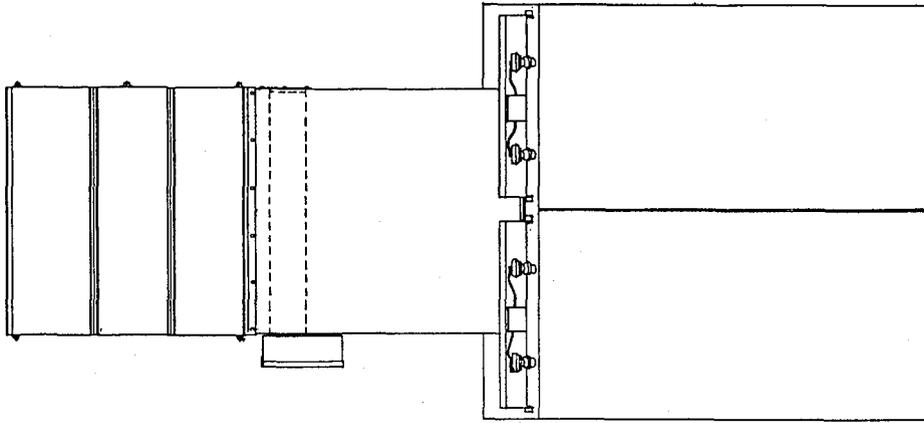


Figure 59. O.A.S.I.S. III

Field evaluation used RAM-1 aerosol monitors calibrated to silica dust, data loggers, and a two pen strip chart recorder. The RAMs were located so the plant dust concentrations could be monitored while simultaneously monitoring the dust levels at the operator. Testing was divided into two cycles (O.A.S.IS. on or off), and equipment was dedicated to collect dust during its assigned cycle only. Data from twenty-one 15 minute and three 30 minute on and off cycles was collected for a total of 405 minutes of data.

Analysis of the data showed that the O.A.S.IS. reduced the operator's exposure to respirable dust an average of 80.30 percent (figure 60). Eight sample periods were obtained to analyze the O.A.S.IS. effect on room dust levels. Time lengths for these periods varied from 10 minutes to 30 minutes for a total of 140 minutes of comparison data. Of the eight samples, six showed a reduction in room levels from 7.80 percent to 42.56 percent. Overall respirable dust levels in the room were lowered by 12.38 percent (figure 61). These results indicated that a slight lowering of respirable dust levels can be expected.

The average respirable dust reduction level of this O.A.S.IS was lower than the generation two O.A.S.I.S. due to the difference in the plant dust levels. Plant dust levels for generation three O.A.S.IS. were significantly lower than generation two.

3.5.3.3 Conclusions

- O.A.S.IS. operation reduces operator exposure to respirable dust levels ranging from 80.3 percent to 98.47 percent
- O.A.S.IS. operation can reduce room respirable dust levels

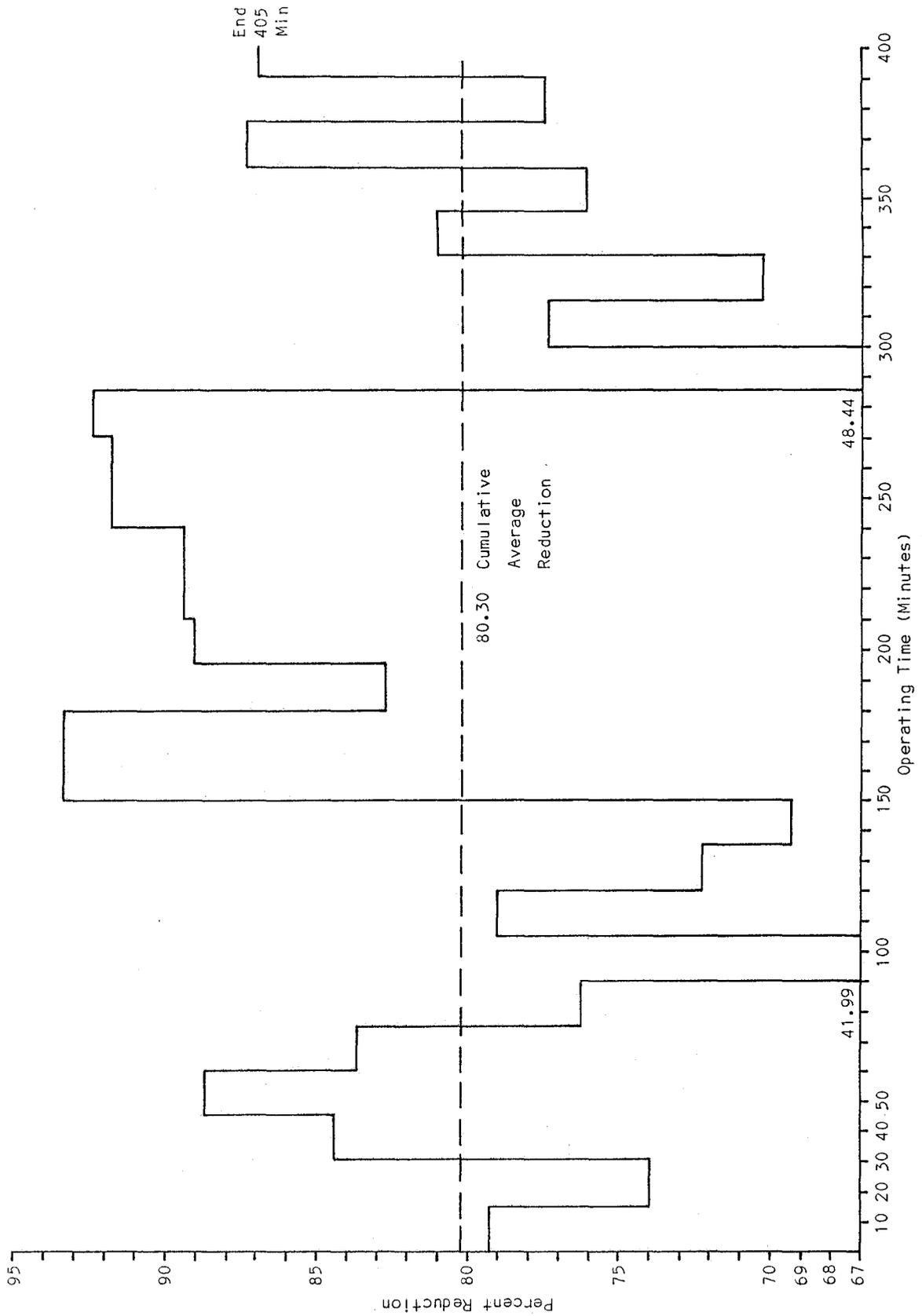


Figure 60. Bagging Operator's Reduction to Respirable Dust During O.A.S.I.S. Operation

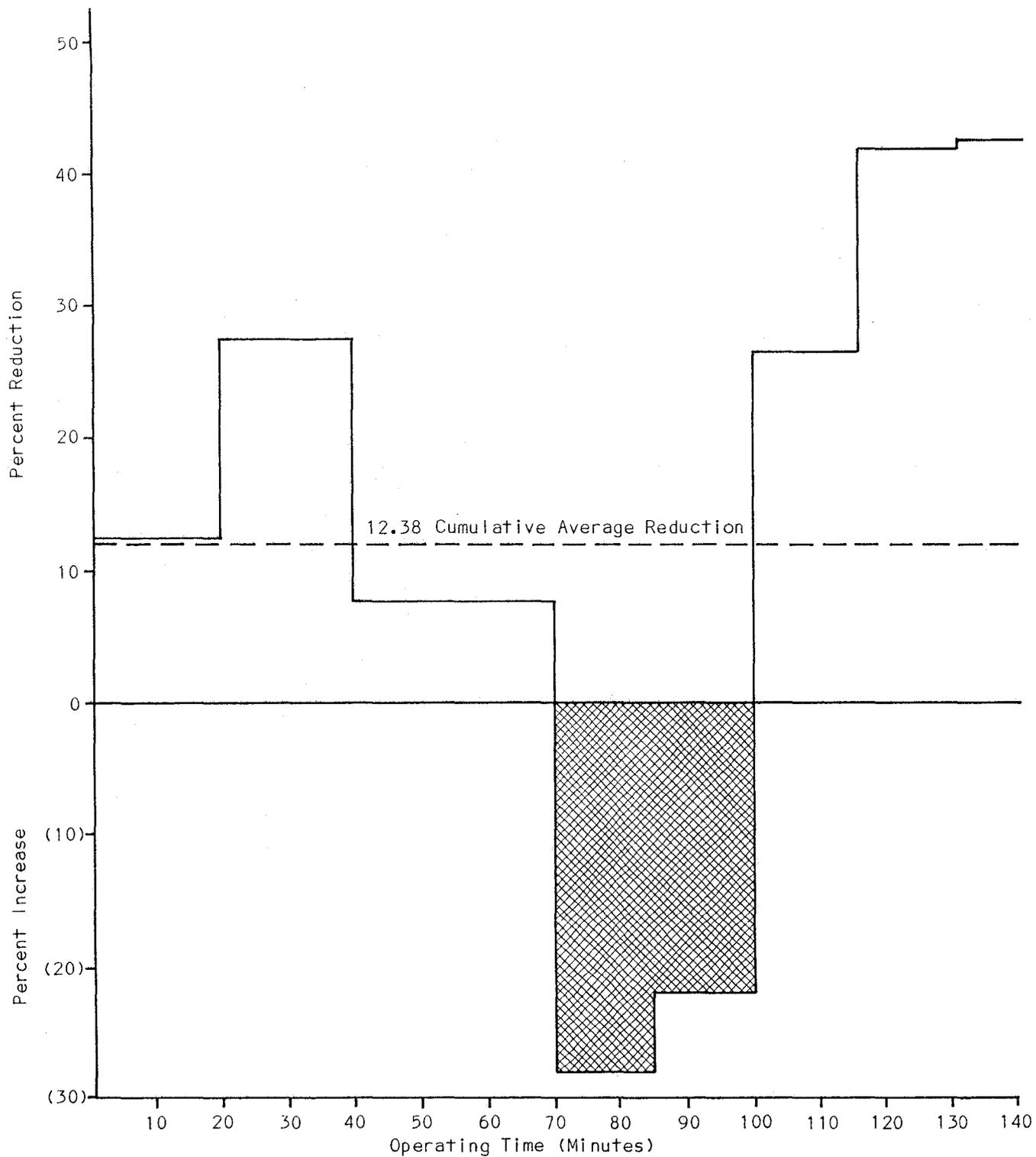


Figure 61. O.A.S.I.S. Operation and Its Effect on Respirable Dust Levels in the Plant

4.0 IMPROVED UNDERGROUND RETROFIT CANOPY AIR CURTAIN

4.1 STUDY OF CURRENT SYSTEMS

The study of Current Systems, was to evaluate currently operating canopy air curtain systems. Ten of these systems were selected for evaluation by an in-mine respirable dust sampling program. This data was not obtained because no canopy air curtains were operating. User feedback and records of Donaldson Company observations were the basis of the discussion of those areas needing improvement.

4.1.1 Canopy Air Curtain User Telephone Survey

A telephone survey was used to obtain information on the air curtain usefulness, shortcomings, operating conditions, and service. In addition, the potential to evaluate an operating canopy air curtain at each of the mine sites contacted was determined.

Donaldson Company maintained records of all the canopy air curtain assemblies built and shipped. Company personnel made phone contact with as many canopy air curtain buyers as possible. The result was a verbal review of operating hours, required maintenance, and problems defining areas for redesign. Table 7 shows telephone survey responses of the canopy air curtain system users. Because the canopy air curtain systems were installed 3 to 5 years prior to the survey much of the user feedback was incomplete. From this survey, Donaldson Company also determined that none of the canopy air curtain systems were currently in use. Table 8 summarizes the responses to this telephone survey.

TABLE 7. Response to Canopy Air Curtain User Telephone Survey.

User	CAC Machine Installation	Length Of Time In Use	Filter Life	System Maintenance	Noise Level Acceptable	Acceptable Temperature	Acceptable Size	Adequate Airflow
Eastern Assoc. Coal Wharton, WV	Joy 12 CM Continuous Miner	6 to 12 months	N/A*	N/A	Too loud	Too cold	N/A	N/A
Eastern Coal Company Stone, KY	---	Unit purchased, never installed	---	---	---	---	---	---
Cargill Salt**** Landsing, NY	Fletcher Face Drill	2 days	3 to 4 hours	N/A	N/A	Too hot because of mounting location	Should be larger	More airflow required
Amax Chem. NM	Aboveground Storage Warehouse	N/A	N/A	N/A	N/A	N/A	N/A	More airflow required
Freeman United Coal Waltonville, IL	Jeffrey 120H Continuous Miner	2 to 3 months	Changed often	Problems	N/A	Yes	Yes	Yes
Domtar Chem. New Iberia, LA	---	Never used, trouble with installation	---	---	---	---	---	---
Westmoreland Coal Panonia, CO	---	Unit purchased, never installed	---	---	---	---	---	---
Amherst Coal Company Amherstdale, WV	Joy 11 CM Continuous Miner	N/A	N/A	Hydraulic problems	N/A	N/A	N/A	N/A
Morton Salt Painsville, OH	Front End Loader (underground)	2 weeks	---	Hydraulic problems	N/A	Too warm (warm ambient air)	N/A	N/A
Keer-McGee Hobbs, NM	Front End Loader (aboveground)	1-1/2 years**	N/A	N/A	Yes	Yes	Yes	Yes
Florence Mining Seward, PA	---	Unit purchased, never installed	---	---	---	---	---	---
Duvall Carlsbad, NM	Cutter Machine	6 to 8 months	Needed excessive servicing	Motor burned out	Yes	Yes	Yes	More airflow required
International Salt Retsoff, NY	Loader	2 weeks	---	---	Yes	Yes	Should be larger	More airflow required
FMC Green River, WY	Jeffrey Continuous Miner	N/A**	N/A	Generally plugged	Yes	Too hot	Yes	More airflow required
Windsor Power House Coal Company Windsor Heights, WV	Continuous Miner	N/A	Acceptable	N/A	Too loud	Yes	Yes	N/A
Stauffer Chem. Green River, WY	Joy CD73 Face Drill	12 months	N/A	Once per week	Too loud	Too hot or cold (not sure which)	Should be larger	N/A

*N/A -- not available

**Original front-end loader replaced with a front-end loader equipped with enclosed cab

***N/A -- out of service for 2 years

****Bureau of Mines evaluation

Table 8. Canopy Air Curtain User Telephone Survey Summary

Average Length Of Time Unit Was In Use	6-1/2 Months
Filter Life	Required Excessive Change (2 users)
Maintenance	High (6 users) Hydraulic Problems (3 users)
Noise Level	Too High (3 users) Acceptable (4 users)
Temperature Under Unit	Too Cold (1 user) Too Hot (4 users) Acceptable (5 users)
Size Of Unit Generator	Should Be Larger (3 users) Acceptable (5 users)
Unit Airflow	More Airflow Required (5 users) Acceptable (2 users)

As shown in table 8, insufficient airflow was considered the most significant shortcoming of the canopy air curtains, followed by hydraulic problems, temperature of canopy air curtain airflow, excessive noise under generator, generator not large enough, and short filter element life. Other user comments included:

- The air curtain helped the operator but could not protect any individual outside of its' parameter
- MSHA would not approve of canopy air curtains because dust source was not "engineered out"
- Air curtains were removed due to maintenance problems even though some operators liked them

4.1.2 Evaluation of Canopy Air Curtains In Use

To enhance an understanding of the previous canopy air curtain systems, a Donaldson Company engineer visited FMC Corp. in Green River, Wyoming. This mine used the largest number of canopy air curtain systems. The objectives of this visit were to check if any portions of the canopy air curtain systems were still installed and to obtain additional user feedback. According to FMC, all the canopy air curtain systems were installed on Jeffrey continuous miners, which were being phased out of production. Although three Jeffrey miners were located, only one miner is currently in use. However, no remnants of canopy air curtain systems were located on the three Jeffrey miners. One canopy air curtain system was aboveground, still in the box, and two unused canopy air curtain generators were underground in a storage area. These generators were unused because of plugging problems with previous generators. Therefore, only the tubing from the blowers was used to provide clean air. The canopy air curtain system also experienced hydraulic motor seal failures, and the operators claimed that the airflow was too hot.

Due to a lack of a regular maintenance schedule, the air filters were not serviced properly. The maintenance foreman stated that the air filters would become so plugged that it was difficult to remove the filter element from the air cleaner body. Even with all these problems, the operators stated that the systems reduced dust levels when operated correctly.

4.1.3 Analysis of Canopy Air Curtain Data

Because no canopy air curtains were found to be operating, data analysis was restricted to the information obtained during the user telephone survey. The data in tables 7 and 8 was the basis for conclusions and recommendations.

4.1.4 Conclusions and Recommendations

Donaldson Company concludes that the objections and problems associated with the canopy air curtain, marketed to date, could be overcome with some engineering changes and a revised installation manual/procedure. Donaldson Company further recommends that the redesign effort be placed on developing one basic system design suitable for a wide range of underground equipment. Areas of additional interest recommended to be investigated include limiting noise, temperature control, improvement of filter life, maintenance indicator, size, mine worthiness, and cost.

4.2 Evaluation of Underground Machine Parameters

Design parameters considered for the CAC included the mine temperature, humidity, type of dust to be filtered, dust concentration, type of machine on which the CAC will be used, available area around the operator, and power available to operate the system.

Dust measurements taken in coal, metal, and nonmetal mines indicated a dust concentration range of 0.916 to 33.960 mg/m³ (respirable). Samples were taken around operator cabs of various equipment. Table 9 lists the data collected on the mine dust samples. This information was obtained from "Engineering Evaluation of Environmental Cabs for Control of Dust and Other Health and Safety Factors", (BOM contract J0308018).

Table 9. Dust Samples from Equipment in Various Underground Mines

Mine	Equipment	Particle Concentration (mg/m ³)		Mean Particle Size (microns)	
		Total (avg)	Respirable	Total (avg)	Respirable
Coal	Shuttle Car	16.753	4.973	8.4	2.75
	Face Drill	67.825	33.960	6.75	2.50
	Loader	34.228	2.051	10.25	2.90
	Shuttle Car*	19.279	2.893	7.00	3.50
	Continuous Miner	31.000	23.508	8.80	3.10
Metal/ Nonmetal	Jumbo Drill	21.834	2.069	3.20	3.20
	Load-Haul-Dump	6.539	0.984	3.15	6.00
	Cat Haul Truck	4.338	0.916	3.65	2.50

*Diesel Coal Mine

The CAC system can be powered electrically, hydraulically, or mechanically. Electric or hydraulic power drives the present system. The type of electric power varies from machine to machine; in general, the source is 3 phase, 440 or 550 volt. Because hydraulic components vary widely, hydraulic power availability depends on the type of equipment and the specific machine.

4.3 Improved Underground Retrofit CAC Designs

The present CAC design utilizes four main components:

- Fan - 8 inch diameter squirrel cage or paddle wheel type (figures 62 and 63)
- Motor - 1.5 hp hydraulic motor or 230/460 volt, 3 phase, 60 cycle 2 hp electric motor
- Air cleaner - Donaldson EGB09-0009 (figure 64)
- Air generator -Donaldson P12-8349 perforated screen (figure 65)

Field reports on this system indicated that the system was not acceptable to mine personnel because of insufficient airflow, hydraulic motor malfunctions, uncomfortable temperature under the air curtain, excessive noise under the air curtain, insufficient generator size, and short element filter life.

The improved CAC design offers these choices:

- Larger and/or higher speed fan
- Air cleaners ranging from a low cost disposable unit to a unit that incorporates an inertial separator for precleaning the incoming air
- Improved air generator design which provides a larger field of coverage at a lower restriction
- Fan drive that can be either electric, hydraulic, or mechanical
- Maintenance indicator

A detailed description of each component follows.

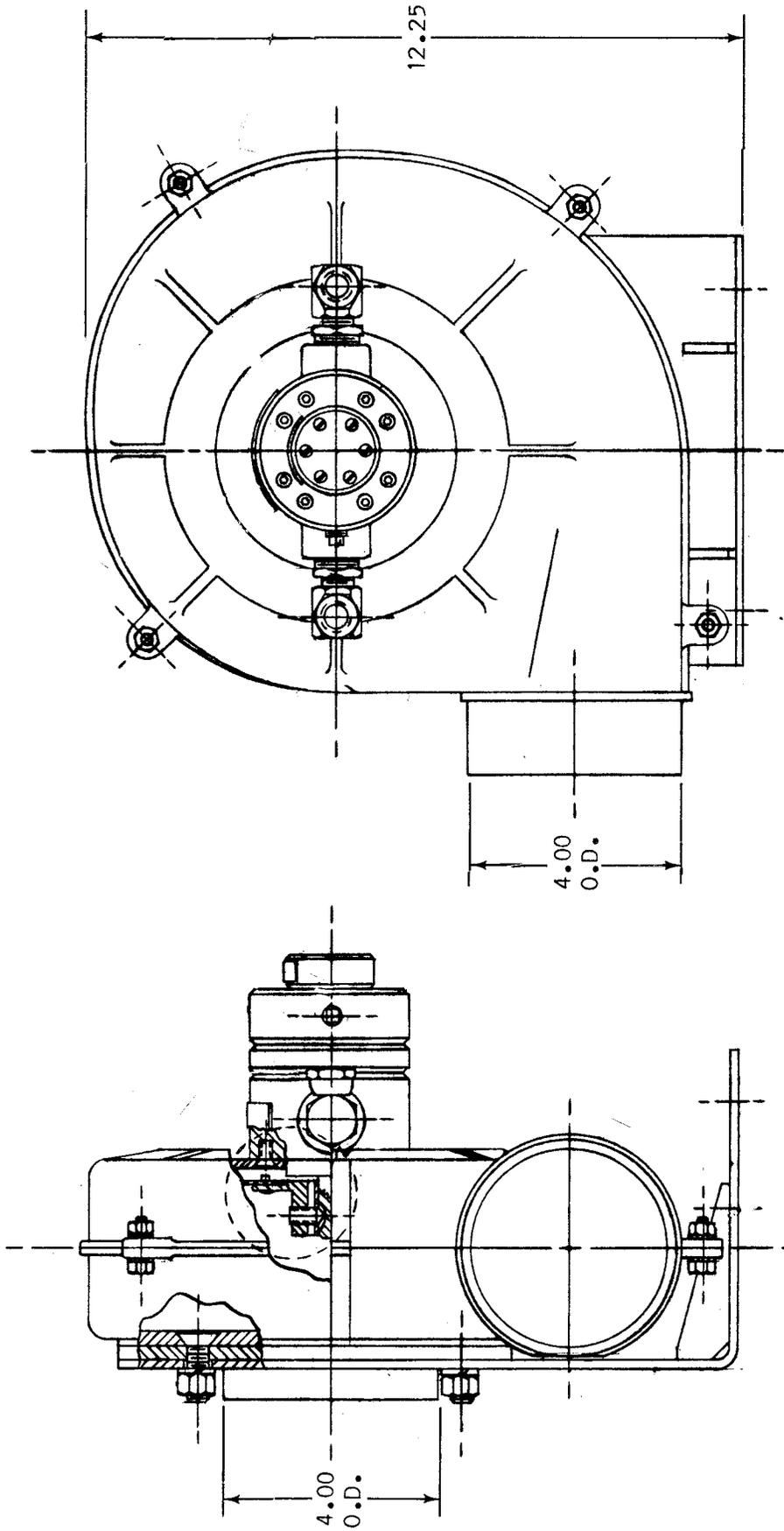


Figure 62. 8-Inch Squirrel Cage Fan with Hydraulic Motor

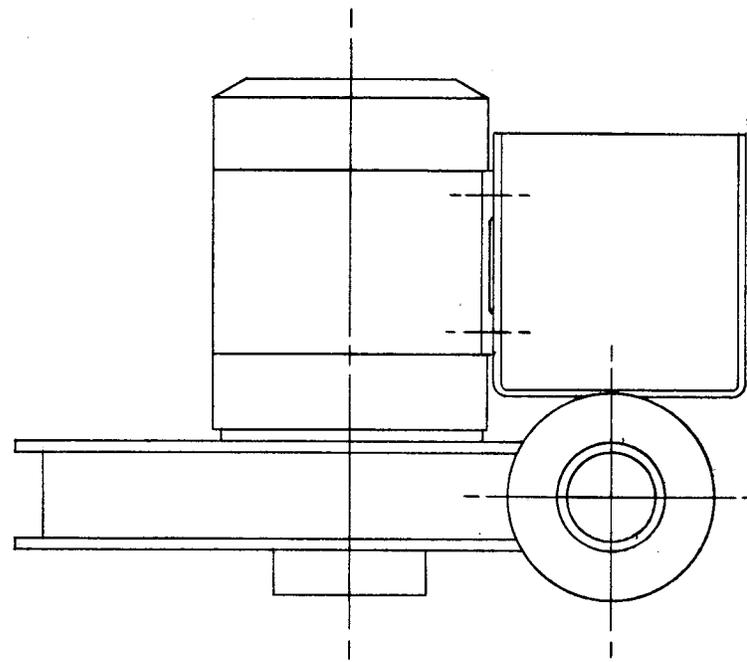
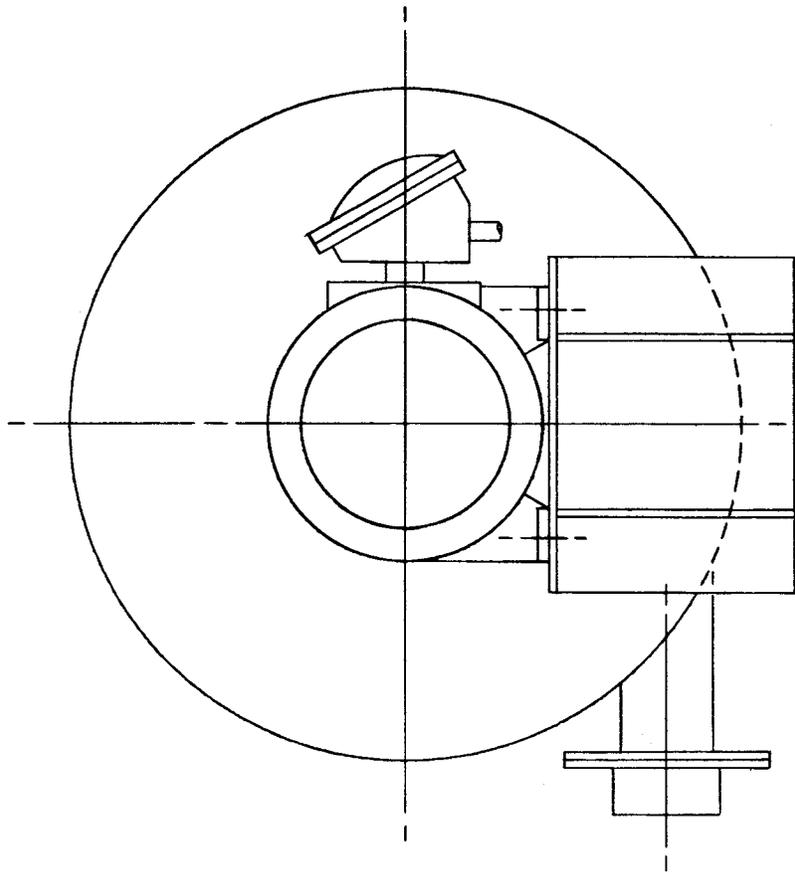


Figure 63. Paddle Wheel Fan with Electric Motor.

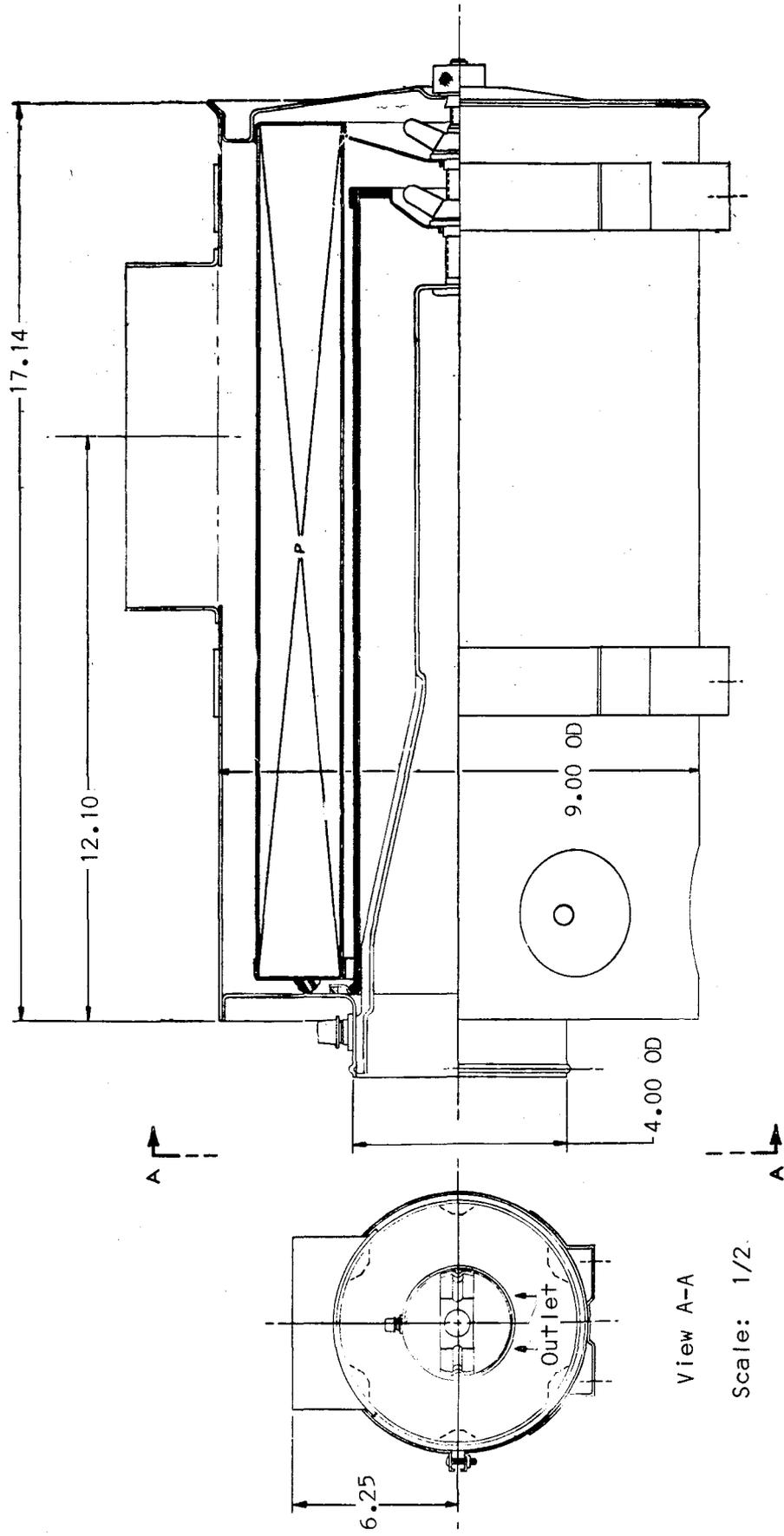


Figure 64. Air Cleaner on Present Underground Canopy Air Curtain.

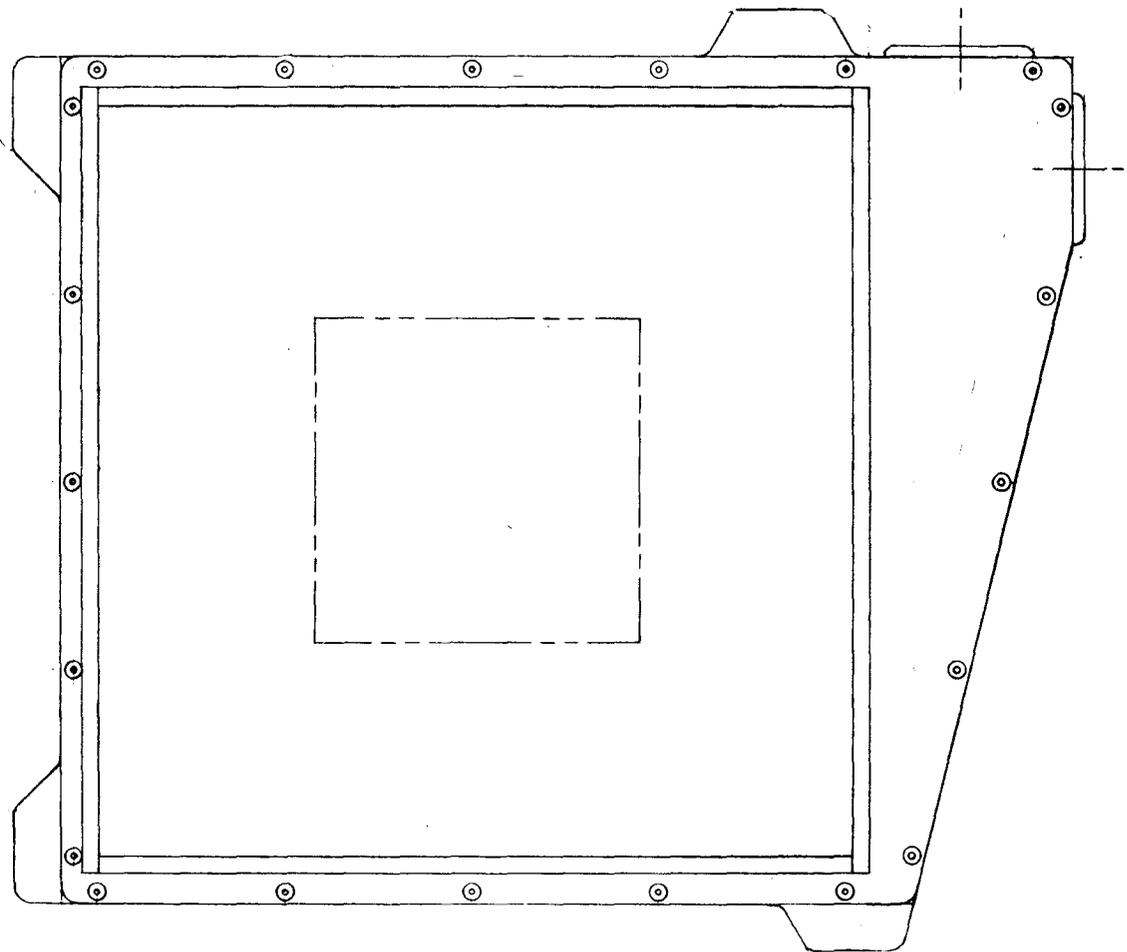
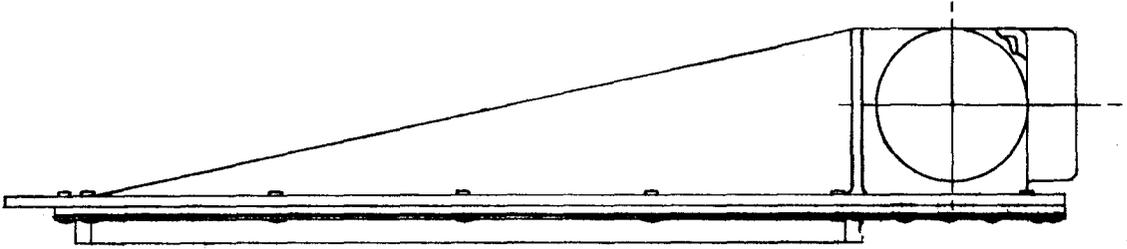


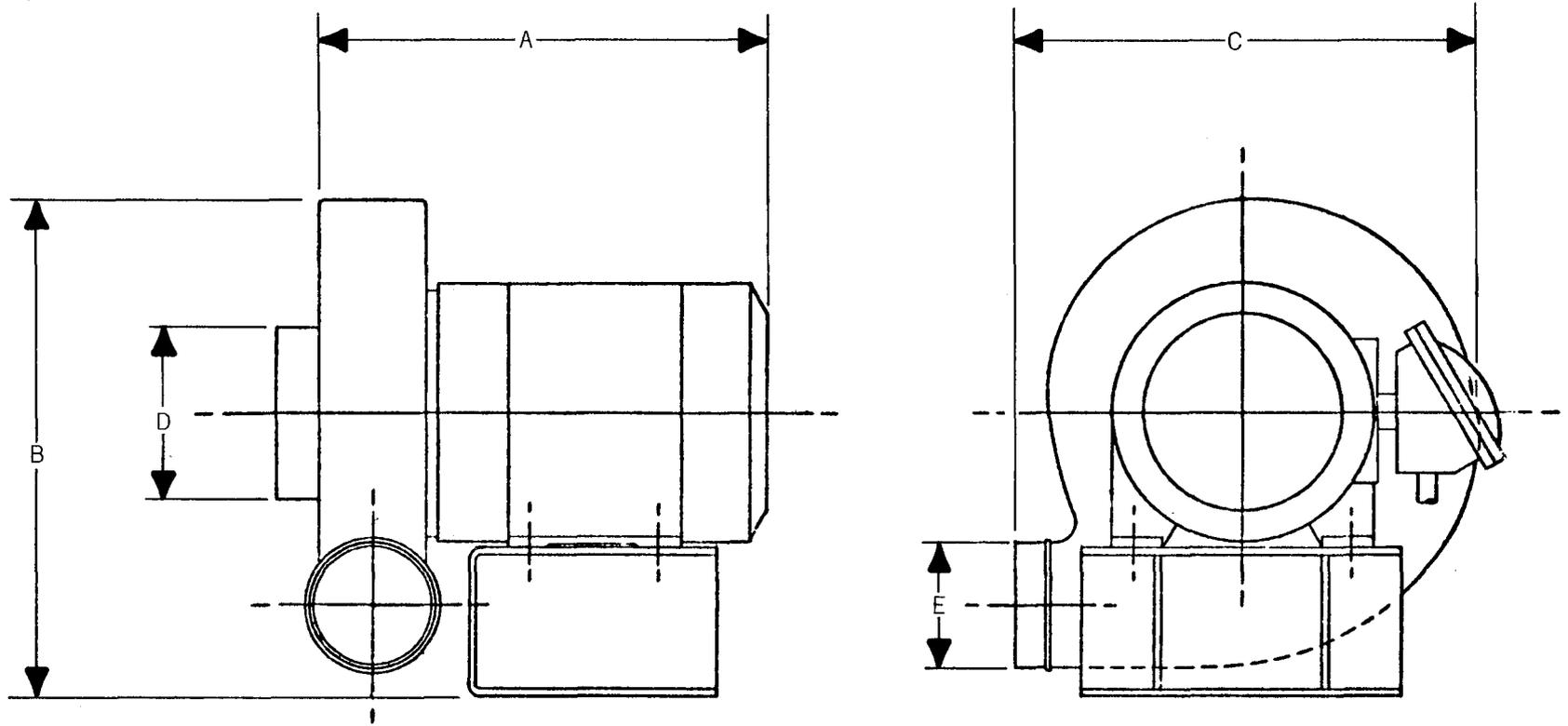
Figure 65. P12-8349 Air Generator

4.3.1 Fan

Two basic types of fans were under consideration. Both fans use centrifugal impellers but with different geometries and speeds. The low speed 12 inch fan (figure 66) operates at approximately 3,450 rpm and delivers a range of airflows from 300 to 600 cfm against a static head of 12.5 to 10.9 in. wg (figure 67). The power requirement for this fan is 1.5 to 2 hp. The benefits are lower power requirements, lower speed, and lower cost. The disadvantages are size and rapid loss of airflow as system restriction increases. As the filter accumulates dust, the airflow protecting the operator drops off rapidly. The high speed fan (figure 68) operates at approximately 13,000 rpm. Depending on size, it delivers a range of airflows from 200 to 500 cfm against a static head of 30 to 14 in. wg (figure 69). This fan requires approximately 5 hp. The advantages of this fan are its ability to pull adequate airflow against a large static pressure and smaller size. The disadvantages are higher speed, possible noise problem, and higher cost. Table 10 outlines a comparison between these units.

Table 10. Fan Comparison

Fan Type	Speed (rpm)	Airflow (cfm)	Static Pressure (in. wg)	Power (hp)	Cost (dollars)
Low Speed (12 inch)	3,450	300	12.5	.9	350
		600	10.9	1.4	
High Speed (10 inch)	13,000	200	30	5	2,200
		500	14	--	



Model No.	A	B	C	D	E
9"	14.57	15.25	13.25	5.00	4.00
10"	14.57	17.50	15.00	6.00	4.38
12"	16.07	20.00	17.25	7.00	5.25

Figure 66. Low Speed Centrifugal Fans

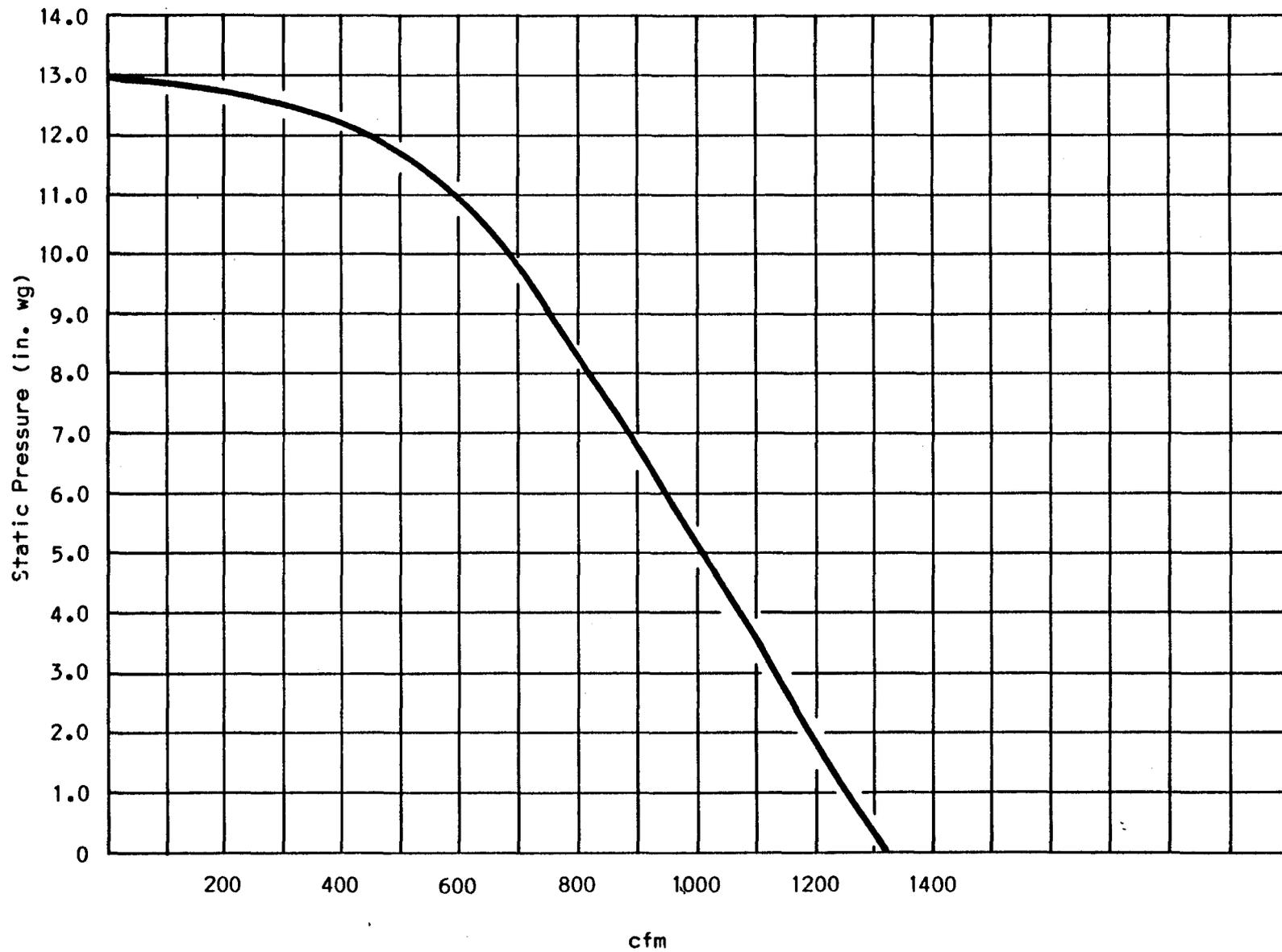


Figure 67. Typical Performance Curve of 12-Inch Low Speed Fan

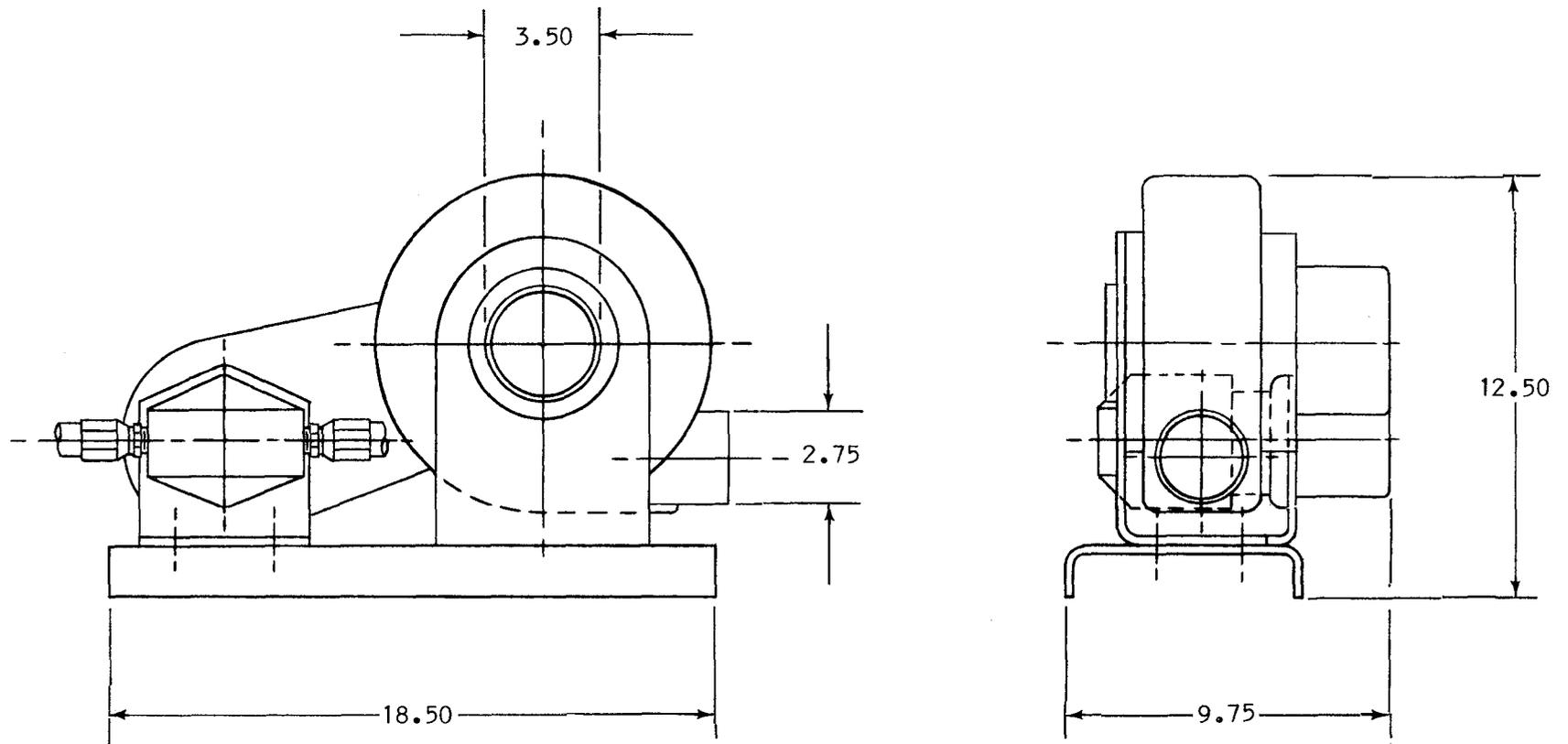


Figure 68. High Speed Centrifugal Blower, Hydraulically Powered

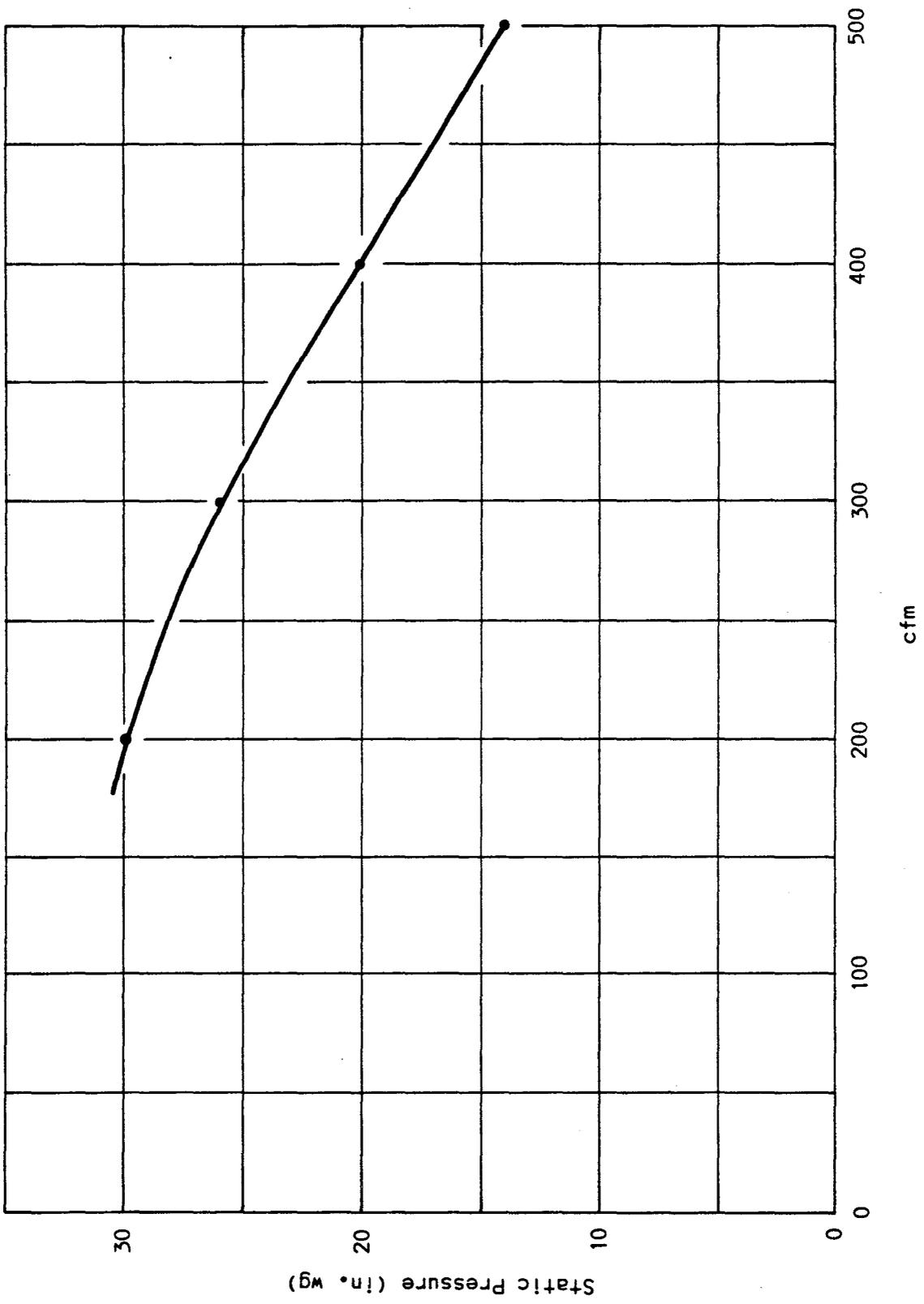


Figure 69. Performance Curve of 12-Inch High Speed Fan

4.3.2 Drive Unit

The specific application will determine the fan drive unit. A continuous miner, face drill, shuttle car, longwall shearer, and cutter were selected for this application. Most machines have electric and/or hydraulic power available. The most common electric power is 3 phase, 440 or 550 volt. Should the machine be in a coal mine, the electric motor must be explosion proof. Hydraulic power should be available from a variety of circuits. Hydraulic flows vary from a few gallons per minute (gpm) to greater than 50 gpm. Circuit pressures vary from less than 1,500 to greater than 2,500 psi. Matching the most appropriate motor to the machine requires a clear understanding of that machine's hydraulic system. A third option is mechanically driving the fan from an available sheave.

The advantages of an electric drive unit are ease of installation, noninterference with other systems on the machine, and flexibility in fan location. The disadvantages of an electric drive unit are package size (especially where explosion proof motors are required) and lack of motor speed control.

The advantages of a hydraulic drive unit are small package, motor speed control, and flexibility in fan location. Installation is a problem and would require assembly of some hoses and fittings, devising a method to tap the existing hydraulic circuit, and devising a way to protect the hydraulic system should our system malfunction. A hydraulic drive unit could have negative effects on the rest of the hydraulic circuit by diverting a portion of the hydraulic fluid flow from an operating system and by adding heat to a hydraulic system that is marginally equipped to deal with heat related problems. The hydraulic circuit that would operate the CAC system would require a flow control to prevent overspeeding and a pressure relief valve to protect the machine circuits from damaging pressures should our system malfunction. Figure 70 shows a control package that contains the flow control and the pressure relief valve; the single housing eases installation. A one-way check valve in the housing prevents reverse flow caused by improper installation.

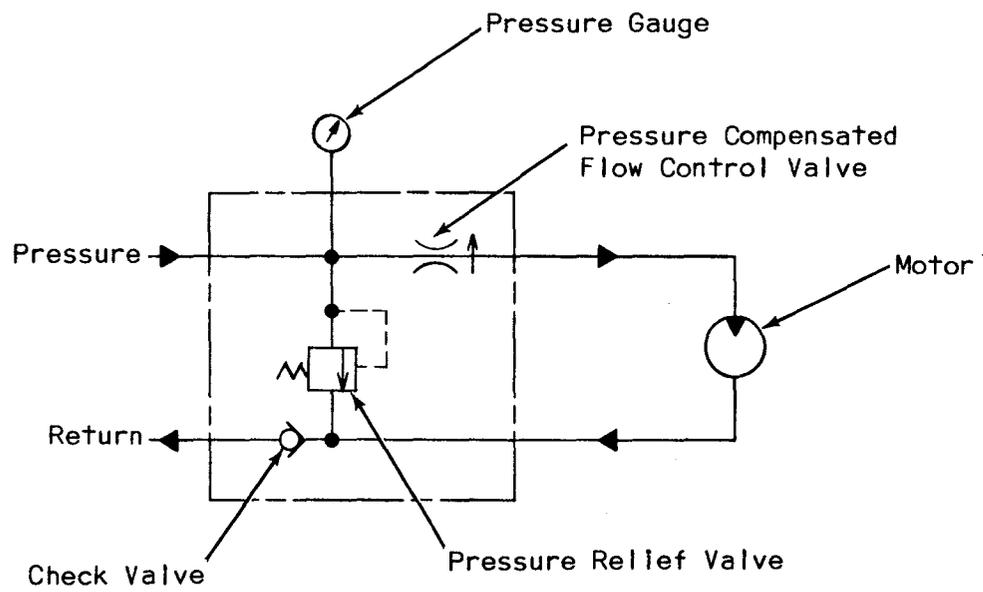
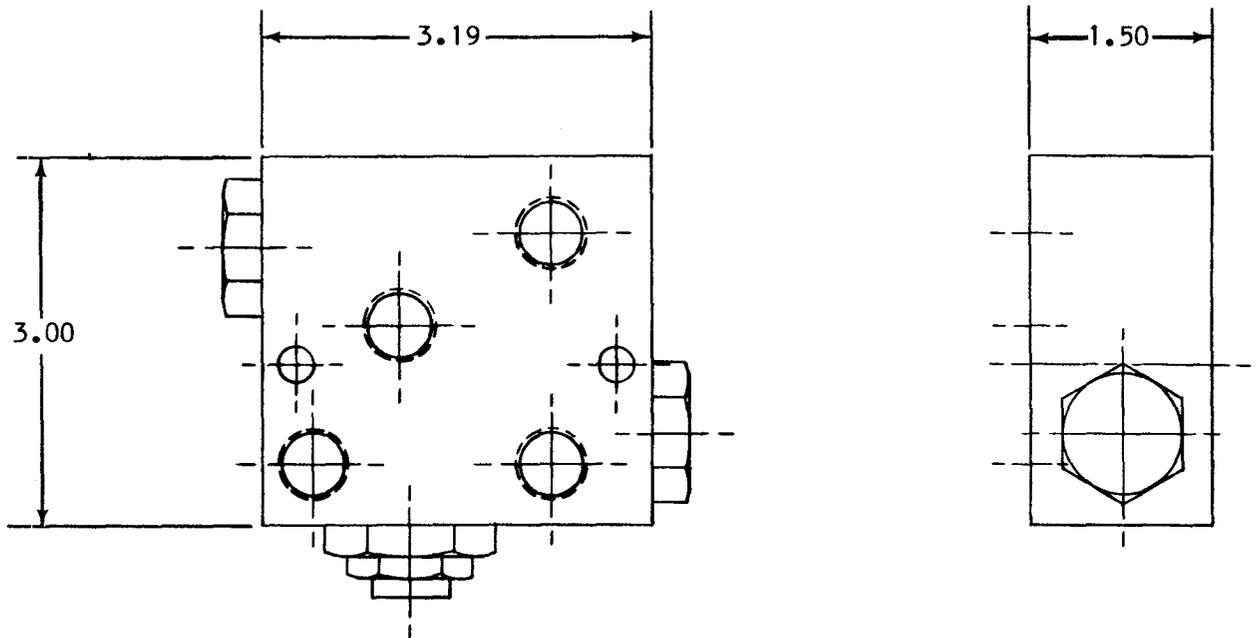


Figure 70. Hydraulic Control Package

The advantage of a mechanical drive unit is cost. The disadvantages are inflexibility in fan location and practical mounting of unit on the machine.

All three of the units could possibly operate as a function of machine cycle based on engine or generator speed.

4.3.3 Air Cleaner

The type of air cleaner would depend on the type of machine used, the environment (dust level, diesel particulate), available space, and capability of the fan.

The most basic air cleaner is a disposable type called the DURALITE™ manufactured by Donaldson Company. This air cleaner is a round pleated paper filter, housed in a plastic and urethane package (figure 71). The entire package is thrown away when service life is reached. This air cleaner is initially inexpensive and has low initial restriction; however, it may not be mine worthy, and its replacement cost over the life of the CAC may be too high.

An option to the DURALITE™ is an air cleaner that also uses a round pleated paper filter but houses the filter in a heavy gage steel can (figure 72). Only the filter is discarded when service life is reached. This air cleaner is mine worthy, moderate in cost, and has low initial restriction.

The third air cleaner design differs from the second design in that it has a rectangular shape (figure 73). The filter is made up of two pleated paper panel filters arranged in a "V" shape. The cost is higher, but the amount of paper in the filter is greater than the other two.

A fourth air cleaner is similar to the second design but utilizes an inertial separator (figure 74). The separator removes 80 to 90 percent of the dust before the airflow reaches the filter. This dramatically reduces the dust loading on the filter and extends filter life. The separator also adds a significant amount of restriction to the air cleaner.

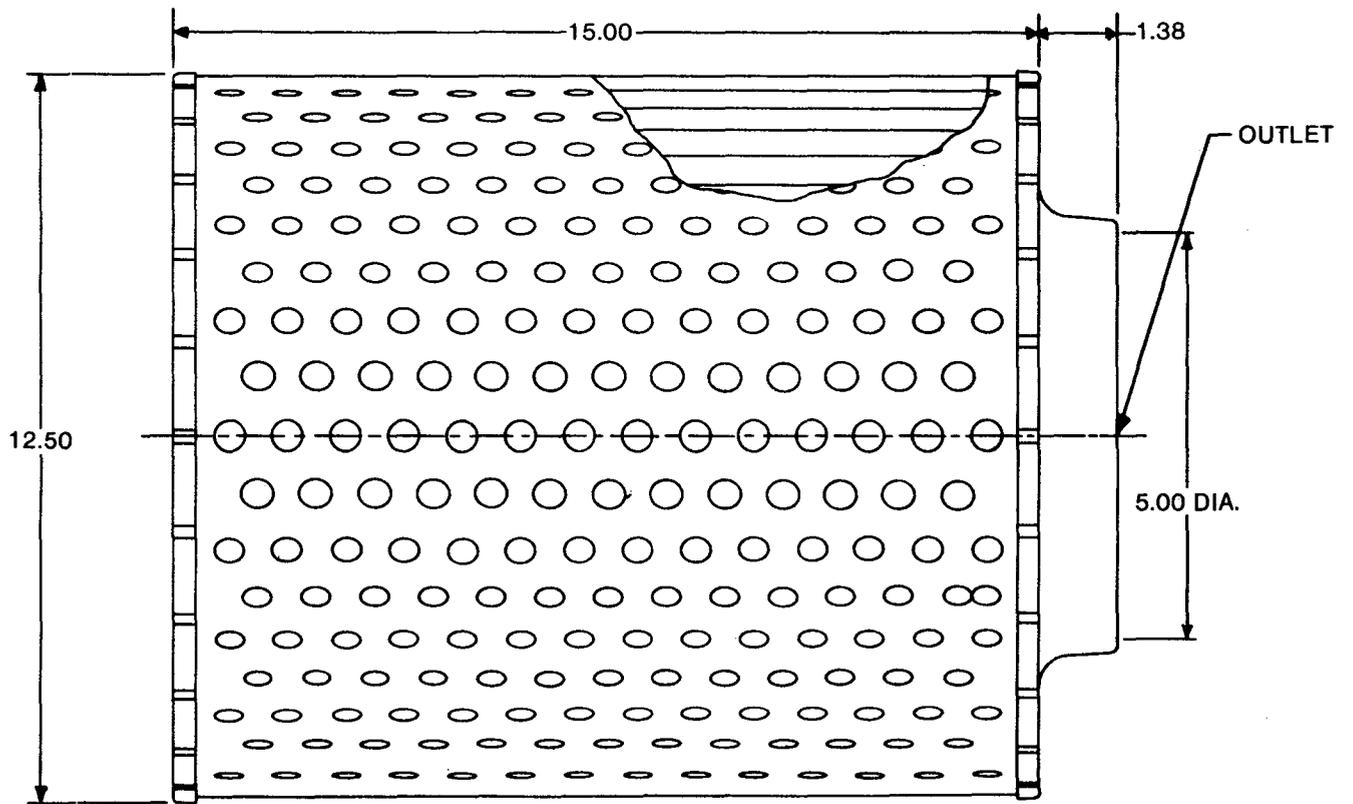
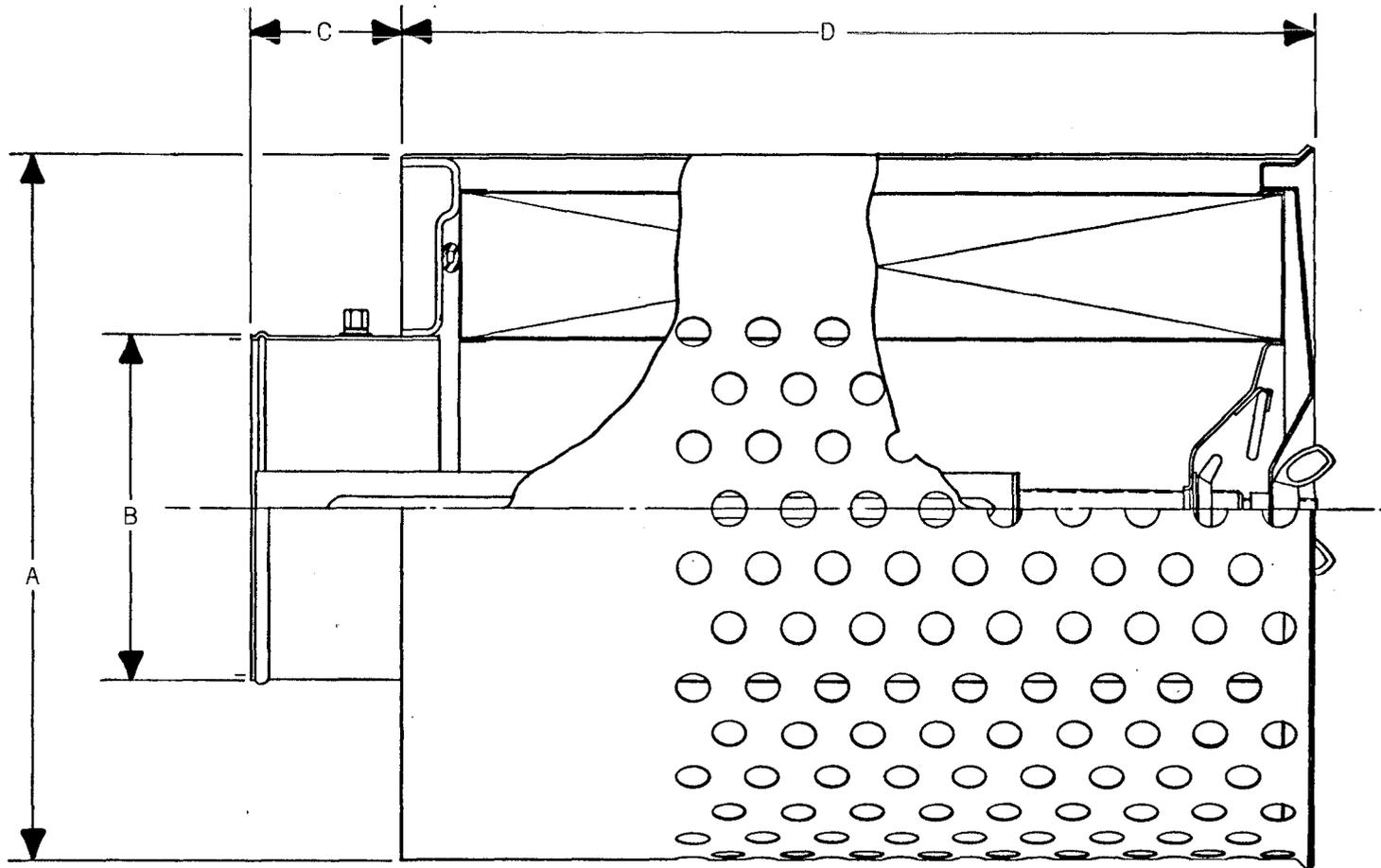


Figure 71. 12-Inch Duralite™ Air Cleaner



SIZE	A	B	C	D
10"	10.25	5.00	2.20	13.25
12"	11.84	6.00	3.00	19.06

Figure 72. Round Steel Air Cleaner with Replaceable Filter

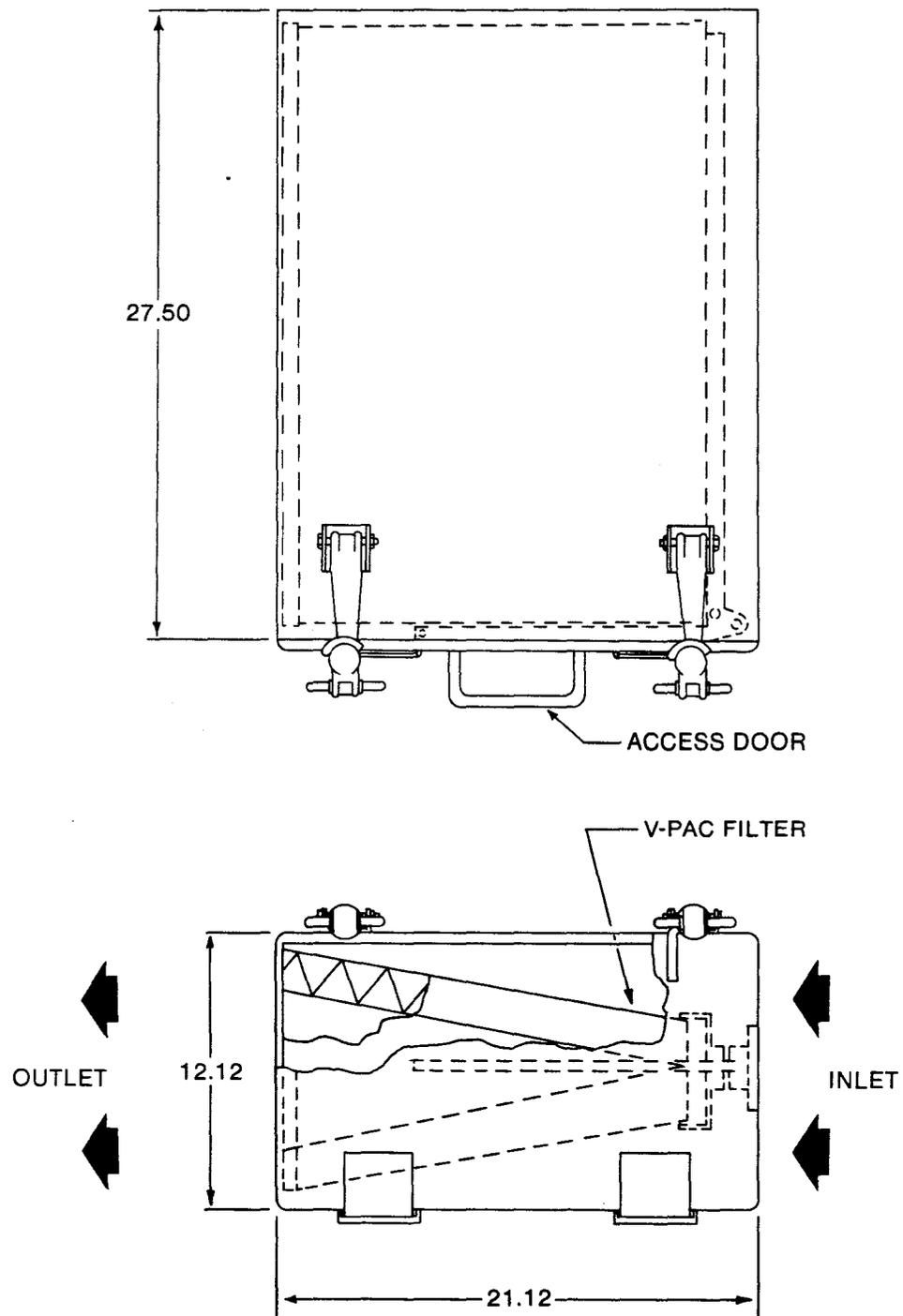


Figure 73. Rectangular Air Filter

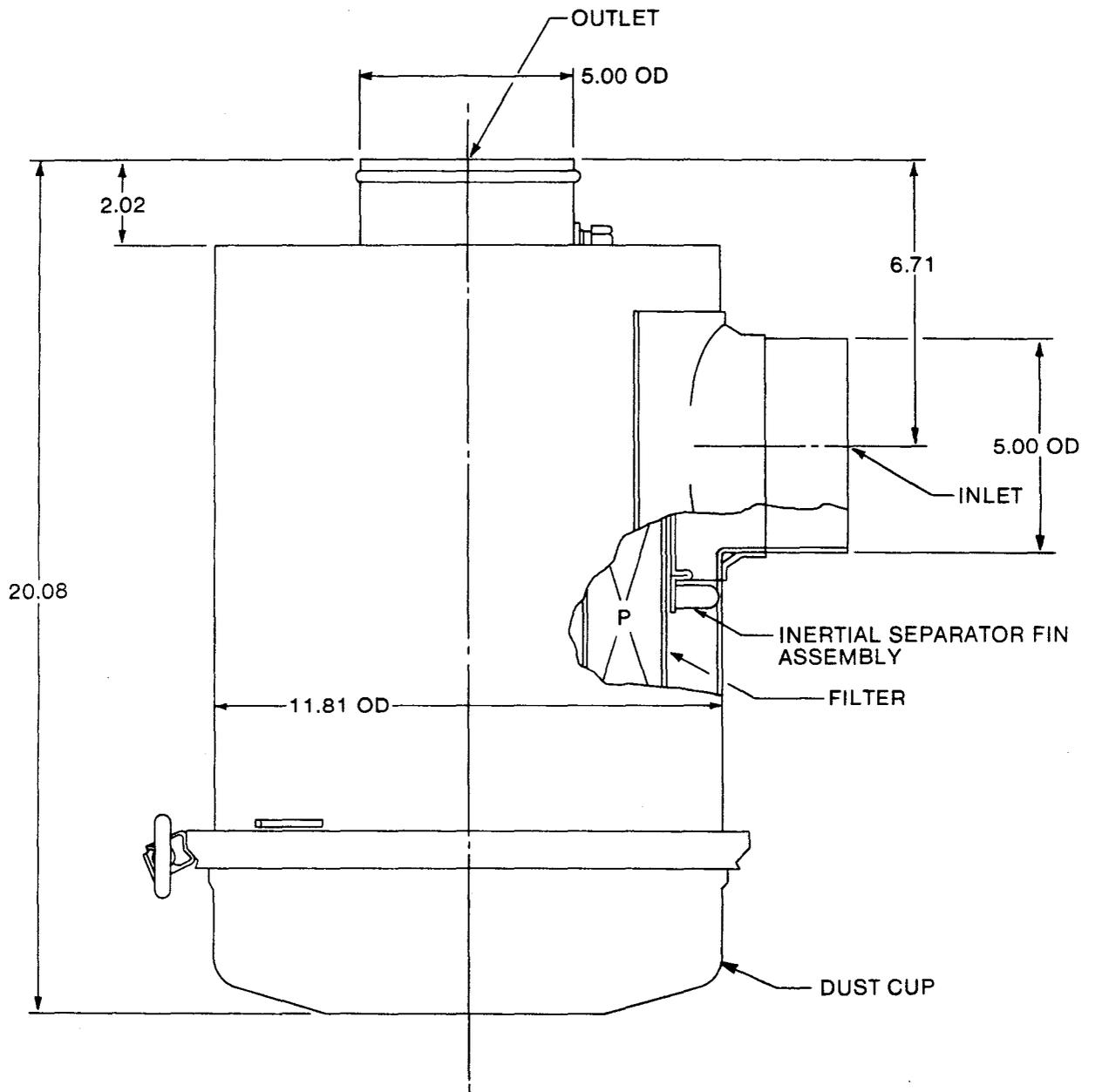


Figure 74. Air Cleaner with Inertial Separator

Estimated initial restriction curves of the above mentioned air cleaner designs are shown in figure 75.

4.3.4 Air Generator

The new air generator design should provide an evenly distributed airflow at a lower restriction than the present model. This design allows the operator to have some control over the direction and amount of air coming from the generator. As seen in figure 76, there is a small air vent (similar to those found in commercial aircraft) that controls and directs a high speed stream of air. The air generator is shaped so that a portion of the clean air is directed to the outside of the operator's compartment. This will provide the operator with clean air protection should he lean outside of the compartment area.

4.3.5 Air Conditioners/Heaters

Including air conditioning as a feature of the canopy air curtain system is not workable for underground mine applications. The two main reasons are finding an acceptable location on the machine and locating an acceptable power source for the compressor. On surface mine equipment, the air conditioner has a poor maintenance record. There is no reason to believe this condition would be any different in an underground mine. In addition, the need for air conditioning in most underground mines may not be necessary.

According to the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) comfort chart, the optimum effective temperature in winter for normally clothed people is 67 to 68°F. The optimum effective temperature in summer for normally clothed people is about 71°F. The effective temperature is an empirical index which correlates the combined effects of air temperature, air humidity, and air movement upon human

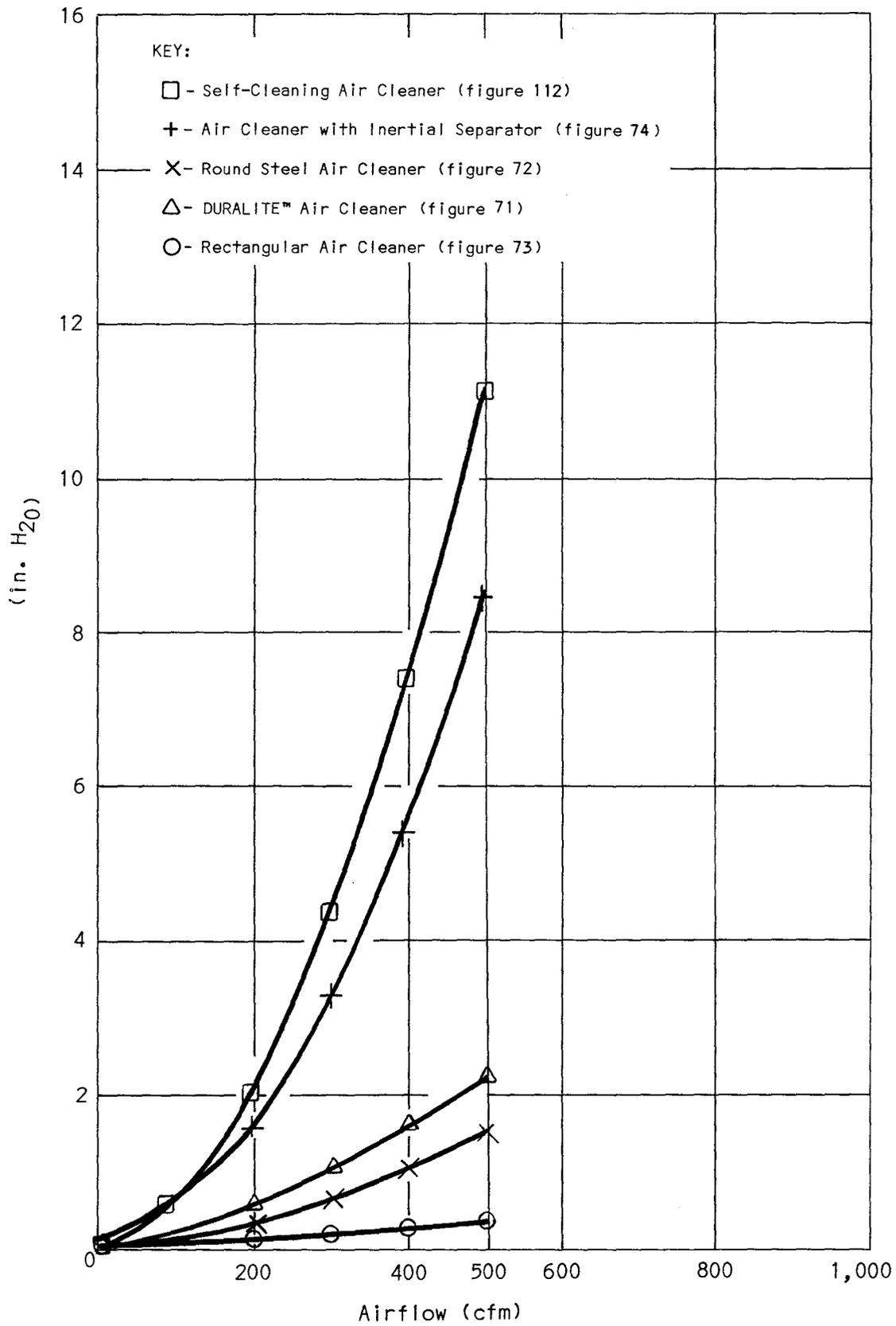


Figure 75. Air Cleaner Initial Restriction

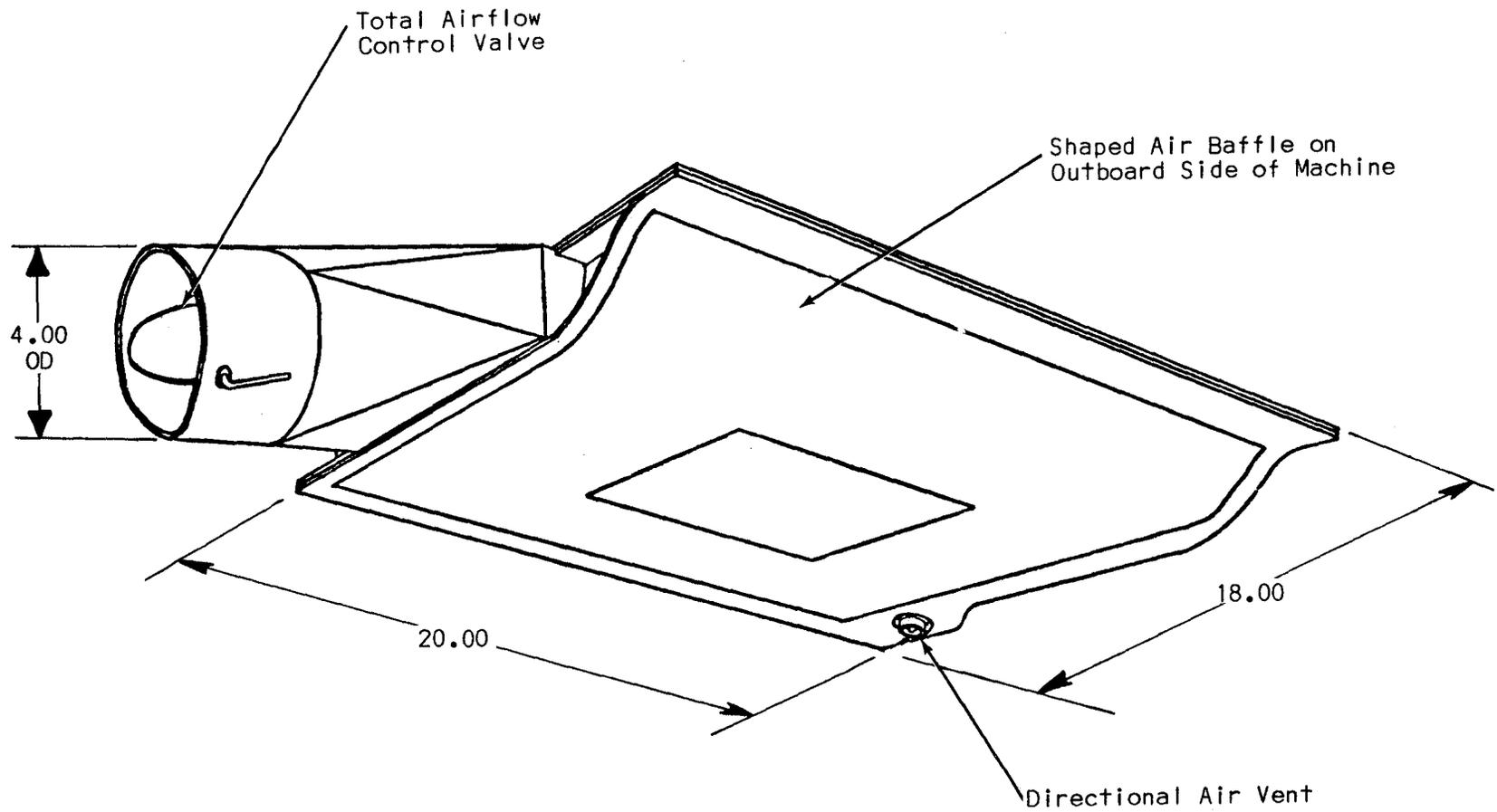


Figure 76. Air Generator for Underground Application

comfort.* For a dry bulb temperature of 75°F, a relative humidity of 70 percent, and an airflow of 15 to 25 feet per minute (near still air), the effective temperature is 72. If the airflow increased to 200 feet per minute the effective temperature would be 69. With the exception of some salt, trona, and potash mines, most underground mines maintain dry bulb temperatures lower than 75°F and humidity greater than 70 percent. This means that in most mines a normally clothed operator, protected by an airflow of 200 feet per minute or greater, will most probably require the ambient air to be heated rather than cooled to achieve the most optimum effective temperature.

Based on the above, it was recommended that only heating be considered for underground mine machine application.

Depending upon the particular machine, the air can be heated by either electric resistance or engine/drive motor coolant. Operator control of the heater is essential. Figure 77 illustrates a typical finned heater for use in the CAC.

4.3.6 Filter Service Indicator

A maintenance indicator informs the operator when the filter needs to be replaced. Replacement of the filter based on air cleaner restriction will prevent the CAC airflow past the operator from dropping below the minimum to provide adequate dust protection. A typical indicator is illustrated in figure 78.

*Thermal Environmental Engineering, by James L. Threlkeld, 1970.

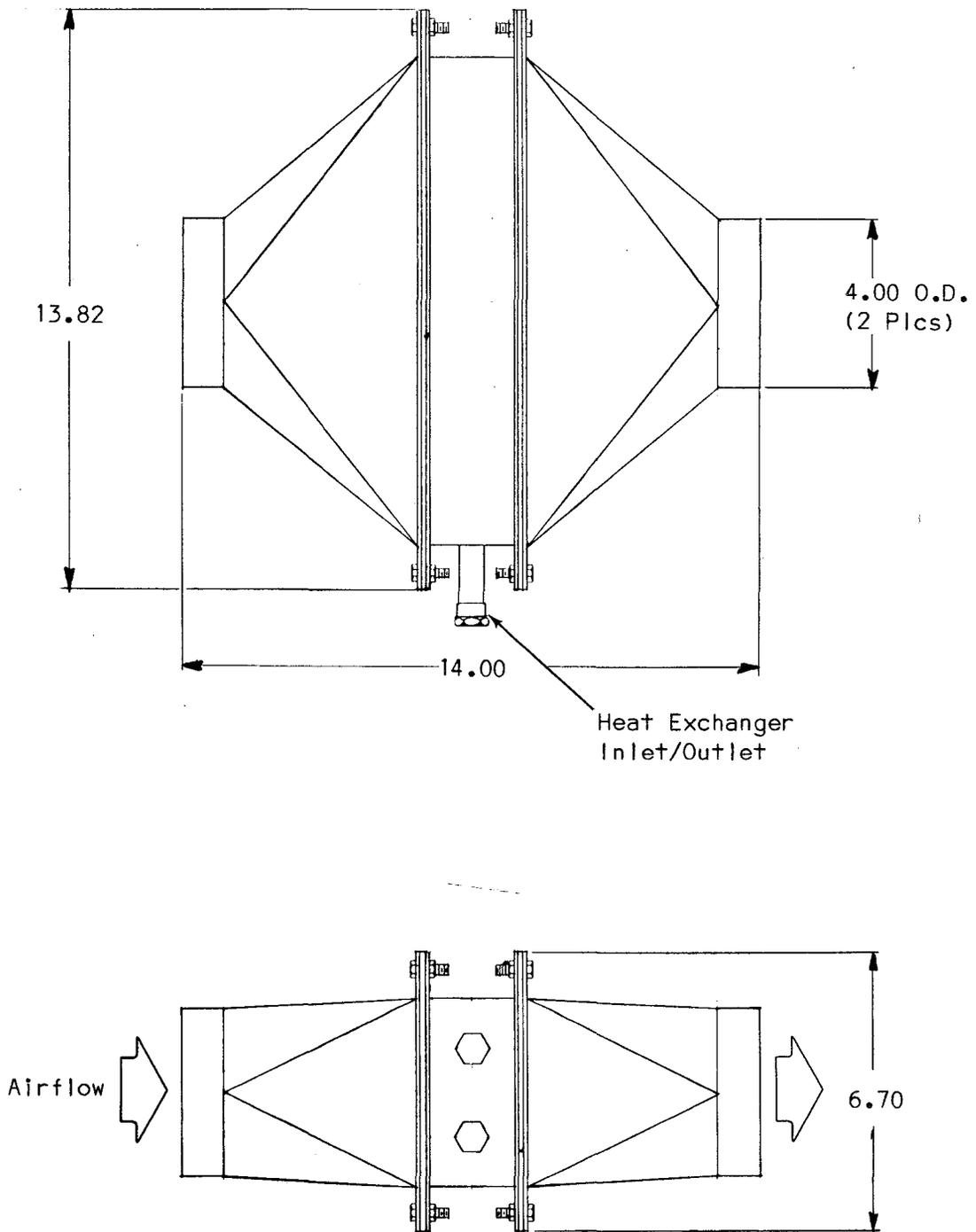


Figure 77. Finned Heat Exchanger for use in Retrofit CAC

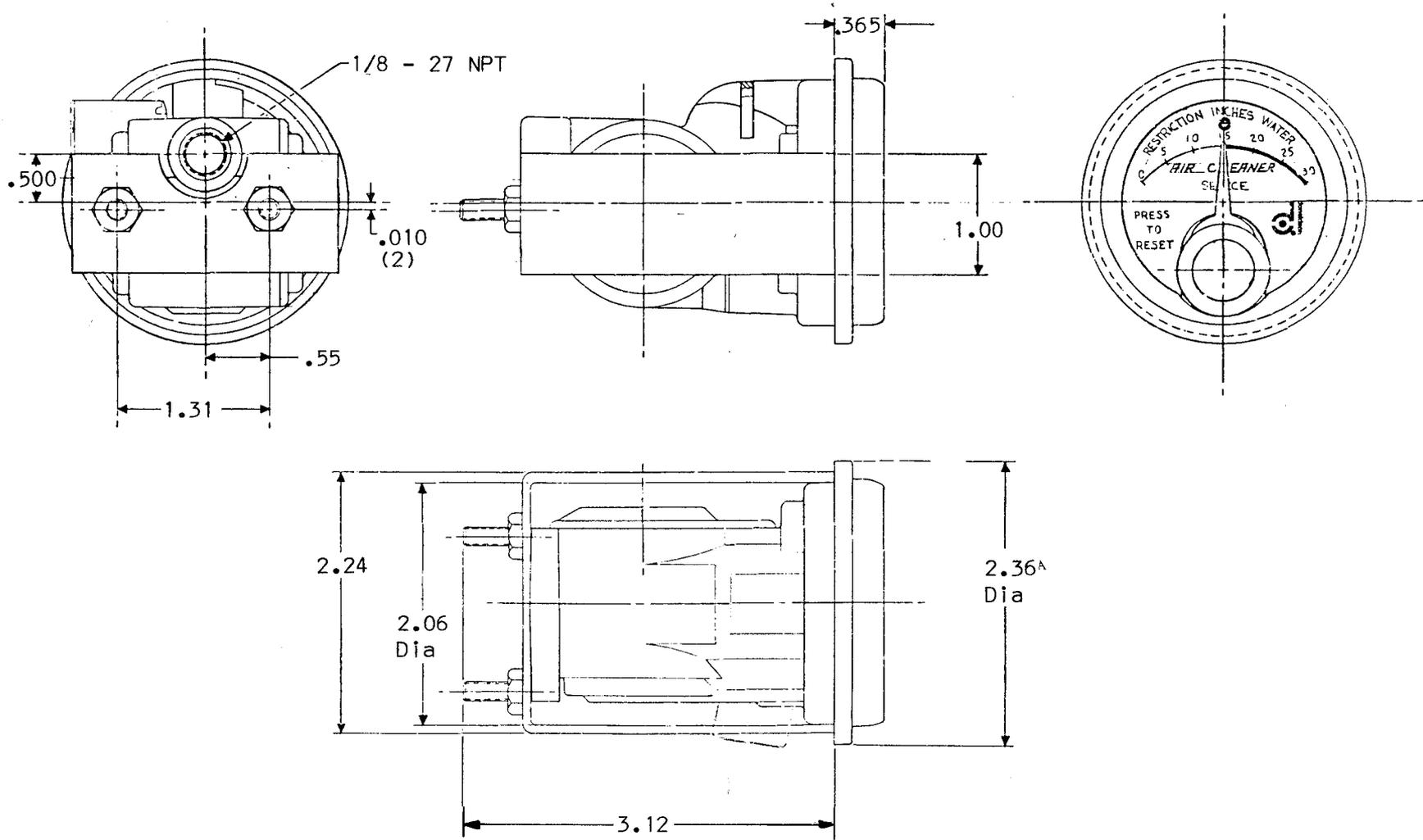


Figure 78. Filter Service Indicator

4.3.7 Conclusions and Recommendations

4.3.7.1 Conclusions

- Respirable dust concentrations in underground mine environments range from .916 to 33.960 mg/m³ (table 9)
- Total dust concentrations in underground mine environments range from 4.338 to 67.825 mg/m³ (table 9)
- An improved CAC system that will meet the broad needs of the various underground mine machines requires the proper selection and matching of all the CAC components to the particular machine, mine environment, and available power
- No single motor/fan/air cleaner combination will meet all the needs of the various underground machines in this contract
- Air conditioning is not required for use in the CAC in most underground mine applications
- Heating is required for use in the CAC in most underground mine applications

4.3.7.2 Recommendations

- Build/purchase and laboratory test the air cleaners and fans described in sections 4.3.1 and 4.3.3 for pressure drop/airflow/dust loading and power requirements
- Build and laboratory test the new air generator described in section 4.3.4 for pressure drop/airflow and air distribution
- Based on the power requirements of the components tested, choose the type of hydraulic and electric motor for the drive unit

4.4 UNDERGROUND RETROFIT CAC BENCH TESTING AND EVALUATION

4.4.1 Air Generator Performance Test Stand and Equipment

A test stand was built to evaluate air generator performance. The test stand, shown in figure 79, was fabricated with 2 inch by 4 inch studs supporting the air generator, test grid pattern, and velometer. The grid pattern was used as test points to measure airflow velocity and airflow distribution patterns of the air generators. The grid pattern was extended 10 inches past the normal area of coverage to test the concepts for providing extended coverage outside the cab area. An Alnor model number 6006AP velometer was used to measure airflow velocity. Test grid dimensions are shown in section 4.4.3.

4.4.2 Airflow Nozzle

To improve operator comfort, an adjustable airflow nozzle was incorporated into the air generator design. Catalog literature showing velocity with respect to distance, cfm, and duct pressure and the nozzle is shown in figure 80. Pressure drop versus flow tests of the nozzle in the full open, 3/4 open and 1/2 open positions were conducted and are shown in figures 81 and 82.

4.4.3 Air Generator Performance Testing

Air generator performance evaluation was based on the following criteria:

- Uniformity of airflow discharged from the air generator, measured at the operator's breathing zone 11 inches to 12 inches below the outlet baffle
- Perpendicularity of discharge airflow to the outlet baffle
- Increase of air generator maximum airflow from the present system airflow of 250 cfm to approximately 400 cfm

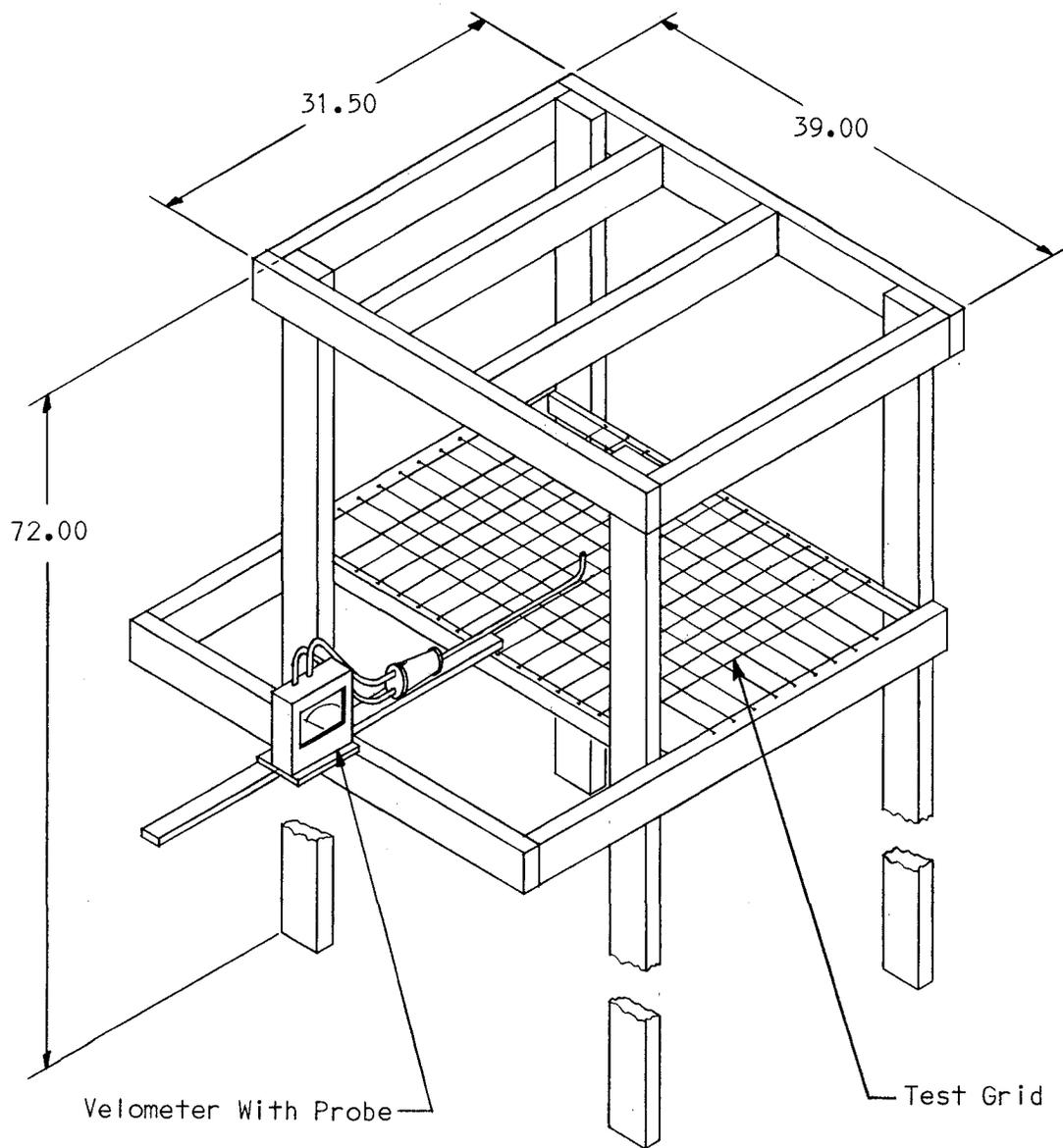


Figure 79. Air Generator Performance Test Stand

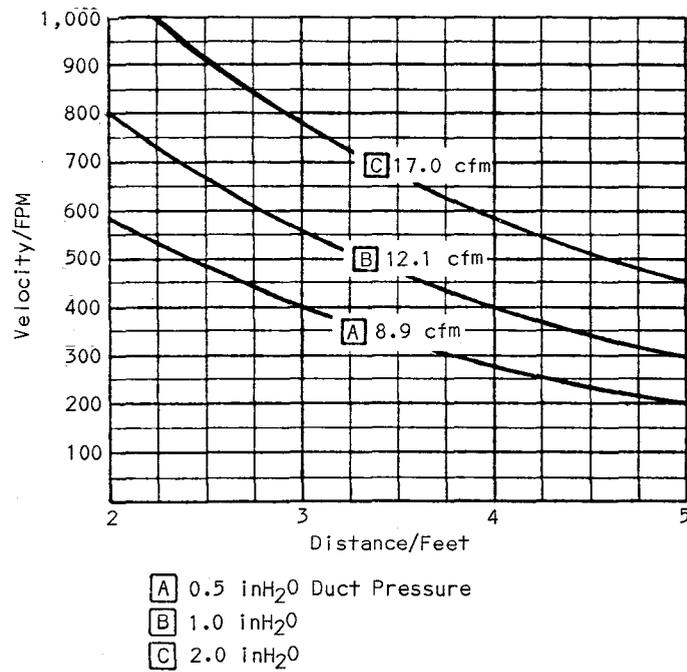
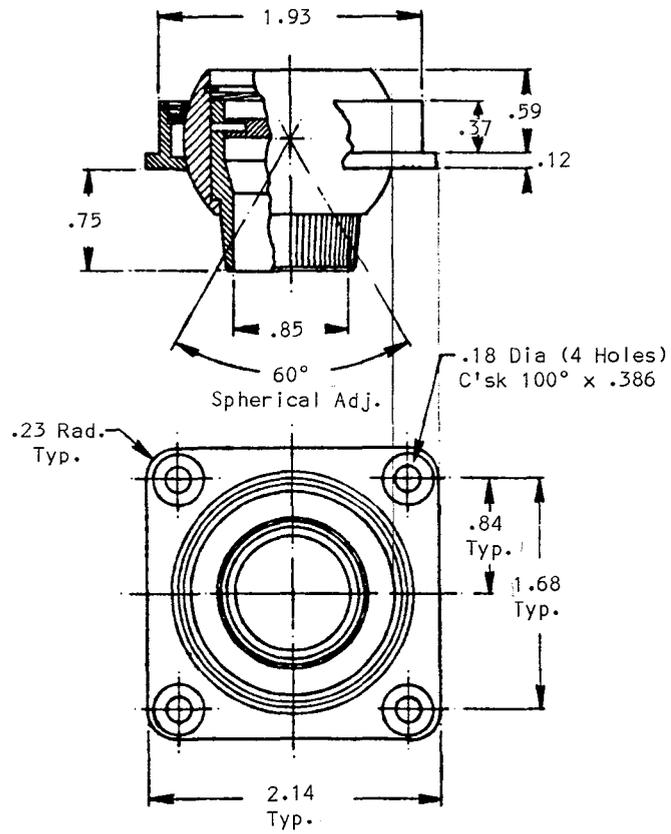


Figure 80. Air Flow Nozzle

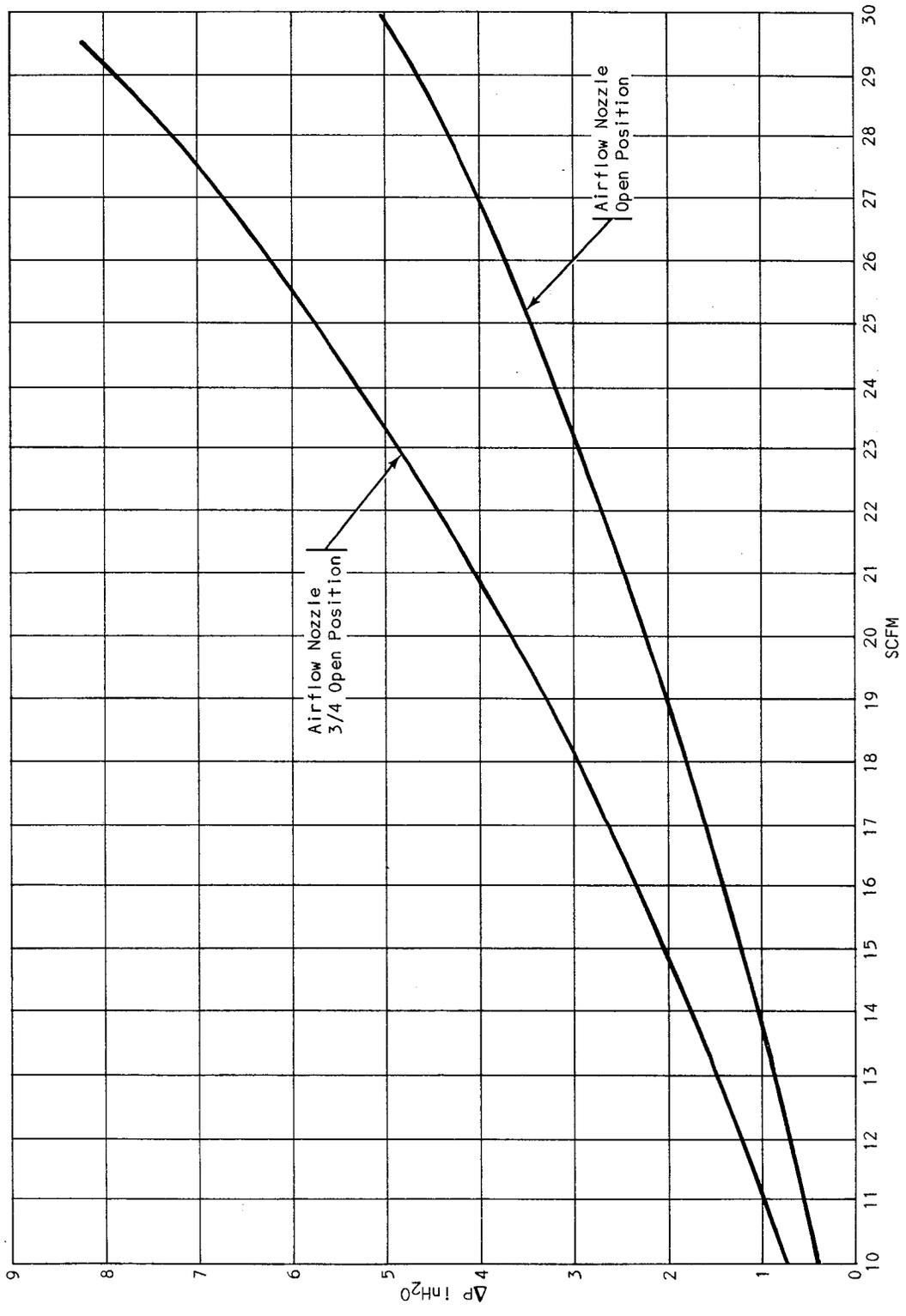


Figure 81. Air Flow Nozzle, Nozzle Open and 3/4 Open

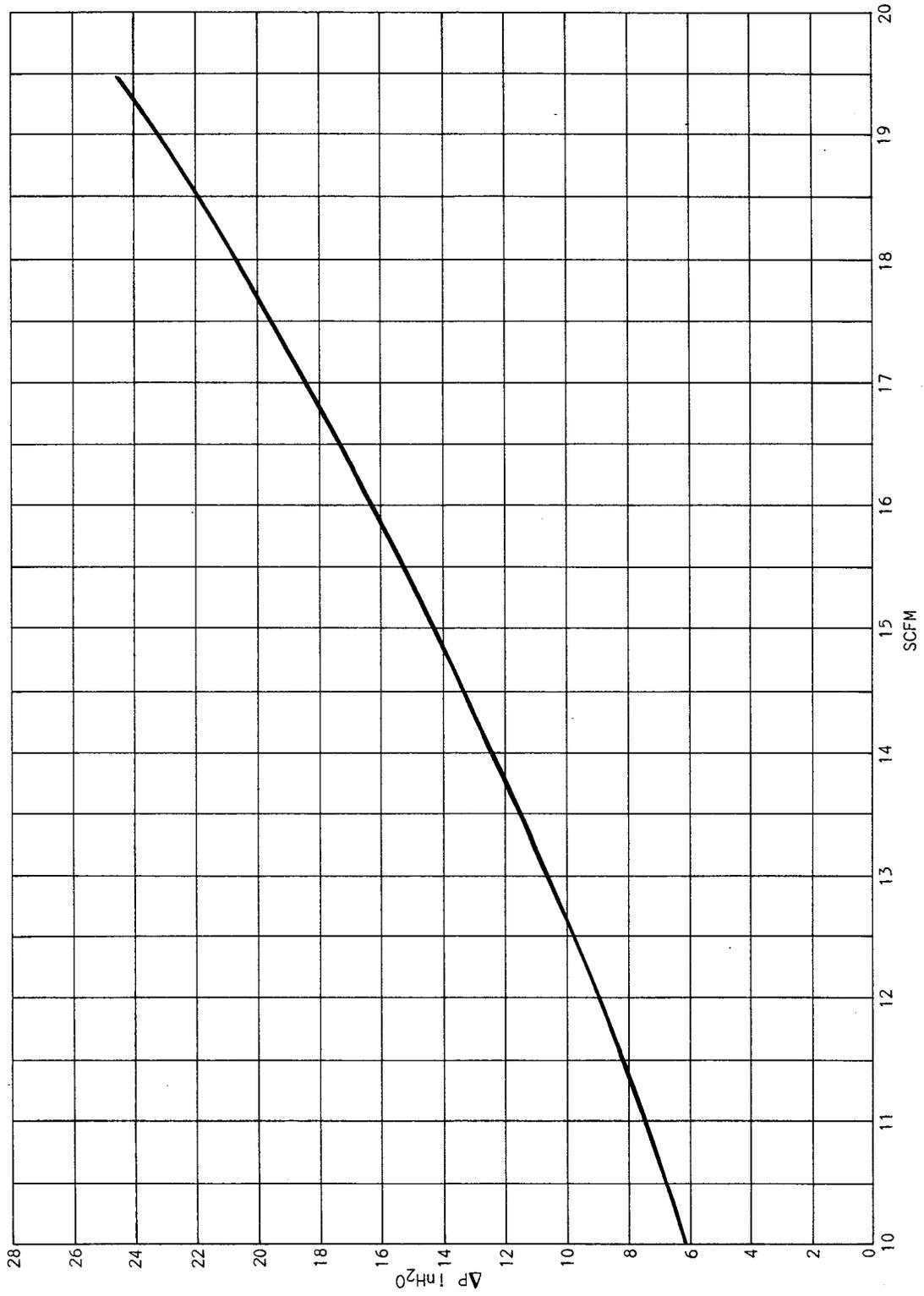


Figure 82. Air Flow Nozzle, Nozzle 1/2 Open

- Restriction of air generator not to exceed 4 inH₂O at 400 cfm
- Zone of protection extending 10 inches past the normal protected area on the outboard side of the air generator to protect operator leaning outside cab area

To evaluate air generator performance, the air generators were installed in the test stand.

Several air generator concepts were tested to arrive at a design that would satisfy the design requirements. The flat profile design discussed in section 4.3.4 (figure 83) was tested at 400 cfm, with the results shown in table II. This design proved unreliable because the airflow distribution varied when the inlet air supply orientation varied.

Several tests were also conducted on the air generator (figure 84), developed under Bureau of Mines contract H0232067. Test results of the standard unit were used as a baseline, and then modifications were made in an attempt to improve performance. Modifications included outlet baffle changes, spacing variations, and omission of the 80 mesh wire cloth used with the inlet and outlet baffles. Also, internal baffles were added in the outlet chamber. A Donaldson Company pleated paper panel filter was tested in place of the screen and perforated baffle in the inlet chamber.

Omitting the 80 mesh screen on the inlet and/or outlet baffles had an adverse effect on air generator performance. Without the screen on the outlet baffle, the airflow was discharged to the front of the air generator at an angle, resulting in virtually no airflow being directed downward at the operator's position.

Tests were also conducted placing the 80 mesh screen directly onto the outlet baffle versus being spaced .12 inch off the baffle as on the standard air generator. Test results showed no difference in performance. As a result, this arrangement was used with the succeeding air generator because fewer parts were required and fabrication was easier.

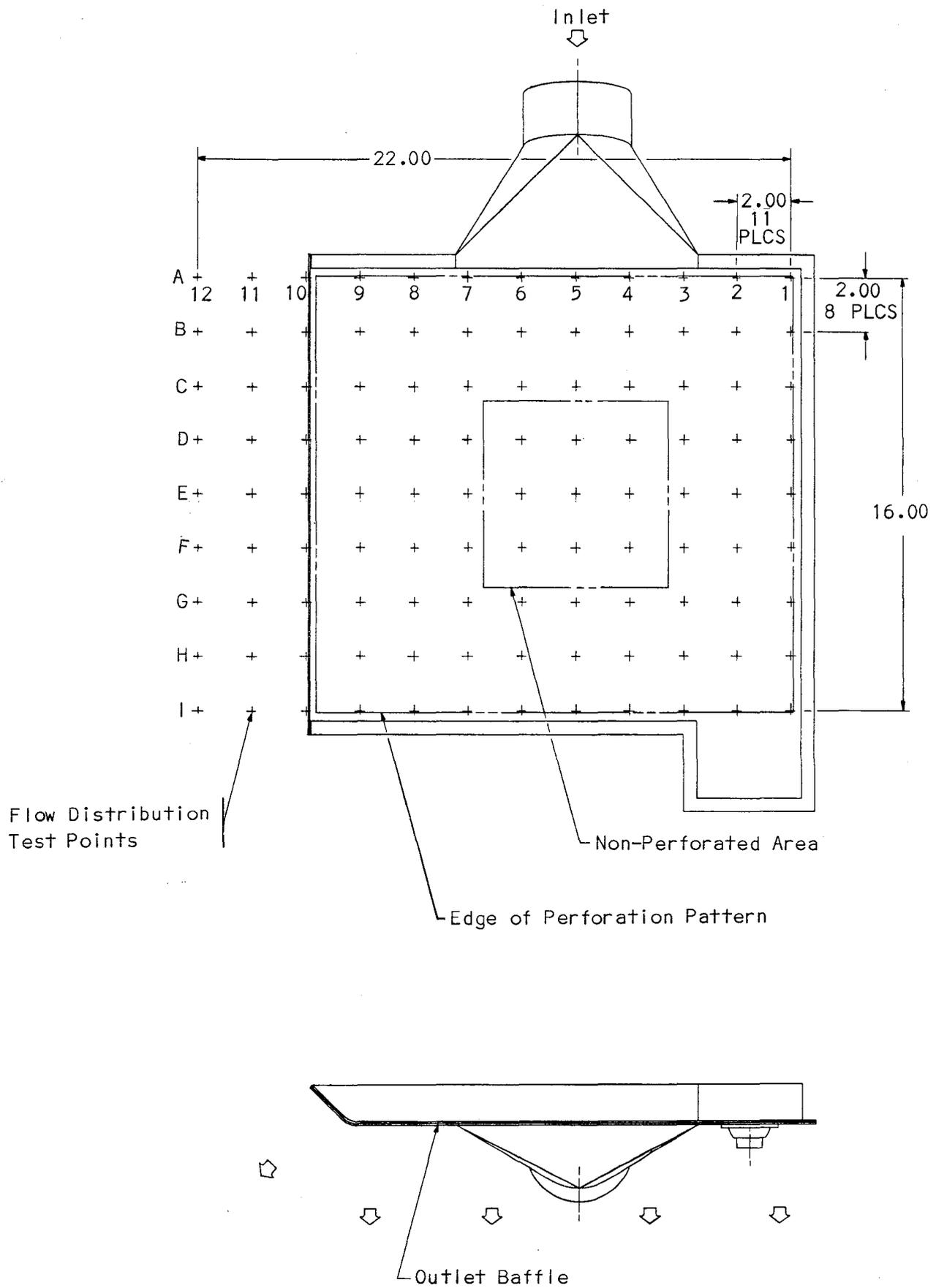


Figure 83. Flat Profile Underground Retrofit CAC Air Generator

TABLE 11. Flat Profile Air Generator Discharge Velocity (feet per minute)

	A	B	C	D	E	F	G	H	I
1	0	0	100	300	250	200	300	400	150
2	0	0	350	500	500	500	600	600	500
3	0	0	300	400	400	550	600	650	600
4	0	0	100	50	50	200	450	600	550
5	100	0	0	150	200	400	500	500	350
6	100	50	0	100	400	600	500	300	0
7	100	0	0	300	600	600	300	0	0
8	100	100	250	500	650	450	50	0	0
9	200	250	450	600	600	450	300	0	0
10	350	450	550	600	700	650	400	0	0
11	450	550	600	550	500	400	200	0	0
12	450	450	400	300	200	200	0	0	0

NOTE: Refer to figure 83 for test grid coordinates.

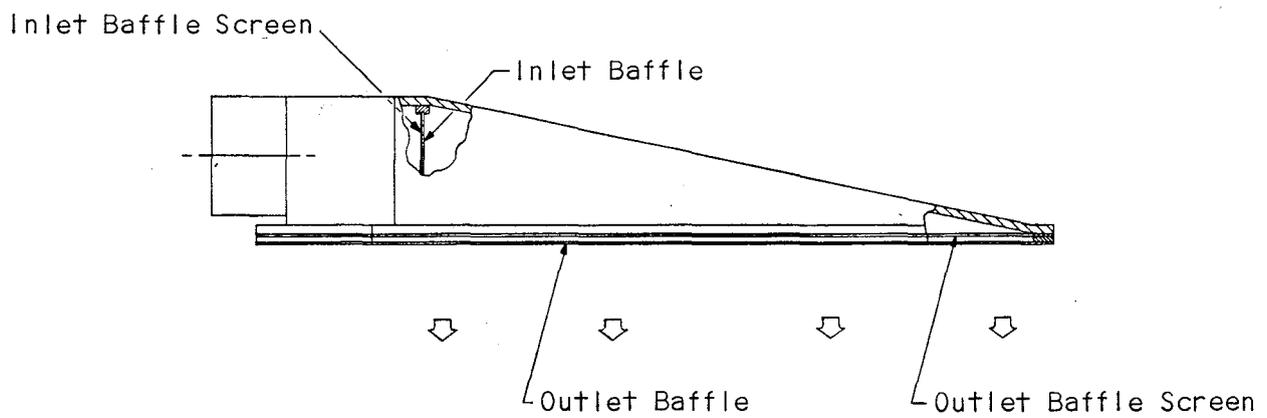
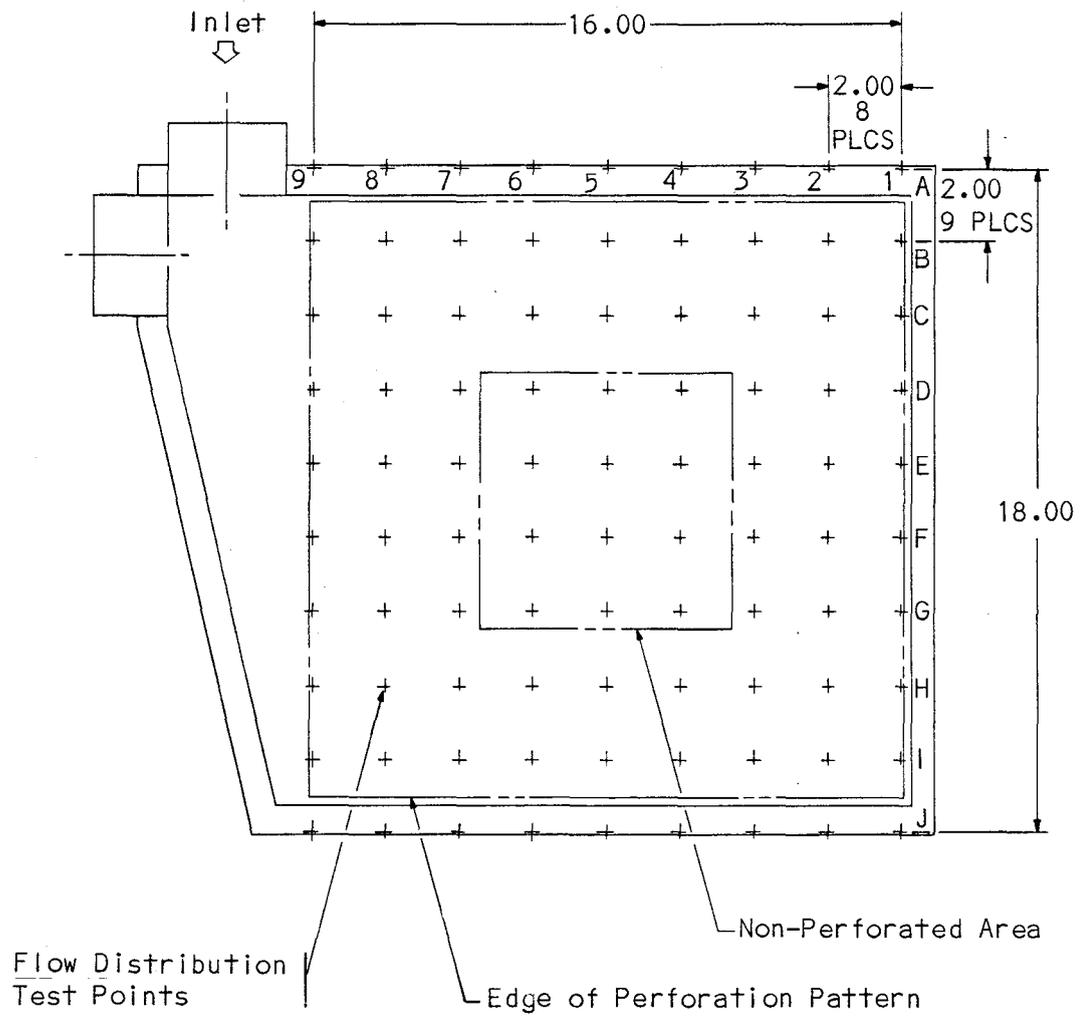


Figure 84. Underground Retrofit CAC Air Generator

Adding three internal baffles in the outlet chamber, replacing the screen and baffle with the panel filter, and using a fully perforated outlet baffle improved air generator performance. Although the panel filter improved airflow uniformity, it was not considered an overall improvement due to increased restriction. The panel filter restriction also continued to rise during use because of dust buildup, which resulted in increased maintenance. The most uniform airflow distribution was achieved by installing the three internal baffles in the air outlet chamber, placing the 80 mesh screen directly onto the outlet baffle with the baffle completely perforated, and using the standard inlet baffle and screen assembly. Test results are shown in table 12. Air generator restriction during these tests varied from 3.45 inH₂O to 5.25 inH₂O at 300 cfm.

Based on the previous tests, a prototype air generator (figure 85) was designed and fabricated. This prototype incorporated the features that improved performance in the previous tests and featured an angled baffle section to provide airflow outside the cab area. It was also designed to allow for various modifications during testing.

The unit was designed so airflow to the angled baffle section could be provided from either the inlet chamber or the outlet chamber. The airflow nozzle was designed to receive airflow from either the air generator inlet via a tube or from the angled baffle section. The shape of the inlet wedge could also be altered to allow for supplying airflow to the angled baffle section and to test the effect of the wedge shape on airflow uniformity.

The results of testing this unit showed that the angled baffle section could not provide adequate airflow to protect an operator leaning outside of the cab area. Airflow distribution and uniformity from the main outlet baffle was worse when airflow to the angle baffle section was supplied from the outlet chamber. When supplied from the inlet chamber, airflow distribution and uniformity were less affected. Airflow uniformity was also affected by the inlet wedge shape. Airflow became more uniform with a curved wedge shape rather than a straight shape. Based on these test results, a redesign effort was directed at profiling both air supply chambers as discussed in section 3.5.2.1 (figure 55). Also, the screen baffle assembly in the inlet chamber and the screen in the outlet chamber were replaced with honeycomb, and a Coanda effect air jet device was incorporated into the redesigned air generator.

TABLE 12. Modified Air Generator Discharge Velocity (feet per minute)

	A	B	C	D	E	F	G	H	I	J
1	50	50	150	200	290	240	210	0	0	0
2	50	160	310	360	500	450	570	340	0	0
3	150	300	480	460	560	460	560	520	110	0
4	160	300	360	450	460	420	480	400	110	0
5	140	300	390	380	420	560	520	300	50	0
6	100	290	370	290	330	450	330	75	0	0
7	75	230	350	240	190	350	210	0	0	0
8	0	100	300	280	210	275	240	0	0	0
9	0	0	170	270	220	230	160	0	0	0

NOTE: Refer to figure 84 for test grid coordinates.

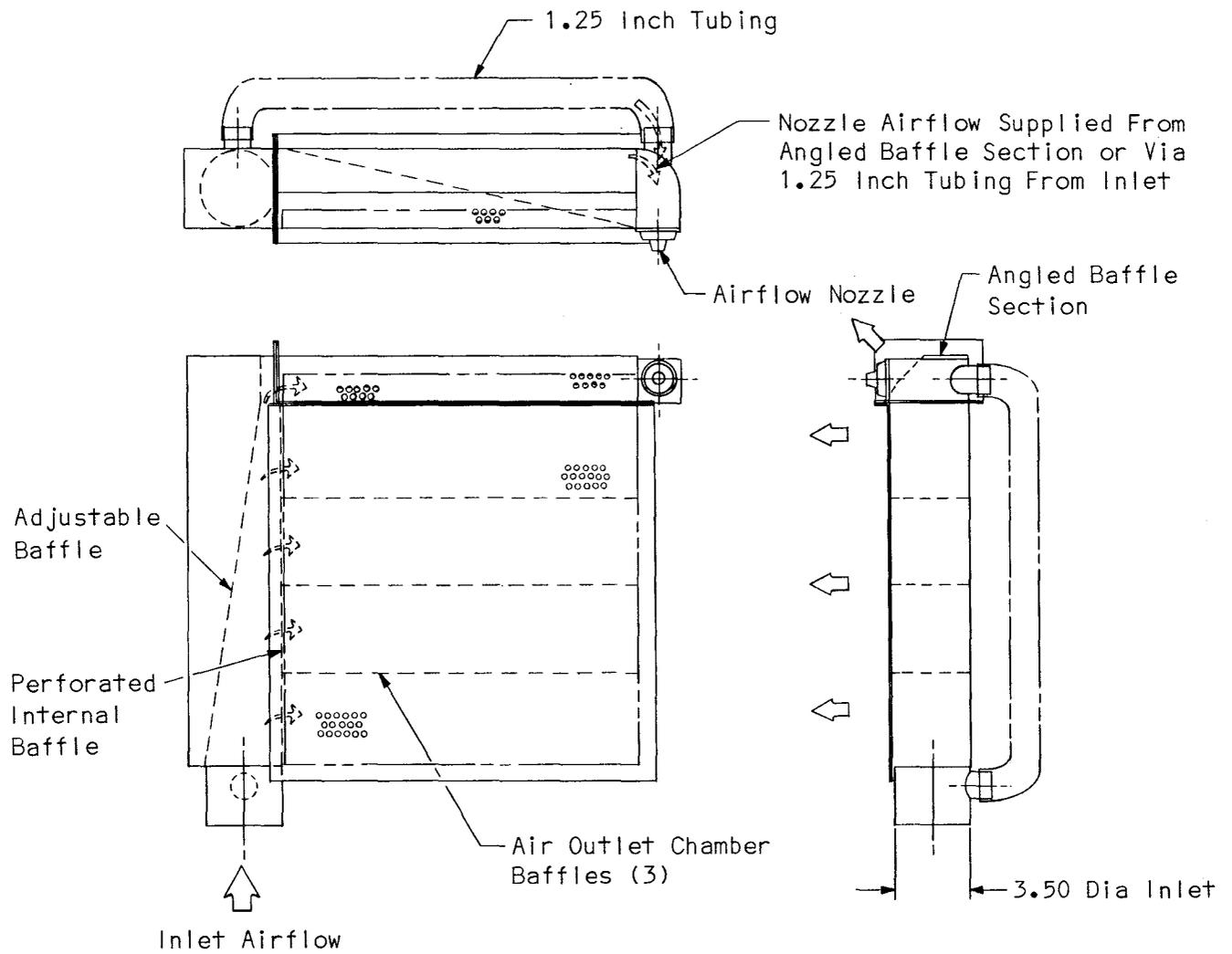


Figure 85. Prototype Air Curtain Generator

The Coanda device was previously used in conjunction with the air generator in work performed in "Studies of Air Curtain Technology With Particular Application to the Provisions of Clean Air For Underground Workers" by Mining Research and Development Establishment (MRDE), 1980. The operating principle of the Coanda effect device was that the airflow leaving the slot followed the tube's curved surface until it was separated from the tube by the splitter. This resulted in a wide, uniform jet of airflow. The tests documented by the MRDE report indicated that the Coanda device could provide dust protection for an operator leaning out of the cab area.

Preliminary test results of a 4.00 inch diameter Coanda device (figure 86) at various flow rates and two slot widths is shown in figure 87. Testing showed that 200 fpm airflow velocity at the test grid could be achieved with 37 cfm through the .12 inch wide slot. Testing also determined that due to the interaction of the air generator and Coanda device airflows, the most uniform Coanda device airflow distribution was achieved with a tapered slot. The tapered slot had an opening at the tube inlet end of .15 inches and tapered down to .09 inches, resulting in an area equal to that of a straight .12 inch slot.

The redesigned prototype air generator is shown in figure 88. The air generator has a relatively long inlet tube section with a honeycomb flow straightener to ensure an even velocity profile as the airflow enters the air generator. The inlet tube also contains an operator controlled airflow nozzle for increased operator comfort. The elbow has turning vanes designed to ensure an even velocity profile as the airflow leaves the elbow. A honeycomb flow straightener is also installed after the elbow. The inlet and outlet airflow plenums are profiled to maintain even airflow distribution and also incorporate honeycomb flow straighteners to ensure that the airflow exists perpendicular to each plenum.

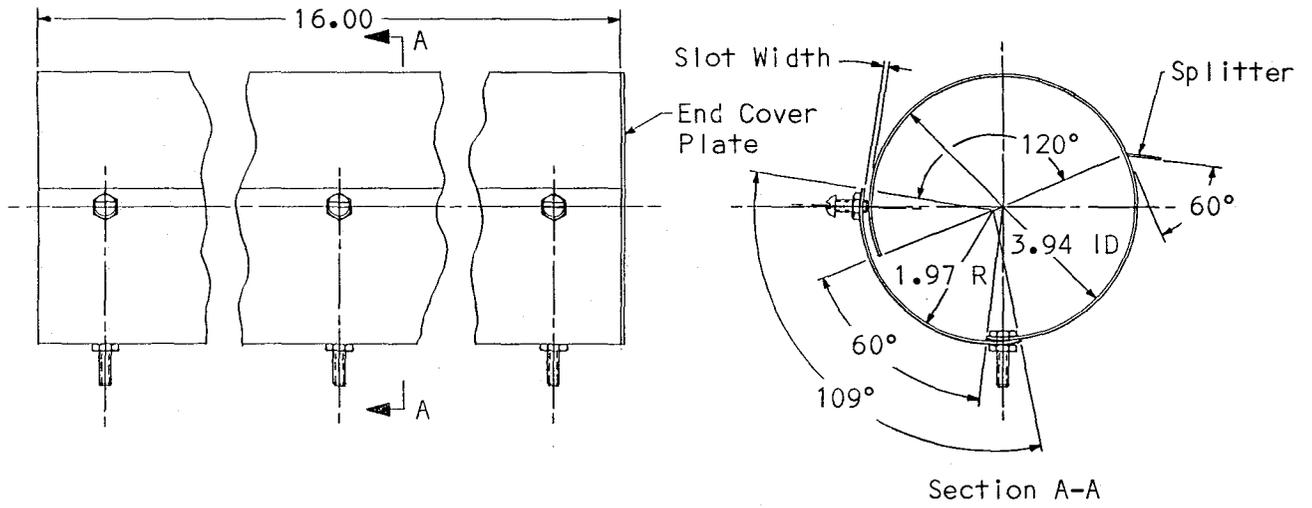


Figure 86. Coanda Air Curtain Device

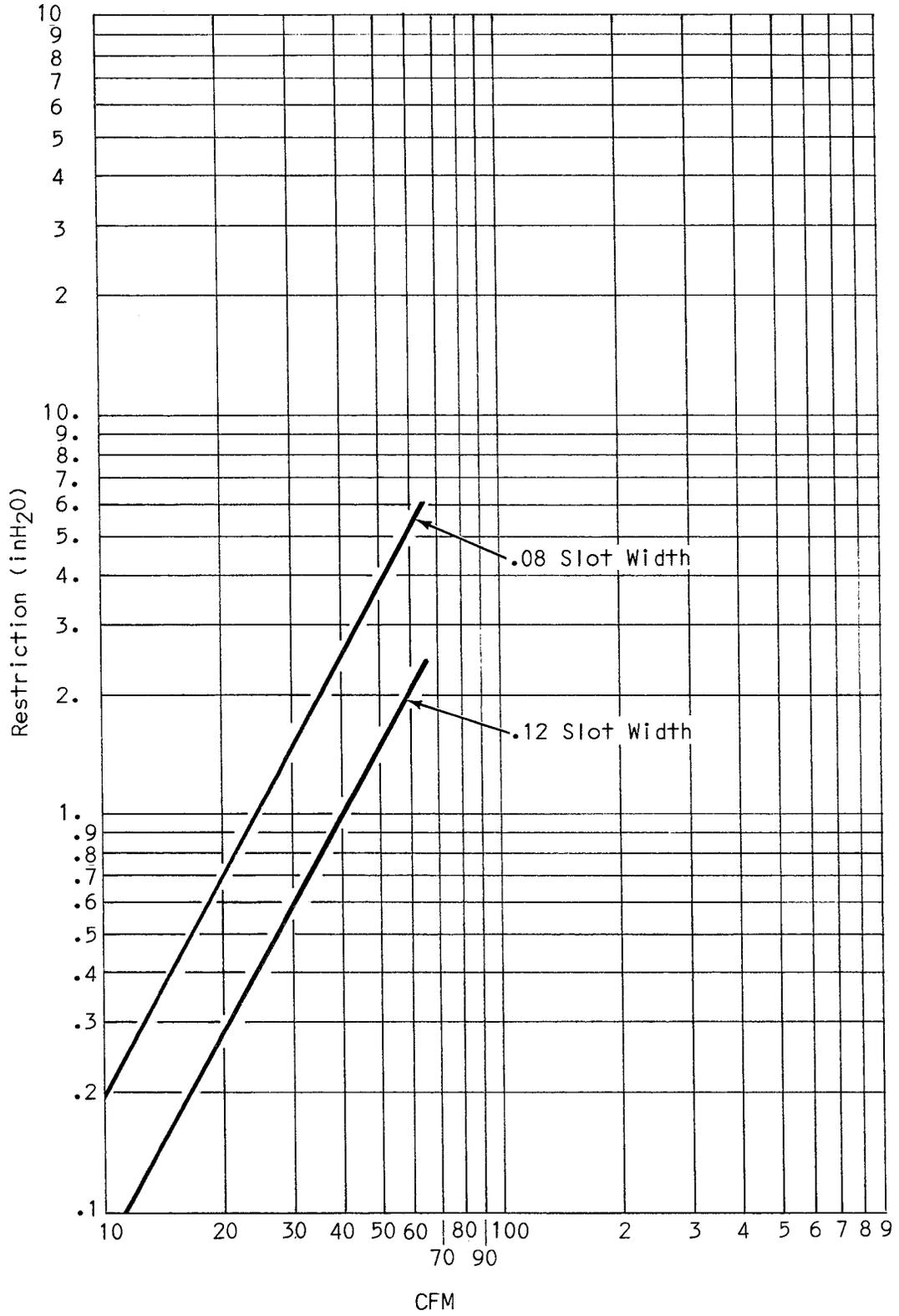


Figure 87. 4.00 Inch Coanda Device - Flow Versus Restriction

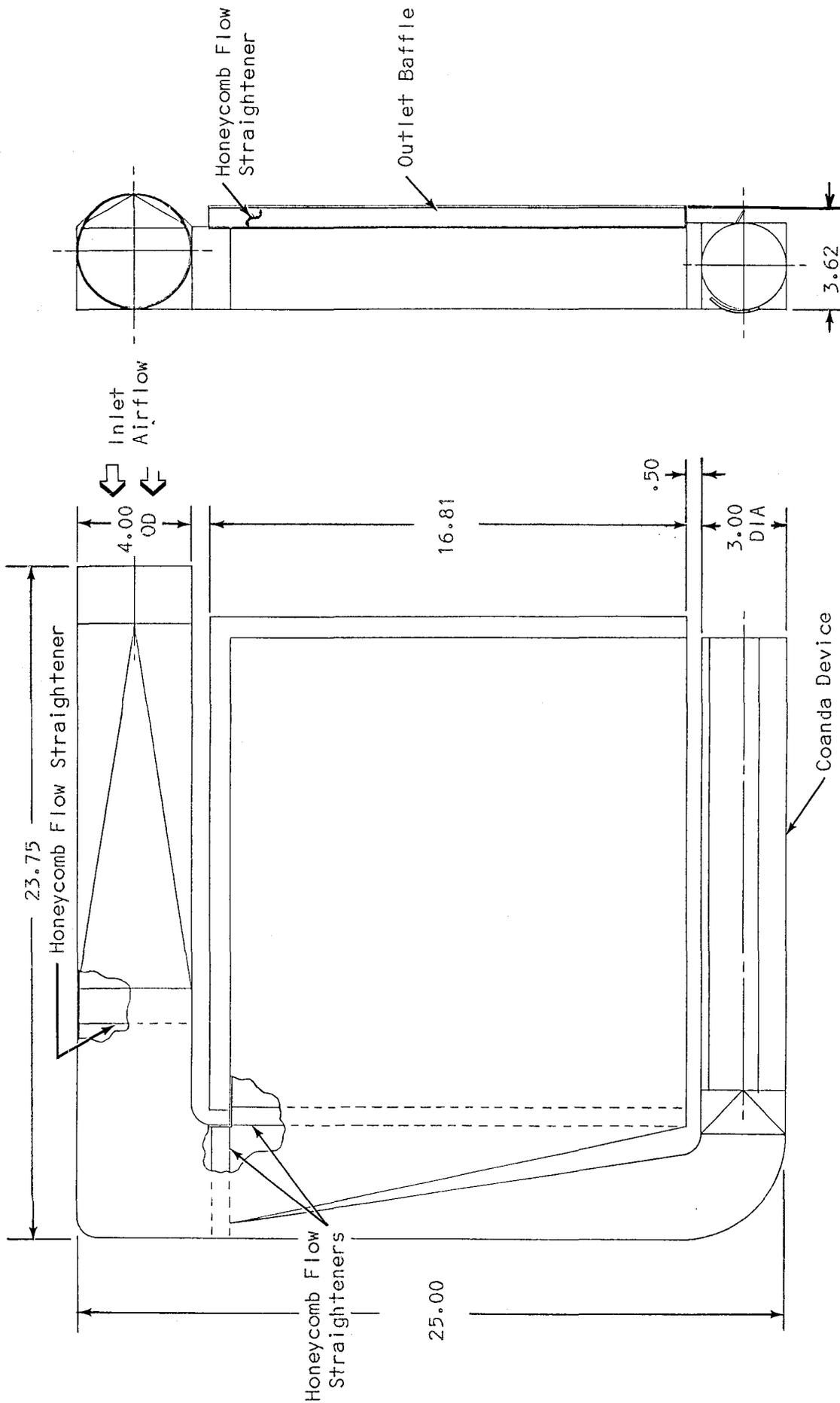


Figure 88. Underground CAC Redesigned Air Generator Hardware

The use of honeycomb is four-fold:

- It acts as a flow straightener
- It ensures that the airflow exists perpendicular from each airflow chamber
- It has a lower pressure drop than the screen
- It will not become plugged should dust bypass the filter, which could happen during air filter servicing

The type of honeycomb used was aluminum with standard 1/8 inch cell size. To ensure that full straightening and/or turning of the airflow was accomplished, the cell length (l) to cell size (d) ratio (l/d) could be no less than 5 and no more than 10. Due to space constraints, an l/d ratio of 5 was used resulting in .625 inch thick honeycomb being used after the inlet elbow and in the inlet and outlet chambers. In the inlet tube, the honeycomb was 1.25 inches thick, an l/d ratio of 10.

The outlet baffle was completely perforated with 3/32 diameter holes, staggered on .250 inch centers resulting in a 13 percent open area. It was installed in the bell-up configuration with the hole pattern perpendicular to the interference airflow, as reported in Bureau of Mines contract H0232067. To supply dust protection when the operator leans out the cab, a 3 inch diameter Coanda device was installed on the outboard side of the air generator. The airflow to the Coanda device and outlet chamber was split after the inlet elbow to ensure a constant volume of airflow to each section. Early in the testing, the honeycomb flow straighteners in the inlet tube and at the end of the elbow were determined to be unnecessary, because they did not affect airflow uniformity and added restriction. They were therefore removed.

Pressure drop versus airflow of the air generator with Coanda device is shown in figure 89. Figure 90 illustrates the air generator with the test grid pattern and table 13 shows the test results. The data in table 13 displays the air velocity 11 inches below the outlet baffle at a total system airflow of 340 cfm. These test results show that the redesigned prototype meets or exceeds the performance criteria previously discussed. Airflow is quite uniform and the Coanda device should provide protective airflow in the breathing zone when the operator leans out of the cab area. Pressure drop is also reduced to 2.35 inH₂O at 400 cfm.

4.4.4 Dust Reduction Efficiency Test Facility

As described in section 2.0, the test chamber provided a controlled environment for dust laden simulated mine ventilation airflow and a mounting platform for a mining machine mockup (figure 91). The mining machine mockup was constructed of plywood and 2 inch by 4 inch studs to simulate the cab of a continuous miner. Specifications of the major components and test instrumentation are listed in table 14. Test dust is described in section 2.1.

4.4.5 Dust Reduction Efficiency Testing

The air curtain generator with the Coanda device was installed in the mining machine mockup with a mannequin placed under the air generator (figure 92) to simulate actual airflow conditions with a machine operator in position. The RAM-1 cyclone was attached to the mannequin at the lapel location. With the mannequin directly under the air generator, the hard hat was 2.00 inches below the air generator outlet baffle and the inlet to the cyclone was 18.50 inches below the outlet baffle. When the mannequin was in a leaning position, the mouth was 8 inches from the edge of the air generator outlet baffle.

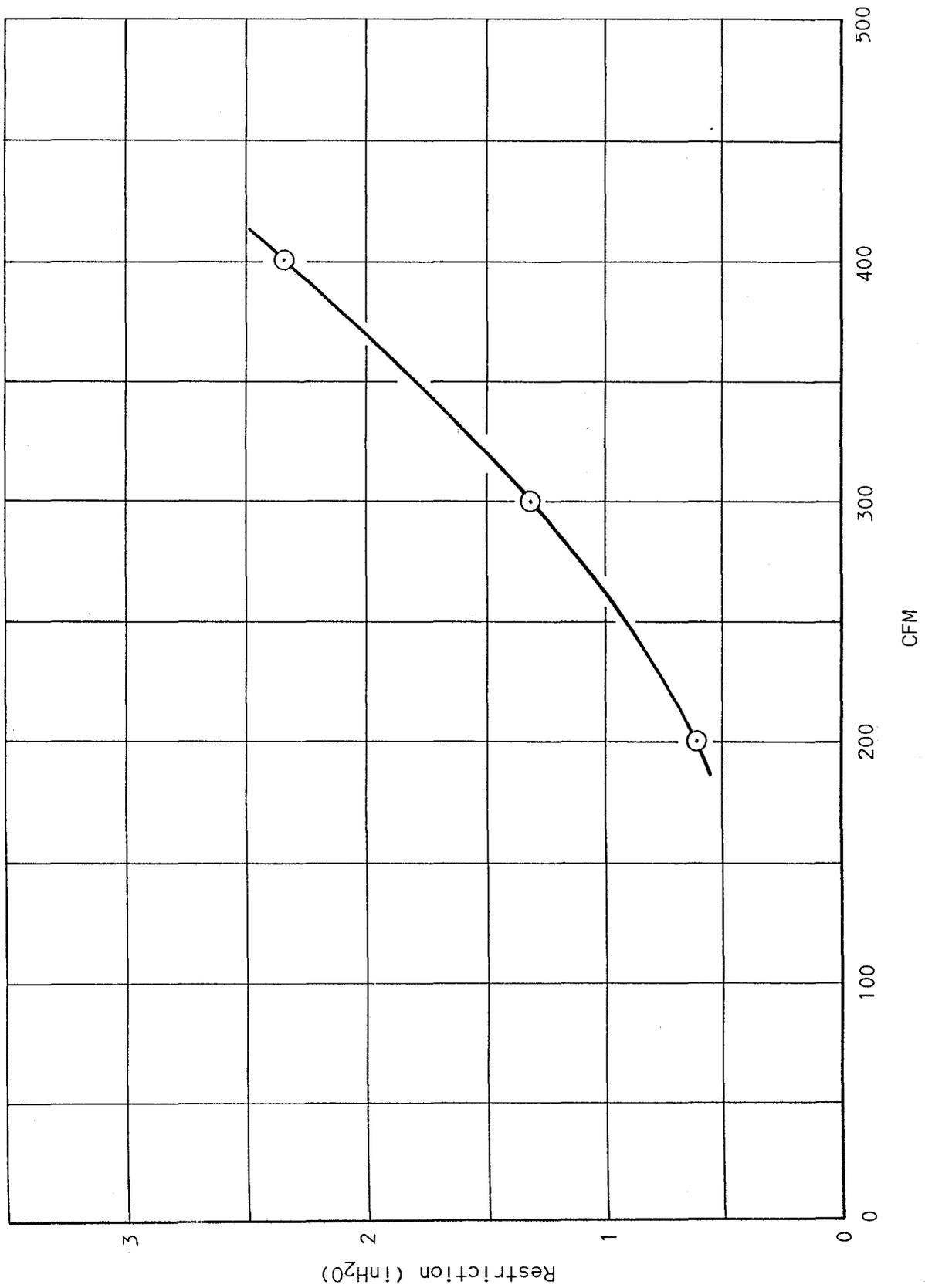


Figure 89. Airflow Restriction for the Underground Retrofit CAC Redesigned Air Generator With Coanda Device

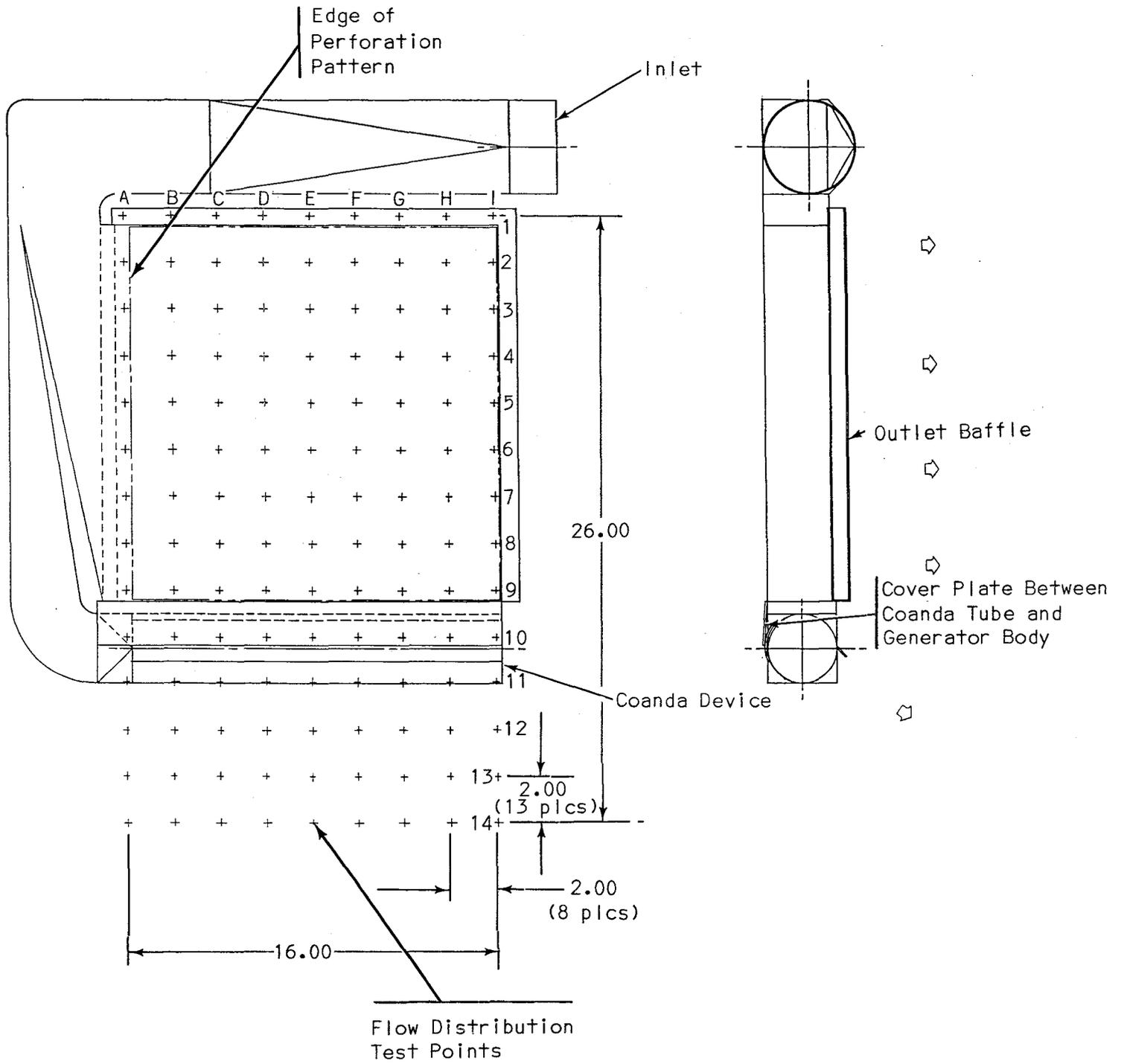


Figure 90. Underground Retrofit CAC Air Generator Design with Superimposed Test Grid

Table 13. Redesigned Air Generator Discharge Velocity (Feet Per Minute)

	A	B	C	D	E	F	G	H	I
1	0	0	0	0	25	25	130	50	25
2	0	80	175	80	100	180	210	240	25
3	130	370	400	320	325	340	350	290	60
4	230	300	350	300	285	280	330	265	25
5	50	160	290	260	265	270	330	210	0
6	50	120	290	250	250	235	280	190	25
7	0	125	285	240	230	240	300	205	25
8	25	150	245	245	490	300	270	160	50
9	0	150	290	260	560	480	295	110	0
10	0	50	200	300	520	560	300	50	25
11	0	0	100	150	250	540	300	60	0
12	0	0	0	50	250	480	275	75	75
13	0	0	50	125	300	400	175	100	50
14	0	0	0	200	300	300	0	0	0

NOTE: Refer to figure 56 for test grid coordinates.

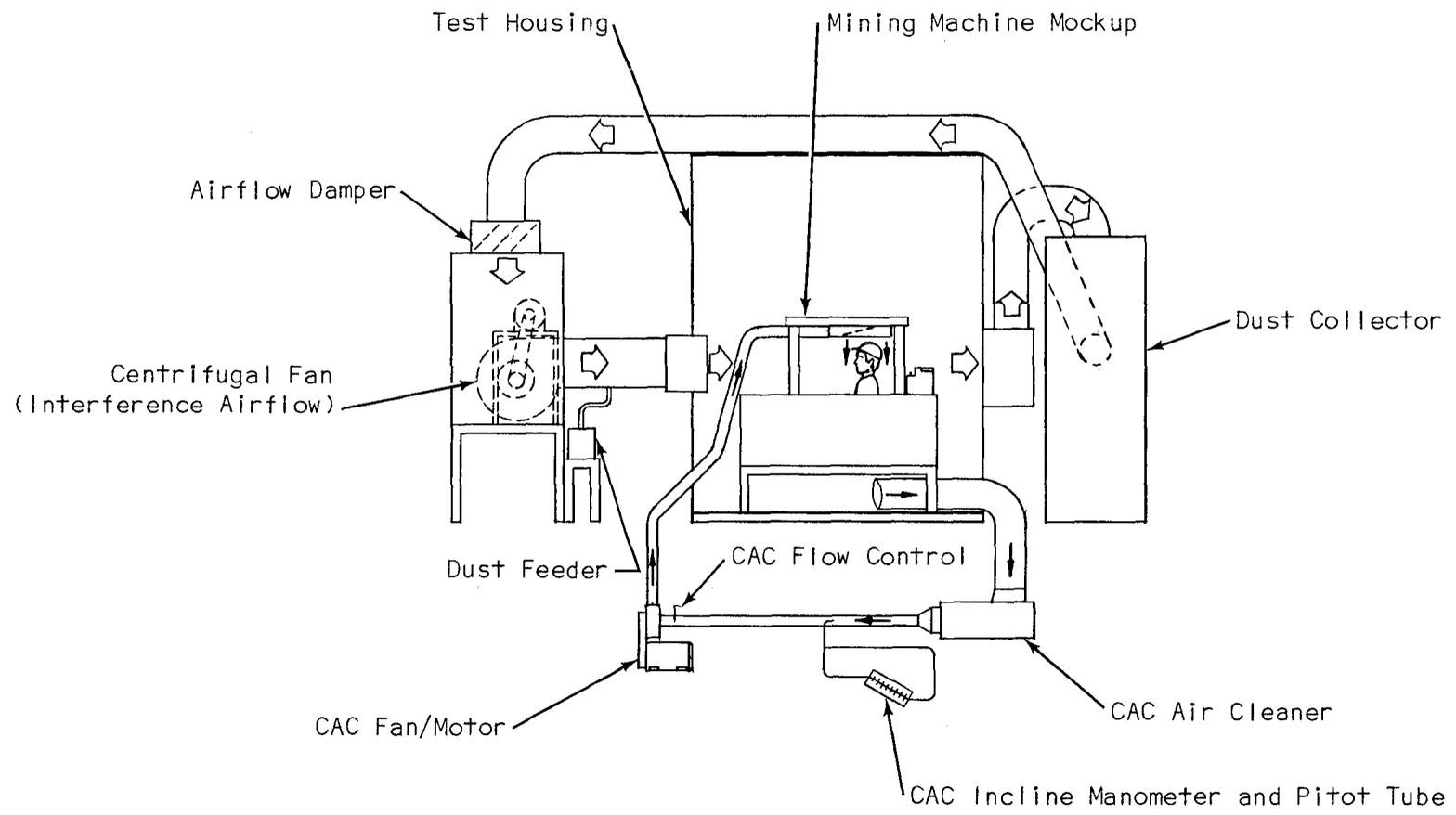


Figure 91. Test Facility

Table 14. Test Facility Components and Instrumentation

Component	Model
Interference Airflow Fan	Twin City Fan, Model #122 Double Inlet Centrifugal
Dust Feeder	AFI Dust Feeder
Aerosol Monitor	GCA RAM-1 Real Time
Strip Chart Recorder	Soltec VP-67235, 2 Pen Portable
Data Logger	Metrosonics, Model d1-331
Velometer	AInor P/N 6006AP
Sound Level Meter	B&K, Model 2215, Includes Octave Band
Thermometer	Omega, Model 199 With Thermocouple

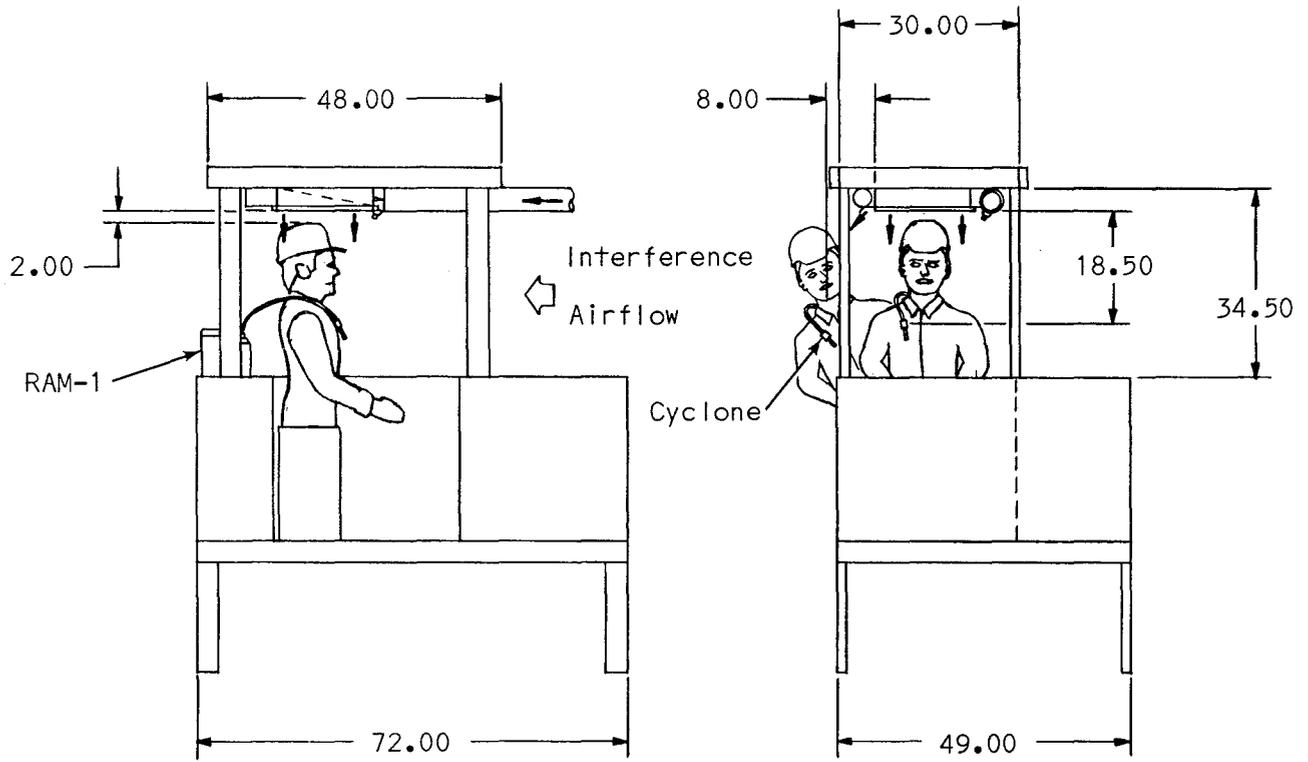


Figure 92. Mining Machine Mockup

During the tests, the dust levels were monitored using the RAM-1. The RAM-1 output was simultaneously fed to the strip chart recorder and the data loggers. The data stored by the data loggers was then fed into an IBM personal computer. This data was stored on disk and a hard copy obtained from the computer printer. One data logger collected data when the air curtain system was on and the other collected data when the air curtain was off. There was a 2 minute time period between on/off times to allow for dust level stabilization. The dust levels in the chamber were maintained at approximately 10 mg/m^3 (respirable). The simulated mine ventilation airflow velocity was measured along the leading edge of the air canopy outlet baffle using the Alnor velometer. Tests were conducted with ventilation airflows of $100 \pm 10 \text{ fpm}$ and $250 \pm 25 \text{ fpm}$.

Figure 93 represents the dust reduction efficiency with the mannequin directly under the air generator. The first test point (400 cfm) was conducted with a clean filter. For each of the following tests, the filter was loaded with dust until the desired airflow, due to filter restriction, was reached. This was done to simulate field use of the air canopy system. In the test with 100 fpm interference airflow, the dust reduction efficiency was greater at 200 cfm and 300 cfm than at 400 cfm due to the initial inefficiency of the filter. As the filter loads with dust, it becomes more efficient. Based on a minimum airflow of 200 cfm, the average dust reduction efficiency was 89 percent. At 250 fpm interference airflow, dust reduction efficiency dropped sharply.

Tests were also conducted to determine if the air nozzle would have an effect on the dust reduction efficiency of the CAC. Test results are shown in table 15. The tests were conducted at 100 fpm interference airflow with the mannequin directly under the air generator with nozzle airflow directed at the facial area. Comparisons were made with the airflow nozzle alternately turned on and off while the air generator supplied continuous airflow. As can be seen by the test results, when the nozzle was on, the dust levels increased. The nozzle was evidently entraining dust from outside the air curtain and, with high nozzle airflow velocity, the dust easily penetrated the protective zone of the air curtain.

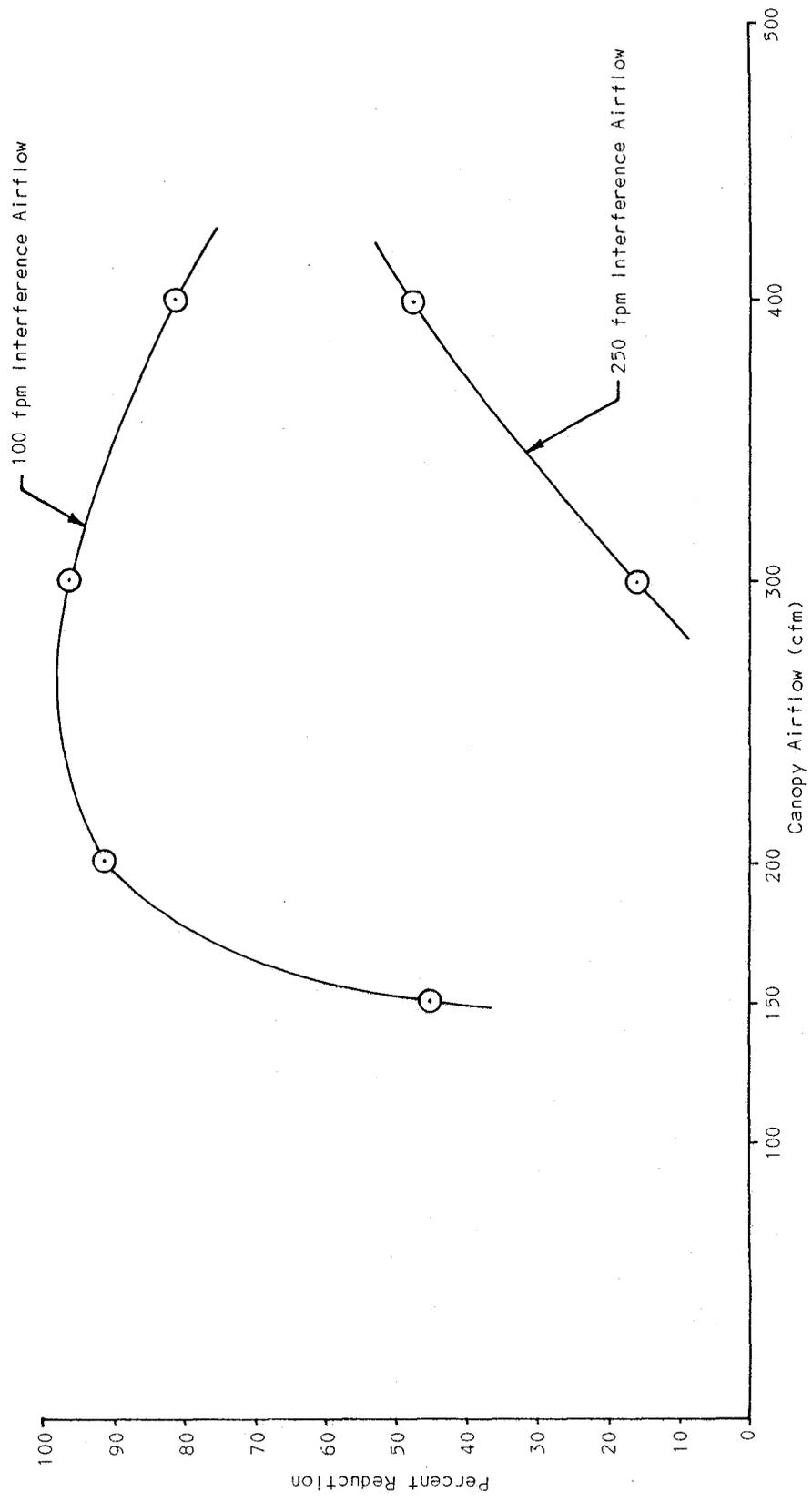


Figure 93. Underground Retrofit CAC Dust Reduction Efficiency

Table 15. Air Nozzle Test

System Airflow	Dust Level (mg/m ³)	
	Nozzle On	Nozzle Off
400 cfm	6.26	1.80
300 cfm	6.13	.38

Tests of the Coanda device's ability to provide protection when the operator leans out of the cab area were also conducted. For these tests, the mannequin was placed in a leaning position. Interference airflow was 100 fpm. The Coanda device only provided a dust reduction of 5 percent. Modifications to the Coanda slot width and orientation were made in an effort to increase dust reduction. A slot was also added at the outlet end of the device (figure 94) to provide a jet of air perpendicular to the interference airflow. None of these modifications, however, improved dust reduction.

4.4.6 Air Cleaner Selection

A filter concept study was conducted to select an air cleaner for the underground retrofit CAC system. Air cleaners were evaluated based on size, initial pressure drop, filter life (dust loading), and mine worthiness. The ideal air cleaner would be small, have a low initial pressure drop and long filter life, and be able to withstand the abuse in a mine. The air cleaners outlined in section 4.3.3 were evaluated, along with two Z-media type air cleaners and an ECG11-2501 air cleaner. All of the air cleaners evaluated are Donaldson Company products.

The most basic air cleaner is a disposable type called the DURALITE™. This air cleaner is a round, pleated paper filter housed in a plastic and urethane package (figure 71). This air cleaner, however, is not considered mine worthy and has been excluded from further consideration.

The next air cleaner design is shown in figure 72. These air cleaners also use a round, pleated paper filter but house the filter in a heavy gage steel canister. These air cleaners are prototypes designed for low initial restriction while maintaining a small package size. The 10 inch air cleaner initial restriction is relatively high when compared to the other air cleaners, so it has also been dropped from further consideration.

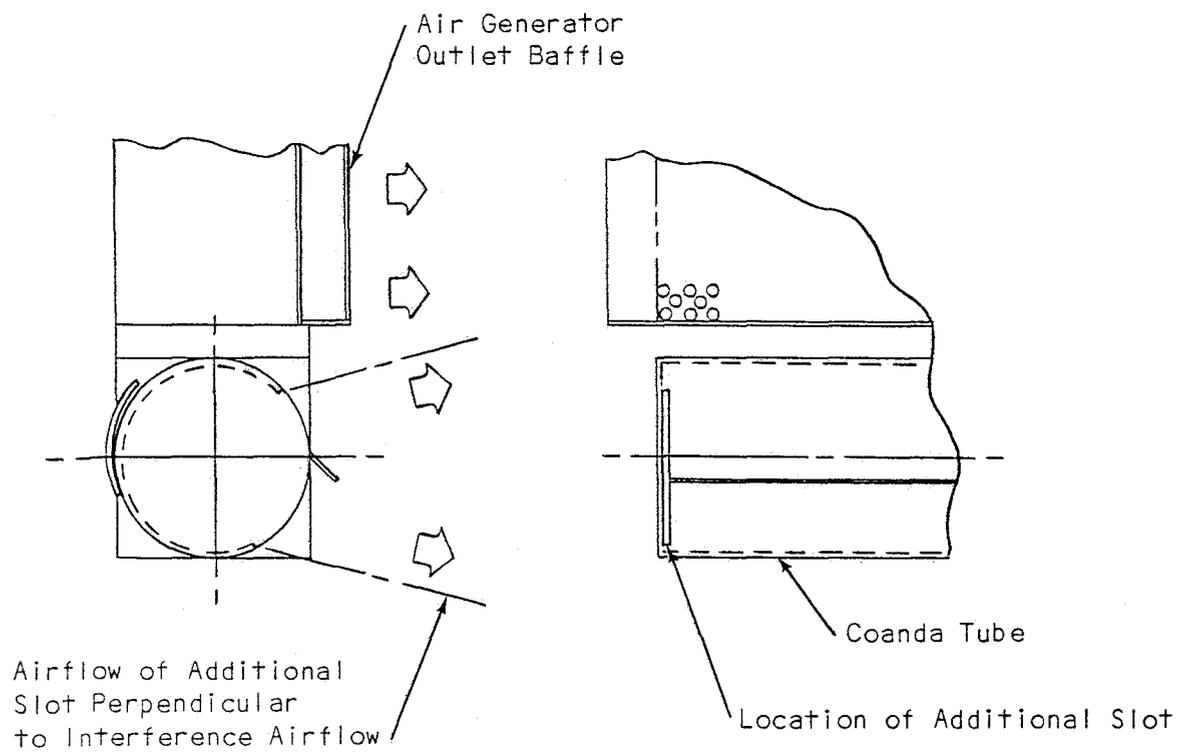


Figure 94. Coanda Device Modification

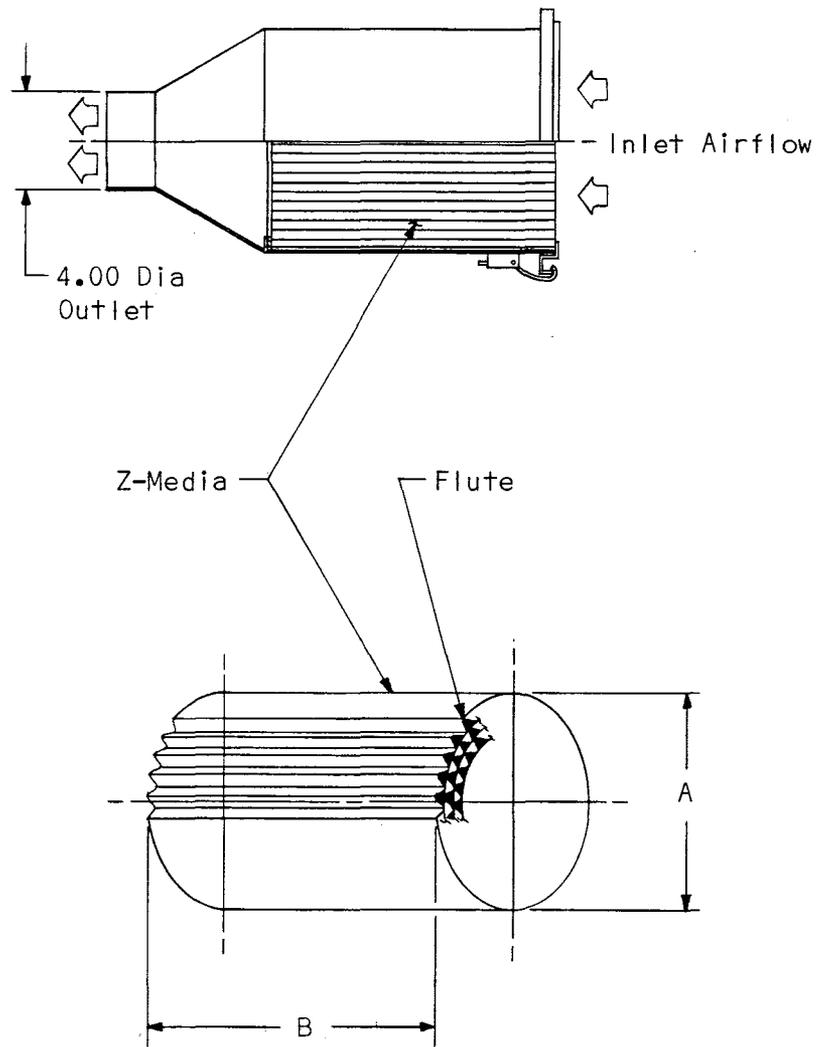
The third air cleaner design differs from the others in that it has a rectangular shape (figure 73). The filter is made up of two pleated panel filters arranged in a V shape. This arrangement allows for a larger amount of filter paper, but the overall size of the air cleaner is also quite large. An outlet transition (not shown in figure 73) is also required, adding to the air cleaner size. The pressure drop data includes an outlet transition with the air cleaner.

The fourth air cleaner design consists of a round, pleated paper filter and an inertial separator (figure 74). The inertial separator removes 80 percent to 90 percent of the dust before the airflow reaches the filter. This dramatically reduces the loading on the filter and extends filter life. The separator also adds a significant amount of restriction to the air cleaner.

The next air cleaner designs are shown in figure 95. These two air cleaners utilize a Z-type media filter housed in a round steel can. The Z-type filter is fabricated from standard type media into a corrugated pattern similar to cardboard. The flutes are alternately plugged and the corrugated sheet is rolled to form the filter. The airflow enters the open flute and, because the opposite end is plugged, must pass through the media to the adjacent flutes.

The sixth air cleaner design is shown in figure 96. This design incorporates a filter element, shaped as an offset truncated cone, housed in a round steel can.

Initial restriction curves of the above mentioned air cleaner designs are shown in figure 97. Restriction rise of these air cleaners during dust loading is shown in figure 98. The restriction rise data is based on estimates and previous dust loading tests.



Size	A	B
9.25	9.25	12.00
11.75	11.75	12.00

Figure 95. Z-Type Media Air Cleaners

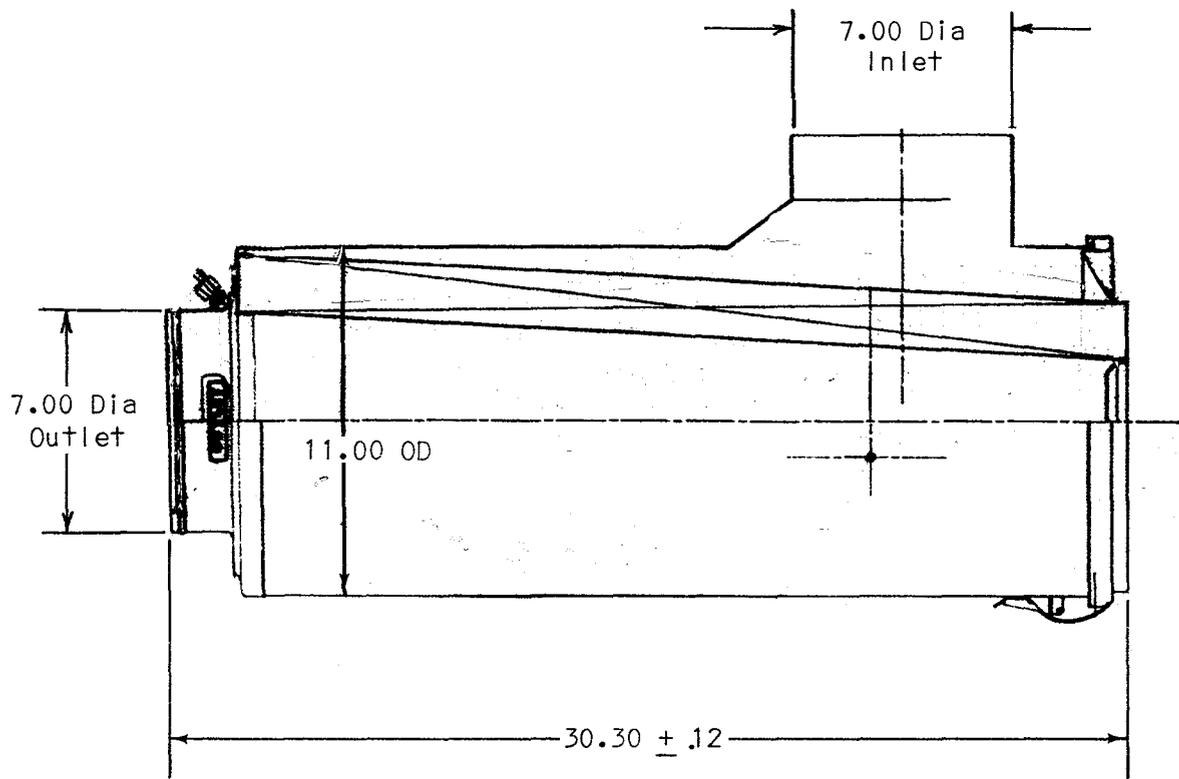
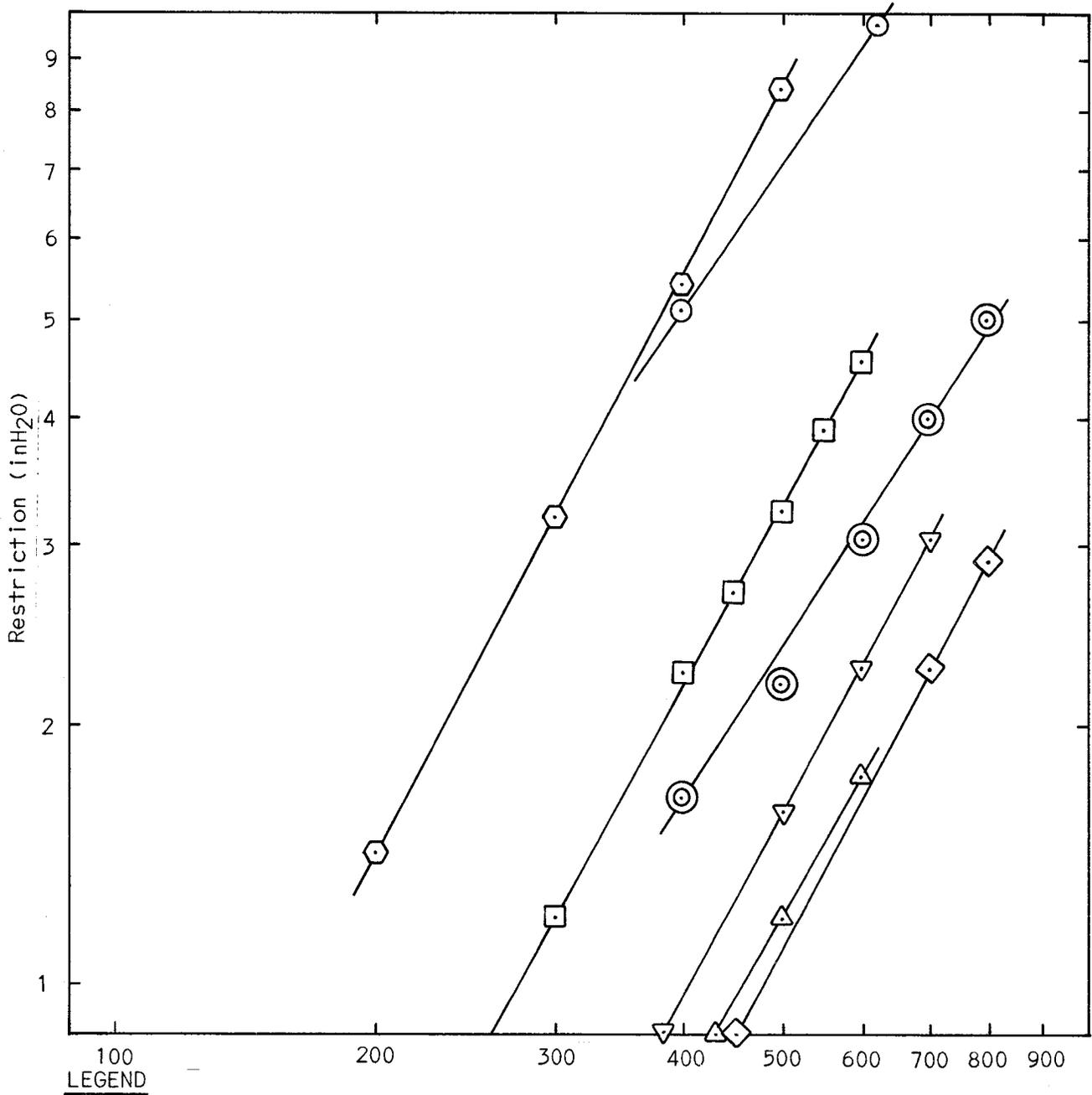


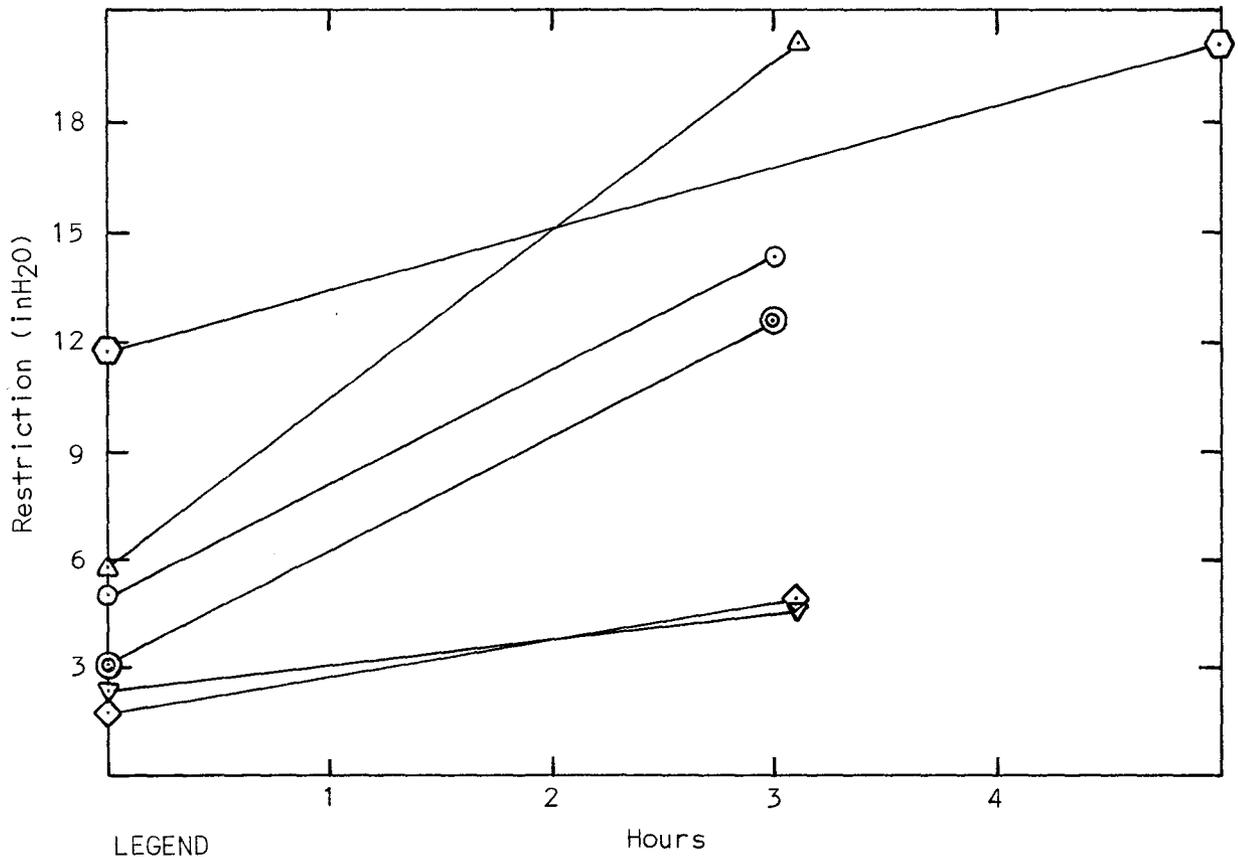
Figure 96. ECG11-2501 Air Cleaner



100
LEGEND

- 10 In. Prototype
- △ 12 In. Prototype
- Z-Media - 9.25 Dia
- ⬡ Air Cleaner With Inertial Separator
- ▽ Rectangular Air Cleaner
- ◇ ECG11-2501
- ⊙ Z-Media - 11.75 Dia

Figure 97. Air Cleaner Restriction versus Flow Curves



LEGEND

- △ 12 in. Prototype
- Z-Media - 9.25 Dia
- ⬡ Air Cleaner With Inertial Separator
- ▽ Rectangular Air Cleaner
- ◇ ECG11-2501
- ⊙ Z-Media - 11.75 Dia

Figure 98. Dust Loading Curves

To achieve an accurate comparison of restriction rise during dust loading, all air cleaners were compared at an airflow of 600 cfm and a dust feed rate of zero visibility. Exceptions were the 9.25 inch diameter Z-media air cleaner, which was tested at 400 cfm, and the 11.75 inch diameter Z-media air cleaner, which was tested at a feed rate of .667 zero visibility. Restriction of the air cleaners were compared after 3 hours of testing. The rectangular air cleaner (VEE PAC®)* and ECG11-2501 air cleaner showed the lowest restriction rise and also have low initial restriction.

Based on size, cost, initial restriction, filter life and mine worthiness, the ECG11-2501 air cleaner was selected as best suited for use with the retrofit CAC system.

4.4.7 Fan

Two basic types of fans were considered and tested for use with the canopy air curtain system. Both fans used centrifugal impellers but with different geometries and speeds. The low speed 12 inch fan (figure 99) was flow tested at various speeds. Test results are shown in figure 100. The high speed fan (figure 101) was tested at 9,500 rpm. Test results are shown in figure 102.

The benefits of the low speed 12 inch fan are low speed, lower cost, and possibly lower noise. The disadvantages are size and rapid loss of airflow as system restriction increases. The benefits of the high speed fan are smaller size and its ability to pull more airflow against a large static pressure. The disadvantages are high speed, noise, and higher cost. The high speed fan was chosen for further CAC system testing purposes due to its ability to supply the required airflow against the large static pressure of the CAC system.

*A registered trademark of Donaldson Company, Inc.

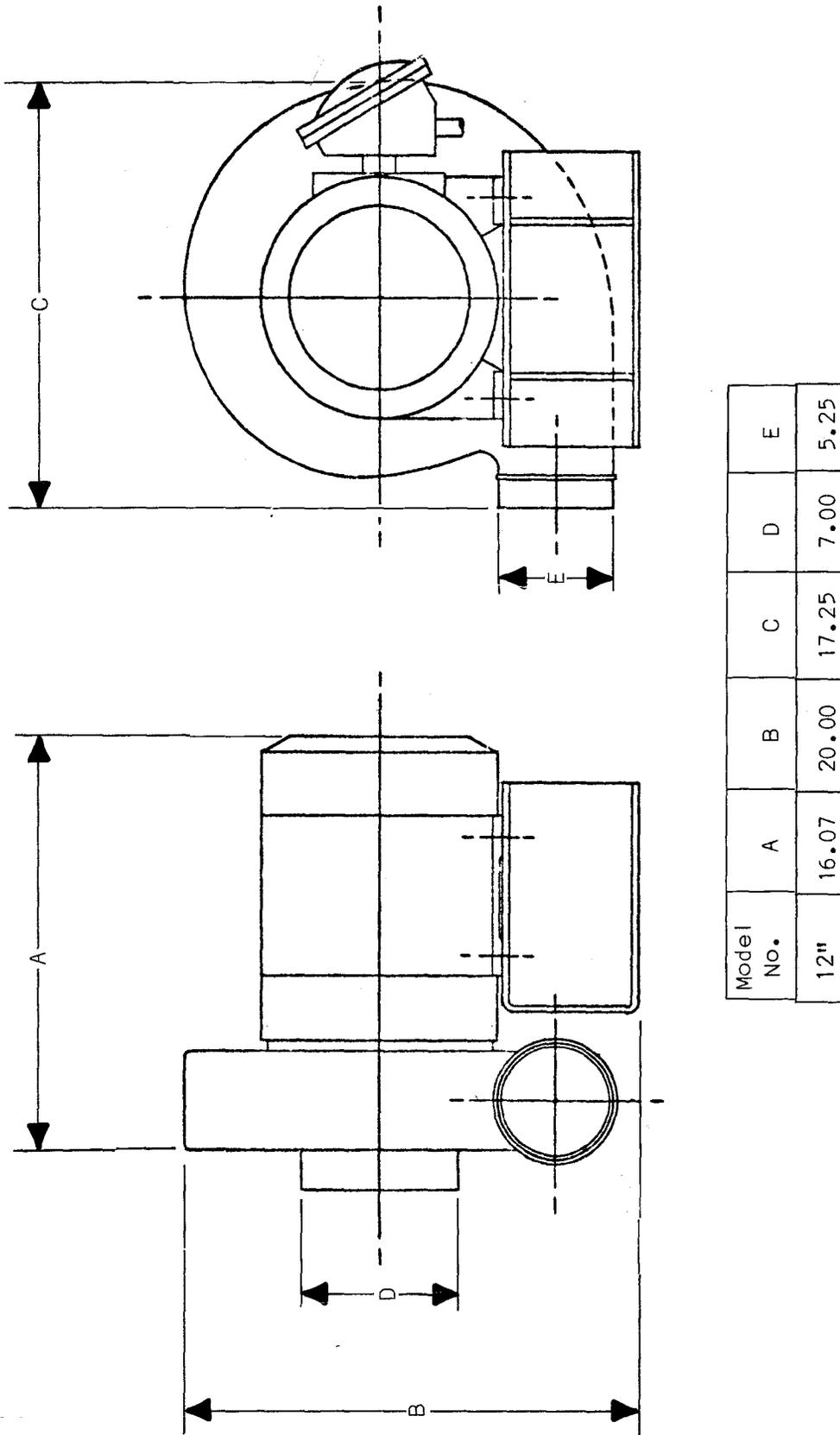
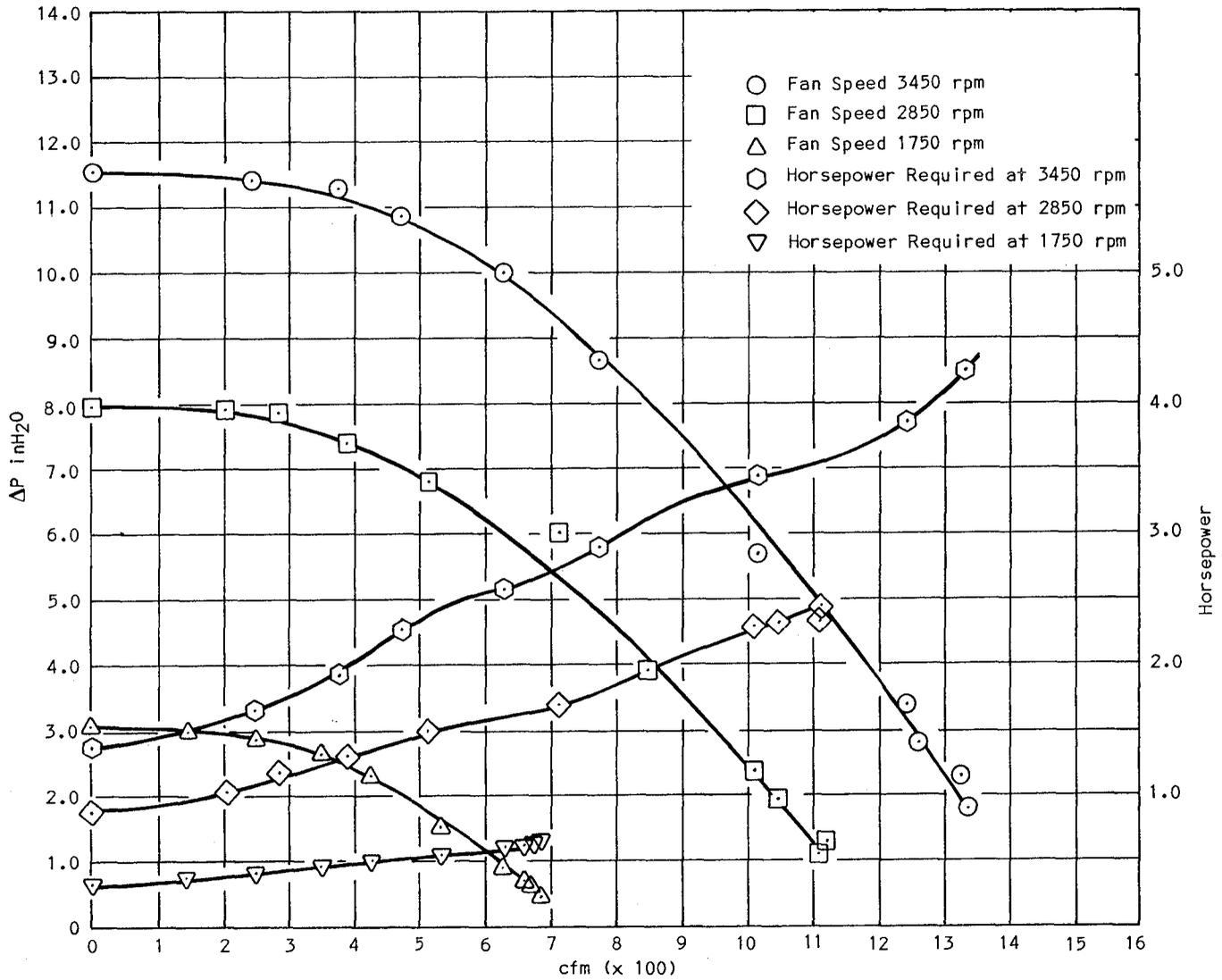
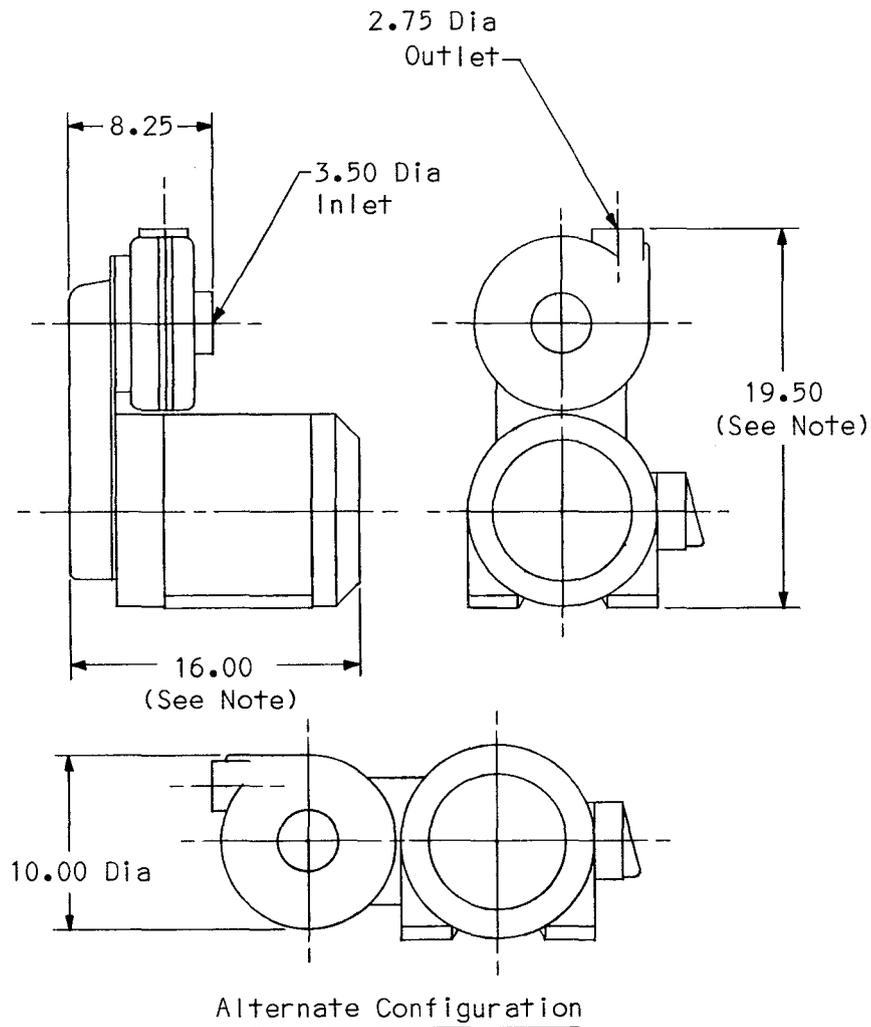


Figure 99. Low Speed Centrifugal Fan

Figure 100. 12" Blower Performance Data





NOTE: Dimensions shown are with Leroy Somer 7-1/2 hp, 230/460 V, 3 phase, 60 Hz motor. Dimensions will vary dependent on motor used.

Figure 101. High Speed Fan

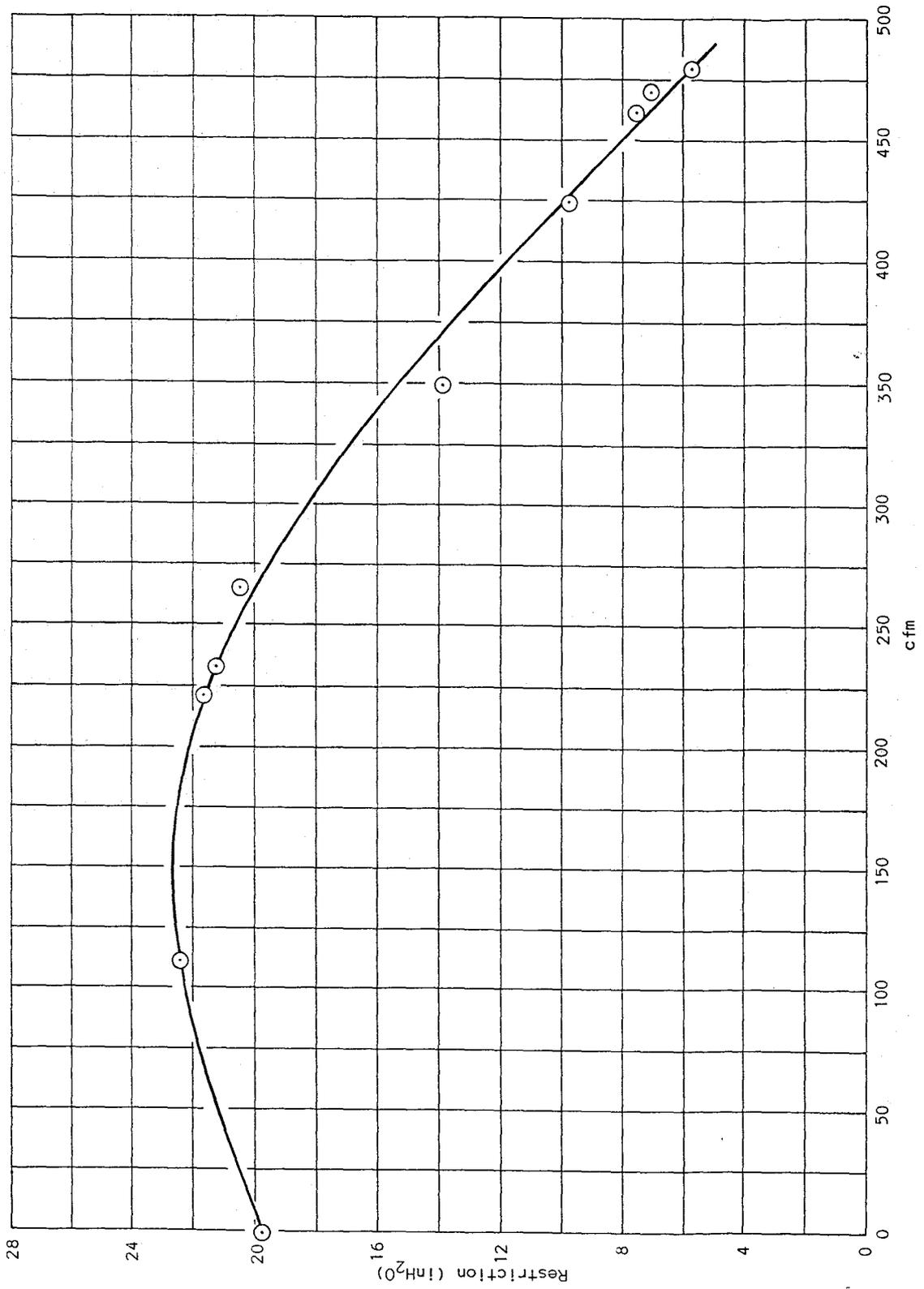


Figure 102. High Speed Fan Test Results

4.4.8 Fan Drive

The specific application and user preference will determine the fan drive unit. Most machines have electric and/or hydraulic power available. The most common electric power is 440 V or 550 V, 3 phase, 60 Hz. Should the machine be in a coal mine, the electric motor must be MSHA certified and explosion proof.

Previous users of CAC systems were contacted to determine if hydraulic or electric drive was preferred. The previous users contacted consisted of three coal mine applications and three noncoal mine applications. Two of the three coal mine applications preferred electric drive, and all three of the noncoal applications also preferred electric drive. Reasons given were that electric drive was easier to install, required less maintenance than hydraulics, and hydraulic circuits were limited on some machines.

Machine manufacturers were also contacted to obtain hydraulic circuit information relative to continuous miners. Hydraulic power on these machines is provided by a fixed displacement type pump which is used to control shear height, gathering head lift, conveyor lift and swing, etc. If a blower motor is added to this type of circuit, blower speed is affected whenever the other hydraulic components are used. The blower motor also adversely affects operation of the existing hydraulic components. To properly install a hydraulically driven blower requires a separate hydraulic circuit consisting of a pump to power the blower motor and the hydraulic components necessary for circuit safety and blower control. The hydraulic pump has to be driven by an existing electric motor in an area where space is limited. Machine layout can vary due to the original equipment manufacturer (OEM) and user changes, making installation of hydraulic units even more difficult. One machine OEM suggested using an electric drive due to the high maintenance requirements of hydraulic systems. An electrically driven blower could be installed on virtually any machine, where as a hydraulic unit would probably have to be designed specifically to each individual machine.

4.4.9 Noise Test

The CAC system was tested to determine the noise level to which the operator would be subjected while under the CAC generator. Noise level measurements were taken with a sound level meter at the ear position with CAC system airflow of 400 cfm. The CAC system consisted of the ECG11-2501 air cleaner, the high speed fan operating at 9,500 rpm, the air generator, and connecting flexible tubing. The noise level of this system was 101.5 dB(A), which indicated that noise attenuation was necessary to reduce the noise level to a maximum of 90 dB(A). An octave band analysis was performed which indicated the noise problem was in the 250 Hz to 1,000 Hz range. To control noise in these octave band ranges, a sound attenuator was required.

Three approaches were considered for controlling the noise. The first was to simply add a muffler to the outlet of the fan. A muffler could easily reduce the noise level; however, the muffler itself would be quite large, approximately 10 inches diameter by 30 inches long.

The second approach was to move the air cleaner from the inlet to the outlet of the fan and add a silencer to the fan inlet. This reduced the noise level to 88 dB(A). With this type of system, however, the fan would be moving dirty air. This could lead to balance problems due to dust accumulation on the fan wheel. The fan wheel could also be damaged by chunks of rock or coal.

The third approach is to enclose the motor and fan in an enclosure (figure 103). With this type of system, clean air from the air cleaner is ducted through the enclosure directly to the fan inlet. The fan discharges the air into the enclosure, which acts as a muffler. The air exits the enclosure via the 4 inch bell mouth to the air generator. The enclosure is also lined with 1 inch foam for maximum sound attenuation. A plywood enclosure was fabricated to test this concept, which resulted in noise levels being reduced to 87.5 dB(A) at 400 cfm. Besides attenuating fan noise, the enclosure protects the fan and motor assembly from rock falls, etc, making it more mine worthy. Pressure drop versus airflow of the enclosure is shown in figure 104.

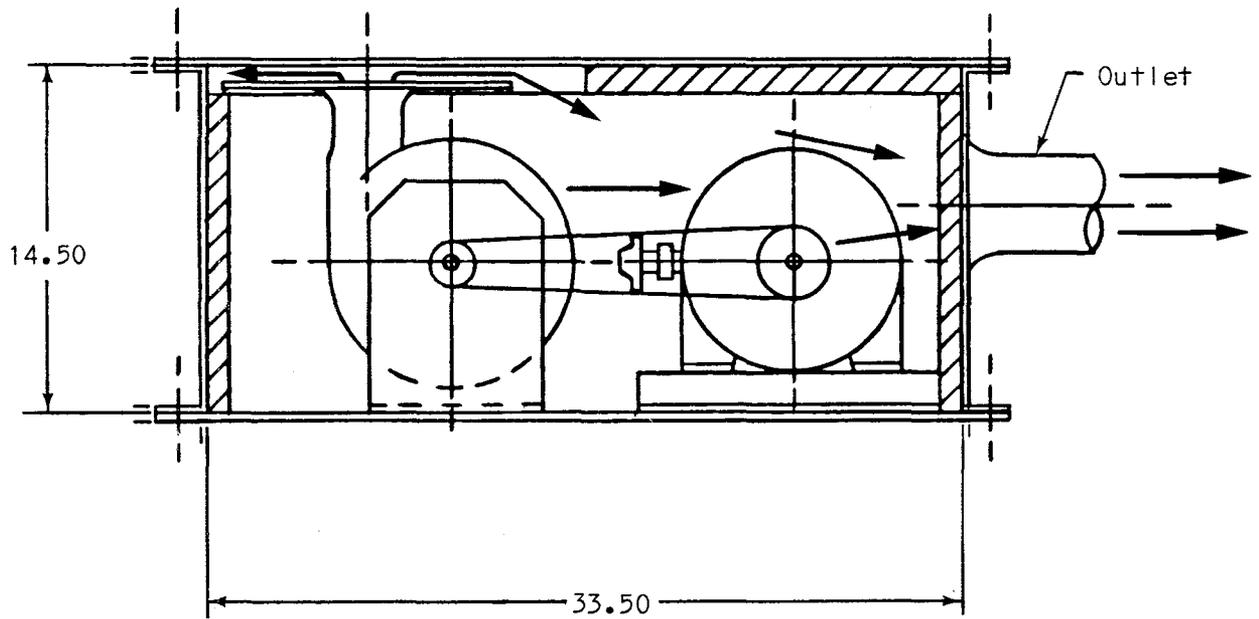
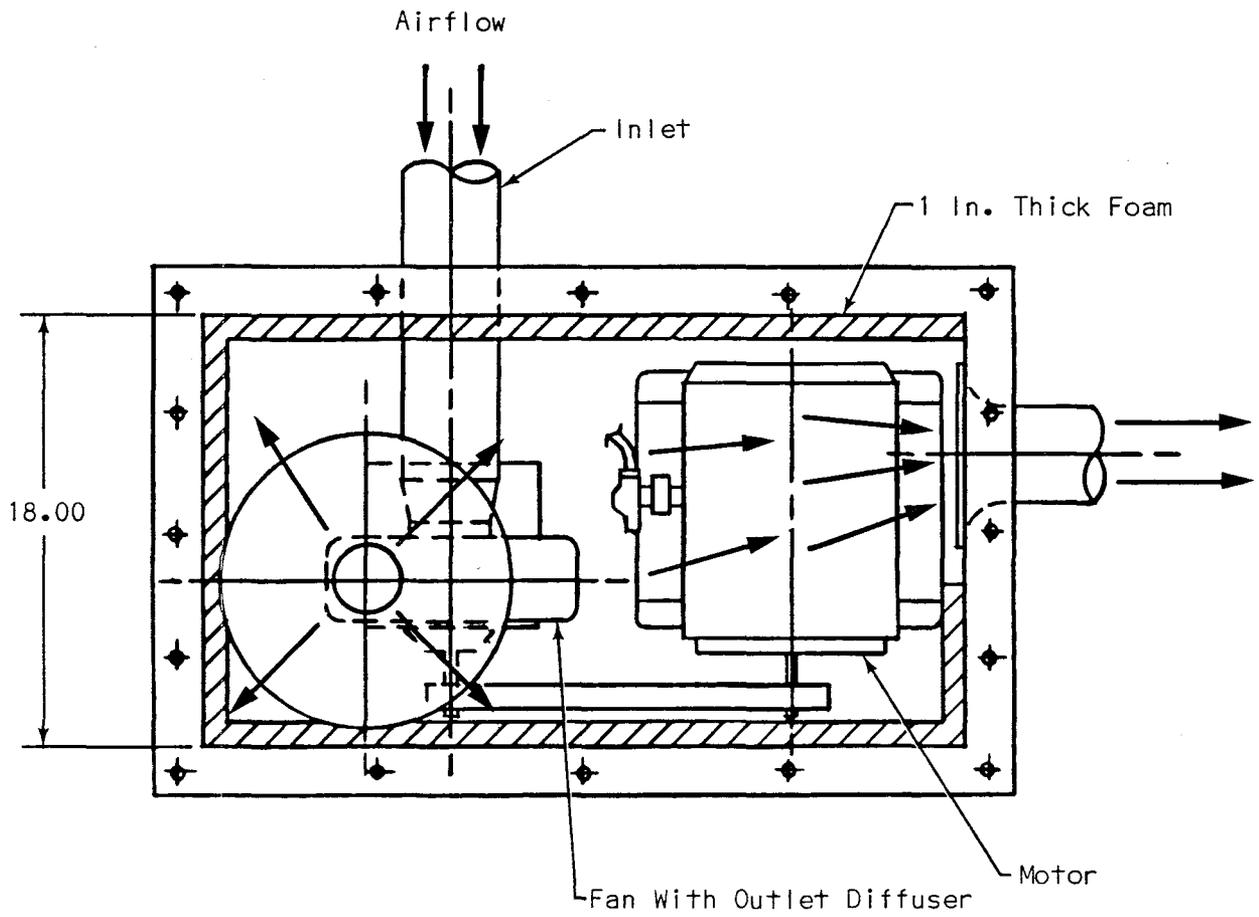


Figure 103. Fan/Motor Enclosure

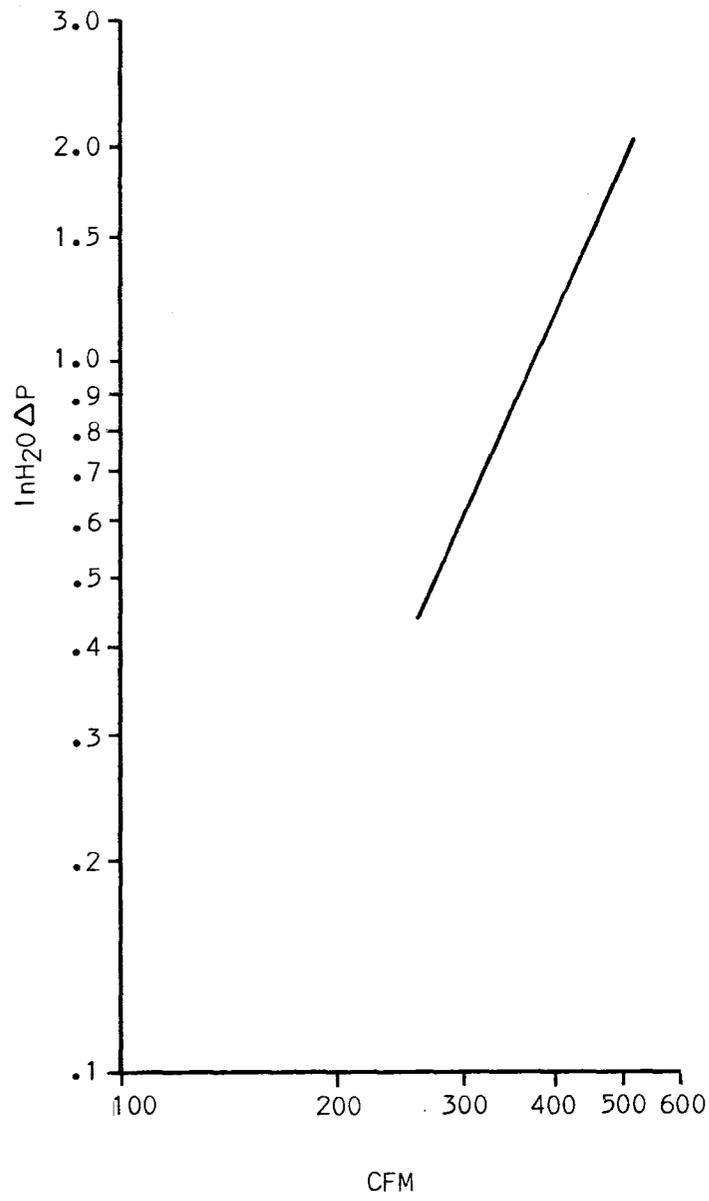


Figure 104. Fan/Motor Enclosure - Flow versus Pressure Drop

4.4.10 Heating

Based on the conclusions and recommendations in section 4.3.5, only heating of the CAC airflow was considered. Heating can be accomplished by the fan alone. Test results showed that the high speed fan increased air temperature 11.5°F at 400 cfm. With the fan and motor installed in the enclosure (figure 103), total air temperature increase was 15.5°F at 400 cfm. With the fan and motor installed in the enclosure and an ambient temperature of 60°F, CAC airflow would be 75.5°F at 400 cfm.

If further heating is required, a finned heat exchanger (figure 105) can be installed with the system. The heat exchanger uses hydraulic fluid from the return circuit (figure 106) to heat the air. Based on OEM information, hydraulic fluid temperature of a continuous miner ranges between 120°F to 150°F. Air temperature can be operator controlled via a flow control valve. This valve either increases or decreases fluid flow through the heat exchanger. A pressure relief valve can be added, as shown, to prevent excessive return line pressure and/or excessive heat exchanger pressure in the event the operator closes the flow control valve completely. Installation of a heat exchanger and the hydraulic controls required is dependent upon machine type. Airflow restriction at 400 cfm is approximately .10 inH₂O.

4.4.11 Service Indicator

The service indicator informs the operator when the filter needs to be replaced. The indicator (figure 107) has red and green highlights to emphasize the proper operating range (green zone) and to indicate when filter replacement becomes necessary (red zone).

The indicator, connected via tubing to the air generator inlet, is calibrated to correspond to the flow versus restriction curve of the air generator. As flow decreases due to filter restriction, the indicator needle will continue to drop until it reaches the red zone. This indicates that system airflow is at the minimum (200 cfm) necessary to provide adequate dust protection, and filter replacement or servicing is necessary. The gage can be mounted in any location convenient to the operator.

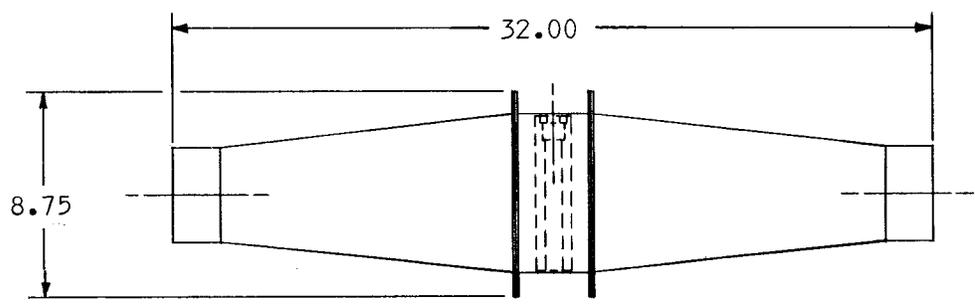
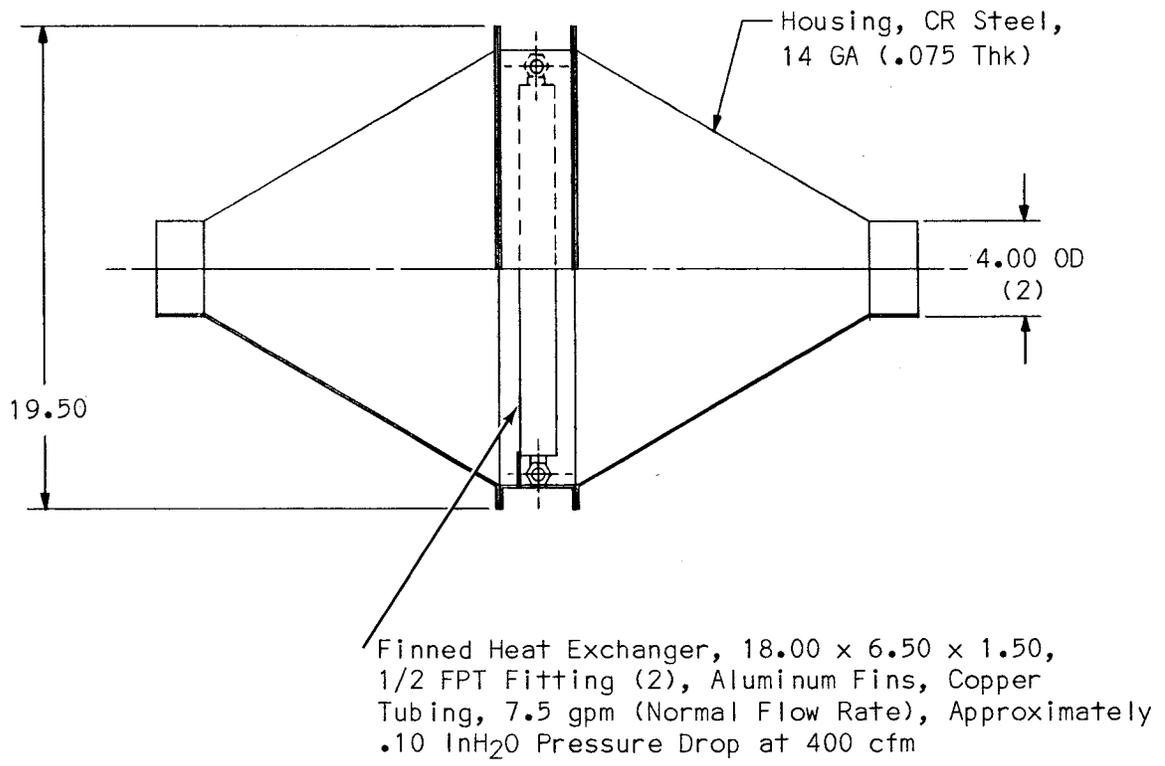


Figure 105. Heat Exchanger

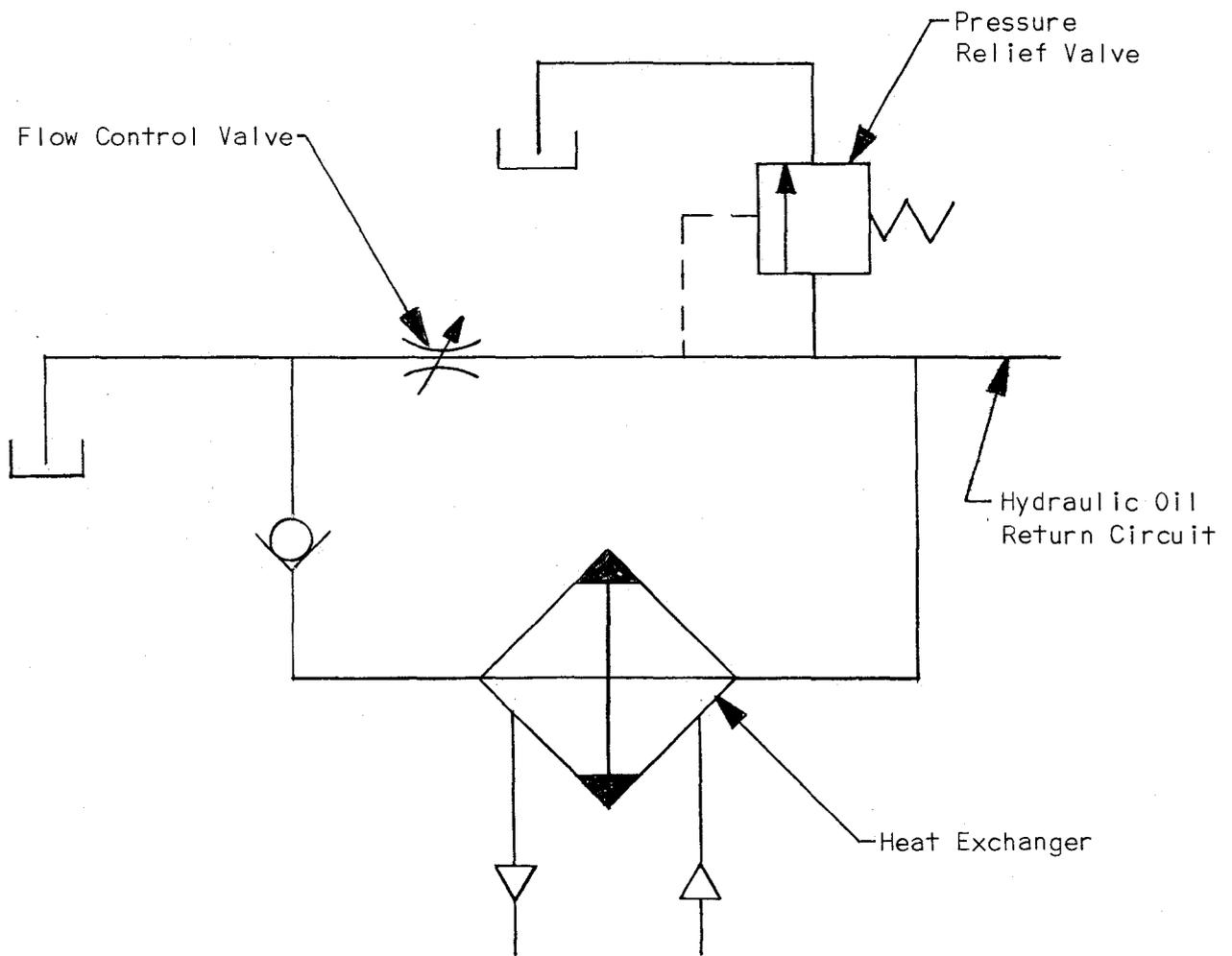


Figure 106. Heat Exchanger Installation Schematic

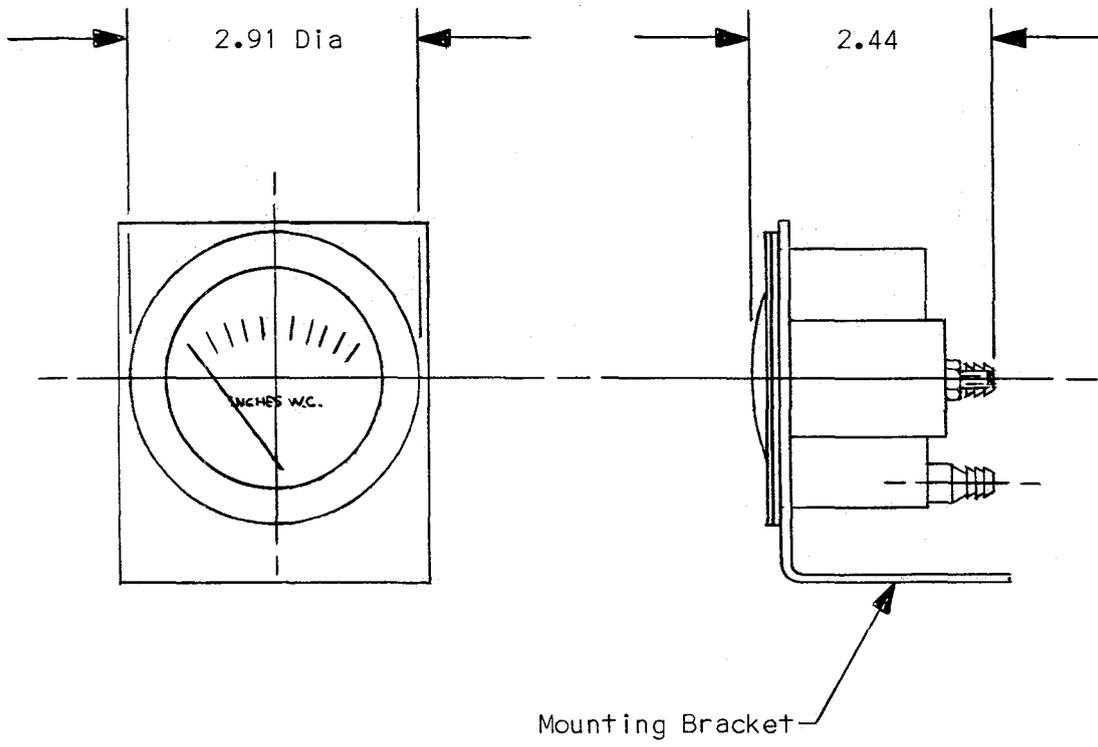


Figure 107. Service Indicator

4.4.12 Conclusions and Recommendations

4.4.12.1 Conclusions

a. Based on test results in section 4.4.5, the Coanda device failed to provide significant dust reduction for the operator leaning outside the cab area. The adjustable airflow nozzle actually raised dust levels under the air generator due to dust entrainment. Minimum system airflow should be 200 cfm to maintain operator protection.

b. Based on size, cost, initial restriction, filter life, and mine worthiness, the ECG11-2501 air cleaner is best suited for use with the retrofit CAC system.

c. The high speed fan is best suited for use with the retrofit CAC system because of its ability to furnish adequate airflow against system restriction.

d. Emphasis should be placed on an electric motor fan drive based on previous user preference, ease of installation, and low maintenance requirements.

e. Heating of the air by the fan alone may be sufficient for operator comfort. If more heating is required, a finned heat exchanger can be added to the system.

f. Noise attenuation is required to reduce the noise level to a maximum of 90 dB(A).

4.4.12.2 Recommendations

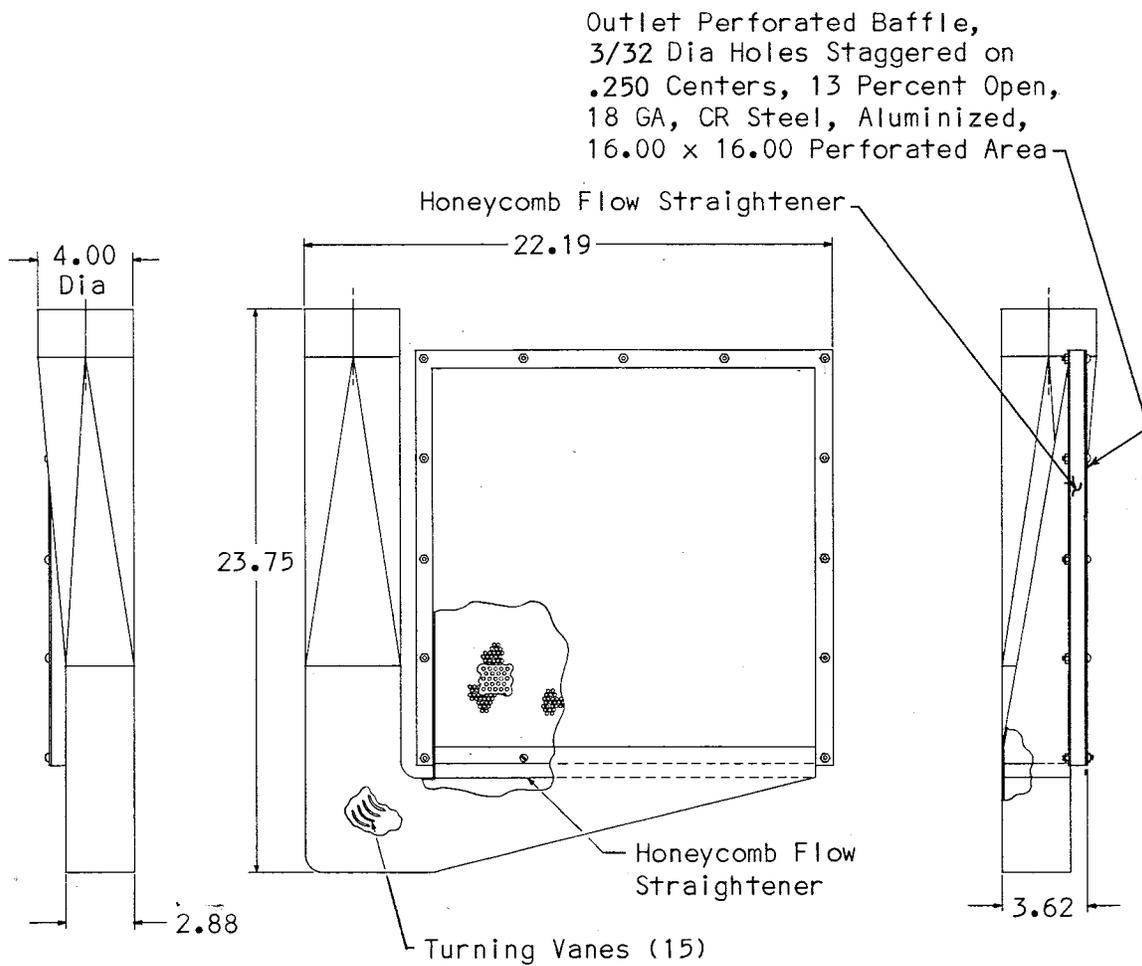
The retrofit CAC system should consist of the following items:

- Air generator (figure 108)
- High speed fan driven at 9,500 rpm by a 5 hp electric motor (voltage to be determined by user), both enclosed (figure 103) to control noise and make system more mine worthy
- ECG11-2501 air cleaner installed on inlet side of fan
- Service indicator described in section 4.4.11
- Heat exchanger (optional) described in section 4.4.10 (figure 105), if required by user
- 4 inch ID flexible tubing, length dependent upon installation

Total system restriction, with 15 feet of flexible tubing and without the heat exchanger, is shown in figure 109 along with the fan curve. Initial system airflow is 425 cfm with 12.07 inches of filter restriction allowable before the minimum system airflow of 200 cfm is reached. The retrofit CAC system is shown in figure 110.

4.4.13 Improved Underground Retrofit CAC Field Evaluation

The retrofit CAC system as shown in figure 110, without the optional heat exchanger, was shipped to its respective field test site for subsequent field evaluation by the Bureau of Mines. An Installation/Operation manual was also completed and sent to the test site.



NOTE:

Honeycomb Material - 5052 aluminum,
.001 thick foil, 1/8 cell, .625 thick
with corrosion resistant treatment.

Figure 108. Air Generator

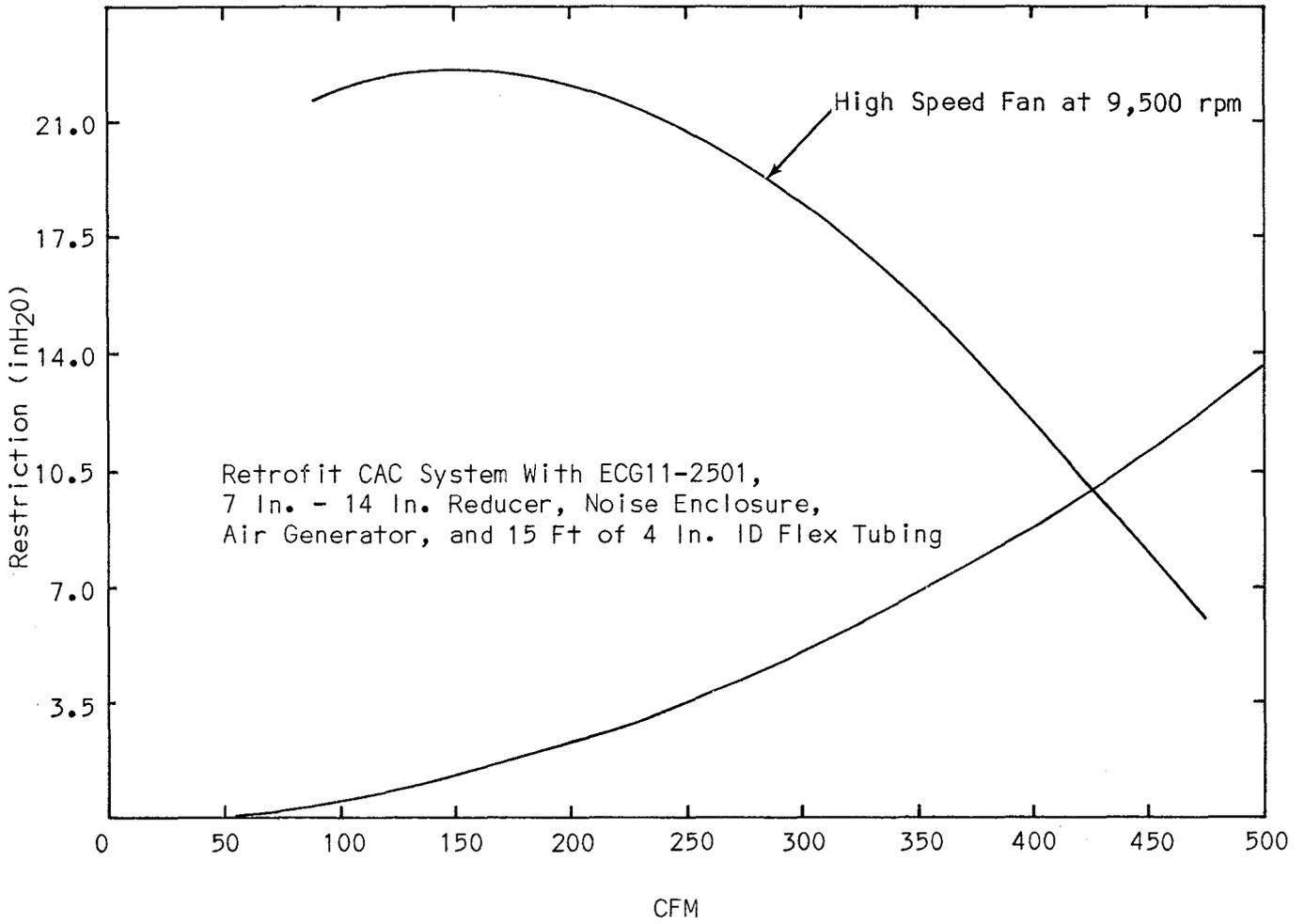
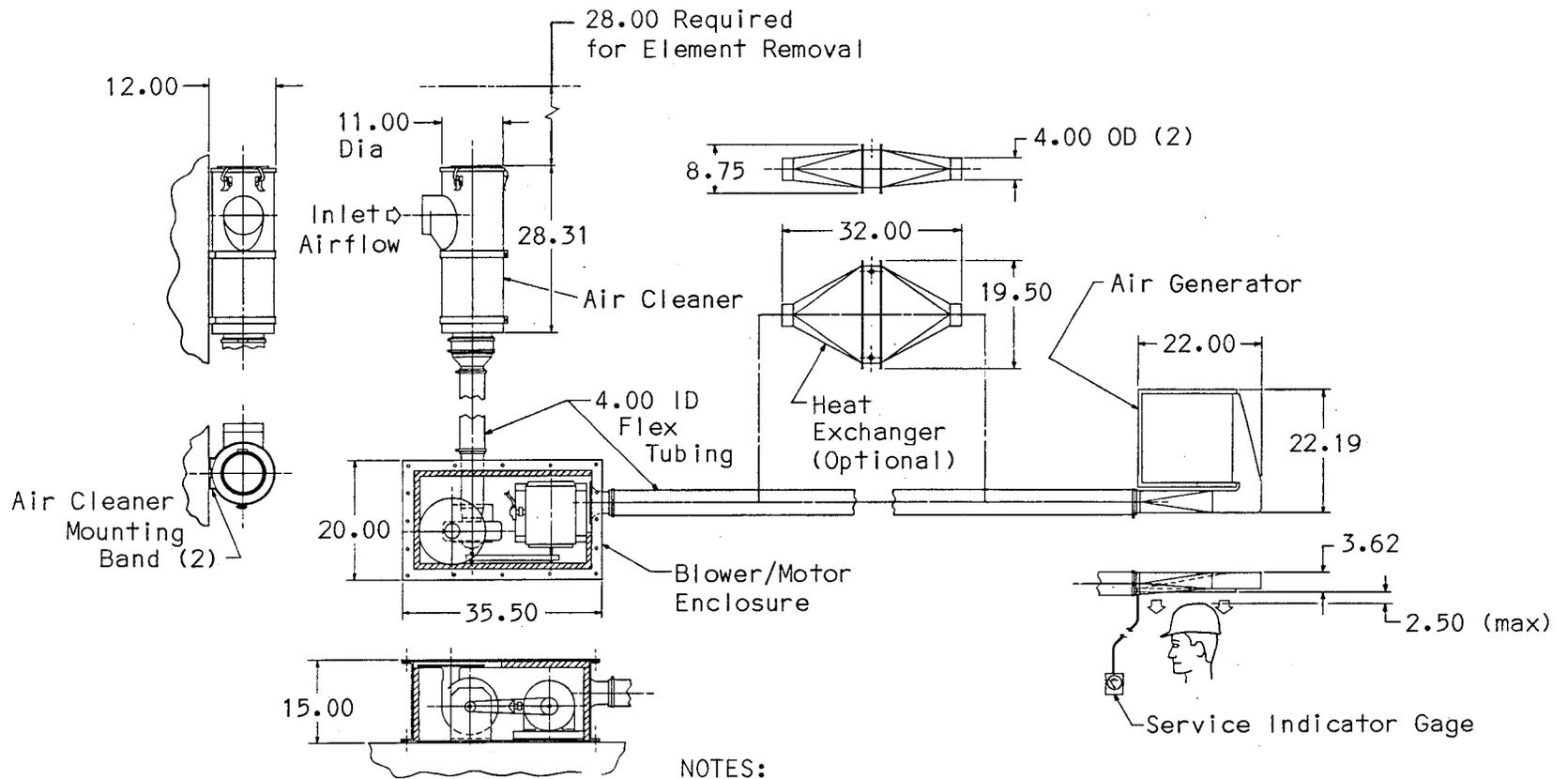


Figure 109. Retrofit CAC System Operating Curve

Figure 110. Retrofit CAC System



NOTES:

1. Install air generator to FOPS structure, centered over operator.
2. Air cleaner mounting position relative to blower/motor enclosure optional.

5.0 EVALUATION AND DESIGN OF GAS PURIFICATION MODULE

To remove gas contaminant delivered by a canopy air curtain system used on dieselized equipment underground, a gas purification module was investigated.

The application of a gas purification module would increase the utility of the canopy air curtain system and provide increased operator protection.

5.1 Evaluation of Gas Filter

Out of the dozen or so gases that are a by-product of diesel combustion, nine are covered under Federal Regulation.* These gases are oxides of nitrogen (NO, NO₂, NO₃), carbon monoxide (CO), carbon dioxide (CO₂), sulphur dioxide (SO₂), sulphuric acid (H₂SO₄), formaldehydes, and benzene. Of these nine gases, NO, NO₂, SO₂, organic gases, and odors were considered for removal from the air flowing through the CAC.

There are three methods of removing gaseous constituents from the airflow: gases may be absorbed in a liquid, adsorbed on a solid surface, or changed chemically into a harmless gas. Chemical changes usually involve the combustion of the organic material, either directly or with the assistance of a catalyst. The basic mechanism in all of these methods is the diffusion of the particular gas either to the surface of an absorbing liquid, an adsorbing solid, a catalyst, or the reaction zone of a chemical reaction.*

Of the three methods, adsorption of the gas onto a solid surface appears to be the most adaptable method of gas filtration for use on the CAC system.

*American Conference of Governmental Industrial Hygienists", Threshold Limit Values for Chemical Substances and Physical Agents in Workroom Environment with Intended Changes for 1981".

*Industrial Gas Cleaning, W. Straus, Pergamon Press, 1966.

The use of a liquid as the gas filter (absorbtion) as compared to a solid (adsorbtion) would be more expensive to service, harder to service, provide an opportunity for leaks in the system, and limit mounting locations on the mine equipment.

In general, chemically changing the gas can be done by combining the gas with a catalyst. By adding heat to this combination a greater amount of the gas in question can be chemically changed. Without adding heat, you not only get less gas changed but also add heat to the airflow due to the inherent exothermic reaction. In both cases heat is added to the system. How this affects the CAC system will be investigated.

The gas filter will use either the adsorbing method (solid) or a combination of an adsorbing solid and a catalyst. Commerically available materials such as Purafil odoroxidant, Calgon activated carbon, MSA hopcalite, and soda lime will be evaluated in conjunction with the CAC system.

A method of determining the life of the gas filter is required for effective protection. This method could be some type of monitor in the cab, such as stain tubes or one of the many portable alarms/monitors available, or simply a scheduled replacement of the filter.

5.2 Gas Purification Module

The design of a gas purification module to remove the gases previously mentioned posed two challenges:

a. Develop a filter that will effectively reduce the gases to safe levels while maintaining a normal maintenance interval for servicing the system.

b. Develop a method of monitoring the effectiveness of the filter to enable mine personnel to replace the filter before the gas levels are above safe levels.

This is, of course, all to be done with a minimum impact on the total cost of the system.

The first challenge requires that the filter not only be effective in filtering the gases, but it also must be cost effective and must not appreciably reduce the performance of the particle filter. There are four basic methods that can be employed to remove gaseous contaminants:

- Ventilation
- Wet scrubber
- Combustion
- Sorbents

Ventilation is assumed to be in operation at the mine. The purpose of the gas filter is to protect the operator during those times when, for various reasons, the mine ventilation is not reducing the gases to the compliance levels.

Wet scrubbing devices are gas-liquid absorption units which are generally used for removing vapors before they are discharged to the atmosphere. (An example is the scrubbers used on the exhaust side of a diesel engine in an underground mine application.) Wet scrubbing devices are large, expensive, and require more maintenance than can be expected on the CAC system.

The combustion process can be accomplished by either catalytic oxidation (exhaust system used on the modern American automobile) or thermal oxidation (used in industrial parts). Reaction temperatures for catalytic oxidation range between 600°F and 900°F. Reaction temperatures for thermal oxidation range between 1,200°F and 1,500°F. The combustion process will convert HC, CO, H₂, and O₃ into H₂O, CO₂ and O₂, but it has no effect on filtering NO, NO₂, and SO₂. In fact, the combustion process can produce NO_x and SO_x when provided an environment of nitrogenated, sulfurated, and/or halogenated hydrocarbons.

Sorbents are dry type materials that will either adsorb (gas molecules are physically held on to the sorbent surface), absorb, or both. One of the most common sorbents is activated charcoal which is used to filter organic vapors such as CCL₄, CS₂, and COH₆. A desirable property of a sorbent is a large surface area to mass ratio (charcoal has a ratio of 600 square meter per gram). Other types of sorbents are soda lime which filters HCL, CO, and CO₂ and silica gel which filters NH₃.

Based on the above information, the method chosen as the most likley system for gas filtering on a CAC was the sorbent method. Table 16 gives the threshold limit value (TLVs) for the gases.

TABLE 16. Threshold Limit Values (TLVS) for gases

Gas	Time Weighted Average (TWA)		Short Term Exposure Level (STEL)	
	ppm	mg/m ³	ppm	mg/m ³
NO (Nitric Oxide)	25	30	35	45
NO ₂ (Nitrogen Dioxide)	3	6	5	10
SO ₂ (Sulfur Dioxide)	2	5	5	10

Three prepacked gas filter vendors were contacted. The following response was received. The first vendor responded with a complete system package design. The gas purification cartridge is made up of three separate media: activated charcoal, Purafil, and a particle filter. The charcoal removes the organic vapors. Efficiency information on the charcoal is not available. The Purafil is a sorbent that removes the NO, NO₂, and SO₂. Based on data published by Purafil, the efficiency of the Purafil sorbent on NO and SO₂ is 68 percent and 95 percent, respectively. This is at 500 cfm on a concentration of 5 ppm. There is no published data on NO₂. The particle filter traps solids that come from either the charcoal or Purafil. The overall package size is 24 inches

wide by 24 inches high by 46 inches long. The package cost is \$2,560. The charcoal and Purafil weigh 64 pounds and 100 pounds, respectively. Replacement cost of the charcoal and Purafil is \$189 and \$289, respectively. The particle filter cost is \$20. Initial pressure drop is about 1.0 inH₂O. All three filters are housed in a stainless steel side access arrangement.

The second vendor contacted responded by indicating that they did not have anything sufficient to do the job. No further information was received from them.

The third vendor sent some information on a sorbent product. The information was inadequate, and we were directed to contact the manufacturer.

Based on the above information, Donaldson Company is of the opinion that any type of gas filter designed to protect the machine operator from these gases would be large, heavy, and expensive compared to any expectations. Under ideal conditions, the effectiveness of the unit may be marginal and, if humidity is a factor, the performance of the unit would be reduced. Testing of a prototype would be expensive and would only confirm that off-the-shelf products are inadequate.

Monitoring the effectiveness of the gas filter on a routine basis to enable mine personnel to service the unit poses some problems. The sorbent materials change color as they absorb more gas. This color change occurs quickly on the surface of the material and is not a good indicator of servicing. When the color has changed throughout the material, it can still be 75 percent effective. Measuring the gas levels downstream of the filters requires either expensive equipment that is too large for routine use or a badge type monitor for measuring personnel exposure to the gases in question. The problem with badges is the need for some type of laboratory process to extract the exposure level data. The implications are obvious.

Based on the above conclusion, Donaldson Company recommended that the gas filter tasks be eliminated from the work effort on the contract. The contract was modified 7 September 1984 to eliminate further gas filtration effort.

6.0 PARTIALLY ENCLOSED CAB CANOPY AIR CURTAIN

6.1 Evaluation of Parameters for Partially Enclosed Cab Applications

Design parameters considered for the CAC included ambient temperature and humidity, type of dust and concentration, type of machine, available area around the operator, and kind of power available to operate the system.

For the purposes of this contract the term partially enclosed cab was defined as any cab with some type of structure mounted over and/or around the cab that may not entirely enclose the operator. This included a FOPS/ROPS or an enclosed cab with open windows or doors, poor seals, or a cab with relatively good sealing capability.

The type of dust that the CAC filter will see will be a combination of dust from the material being mined and overburden. Dust measurements taken by Donaldson personnel** in various mines indicate a dust concentration range of 2.338 to 89.671 mg/m³ (respirable). Table 17 gives specific information on the mine dust sample.

Table 17. Dust Samples from Equipment in Various Surface Mines

		Dust Concentration (mg/m ³)		Mean Particle Size (microns)	
Mine	Vehicle	Total (Avg)	Respirable	Total (Avg)	Respirable
Coal	Loader	85.686*	89.671	10.00	2.80
Metal	Dozer	10.076	9.361	4.85	5.70
Metal	Scraper	5.027*	2.338	5.25	2.90
Coal	Blast Hole Drill	52.686	87.904	3.42	2.40

*Single Reading

**From "Engineering Evaluation of Environmental Cabs for Control of Dust and Other Health and Safety Factors", BOM Contract J0308018.

The CAC system will be exposed to outside ambient conditions and will be required to provide not only dust protection but also protection from temperature extremes (below freezing to 100+°F).

Since the cab area for most surface mine equipment is larger than in underground mine machines, the area of protection is also larger. This requires a larger overall package. Fortunately, on most surface equipment there is more room for the CAC components.

Power on most surface mine equipment can be either electric, hydraulic, or mechanical.

The electric power available is usually 24 volt dc. Most surface equipment uses hydraulic power for steering; operating shovels, buckets, blades, or rippers; and for raising dump boxes. The hydraulic flow (gpm) and pressure available from these systems vary widely with the size and type of machine. On some equipment, mechanical power can be obtained from power-take-offs (PTO) or from belt drive sheaves.

6.2 Canopy Air Curtain Designs for Partially Enclosed Cabs

With some modifications the CAC concepts for the underground application can be used for the partially enclosed system. A detailed description of each component follows.

6.2.1 Air Generator

The air generator (figure 111) would be larger, and would direct additional air towards the front rather than to the side. This would provide clean air to the operator should he move his seat forward. The operator would also have some control over the amount and direction of air from the generator through the use of a control package and/or a small air vent similar to the one proposed for the underground air generator (section 4.4.2).

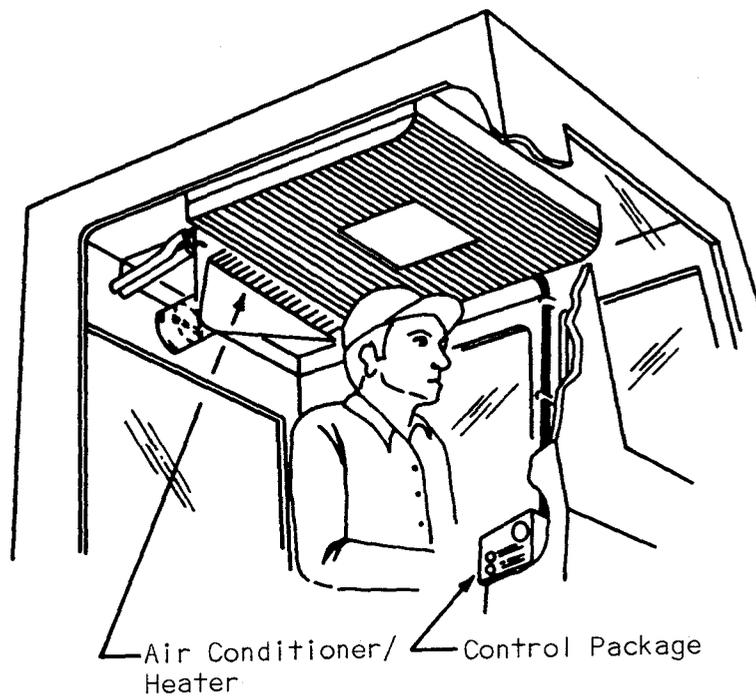


Figure 111. Air Generator for Partially Enclosed Cab

6.2.2 Air Cleaner

The air cleaners used in the underground application can also be used for this system. Since this application will primarily be used on surface equipment, which allows for more room, an additional air cleaner design was considered. This air cleaner (figure 112) uses compressed air to backflush the paper element. The backflushing would occur at least once a shift. Field tests of this type of self-cleaning air cleaner indicate that diesel particulate has no adverse effect on filter life. The other four air cleaners under evaluation, when exposed to diesel particulate, would have a reduction in filter life ranging from a factor of 1/2 to 1/10 the life under normal conditions depending on the concentration of diesel particulate.

The self-cleaning air cleaner concept would initially be more expensive than the other designs; however, under certain circumstances it might extend filter life to the point that it would be more cost effective. An estimated cost comparison of the various air cleaners under some of these conditions is shown in figures 113 and 114. These figures are based on 400 cfm airflow, initial restrictions found in figure 75, and dust concentrations of 50 mg/m³ or 10 mg/m³ with and without diesel particulate. Manhour cost required by the mine for servicing the air cleaner is not included.

6.2.3 Fan

The type of fans considered for the partially enclosed cab application were the same as for the underground application. Information can be found in section 4.3.1.

6.2.4 Drive Unit

The types of drive unit considered for the partially enclosed cab application are the same as for the underground application, with the exception of two additional units. Reference section 4.3.2.

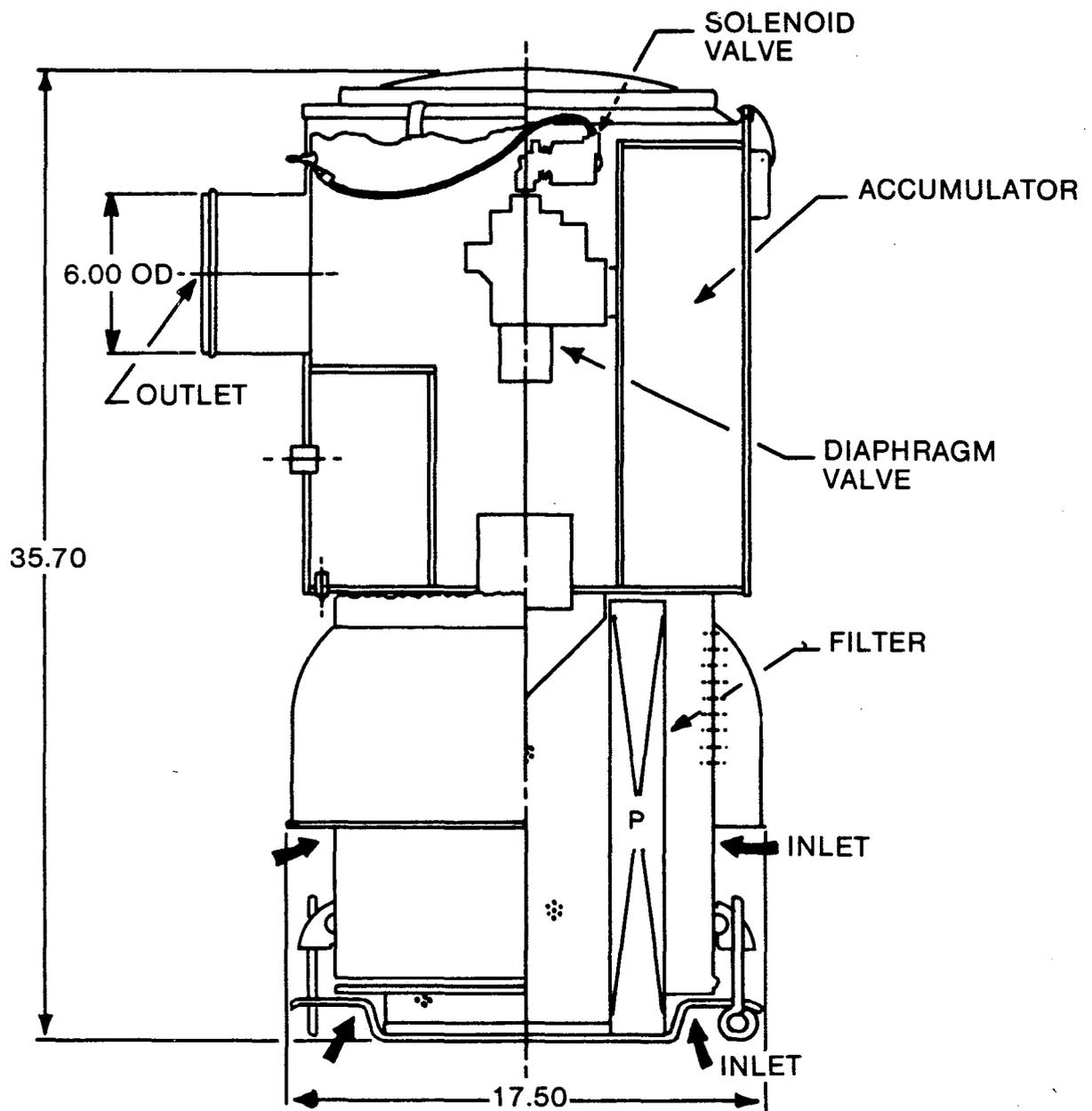


Figure 112. Self-Cleaning Air Cleaner

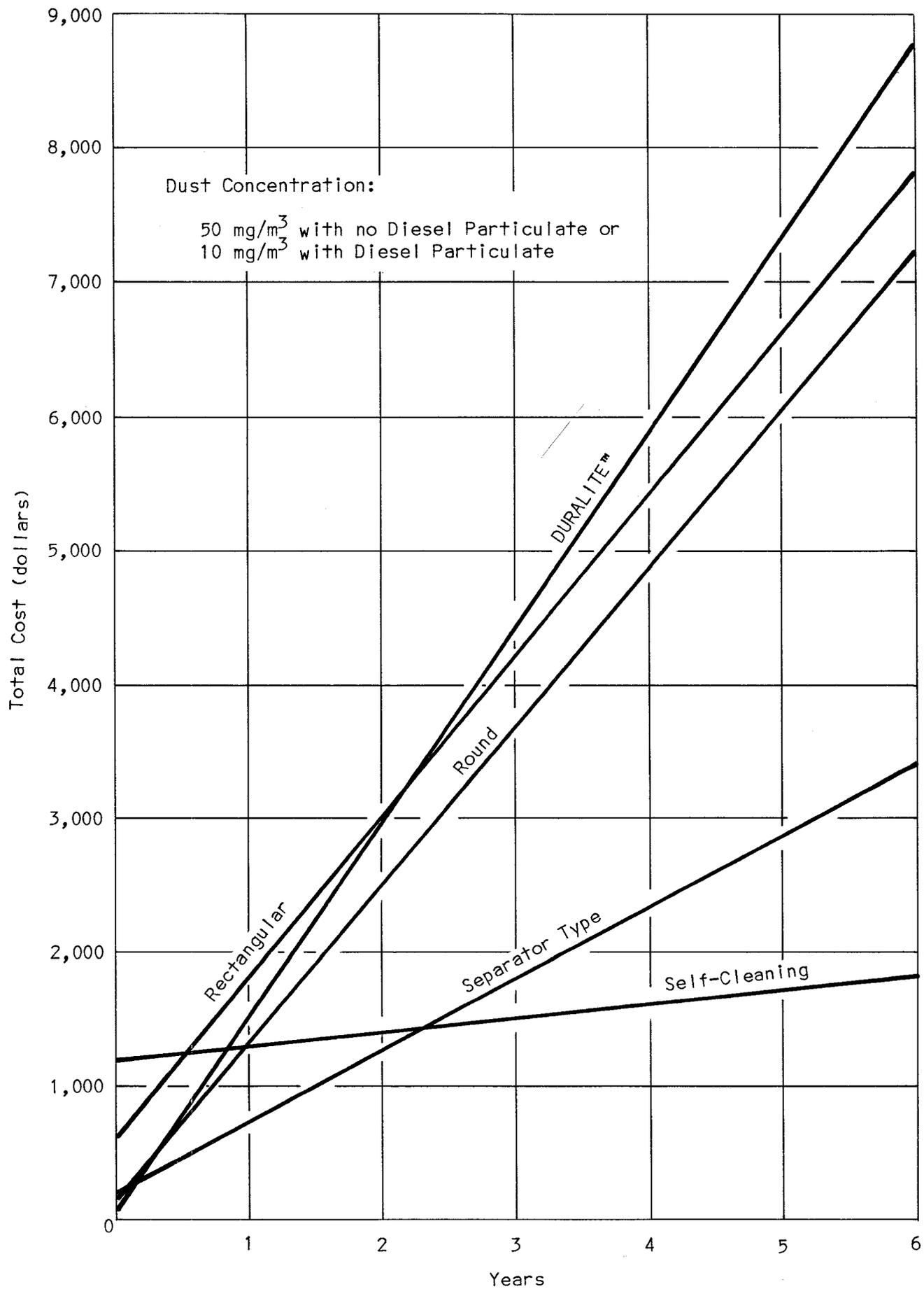


Figure 113. Estimated Air Cleaner Cost versus Years

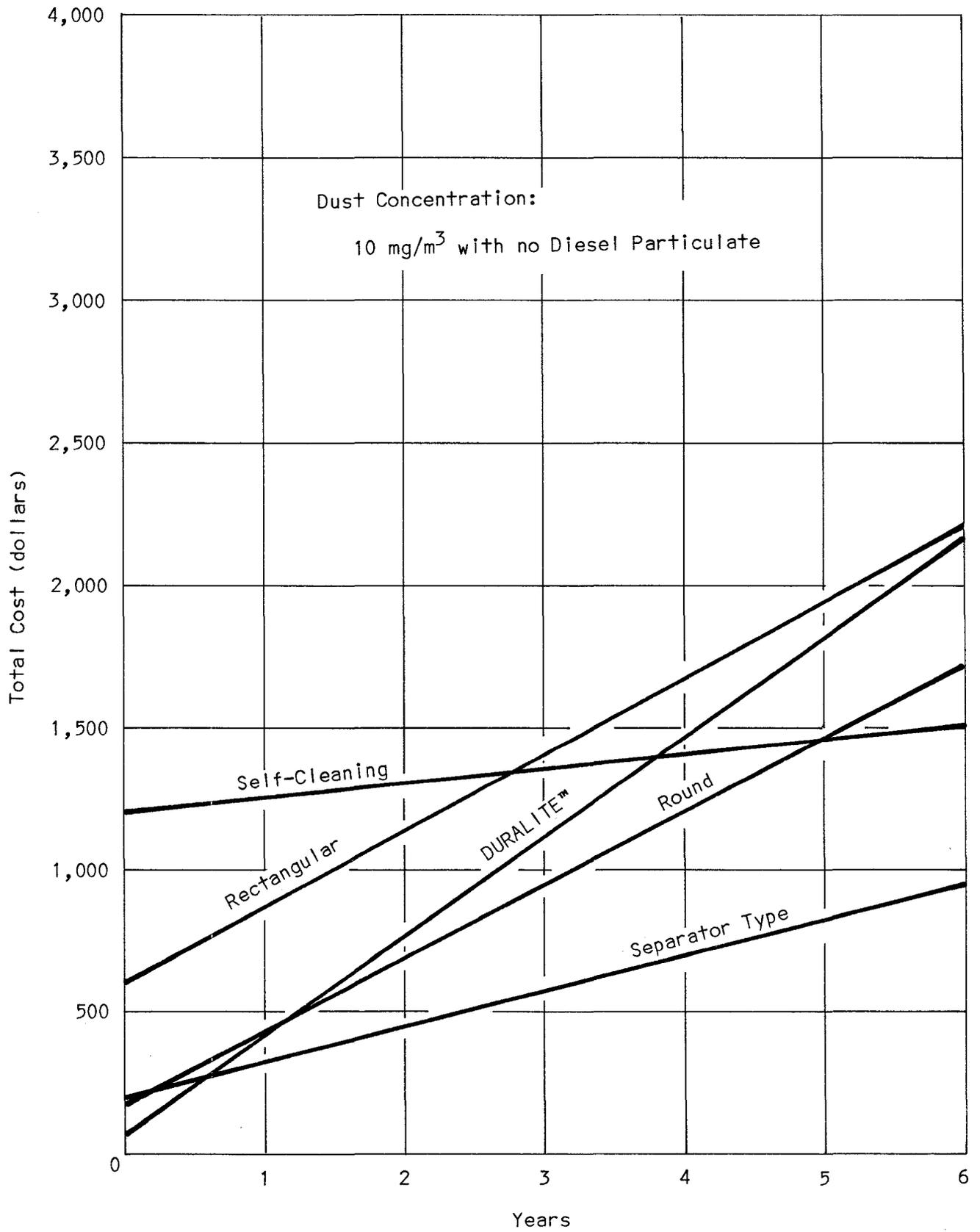


Figure 114. Estimated Air Cleaner Cost versus Years

The additional units are a 24 volt dc motor and a mechanically driven generator (alternator) supplying power to a compatible motor. Amperage draw for a 24 volt system would range from 31 amps (1 hp) to 155 amps (5 hp). An option to the 24 volt system would be a mechanically driven generator that would produce output voltages high enough to reduce the amp draw.

6.3 Evaluation of Air Conditioning/Heating Requirements

For a cab on a piece of surface mine equipment, both air conditioning and heating is required. The temperature swing that these units must work under can range from well below 32°F to 100+°F.

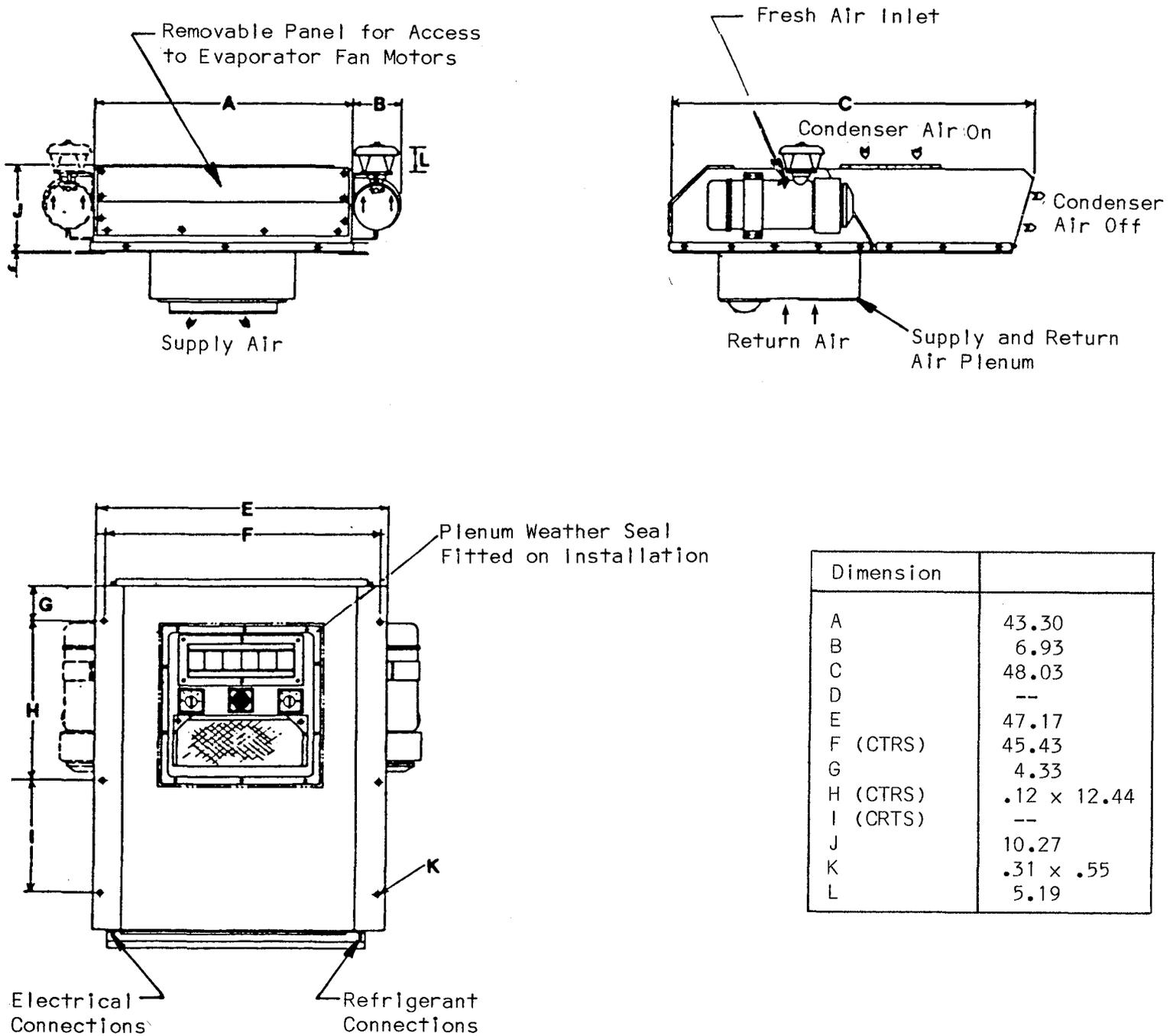
Several prepackaged air conditioning/heating units are available for mining and heavy construction equipment (figure 115). These units include the air conditioning components, heating components, filter, and fans. Some units do not supply a compressor for the air conditioner. Most of these units use the engine cooling system as the source of energy for heating. The cooling capacity ranges from 10,000 to 24,000 Btu/hour. Heating capacities range from 7,000 to 30,000 Btu/hour. The heating and air conditioning components from these types of units can be used to make up the heating/cooling package for the CAC system. It would be difficult to incorporate an entire prepackaged unit into the CAC system.

6.3.1 Air Conditioning

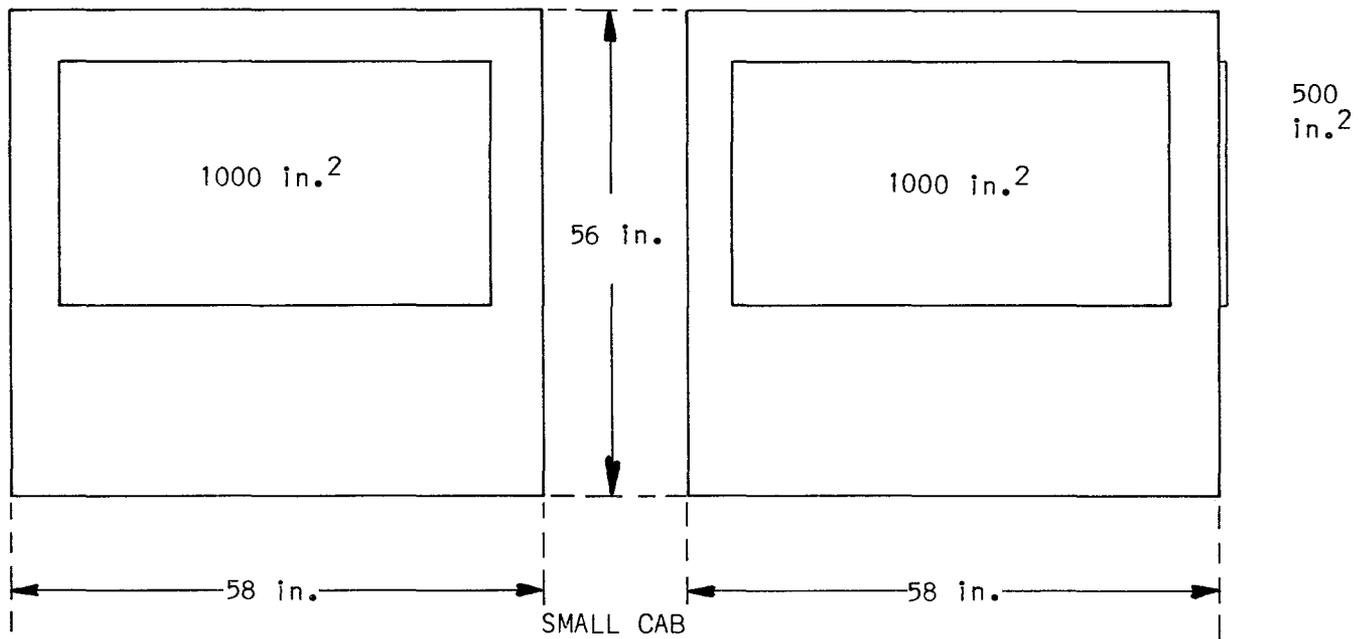
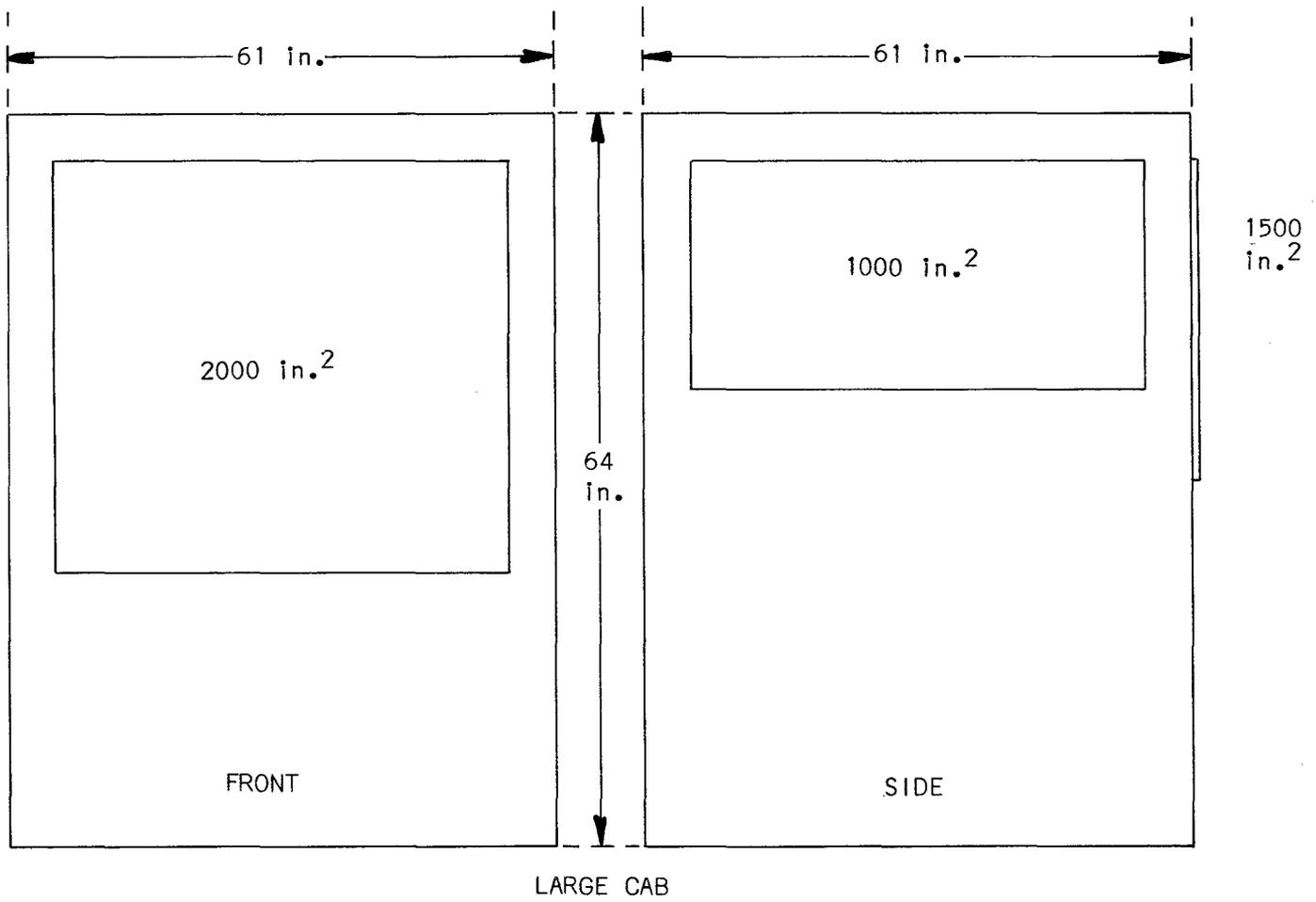
The cooling load requirement is approximately 28,500 Btu/hour for a small cab and 32,000 Btu/hour for a large cab. The cooling loads are based on cab dimensions found in figure 116, and on equations and tables from "ASHRAE Handbook 1981 Fundamentals", published by the American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. The design parameters used in the equations and tables are as follows:

- Outside temperature - 100°F
- Inside temperature - 75°F

Figure 115. Prepackaged Air Conditioning/Heating Unit.



Dimension	
A	43.30
B	6.93
C	48.03
D	--
E	47.17
F (CTRS)	45.43
G	4.33
H (CTRS)	.12 x 12.44
I (CRTS)	--
J	10.27
K	.31 x .55
L	5.19



Housing Material = 1/8 in. Sheet Metal

Figure 116. Cab Dimensions

- Humidity ratio - .0335 lb/lb dry air
- Ventilation airflow - 400 cfm
- Engine power - 500 hp

6.3.2 Heating

The heating load requirement is approximately 11,300 Btu/hour for both the small and large cab. The heating loads are based on cab dimensions found in figure 116 and on equations and tables found in "ASHRAE handbook 1981 Fundamentals", published by the American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. The design parameters used in the equations and tables are as follows:

- Outside temperature - 0°F
- Inside temperature - 60°F
- Humidity ratio - .0007875 Btu/lb (dry air)
- Ventilation airflow - 400 cfm
- Engine power - 500 hp

*American Conference of Governmental Industrial Hygienists", Threshold Limit Values for Chemical Substances and Physical Agents in Workroom Environment with Intended Changes for 1981".

6.4 Conclusions and Recommendations

6.4.1 Conclusions

- Respirable dust concentration in surface mine environments ranges between 2.338 to 89.671 mg/m³ (table 17)
- Total dust concentration in surface mine environments ranges between 5.027 to 85.686 mg/m³ (table 17)
- The air cleaners for the underground CAC can also be used for the partially enclosed cab
- A self-cleaning air cleaner can also be used for the partially enclosed cab (reference section 6.2.2 and figure 112)
- Air conditioning and heating is required for the partially enclosed cab CAC

6.4.2 Recommendations

- Use the air cleaner evaluation data recommended in section 4.3.3 for the partially enclosed CAC system
- Since there is more space available on the types of equipment that utilize partially enclosed cabs, evaluate one additional air cleaner design outlined in 6.2.2 (figure 112)
- Use the fan evaluation data recommended in section 4.3.1 for the partially enclosed CAC system
- Build and lab test the air generator described in section 6.2.1 for pressure drop/airflow and airflow distribution

6.5 Machine and Power Design Evaluation

The application of the CAC system on mobile equipment required an investigation into power availability. Two sources of power on mobile mining equipment are available for powering the CAC: the engine and the electrical system. Standard electrical systems on off-highway machinery are 24 V dc and are dedicated to operating machine lights and other accessories. Electricity is commonly used to run most air conditioner fans while the engine powers the compressor. Commercial air conditioners typically use from 16 amperes to 35 amperes to operate fans. However, due to the addition of the canopy air generator and an efficient filter, more amperage is required to operate a higher performance fan than the 24 V dc system can deliver. (Refer to table 18 for a listing of available 24 V dc motors.) Amperage requirements vary from 38 amperes to 90 amperes; only motors up to 2-1/2 hp are available at 24 V dc, and all exceed the available amperage. This information led to an investigation into both ac and dc power generation for operating the CAC system.

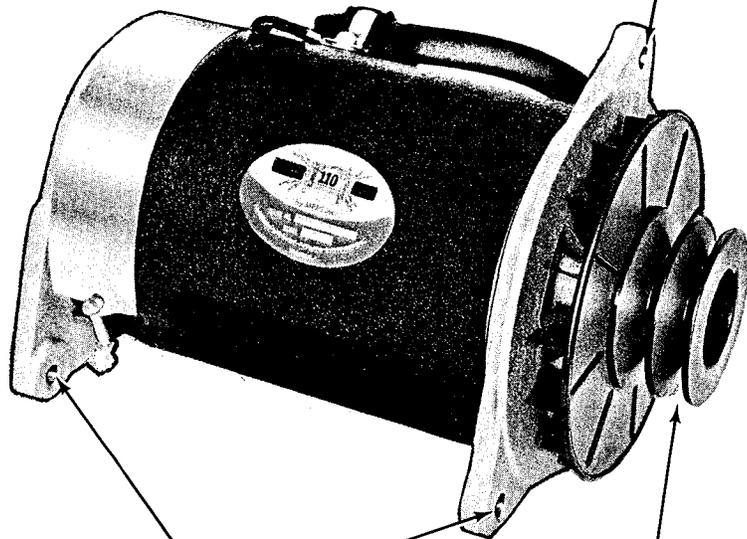
The investigation was conducted in three phases. First, a general search was made to locate as many and varied generator products as available. The second phase involved the analysis of these available products. The final phase consisted of contacting vendors to discuss the application and receive quotes.

Two companies were contacted regarding two different types of electrical generators. The first product, similar in construction to an automobile alternator, was designed to be connected and belt driven off an automobile engine (figure 117). The generator would produce 115 V, single phase, electricity capable of operating up to a 1 hp motor. Referring to the fan discussion in section 4.3.1, the blower combination used in the CAC would require from 1.5 hp to 5.0 hp. Discussions with the vendor indicated that a similar product for these greater horsepower requirements was not available. This led to discussions with a manufacturer of larger commercial generators and generator sets.

Table 18. 24 V dc Motors

Volts	Hp	RPM	Amperes	In./Lb	Encl	Length (in.)	Duty	Weight (lbs)
24	1	1,200	38	53	Open	11-3/8	Cont	40
24	1	1,700	39	37	Open	9-3/8	Cont	25
24	1-1/2	2,800	59	34	Open	9-3/8	Cont	25
24	2	1,700	75	74	Open	12-3/8	Cont	48
24	2	2,900	75	44	Open	11-3/8	Cont	40
24	2-1/2	3,600	90	44	Open	12-3/8	Cont	48

Mounting Bracket Hole for Adjusting Belt Tension



Engine Mounting Bracket Holes

Sheaves for Belt Drive Connection to Vehicle Engine

Figure 117. Automotive-Style AC Generator

At this time, dc motors were also investigated and vendors contacted. Quotes for a dc and an ac electrical system were received. Costs for a dc system are as follows:

2 hp motor	\$1,408
Controls	4,714
Generator	<u>1,670</u>
Total	\$7,792

Costs for an ac electrical system:

1.5 hp motor	\$ 70
Generator and controls	<u>1,675</u>
Total	\$1,745

The total costs do not reflect the costs associated with the design and fabrication of all hardware necessary to mount equipment to the engine. This varies for each machine and engine and adds considerable time and cost. A major concern now is the availability of space to install the generator equipment.

Three trips were taken to visit both the manufacturers and users of engine driven mobile mining equipment to discuss the application. The first trip was to a taconite mine in northern Minnesota. The second trip was to the International Coal Show in Chicago, Illinois. The final trip was to a diesel engine distributor. In all, five different equipment manufacturers were contacted and 21 machines were examined and evaluated (table 19). The discussions with maintenance personnel, distributors, and manufacturers led to the following conclusions and recommendations.

Table 19. Surface Mining Equipment Survey and Evaluation
for compatibility with CAC System and Electrical
Generation

Manufacturer	Model	Engine Compartment Space Availability	Cab	
			Approximate Size (in.)	Space Availability
Caterpillar	D8	Poor	36 x 36	Good
	D9	Poor	36 x 36	Good
	D10	Poor	36 x 36	Good
	960C	Fair	36 x 36	Good
	966C	Fair	36 x 50	Good
	988B	Fair	32 x 42	Good
	992C	Good	32 x 42	Good
	824	Fair	32 x 42	Good
Clark Michigan	75C	Fair	33 x 20	Good
	125C	Fair	36 x 36	Good
	175C	Fair	36 x 36	Good
	275C	Fair	36 x 36	Good
	230C	Fair	36 x 36	Good
	280B	Fair	36 x 36	Good
	380B	Fair	36 x 36	Poor*
	475C	Best	36 x 36	Poor*
International	400	Poor	48 x 48	Fair**
	560B	Poor		
	580B	Poor		
Letourneau	L700	Good	48 x 36	Good***
Ford	A66	Poor	48 x 36	Fair

*ROPS/FOPS structure placed above cab will make installation difficult.

**Large lights on cab roof limit positioning of system.

***Letourneau has slanting cab roof.

6.5.1 Conclusions

- a. An electrical generator to operate the CAC system requires the design and fabrication of special installation and mounting hardware.
- b. Limited space is available to mount an electrical generator to the engine on dieselized mine equipment.
- c. The cost associated with electrical generating hardware is high.
- d. Cab sizes, ROPS/FOPS structures, and machine components limit positioning of CAC system components.
- e. Cab interiors (i.e., sound attenuating materials) limit space available for air generator.

6.5.2 Recommendations

- a. Eliminate the ac or dc drive alternative in favor of a hydraulically driven CAC system.
- b. The CAC system should be one package to be mounted on cab roof.
- c. The CAC air generator should be minimal profile and similar in size to that used for underground retrofit.

6.6 REVIEW OF PARAMETERS

Design parameters considered for the CAC system design included ambient temperature and humidity, type of dust and concentration, type of machine, available area around operator, and kind of power available to operate the system.

For this contract, the term partially enclosed cab was defined as any cab with some kind of structure mounted over and/or around the cab that may not entirely enclose the operator. This included a FOPS/ROPS or an enclosed cab with open windows or doors, poor seals, or a cab with relatively good sealing capability.

Design of a single system to include both extremes of the definition and include all design parameters was impractical. Therefore, the partially enclosed cab was designed as two systems to cover the entire partially enclosed cab definition (figure 118). These two systems consisted of one system with air conditioning and heat and one system with heat only.

6.7 AIR CONDITIONED PARTIALLY ENCLOSED CAB CANOPY AIR CURTAIN

6.7.1 Heating and Air Conditioning

A review of the heating and air conditioning requirements discussed in section 6.3 indicated that commercial cab air conditioning units were available. Rather than designing an air conditioner, a search was conducted for an off-the-shelf system to be incorporated into a CAC system.

These units are designed for the mining industry; specifically for cab ventilation. The air conditioners typically provide from 1 ton to 2 ton of cooling (12,000 Btu/hr to 24,000 Btu/hr), including recirculated air from the cab. These air conditioners also provide for heating of the cab air by directing hot water from the engine to a coil located directly after the air conditioner evaporator coil. Air quantity to the cab varies with each system, but should provide from 275 cfm to 375 cfm for heating and 350 cfm to 400 cfm for cooling.*

*Society of Automotive Engineers, "Cab Condition - Heating and Cooling - Heavy Duty Truck and Off-Highway Equipment", F.W. Fisher, Automotive Engineering Congress and Expositions, Detroit, Michigan, February 24-28, 1975.

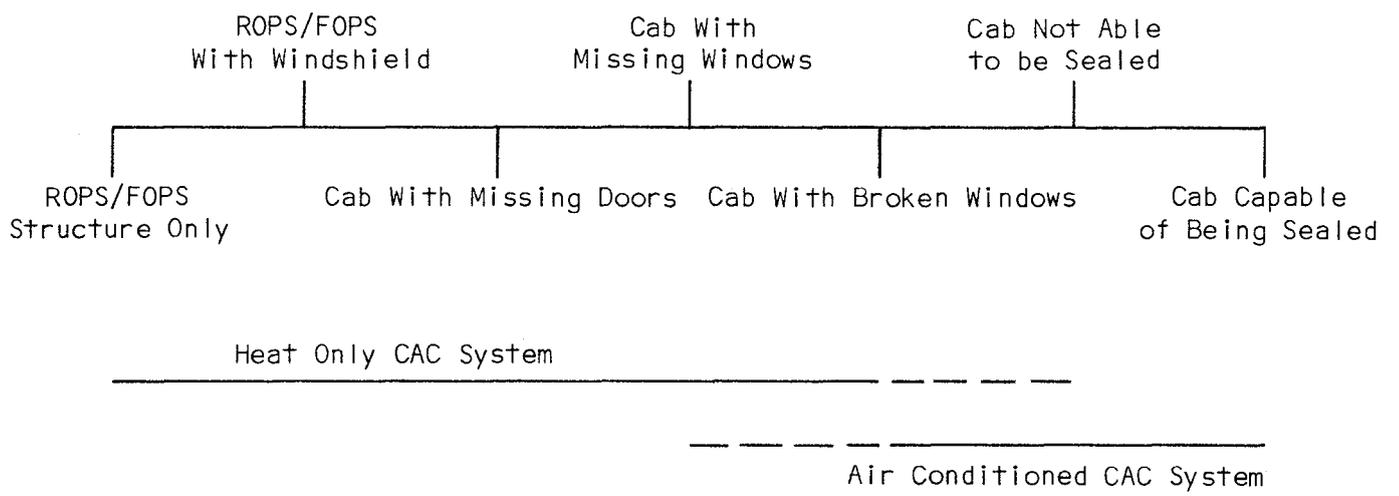


Figure 118. CAC Application Continuum

The air conditioner chosen had to meet several standards. First, because the standard 24 V dc power available on off-highway mine equipment was inadequate to drive the necessary system components, the air conditioner had to be modifiable to accept a hydraulic drive package, or come standard with one. Second, the system had to be commercially available and designed for use in a mining application. Third, the system had to be modular in construction to facilitate adding a new filtration package, fan, and air canopy generator.

Information from seven air conditioning manufacturers was received. Three were contacted for discussions to determine which would best suit our needs.

The air conditioner chosen, manufactured by Tube-Lok Products, operates by a self-contained hydraulic system. This system is driven by a flow regulated, pressure compensated, axial piston pump which is mounted to the vehicle engine. A fixed displacement piston motor powers both the Freon compressor and system fans. An oil cooler, reservoir, hydraulic filters, and controls are all contained in the air conditioner enclosure. In addition, it is modularly constructed and can be easily modified to accept adding new components.

The air conditioner was purchased as two parts; the hydraulic module and the Freon module (figure 119). The hydraulic module contained the two system fans, the piston motor, reservoir, oil cooler, and controls. The Freon module contained the evaporator, heater, and condenser coils as well as the belt drive Freon compressor. The hydraulic module slid in place between the two coils, sealing the two fans with gasket against the condenser/heater and evaporator ducting. By removing the coils from the original mounting plate, the distance between them varied to accommodate different fan choices.

6.7.2 Fan Selection

Several fans and fan types recommended for use in both the underground and partially enclosed cab CAC system were investigated. Due to space, noise, and power limitations, a forward curved fan wheel in a modified housing and inlet arrangement was specified.

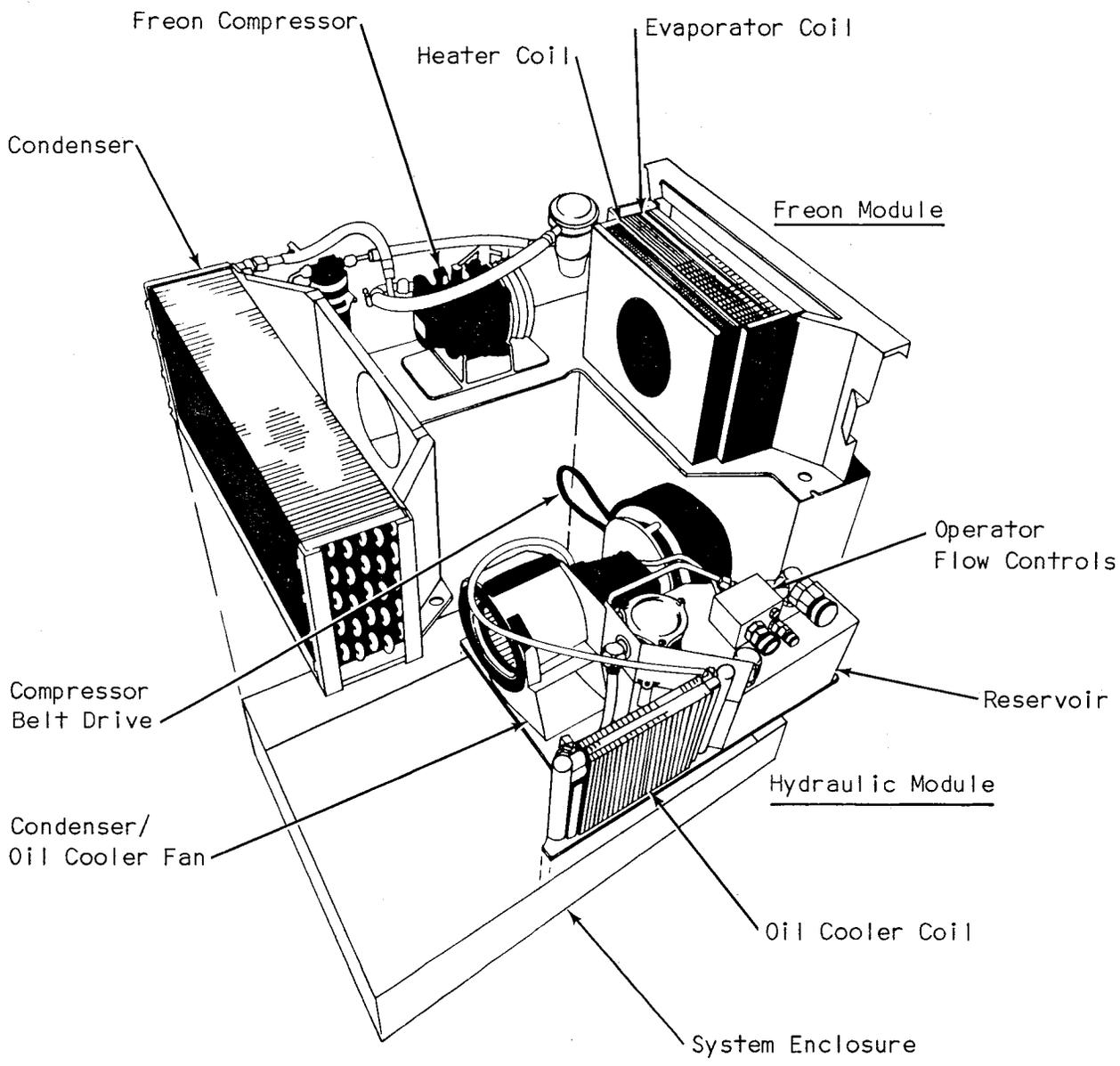


Figure 119. Air Conditioner Components

The fan used was adapted from a standard Donaldson Company product containing a 9-1/8 inch diameter wheel. Airflow from this fan was more than the air conditioner was designed to handle. To reduce airflow, the housing width and fan wheel width were decreased and modified to accept a different inlet (figure 120). Standard inlets for these fans typically are light gage metal with a small radius curve. To improve the flow to the wheel, a new inlet was fabricated. Two smaller 5-3/4 inch ID inlet rings were welded together and attached to the fan housing to improve flow to the fan wheel (figure 121). Flow tests were run on this modified fan with the original inlet ring and the modified inlet ring (figure 122). A slight increase in static was evident; however, airflow was lower than desired. A second inlet was designed and fabricated to regain some of the flow lost due to the inlet arrangement (figure 123). Fan performance tests were run for the final fan housing and inlet design (figure 124).

6.7.3 Filter Design and Selection

Recommendations were made to test four standard Donaldson Company filter elements and a self-cleaning air filter (SCAF) (figure 112). The four elements were a replaceable, cylindrical, pleated element installed in a perforated steel housing; a similar filter element housed in a steel housing with an integral inertial separator; a rectangular, pleated filter installed in a steel housing; a Donaldson DURALITE throw away cylindrical pleated filter. (Sketches and a discussion of these filters are found in section 4.3.3, figures 71, 72, 73 and 74). An additional self-cleaning filter concept was added to this list to be evaluated and will be discussed later. Evaluation for filter selection involved two specific design criteria.

The first criterion dictated that the air cleaner be physically as close to the fan as possible. This eliminated additional static pressure losses in ducting and maintained a single package system design. A second consideration for filter selection involved filter life and pressure drop characteristics. These evaluation criteria eliminated the first three filter concepts and left the two self-cleaning air cleaners to be investigated and tested.

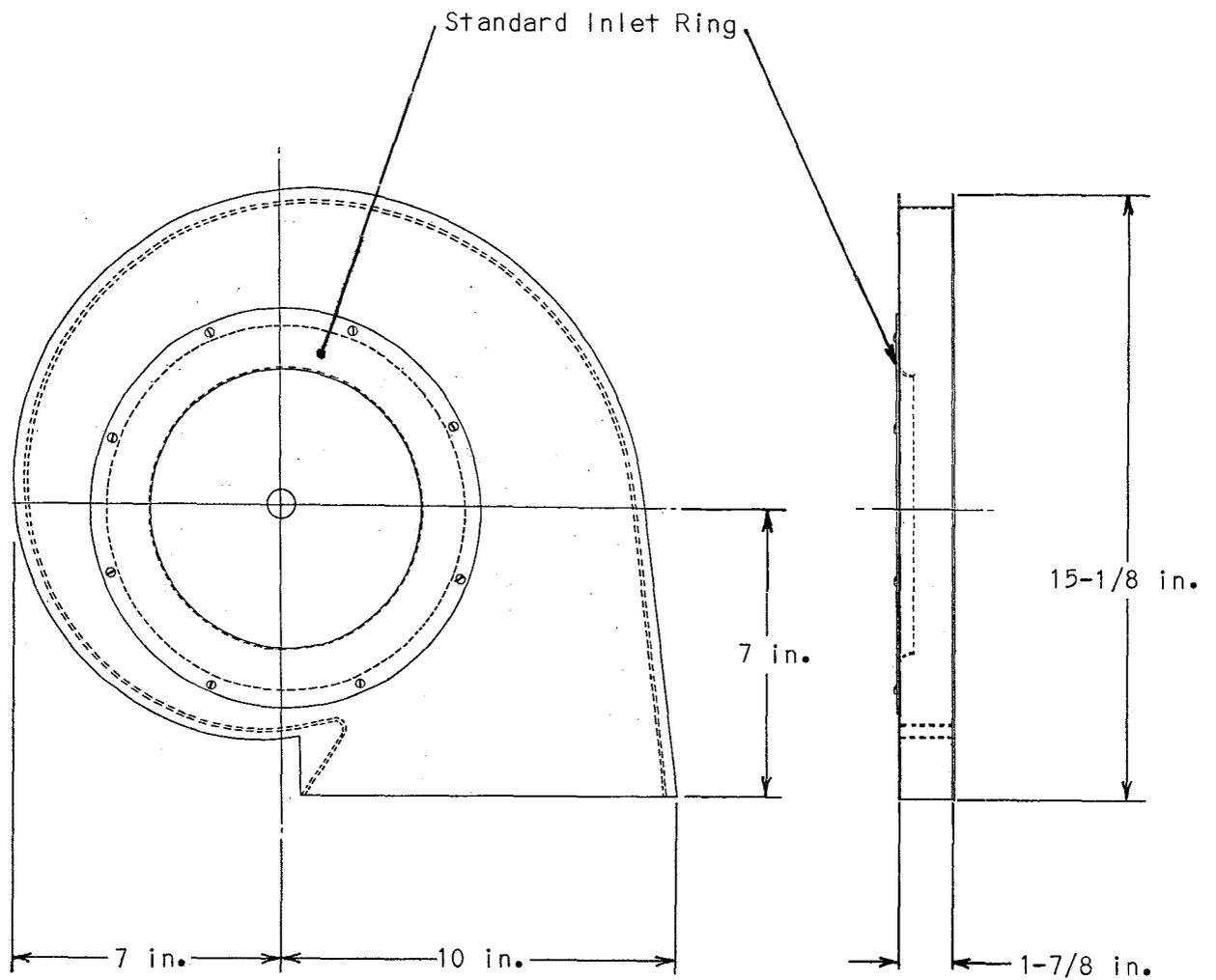


Figure 120. Modified Fan

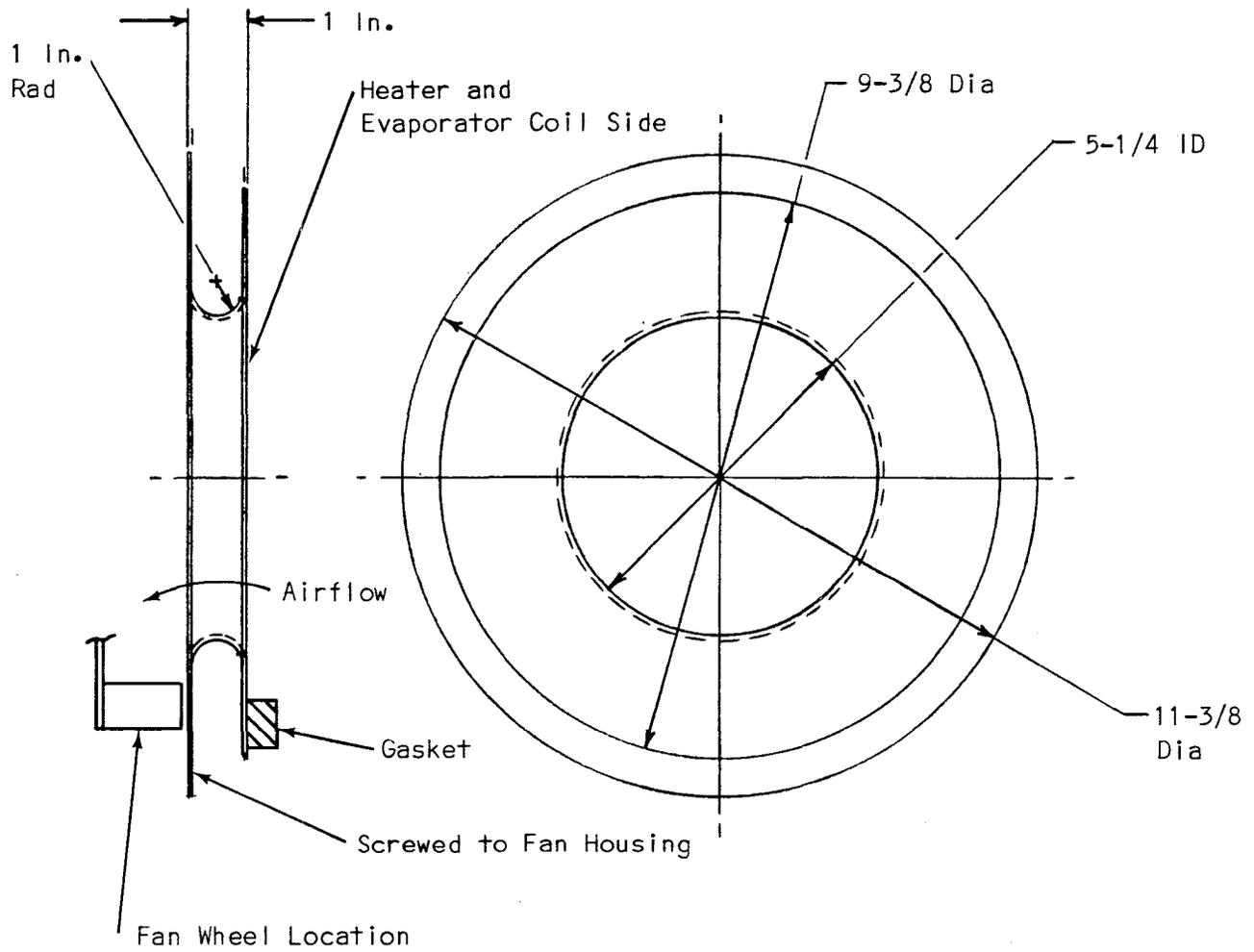
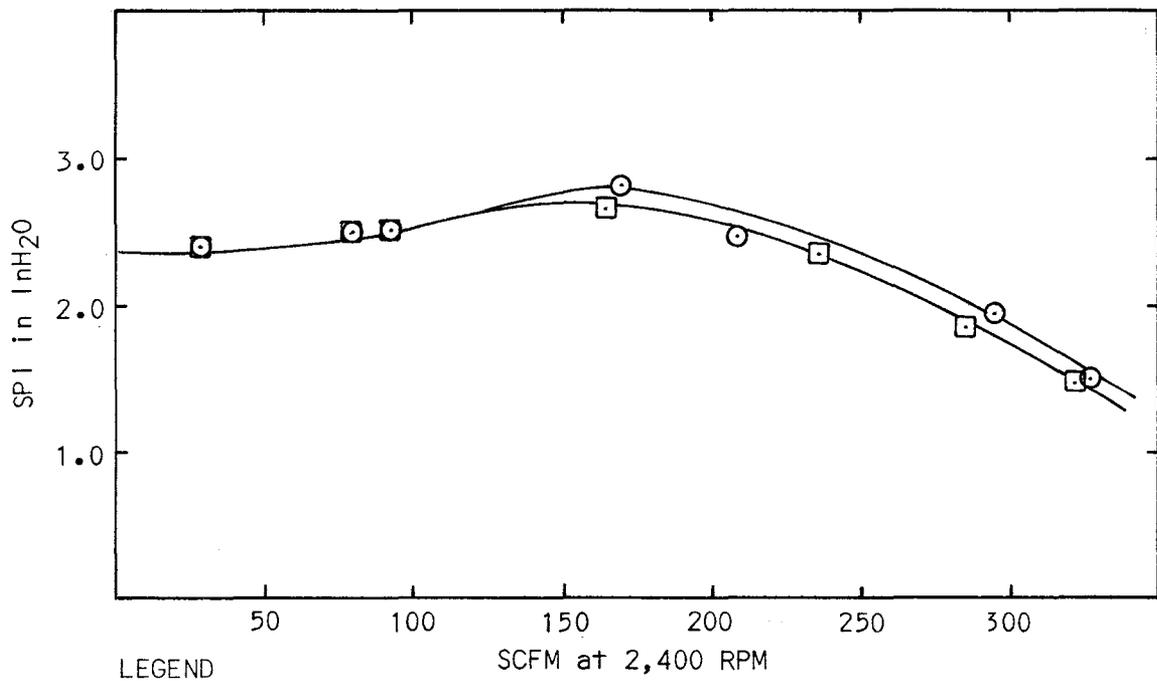
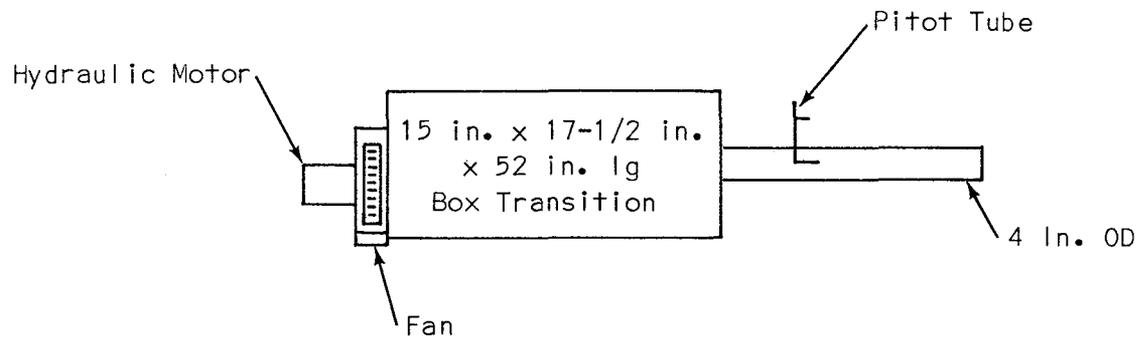


Figure 121. Modified Fan Inlet



LEGEND

- ⊙ Modified Inlet to Fan
- Standard Inlet to Fan

Figure 122. Fan Performance Comparison for Two Inlet Designs

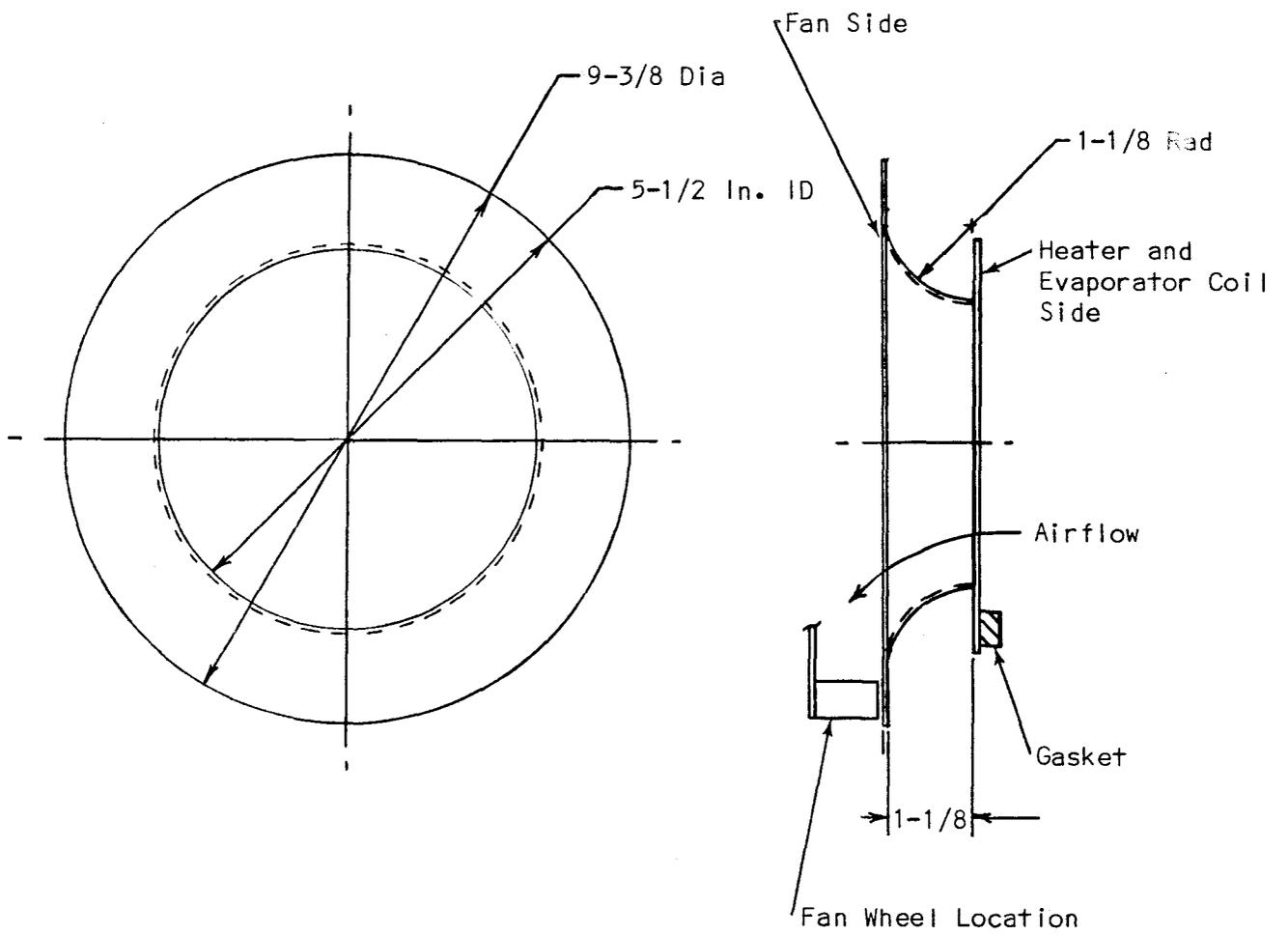


Figure 123. Reverse Bell Inlet Design

1 In. Radius Well Rounded Inlet to Fan

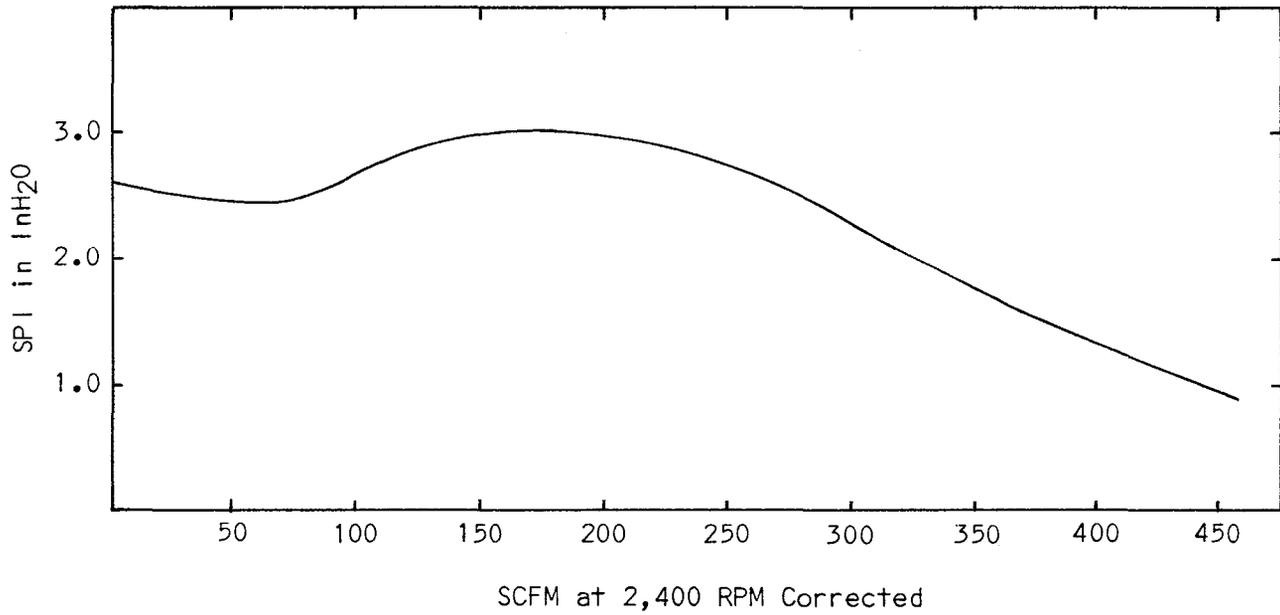
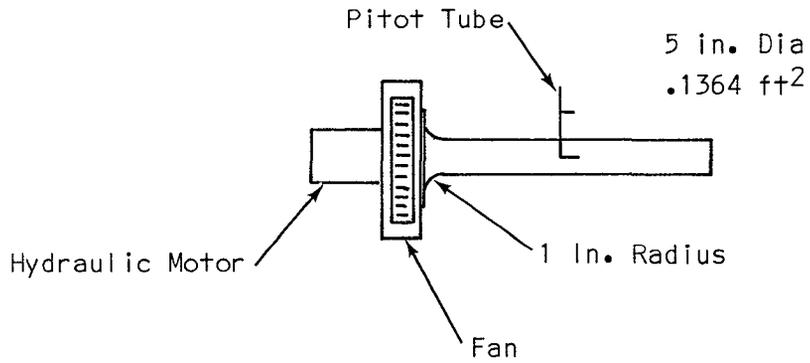


Figure 124. Fan Performance Curve for Final Design

The self-cleaning air filter (SCAF) (figure 112) was tested for life and pressure drop when filtering 200 cfm to 400 cfm. Tests were conducted with AC Fine dust at 8.4 grams per minute loading. With a clean filter, airflow restriction at 400 cfm was 1.18 inH₂O. The test was set up to automatically initiate pulse cleaning when the airflow dropped to 200 cfm (figure 125). Compressed air at 15 psig was used in short duration blasts to dislodge collected dust from the filter. After 15 load clean cycles, the cleaned airflow restriction was 4.74 inH₂O, indicating inadequate filter cleaning (figure 126). No further testing or evaluation was performed.

The second self-cleaning filter concept used two wedge shaped, pleated synthetic media filters (figure 127). This concept self-cleaned by shaking the filters when airflow resistance becomes excessive. The filters had one end securely mounted to a housing while the other end was free to move in one direction. This free end was in contact with a shaker mechanism that oscillated; dislodging caked-on dust and thereby lowering pressure drop across the filter. Testing was performed to determine life and loading characteristics and airflow versus restriction.

Tests were based on 700 cfm inlet air at zero visibility using AC Coarse test dust (table 20). Airflow declined as filter restriction increased, as seen in figure 128. The fan operated at a constant 2,400 rpm. Test duration averaged 150 minutes for the filter to become fully dust laden. The filters were then shaken after each of the four dust loadings to obtain an average load time. A comparison of the filter loading performance for the two concepts tested is shown in figure 129. Based on this curve, dimensional constraints, and the fact that compressed air was not required for cleaning, the wedge filter concept was pursued for the final design.

6.7.4 Air Generator

The canopy air generator was designed based on fan performance and dimensions as well as consideration of dimensional constraints determined by the cab. The canopy air generator for the air conditioned CAC provided the same amount of coverage as the underground retrofit. For a complete discussion of air

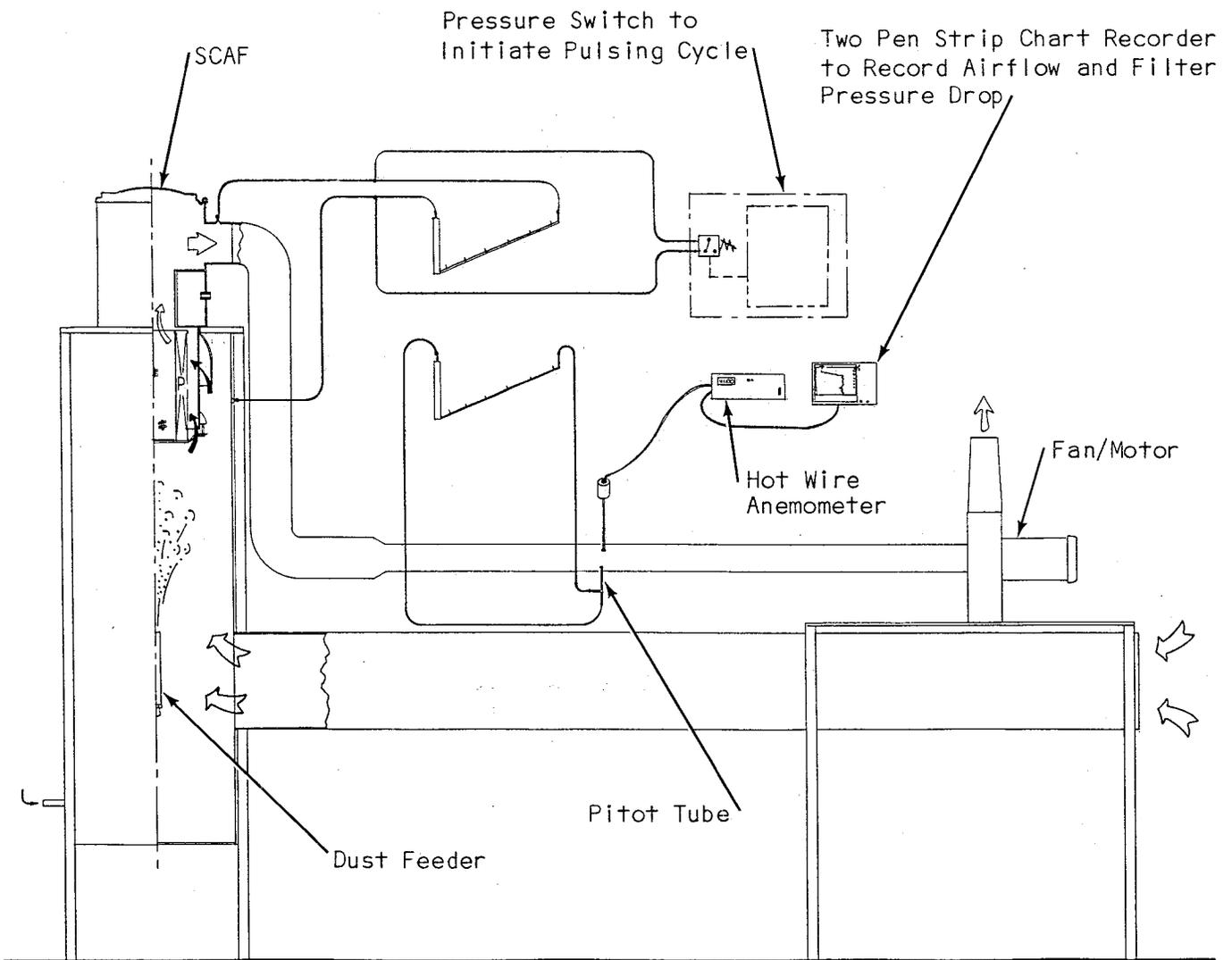
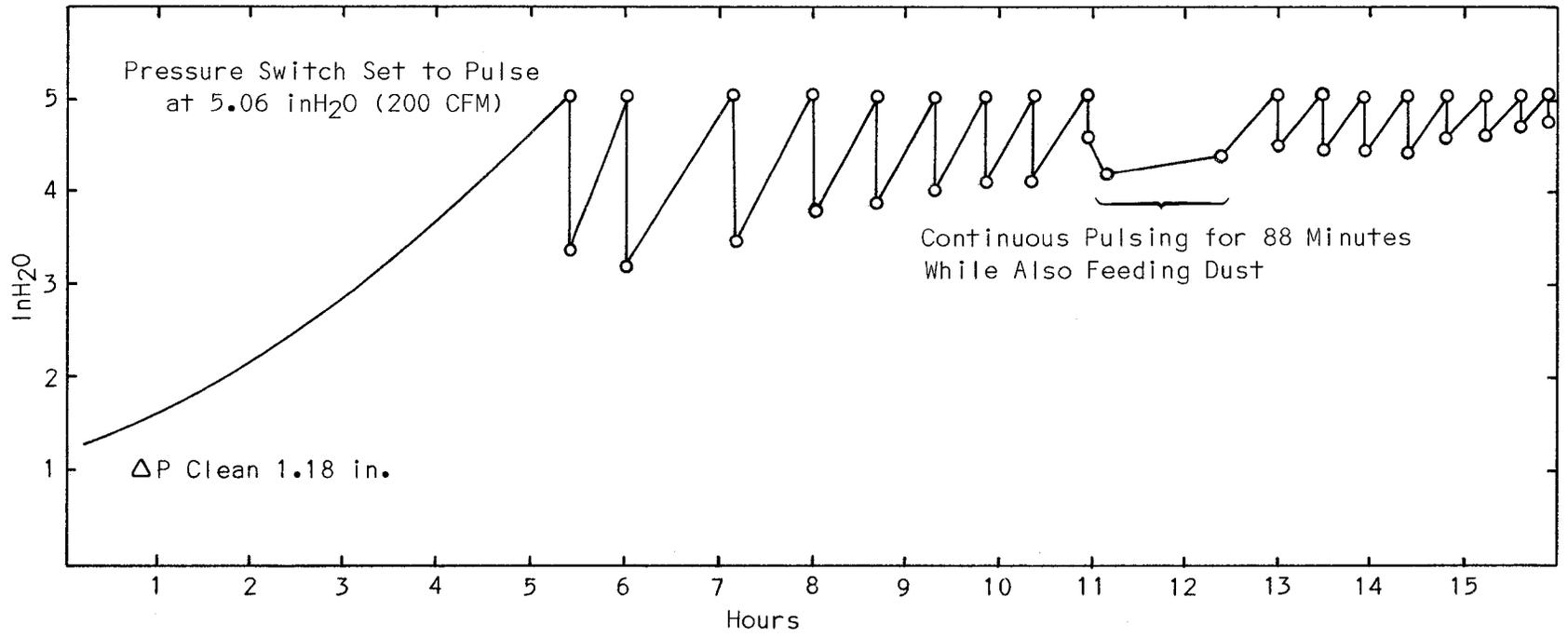


Figure 125. SCAF Test Setup

Figure 126. Life Testing of SCAF



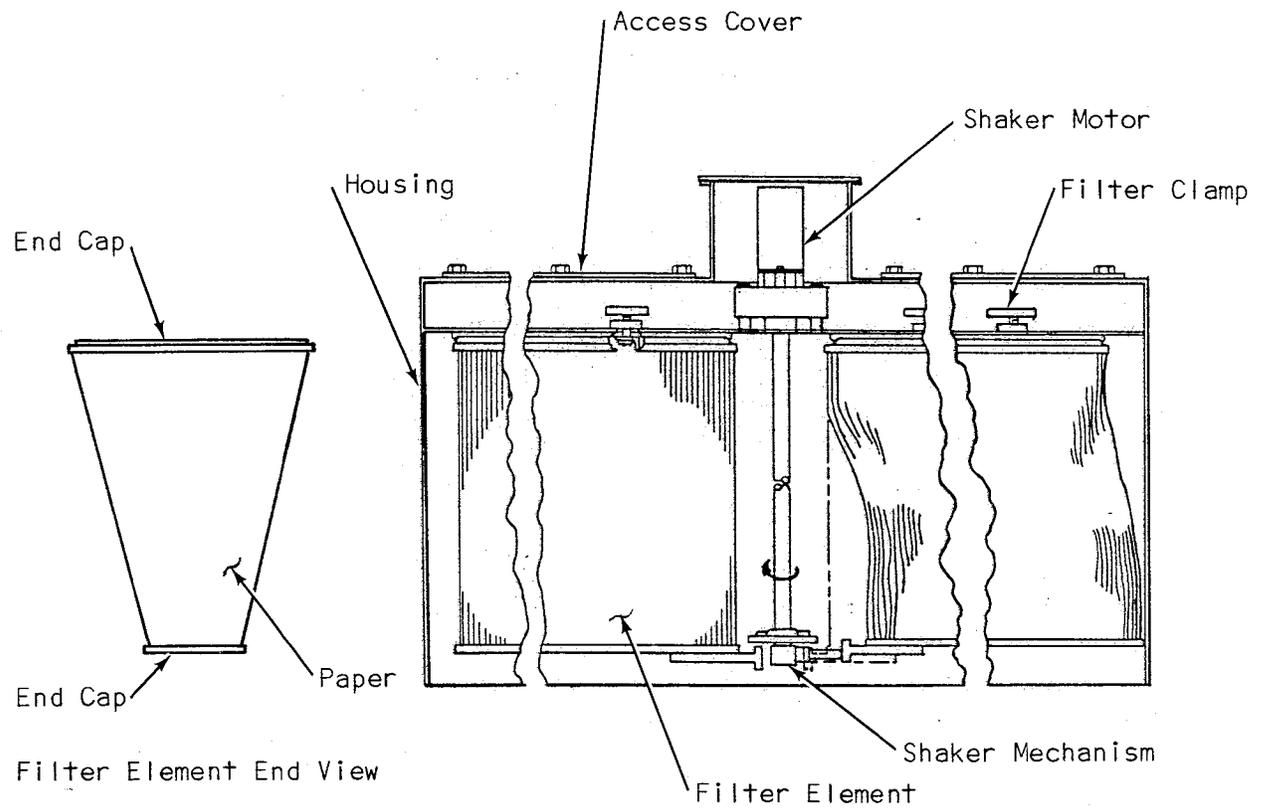


Figure 127. Wedge-Shaped Air Cleaner

Table 20. Coarse Air Cleaner Test Dust Specification

Channel Upper Limit (Micrometers)	Cumulative Data Percent Smaller Than Channel Upper Limit	Percent Difference Between Channel and Next Smaller Channel
176	100.0	5.2
125	94.7	12.9
88	81.8	12.7
62	69.0	12.9
44	56.0	10.2
31	45.8	7.9
22	37.8	8.6
16	29.1	7.0
11	22.1	5.1
7.8	16.9	2.5
5.5	14.4	5.4
3.9	8.9	4.9
2.8	3.9	3.9

NOTE:

Particle size distribution analysis shown is provided by manufacturer and is by L&N Microtrac Analyzer.

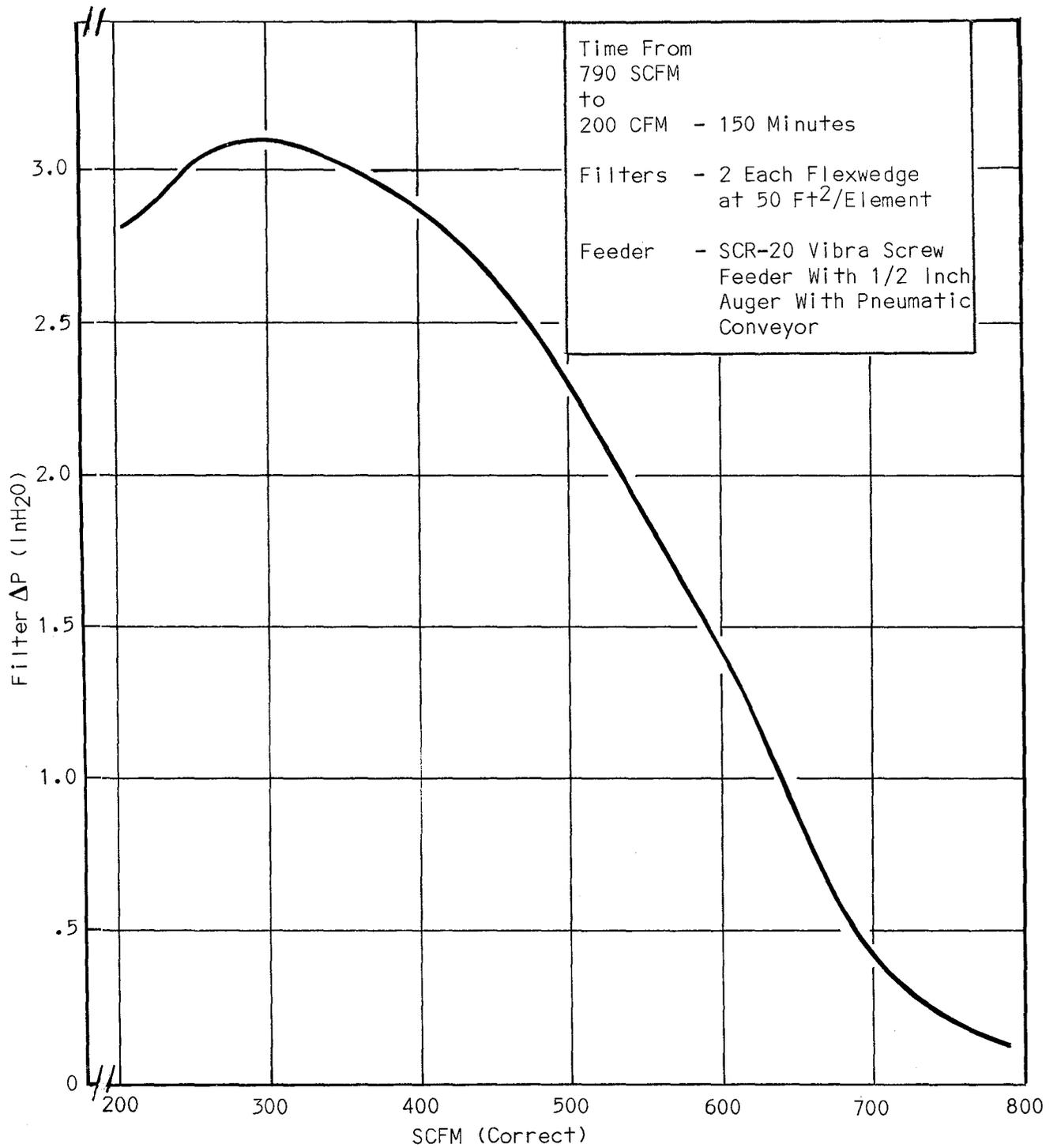


Figure 128. Filter Airflow versus Restriction

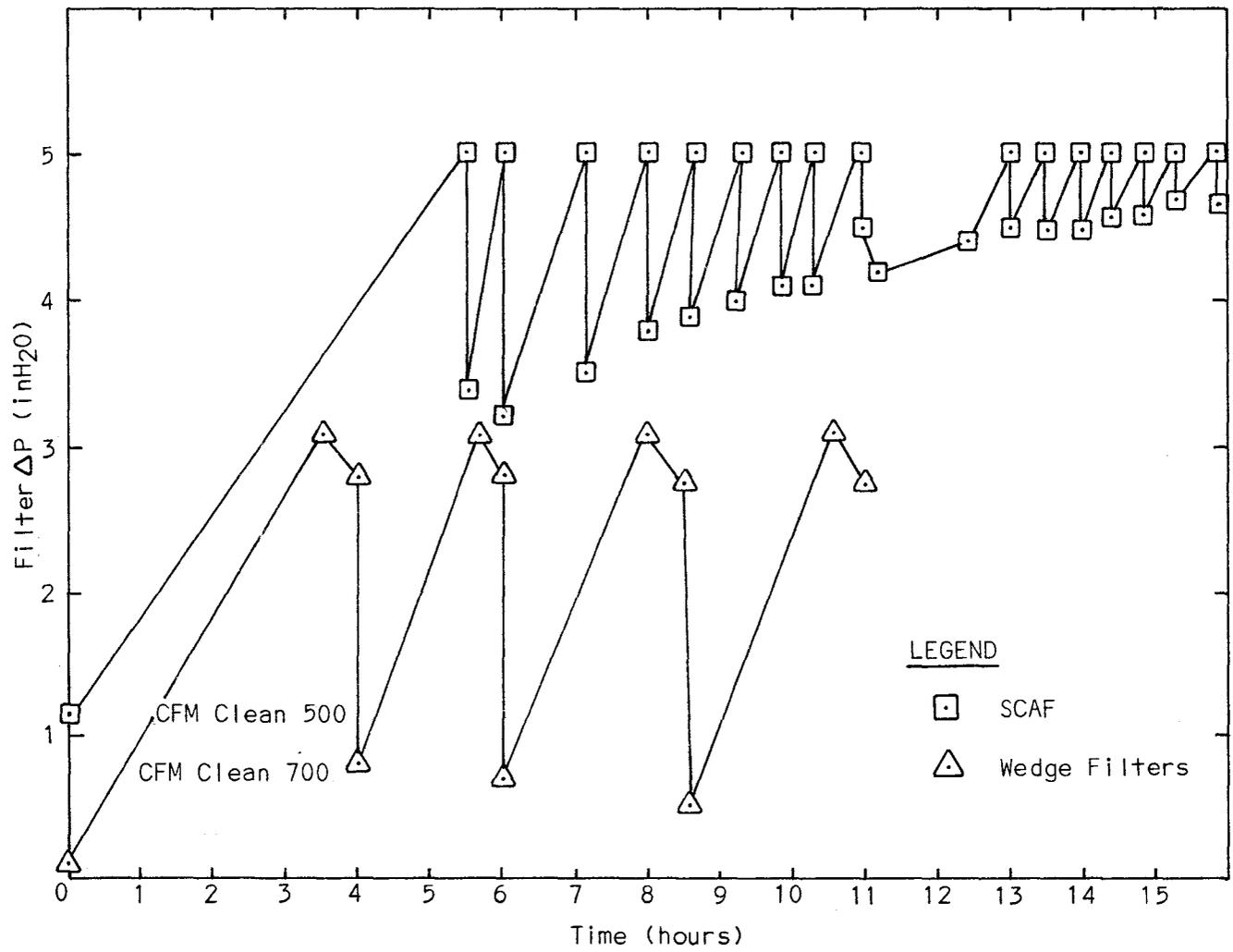


Figure 129. Filter Life Comparison Curve

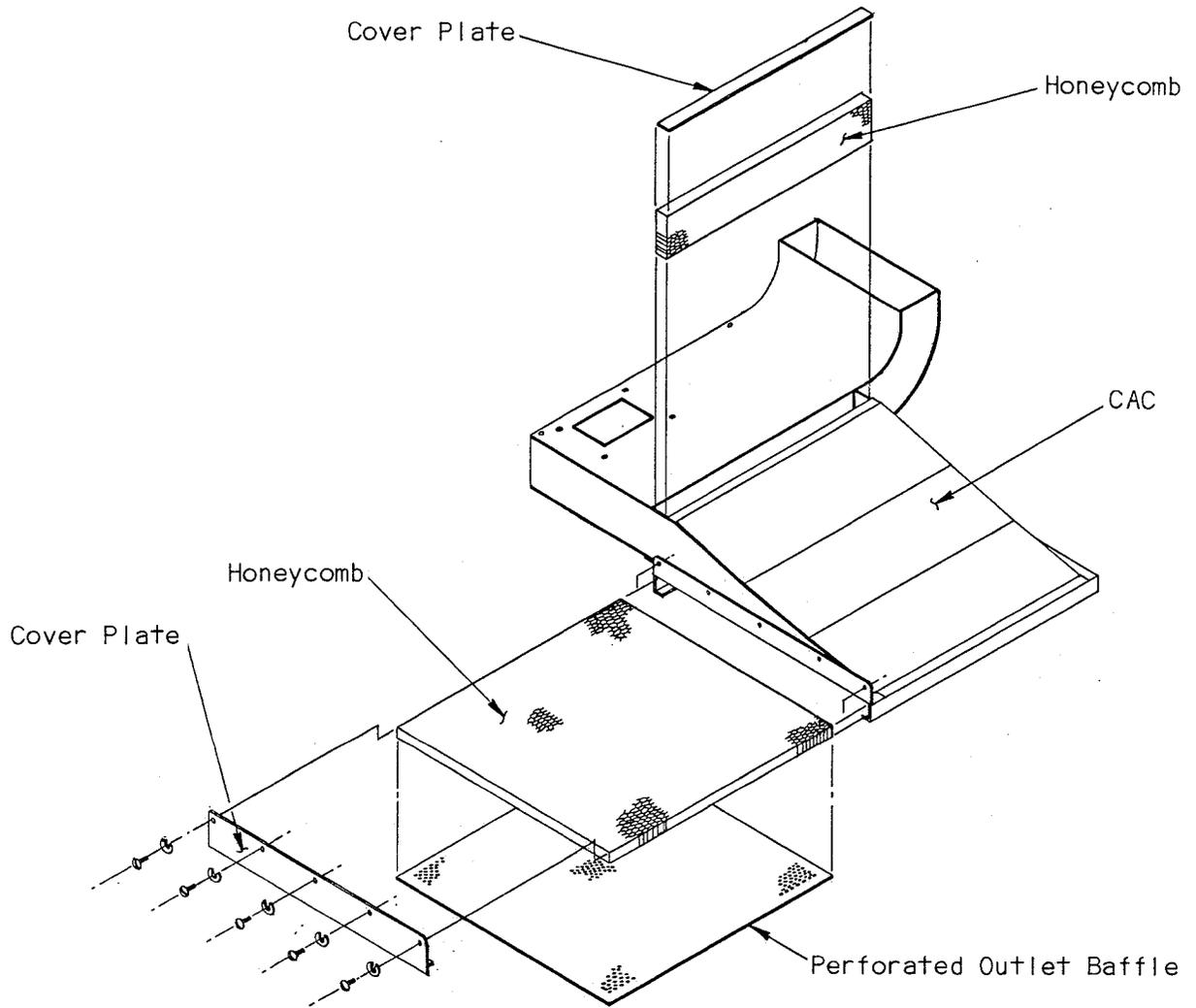


Figure 130. Canopy Air Generator for the Air Conditioned Partially Enclosed Cab System

generator design, refer to section 3.5.2.1. A drawing of the canopy air generator is found in figure 130.

Testing was performed to determine the velocity profiles 12 inches below the canopy at two fan speeds (figure 131 and tables 21 and 22). The fan speeds tested were at 2,400 rpm and 1,670 rpm; 340 cfm and 200 cfm, respectively. Additional modifications to the fan produced 440 cfm.

6.7.5 Package and Installation Design

All four components that make up the air conditioned PEC CAC system were installed in a single roof mounted package (figure 132). Modifications were made to the components to keep the overall system dimensions near that of the original size of the purchased air conditioner. The original dimensions were 41.375 inches by 29.5 inches by 12.75 inches. The package size without the self-cleaning filter was 37.75 inches by 36.5 inches by 13.75 inches. The filter added an additional 10 inches to length and 2.125 inches in width on both sides. The unit was designed to be attached to the roof of a cab with the inlet to the filter positioned off the roof (figure 133) which allows dust dislodged during filter cleaning to fall out of the filter housing.

6.7.6 Air Conditioned Partially Enclosed Cab Canopy Air Curtain Field Evaluation

The air conditioned PEC CAC was retrofitted to a Caterpillar, model 657B, coal hauler at a coal burning power generating plant. The air conditioning/heating unit was roof mounted as shown in figure 133, with the air generator mounted inside the cab directly over the operator. The hydraulic pump was mounted to the front engine and driven by a V-belt. An installation/operation manual was completed and supplied with the system.

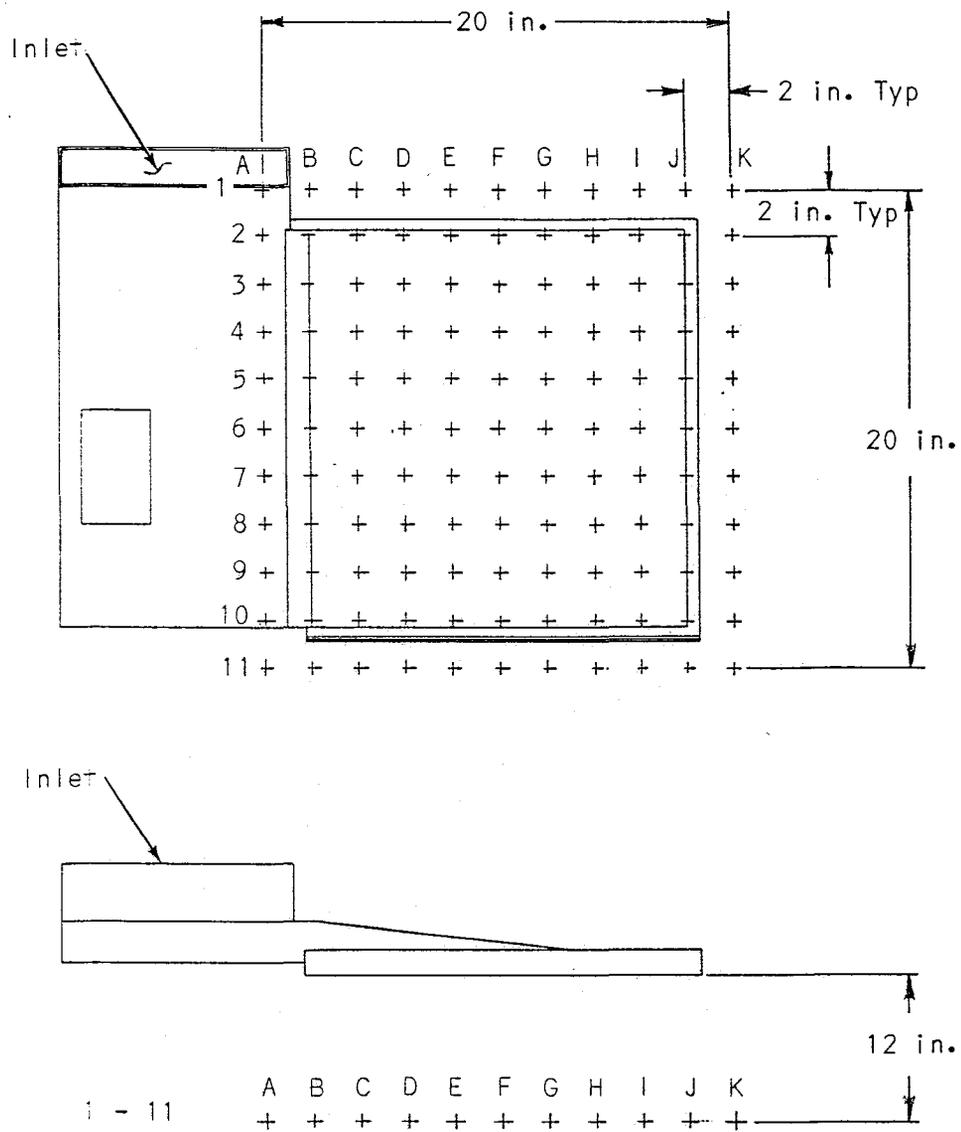


Figure 131. Partially Enclosed Cab Air Generator with Superimposed Velocity Test Grid

Table 21. Partially Enclosed Cab Air Canopy Airflow Distribution (340 CFM)

	A	B	C	D	E	F	G	H	I	J	K
1	0	0	50	150	280	200	75	75	50	0	0
2	0	0	175	250	440	280	220	225	225	100	0
3	0	0	175	370	540	410	380	380	420	200	0
4	25	50	200	410	370	400	380	400	410	125	0
5	30	75	310	430	360	340	380	420	330	100	0
6	80	140	310	480	480	440	380	380	230	75	25
7	125	160	310	450	490	460	400	430	230	100	0
8	40	50	220	430	530	520	430	370	230	100	0
9	0	0	200	420	500	250	440	250	250	0	0
10	0	0	0	100	75	40	150	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0

NOTE: Refer to figure 95 for test grid coordinates.
 Values shown are in feet per minute.

Table 22. Partially Enclosed Cab Air Canopy Airflow Distribution (200 CFM)

	A	B	C	D	E	F	G	H	I	J	K
1	0	0	0	0	100	0	0	0	0	0	0
2	0	25	50	180	240	140	100	80	60	0	0
3	90	100	140	230	290	210	210	210	220	50	0
4	100	100	250	260	250	210	200	210	230	100	0
5	100	160	210	250	170	200	190	230	160	50	0
6	80	80	230	270	210	210	240	240	80	0	0
7	0	50	210	300	280	250	230	210	70	0	0
8	0	60	180	300	275	260	250	170	140	0	0
9	0	0	100	300	300	260	170	180	140	0	0
10	0	0	50	110	160	80	50	50	25	0	0
11	0	0	0	0	50	0	0	0	0	0	0

NOTE: Refer to figure 95 for test grid coordinates.
 Values shown are in feet per minute.

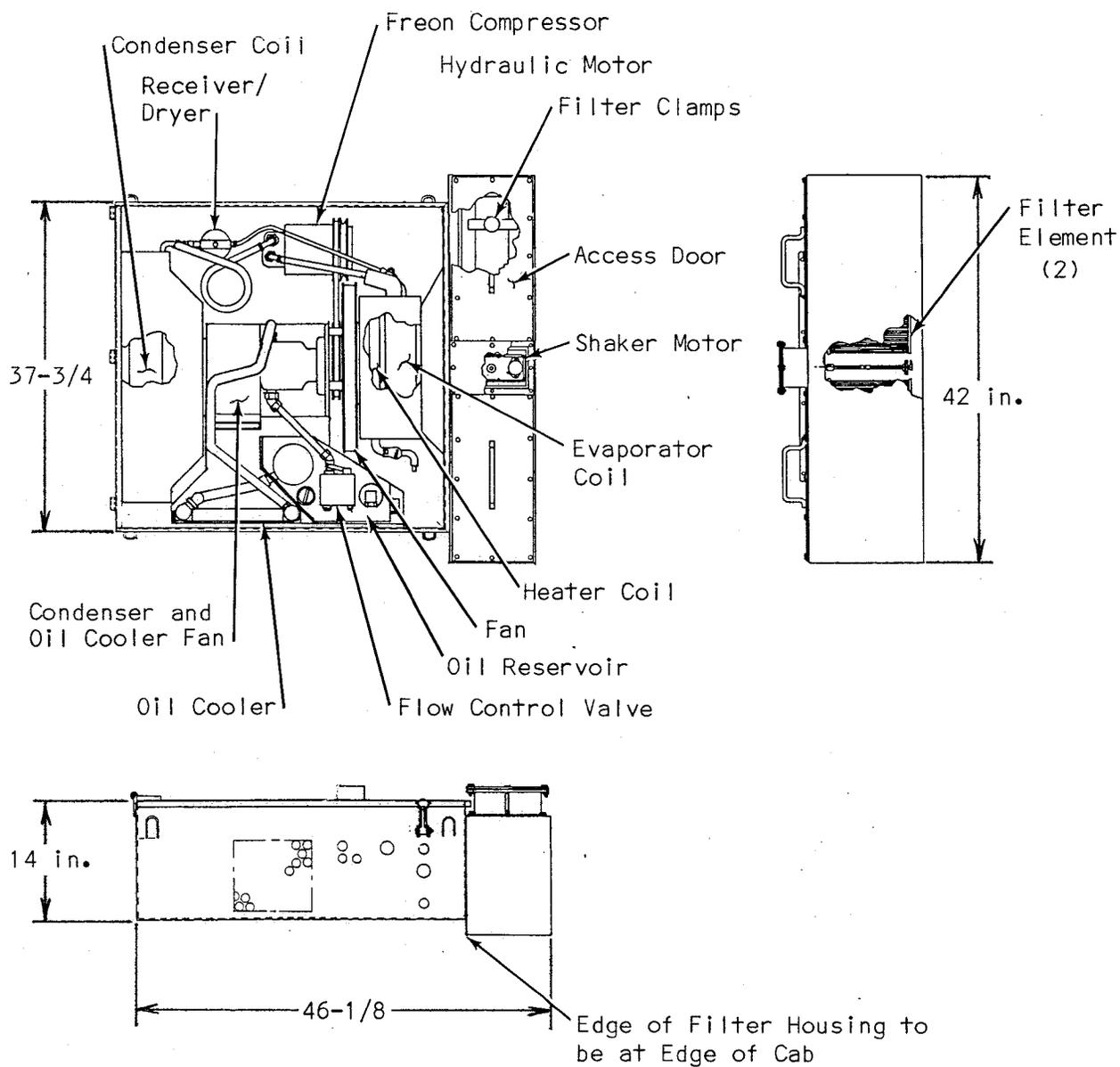


Figure 132. Air Conditioned, Partially Enclosed Cab System

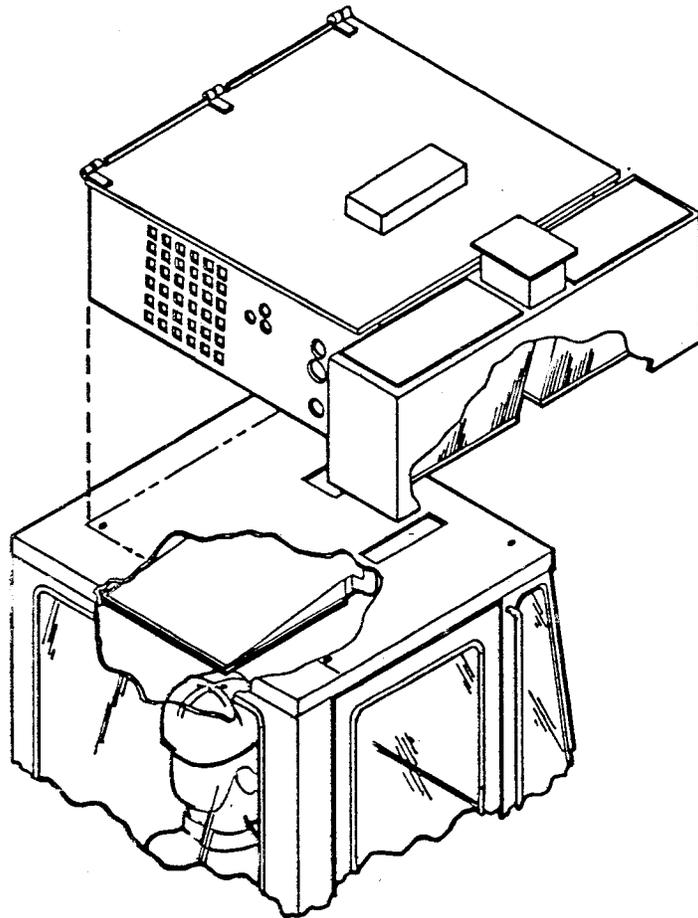


Figure 133. Air Conditioned, Partially Enclosed Cab System Installation

Following installation, the air conditioned PEC CAC system was monitored to determine operator acceptance and overall performance. Since the system was installed and used during the winter months, only heating capabilities could be determined.

Due to the location and low velocity air flow delivered by the air generator, the operators complained of uneven heat distribution inside the cab. Because of the overhead location of the air generator, the upper half of the cab was too warm while the lower half was too cold. It is believed that the low velocity airflow was not mixing the cab air sufficiently to evenly heat the cab. The operators also complained about the absence of a windshield defroster.

To rectify these problems, the air generator was removed and replaced by an air delivery duct patterned after the OEM supplied equipment. This contained directional airflow louvers for operator control and defroster ducting directed at the windshield. It also contained heater/defroster and the PEC CAC system controls. These changes corrected the defrosting problem, but the operators still complained about the lack of airflow and heat.

To increase the heat output, the system was modified so cab air could be recirculated. This recirculation system allowed previously heated cab air to be recirculated back thru the heating coil. Controls were also added so the amount of recirculated air could be operator controlled. To increase system airflow, pump modifications were made which increased fan speed. These modifications, however, failed to raise the heat output of the system enough to adequately heat the cab. Also, due to the increased fan speed, fan noise reached an unacceptable level.

Inadequate heat output of the system was eventually attributed to the heating coil being too small. Consequently, the system was removed from operation before dust reduction testing was performed because of insufficient heating and excessive fan noise.

Other problems encountered with this system were a leaky reservoir breather and pump seal. Attempts were made to correct these problems, but small amounts of hydraulic oil leakage was a constant problem.

6.8 HEAT ONLY PARTIALLY ENCLOSED CAB CANOPY AIR CURTAIN

The PEC CAC system for machines where operating an air conditioner was not practical was designed using basically the same components contained in the air conditioned system. Design modifications were made to the drive components, the air canopy generator, and the system package. The air filtration system design was the same design used with the air conditioned system.

6.8.1 Air Canopy Generator

The basic design of the canopy air generator remained the same as for the air conditioned partially enclosed cab CAC. The only design change was the increase in height from 1-9/16 inch to 3 inch. This was done to reduce the pressure loss through the air generator. (Refer to figure 130 and section 6.7.4 for a discussion of air generator design.)

6.8.2 Package Design and Power Specifications

The power for operation of the CAC system is similar to that used in the air conditioned CAC system. The difference is the reduced power requirements to drive the air generator fan motor. Previously, about 8 gpm at 2,275 psi were required to operate the air conditioner compressor and both fans. For this system, the requirement is only 3.5 gpm at 1,200 psi for the air generator fan. A drawing of the circuit is shown on figure 134. The fan which provides airflow to the oil cooling coil is driven by a 1/4 hp, 24 Vdc motor. Design and fabrication of mounting hardware for installation depends on the engine.

The complete package design contains the filter, fans, controls, heating coil, and hydraulic components (figure 135 and 136). The hydraulic components include the reservoir, oil cooler, filters, motor, and hydraulic controls. Overall system size is 34 inches wide by 16 inches high by 42 inches long. Installation is planned for the roof of the cab with the filter extending over the edge (figure 136).

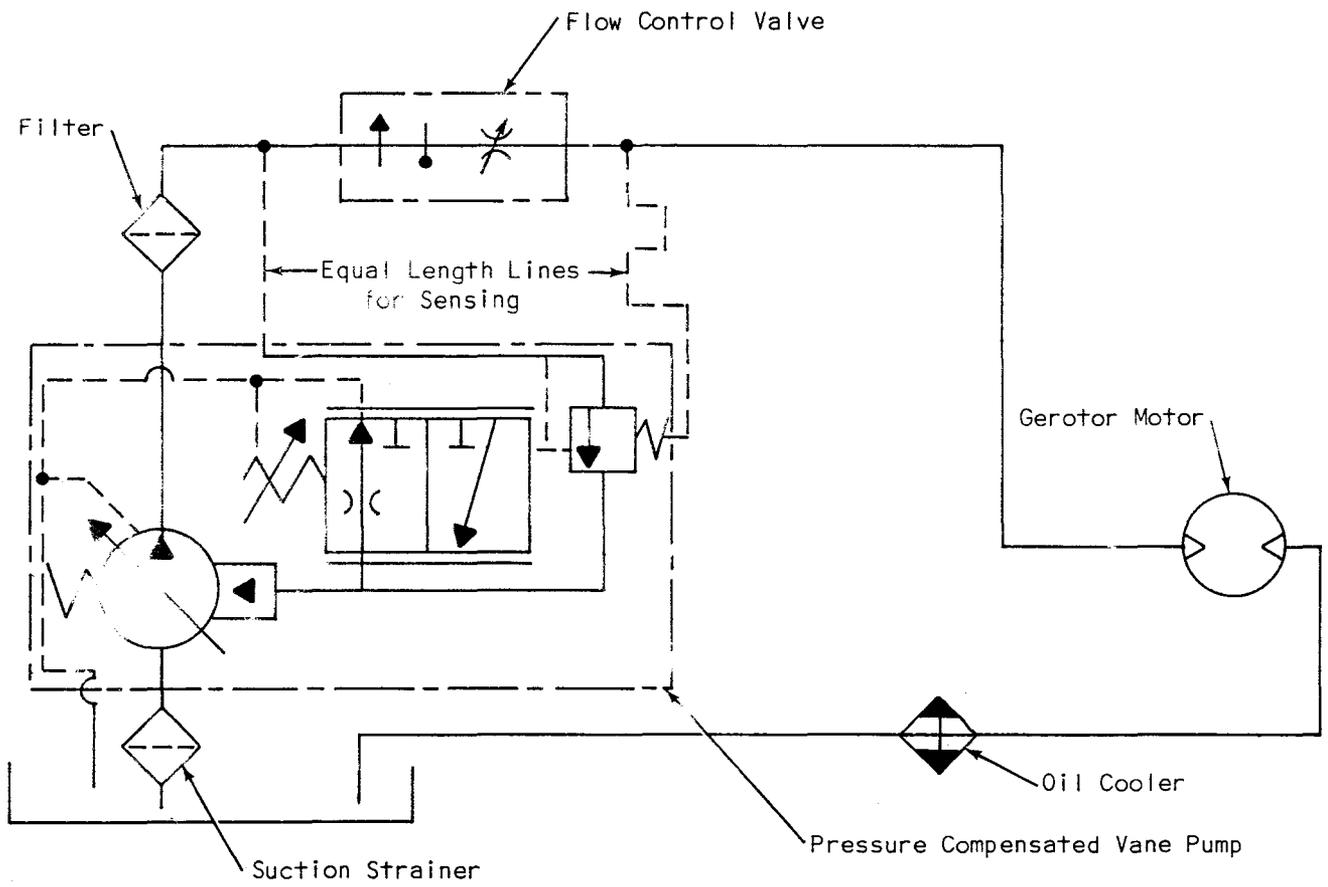
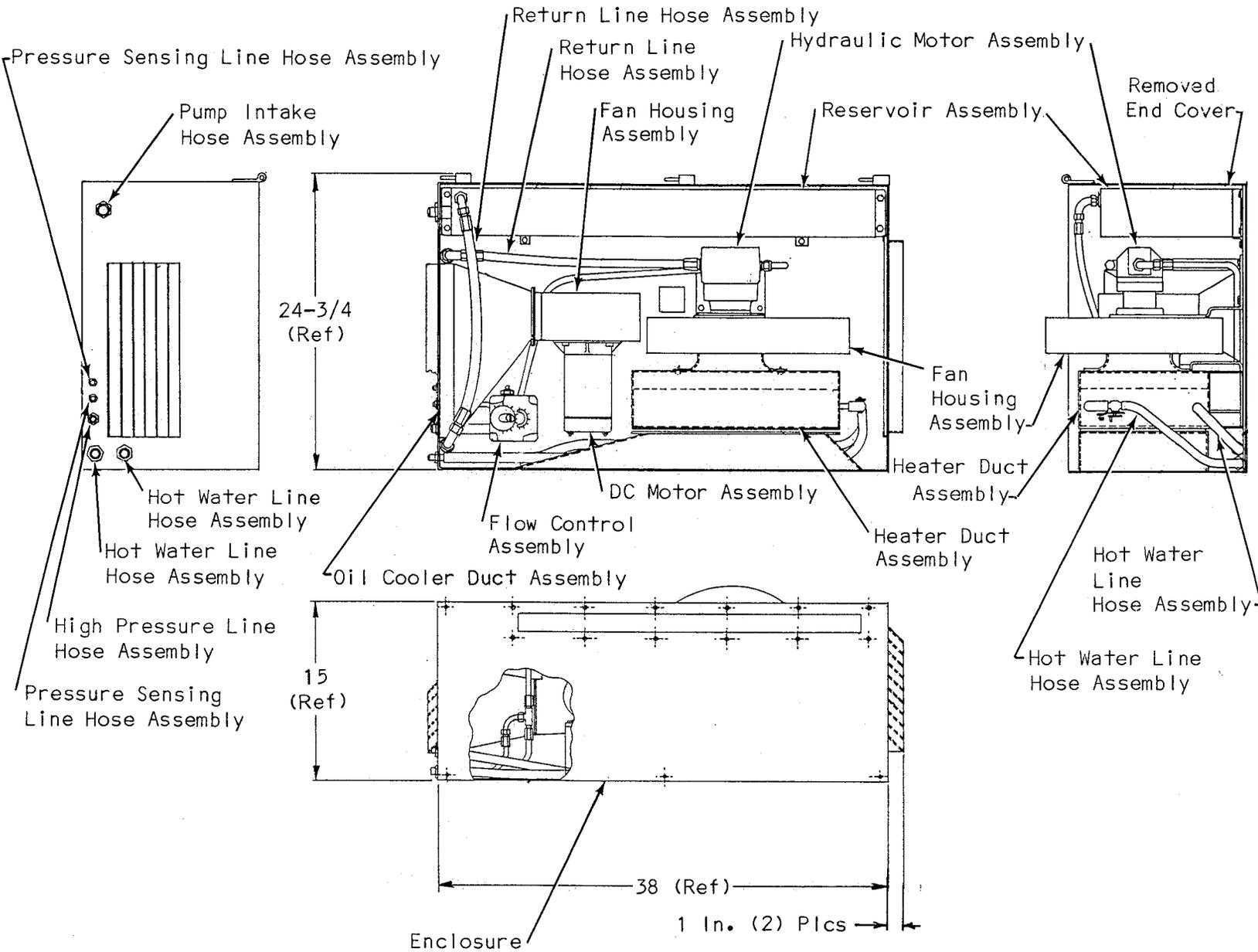


Figure 134. Heat Only, Partially Enclosed Cab Hydraulic Drive Circuit

Figure 135. Hydraulic Drive Enclosure Assembly



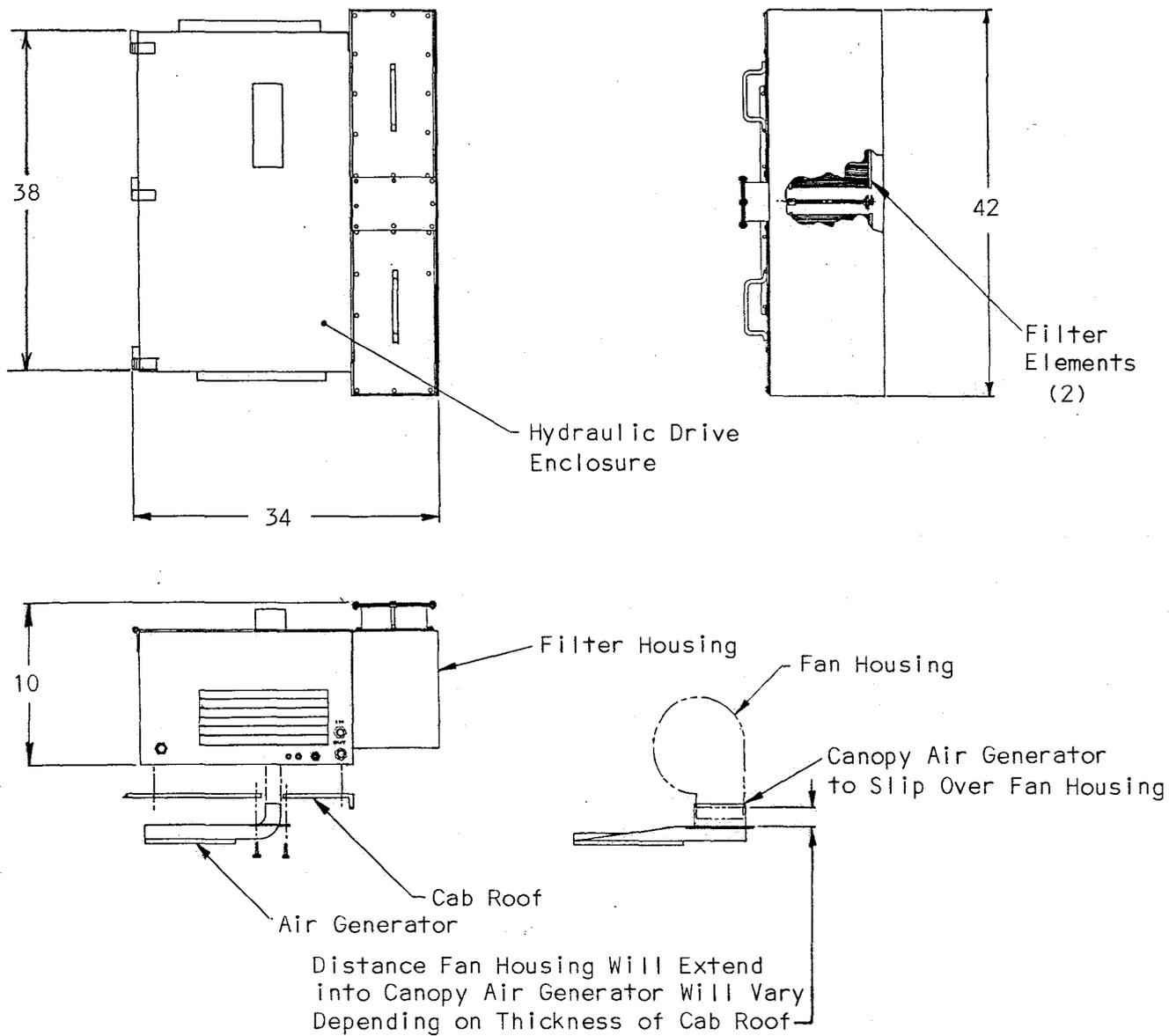


Figure 136. Heat Only Partially Enclosed Cab CAC System

6.8.3 Heat Only Partially Enclosed Canopy Air Curtain System

Due to a contract modification, the heat only PEC CAC was redesigned and fabricated specifically for an underground mine application.

The redesigned system consisted of the same basic filter design used with the air conditioned PEC CAC. This unit, however, was redesigned so a hydraulically driven blower could be mounted to the clean air chamber. Power for the motor was to be supplied by the machine hydraulic system. The filter box was also redesigned so it could be fender mounted. Space under the filters was provided for removal of dust during the cleaning cycle.

The air conditioned system air generator was modified so it could be used for this application. Modifications consisted of replacing the rectangular inlet with a 6.00 inch round inlet section and removing the panels used to mount the air conditioning system controls. These modifications allowed the air generator to fit within the space constraints typically encountered underground.

The system was designed to use 6.00 inch diameter flexible tubing to connect the blower and air generator.

6.8.4 Field Evaluation

The field test site and field evaluation of this system was to be managed by the Bureau of Mines.

7.0 CAB AIR FILTRATION STUDY

A cab air filtration study was performed in order to evaluate the performance of cab air systems currently used on enclosed cab off road mining equipment. This study was completed using telephone surveys. Sources were chosen from the regions of the country where the greatest number of mines were located using the Keystone Coal manual, the International Directory of Mines, the Thomas Register,

and local telephone books. Fifty mines or coal using companies (25 eastern companies and 25 western companies) and eight original equipment manufacturers (OEMs) of air conditioning equipment for off road vehicles were surveyed. Within these companies a wide range of personnel were surveyed to avoid biased results, with primary emphasis being on maintenance personnel.

In recent years several studies have directed their effort at resolving the problems of dust exposure for operators of mining equipment. Environmentally enclosed cabs have been used to try and alleviate many of these problems with limited success. A summation of portions of the results and conclusions from a study titled, Engineering Evaluation of Environmental Cabs for Control of Dust and Other Safety Factors USBM contract J0308018, states:

Environmentally enclosed cabs, which have been in use in surface mines for a number of years are the best method for protecting an equipment operator from the effect of a harsh and unhealthy environment.

The cab air filtration study was conducted to determine what kind of filtration equipment is presently being used and the effectiveness of such equipment, what the present costs of filtration are, and if there is a need for an improved cab air condition/ventilation/heating system to provide improved filtration and air distribution respiratory protection.

7.1 Conclusions and Recommendations

7.1.1 Conclusions

The study has shown that a significant number of companies were having problems primarily with coal dust. A few of these companies were having trouble meeting requirements set by government agencies or unions and some were eagerly looking for a better system.

Existing filtration systems basically use barrier filtration with some effectiveness. Overall, the study showed that present systems are not rugged enough. Maintenance problems were seen frequently and one mine commented that "If you could make an air conditioning/filtration system that could stand up to the rigorous mine conditions, then you would have a product." In certain areas of the country the costs of filtration were extremely high.

Presently, there is no self-cleaning filtration system on the market. Many companies expressed interest but were skeptical of cost and effectiveness of such a system; although, some companies did not care about cost and were willing to pay for quality. When asked what kind of filtration system they would like, companies' personnel responded, "with air conditioning and heating while providing good filtration." Some of these companies are presently working under extreme weather conditions and would like to have a better controlled climate in the cab.

Almost all of the OEMs surveyed were interested in cooperating to develop such a system. They seemed to realize that present systems were not adequate. They did , however, see an opportunity with a self-cleaning filtration system.

7.1.2 Recommendations

This study has shown that there is interest and a potential market for a self-cleaning cab air system with heat and air conditioning. A thorough cost evaluation should be performed for the new canopy air curtain system. If the evaluation shows that the system is cost effective and can be sold at a competitive price, the system should be further developed and marketed.

APPENDIX A

PANEL FILTER FRACTIONAL EFFICIENCY DATA

Table A-1. Fractional Efficiency Versus Dust Loading - Standard Media, Sample 1

Manufacturer: D.C.I. Model#: P13-5930
 Dust: ACF Feed Rate 2.5 grams/min
 Airflow: 1875 scfm (ref 59F, 29.92 in. Hg.)
 Duct Size: 22 7/16x 22 1/2 in. (3.51 sq ft)
 Temperature: 75 F Relative Humidity: 32 %
 Date: 16-NOV-83 Time: 12:52:12

PARTICLE SIZE RANGE (micron)	GEOMETRIC MEAN DIAMETER (micron)	UPSTREAM COUNTS	DOWNSTREAM COUNTS
0.442 - 0.562	0.499	1199218	291353
0.562 - 0.750	0.649	1206674	182514
0.750 - 1.000	0.866	847512	77484
1.000 - 1.334	1.155	634296	33048
1.334 - 1.778	1.540	364830	7086
1.778 - 2.371	2.054	148383	999
2.371 - 3.162	2.738	53844	143
3.162 - 4.217	3.652	18324	55
4.217 - 5.623	4.870	4031	18
5.623 - 7.499	6.494	675	5
7.499 - 8.000	7.745	73	0

LIVE TIME (SECONDS) 336 386
 REAL TIME (SECONDS) 450 450

PARTICLE SIZE RANGE (micron)	NUMBER CONCENTRATION (number/cc)		VOLUME CONCENTRATION (cubic micron/cc)		FRACTIONAL EFFICIENCY (percent)
	UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	
0.442 - 0.562	1807.335	356.97551	117.266	23.162	80.248515
0.562 - 0.750	1818.572	278.00887	260.753	39.862	84.712792
0.750 - 1.000	1277.281	116.60268	434.295	39.647	90.871022
1.000 - 1.334	955.944	44.11176	770.781	35.567	95.385530
1.334 - 1.778	549.833	9.37623	1051.307	17.928	98.294714
1.778 - 2.371	223.627	1.22839	1013.966	5.570	99.450697
2.371 - 3.162	81.148	0.18777	872.522	2.019	99.768607
3.162 - 4.217	27.616	0.07554	704.141	1.926	99.726456
4.217 - 5.623	6.075	0.02472	367.326	1.495	99.593047
5.623 - 7.499	1.017	0.00687	145.862	0.985	99.324928
7.499 - 8.000	0.110	0.00000	26.767	0.000	100.000000
Total	6748.559	806.59835	5764.986	168.160	

OVERALL EFFICIENCY ON PARTICLES < 8.000 MICRON
 BY NUMBER 88.047843
 BY VOLUME 97.083083

Table A-2. Fractional Efficiency Versus Dust Loading - Standard Media, Sample 2

Manufacturer: D.C.I. Model#: P13-5930
 Dust: ACF Feed Rate 2.5 grams/min
 Airflow: 1875 scfm (ref 59F, 29.92 in. Hg.)
 Duct Size: 22 7/16x 22 1/2 in. (3.51 sq ft)
 Temperature 75 F Relative Humidity: 32 %
 Date 16-NOV-83 Time 13:00:54

PARTICLE SIZE RANGE (micron)	GEOMETRIC MEAN DIAMETER (micron)	UPSTREAM COUNTS	DOWNSTREAM COUNTS
0.442 - 0.562	0.499	1239453	260546
0.562 - 0.750	0.649	1277194	162307
0.750 - 1.000	0.866	908551	67909
1.000 - 1.334	1.155	695714	28634
1.334 - 1.778	1.540	419100	6191
1.778 - 2.371	2.054	177980	855
2.371 - 3.162	2.738	65939	173
3.162 - 4.217	3.652	22021	48
4.217 - 5.623	4.870	4641	27
5.623 - 7.499	6.494	789	2
7.499 - 8.000	7.745	79	1
LIVE TIME (SECONDS)		334	391
REAL TIME (SECONDS)		450	450

PARTICLE SIZE RANGE (micron)	NUMBER CONCENTRATION (number/cc)		VOLUME CONCENTRATION (cubic micron/cc)		FRACTIONAL EFFICIENCY (percent)
	UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	
0.442 - 0.562	1874.597	316.12439	121.630	20.511	83.136408
0.562 - 0.750	1931.678	244.82422	276.970	35.104	87.325826
0.750 - 1.000	1374.128	101.19953	467.225	34.409	92.635363
1.000 - 1.334	1052.225	37.84825	848.413	30.517	96.403026
1.334 - 1.778	633.863	8.11227	1211.976	15.511	98.720185
1.778 - 2.371	272.209	1.04110	1234.243	4.721	99.617536
2.371 - 3.162	99.729	0.22495	1072.306	2.419	99.774434
3.162 - 4.217	33.305	0.06529	849.207	1.665	99.803978
4.217 - 5.623	7.019	0.03672	424.412	2.220	99.476817
5.623 - 7.499	1.193	0.00272	171.101	0.390	99.772042
7.499 - 8.000	0.119	0.00136	29.070	0.331	98.861654
Total	7280.066	709.48082	6706.554	147.798	

OVERALL EFFICIENCY ON PARTICLES < 8.000 MICRON
 BY NUMBER 90.254473
 BY VOLUME 97.796218

Table A-3. Fractional Efficiency Versus Dust Loading - Standard Media, Sample 3

Manufacturer: D.C.I. Model#: P13-5930
 Dust: ACF Feed Rate 2.5 grams/min
 Airflow: 1875 scfm (ref 59F, 29.92 in. Hg.)
 Duct Size: 22 7/16x 22 1/2 in. (3.51 sq ft)
 Temperature 75 F Relative Humidity: 32 %
 Date 16-NOV-83 Time 13:24:27

PARTICLE SIZE RANGE (micron)	GEOMETRIC MEAN DIAMETER (micron)	UPSTREAM COUNTS	DOWNSTREAM COUNTS
0.442 - 0.562	0.499	1150176	79432
0.562 - 0.750	0.649	1220732	44545
0.750 - 1.000	0.866	871373	15706
1.000 - 1.334	1.155	671450	5545
1.334 - 1.778	1.540	402935	1091
1.778 - 2.371	2.054	171454	305
2.371 - 3.162	2.738	62404	145
3.162 - 4.217	3.652	19397	91
4.217 - 5.623	4.870	3704	39
5.623 - 7.499	6.494	663	15
7.499 - 8.000	7.745	67	2

LIVE TIME (SECONDS) 341 428
 REAL TIME (SECONDS) 450 450

PARTICLE SIZE RANGE (micron)	NUMBER CONCENTRATION (number/cc)		VOLUME CONCENTRATION (cubic micron/cc)		FRACTIONAL EFFICIENCY (percent)
	UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	
0.442 - 0.562	1718.057	89.37032	111.473	5.799	94.798175
0.562 - 0.750	1823.449	62.30750	261.452	8.934	96.582986
0.750 - 1.000	1301.599	21.70406	442.564	7.380	98.332508
1.000 - 1.334	1002.968	6.79657	808.696	5.480	99.322354
1.334 - 1.778	601.878	1.32566	1150.819	2.535	99.779747
1.778 - 2.371	256.107	0.34439	1161.233	1.562	99.865529
2.371 - 3.162	93.215	0.17484	1002.269	1.880	99.812434
3.162 - 4.217	28.974	0.11477	738.765	2.926	99.603871
4.217 - 5.623	5.533	0.04919	334.536	2.974	99.110955
5.623 - 7.499	0.990	0.01892	141.999	2.713	98.089672
7.499 - 8.000	0.100	0.00252	24.349	0.614	97.479508
Total	6832.869	182.20873	6178.155	42.795	

OVERALL EFFICIENCY ON PARTICLES < 8.000 MICRON
 BY NUMBER 97.333350
 BY VOLUME 99.307310

Table A-4. Fractional Efficiency Versus Dust Loading - Standard Media, Sample 4

Manufacturer: D.C.I. Model#: P13-5930
 Dust: ACF Feed Rate 2.5 grams/min
 Airflow: 1875 scfm (ref 59F, 29.92 in. Hg.)
 Duct Size: 22 7/16x 22 1/2 in. (3.51 sq ft)
 Temperature 75 F Relative Humidity: 32 %
 Date 16-NOV-83 Time 13:51:33

PARTICLE SIZE RANGE (micron)	GEOMETRIC MEAN DIAMETER (micron)	UPSTREAM COUNTS	DOWNSTREAM COUNTS
0.442 - 0.562	0.499	1175678	19321
0.562 - 0.750	0.649	1266959	8999
0.750 - 1.000	0.866	902000	2494
1.000 - 1.334	1.155	692811	714
1.334 - 1.778	1.540	418774	215
1.778 - 2.371	2.054	181385	95
2.371 - 3.162	2.738	68617	57
3.162 - 4.217	3.652	22457	42
4.217 - 5.623	4.870	4638	17
5.623 - 7.499	6.494	835	7
7.499 - 8.000	7.745	114	2

LIVE TIME (SECONDS) 339 444
 REAL TIME (SECONDS) 450 450

PARTICLE SIZE RANGE (micron)	NUMBER CONCENTRATION (number/cc)		VOLUME CONCENTRATION (cubic micron/cc)		FRACTIONAL EFFICIENCY (percent)
	UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	
0.442 - 0.562	1762.433	21.00150	114.352	1.363	98.808381
0.562 - 0.750	1899.271	12.16070	272.324	1.744	99.359718
0.750 - 1.000	1352.169	3.32962	459.758	1.132	99.753757
1.000 - 1.334	1038.578	0.84549	837.409	0.682	99.918591
1.334 - 1.778	627.775	0.25239	1200.335	0.483	99.959797
1.778 - 2.371	271.910	0.10343	1232.890	0.470	99.961887
2.371 - 3.162	102.862	0.06640	1105.999	0.714	99.935447
3.162 - 4.217	33.665	0.05118	858.370	1.305	99.847980
4.217 - 5.623	6.953	0.02071	420.391	1.252	99.702066
5.623 - 7.499	1.252	0.00853	179.477	1.223	99.318582
7.499 - 8.000	0.171	0.00244	41.578	0.593	98.573975
Total	7097.038	37.84258	6722.884	10.960	

OVERALL EFFICIENCY ON PARTICLES < 8.000 MICRON
 BY NUMBER 99.466783
 BY VOLUME 99.836977

Table A-5. Fractional Efficiency Versus Dust Loading - Standard Media, Sample 5

Manufacturer: D.C.I. Model#: F13-5930
 Dust: ACF Feed Rate 2.5 grams/min
 Airflow: 1875 scfm (ref ~~89F~~ 29.92 in. Hg.)
 Duct Size: 22 7/16x 22 1/2 in. (3.51 sq ft)
 Temperature 75 F Relative Humidity: 32 %
 Date 16-NOV-83 Time 14:14:26

PARTICLE SIZE RANGE (micron)	GEOMETRIC MEAN DIAMETER (micron)	UPSTREAM COUNTS	DOWNSTREAM COUNTS
0.442 - 0.562	0.499	1142194	4648
0.562 - 0.750	0.649	1263327	1932
0.750 - 1.000	0.866	899850	484
1.000 - 1.334	1.155	692925	182
1.334 - 1.778	1.540	416173	99
1.778 - 2.371	2.054	177560	58
2.371 - 3.162	2.738	65591	49
3.162 - 4.217	3.652	21379	21
4.217 - 5.623	4.870	4836	9
5.623 - 7.499	6.494	1103	3
7.499 - 8.000	7.745	136	0
LIVE TIME (SECONDS)		342	448
REAL TIME (SECONDS)		450	450

PARTICLE SIZE RANGE (micron)	NUMBER CONCENTRATION (number/cc)		VOLUME CONCENTRATION (cubic micron/cc)		FRACTIONAL EFFICIENCY (percent)
	UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	
0.442 - 0.562	1703.082	5.00795	110.501	0.325	99.705948
0.562 - 0.750	1883.699	2.58788	270.091	0.371	99.862617
0.750 - 1.000	1341.732	0.64050	456.210	0.218	99.952263
1.000 - 1.334	1033.194	0.21363	833.068	0.172	99.979324
1.334 - 1.778	620.540	0.11520	1186.501	0.220	99.981436
1.778 - 2.371	264.753	0.06272	1200.437	0.284	99.976312
2.371 - 3.162	97.800	0.05658	1051.571	0.608	99.542147
3.162 - 4.217	31.877	0.02536	812.796	0.647	99.920432
4.217 - 5.623	7.211	0.01087	435.994	0.657	99.849249
5.623 - 7.499	1.645	0.00362	235.814	0.520	99.779682
7.499 - 8.000	0.203	0.00000	49.336	0.000	100.000000
Total	6985.735	8.72431	6642.319	4.023	

OVERALL EFFICIENCY ON PARTICLES < 8.000 MICRON
 BY NUMBER 99.875112
 BY VOLUME 99.939441

Table A-6. Fractional Efficiency Versus Dust Loading - Standard Media, Sample 6

Manufacturer: D.C.I. Model#: P13-5930
 Dust: ACF Feed Rate 2.5 grams/min
 Airflow: 1875 scfm (ref 59F, 29.92 in. Hg.)
 Duct Size: 22 7/16x 22 1/2 in. (3.51 sq ft)
 Temperature 75 F Relative Humidity: 32 %
 Date 16-NOV-83 Time 14:38:02

PARTICLE SIZE RANGE (micron)	GEOMETRIC MEAN DIAMETER (micron)	UPSTREAM COUNTS	DOWNSTREAM COUNTS
0.442 - 0.562	0.499	1057389	2277
0.562 - 0.750	0.649	1177187	986
0.750 - 1.000	0.866	828166	283
1.000 - 1.334	1.155	628002	180
1.334 - 1.778	1.540	369716	149
1.778 - 2.371	2.054	154561	113
2.371 - 3.162	2.738	55148	89
3.162 - 4.217	3.652	17763	44
4.217 - 5.623	4.870	4116	10
5.623 - 7.499	6.494	822	3
7.499 - 8.000	7.745	88	1

LIVE TIME (SECONDS) 347 449
 REAL TIME (SECONDS) 450 450

PARTICLE SIZE RANGE (micron)	NUMBER CONCENTRATION (number/cc)		VOLUME CONCENTRATION (cubic micron/cc)		FRACTIONAL EFFICIENCY (percent)
	UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	
0.442 - 0.562	1562.505	2.44791	101.380	0.159	99.843334
0.562 - 0.750	1739.530	1.31781	249.420	0.189	99.924243
0.750 - 1.000	1223.782	0.37368	416.105	0.127	99.969465
1.000 - 1.334	927.999	0.21081	748.249	0.170	99.977283
1.334 - 1.778	546.330	0.17299	1044.608	0.331	99.968336
1.778 - 2.371	228.395	0.12192	1035.583	0.553	99.946620
2.371 - 3.162	81.492	0.10254	876.224	1.103	99.874171
3.162 - 4.217	26.248	0.05303	669.270	1.352	99.797983
4.217 - 5.623	6.082	0.01205	367.757	0.729	99.801858
5.623 - 7.499	1.215	0.00362	174.163	0.518	99.702353
7.499 - 8.000	0.130	0.00121	31.638	0.293	99.073237
Total	6343.708	4.81756	5714.397	5.523	

OVERALL EFFICIENCY ON PARTICLES < 8.000 MICRON
 BY NUMBER 99.924058
 BY VOLUME 99.903345

Table A-7. Fractional Efficiency Versus Dust Loading - Standard Media, Sample 7

Manufacturer: D.C.I. Model#: F13-5930
 Dust: ACF Feed Rate 2.5 grams/min
 Airflow: 1875 scfm (ref 59F, 29.92 in. Hg.)
 Duct Size: 22 7/16x 22 1/2 in. (3.51 sq ft)
 Temperature 75 F Relative Humidity: 32 %
 Date 16-NOV-83 Time 14:47:03

PARTICLE SIZE RANGE (micron)	GEOMETRIC MEAN DIAMETER (micron)	UPSTREAM COUNTS	DOWNSTREAM COUNTS
0.442 - 0.562	0.499	1068515	1489
0.562 - 0.750	0.649	1199010	533
0.750 - 1.000	0.866	845501	161
1.000 - 1.334	1.155	640138	75
1.334 - 1.778	1.540	379618	68
1.778 - 2.371	2.054	159027	50
2.371 - 3.162	2.738	56047	35
3.162 - 4.217	3.652	17965	33
4.217 - 5.623	4.870	4583	9
5.623 - 7.499	6.494	959	4
7.499 - 8.000	7.745	98	0
LIVE TIME (SECONDS)		346	449
REAL TIME (SECONDS)		450	450

PARTICLE SIZE RANGE (micron)	NUMBER CONCENTRATION (number/cc)		VOLUME CONCENTRATION (cubic micron/cc)		FRACTIONAL EFFICIENCY (percent)
	UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	
0.442 - 0.562	1581.801	1.60076	102.632	0.104	99.898801
0.562 - 0.750	1774.982	0.71237	254.503	0.102	99.959866
0.750 - 1.000	1251.657	0.21259	425.583	0.072	99.983016
1.000 - 1.334	947.643	0.08784	764.088	0.071	99.990731
1.334 - 1.778	561.976	0.07895	1074.525	0.151	99.985951
1.778 - 2.371	235.419	0.05395	1067.433	0.245	99.977085
2.371 - 3.162	82.970	0.04032	892.118	0.434	99.951358
3.162 - 4.217	26.595	0.03977	678.105	1.014	99.850461
4.217 - 5.623	6.785	0.01085	410.223	0.656	99.840133
5.623 - 7.499	1.420	0.00482	203.558	0.691	99.660447
7.499 - 8.000	0.145	0.00000	35.296	0.000	100.000000
Total	6471.393	2.84221	5908.064	3.539	

OVERALL EFFICIENCY ON PARTICLES < 8.000 MICRON
 BY NUMBER 99.956080
 BY VOLUME 99.940094

Table A-8. Fractional Efficiency Versus Dust Loading - Nonstandard Media, Sample 1

Manufacturer: D.C.I. Model#: P13-5930 (S)
 Dust: ACF Feed Rate 2.5 grams/min
 Airflow: 1875 scfm (ref 59F, 29.92 in. Hg.)
 Duct Size: 22 7/16x 22 1/2 in. (3.51 sq ft)
 Temperature 75 F Relative Humidity: 39 %
 Date 16-NOV-83 Time 17:21:34

PARTICLE SIZE RANGE (micron)	GEOMETRIC MEAN DIAMETER (micron)	UPSTREAM COUNTS	DOWNSTREAM COUNTS
0.442 - 0.562	0.499	1375246	36989
0.562 - 0.750	0.649	1430472	18980
0.750 - 1.000	0.866	1025811	5609
1.000 - 1.334	1.155	790547	1583
1.334 - 1.778	1.540	474329	250
1.778 - 2.371	2.054	203116	63
2.371 - 3.162	2.738	74414	35
3.162 - 4.217	3.652	24638	16
4.217 - 5.623	4.870	5869	8
5.623 - 7.499	6.494	1306	6
7.499 - 8.000	7.745	153	0
LIVE TIME (SECONDS)		327	439
REAL TIME (SECONDS)		450	450

PARTICLE SIZE RANGE (micron)	NUMBER CONCENTRATION (number/cc)		VOLUME CONCENTRATION (cubic micron/cc)		FRACTIONAL EFFICIENCY (percent)
	UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	
0.442 - 0.562	2105.700	40.64708	136.624	2.637	98.069664
0.562 - 0.750	2190.259	25.92964	314.047	3.718	98.816138
0.750 - 1.000	1570.664	7.57042	534.050	2.574	99.518012
1.000 - 1.334	1210.441	1.89508	975.983	1.528	99.843439
1.334 - 1.778	726.266	0.29669	1388.655	0.567	99.959148
1.778 - 2.371	311.000	0.06948	1410.129	0.315	99.977660
2.371 - 3.162	113.939	0.04122	1225.094	0.443	99.963823
3.162 - 4.217	37.724	0.01971	961.878	0.503	99.947753
4.217 - 5.623	8.986	0.00985	543.349	0.596	99.890334
5.623 - 7.499	2.000	0.00739	286.720	1.060	99.630381
7.499 - 8.000	0.234	0.00000	56.996	0.000	100.000000
Total	8277.213	76.48656	7833.525	13.941	

OVERALL EFFICIENCY ON PARTICLES < 8.000 MICRON
 BY NUMBER 99.075938
 BY VOLUME 99.822035

Table A-9. Fractional Efficiency Versus Dust Loading - Nonstandard Media, Sample 2

Manufacturer: D.C.I. Model#: P13-5930(2)
 Dust: ACF Feed Rate 2.5 grams/min
 Airflow: 1875 scfm (ref 59F, 29.92 in. Hg.)
 Duct Size: 22 7/16x 22 1/2 in. (3.51 sq ft)
 Temperature 75 F Relative Humidity: 39 %
 Date 16-NOV-83 Time 17:32:08

PARTICLE SIZE RANGE (micron)	GEOMETRIC MEAN DIAMETER (micron)	UPSTREAM COUNTS	DOWNSTREAM COUNTS
0.442 - 0.562	0.499	1397935	27578
0.562 - 0.750	0.649	1488547	13823
0.750 - 1.000	0.866	1087295	4050
1.000 - 1.334	1.155	861077	1128
1.334 - 1.778	1.540	540442	175
1.778 - 2.371	2.054	242205	54
2.371 - 3.162	2.738	90363	30
3.162 - 4.217	3.652	29773	14
4.217 - 5.623	4.870	6866	7
5.623 - 7.499	6.494	1548	2
7.499 - 8.000	7.745	195	1
LIVE TIME (SECONDS)		326	441
REAL TIME (SECONDS)		450	450

PARTICLE SIZE RANGE (micron)	NUMBER CONCENTRATION (number/cc)		VOLUME CONCENTRATION (cubic micron/cc)		FRACTIONAL EFFICIENCY (percent)
	UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	
0.442 - 0.562	2144.175	30.17389	139.121	1.958	98.592751
0.562 - 0.750	2283.157	18.80245	327.367	2.696	99.176472
0.750 - 1.000	1667.711	5.44253	567.047	1.851	99.673652
1.000 - 1.334	1320.734	1.34452	1064.913	1.084	99.898199
1.334 - 1.778	828.939	0.20678	1584.970	0.395	99.975054
1.778 - 2.371	371.498	0.05929	1684.438	0.269	99.984039
2.371 - 3.162	138.600	0.03518	1490.262	0.378	99.974620
3.162 - 4.217	45.666	0.01717	1164.379	0.438	99.962398
4.217 - 5.623	10.531	0.00859	636.760	0.519	99.918474
5.623 - 7.499	2.374	0.00245	340.442	0.352	99.896686
7.499 - 8.000	0.299	0.00123	72.768	0.298	99.589922
Total	8913.685	56.09408	9072.467	10.238	

OVERALL EFFICIENCY ON PARTICLES < 8.000 MICRON
 BY NUMBER 99.363557
 BY VOLUME 99.887154

Table A-10. Fractional Efficiency Versus Dust Loading - Nonstandard Media, Sample 3

Manufacturer: D.C.I. Model#: P13-5930
 Dust: ACF Feed Rate 2.5 grams/min
 Airflow: 1875 scfm (Ref 59F, 29.92 in. Hg.)
 Duct Size: 22 7/16x 22 1/2 in. (3.51 sq ft)
 Temperature 75 F Relative Humidity: 39 %
 Date 16-NOV-83 Time 17:42:24

PARTICLE SIZE RANGE (micron)	GEOMETRIC MEAN DIAMETER (micron)	UPSTREAM COUNTS	DOWNSTREAM COUNTS
0.442 - 0.562	0.499	1375348	20536
0.562 - 0.750	0.649	1500123	10393
0.750 - 1.000	0.866	1104785	2977
1.000 - 1.334	1.155	889716	860
1.334 - 1.778	1.540	573573	150
1.778 - 2.371	2.054	264890	48
2.371 - 3.162	2.738	101616	17
3.162 - 4.217	3.652	33014	8
4.217 - 5.623	4.870	7607	5
5.623 - 7.499	6.494	1711	3
7.499 - 8.000	7.745	188	0
LIVE TIME (SECONDS)		327	443
REAL TIME (SECONDS)		450	450

PARTICLE SIZE RANGE (micron)	NUMBER CONCENTRATION (number/cc)		VOLUME CONCENTRATION (cubic micron/cc)		FRACTIONAL EFFICIENCY (percent)
	UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	
0.442 - 0.562	2105.856	22.37113	136.635	1.452	98.937671
0.562 - 0.750	2296.904	14.07526	329.338	2.018	99.387207
0.750 - 1.000	1691.585	3.98317	575.165	1.354	99.764531
1.000 - 1.334	1362.283	1.02061	1098.414	0.823	99.925081
1.334 - 1.778	878.223	0.17647	1679.204	0.337	99.979906
1.778 - 2.371	405.585	0.05248	1838.994	0.238	99.987061
2.371 - 3.162	155.589	0.01985	1672.926	0.213	99.987244
3.162 - 4.217	50.549	0.00977	1288.881	0.249	99.980673
4.217 - 5.623	11.647	0.00611	704.252	0.369	99.947577
5.623 - 7.499	2.620	0.00366	375.634	0.525	99.860160
7.499 - 8.000	0.288	0.00000	70.034	0.000	100.000000
Total	8961.129	41.71850	9769.475	7.579	

OVERALL EFFICIENCY ON PARTICLES < 8.000 MICRON
 BY NUMBER 99.534450
 BY VOLUME 99.922419

APPENDIX B

CAB AIR FILTRATION STUDY REPORT

SURVEY OF COMPANIES OPERATING MINING EQUIPMENT

The mining and coal using company portion of the study included 50 surveys from companies around the country (25 eastern companies and 25 western companies). A map showing the states in which the eastern and western companies are located is given (See Figure 1). Initially, attempts were made to survey hazardous material mines such as uranium, beryllium, and silica mines, however, all but a few of these mines were not operating. As a result, most of the surveys were from coal mines (76%) and coal burning power plants (18%). A list of the location and description of each company surveyed is given in Table 1.

The survey used for this part of the study is given in Figure 2. The companies and results were classified into the following four categories:

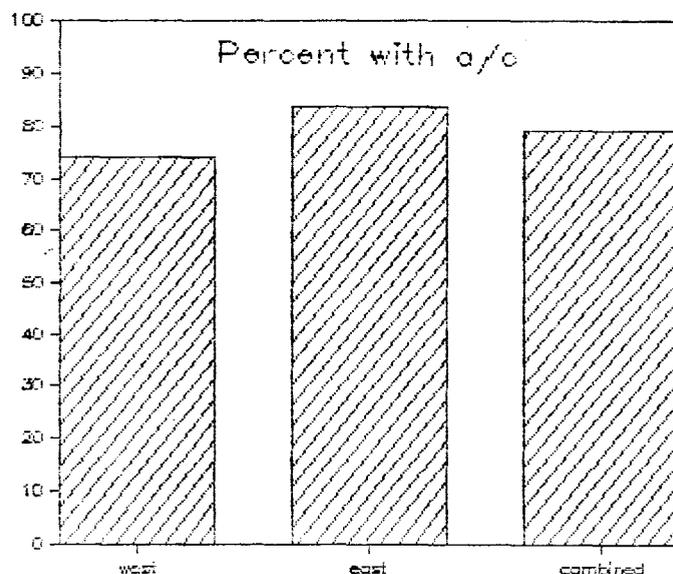
1. Western companies operating equipment with cab air filtration.
2. Eastern companies operating equipment with cab air filtration.
3. Western companies operating equipment without cab air filtration.
4. Eastern companies operating equipment without cab air filtration.

The survey responses from each company in the four categories are given in Tables 2 through 5. The company numbers in the tables correspond to the company numbers giving the location and descriptions in Table 1.

The following discussion will work through the survey by analyzing and evaluating each question. Results that are presented as a percentage are based only on those companies directly answering the question unless otherwise indicated. Bar graphs are used to differentiate between eastern and western company responses.

Discussion of Results:

Virtually all companies surveyed indicated that their cabs contained both ventilation and heat while 79% had air conditioning and 65% had air filtration. See Graphs 1 and 2.



Graph 1

SURVEY COMPANY DESCRIPTION

<u>Number</u>	<u>Location</u>	<u>Description</u>
1.	AZ	Coal Mine
2.	CO	Coal Mine
3.	NM	Coal Mine
4.	NM	Coal Mine
5.	NM	Coal Mine
6.	NM	Coal Mine
7.	ND	Coal Mine
8.	ND	Coal Mine
9.	ND	Coal Mine
10.	MT	Coal Mine
11.	MT	Coal Mine
12.	MT	Coal Mine
13.	MT	Coal Mine
14.	MT	Coal Mine
15.	WA	Coal Mine
16.	UT	Beryllium Mine
17.	WY	Coal Mine
18.	WY	Coal Mine
19.	WY	Coal Mine
20.	WY	Coal Mine
21.	OH	Coal Mine
22.	TN	Coal Mine
23.	PA	Coal Mine
24.	OH	Silica Sand Quarry
25.	MO	Coal Mine
26.	AL	Coal Mine
27.	IL	Coal Mine
28.	WV	Coal Mine
29.	WV	Coal Mine
30.	OH	Coal Mine
31.	OH	Coal Mine
32.	OH	Coal Mine
33.	OH	Coal Mine
34.	MN	Coal - Power Plant
35.	MN	Coal - Power Plant
36.	TX	Coal Mine
37.	NM	Ferro Alloy/Rave Earth Mine
38.	MT	Coal Mine
39.	WY	Coal Mine
40.	WY	Coal Mine
41.	KY	Coal Mine
42.	AR	Coal Mine
43.	IA	Coal - Power Plant
44.	OH	Coal Mine
45.	MN	Coal - Power Plant
46.	MN	Coal - Power Plant
47.	MN	Coal - Power Plant
48.	MN	Coal - Power Plant
49.	MN	Coal - Power Plant
50.	MN	Coal - Power Plant

Table 1

MINING COMPANY SURVEY

Company:

Address:

Phone:

Contact:

Position:

Date:

Time:

Comments:

Does your equipment have cabs? If so, does the cab have:

- Ventilation: (forced, windows)
- Heating:
- Air Conditioning:
- Air Filtration:

How would you rate the overall cab condition?

- clean
- well sealed
- quiet

Questions for cabs with filtration:

1. What type of air filtration?

2. How much airflow in the system? Is this adequate?

3. What type of heating or air conditioning units are used?
 - type
 - model
 - electric
 - hydraulic

MINING COMPANY SURVEY
page 2

4. How is air distributed in cab?
 - on/off
 - adjustable air volume.
 - other explain:

5. How is filter cleaned (manually, continuously)? explain:

6. How often and for what reason is a filter cleaned?
How long does it take to clean filter?

7. What other system maintenance is required?
 - Coils cleaned? How often?

8. What is the cost of maintenance on the system?
 - replacement filters
 - downtime
 - problems with meeting requirements set by govt. agencies.
 - other equipment failures as a result of the system
 - frequency of filter replacement.
 - other

9. Any operator complaints?

10. Would an improved filtration system be of value to you?
Explain:

11. What would your opinion of a self cleaning filtration system be? What would this be worth to you?

MINING COMPANY SURVEY
page 3

Questions for cabs without filtration:

1. Would a low maintenance cab filtration system be useful for dust or other contaminants in your business?

2. What kind of air filtration product would you like?
 - air conditioning included
 - others

3. How much could you improve productivity if cabs were cleaner and more comfortable to operate?
 - reduced downtime.
 - healthier environment
 - less government enforcement activities.

TABLE 2. WESTERN COMPANIES OPERATING EQUIPMENT WITH CAB AIR FILTRATION (Sheet 1 of 3)

COMPANY	DOES THE CAB HAVE:				HOW WOULD YOU RATE THE OVERALL CAB CONDITION ?		
	VENTILATION ?	HEATING ?	AIR CONDITIONING ?	AIR FILTRATION ?	IS THE CAB CLEAN ?	IS THE CAB WELL SEALED?	IS THE CAB QUIET ?
COMPANY 1	—	YES	YES	YES	YES	VERY WELL	YES
COMPANY 2	YES	YES	NO	YES	FAIRLY GOOD	FAIRLY GOOD	FAIRLY GOOD
COMPANY 3	YES	YES	YES	YES	YES, OLDER EQUIPMENT IS DIRTY	NEWER MODELS ARE	NEWER MODELS ARE
COMPANY 4	YES	YES	YES	YES	NOT REALLY	YES	YES
COMPANY 5	PRESSURIZED	YES	YES 50%	YES	FAIR TO GOOD	MOST OF THEM	NEWER MODELS ARE, FOR THE MOST PART NO
COMPANY 6	YES	YES	YES	YES	DO HAVE PROBLEMS FAIR	MOST OF THE TIME	NO (WEAR EAR PLUGS)
COMPANY 7	—	YES	YES	YES	YES	YES	YES
COMPANY 8	—	YES	YES	YES	EXCELLENT	EXCELLENT	EXCELLENT
COMPANY 9	—	YES	YES	YES	SOME ARE GOOD, OTHERS ARE NOT SO GOOD	SOME ARE GOOD, OTHERS ARE NOT SO GOOD	SOME ARE GOOD, OTHERS ARE NOT SO GOOD
COMPANY 10	YES	YES	YES	SOME	FAIR	LOOSEN AFTER NORMAL WEAR	WELL BELOW ALLOWABLE NOISE LEVEL
COMPANY 11	PRESSURIZED DRAGLINES & SHOVELS	YES	YES ON HAULERS, DOZERS	ONE'S WITH AC DO, HEAT ONLY DON'T	GOOD	IN GENERAL	MEETS STANDARDS
COMPANY 12	PRESSURIZED	YES	YES	YES	NOT IF OPERATORS KEEP WINDOWS SHUT	BEST WE CAN DO	GOOD, MEETS REQUIREMENTS
COMPANY 13	YES	YES	YES, EITHER PRESSURIZED OR AC	YES ON SHOVELS, DRAGLINES	YES	YES	YES
COMPANY 14	PRESSURIZED	YES	NO	YES	GOOD	YES	YES
COMPANY 15	—	YES	SOME MOST DON'T	YES	REASONABLE	REASONABLE	REASONABLE
COMPANY 16	YES	YES	YES	YES	—	—	—
COMPANY 17	WINDOW	YES	NO	YES	—	NOT TIGHTLY	—
COMPANY 18	YES	YES	YES	YES	—	—	—
COMPANY 19	YES PRESSURIZED	YES	YES	YES	—	—	—
COMPANY 20	YES	YES	NO	YES	—	—	—

TABLE 2. WESTERN COMPANIES OPERATING EQUIPMENT WITH CAB AIR FILTRATION (Sheet 2 of 3)

COMPANY	WHAT TYPE OF AIR FILTRATION ?	IS THE AIRFLOW IN THE SYSTEM ADEQUATE ?	WHAT TYPE OF HEATING/AC UNITS ARE USED ?	HOW IS THE AIR DISTRIBUTED IN THE CAB ?	HOW IS THE FILTER CLEANED ?	HOW OFTEN IS THE FILTER CLEANED ?	FOR WHAT REASON IS THE FILTER CLEANED ?	HOW LONG DOES IT TAKE TO CLEAN FILTER ?	WHAT OTHER SYSTEM MAINTENANCE IS REQUIRED ?
COMPANY 1	DONALDSON CYLINDRICAL FILTERS	YES	RIMPULL-AC ELECTRIC	OVERHEAD ADJUSTABLE AIR VOLUME	MANUALLY REPLACE	—	VARIABLES	—	MINOR ELECT. PROBLEMS, OCCASIONAL FREON LEAKS
COMPANY 2	CAT PANELS	DEPENDS HOW COLD IT IS, BUT USUALLY ADEQUATE	ELECTRIC ENGINE WATER	BOTH DUCT WORK AND DIRECT	MANUALLY	EVERY 250 HRS	—	SEVERAL MINUTES (10 MIN)	NONE
COMPANY 3	CAT. 798116 (3 PER UNIT) BALDWIN #22	—	—	—	MANUALLY	EVERY 125 HRS	—	30 MIN	—
COMPANY 4	WIX PANEL	YES	ELECTRIC	ON/OFF AND ADJUSTABLE	MANUALLY	EVERY 8 HRS	—	—	NOT REALLY
COMPANY 5	DONALDSON PANEL 30" X 4" X 6"	YES	ELECTRIC	ADJUSTABLE AIR VOLUME	MANUALLY REPLACE	—	—	—	CAT HAVE PROBLEMS WHEN IT IS HUMID & MOIST
COMPANY 6	DONALDSON PANEL 18-20" LONG 8-8" WIDE 2" DEEP	NO COMPLAINTS	CAT ELECTRIC	ON/OFF ADJUSTABLE (TOP OF CAB)	MANUALLY REPLACE	—	—	10 MIN PER FILTER	A LOT OF PROBLEMS WITH COAL PLUSSING EQUIPMENT
COMPANY 7	PANEL	YES	ELECTRIC	3 SPEED ADJUSTABLE	MANUALLY	WEEKLY	—	—	NONE
COMPANY 8	PANEL	YES	CAT ELECTRIC	ADJUSTABLE	MANUALLY	250 HRS (CLEANED 3 TIMES THEN REPLACED)	RESTRICTION	—	CHANGE COMPRESSORS ETC
COMPANY 9	CAT STANDARD	YES	OEM ELECTRIC	ADJUSTABLE	MANUALLY	WHEN RESTRICTED FLOW (VARIABLES)	RESTRICTION	—	NONE
COMPANY 10	CAT FILTERS DISKS/SCREENS	YES	CUMMINS (TRUCKS) CAT (OTHERWISE)	ON/OFF ADJUSTABLE	MANUALLY	DEPENDS ON CONDITIONS CHANGE EVERY TWO MONTHS)	—	15 MIN	NONE
COMPANY 11	—	YES (HIGH VOLUME)	SHOVEL (SIGMA) HAULERS (EASLE)	ADJUSTABLE (FROM OVERHEAD)	MANUALLY	BASED ON CONDITIONS (FIELD SERVICE DAILY)	—	—	COMPRESSOR FAN
COMPANY 12	OEM CAT	YES	CAT (CAT EQUIP) KYSOR (TRUCKS)	ADJUSTABLE 3 SPEED FAN	MANUALLY REPLACE	—	REPLACE ACCORDING TO AMOUNT OF DUST	—	BURNED OUT FAN MOTOR, COIL LEAKING
COMPANY 13	SOME CONES AMERICAN AIR FILTER	YES	KYSOR EAGLE CAT	AUTOMATIC	MANUALLY	PIT (EVERYDAY) TOP (2-3 MONTHS)	FAILURE TO PASS PERIODIC TESTING	—	ELECTRIC (NORMAL PROBLEMS)
COMPANY 14	PANEL	YES	MANUF. STANDARD	ADJUSTABLE	MANUALLY	SCHEDULED PM EVERY 250 HRS	—	15 MIN	NONE
COMPANY 15	—	—	STANDARD ELECTRIC	BOTH TOP AND INSIDE MOUNTED UNITS	REPLACED	—	—	—	LOTS, RECHARGING ETC
COMPANY 16	—	YES	—	ON/OFF WITH MANUAL HIGH/LOW ADJUSTMENTS	MANUALLY REPLACE	DEPENDS ON HOW MUCH WE ARE RUNNING	RESTRICTED AIR FLOW	—	NORMAL OPERATING MAINTENANCE
COMPANY 17	CAT STANDARD	YES	FACTORY	ON/OFF AND ADJUSTABLE	REPLACED	—	—	—	NONE
COMPANY 18	STANDARD	YES	—	ADJUSTABLE	MANUALLY	WITH REGULARLY SCHEDULED MAINTENANCE	—	—	CLEANED COILS, REGULAR MAINTENANCE
COMPANY 19	CARTRIDGE THEY THINK DONALDSON	YES	—	ADJUSTABLE	MANUALLY	SCHEDULED MAINTENANCE	—	—	IF FILTERS ARE REPLACED OFTEN, COILS STAY PRETTY CLEAN
COMPANY 20	FILTER THAT IS SEPERATE FROM HEATER (SEPERATE INLET FROM OUTSIDE)	YES	STANDARD WITH EQUIPMENT	ADJUSTABLE	MANUALLY	WEEKLY DEPENDING ON CONDITIONS	—	—	NONE

TABLE 2. WESTERN COMPANIES OPERATING EQUIPMENT WITH CAB AIR FILTRATION (Sheet 3 of 3)

WHAT IS THE COST OF MAINTENANCE ON THE SYSTEM ?										
COMPANY	REPLACEMENT FILTERS	DOWNTIME PER FILTER CHANGE	PROBLEMS MEETING REQUIREMENTS SET BY GOVT. AGENCIES ?	OTHER EQUIP. FAILURES AS A RESULT OF THE SYSTEM ?	FREQUENCY OF FILTER REPLACEMENT	OTHER COST RELATED INFORMATION	ANY OPERATOR COMPLAINTS ?	WOULD AN IMPROVED FILTRATION SYSTEM BE VALUABLE ?	OPINION OF SELF CLEANING FILTRATION SYSTEM	WORTH OF SELF CLEANING FILTRATION SYSTEM
COMPANY 1	FROM OUTSIDE MAINTENANCE CONTRACTOR	5 MIN	NO	NO	VARIES WITH EQUIPMENT AND CONDITIONS	---	NO, ONLY WHEN IT QUILTS WORKING (NOT OFTEN)	NO	MIGHT BE WORTH A TRY	BASICALLY SATISFIED WITH OUR SYSTEM
COMPANY 2	\$13 - \$16 PER FILTER	DURING ROUTINE OIL CHANGES (10 MIN)	NO	NO	1000 HRS	1 SHIFT/DAY 9 HRS/SHIFT 5 DAYS/WEEK \$13/HR LABOR	NOT USUALLY, BUT OCCASIONALLY	YES	SOUNDS REAL GOOD	WORRIED ABOUT COST OF SUCH SYSTEM
COMPANY 3	\$26.61 PER FILTER	15 MIN	NO	---	EVERY 250 HRS PM EVERY 4 HRS-TRAIN (60 TRAINS/YR)	2 SHIFTS/DAY 10 HRS/SHIFT 4 DAYS/WEEK \$16/HR LABOR	NO	---	---	---
COMPANY 4	---	5 MIN	NO	---	250 HRS	5 DAY/WEEK 3 SHIFTS/DAY 8 HRS/SHIFT	LOOSE WEATHER STRIPPING (VERY MINOR)	IT COULD, SEND TECH BULLETIN	ALREADY HAVE PRECLEANER	---
COMPANY 5	---	5 MIN	NO	NO	DEPENDS ON CONDITIONS	5 DAY/WEEK 3 SHIFTS/DAY 8 HRS/SHIFT	NO	YES	GOOD	---
COMPANY 6	---	10 MIN	YES HAVE TO RESEAL CABS	---	REGULAR SCHEDULE DURING LUNCH	5 DAY/WEEK 2 SHIFTS/DAY 8 HRS/SHIFT	NO	YES, CANT SAY HOW MUCH	GOOD IDEA	---
COMPANY 7	---	NONE REGULAR MAINTENANCE	---	---	FEW MONTHS	---	RELATED TO AC (VERY FEW)	NO	NOT INTERESTED	---
COMPANY 8	---	PM SCHEDULE	NO	NO	AFTER 3 CLEANINGS 1000 HRS	---	NO	DEPENDS ON COST	YES, WOULD BE VALUABLE	YES, WOULD BE VALUABLE
COMPANY 9	---	---	NO	NO	DEPENDS ON CONDITIONS	---	NO	YES	ANYTHING THAT SPEEDS OR SIMPLIFIES OPERATION OR MAINTENANCE	ANYTHING THAT SPEEDS OR SIMPLIFIES OPERATION OR MAINTENANCE
COMPANY 10	\$3.60 PER FILTER	15 MIN	NO	NO	2 MONTHS	---	NO	NO NEED AT PRESENT	NO NEED, ALREADY HAVE PRECLEANER	NO NEED, ALREADY HAVE PRECLEANER
COMPANY 11	\$500.00 PER YEAR PER UNIT ON GENERAL MAINTENANCE	---	NO, MSHA HAS BEEN IN CONTINUOUSLY	---	DAILY OR SHIFT	IN 1985 PUT ALL NEW AC ON HAULERS - WATER ROADS	NOT THE ONE'S THAT HAVE AC	THOSE INTERESTED IN AC MAY BE HELPFUL IF BETTER AND CHEAPER	ADVANTAGE IF COST EFFECTIVE	ADVANTAGE IF COST EFFECTIVE
COMPANY 12	\$8.00 PER FILTER	10 MIN DONE AS PM	NO	NO	125 HRS EXCEPT WHEN CANT CONTROL DUST (24 HRS)	---	ONLY WHEN IT DOESN'T WORK	DOUBT IF WE WOULD NEED MORE	MIGHT BE PRETTY GOOD	DEPENDS ON WHAT WE ARE PAYING TO REPLACE FILTERS
COMPANY 13	DRAGLINE 6 FILTERS \$2.20-\$8.00 PER FILTER	NONE ENOUGH SUPPLEMENT EQUIPMENT	NO	YES NO DETAILS	DEPENDS ON CONDITIONS 1 DAY TO 3 MONTHS	---	NO	COULD BE IN SOME AREAS ALWAYS CAN IMPROVE	DEPENDS	---
COMPANY 14	---	10-15 MIN	NOT YET	---	210 HRS	---	ONLY IF THEY GET PLUGGED	YES, ANYTHING THAT IS IMPROVEMENT AND SAVES MONEY	FINE, IF IT WORKS	COULD CREATE MORE PROBLEMS AND END UP SPENDING MORE
COMPANY 15	---	10 MIN	NO	NO	1 MONTH IN SUMMER, EVERY 6 MONTHS IN WINTER	---	FEW IF ANY	DOUBTFUL	DEPENDS ON COST	DOESN'T KNOW IF COST WOULD BE JUSTIFIED
COMPANY 16	---	---	---	---	---	---	NONE THAT THEY HEARD OF	NO	---	---
COMPANY 17	---	---	---	---	EVERY 500 OPERATING HRS	---	ONLY WHEN IT IS EXTREMELY COLD	NO	---	---
COMPANY 18	---	---	---	---	---	---	OCCASIONALLY IF BROKEN, OTHERWISE SATISFIED	NO	---	---
COMPANY 19	---	---	---	---	---	---	ONLY WHEN SYSTEM IS BROKEN	NO	---	---
COMPANY 20	---	---	---	---	---	---	NO	NOT REALLY	---	---

TABLE 3. EASTERN COMPANIES OPERATING EQUIPMENT WITH CAB AIR FILTRATION (Sheet 1 of 3)

COMPANY	DOES THE CAB HAVE:				HOW WOULD YOU RATE THE OVERALL CAB CONDITION ?		
	VENTILATION ?	HEATING ?	AIR CONDITIONING ?	AIR FILTRATION ?	IS THE CAB CLEAN ?	IS THE CAB WELL SEALED?	IS THE CAB QUIET ?
COMPANY 21	YES	YES	MOST	SOME	YES	YES	DEPENDS ON MACHINE
COMPANY 22	YES, SOME ARE PRESSURIZED	YES	YES	SOME	PRETTY GOOD	FAIRLY	PRETTY GOOD
COMPANY 23	YES, NEW EQUIP. IS PRESSURIZED	YES	YES	YES	YES GOOD	YES GOOD	YES GOOD
COMPANY 24	YES (OPEN WINDOW)	YES	NO	YES	---	---	---
COMPANY 25	YES	YES	YES	YES	FAIRLY	FAIRLY	FAIRLY
COMPANY 26	YES	YES	YES	SOME	YES	YES	YES
COMPANY 27	YES	YES	YES	YES	YES	YES	YES
COMPANY 28	YES	YES	YES	YES	YES	YES	YES
COMPANY 29	YES	YES	YES	YES	YES GOOD	YES GOOD	YES GOOD
COMPANY 30	YES	YES	YES	YES	YES GOOD	YES GOOD	YES GOOD
COMPANY 31	YES	YES	YES	YES	FAIRLY	FAIRLY	FAIRLY
COMPANY 32	YES, PRESSURIZED	YES	YES	YES	YES	YES	NEW EQUIP. YES, OLD EQUIP. EARPLUGS
COMPANY 33	YES	YES	YES	YES	---	---	---
COMPANY 34	YES	YES	YES	YES	---	---	---
COMPANY 35	YES	YES	YES	YES	---	---	---

TABLE 3. EASTERN COMPANIES OPERATING EQUIPMENT WITH CAB AIR FILTRATION (Sheet 2 of 3)

COMPANY	WHAT TYPE OF AIR FILTRATION ?	IS THE AIRFLOW IN THE SYSTEM ADEQUATE ?	WHAT TYPE OF HEATING/AC UNITS ARE USED ?	HOW IS THE AIR DISTRIBUTED IN THE CAB ?	HOW IS THE FILTER CLEANED ?	HOW OFTEN IS THE FILTER CLEANED ?	FOR WHAT REASON IS THE FILTER CLEANED ?	HOW LONG DOES IT TAKE TO CLEAN FILTER ?	WHAT OTHER SYSTEM MAINTENANCE IS REQUIRED ?
COMPANY 21	OEM PROVIDED	---	CAT ELECTRIC	ON-OFF AND ADJUSTABLE AIR FLOW	REPLACED ONLY	---	---	---	---
COMPANY 22	DONALDSON PANELS, CYLINDERS	YES	OEM	---	MANUALLY	REPLACED	REPLACED WHEN DIRTY	10 MIN TO REPLACE	NONE
COMPANY 23	SMALL FILTERS	YES	CAT ELECTRIC	ON-OFF	MANUALLY REPLACED	NOT CLEANED	---	5 MIN TO REPLACE	---
COMPANY 24	ATTACHED TO HEATER	YES	CAT AND CLARK OEM	VARICUS FAN SPEEDS	MANUALLY	OPERATOR DISCRETION	---	---	HEATER CORE FAILURE
COMPANY 25	SEVERAL DIFFERENT OEM TYPES	---	ELECTRIC	TOP OF CAB DUCTWORK	REPLACED ONLY	---	---	---	CLEAN OR RECHARGE AC
COMPANY 26	OEM PANELS	YES	CAT ELECTRIC	FORCED AIR FROM TOP AND SIDE	REPLACED ONLY	---	REPLACED WHEN DIRTY	15 MIN TO REPLACE	RECHARGING AND GENERAL MAINTENANCE
COMPANY 27	STANDARD OEM	YES	MOST ELECTRIC SOME HYDRAULIC	ADJUSTABLE AIR FLOW	MANUALLY	---	ROUTINE MAINTENANCE	---	GENERAL AC MAINTENANCE (NOBODY BUILDS A GOOD AC UNIT)
COMPANY 28	STANDARD OEM	YES	ELECTRIC	FROM UNIT NO DUCTS	MANUALLY	REGULAR MAINTENANCE	WHEN NEEDED	---	FREON CHARGE
COMPANY 29	CAT STANDARD	YES	CAT ELECTRIC	BLOWERS AND DUCTWORK	REPLACED ONLY	---	REPLACED WHEN DIRTY	---	NONE EXCEPT ROUTINE MOTORS RECHARGE, ETC
COMPANY 30	CAT STANDARD	YES	CAT ELECTRIC	3 SPEED FAN	MANUALLY	EVERY 2 WEEKS	PERIODIC (2 WEEKS)	15 MIN	NONE
COMPANY 31	PAPER PANELS	YES	OEM	ADJUSTABLE SPEED BLOWER	REPLACED ONLY	---	---	---	AC COMPONENTS, CONTROLS
COMPANY 32	CAT PANELS	YES	CAT ELECTRIC	ON-OFF	MANUALLY	EVERY 500 HRS	REPLACED WHEN DIRTY	15 MIN	SCHEDULED MAINTENANCE
COMPANY 33	PANELS AND CYLINDRICAL	YES	CAT STANDARD	---	REPLACED ONLY	---	REPLACED WHEN DIRTY	15-20 MIN	---
COMPANY 34	PANEL	YES	---	ADJUSTABLE AIR FLOW	MANUALLY	SUMMER TWICE/WK WINTER TWICE/MONTH	WHEN AIR FLOW RESTRICTED	---	NONE
COMPANY 35	---	YES	---	ADJUSTABLE AIR FLOW	---	---	---	---	NONE

TABLE 3. EASTERN COMPANIES OPERATING EQUIPMENT WITH CAB AIR FILTRATION (Sheet 3 of 3)

WHAT IS THE COST OF MAINTENANCE ON THE SYSTEM ?											
COMPANY	REPLACEMENT FILTERS	DOWNTIME PER FILTER CHANGE	PROBLEMS MEETING REQUIREMENTS SET BY GOVT. AGENCIES ?	OTHER EQUIP. FAILURES AS A RESULT OF THE SYSTEM ?	FREQUENCY OF FILTER REPLACEMENT	OTHER COST RELATED INFORMATION	ANY OPERATOR COMPLAINTS ?	WOULD AN IMPROVED FILTRATION SYSTEM BE VALUABLE ?	OPINION OF SELF CLEANING FILTRATION SYSTEM	WORTH OF SELF CLEANING FILTRATION SYSTEM	
COMPANY 21	UNDER \$20 PER FILTER	NONE DONE BETWEEN SHIFTS	NO	NO	---	---	NO	YES	WONDERFUL	---	
COMPANY 22	---	---	NO	---	EVERY 1-2 MONTHS	5 DAYS/WK 8 HRS/SHIFT 1-3 SHIFTS PER DAY	NO	NO	---	---	
COMPANY 23	\$8 PER FILTER, 2 UNITS USED	5 MIN	NO	NO	EVERY 1.5 MONTHS	---	NO	NO	WOULD NOT LAST LONG	---	
COMPANY 24	---	---	NO	NO	---	1 SHIFT PER DAY	ONLY WHEN HEATER IS NOT WORKING	NO	---	---	
COMPANY 25	---	---	NO	NO	---	---	SELDOM	YES	NICE IF IT WORKED CONCERNED THAT SELF CLEANING SYSTEM WOULD DAMAGE FILTERS	---	
COMPANY 26	---	NONE	YES SOMETIMES	NO	1 WEEK TO 1 MONTH	1 SHIFT	DIFFICULT TO SERVICE AC UNITS. (PULL CAB APART)	YES	YES, WOULD LIKE TO SEE	---	
COMPANY 27	---	---	NO	NO	---	---	AC UNITS BROKEN, NO FILTRATION COMPLAINTS	NO	IT WOULD HELP	---	
COMPANY 28	---	NONE	NO	NO	---	---	NO	NO	NOT INTERESTED	NOTHING	
COMPANY 29	\$6-7 PER FILTER	NONE	NO	NO	TWICE/SUMMER ONCE/WINTER	---	JUST WHEN UNIT BREAKS	---	INTERESTED	CONCERNED ABOUT COST	
COMPANY 30	---	15-20 MINUTES	NO	NO	1 TIME PER MONTH	2 SHIFTS 8 HRS/SHIFT 5 DAYS/WEEK	NO, UNITS ARE VERY CLEAN	YES	VARIES	---	
COMPANY 31	---	NONE	NO	MOTORS, CONTROLS, AC COMP.	225 HRS	---	NOT HOT OR COOL ENOUGH, DUSTY	YES	MUST BE ADAPTABLE TO CAB	COST MUST BE WEIGHED	
COMPANY 32	---	SOMETIMES, BUT TRY TO DO DURING PM	NO	---	2000 HRS	---	NO	NO	PROBABLY TOO EXPENSIVE	EXPENSIVE	
COMPANY 33	\$20 PER FILTER	15-20 MINUTES	NO	NO	---	---	---	YES	COULDN'T SAY	CONCERNED ABOUT COST	
COMPANY 34	---	NONE	NO	NO	---	---	NO	NO	---	---	
COMPANY 35	---	---	---	---	---	---	NO	NO	---	---	

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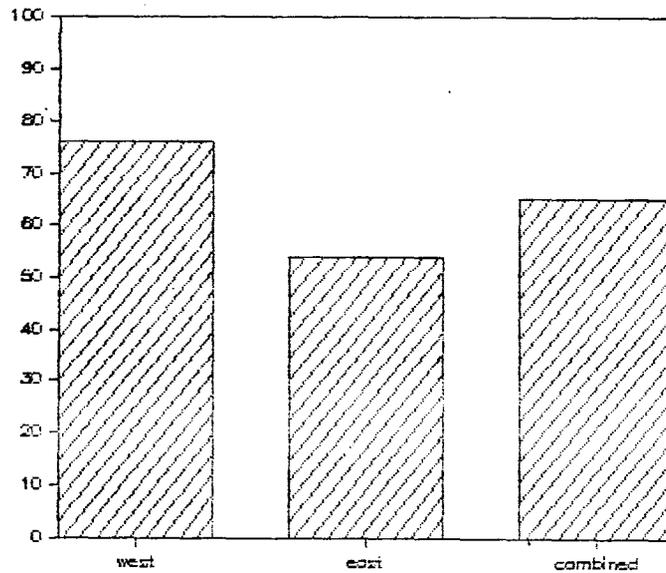
WESTERN COMPANIES OPERATING EQUIPMENT WITHOUT CAB AIR FILTRATION										
COMPANY	DOES THE CAB HAVE:				HOW WOULD YOU RATE THE OVERALL CAB CONDITION ?			WOULD A LOW MAINTENANCE CAB FILTRATION SYSTEM BE USEFUL FOR DUST OR OTHER CONTAMINANTS IN YOUR BUSINESS ?	WHAT KIND OF AIR FILTRATION PRODUCT WOULD YOU LIKE ?	HOW MUCH COULD YOU IMPROVE PRODUCTIVITY IF CABS WERE CLEANER ?
	VENTILATION ?	HEATING ?	AIR CONDITIONING ?	AIR FILTRATION ?	IS THE CAB CLEAN ?	IS THE CAB WELL SEALED?	IS THE CAB QUIET ?			
COMPANY 36	YES	YES	YES	NO	MEDIUM	I IS GOOD REPLACING DOOR SEALS ON OTHERS	RELATIVELY	NO	AIR CONDITIONING	MINIMAL INCREASE
COMPANY 37	NO	NO	NO	NO	---	---	---	SURE, BUT IT IS ONLY A MODERATE PROBLEM	HEATING MORE THAN AIR CONDITIONING (HIGH ELEVATION -DROPS TO 20' TO 30' BELOW 0	NONE, DONT HAVE MUCH OF A PROBLEM NOW
COMPANY 38	YES	YES	SOME	NO	SCRAPERS-FAIR DOZERS-BETTER HAULERS-GOOD (HAVE AC)	YES	SCRAPERS ARE NOISY	YES, USED TO HAVE A PROBLEM WITH COAL HAULERS AND LOADERS BEFORE AC UNITS WERE INSTALLED	BIGGEST PRIORITY WOULD BE ONE THAT CONTAINED HEAT	NOT SURE
COMPANY 39	YES	YES	YES	NO	---	---	---	NO	AIR CONDITIONING AND PROVIDE CLEAN CABS	NO PROBLEMS
COMPANY 40	---	YES	SOME	NO	---	---	---	YES	AIR CLEANING IS MOST IMPORTANT	NOT SURE

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EASTERN COMPANIES OPERATING EQUIPMENT
WITHOUT CAB AIR FILTRATION

COMPANY	DOES THE CAB HAVE:				HOW WOULD YOU RATE THE OVERALL CAB CONDITION ?			WOULD A LOW MAINTENANCE CAB FILTRATION SYSTEM BE USEFUL FOR DUST OR OTHER CONTAMINANTS IN YOUR BUSINESS ?	WHAT KIND OF AIR FILTRATION PRODUCT WOULD YOU LIKE ?	HOW MUCH COULD YOU IMPROVE PRODUCTIVITY IF CABS WERE CLEANER ?
	VENTILATION ?	HEATING ?	AIR CONDITIONING ?	AIR FILTRATION ?	IS THE CAB CLEAN ?	IS THE CAB WELL SEALED?	IS THE CAB QUIET ?			
COMPANY 41	---	YES	YES	NO	YES	SOME	YES, MEETS REQUIREMENTS	NO	FILTERED AIR WITH HEAT AND AC	HARD TO ESTIMATE
COMPANY 42	YES	YES FROM RADIATOR	SOME	NO	YES	NO	MEETS STANDARDS BUT ARE NOISY	NOT REALLY	DEPENDS ON WHAT PART OF THE COUNTRY. AC WOULD BE NICE	HARD TO SAY, PROBABLY NOT A GREAT DEAL
COMPANY 43	YES	YES	YES	NO	---	---	---	NO	NONE	DONT KNOW
COMPANY 44	---	YES	YES	NO	YES	YES	MEETS REQUIREMENTS	NO, WE ALREADY HAVE AC	DONT REALLY NEED	ALREADY CLEAN
COMPANY 45	FAN	YES	NO	NO	---	---	---	AT TIMES (COAL DUST PRIMARILY)	HEATING, WORK IN WINTER AND THERE IS STILL A PROBLEM WITH COAL DUST	NONE
COMPANY 46	YES	YES	YES	NO	---	---	---	NO, WATER SYSTEM KEEPS DOWN DUST	NONE	NONE
COMPANY 47	YES	YES	YES	NO	---	---	---	THERE WAS A MAJOR PROBLEM BEFORE AC UNITS WERE INSTALLED	HEATING AND AIR CONDITIONING (SOMETIMES VERY UNCOMFORTABLE IN EXTREME CONDITIONS)	NONE
COMPANY 48	YES	YES	NO	NO	---	---	---	NO	NONE	NONE
COMPANY 49	YES	YES	YES	NO	---	---	---	NOT THAT HE IS AWARE OF	NONE	NOT SURE
COMPANY 50	YES	YES	YES	POOR	---	---	---	YES, PROBLEMS WITH REGULATIONS AND SAFETY INSPECTORS (ESPECIALLY WITH PETROLEUM, COAL)	AIR CONDITIONING AND HEAT PRESSURIZED CAB, 100 % FILTERED AIR, PLEATED FILTERS, EASY TO CLEAN & REPLACE. OPERATORS WONT NEED TO WEAR A MASK	NOT SURE, AS OF NOW -LONG TERM EFFECTS ARE QUESTIONABLE BUT STILL WORRY SOME

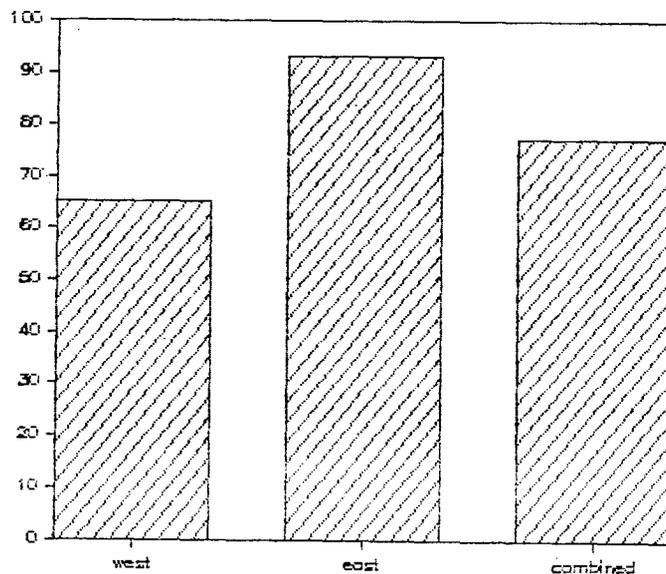
Percent with cab filtration



Graph 2

Seventy-seven percent of those responding said their cabs were clean inside (Graph 3). A rating system was devised to evaluate the overall cab condition based on how clean, well sealed, and quiet the cabs were. Based on these criteria, each cab was rated from 1-5, 5 being in excellent condition, 4-very good, 3-good, 2-fair, and 1-poor. The average rating for all cabs was 2.95 indicating that the overall cab condition was good.

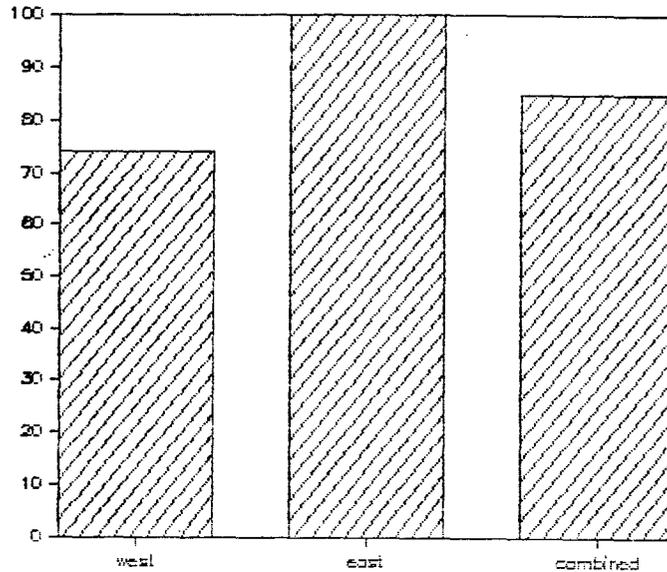
Percent claiming clean cabs



Graph 3

Of the heating/AC units used, 85% were standard OEM equipment while 15% were from outside manufacturers such as Eagle, Sigma, etc. (Graph 4). Filtration systems consisted primarily of standard cylindrical and panel filters.

Percent using OEM equipment



Graph 4

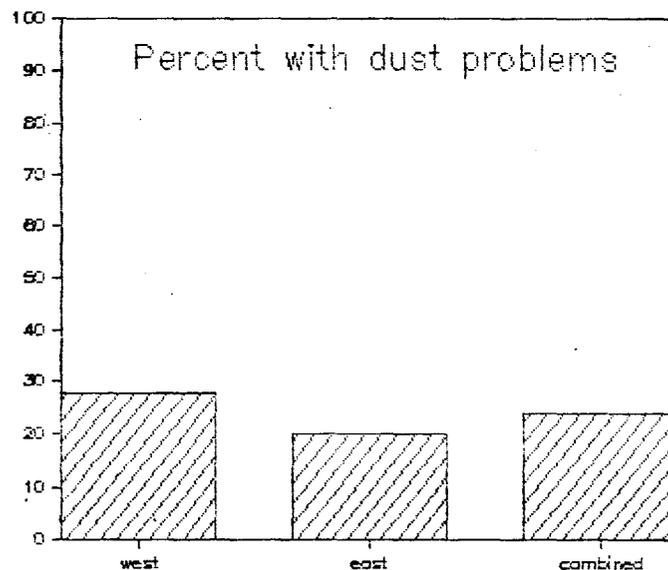
All companies indicated that variable speed blowers were used to deliver air to the cabs and nine companies added that a ductwork system was employed which delivered the air into the top or side of the cab.

None of the companies surveyed could give a quantitative answer to the amount of airflow in their system, although all companies felt the airflow in their system was adequate.

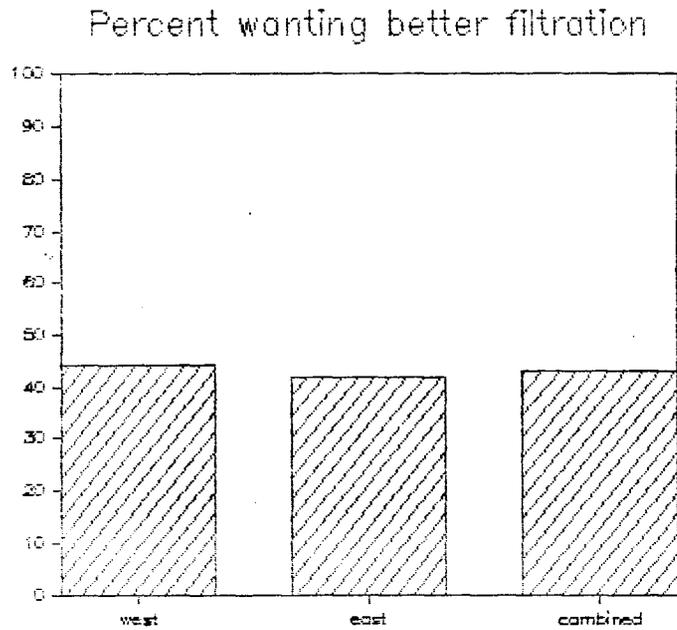
Although most (68%) operators had no complaints about their cab air system, some typical operator complaints included:

- AC components break often
- cabs are dusty inside
- heating system is not adequate when very cold
- units are difficult to service

Overall, 24% of those surveyed claimed that they had a dust problem, while 43% of those with filtration indicated they would like an improved filtration system (Graphs 5 and 6).

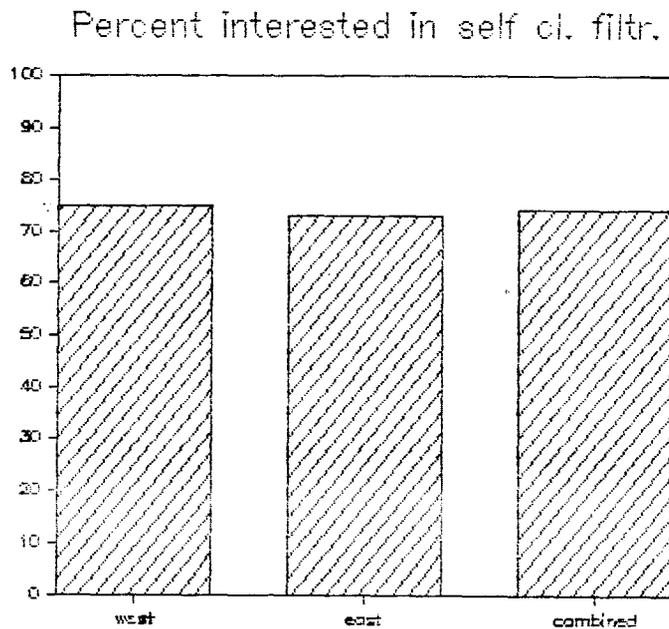


Graph 5



Graph 6

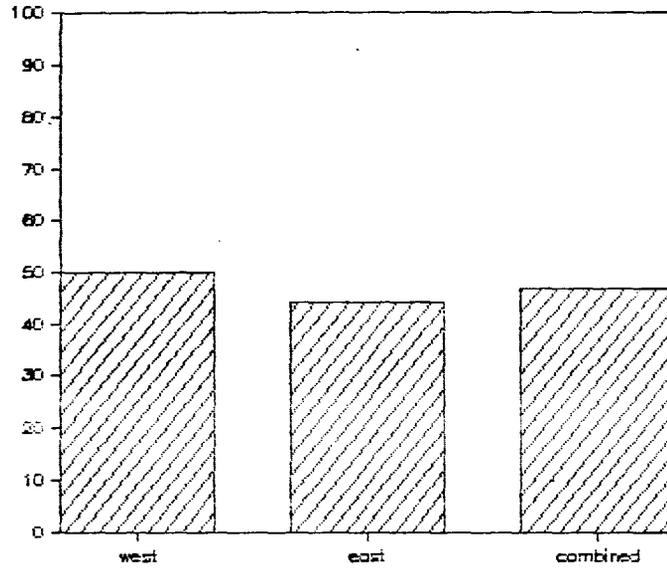
Seventy-four percent of those with filtration said they would be interested in a self-cleaning system (Graph 7).



Graph 7

Of those interested in a self-cleaning system, 47% were very concerned about the cost of such a system (Graph 8).

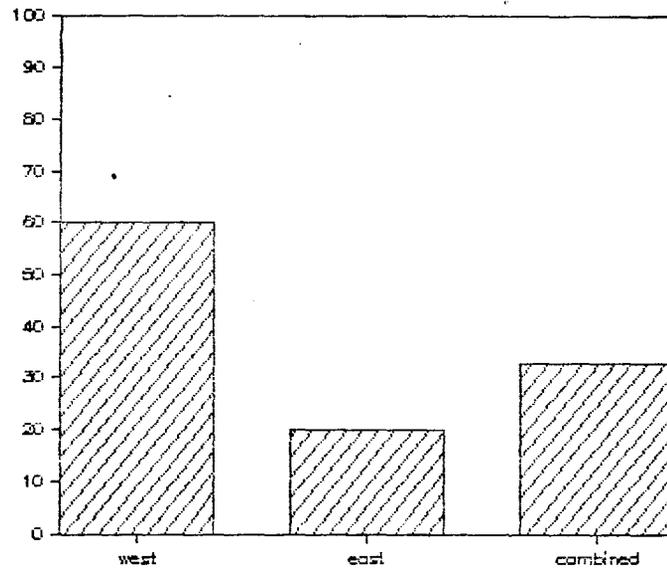
Percent concerned about system cost



Graph 8

Of those companies whose cabs had no air filtration, 33% expressed a desire for filtration (Graph 9).

Percent w/o filtr. desiring filtration



Graph 9

COST ESTIMATES

The following cost analysis is provided for those companies with filtration. The initial estimates are based on approximate average costs from all responses. Cost estimates are then given for particular companies who provided all the necessary information to calculate such estimates.

Cost Analysis Averages

AVERAGE OPERATING SHIFT DATA:

Hrs./shift = 8.429
shifts/day = 1.611
days/wk = 4.857
wks/month = 4

250 hrs/month

3000 hrs/yr

AVERAGE FILTER CLEANING COSTS:

Cleaning Frequency 200 hrs
Number of Cleanings/yr 12 cleanings/yr*
Cleaning Time 15 min = .25 hrs.
Labor Costs \$14.50/hr

\$ 43.50/yr

AVERAGE FILTER REPLACEMENT COSTS:

Filter Replacement Cost \$ 14.40/filter
Replacement Frequency 500 hrs
Number of Replacements/yr 6 replac/yr*
Replacement Time 6 min = 0.1 hrs
Labor Costs \$ 14.50/hr

\$ 95.10/yr

DOWNTIME:

None - done during periodic maintenance or
after shifts -

NO LOSS OF PRODUCTION

Federal Agency Requirements:

6% claimed they had problems

TOTAL ANNUAL COST OF FILTRATION FOR EACH UNIT:

Estimated \$140/yr

* On the average, filters were cleaned twice before replacing.

Cost Analysis For Company #3

Operation:

- days/wk = 4
- shifts/day = 2
- hrs/shift = 10

- Replacement filters: Cab air filter = \$26.69
Vent. 777 air filter = \$12.91

- Frequency of replacement: - every 250 hrs - preventative maintenance
- on 777s every 125 hrs. - preventative maintenance
- every 4 hrs. when loading train (4 hrs. to load train - 60 trains/yr.)

- Labor cost: \$16/hr 15 minutes to replace filter.

- Loss of production as result of downtime: none

- System maintenance as result of poor filtration: none

COST EVALUATION

Regular preventative maintenance (avg. 125-250 hrs). 187.5 hrs.	
replacements/yr = 22.187	
filter costs = \$26.69	= \$592.16
Labor costs (22.187 replacements * 15 min * \$16/hr) =	\$ 88.75
Loading train: (60 replacements * \$26.69)	\$1,601.40
Labor costs (loading train): (60 replacements * 15 min * \$16/hr)	\$240.00
Cost for filtration/yr =	<u>\$2,522.31</u>
for each unit.	

Cost Analysis For Company #10

Replacement:	3.60/filter	\$ 21.60
Frequency:	Every 2 months	
Labor cost:	Estimated at \$16.00/hr	\$ 24.00
		<hr/>
	Cost for filtration/yr = for each unit.	<u>\$ 45.60</u>

Cost Analysis For Company #11

Operation:

- 3 shifts/day:
- Replacement filters: Estimated at about \$20.00
- Frequency of replacement: 2 months
- Frequency of cleaning: every 1-3 shifts (avg = 1.5 shifts)
- Labor cost: Estimated at \$16/hr
- Loss of production as result of downtime: none
- System maintenance as result of poor filtration: \$500/yr

COST EVALUATION

Cleaning filters:

Labor costs (10 times/wk * \$16/hr* 52 weeks/yr * 15 min)) =	\$2,080.00
Replacing filters: (6 times/yr @ 20.00 filter) =	\$120.00
Labor costs (6 times/yr * 15 min/time * \$16.00/hr) =	\$ 24.00
Annual system maintenance	\$500.00

Cost for filtration/yr = \$2,724.00
for each unit.

Cost Analysis For Company #12

Operation:

- 2 shifts/day:
- Replacement filters: \$8.00/filter
- Frequency of replacement: 24-125 hrs (avg. 74.5 hrs)
- Time to replace: 10 minutes
- System maintenance as a result of poor filtration: none
- Loss of production as a result of downtime: none
- Labor cost: Estimated at \$16/hr

COST EVALUATION

Replacement filters: - (4160 hrs/yr * 1/75 = 55.47 replacements)	
55.47 * \$8/filter =	\$443.76
Labor costs (55.47 replacements * 10 min. * \$16.00/hr)=	\$147.92
	<hr/>
Cost for filtration/yr =	\$591.68
for each unit.	<hr/> <hr/>

Cost Analysis For Company #13

(Estimate for dragline)

Dragline: 6 filters @ \$2.20-8.00/filter (avg. \$5.10/filter)	\$ 30.60 dragline
Replace every 15.5 days (23 replacements/yr)	\$710.60/yr
Labor costs: (23 replacements * 6 filters * 15 min * 16/hr)	\$557.40
	<hr/>
Cost for filtration/yr = for each dragline	<u>\$1,298.60</u>

SURVEY OF HEATING/AC UNIT ORIGINAL EQUIPMENT MANUFACTURERS

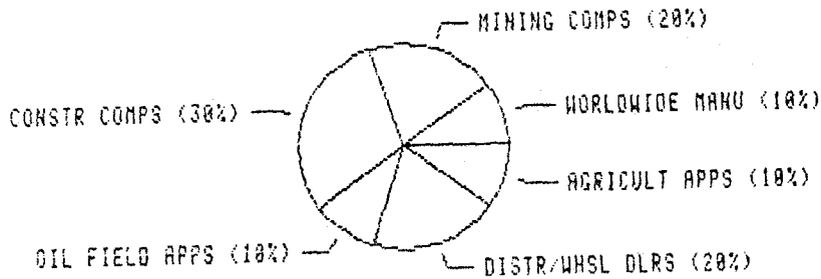
The OEM portion of the study included surveys from eight companies around the country. The purpose of surveying the OEMs was to determine problems, costs, etc. of existing systems from the OEM perspective. The survey used can be found in Figure 3. The survey responses from each company are given in Table 6.

Discussion of Results:

- 1) Of the OEMs who gave the air filter manufacturers name associated with their air conditioning/heating equipment, 4 out of 5 (80%) used Donaldson products. There were an equal number of panel and cylindrical elements. Also an equal number of filters used paper as opposed to fiber media.
- 2) The OEM's customers ranged from oil field applications to worldwide manufacturers. The responses were as follows:

Distributor/wholesale dealers	2 out of 10
Worldwide manufacturers	1 out of 10
Mining companies	2 out of 10
Construction companies	3 out of 10
Oil field applications	1 out of 10
Agricultural applications	1 out of 10

Note: 10 responses were obtained from the 8 companies.



Their customers were primarily located as follows:

Near mines	2 out of 6
Regionally	1 out of 6
United States	1 out of 6
Worldwide	2 out of 6

Company:

Address:

Phone:

Contact:

Position:

Date:

Time:

-
1. What type of air filtration do you use with your air conditioning/heating equipment in the off-road mining application? (type, model number).

 2. Who are your customers and where are they primarily located? (region of country).

 3. What is the operating airflow?
What is the predicted life of the air filter?
What is the recommended maintenance?
What is the replacement filter cost?

 4. Have you noticed any.....with your system?
 - restricted airflow
 - uneven dust loading
 - poor efficiency
 - dirty coils (how often do they need cleaning).
 - do filters protect AC equipment
 - others

 5. Have your customers noted any.....with the system?
 - restricted airflow
 - uneven dust loading
 - poor efficiency
 - dirty coils
 - do filters protect AC equipment
 - others

OEM Survey
page 2

6. What are the customers concerns?

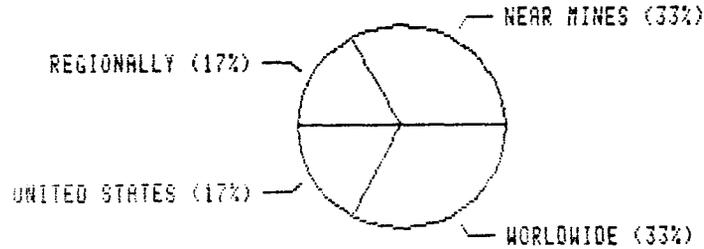
7. Can we contact your customers about their concerns?

Comments:

			OEM					
OEM	WHAT TYPE OF AIR FILTRATION DO YOU USE IN YOUR HEAT/AC UNITS ?	WHO ARE YOUR CUSTOMERS AND WHERE ARE THEY PRIMARILY LOCATED ?	WHAT IS THE OPERATIONAL AIRFLOW ?	WHAT IS THE PREDICTED LIFE OF THE FILTER ?	WHAT IS THE RECOMMENDED MAINTENANCE OF THE FILTER ?	EVALUATE SYSTEM PERFORMANCE IN REGARDS TO: AIRFLOW, DUST LOADING, EFFICIENCY, COIL CLEANLINESS	HOW DO YOUR CUSTOMERS EVALUATE THE SYSTEM PERFORMANCE ?	WHAT ARE YOUR CUSTOMER CONCERNS ?
OEM 1	DONALDSON PANELS AND OCI ROUND FILTERS	WHOLESALE DEALERS SUCH AS CAT, NEAR MINES IN KENTUCKY, MISSOURI, ETC.	1-400 CFM	—	CLEAN EVERY SHIFT, REPLACE WHEN NECESSARY	GOOD OPERATION WHEN SCHEDULED MAINTENANCE IS PERFORMED	NO FILTRATION PROBLEMS	—
OEM 2	DONALDSON	WORLDWIDE MANUFACTURERS, AMBULANCE, FIRE-TRUCKS, FARM EQUIPMENT, ETC.	1-300 CFM	—	SUPPLIED BY MANUFACTURES	GOOD OPERATION SOME MINOR PROBLEMS HAVE BEEN CORRECTED	NO FILTRATION PROBLEMS	—
OEM 3	NAPA FILTER (BOUGHT LOCALLY IN STORES)	MINING AND CONSTRUCTION, WORLDWIDE	UNKNOWN	—	SERVICE ONCE/YEAR REPLACE EXPANSION VALVE, DRYERS, COAL INDUSTRY-BLOW OUT ONCE A WEEK	NO PROBLEMS BUT SOME COULD BE EXPECTED IN HEAVY INDUSTRY APPLICATIONS	NO FILTRATION PROBLEMS	—
OEM 4	SEVERAL FIBER FILTERS IN RETURN AIR PORTION	OIL FIELD APPLICATIONS IN SOUTHWEST USA, TEXAS, ETC.	—	—	WASH FILTER	NO PROBLEMS	NO FILTRATION PROBLEMS	—
OEM 5	PAPER FILTER 1/2" FOAM CHARCOAL	MINING AND CONSTRUCTION, ALL OVER USA	450 - 550 CFM	—	CLEAN FILTER AS NEEDED	NO PROBLEMS	NO FILTRATION PROBLEMS	—
OEM 6	PAPER FILTERS	WOULDN'T SAY WHO, ALL OVER USA	230 - 240 CFM 480 - 480 CFM	—	VARIES ON APPLICATION -WHEN AIRFLOW IS RESTRICTED	NO PROBLEMS	NO FILTRATION PROBLEMS	PEOPLE IN CHEMICAL INDUSTRY ARE WARY. COMPANY GUARANTEES DUST-NOT CHEMICAL REMOVAL.
OEM 7	DONALDSON AND OEM RECOMMENDED	AGRICULTURE & CONSTRUCTION OEM AND AFTERMARKET IN MANY INDUSTRY	250 - 800 CFM 20% FOR PRESSURIZATION	1-2 DAYS TO 1-2 WEEKS	CLEAN AS REQUIRED REPLACE AS REQUIRED	SOME PROBLEMS IN LOADING/RESTRICTION IF NOT ENOUGH RECIRCULATED AIR IS USED	FILTERS ARE INEFFICIENT ON SMALL PARTICLES. EVAPORATOR COIL PLUGS UP.	—
OEM 8	DONALDSON CYCLOPAK (8" FILTER OPTIONAL)	WAREHOUSE DISTRIBUTION DEW'S KENTUCKY COAL MINES	320 CFM	DEPENDS ON ENVIRONMENT	OCI SPECS OR WHEN CAB GETS DIRTY	GOOD OPERATION	NO PRESSURIZATION IN WINTER BUT IT'S NOT NEEDED BECAUSE IT'S USUALLY WET	COST

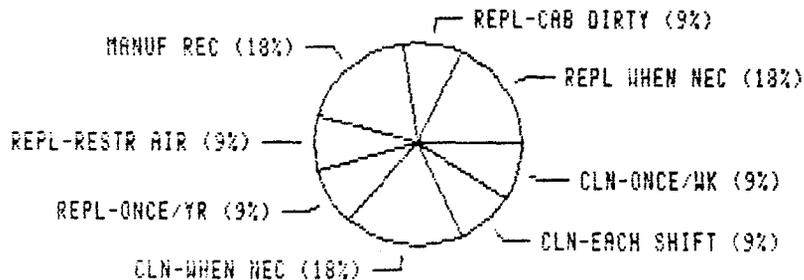
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OEM CUSTOMER LOCATIONS



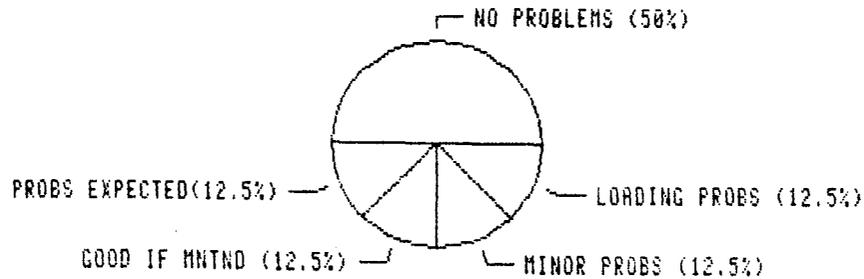
- 3) In determining operating airflow, the responses ranged from 1-600 cfm with an average maximum airflow of 412 cfm. One OEM indicated that pressurization accounted for 20% of required cfm.
- 4) In determining the predicted life of the filter, a quantitative response was obtained from only 1 OEM. This response indicated that the predicted life is 1 day - 2 weeks. The other responses indicated that filter life depended on environmental conditions.
- 5) There was a wide range of recommended filter maintenance from the different OEMs. These responses were as follows:

Manufacturers recommendation	2 out of 11
Replace - When necessary	2 out of 11
Replace - When cab gets dirty	1 out of 11
Replace - When airflow is restricted	1 out of 11
Replace - Once/yr	1 out of 11
Clean - When necessary	2 out of 11
Clean - Every shift	1 out of 11
Clean - (Blow out) once/wk.	1 out of 11



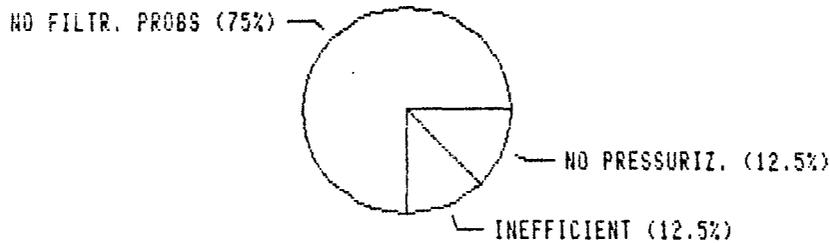
6) In evaluating the system performance with respect to airflow, dust-loading, efficiency, and cleanliness, OEM responses were as follows:

No problems	4 out of 8
No problems-some could be expected in heavy industries	1 out of 8
Good-when maintenance is performed	1 out of 8
Good-with minor problems	1 out of 8
Some problems with loading/restriction	1 out of 8



7) The OEMs' customers evaluation of system performance as stated by the OEM were as follows:

No filtration problems	6 out of 8
Inefficient on small particles	1 out of 8
No pressurization in winter, although it is not really needed.	1 out of 8



8) The two responses given to customer concerns were from people in the chemical industry in regards to chemical contaminants. The dust problems in this industry were taken care of but the chemical problems have not been addressed.

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