



FLOODED-BED SCRUBBER FOR MACHINE-MOUNTED  
COAL MINE APPLICATIONS

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR  
BUREAU OF MINES

by

DONALDSON COMPANY, INC.  
Minneapolis, Minnesota 55440

FINAL REPORT

on

Contract JO188098

CLOGGING OF FLOODED-BED SCRUBBER

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## FOREWORD

This report was prepared by Donaldson Company, Inc., Minneapolis, Minnesota under USBM Contract No. J0188098. 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 PMSRC, with Mr. Edward F. Divers acting as the Technical Project Officer. Mr. H.R. Eveland was the Contract Administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period June 1978 to May 1979. This report was submitted by the authors in May 1979.

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

## EXECUTIVE SUMMARY

This report summarizes the work performed during the course of Contract JO188098 entitled, "Clogging of the Flooded-bed Scrubber".

The objective of this contract was to monitor operating conditions for, four flooded, fibrous-bed filter panels used during normal mining operation and to analyse clogging and breakage problems. After observing these problems, a final, flooded, fibrous-bed filter design which minimizes clogging and breakage problems was recommended to the Bureau of Mines. A second objective of this contract was to determine the dust concentration at the flooded, fibrous-bed scrubber intake duct.

To accomplish these contract objectives, Donaldson Company representatives visited Peabody Coal Mine Camp 11. During these visits, the flooded, fibrous-bed filter designs were tested in a mining situation. Donaldson Company representatives also obtained dust samples for laboratory analysis. Both the flooded, fibrous-bed filters and sampling filters were analysed in the Donaldson Company laboratory.

This final report describes the work accomplished, the problems investigated, the laboratory evaluation and the recommended solutions.

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## 1.0 BACKGROUND/STATEMENT OF THE PROBLEM

Toxic ore dusts and respirable airborne dust generated during underground mining operations constitute a human-health hazard, thus making dust control imperative. Other reasons for reducing dust levels include reducing rock dusting requirements in coal mines, improving face visibility and increasing mining production.

The continuous miner which generates respirable dust by the crushing action of the cutting bits is a major source of respirable dust at the mine face. With increased emphasis on production and strict Mine Safety and Health Administration (MSHA) laws, it becomes important to prevent dust from diffusing into the air supply.

Several forms of machine-mounted dust collection devices have been utilized to control dust with limited success since 1970. Flooded, fibrous-bed filters have been used successfully to filter respirable and nuisance dust in coal mines for only a short time duration. During this short time, several problems have occurred concerning the durability and clogging of these filters. The flooded, fibrous-bed filters tend to become clogged with coal particles. These large particles lodge in the wire mesh media restricting airflow. Once clogged, these filters must be dried and cleaned before reuse. These large particles also cause the welds which secure the wire screen to the frame and the screen wires to break.

Recognizing these problems, the Bureau of Mines issued Contract J0188098 to Donaldson Company to investigate these problem areas and recommend the most efficient, practical and economical flooded, fibrous-bed filter design.

## 2.0 CONTINUOUS MINER DUST CONTROL SYSTEM

### 2.1 Continuous Miner Operation

The continuous miner referenced in this report is a Joy 14CM. The dust control system on this miner was designed and built by Joy Manufacturing to control respirable and nuisance dust at the cutting face. The flooded fibrous-bed filter used on this machine is designed and built by Donaldson Company for Joy Manufacturing.

The continuous miner, figure 1, operates by digging at the mine face with a spinning cutting drum. Mined ore falls to the floor and is scooped to a conveyor by two mechanical arms. Once on the conveyor, the ore travels the length of the miner and is dumped into a shuttle car so that the mining machine can operate continuously.

### 2.2 Dust Control System Description

The dust control system consists of intake ducts, a 6500 ft<sup>3</sup>/min, 25 hp Model 500792735 Joy fan, transitions, a flooded, fibrous-bed filter, spray nozzles, a mist eliminator and a slurry pump. The flooded, fibrous-bed filter is mounted at a 48° angle in the main duct (figure 1).

In this system, dirty air is pulled through an intake duct through a transition into the flooded, fibrous-bed filter. As the dust-laden air passes through the flooded, fibrous-bed panel, dust in the airstream becomes entrained in the water droplets. Large ore particles are trapped in the wire-mesh filter media. The dirty water and clean air are then pulled by the fan into the mist eliminator. In the mist eliminator, moisture is removed from the air, and clean air is discharged near the left rear of the machine.

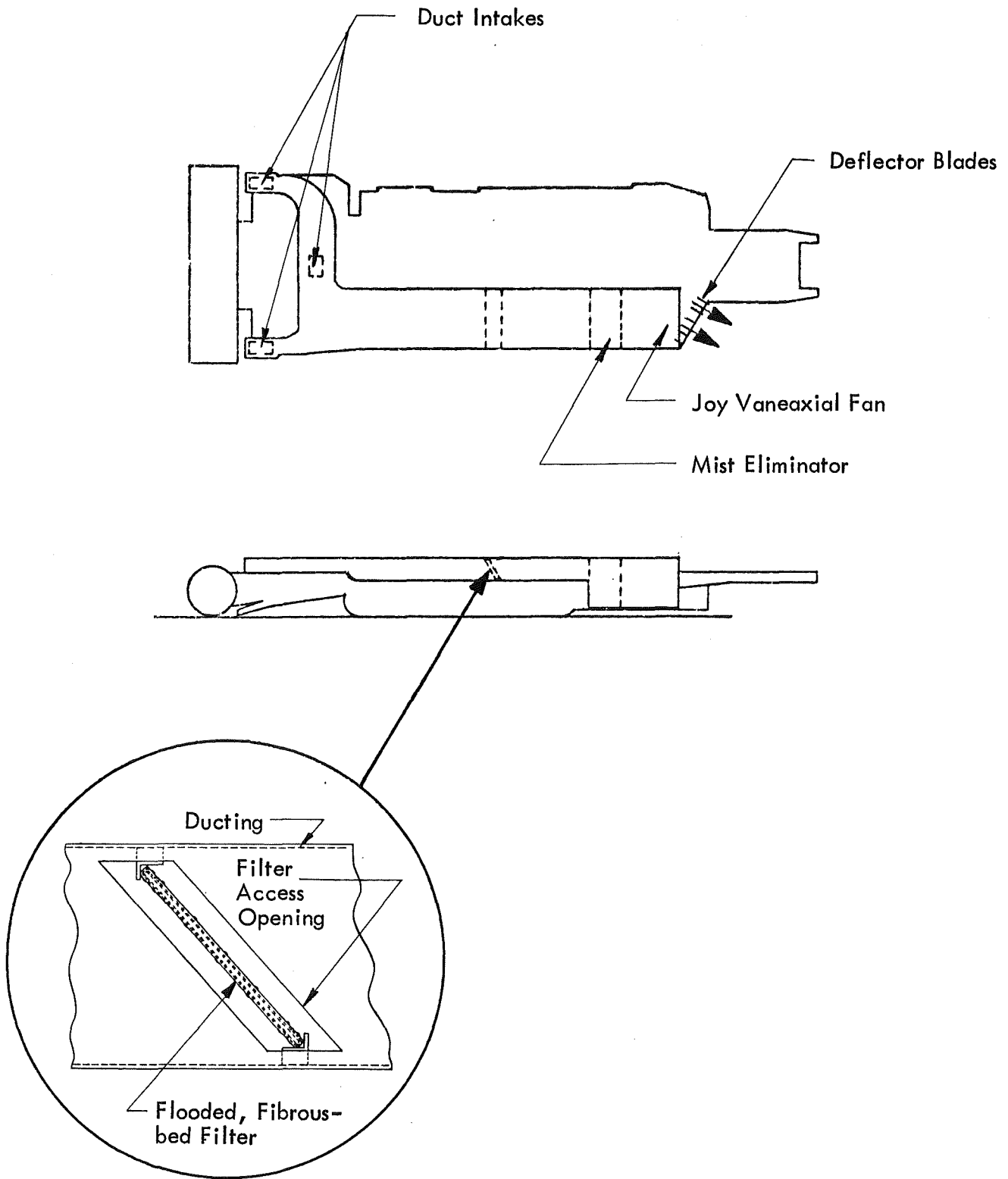


Figure 1. Continuous Miner with Flooded, Fibrous-bed Dust Control System

### 2.3 Original Flooded, Fibrous-bed Filter Design

The original flooded, fibrous-bed filter design (figure 2) consisted of:

- a four-piece, welded, channel iron frame
- forty layers of fine stainless steel wire mesh filter media  
(This woven wire mesh has seven openings per inch. The wire diameter is .0026 inch.)
- two layers of 2 in. x 2 in. x .060 in. wire screen

In this design, the wire mesh is sandwiched between the layers of wire screen. The wire screens are held in place by the frame channel. The wire screen is welded at three to five places per edge or approximately sixteen places per filter side. The entire flooded, fibrous-bed filter assembly consists of stainless steel.

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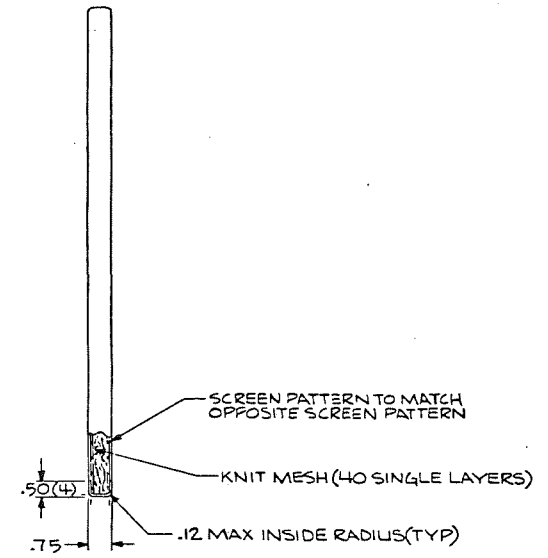
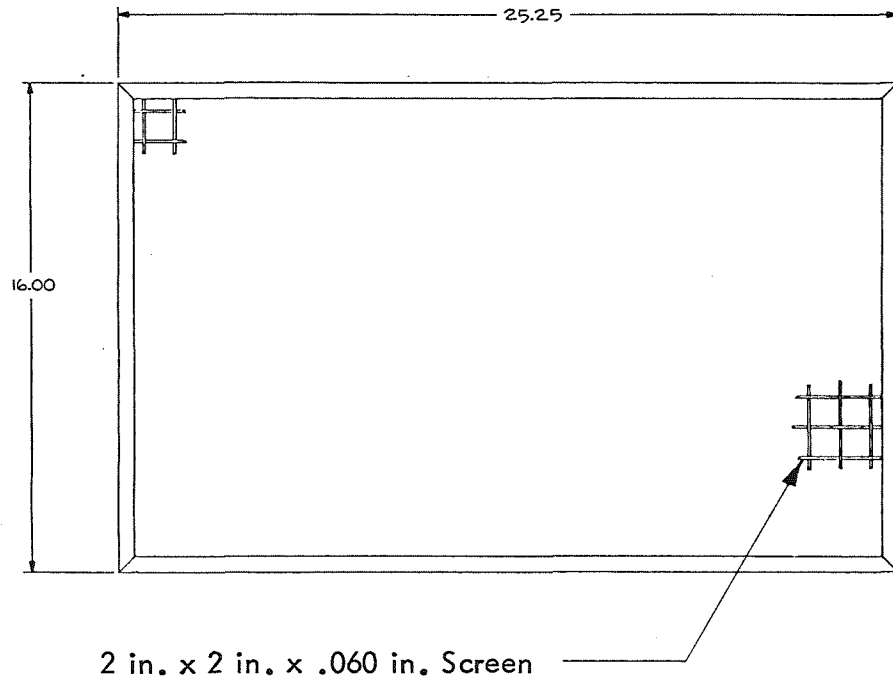


Figure 2. Original Design, Flooded, Fibrous-bed Filter

### 3.0 MINE VISITS

During the course of this Contract, Donaldson Company representatives visited Peabody Camp 11 Coal Mine to:

- Observe breakage and clogging problems with the flooded, fibrous-bed filter
- Install alternative design flooded, fibrous-bed filters which minimize clogging and breakage problems
- Check flooded, fibrous-bed duct size and interface for installing the dust sampling filters
- Obtain coal dust samples for laboratory analysis at Donaldson Company

After discussions with mining personnel, Donaldson Company representatives determined that it was more practical to locate the dust sampling filters in the flooded, fibrous-bed ducts rather than the intake ducts. (See figure 1.) First, locating the dust sampling filters at the intake ducts could potentially damage these test filters when the boom is lowered onto cut coal. Second, Peabody Coal Company allowed Donaldson Company to interrupt production only fifteen minutes per work shift. Installing the sampling filters in the intake ducts would interrupt production longer than fifteen minutes per work shift since each filter sample change would require the continuous miner to be pulled out of the entry. Third, locating the sampling filter near the flooded, fibrous-bed scrubber allowed enough space so that all the airflow could flow through one large sampling filter. The sampling filter had to be sufficiently large so that the pressure drop across the sampling filter would be approximately equal to the flooded, fibrous-bed filter. Therefore, installing the sampling filter in the flooded, fibrous-bed ducting was a practical alternative.

#### 3.1 Trip 1 - Flooded, Fibrous-bed Filter Observation

Donaldson Company representatives visited Peabody Camp 11 Mine on 9 June 1978 to observe clogging, and breakage problems with the original design flooded, fibrous-bed filter. Also, Donaldson Company representatives delivered four, first alternative design flooded bed filter panels for in-mine testing.

During this visit, Donaldson Company representatives observed specific problems with the original flooded, fibrous-bed filter panel. One problem concerned the screen wires bulging out from the filter frame. This bulging allowed the large coal particles to migrate between the layers of wire mesh. Gravity and air velocity on the slanted filter caused the particles to build-up from the bottom to top of the panel. This large-particle build-up caused filter maintenance difficulties. Although the filter panel is usually cleaned by briskly tapping the coal particles out of the dried screen, some of these large coal particles were still trapped in the screen after each cleaning. Therefore, these filters had a limited life. A second problem involved filter disintegration during continuous miner operation. When operating the machine, both welds securing the screen to the frame and the screen wires were breaking. This breakage allowed the fine knit mesh to become dislodged from the filter frame. These mechanical breakage problems were apparently caused by machine vibration, dust loading and rough handling during cleaning.

After observing these clogging and breakage problems, Donaldson Company representatives concluded that the new flooded, fibrous-bed filter design must incorporate design changes which provide greater resistance to breaking and clogging. In the original design, the screen wire was welded at three to five places on each frame edge. In the first alternative design filter, the screen wire was welded in fifteen to seventeen places. These additional welds were intended to provide greater filter durability. (Other than the additional frame welds, the first alternative design is identical to the original filter design.)

These alternative design panels were installed in continuous miners to determine if this new design was more durable than the original design. The clogged, original design filter was returned to Donaldson Company for laboratory analysis. (See Section 4.0.)

### 3.2 Trip 2 - Sample Filter Dimensions

During this second visit to Camp 11 on 21 June 1978, Donaldson Company representatives obtained machine and bed ducting dimensions in order to design a

properly fitting sample filter. Donaldson Company representatives also discussed the performance of the first alternative design flooded, fibrous-bed filter with mine personnel.

Dimensions of the flooded, fibrous-bed ducting and filter access opening (figure 1) were obtained to determine the size of the dust sampling filter. Two production-type panel filters were utilized in the mine to determine sampling filter location. After observing the panel in several locations, a decision was made to locate the dust sampling filter between the flooded, fibrous-bed filter mounting and the mist eliminator.

Peabody Coal Company personnel indicated that the first alternative design filters were still experiencing some breakage and disintegration problems after twelve days of testing.

### 3.3 Trip 3 - Installation of Second Alternative Design Filters

Donaldson Company representatives visited Peabody Camp 11 Mine on 1 August 1978 to obtain short-duration dust samples in the continuous miner ducting. Donaldson Company representatives also delivered three, second alternative design flooded, fibrous-bed filters for additional in-mine testing.

After arriving at the mine, Donaldson Company representatives discovered that the miners were striking. Therefore, it was not possible to obtain dust samples during the visit. However, it was possible to check dust sampling filter (figure 3) fit in the flooded, fibrous-bed duct. Because of duct distortion due to mine roof fall damage, the sampling filter did not fit in the duct. Therefore, an edge of the sampling filter was modified for future installation.

The second alternative design flooded, fibrous-bed filters (figure 4) were left at Camp 11 Mine for durability testing. These filters utilized a heavy-duty 1 in. x 1 in. x .120 in. screen instead of the 2 in. x 2 in. x .060 in. screen used for the first two designs. Also, all of the screen wires contacting

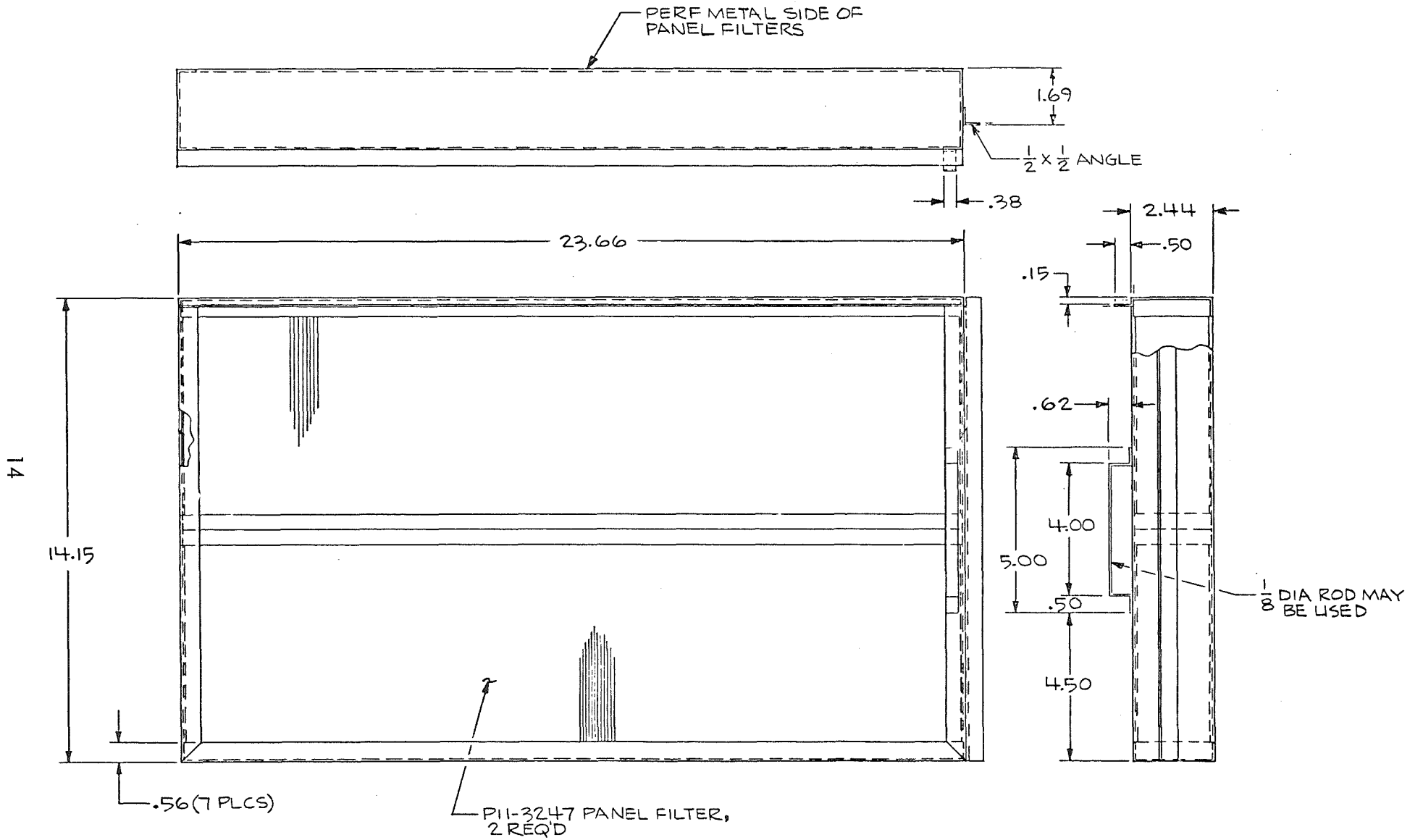


Figure 3. First Dust Sampling Filter Design

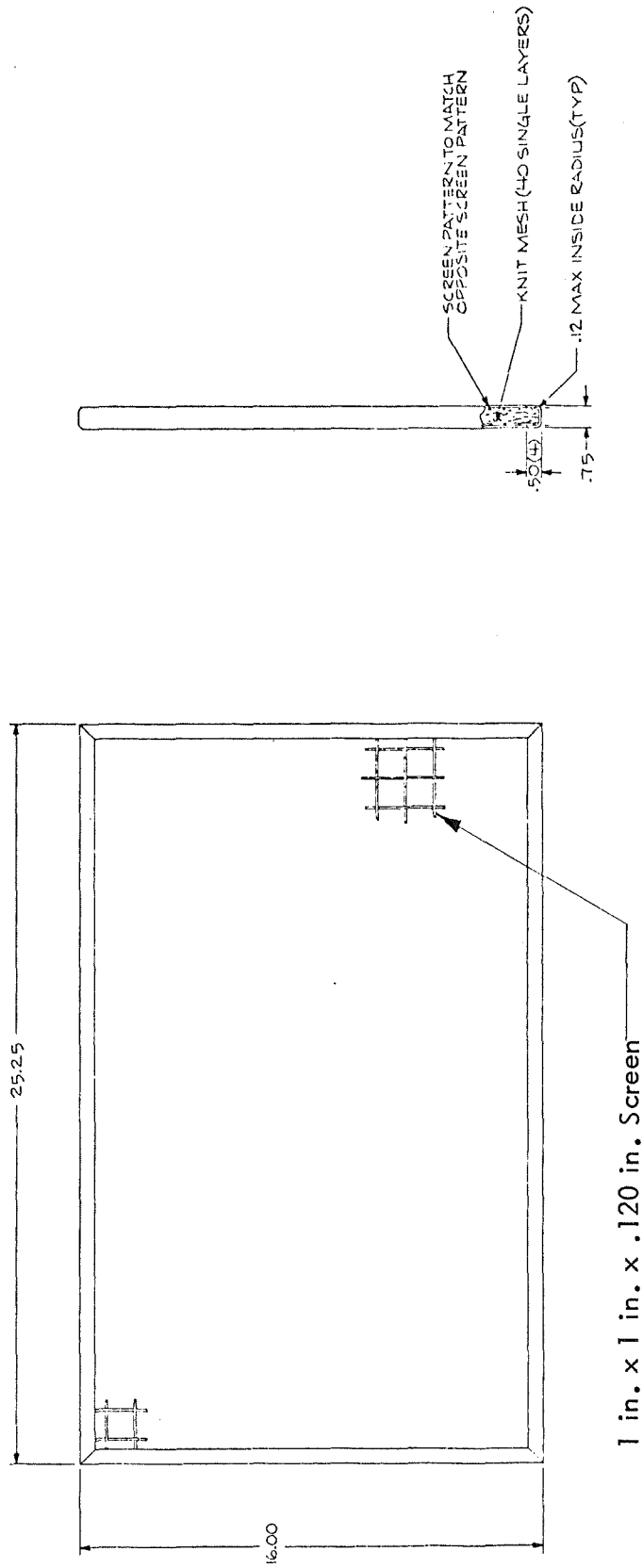


Figure 4. Second Alternative Design, Flooded, Fibrous-bed Filter

the frame were welded on each side. This heavy screen was expected to minimize the bulging and breakage difficulties.

#### 3.4 Trip 4 - First Sampling Procedure

Donaldson Company representatives visited Peabody Camp 11 Mine on 16 August 1978 to obtain short duration dust samples. Donaldson Company representatives also observed the performance of the second alternative design flooded, fibrous-bed filter.

During this visit, a dust sampling filter (figure 3) was installed in the flooded, fibrous-bed ducting. The dust sampling filter utilized pleated-paper media. After approximately one-half minute of continuous miner operation, the increased restriction caused by the sampling filter lowered the airflow to approximately 1000 ft<sup>3</sup>/min. Billowing dust from the mine face forced Donaldson Company representatives to remove the sampling filter after approximately two minutes.

At the beginning of this test, the airflow restriction across the clean sampling filter measured 8.0 in. wg. Almost immediately, the restriction increased, thus forcing the fan into a stall condition. When operating in this stall condition, the fan provided a lower airflow through the filter. This lower airflow resulted in a decrease in the restriction to 6.5 in. wg, measured across the dirty sampling filter. A second sampling test was performed with identical results. As a result, this first series of sampling tests was invalid.

Donaldson Company representatives reached a decision to design a new dust sampling filter with increased media area and to use a filter media which provides less airflow restriction.

While underground, Donaldson Company representatives observed the performance of the second alternative design flooded, fibrous-bed filter. During this observation, Donaldson Company representatives noted problems with the looseness

of the wire mesh. Since the wire screens do not pinch the wire mesh together, the mesh is free to float about, possibly opening one edge of the filter to dust flow. This looseness also promotes migration of coal dust particles into the wire mesh. Although the second alternative filters were not disintegrating, these filters were quickly loading with particles.

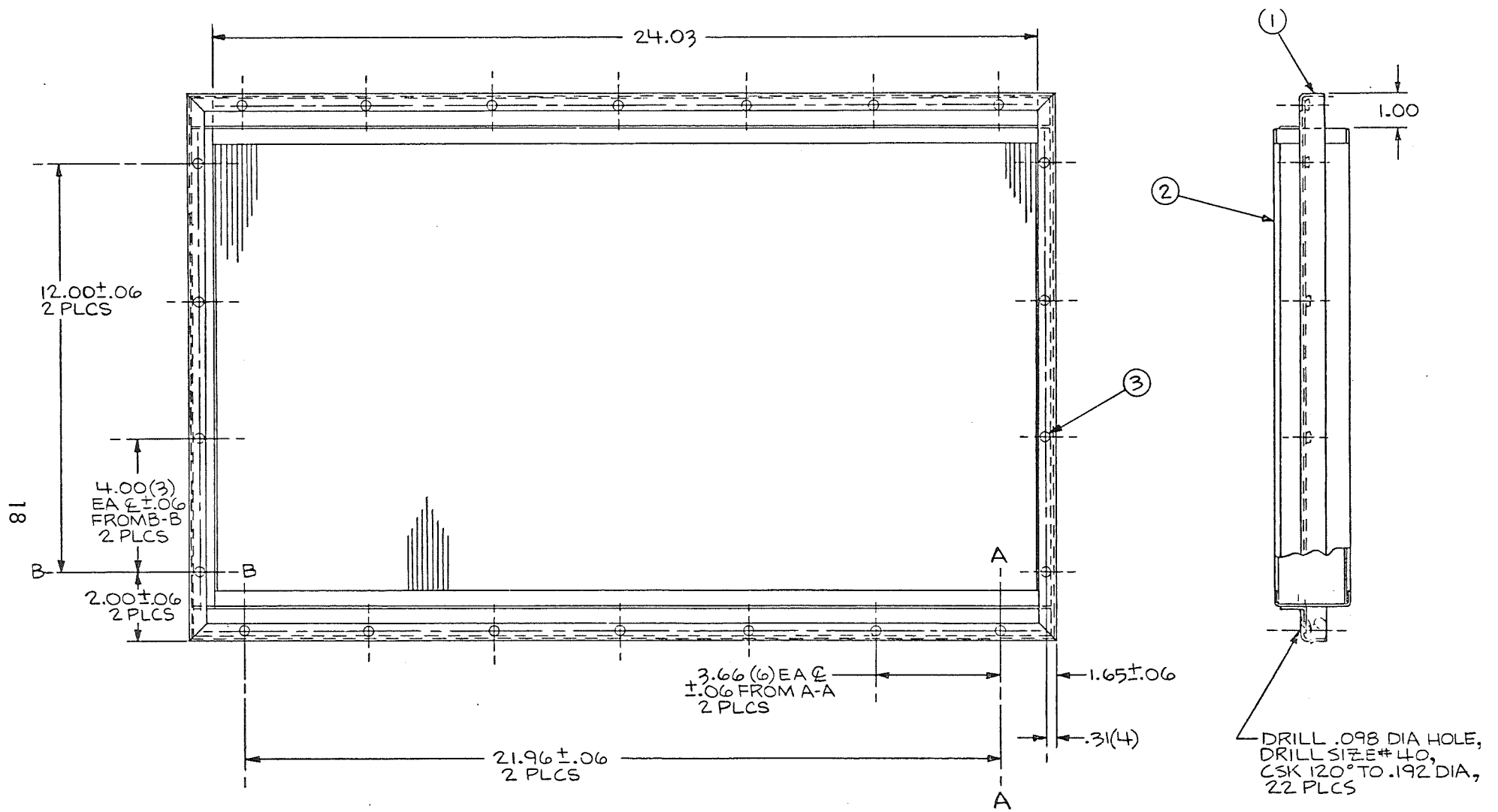
### 3.5 Trip 5 - Second Sampling Procedure

Additional short-duration dust samples were obtained during this fifth visit on November 22, 1978. Because of previous problems with the sampling media, Donaldson Company representatives designed two new dust sampling filters (figures 5 and 6). During this visit, the third alternative flooded, fibrous-bed filter (figure 7) was installed in the continuous miner for testing.

Three short-duration dust samples were obtained during this visit. The first two samples were obtained with a filter which utilized pleated-paper media. The third sample was obtained with a filter which utilized stainless steel wire-cloth media. Each dust sampling filter was tested for approximately four to five minutes before clogging caused an extreme decrease in airflow.

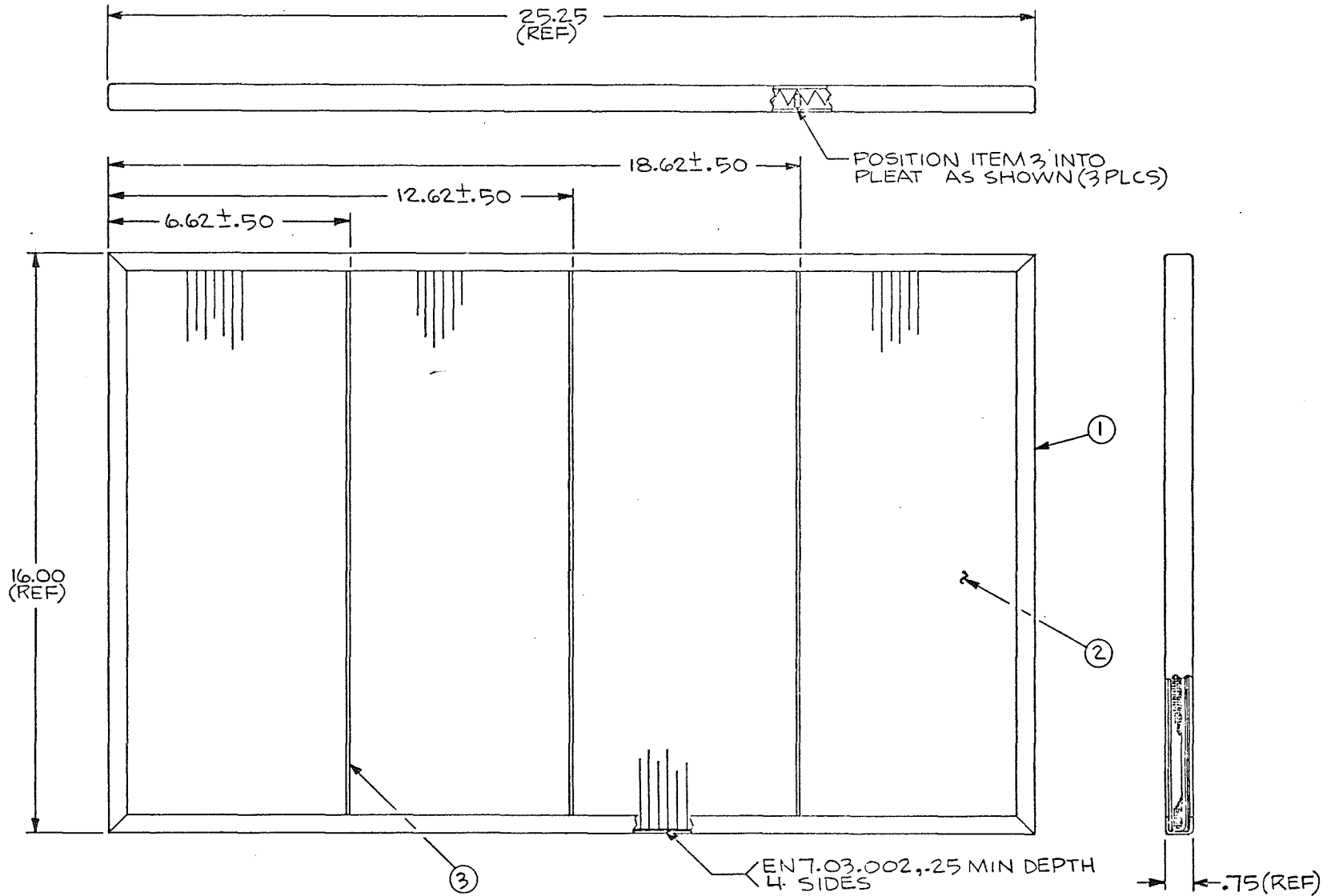
The sample filters were returned to Donaldson Company for laboratory evaluation. (See Section 4.0.)

The third alternative flooded, fibrous-bed filter was installed in the mine for performance evaluation by Peabody Coal Company. This heavy-duty filter panel (figure 7) uses angle iron instead of channel iron for the frame. This filter also utilizes 1 in. x 1 in. x .120 in. wire screen. This screen snugly pinches the wire mesh together because the frame is rivited together. Therefore, the wire mesh will not migrate to one corner of the frame during mining operations.



ITEM	QTY	DESCRIPTION
B203A581 PANEL FILTER ASSY		
1	1	8203A582 CHANNEL ASSY
2	1	8203A580 FILTER ASSY, PANEL
3	22	P12-4986 RIVET, BLIND

Figure 5. Second Dust Sampling Filter Panel  
(Paper-type)



ITEM	8203A566	SCREEN PANEL ASSY
1	1	FRAME (P13-6524) (SEE NOTE 1)
2	1	8203A564 SCREEN
3	3	8203A565 ROD

NOTE

1. USE FRAME FROM P13-6524 SCREEN PANEL ASSY.

Figure 6. Second Dust Sampling Filter Panel (Screen-type)

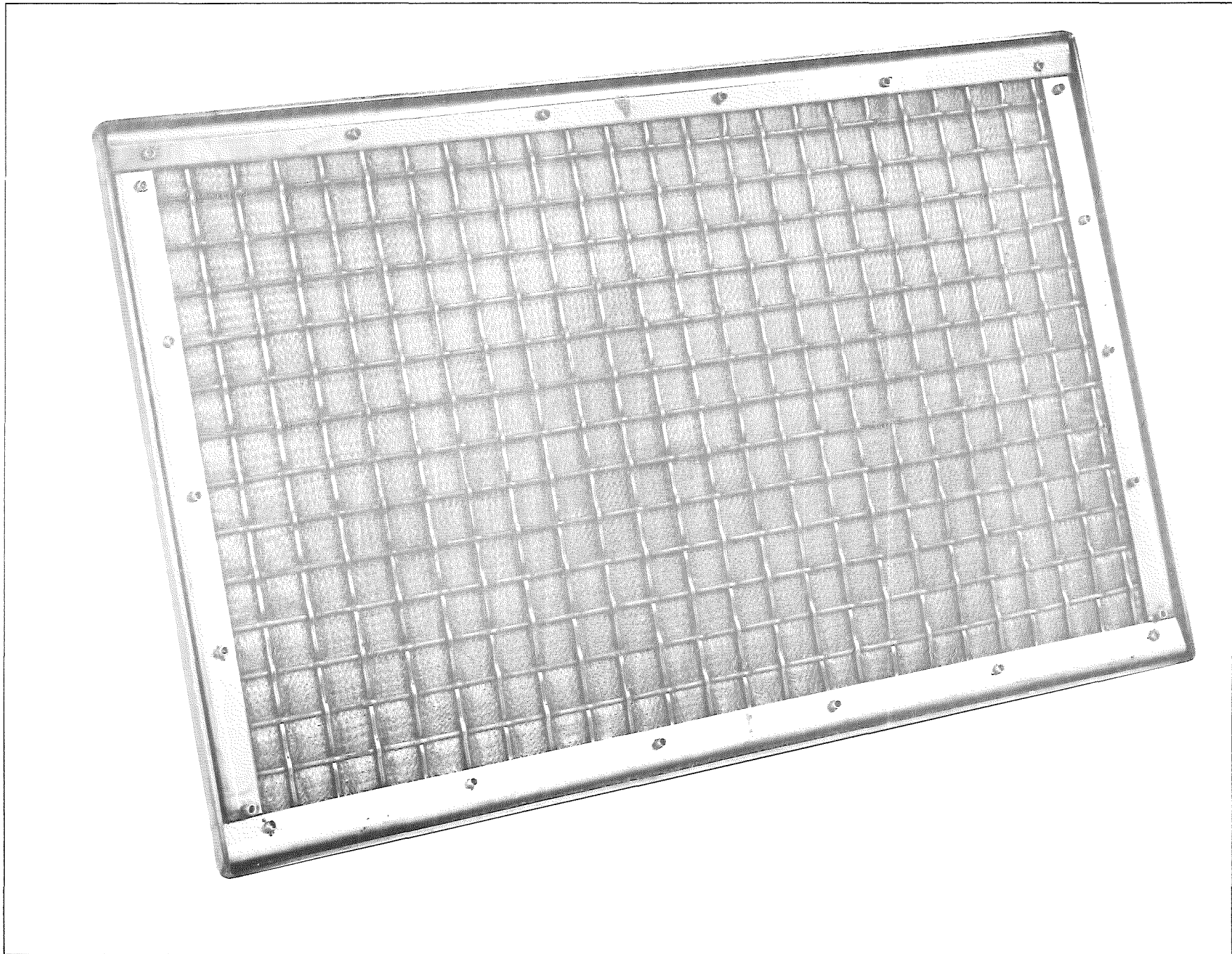


Figure 7. Third Alternative Design, Flooded, Fibrous-bed Filter  
(Approved Design)

## 4.0 DATA ANALYSIS

### 4.1 Test Results

Laboratory tests were performed on flooded, fibrous-bed filters and dust sampling filters to determine pressure drop versus airflow characteristics and to determine particle size distributions. Information from these tests was used to determine design of the second dust sampling filter and to determine a more effective flooded, fibrous-bed media.

Tests were performed to determine the pressure drop versus airflow characteristics of the first dust sampling filter which was loaded with coal dust at Camp 11 (figure 8). Tests were also performed to determine the pressure drop versus airflow characteristics for the second dust sampling filters (paper-type and screen-type) when loaded with test dust in the laboratory (figures 9 and 10). Tests were also performed to determine the pressure drop versus airflow characteristics of a clean original design flooded, fibrous-bed filter (figure 11). After performing these tests, it appeared that there is not a significant difference between the four filters when clean (figures 8, 9, 10 and 11). However, because the fan went into a stall condition shortly after the testing commenced, the airflow through the first sampling filter was dramatically reduced (figure 8) in a loaded condition. After performing airflow tests for the second sample filter in a loaded condition, it appeared that the second sample filters would effectively capture dust samples in a mining situation.

Additional tests were conducted to determine what dust particle size would be captured by the second dust sampling filters in the field. Figure 12 presents the particle size distribution of test coal dust. Figures 13 and 14 present particle size distribution of dust collected by the pleated-paper and pleated-screen dust sampling filter and the particle size distribution of the dust collected on absolute filter in the test setup. (See figure 19.) The paper-type filter media (figure 13) captured approximately the same particle size distribution as the absolute filter. However, the screen-type filter media only captured the larger particles.

# MINE TEST DATA

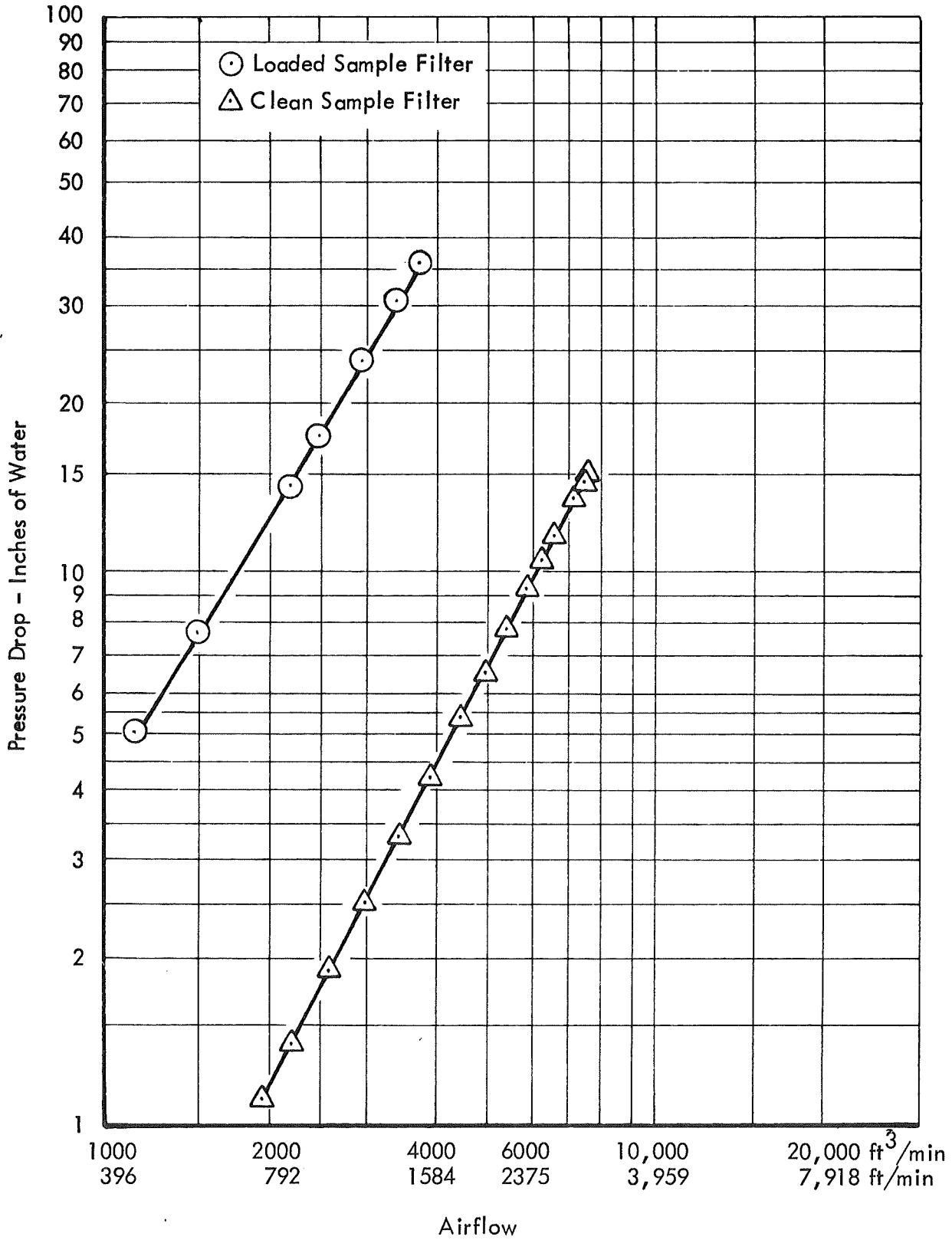


Figure 8. Pressure Drop vs. Airflow, First Sample Filter Loaded in the Field at Camp 11 Mine

LABORATORY DATA

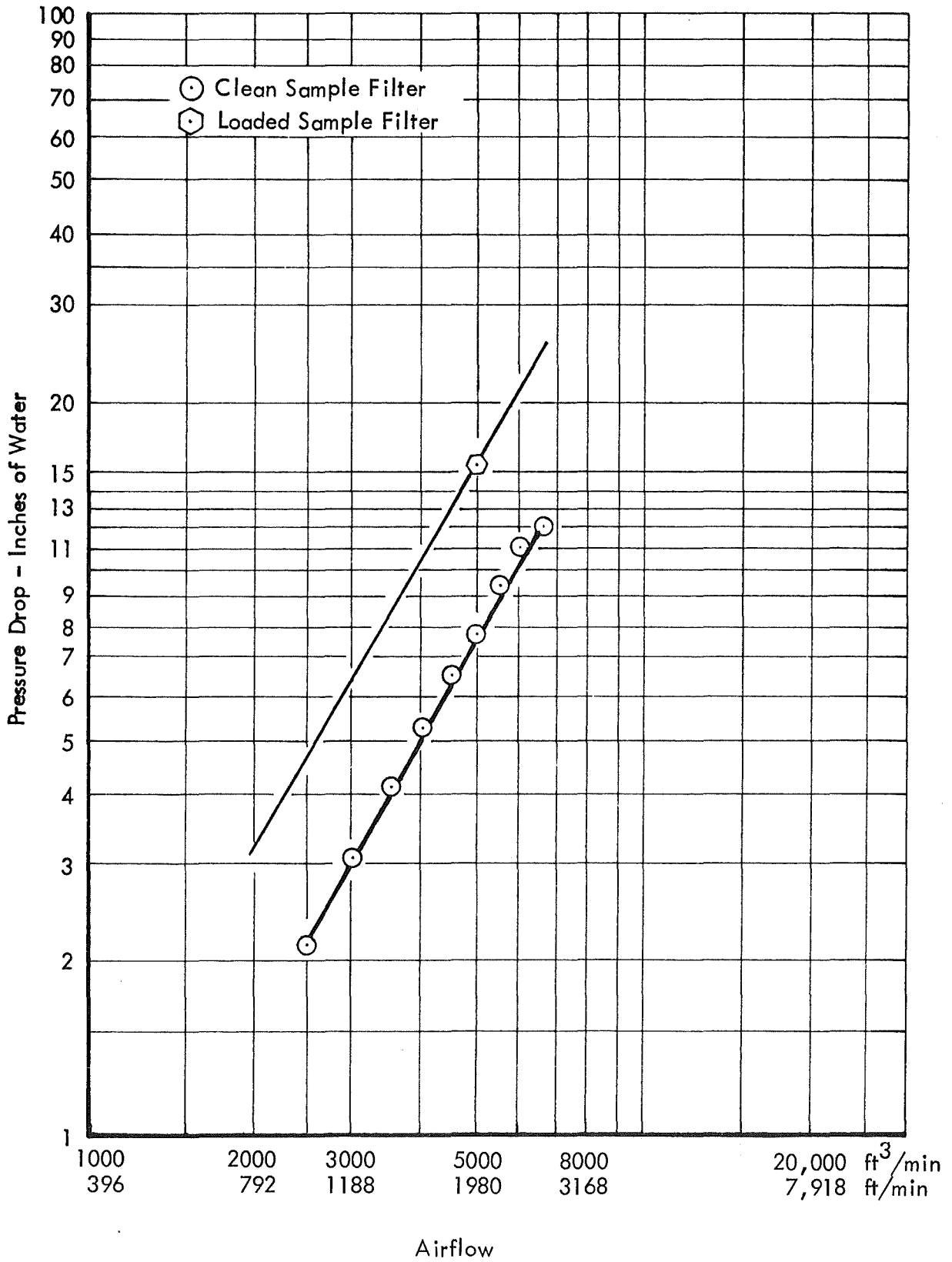


Figure 9. Pressure Drop vs. Airflow, Second Sample Filter (Paper-type) Loaded in the Laboratory with Test Coal Dust

LABORATORY DATA

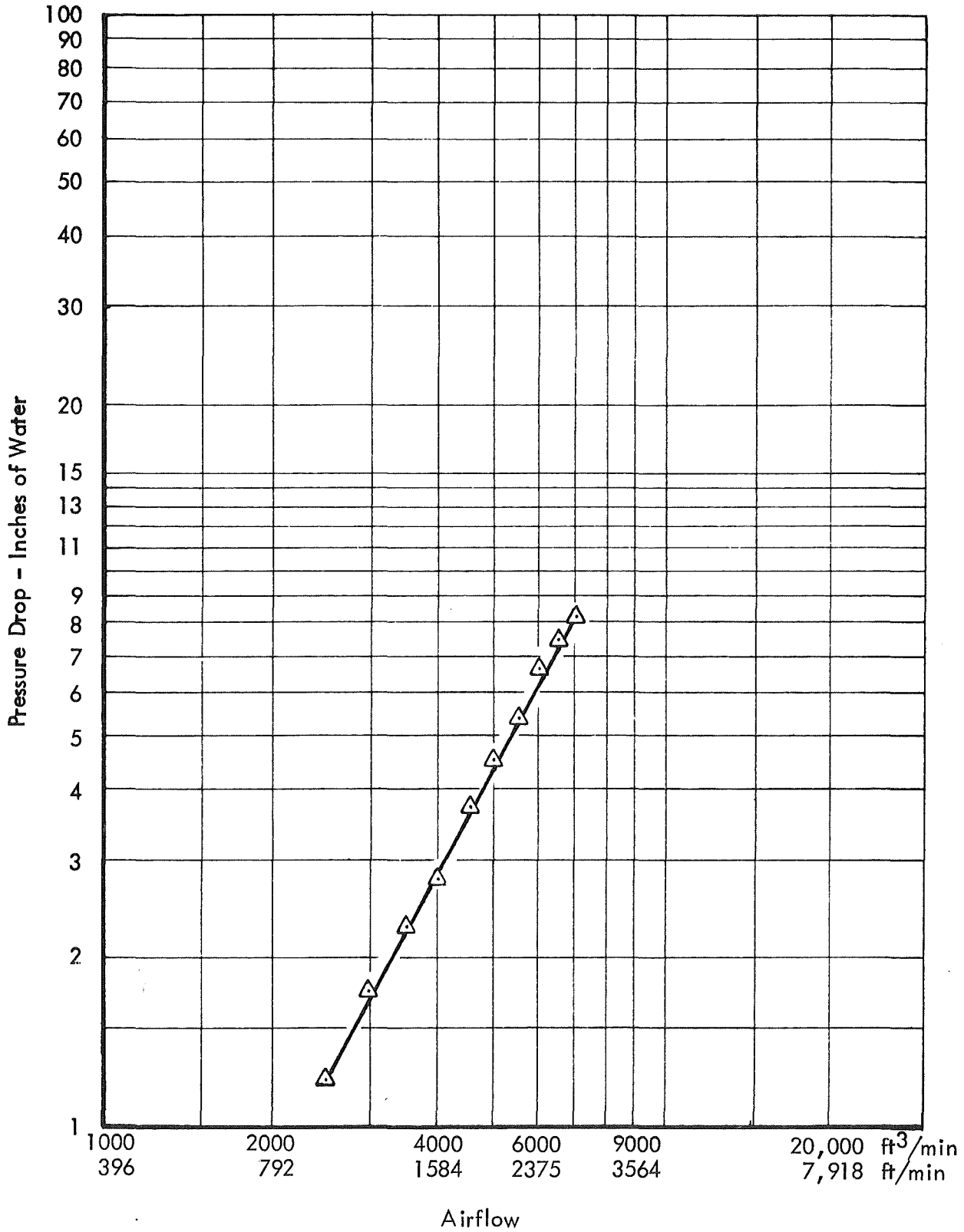


Figure 10. Pressure Drop vs. Airflow, Second Sample Filter (Screen-type) Loaded in the Laboratory with Test Coal Dust

Note: The dirty filter and the clean filter have the same pressure drop characteristics.

LABORATORY DATA

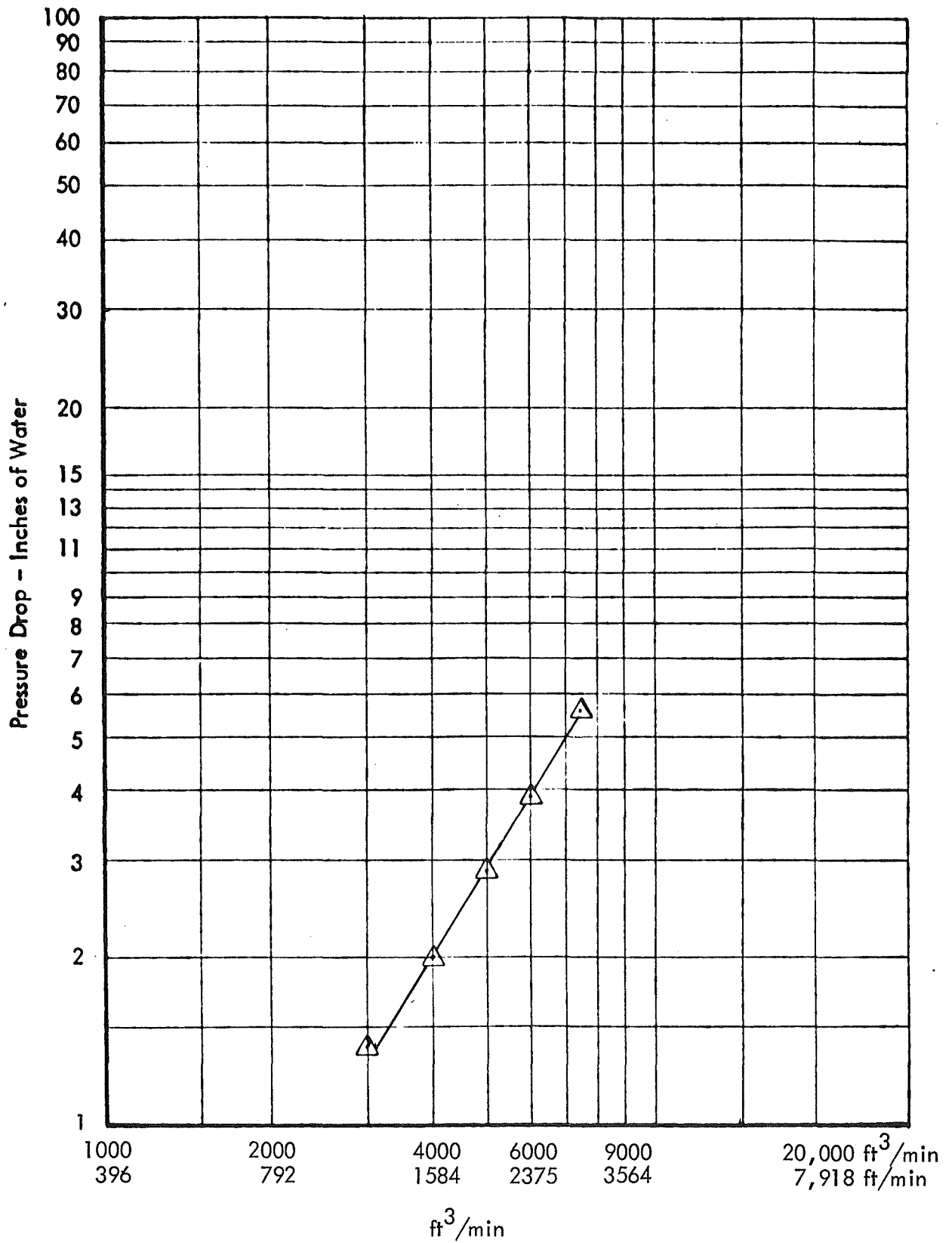


Figure 11. Pressure Drop vs. Airflow Clean Flooded, Fibrous-bed Filter (All Design Concepts)

LABORATORY DATA

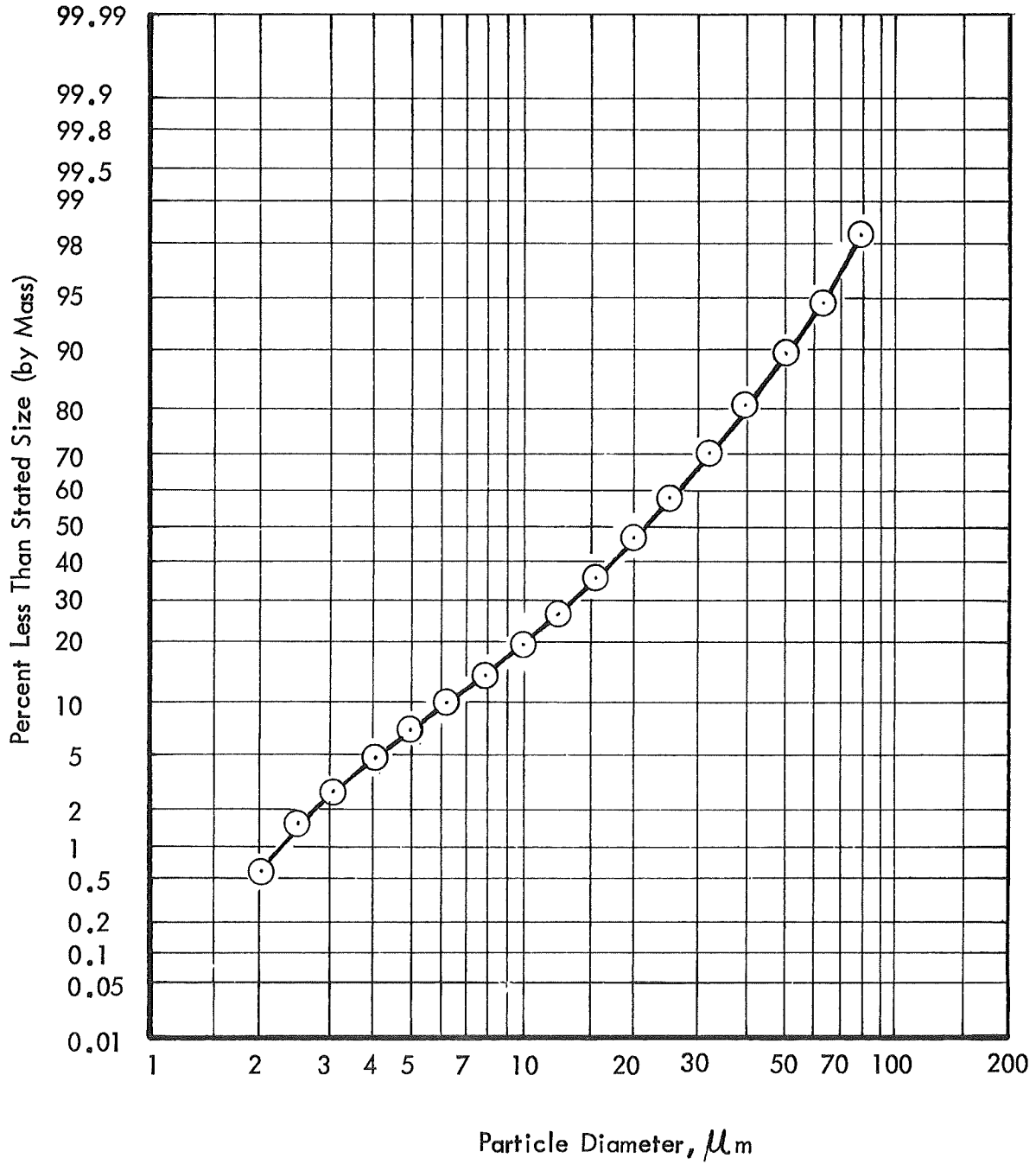


Figure 12. Laboratory Coal Test Dust for Laboratory Tests

Note: See Appendix A for Particle Distribution by Count

LABORATORY DATA

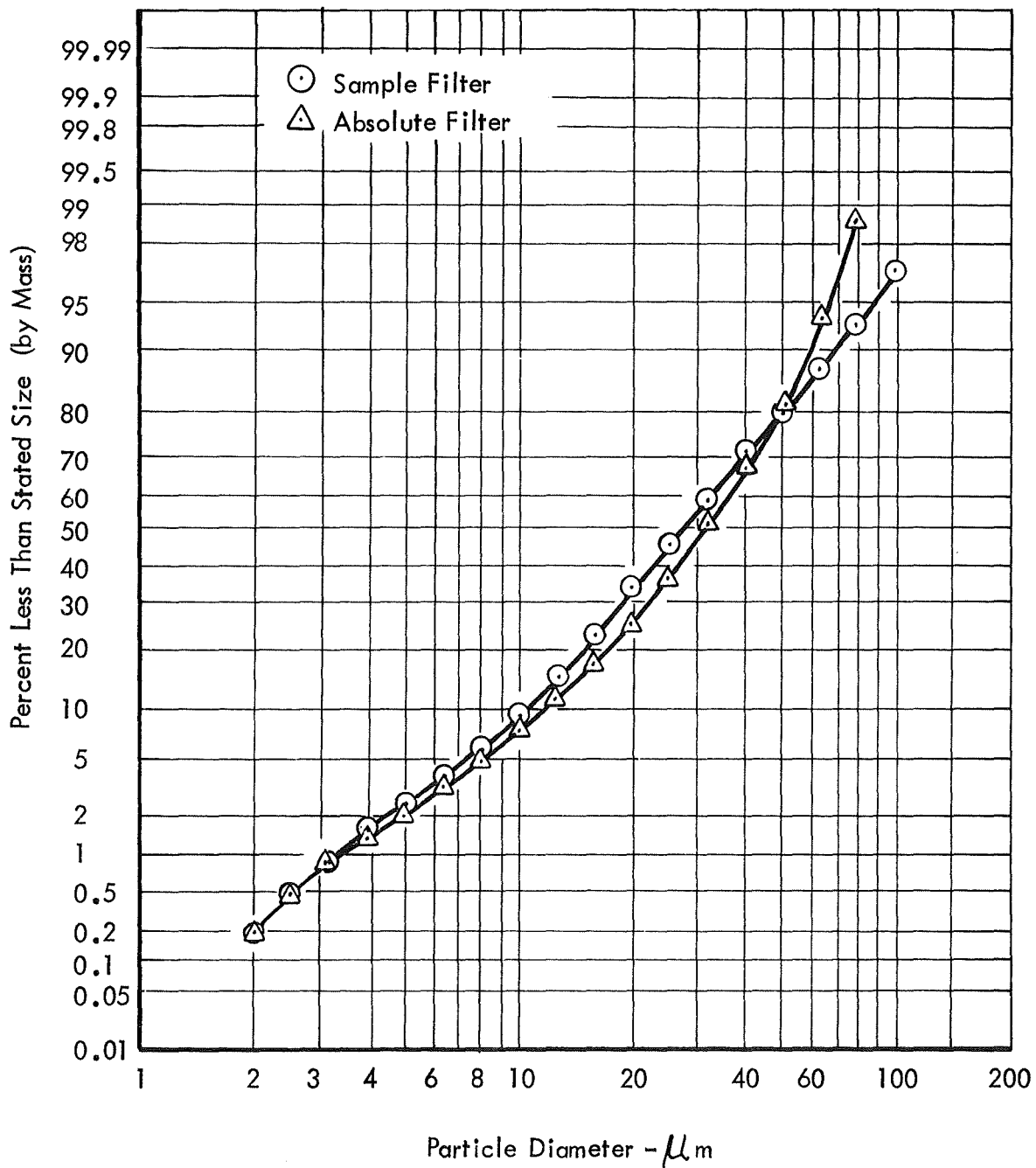


Figure 13. Comparison of Dust Particles Collected by the Second Sample Filter (Paper-type) and the Absolute Test Filter During Laboratory Tests

LABORATORY DATA

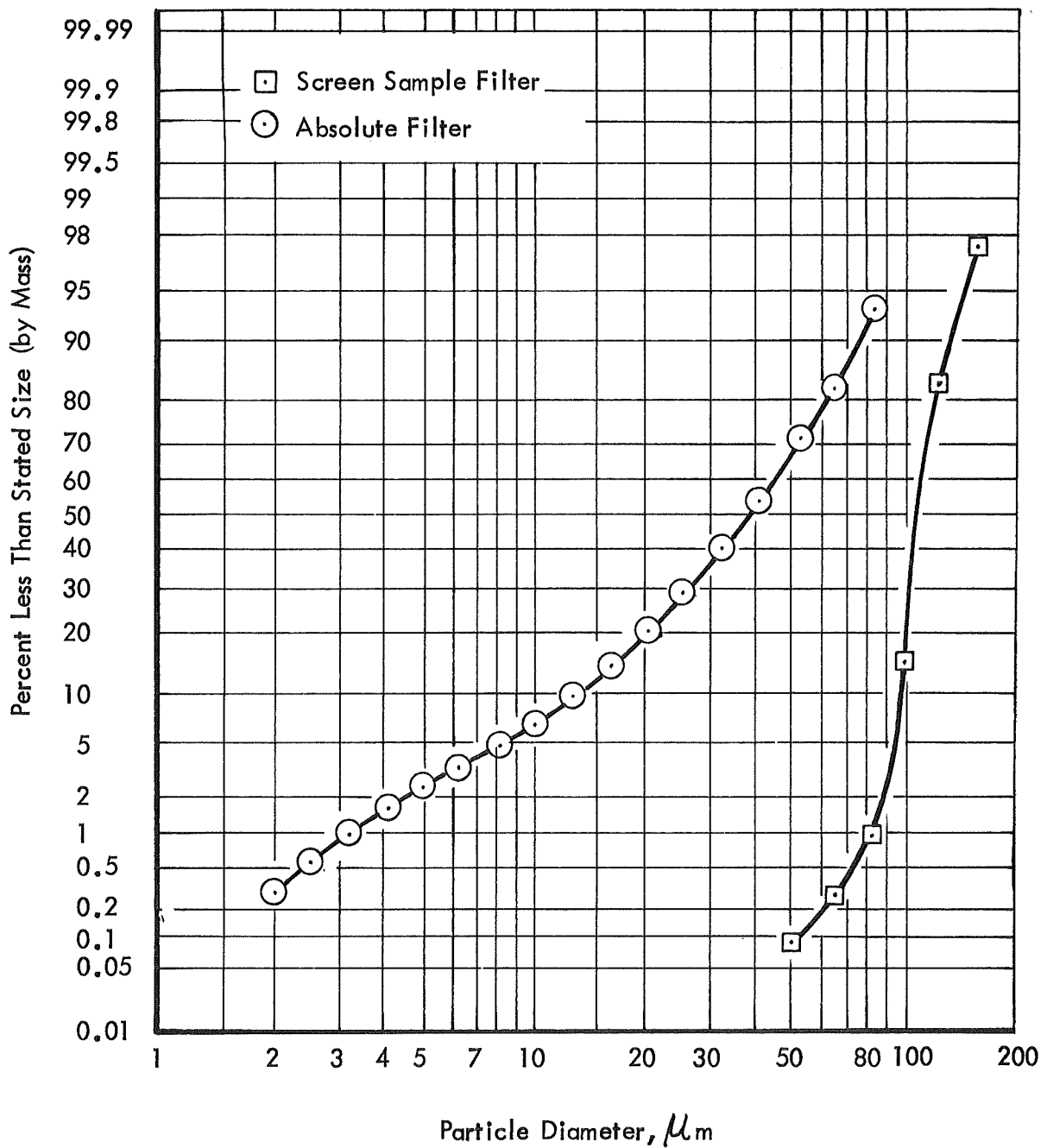


Figure 14. Comparison of Dust Particles Collected by the Second Sample Filter (Screen-type) and the Absolute Test Filter During Laboratory Tests

When tested in the field, the second sample filters took longer to load and trapped larger particles than the first sample filters (figures 15, 16 and 17). These results are caused by the lower restriction of the second sample filters.

It was predicted that the pleated wire-screen sample filter would capture larger particles than the flooded, fibrous-bed filter since it has less pressure drop. However, the clogged, original flooded, fibrous-bed filter (figure 3) captures larger particles than all the sampling filters for several reasons. (See figures 15, 16, 17 and 18.) First, there is a lower pressure drop through the flooded, fibrous-bed filter than through the sampling filters. Most important, the flooded, fibrous-bed filter is run for an entire shift compared to five minutes for sampling filters. During the work shift, the continuous miner boom is lowered and raised numerous times to cut coal. Lowering the boom forces large coal particles into the intake ducts. These large coal particles clog the filter panels. Donaldson Company representatives also observed a large pile of particles approximately three feet in front of the flooded, fibrous-bed filter panel. This pile was approximately 1 foot high and as wide as the intake duct. These particles were forced into the intake ducts and settled out in front of the flooded, fibrous-bed filters.

#### 4.2 Test Apparatus

The test set-up (figure 19) to load sample filters in the lab consists of a dust feeder blowing coal dust into an intake duct. This dust-laden air was pulled through the sampling filter by a fan. Air exiting the filter was pulled through an absolute filter media. Discharged air from the absolute filter is drawn through a flow meter and is discharged by the fan. Pressure drops are taken across the sampling filter and the flow meter. The only difference in equipment to perform pressure drop tests is that the dust feeder and absolute filter are not used (figure 20) in these tests.

All filter media is analyzed in the Donaldson Company Particle Lab by a Coulter Counter and Sieves. The Sieves is a series of screens attached vertically with screens of decreasing openings going downward. As the dust falls through these screens, the larger particles are removed first and progressively smaller particles are removed next. Each screen is weighed to get the

# MINE TEST DATA

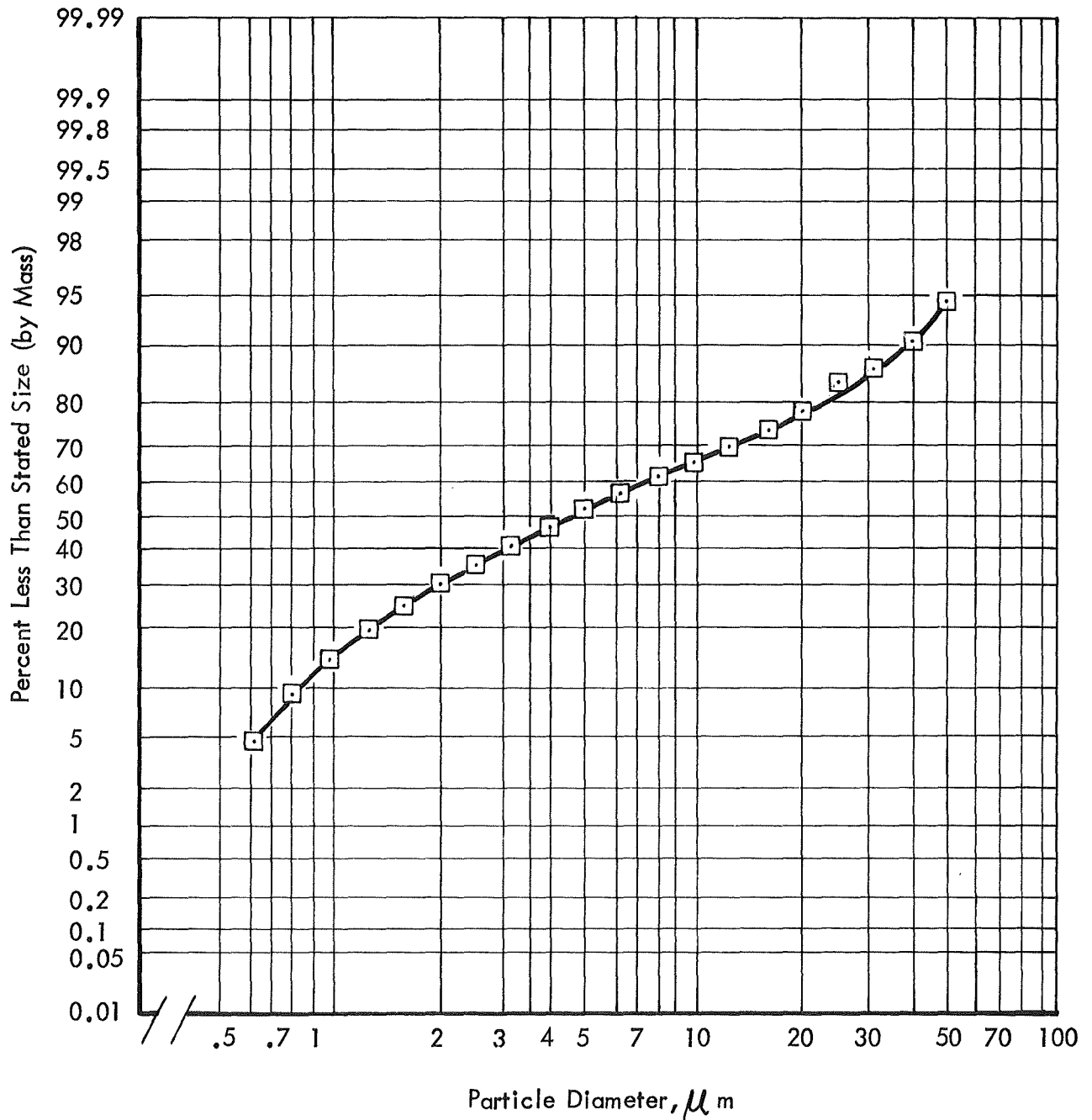


Figure 15. Particle Size Distribution of First Sample Filter Loaded in the Field at Camp 11 Mine

Note: Loading Time: 2 minutes of Machine Operation

MINE TEST DATA

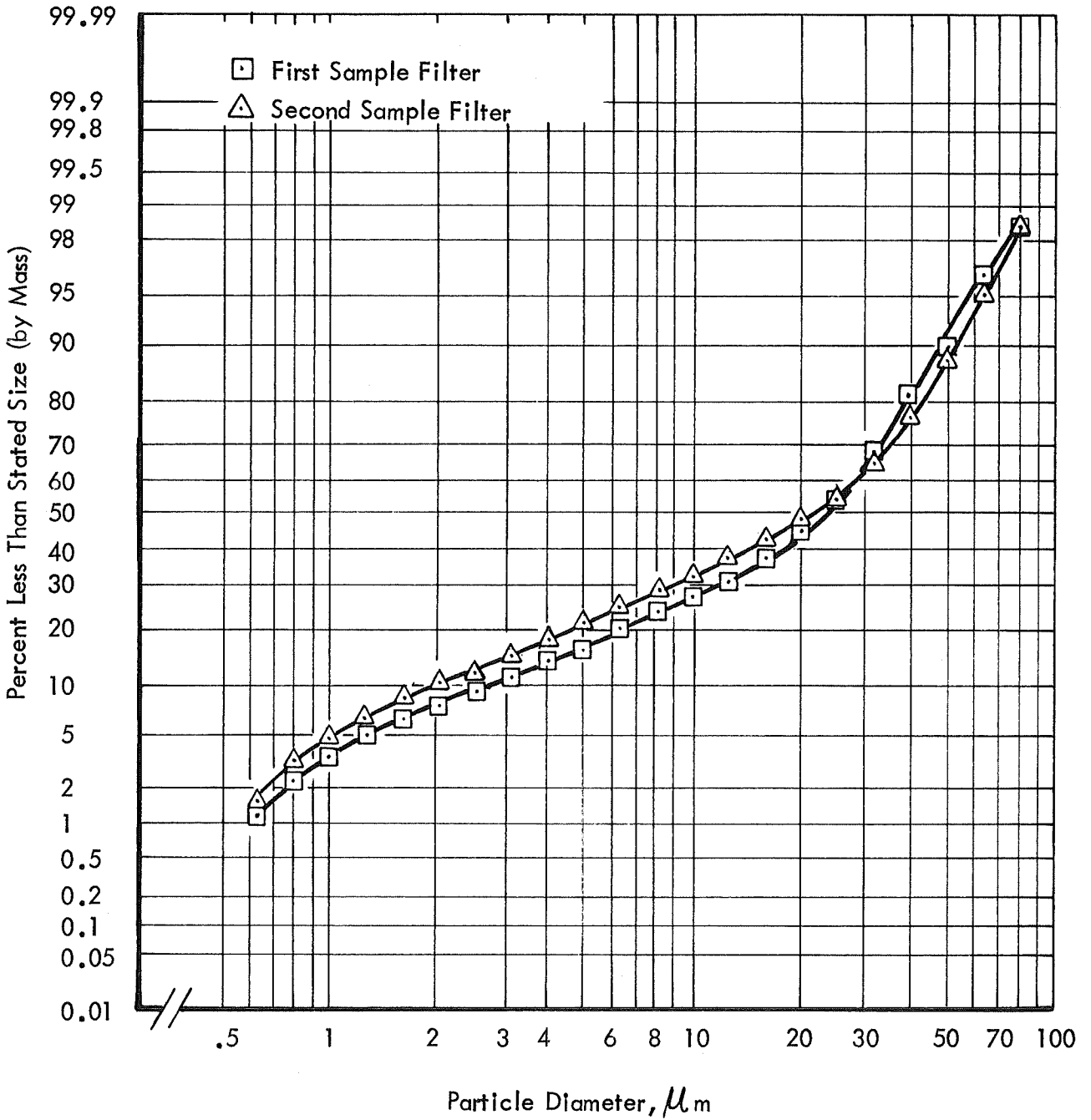


Figure 16. Particle Size Distribution of Second Sample Filter (Paper-type) Loaded in the Field at Camp 11 Mine

Note: Loading Time: 4-5 minutes of Machine Operation

# MINE TEST DATA

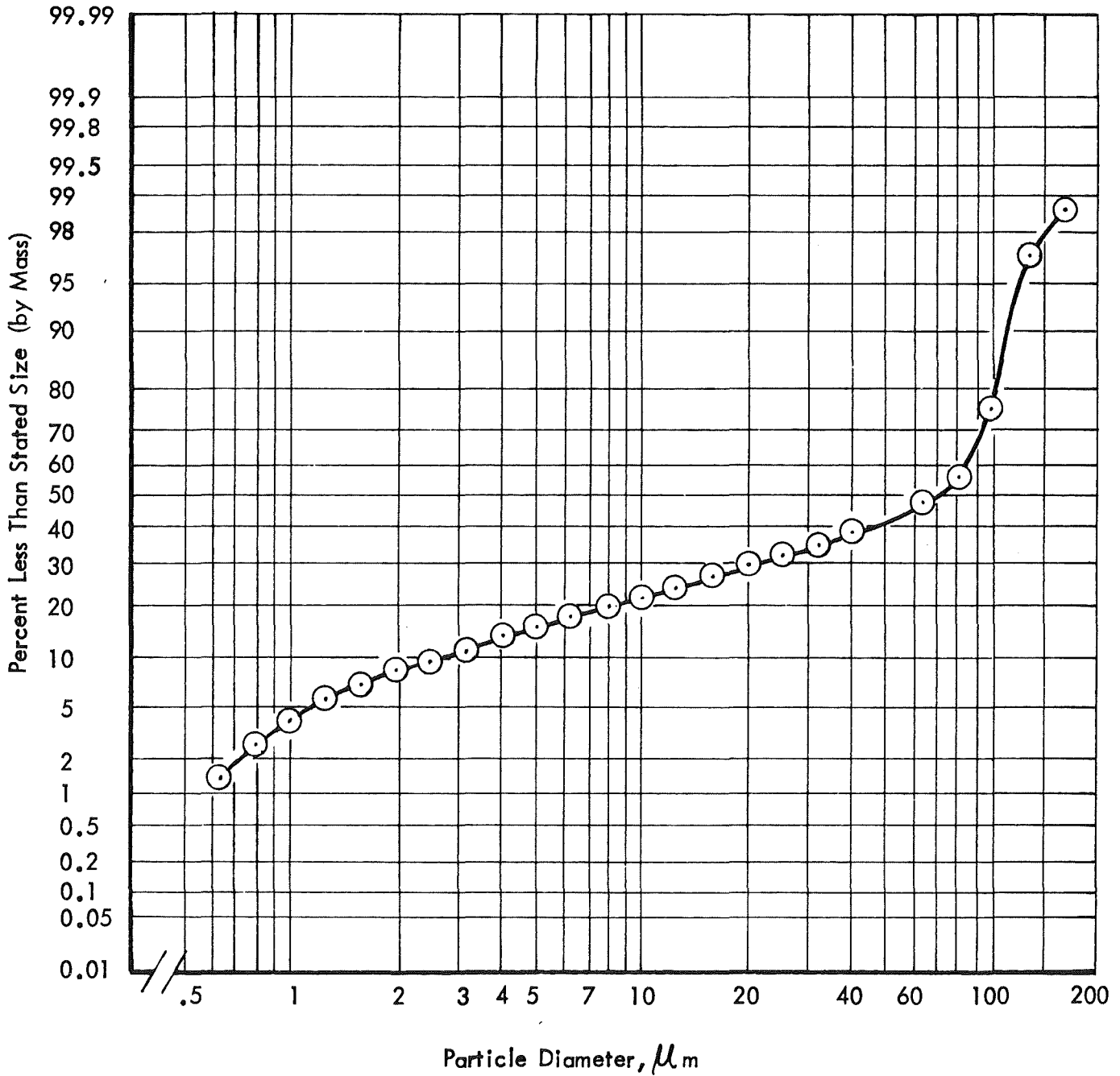


Figure 17. Particle Size Distribution of Second Sample Filter (Screen-type) Loaded in the Field at Camp 11 Mine

- Notes: (1) Loading Time: 4-5 minutes of Machine Operation  
(2) Unusual Test results due to 104 μm opening in screen

MINE TEST DATA

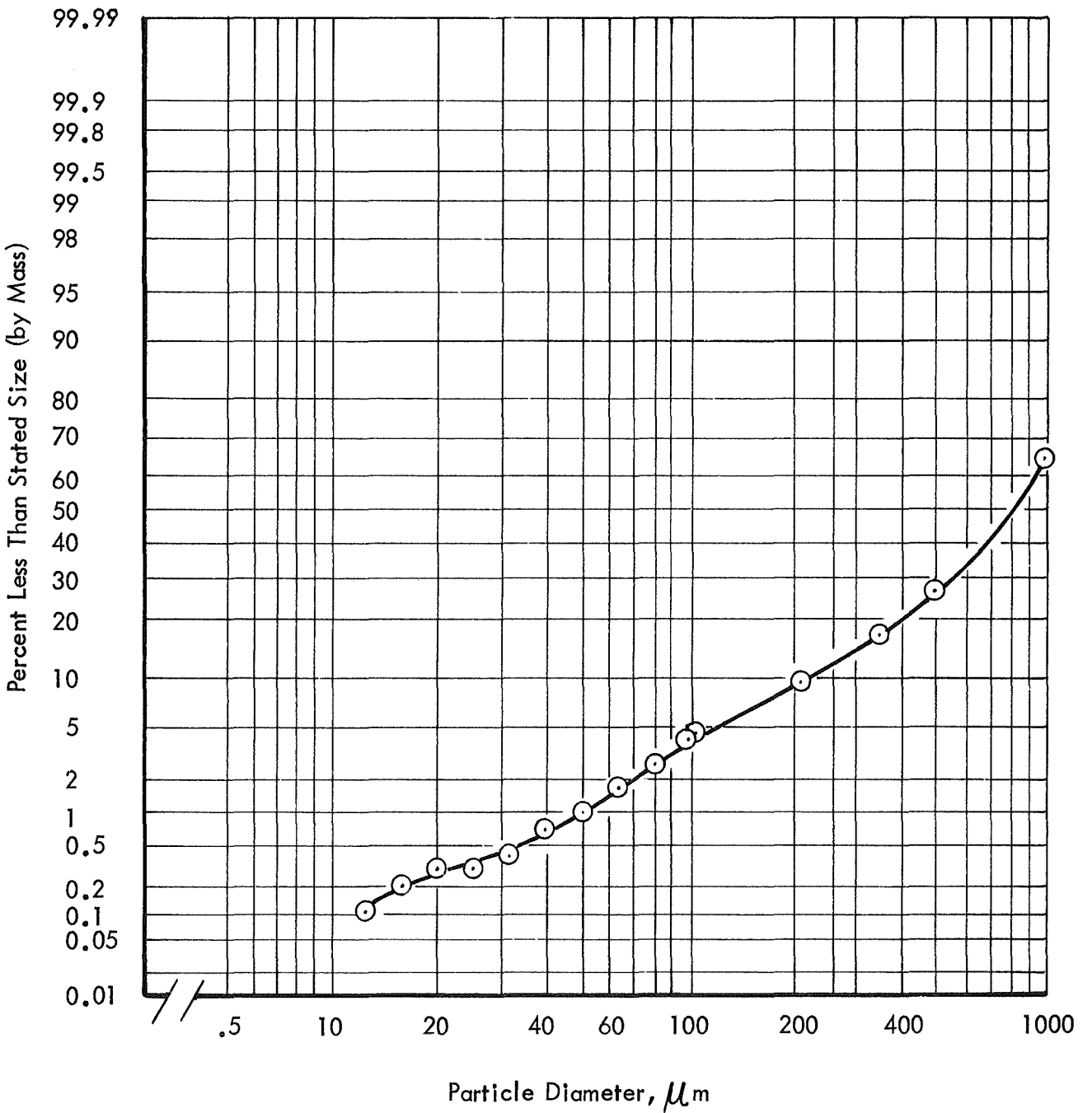


Figure 18. Original Flooded, Fibrous-bed Filter Loaded Until Clogged in the Field at Camp 11 Mine

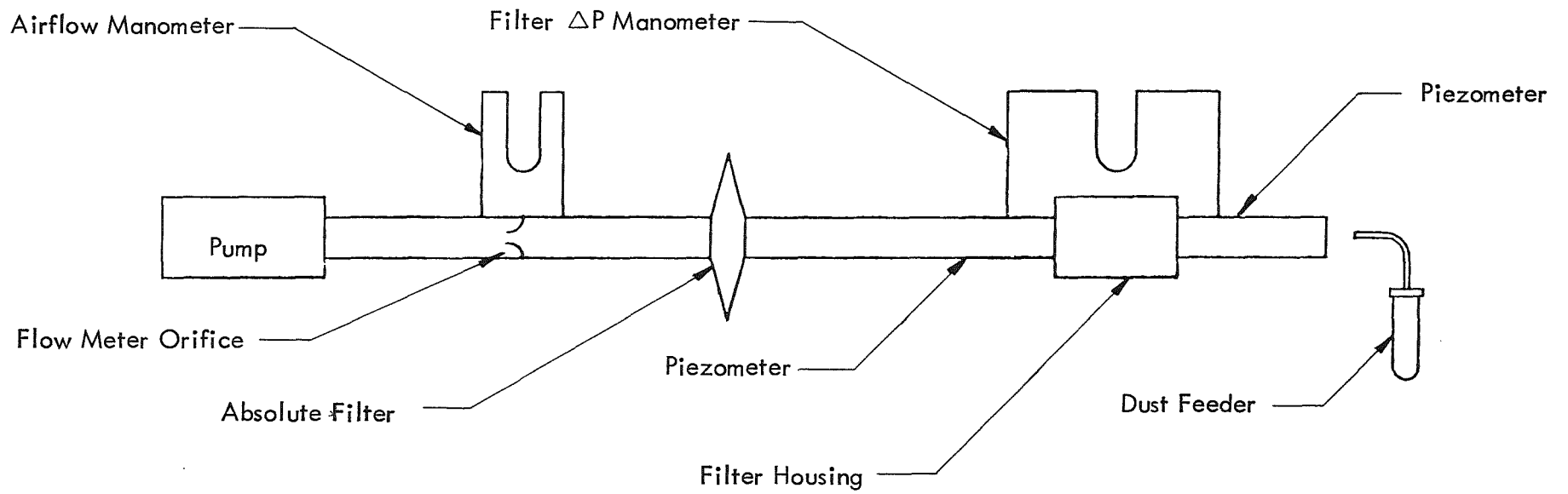


Figure 19. Dust Efficiency and Loading Test Fixture  
(Laboratory Flow Chart)

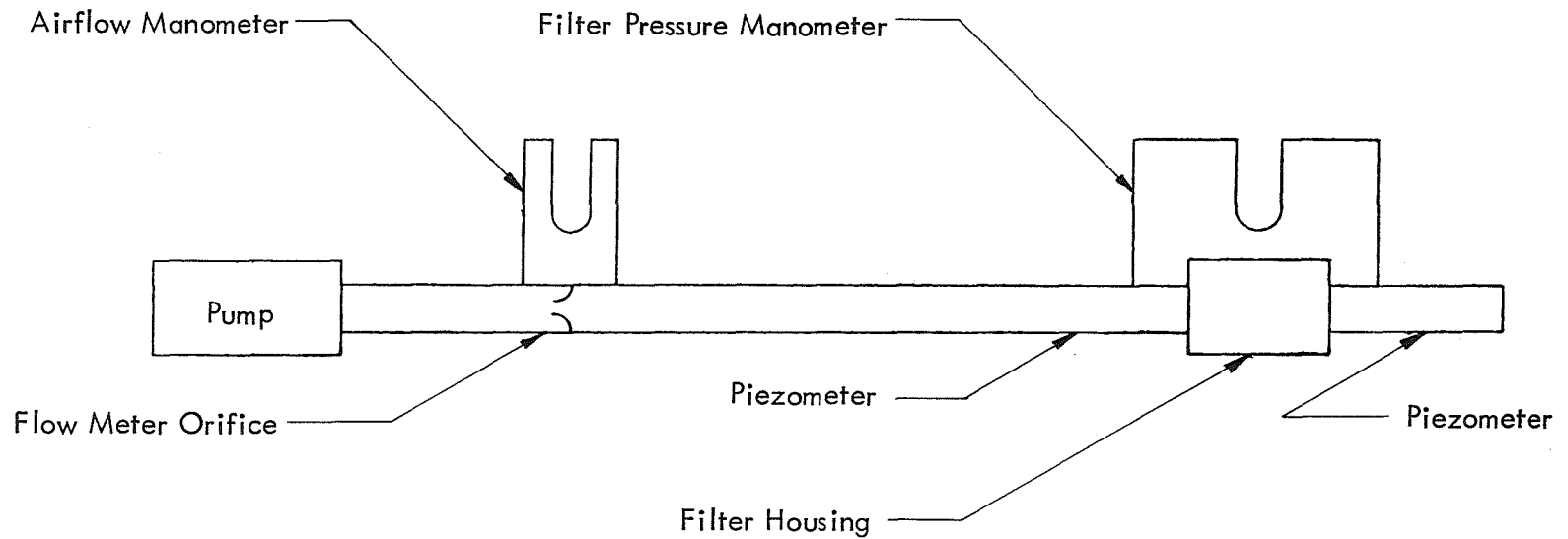


Figure 20. Pressure Drop Test Fixture  
(Laboratory Flow Chart)

percent dust by mass of its size category. This test is accurate from 70 microns on up. The Coulter Counter works by suspending the dust in an electrolyte fluid. This fluid is passed through a 200 micron orifice. An electric current is also passed through this orifice. As the suspended dust particles pass through the orifice, the change in resistance is electronically measured. The particle weight percents are recorded in 16 size categories. This test is accurate from .6 to 250 microns.

## 5.0 FINAL FLOODED, FIBROUS-BED DESIGN

The final design (third alternative flooded, fibrous-bed filter, figure 8), utilizes a five-piece angle iron frame. During assembly, the wire mesh media is squeezed between the wire screen when the frame is rivited together. This squeezing securely holds the wire mesh in the filter frame.

This flooded, fibrous-bed filter design has several distinct advantages. First, because of the denser filter media, the wire mesh is more resistant to the migration of coal particles. Second, this design permits changing wire mesh without discarding the frame. This new maintenance feature permits changing the wire mesh in a clogged filter for approximately half the price of a new filter. Third, this new filter design has a longer life expectancy than the original filter design. Filter life for this new flooded, fibrous-bed filter is 3 to 4 months. After 3 to 4 months, the wire mesh media can be replaced without discarding the filter frame.

## 6.0 RECOMMENDATIONS FOR FURTHER WORK

During this contract, Donaldson Company designed a flooded, fibrous-bed filter which has greater durability, has increased resistance to clogging, has longer filter media life, and has the potential for changing wire mesh media without replacing the frame.

During the laboratory analysis, the flooded, fibrous-bed clogging problem was traced mainly to the location of the duct intakes. Large particles are forced into these inlets when the continuous miner boom is lowered. (See Section 4.0.) These large particles migrate into the flooded, fibrous-bed media and eventually plug the filter. Donaldson Company recommends that further studies be conducted to optimize the location of the flooded, fibrous-bed intake ducts. The new duct location should provide additional protection from the intake of large coal particles into the filter. For example, locating the intakes on the mining machine sides near the boom or lowering the intake velocities could restrict the intake of these large particles.

It is also necessary to perform additional tests to isolate many of the other operating variables to optimize the effectiveness of the flooded, fibrous-bed filter. For example, it would be desirable to perform additional tests concerning:

- The amount of water sprayed on the flooded, fibrous-bed filter
- The velocity of air flowing through the flooded, fibrous-bed filter
- The optimum number of layers of mesh
- The optimum wire diameter and weave of the mesh
- density of the mesh
- The optimum angle that the flooded, fibrous-bed is positioned with respect to the airflow

Optimizing these variables could significantly increase the efficiency of the flooded, fibrous-bed filter.

APPENDIX A

LABORATORY COAL TEST DUST,  
PARTICLE DISTRIBUTION BY COUNT

Particle Diameter (in microns)	Number of Particles (differential)
.500-.630	1,587,900
.630-.794	718,900
.794-1.00	280,600
1.00-1.26	178,800
1.26-1.59	108,400
1.59-2.00	74,700
2.00-2.52	45,700
2.52-3.17	31,000
3.17-4.00	21,190
4.00-5.04	13,020
5.04-6.35	8,720
6.35-8.00	5,850
8.00-10.08	3,640
10.08-12.7	2,662
12.7-16.0	1,765
16.0-20.2	1,051
20.2-25.4	600
25.4-32.0	320
32.0-40.3	140
40.3-50.8	47
50.8-64.0	22
64.0-80.6	2
80.6-101.6	1
Total Number of Particles = 3,085,030	