**A minerals research contract report**
**September 1981**

# DEMONSTRATION OF A DUST CONTROL SYSTEM FOR BOOM-TYPE ROADHEADER

Contract J0199093
Foster-Miller Associates, Inc.
350 Second Avenue
Waltham, Massachusetts 02154





BUREAU OF MINES ★ UNITED STATES DEPARTMENT OF THE INTERIOR
**Minerals Health and Safety Technology**

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**16. Abstract (Limit: 200 words)**
This program was initiated by USBM to quantify the respirable dust problem caused by the use of roadheaders in underground metal/nonmetal mines with special emphasis on this problem in uranium mines. The contract called for the development of methods or equipment to alleviate the respirable dust and to implement the solution in a mine. Attempts to quantify the dust problem were made in the following way: survey of MSHA records, survey of state mine enforcement agencies, survey of mine records, dust measurements taken at two mines using roadheaders.

The results of this study are not conclusive due to very limited and sometimes less than useful data; however, the study does indicate that a serious dust problem could and may exist. If and when roadheader use becomes more popular, it is almost certain that development of dust control procedures and equipment will be necessary.

This contract was concluded without developing this equipment since only one roadheader is currently in use in an American uranium mine and the mine prefers not to participate in the program at this time. This report discusses the available data concerning respirable dust problems and presents a solution which can potentially help to solve the problem. The solution requires the use of blowing ventilation, on-board dust extraction at the source, and filtration, as well as continued use of water sprays. The on-site tuning of such a system is necessary to demonstrate the degree of improvement possible.

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# FOREWORD

This report was prepared by Foster-Miller Associates, Inc., 350 Second Avenue, Waltham, MA 02154 under USBM Contract No. J0199093. The contract was initiated under Minerals Health and Safety Technology Program. It was administered under the technical direction of the Twin Cities Mining Research Center with Mr. James Olson acting as Technical Project Officer. Mr. William McCarty was the contract administrator for the USBM. This report is a summary of the work recently completed as a part of this contract during the period September 1979 to July 1981. This report was submitted by the authors on 4 September 1981.

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

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# EXECUTIVE SUMMARY

The purpose of this program was to define the problem of respirable dust created by roadheading machines in metal/non-metal mines. Once defined, a solution was to be conceived and implemented to alleviate the problem.

During Phase I, a thorough investigation into the respirable dust attributable to roadheaders was conducted. Data obtained from MSHA, the state agencies and the mines was inconclusive. MSHA had not found roadheaders out of compliance; however, some state agencies had cited mines for noncompliance. Mine records were generally nonexistent.

Visits to four mines were conducted, and in two mines, dust measurements were taken. These data indicate that roadheaders create dust conditions which would be out of compliance if officially measured by MSHA. The data presented in Table ES-1 are typical of the measurements taken at these two mines at the roadheader operator position. The data indicate that roadheader operation has potential compliance problems.

TABLE ES-1. Respirable dust concentrations measured at the operator's position of a boom-type roadheader

| Mine | Peak respirable dust concentration ($mg/m^3$) | 8-hr average ($mg/m^3$) | TLV (threshold-limit value) ($mg/m^3$)* |
|---|---|---|---|
| Borate | 20 | 4.8 | 5** |
| Borate | 156 | 30.2 | 5** |
| Borate | 74 | 5.6 | 5** |
| Uranium | 164 | 8.1 | 0.22 |
| Uranium | 160 | 8.6 | 0.22 |

*Basis of TLV reported = $\frac{10}{2 + \text{percent silica}}$

**For dust containing no silica, MSHA uses a total dust TLV of 10 $mg/m^3$.

A dust collection and filtration scheme was conceived which could address the dust problems as witnessed during the visits. It consists of an on-board collection and filtration system working in conjunction with blowing ventilation. Figure ES-1 shows the conceptual arrangement and Figure ES-2 shows the proposed ventilation arrangement. This concept has the benefit of passing clean air over the operator while confining the dust cloud in front. Dust is collected as near the source as possible. A dry filter is recommended because of the solubility of some minerals.

The program was halted following the Phase I work because no suitable mine was available for in-mine tests and because very few mines currently use roadheaders.

When roadheaders come into general use, the problem of respirable dust should be addressed.

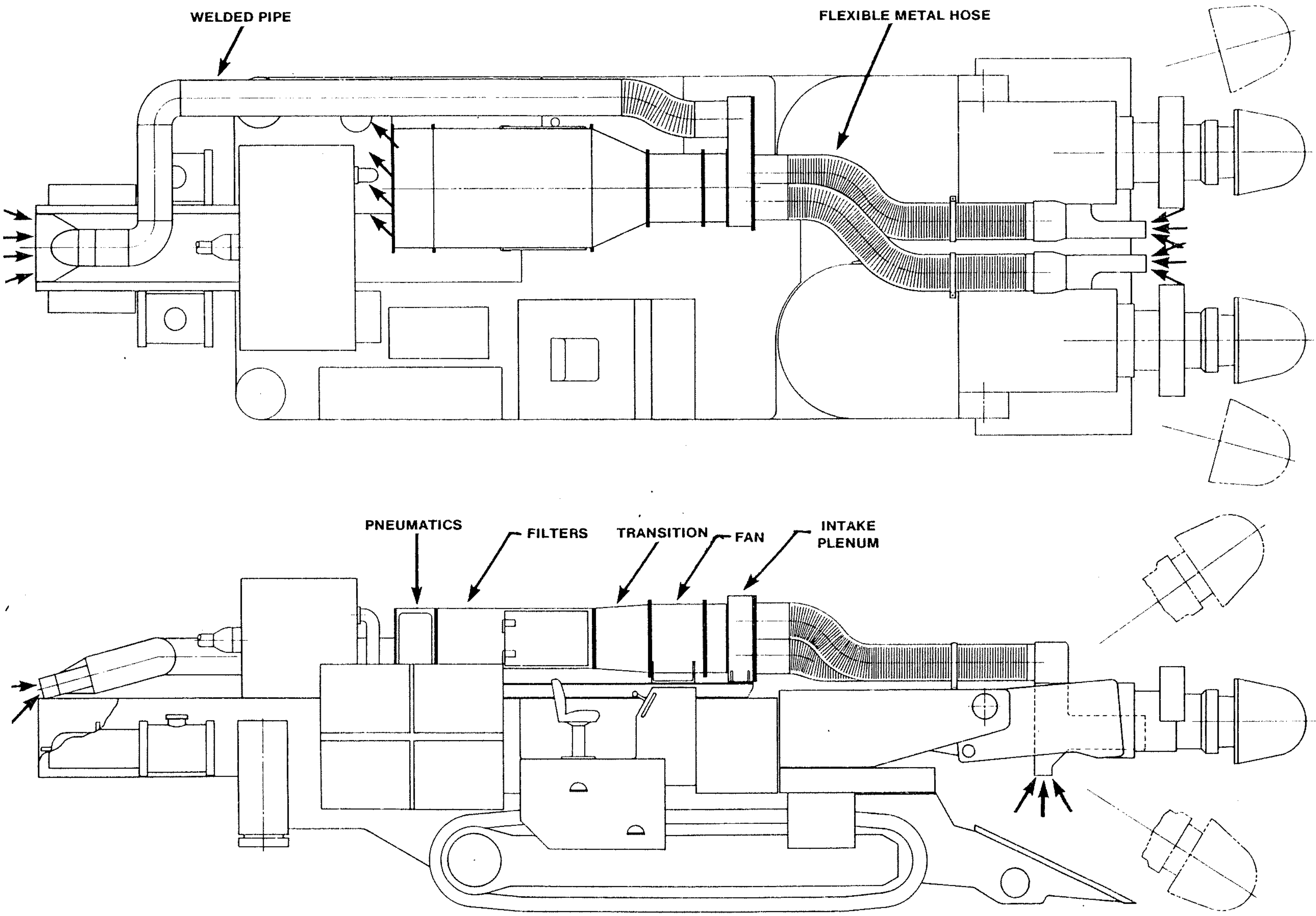



FIGURE ES-1. - Conceptual arrangement.

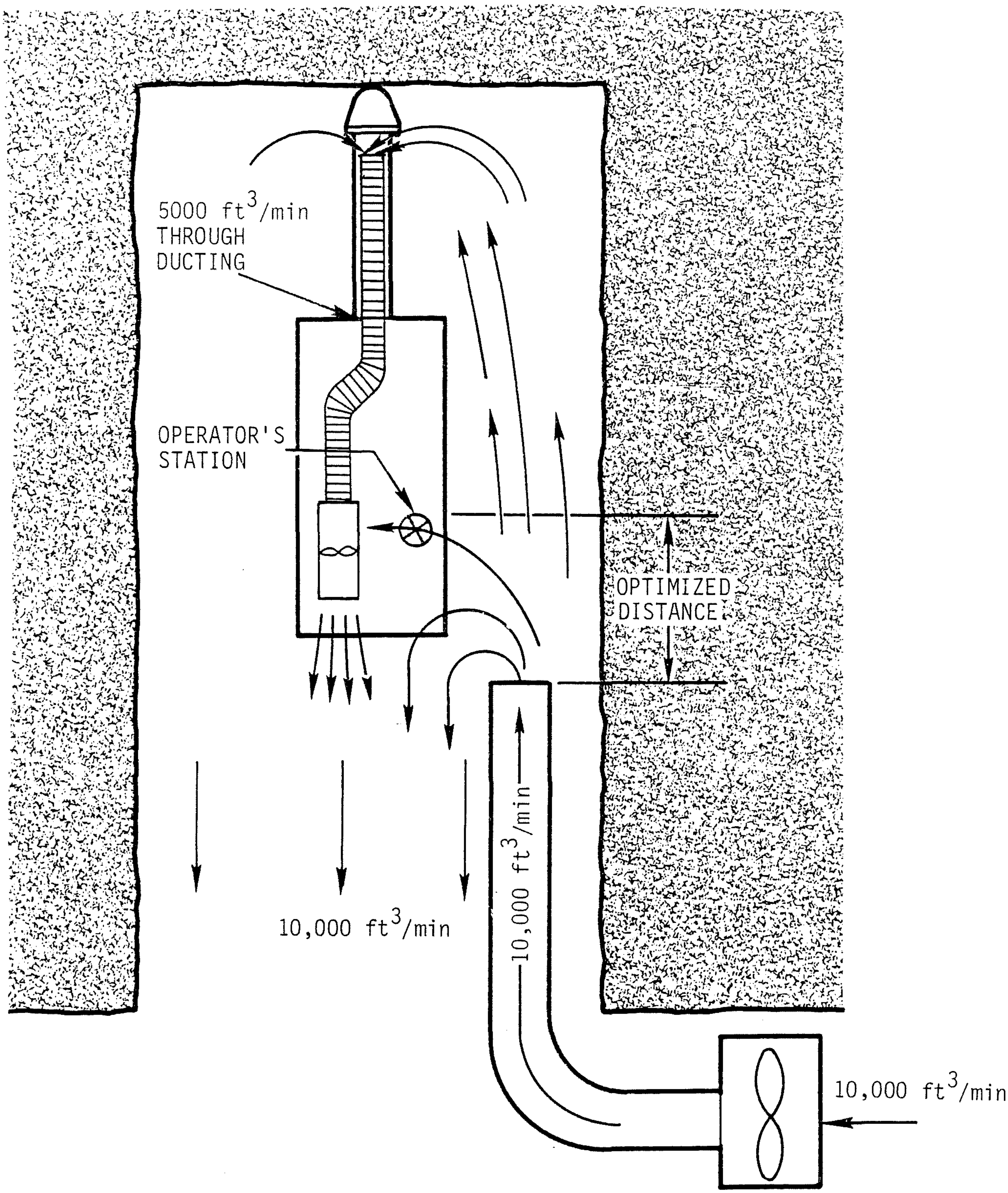



FIGURE ES-2. - Proposed ventilation arrangement.

# 1. INTRODUCTION

The objective of this program was to quantify the respirable dust problem on boom-type roadheaders and to alleviate the problem by installing a dust control system on a roadheader in an active mining situation.

The program was to have been conducted in two phases:

a. Phase I - Problem analysis, data planning, and location of test mine and dust control equipment

b. Phase II - Acquisition and test of dust control system in-mine.

The lack of a suitable test mine prevented the program from proceeding into Phase II.

The remainder of this report is broken down into the following major sections:

a. Dust problem survey

   1. Allowable dust exposure
   2. Records of MSHA, state and mines
   3. Mine visits
   4. Dust collection, separation, and suppression

b. Dust control recommendation

c. References.

# 2. DUST PROBLEM SURVEY

In order to quantify the current dust problem that exists in roadheader operations, an information survey was conducted. MSHA offices, state agencies, and mining operations were interviewed. Inspection forms and citations were studied at one state agency and a dust survey was done by FMA at a borate and a uranium mine.

## 2.1 Allowable Dust Exposure

The maximum dust exposure permitted by MSHA is a function of the mineral composition. The maximum exposure allowed is expressed as a Threshold Limit Value (TLV). The maximum allowable TLV without $SiO_2$ is 10 $mg/m^3$ (total airborne dust). The TLV for materials containing silica is typically based on the calculation:

$$\text{TLV } (mg/m^3)\text{respirable} = \frac{10}{\%\ \text{Quartz} + 2}$$

The 8-hr time-weighted average (TWA) is determined by weighing the gravimetric filter cassette from a personal sampler. For sampling only the respirable fraction, the sampler is fitted with a cyclone that collects only the respirable dust fraction. For sampling total airborne dust, the cyclone is removed.

State agencies have often used a midget impinger to collect dust samples to determine compliance. Dust particles less than $5\mu$ are counted to determine the TWA and are reported as the number of particles per cubic foot of sampled air. The TLV for the impinger sampling is based on the expression:

$$\text{TLV} = \frac{300}{\%\ \text{Quartz} + 10} \times \frac{\text{million particles}}{ft^3}\ \text{(mppcf)}$$

No correlation between the gravimetric sampling and the impinger sampling techniques has been established. MSHA technical support has found, however, that high impinger counts do indicate high gravimetric results.

## 2.2 Survey of MSHA Offices

Five MSHA field, subdistrict, or district offices were contacted for dust sampling and environmental information in mines using roadheaders. It was generally found that little dust sampling had been done in roadheader operations by MSHA since it took over this responsibility from state agencies in 1978. Table 1 summarizes the results of the survey of these offices. When these dust surveys were done, they showed no compliance problem.

Three MSHA dust samples recorded for one uranium mine using a roadheader, but at three different mine locations, are shown below:

| Occupation | Allowable TLV ($mg/m^3$) | Actual Exposure ($mg/m^3$) |
|---|---|---|
| Miner 1 | 1.06 | 0.38 |
| Miner 2 | 5.00 | 0.41 |
| Motorman | 5.00 | 0.27 |

Operating conditions at the time of sampling, however, were not recorded.

The Vermont talc mines have not been sampled recently but initial sampling by MSHA had shown that they were out of compliance with the talc standard. These roadheaders are operated outdoors during the spring and summer months and no outdoor samples have been taken. Since the initial sampling, the machines were retrofitted with an enclosed operator cab supplied with filtered air. No data were available, however, as to any compliance problems with the attendant crew or operators since the cabs were installed.

Of the four western MSHA offices contacted, none has ever issued a dust citation in either uranium or borates. Material analysis performed on samples from the California borates, however, indicated no fibers or $SiO_2$.

At this time, only a subjective evaluation can be made of the MSHA survey regarding the severity of the dust problem in the use of roadheaders. Nuisance dust or total dust concentration

TABLE 1. - Summary of survey of MSHA offices

| Location | Type of office | Area/mines covered | Dust level sampling on roadheaders done | Dust citations issued | Notes |
|---|---|---|---|---|---|
| Dallas, TX | District | New Mexico/uranium | No | None | Prior to 1978, state inspectors did survey - primarily concerned with radon daughters. |
| Riverton, WY | Field | Wyoming/uranium | Yes | None | Samples well within compliance. "Many samples ruined by water in the air." |
| Grand Junction, CO | Field | Colorado/uranium | No | None | No samples taken with machines running. One "walking" sample showed TWA = 0.21, TLV = 5.0. |
| Springfield, MA | Field | Vermont/talc | Yes | Yes (number unknown) | All machines now have enclosed cabs, no citations since cabs were installed. Talc standard applicable. Generally no fibers. |
| Boulder City, NV | Field | California/borates | No | None | Analysis indicates no $SiO_2$ and no fibers. Nuisance dust only concern. |

appears to be the major dust problem reported for a dry mine. The consensus reported by MSHA inspectors is that wet mines appear to have minimal dust problems.

An attempt was made to access the MSHA computer records to further search for quantitative data. It was decided, however, that these records could not be effectively used for this program.

## 2.3 Survey of State Agencies

Until 1978, state agencies were responsible for monitoring the dust levels in most mines using roadheaders. When FMA surveyed the states that had mining operations using roadheaders, it was found that most of their records were in storage and not accessible. Furthermore, most of the data was compiled by sampling with the midget impinger rather than a gravimetric sampler. These data have been included in the following subsections for completeness and to show how the roadheader was classified a dust problem by health and safety inspectors working for state agencies.

### 2.3.1 State of New Mexico Survey

The state of New Mexico Energy and Minerals Department cooperated in a review of dust inspection records of the large uranium mines that had used or are using roadheaders in their area. They recalled records from their archives dating from 1969 through 1977. An inspector personally involved in the sampling of roadheader operations was made available. Because of their cooperation, and the completeness of their records, a good chronology of the problem was established and some information directly relating to a roadheader mining operation can be reported.

Settled dust samples were used to determine the TLVs. The uranium mines where samples were taken had silica contents ranging from 25 to 80 percent as determined in the laboratory by X-ray diffraction or wet chemistry. The calculated TLVs then would range from 3.6 to 9.6 mppcf of air and the data presented below should be evaluated with these limits in mind.

The state of New Mexico started dust sampling in roadheader operations in 1969, when the machines were first introduced to uranium mining. Inspectors, operators and manufacturers were apparently concerned because the mineral deposits literally exploded when they were cut from the mine face. The apparent severity of the dust problem was reported as extreme regardless of the amount of moisture present in the material or the mine.

The review of the sampling records indicated that both the Dosco and Alpine roadheaders used in the New Mexico uranium mines created a dust problem that had not been abated. The state had cited all of the mines using roadheaders for dust overexposure and had, at times, temporarily shut down mines for not being in compliance with its standards.

The records of three mines representing 15 dust surveys done specifically on roadheaders were reviewed. "Acceptable ventilation" was noted on the inspection forms with only the comment that it was exhausting, blowing or a push-pull type. "Water sprays on" was also a typical note but no other specifics were logged. Production rates and cutting modes were not recorded. All of these inspections showed the mines to be out of compliance with existing state standards.

One inspection report had much more detail in it because the uranium mine operator had requested the state to do the survey on a new roadheader trial with the manufacturer present. The following data were recorded:

| Work Activity | 8-hr Average Dust Count (mppcf) | |
|---|---|---|
| Roadheader Operator | 153.8 | |
| Motorman | 312.8 | Allowable |
| Laborers | 214.6 | TLV = 5.7 mppcf |
| Belt Discharge Laborer | 321.8 | |

These readings were time-weighted averages for 8 hr. The roadheader performed in all operating modes. Two laborers were hand-mucking beside the roadheader. One laborer was required to be at the roadheader conveyor belt discharge. The motorman operated a Load Haul Dump (LHD) vehicle. The face was exhaust-vented by a 9000-$ft^3$/min fan into a 20-in. diam duct located 10 ft from the operator. The intake air to the heading was described as clear and showed a 2.1 mppcf dust count. The mine visible atmosphere was described as damp and wet with heavy dust and smoke.

Mine management tried various techniques to bring the operation into compliance:

a. Pressurized respirator helmets

b. Face masks/respirators

c. Various water sprays

d. Steam suppression

e. Wet collection

f. Calcium chloride on travelways.

The results of these efforts were not documented. Some comments on the reports, however, did indicate that water sprays "halved" the dust counts and that the respirators were uncomfortable for the workers to wear.

Although the other inspection reports reviewed did not have this type of detail in them, the worker activity, average dust counts, and TLVs were similar.

### 2.3.2 State of Colorado Survey

The resident inspector for the state of Colorado recalled the only two inspection reports involving a roadheader in their files. Inspection No. 1 was done on 29 June 1976 in a uranium mine decline using a roadheader. The midget impinger data were taken with "heavy water sprays on." The results of the dust sampling are as follows:

Allowable TLV = 3.5 mppcf
8-hr TWA = 22 mppcf
$SiO_2$ = 75 percent

Survey No. 2 was done on 30 March 1977 in the same uranium mine decline, but in a shale deposit. This time the sampling was done gravimetrically. The inspector's personal recollection was that a steam suppression system was in use.

The results of the dust sampling are as follows:

| Occupation | Allowable TLV ($mg/m^3$) | Actual Exposure ($mg/m^3$) | $SiO_2$ (%) |
|---|---|---|---|
| Foreman | 1.6 | 1.0 | 4.2 |
| Miner 1 | 1.3 | 1.1 | 5.7 |
| Miner 2 | 2.4 | 1.2 | 2.2 |

Since the sampling was done in a relatively nonsilacious area, no compliance problem existed.

#### 2.3.3 State of Wyoming Survey

In Wyoming, no state dust statute exists; therefore, no samples have been taken for records.

#### 2.3.4 State of Utah Survey

Utah does no routine sampling. Sampling might have been performed when an inspector saw an "overpowering dust situation." The resident inspector, however, had no other information to offer and all of the state's records are in the archives.

#### 2.3.5 Enforcement Agency Survey Conclusion

The state of New Mexico had the largest population of roadheaders in metal/nonmetal mining and all were operating in uranium mines. They have classified the roadheader as a major dust problem based on their monitoring of the dust levels in roadheader operations and the unsuccessful mine efforts to abate the problem.

MSHA and other state agencies have no documentation of the magnitude of any roadheader dust problems.

### 2.4 Mining Operations Survey

An operations survey was organized by FMA and the USBM early in the program. It was anticipated that salient data from the mining companies about the dust monitored during roadheader operation, technique of mining, ventilation design, type of roadheader, the use of sprays, and other suppression techniques would further quantify the dust problem. An informal survey format was agreed upon and the following operations were contacted:

a. Kerr-McGee

b. United Nuclear

c. United Nuclear - Homestake Partners

d. Anaconda

e. Cotter Corporation

f. Gulf

g. Exxon

h. American Borate

i. Windsor Talc.

The results of the survey, however, showed that very little data exist or would be made available to FMA. The miner operators' opinions on the severity of the problem varied from none to severe. Those who considered dust a problem usually referred to visible dust. Most wet operations stated that there was no dust problem. No data relating the dust levels to the dust control techniques employed by the mine were made available for review by FMA.

## 2.5 Mine Visits

Four mines were visited so that dust surveys could be performed and the circumstances of the roadheader operation could be documented. Sampling was conducted at two of the mines. The other two mines were unable to operate their machines during the visits.

### 2.5.1 Instrumentation and Sampling Techniques

Two dust sampling methods were used at the mines where sampling was conducted. Gravimetric sampling was performed using Dupont pumps and filter cassettes. Continuous monitoring was performed using a RAM I instantaneous dust monitor manufactured by GCA, Inc. The output of the RAM I was recorded on a strip chart. Both types of samplers were outfitted with cyclones to sample only respirable dust. Both samplers were located on the roadheader at the operator's station.

The TLVs were determined by analyzing the gravimetric dust samples for silica at either the USBM, Bruceton, PA, or at Skinner and Sherman Laboratories, Waltham, MA. The filter cassettes were desiccated and weighed at FMA.

The 8-hr average concentrations reported were extrapolated from the strip chart recorder used with the continuous monitor. The areas under the curves were determined with a planimeter and then an average value for 8 hr was determined. The filter cassettes were evaluated by extrapolating the data to an 8-hr average.

### 2.5.2 Mine A Visit

A Dosco Twin Boom TB600 operating in a borate mine was surveyed for several shifts. The roadheader was driving a development heading during the survey period.

#### 2.5.2.1 General Operation Description

Drifts are about 18 ft wide and 15 ft high. The normal mining cycle involves a roadheader advance of 20 ft, which takes a complete shift. The roadheader discharges into the bucket of an LHD, which transfers the ore to a haulage vehicle. These transport the ore to stockpiles outside the mine.

Main ventilation was provided by two blowing fans located in a bulkhead in one of the drift entries. The main ventilation flow rate was approximately 40,000 $ft^3$/min. Auxiliary ventilation in the heading is provided by two exhausting fan and tube systems. The tube diameter is 30 in. Each fan has a flow rate of approximately 14,000 $ft^3$/min.

Dust control measures at the working face consisted of four water spray nozzles on each cutterhead. During the survey, several of these nozzles were plugged. To control dust in main haulageways, a commercial deliquescent called Cohex* is applied to the road surface. This chemical is mixed at a ratio of about 4 gal to 200 gal of water and distributed from a tank trailer.

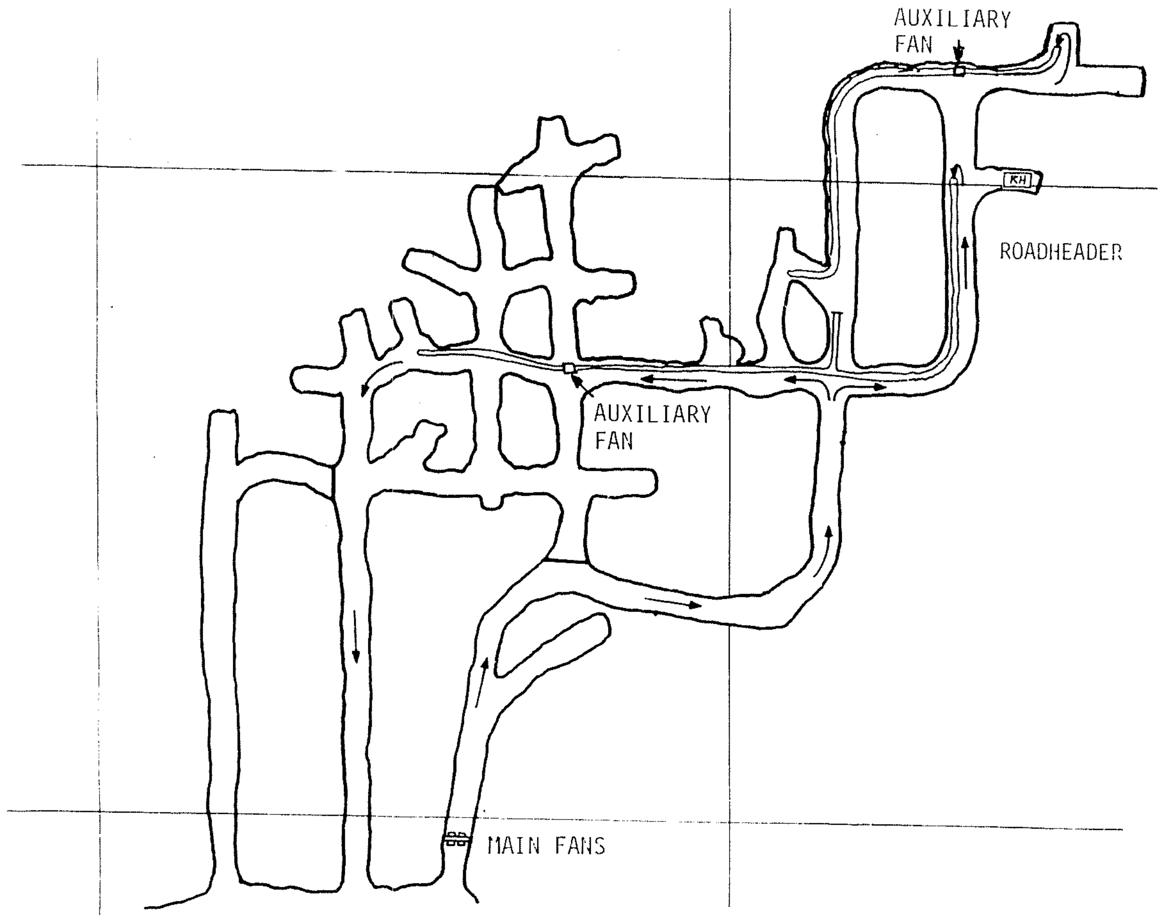
#### 2.5.2.2 Mine A Dust Survey

FMA conducted dust sampling on three shifts. One gravimetric sampler was located in the cab of the roadheader, and another was located either at the helper's position on the roadheader or in the cab of the LHD. The instantaneous monitor was either held by a person standing next to the cab of the roadheader, or placed on top of the roadheader next to the cab.

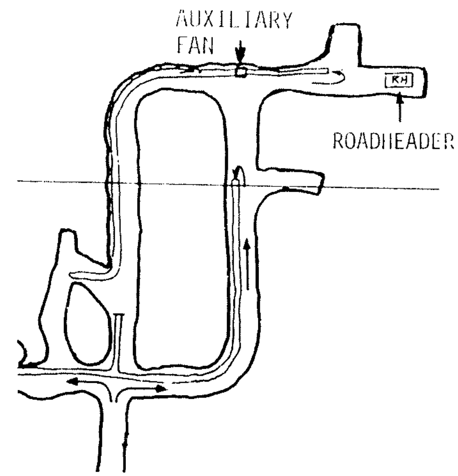
Figure 1 is a general mine layout showing the roadheader location and the ventilation arrangement during the dust survey period.

Table 2 summarizes the operating variables and the dust concentrations measured during the survey. The TLV for this mine is 10 $mg/m^3$ total dust and a 5 $mg/m^3$ respirable. The concentrations measured during shift No. 2 indicated a potential compliance

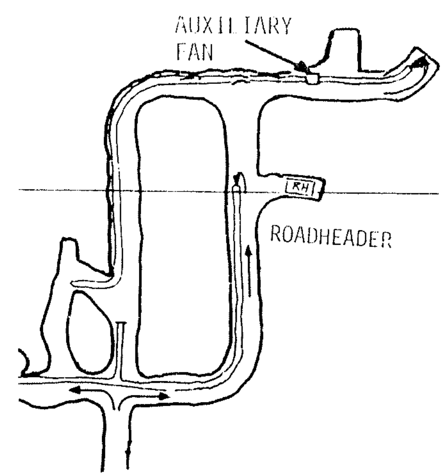
*Reference to specific brands, equipment, or trade names in this report is made to facilitate understanding and does not imply endorsement by the USBM.




a) MINE A - SHIFT NO. 1




b) MINE A - SHIFT No. 2




c) MINE A - SHIFT No. 3

FIGURE 1. - Mine layout - Mine A.

TABLE 2. - Roadheader dust concentrations - Mine A

| Shift Number | Cutting time (min) | Vent tube setback (ft) | Peak respirable dust concentrations, (mg/m$^3$) (instantaneous monitor) | 8-hr average respirable dust concentrations, (mg/m$^3$) (instantaneous monitor) | 8-hr average for both gravimetric samplers (mg/m$^3$) | Comments |
|---|---|---|---|---|---|---|
| 1 | 124 | 60 | 20 | 1.7 | 4.8 | |
| 2 | 189 | 80 | 156 | 15.6 | 30.2 | |
| 3 | 272 | 90 | 74 | 4.3 | 5.6 | Only one boom used |

Note: The TLV for this material is 10 mg/m$^3$ total dust and 5 mg/m$^3$ respirable dust. For dust containing no silica, MSHA enforces the 10 mg/m$^3$ total dust TLV.

problem. Figure 2 shows the strip chart recording taken during shift No. 2. As can be seen, the peak concentrations are short-term and infrequent and appear during the period that the cutter-heads sump into the face.

2.5.2.3 Mine A Survey Conclusions

A correlation between the measured dust concentration and the cutting cycle was observed during the survey. Figure 3 shows the dust concentrations during two cutting cycles. The peak concentrations were measured when the cutter booms sumped in for the initial cut at the new face. This is the only time during a cutting cycle that the entire circumference of the cutterhead is in contact with the material being excavated.

Once the cutters were sumped into the face and advanced for about 2 ft, they were raised and lowered to form a slot. The slots were then widened outward, and finally a thin ribbon between slots was removed. The dust concentration follows closely the amount of material being liberated.

2.5.3 Mine B Visit

Mine B, also a borate mine, is similar to Mine A and is heavily committed to roadheader mining. At the time of FMA's visit, three roadheaders were underground, but none were operating. The largest unit is a Dosco TB600.

The mine is a shaft entry mine currently under development. It is designed to use both conventional mining methods and road-headers. The long-range plan is to develop a cut-and-fill stoping system.

During the visit, it was not possible to examine the face ventilation equipment, but the fans and vent tube were reported to be the same type used in Mine A.

2.5.4 Mine C Visit

Mine C is a uranium mine. It is a newly developed, slope entry mine that uses a Dosco Model 2.4M Mk IIA single-boom road-header. Ten-ton Elmac trucks are used for haulage. At the time of the visit, the roadheader was not operating, nor were the main or auxiliary fans. The mine was under natural ventilation. A roof fall the night before our visit had temporarily put the road-header out of service.

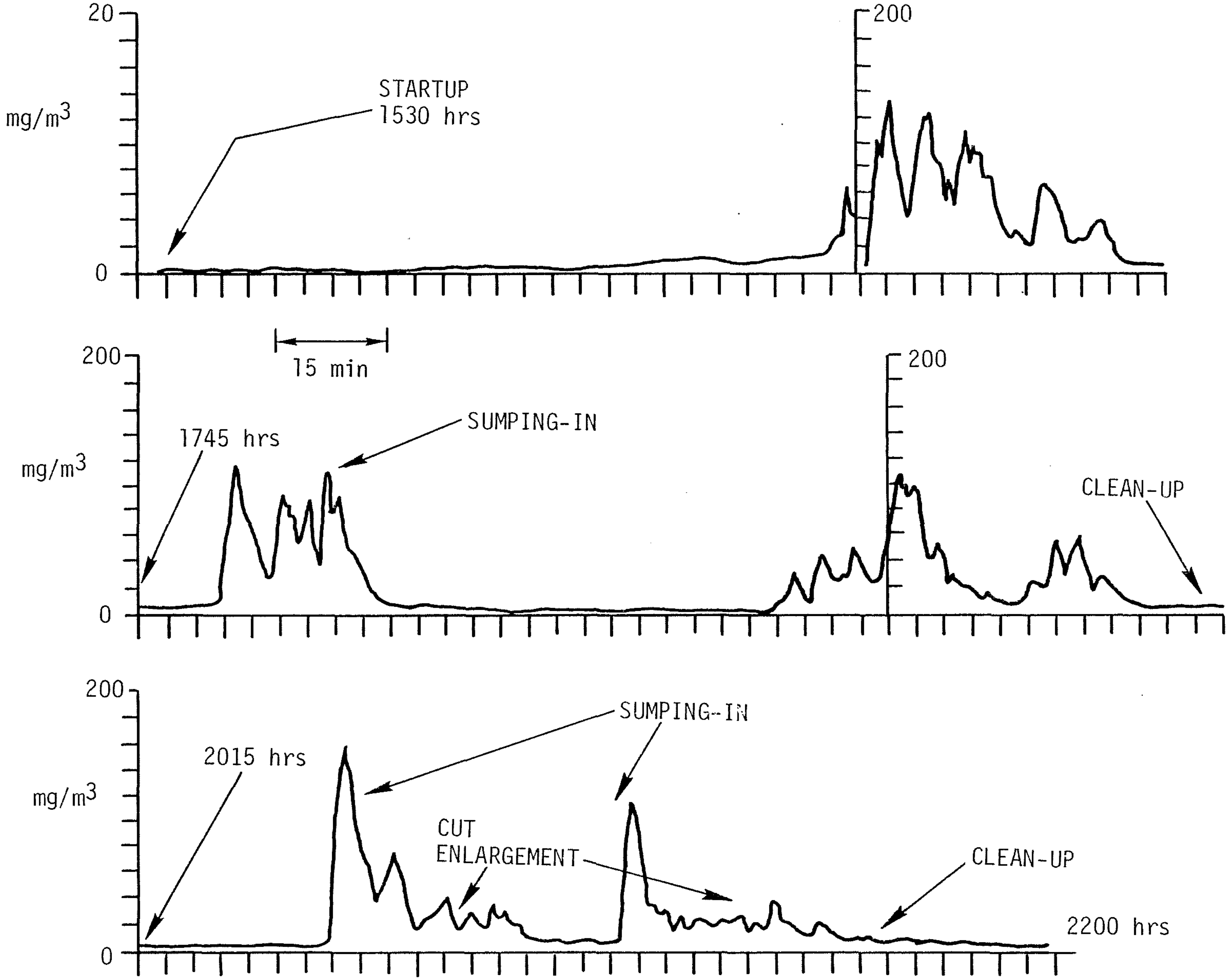



FIGURE 2. - Strip chart recording - Mine A - shift No. 2 - complete shift monitoring.

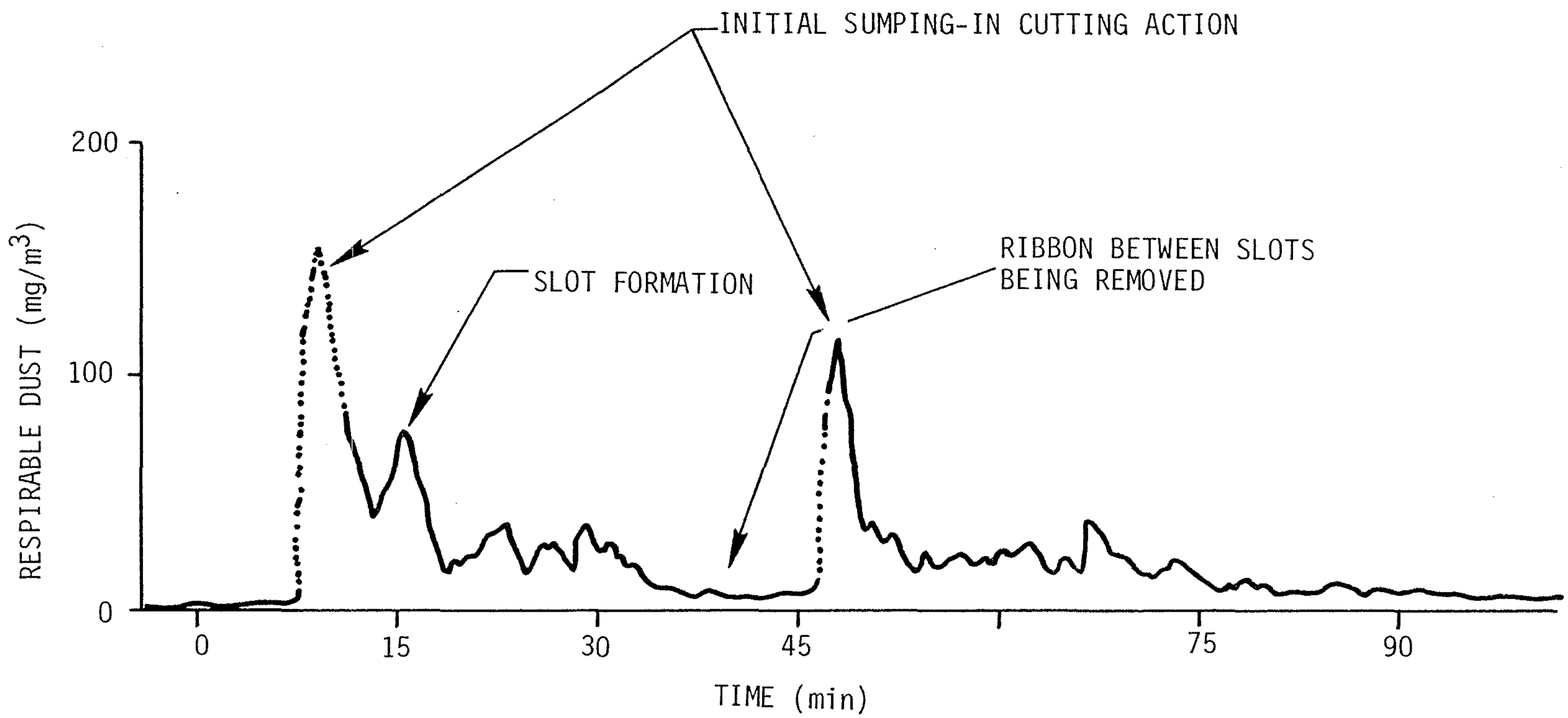



FIGURE 3. - Two complete cutting cycles - strip chart data.

The auxiliary fan was a 30-in., 50-hp type with an estimated exhausting flow rate of 12,000 $ft^3$/min. Miners stated that the maximum tube setback is 10 ft. Miners also stated that due to the wet ground, there was little dust generated during cutting.

This uranium mine was the only production uranium operation using a roadheader during this program. Operations at this mine are currently stopped.

### 2.5.5 Mine D Visit

Mine D is a new uranium mine currently under development and is using a new third-generation AEC ROC-MINER roadheader. When fully operational, the mine plans to commit a crew of six men to the roadheader.

#### 2.5.5.1 General Description

The geothermally heated uranium ore body is being mined at the 3200-ft level. Mine water and the ore are approximately 128°F. Water is pumped out of the mine at a rate of 5100 gal/min and as high as 20 gal/min away from the face. Two 50-ton chillers are used to maintain the face temperature between 90° and 95°F. The 100 percent humidity in the high temperatures and the flowing hot water accelerate corrosion problems dramatically.

The single-boom roadheader cuts a rectangular drift 9 ft high by 12 ft wide at a rate of 4 to 6 ft/hr. When the mine is fully operative, the planned advance is 18 ft/hr. A ripper-type or coarse cutting head is being used and the bits wear out rapidly. Current cutting time is about 2.5 hr/shift. Figure 4 is a schematic of the face area where the roadheader was operating and the ventilation system being used during the survey. The ripper-type cutterhead is flushed by 16, 1/4-in. diam nozzles at a rate of 25 gal/min, including 5 gal/min recirculated after cooling the roadheader motors. Seven nozzles are immediately behind the cutter as an integral part of the boom and nine are part of a collar installed by the mine. An Elmac MMP Venturi system will be installed at the cutterhead in the future. The mine is also considering a spray system over the loading conveyor and on the length of the 23-ft rubber belt discharge conveyor.

#### 2.5.5.2 Mine D Dust Survey

Dust sampling was done during two shifts and in the same manner as previously described. The gravimetric samplers and the

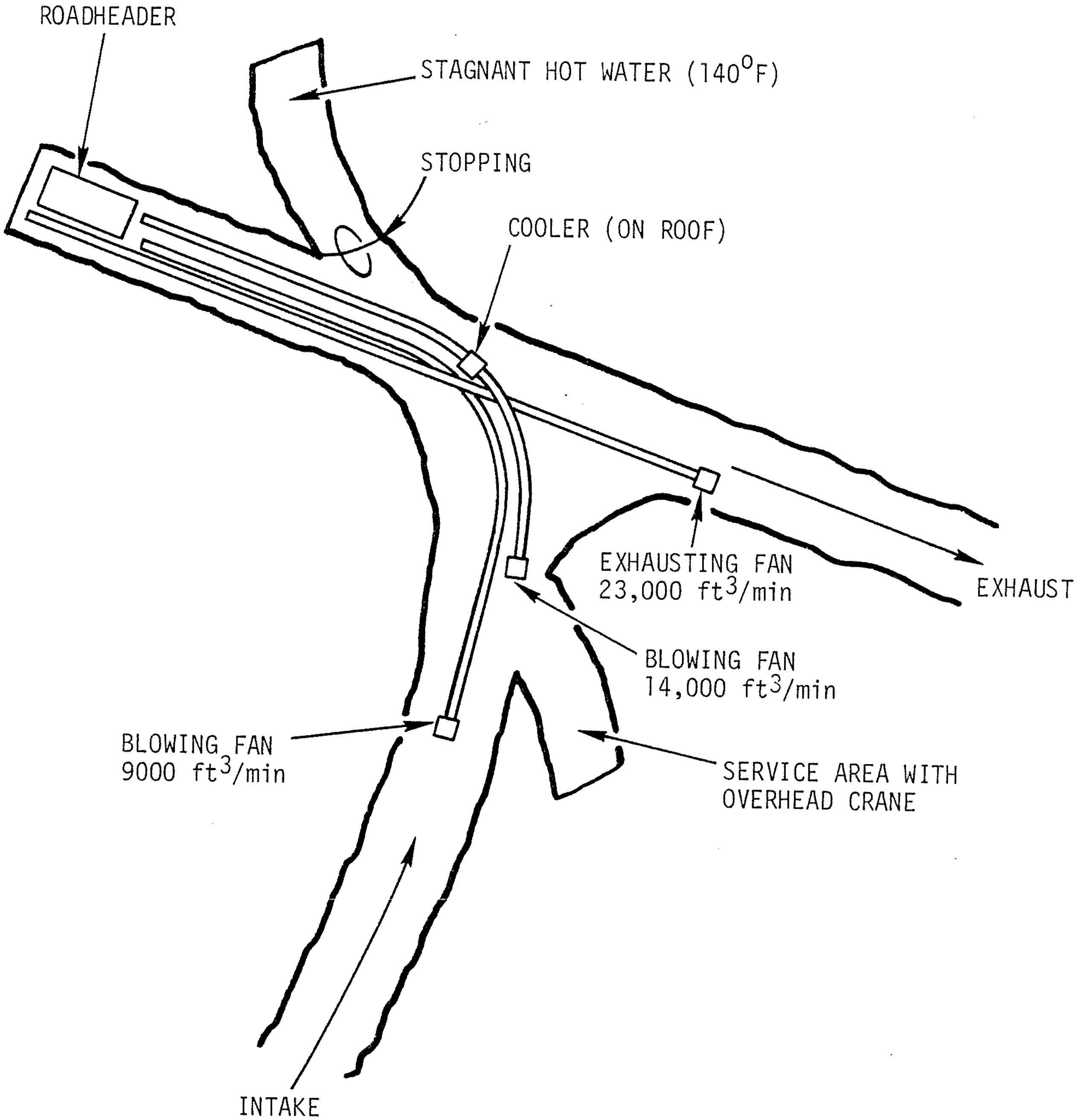



FIGURE 4. - Roadheader face area - Mine D.

RAM I were located at the operator's station and monitored dust during the time that the crew was cutting, loading and leveling. The results are shown in Table 3.

The TLV for this mine was 0.22 mg/m$^3$, based on a $SiO_2$ analysis of 44 percent. The sampling results shown in Table 3 indicate a potential compliance problem.

2.5.5.3 Mine D Survey Conclusions

Mine D is concerned about the dust problem caused by the roadheader. They have addressed the problem in the following ways:

a. Respirators

b. Dust helmets (air stream hoods)

c. Airflow experimentation

d. Water spray experimentation.

Ventilation systems are continually varied in an effort to control both dust collection and cooling. Only the push-pull system shown in Figure 4 is used, but tubing setbacks, air volumes, velocities and chiller capacities are varied. The number of water sprays has been increased over the original seven supplied by the roadheader manufacturer, and more will be added; in addition, they vary nozzle sizes and water pressure often. None of these techniques has been optimized at the mine and the problem is reportedly becoming more serious as development progresses.

TABLE 3. - Mine D dust survey results

| Shift Number | Cutting time (min) | Peak respirable dust concentration (mg/m$^3$) | 8-hr average RAM I (mg/m$^3$) | 8-hr average gravimetric cassette No. 1 (mg/m$^3$) | 8-hr average gravimetric cassette No. 2 (mg/m$^3$) |
|---|---|---|---|---|---|
| 1 | 232 | 164 | 8 | 8.4 | 7.8 |
| 2 | 207 | 160 | 6 | 8.7 | 8.6 |

## 2.6 Literature Review

To further quantify the roadheader dust problem, a domestic and foreign literature search was made. The results indicate that a significant contribution to the total dust generated by a roadheader can be attributed to the following:

a. Use of a light-duty machine in a heavy-duty application

b. Inadequate cutting depth

c. Improper cutting speed

d. Improper use of ventilation

e. Movement of the material

f. The hardness of the mineral.

MRDE, the Mining Research and Development Establishment, National Coal Board, Great Britain, reports that standard roadheaders are being phased out in Europe and that the new third generation is becoming popular. The new roadheaders can advance 2m/shift faster than the second generation type, but produce over twice as much total dust in hard materials.

MRDE has initiated programs to evaluate the effects of changing roadheader cutting parameters, such as arcing and cutting speeds, on dust generation rates. Preliminary results indicate that a deep cut, with all other variables held constant, may reduce dust generation by as much as 50 percent. More quantitative data will be available when they complete their programs. However, MRDE and some of the roadheader manufacturers have developed and tested several dust control methods specifically for use with roadheaders.

Although the published data on dust control measures used with roadheader mining are predominantly coal-mining-related, FMA feels that it is not unreasonable to expect that these same control measures will have a positive influence on controlling dust in a metal/nonmetal mine. Some of the tested methods are discussed in the following subsections.

## 2.6.1 Water Sprays

Water sprays are the most common dust control method reported on to suppress the dust at the roadheader cutterhead(s). The initial work focused on high-pressure sprays impinging directly on the cutter bits (wetheads). Although a dust reduction of 30 percent (compared to conventional sprays) was noted, clean water was required to prevent clogging and water seals on the rotating cutterhead were a chronic problem. The method of getting the water into the cutting zone was the major problem addressed.

MRDE tested the integral cutting head spray systems shown in Figures 5 and 6.

Although the dust was reduced by more than half over the external sprays, nozzles clogged continually because of the use of unfiltered water and material blinding the nozzles.

The most effective cutting head spray suppression system tested to date uses a scrolled vane cutting head, as shown in Figure 7. The use of this system permits the spray to be directed

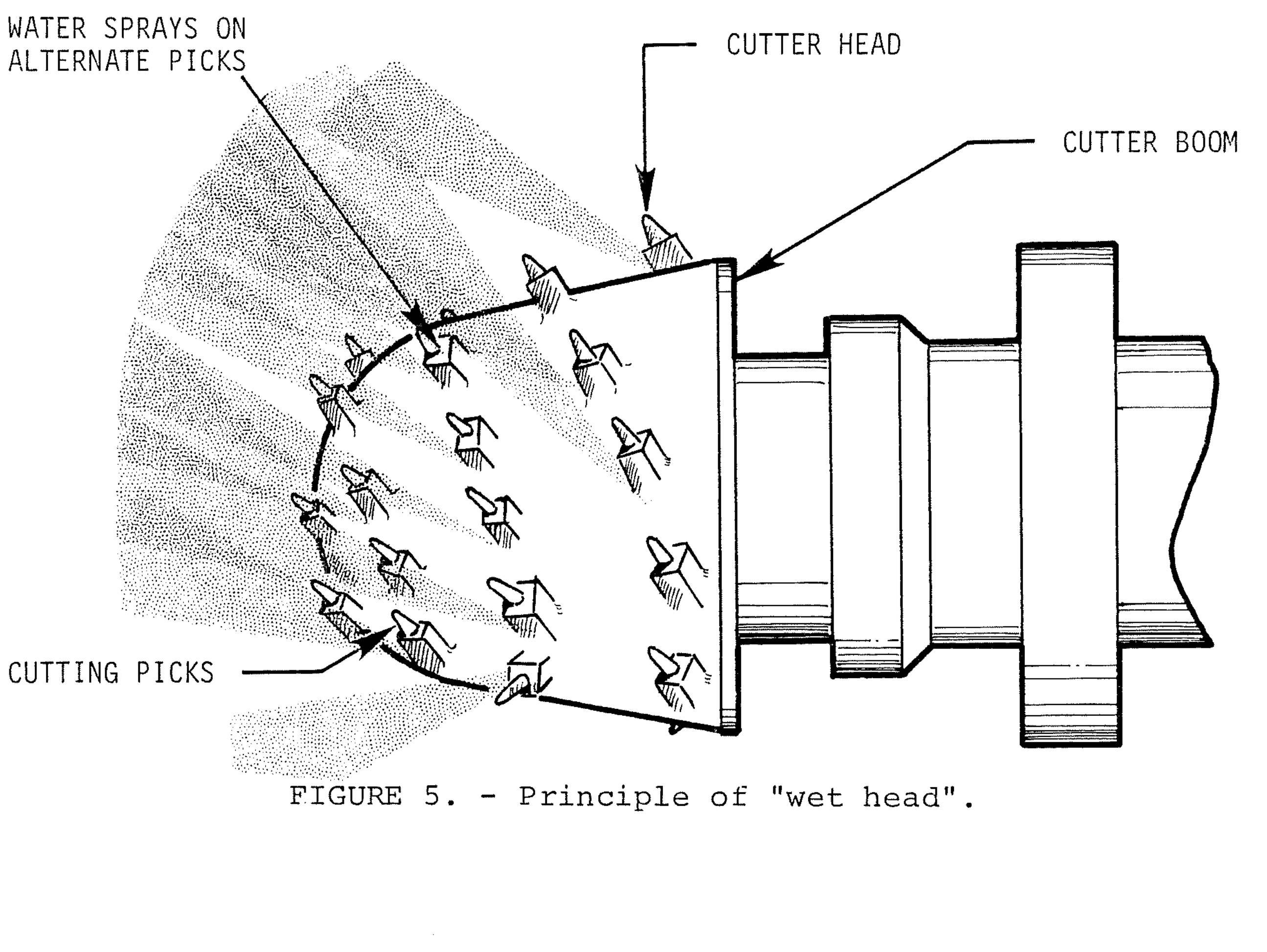



FIGURE 5. - Principle of "wet head".

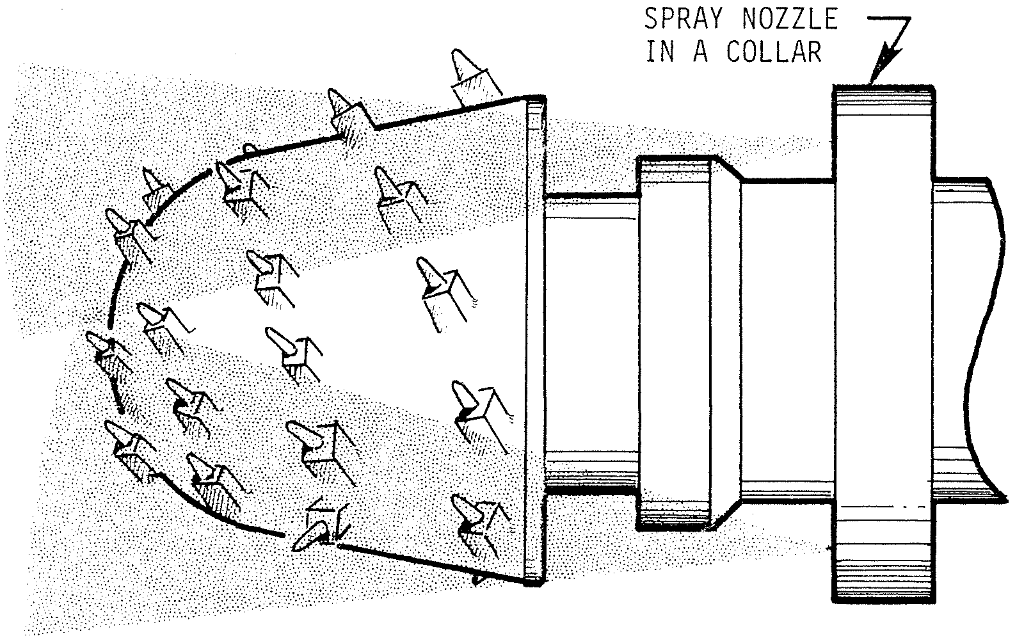



FIGURE 6. - Principle of water spray dust suppression on a roadheader.

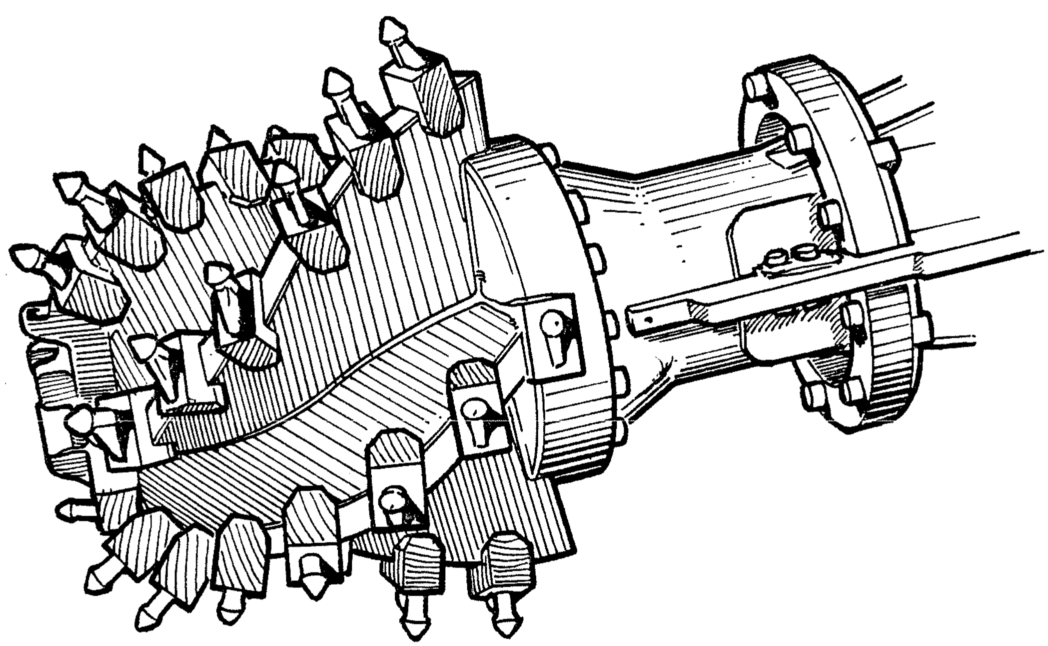


FIGURE 7. - Scroll-type cutterhead.

toward the cutting zone. The spray nozzles and the water supply piping are mounted on the cutterboom away from the cutterhead and remain out of harm's way during operation. The cutting efficiency of the scrolled head, however, is reported to be less than that of a conventional head. The head bounces when the cutting boom arches and some concern has been shown by the manufacturers about potential fatigue problems in the boom and other roadheader components.

Table 4 summarizes the results of tests performed by MRDE at one United Kingdom mine while the roadheader was cutting hard material. It can be seen that pick face flushing is more effective than conventional sprays. Data also shows that increased water further improves the effectiveness of the pick face flushing system. Increased water usage, however, can create operational problems in soluble ores and in mines with poor bottom conditions.

### 2.6.2 Steam Suppression

A roadheader manufacturer has developed a dust suppression technique that uses steam jets in place of the water sprays. It is reported that the steam cloud in the cutting area suppresses the dust more effectively while using less water because of the smaller droplet size.

TABLE 4. - Respirable dust dispersed from cutting a cubic meter of rock-ripping machine at Creswell Colliery

| Type of Spray | Flow rate (gal/min) | Dust dispersion (grams/$m^3$ of rock cut) |
|---|---|---|
| External Sprays | 12 | 33.8 |
| Pick Face Flushing | 7 | 19.3 |
| Pick Face Flushing | 12 | 14.2 |

Steam is produced by a large, skid-mounted electric boiler either towed by the roadheader or remotely located. The steam is delivered to the spray nozzles in the same manner as water, but below the scalding temperature. Table 5 shows the results of an MRDE test in a colliery in England. It can be seen that these tests with steam show a large improvement over water sprays while using a relatively small amount of water.

The use of steam suppression, however, seems limited because of the size and general lack of mobility of the required boiler.

### 2.6.3 The Use of Surfactants and Foam

The use of water as a dust control method in some minerals can be enhanced by the addition of surfactants or wetting agents. Foam suppression could also have some utility as a suppressant if the mineral beneficiation process was not affected. However, no data on a roadheader installation using these techniques were found.

### 2.6.4 Dust Collection/Separation System

Boom-type ripping machines and roadheaders retrofitted with dust collection systems have been tested by MRDE. Machine-mounted ducting was connected by flexible tubing to a towed or trolley-supported dust collector/scrubber.

TABLE 5. - Dust measurements with steamed spray ($mg/m^3$)

| Position | Water Sprays at 4 gal/min | Steam at 4 gal/hr |
|---|---|---|
| At operator's position | 7.6 | 2.4 |
| At front of roadheader | 60.5 | 11.0 |

Figure 8 schematically shows the MRDE-developed wetted fibrous bed scrubber system being towed on a trolley behind a dintheader. Dust-laden air was drawn in through an entry just above the back of the cutter pick mat.

MRDE retrofitted a DOSCO MK2A roadheader with a dust extraction system. A dust collection port was installed behind the cutting head. The flexible tubing was connected to an MRDE irrigated filter unit towed on a trailer behind the roadheader.

The reduction in dust levels reported during the MRDE programs varied according to the type of ventilation system used and the type of filter attached to the collection ducts. These programs have demonstrated that dust can be collected near the source and that an articulated boom cutter can be retrofitted with the necessary ducting. Figure 9 schematically shows the optimized system tested by MRDE in combination with an overlap ventilation system.

Table 6 shows the relative concentrations at the operator, in the exhaust ducting and downwind of the filter.

The above data become somewhat significant when compared with similar data at the same colliery with an exhaust ventilation system. Figure 10 shows this arrangement. The mean dust reading at the operator's position was 37.9 $mg/m^3$, which is about six times greater than the integrated system.

Although this research was done in coal, FMA feels that the same technology used to address the United Kingdom's roadheader dust problem is applicable to our domestic use of roadheaders in metal/nonmetal mining. The primary problem that must be addressed is mobility.

Roadheader usage in United States mines requires maneuverability. The auxiliary systems tested to date would impede the functional utility of the machine. Bulky skid-mounted, towed, and trolley-mounted systems do not allow the roadheader to advance and retreat as required in United States applications.

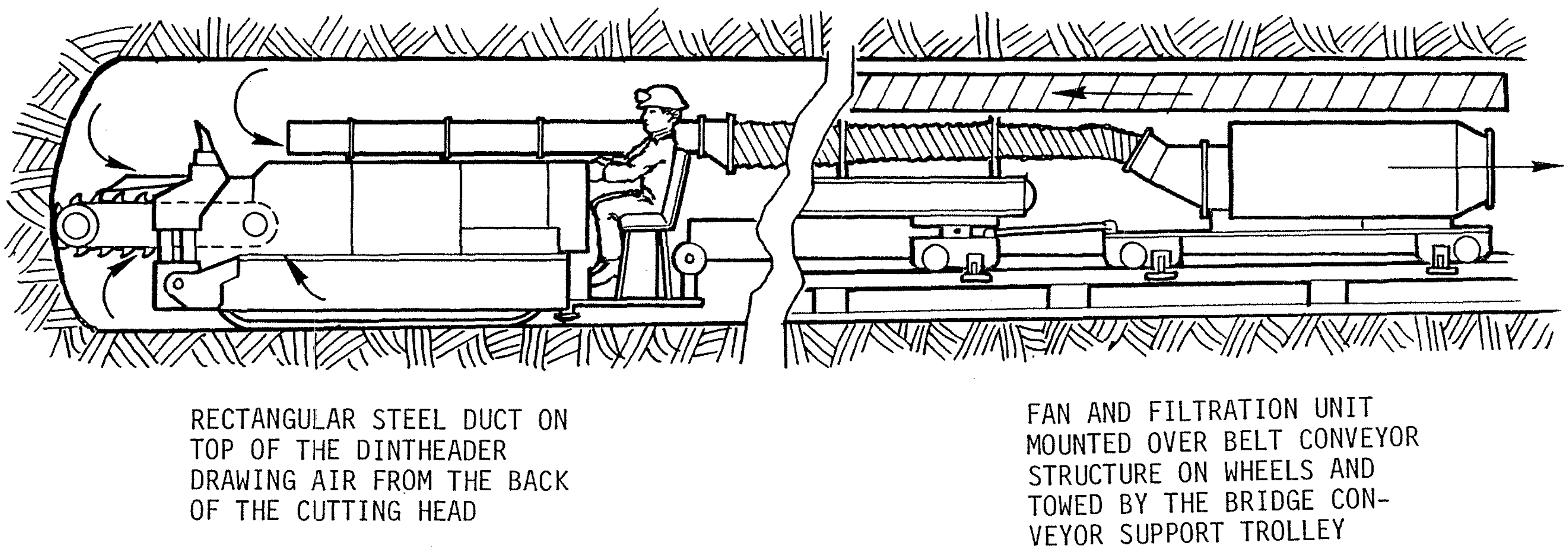



FIGURE 8. - Schematic view of typical dust filtration system for the Dosco dintheader.

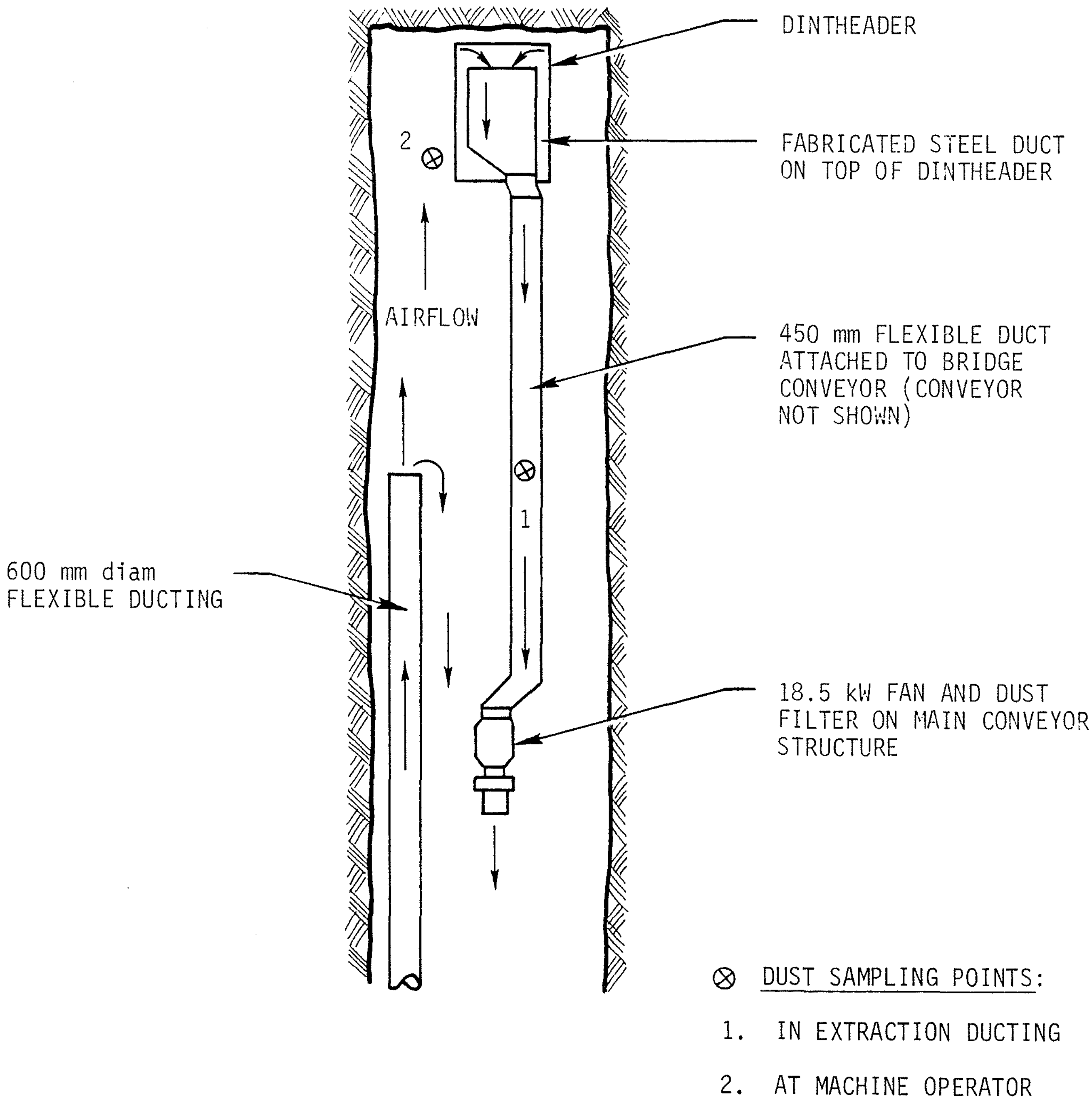



FIGURE 9. - Overlap ventilation system at Elsecar Colliery.

TABLE 6. - Dust concentration during cutting using the dintheader, with integrated overlap ventilation system

| Exhaust duct ($mg/m^3$) | Operator's position ($mg/m^3$) | Downwind of filter ($mg/m^3$) |
|---|---|---|
| 95.5 | 9.0 | 3.8 |
| 80.0 | 6.1 | 3.3 |
| 164.2 | 11.6 | 6.5 |
| 104.4 | 6.5 | 4.1 |
| 163.1 | 7.8 | 6.7 |
| 118.7 | 6.9 | 3.0 |
| 73.5 | 2.5 | 3.8 |
| 63.3 | 2.4 | 3.7 |
| 137.3 | 8.6 | 7.8 |
| 160.0 | 9.4 | 9.1 |
| 151.7 | 5.3 | 8.6 |
| Mean 131.0 | 6.9 | 5.5 |

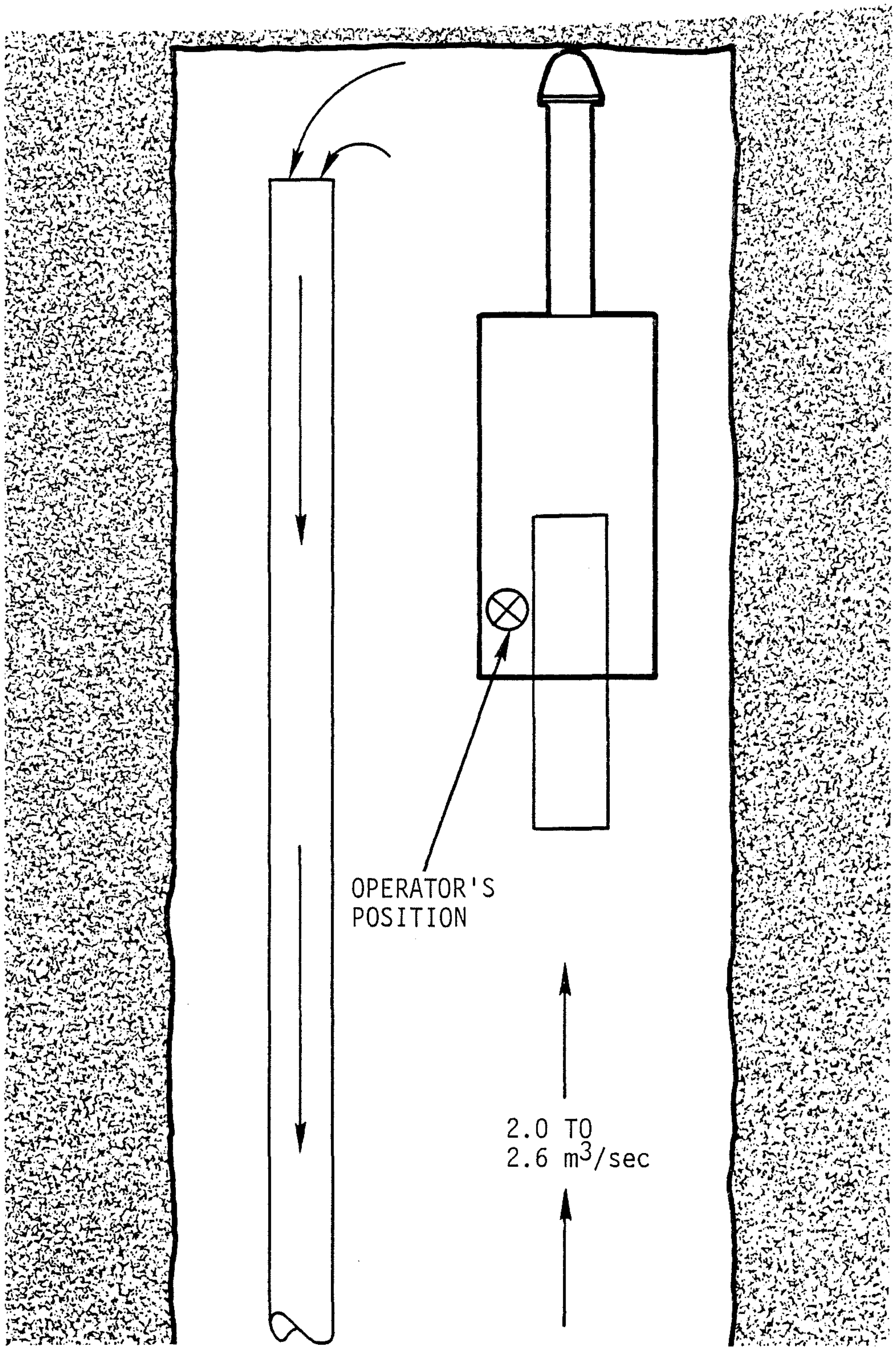



FIGURE 10. - Exhaust ventilation at Elsecar Colliery.

## 2.7 Survey Conclusions

The results of the Phase I survey can be summarized as follows:

a. None of the original 17 roadheaders used in United States uranium mines are currently operating and only one new third-generation machine is currently in use.

b. MSHA has not done enough sampling on roadheaders to determine their compliance position.

c. The state agency data indicate that when roadheaders were used, there was a compliance problem.

d. The mines agree that dust does hamper visibility at the face.

e. FMA's sampling at Mine D revealed a potentially serious compliance problem when a roadheader is used in a uranium mining application.

The quantification of the roadheader dust problem, as required by the contract's statement of work, is relative to the reader's viewpoint. What can be stated with certainty is that a large amount of dust, both respirable and nuisance, is generated by a roadheader when it is used. If the roadheader at Mine D continues to be used and if the other machines are put back into use, the potential for serious compliance problems exist.

The following sections of this report summarize FMA's proposed approaches to dust controls for roadheader operations.

# 3. RECOMMENDED DUST CONTROLS FOR BOOM-TYPE ROADHEADERS

The proper application of blowing ventilation, dust collection at the source of the dust, and filtration has been demonstrated by MRDE to be an effective dust control technique for roadheaders.

Two problems not necessarily found in British coal mining applications, however, place an additional burden on the solution to the dust problems on roadheaders in United States' metal and nonmetal operations:

a. Portability

b. Water soluble materials.

To address these two problems, an on-board dry filtration system was conceptually designed from commercially available components for a single-boom and twin-boom roadheader. A nonfunctional mockup of the system was constructed and installed in an underground borate mine on a twin-boom roadheader to check maneuverability and adaptability on a retrofit basis and to minimize operator interference.

## 3.1 Ventilation

The performance of an on-board collector can be optimized when used with a blowing ventilation system that splits the clean air so that:

a. The operator is kept in clean air.

b. The dust cloud is confined forward of the operator in the vicinity of the dust collection ports.

Figure 11 schematically shows the optimized airflow in a roadheader entry. The exact tubing setback and flows will vary because of the size of the entry, mineral, position of the operator, ventilation system capacity, and size of the roadheader. Experimentation will have to be done to determine the proper tubing setback and auxiliary ventilation flows required for optimized performance.

## 3.2 Dust Collection

Dust is generated by the cutting action at the boom(s), the fall of material onto the gathering head, and at the transfer

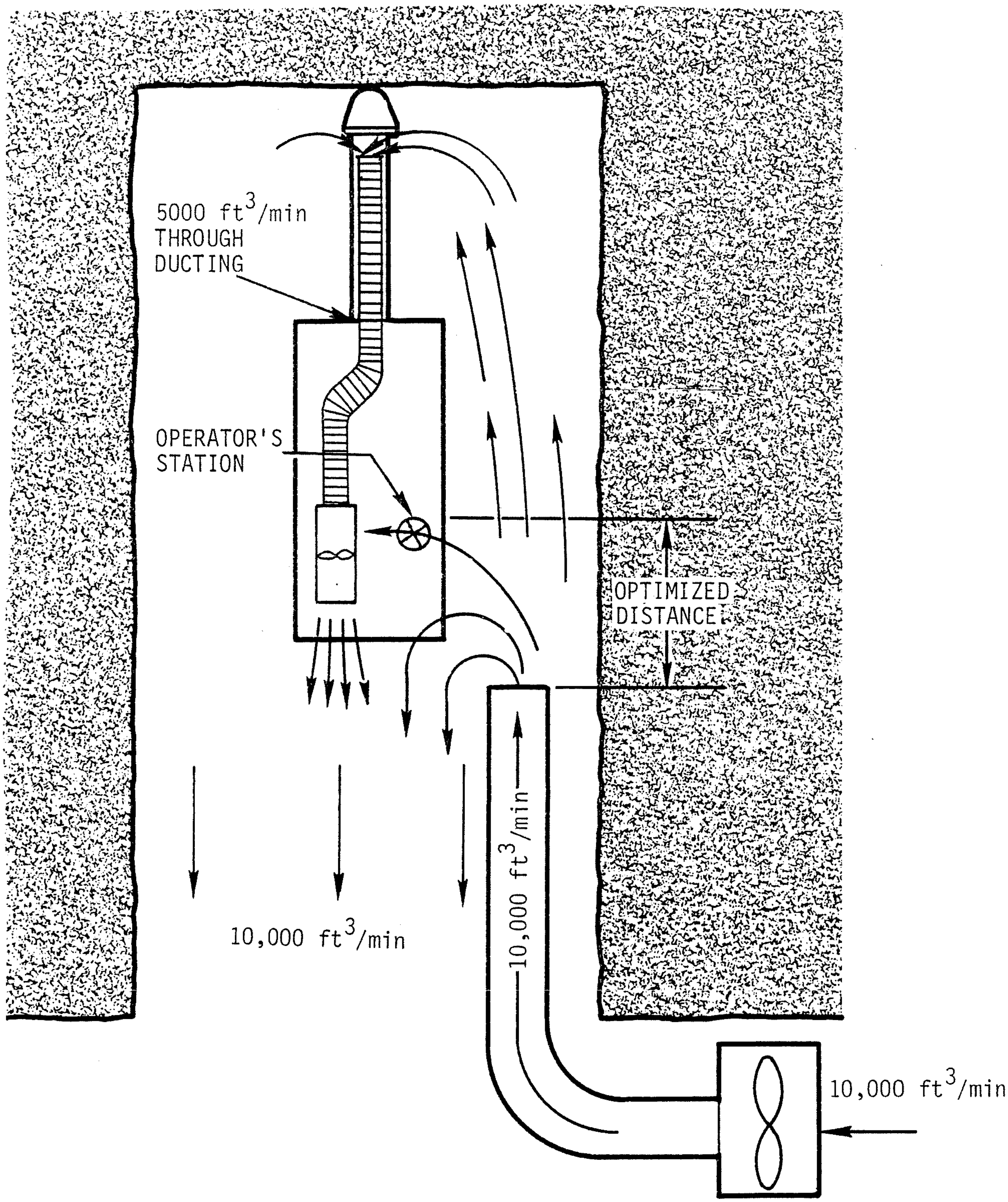



FIGURE 11. - On-board collection ventilation.

point at the rear of the roadheader. Figure 12 shows the suggested ducting for a twin-boom machine and Figure 13 illustrates a retrofit for a single-boom roadheader.

For the examples shown, carbon structural steel rectangular tubing is easily welded to the cutterboom(s), providing the freedom to hardface the critical areas if necessary. Inlet openings must be screened to keep large material out of the ducting. Directional louvers can also be a part of the inlet opening. Cleanout ports must be provided between the inlet opening and the collector so that accumulated fines can be flushed out.

A flexible connection between the duct work and the collector is necessary to allow the cutterboom(s) the freedom of movement inherent in a roadheader boom. Heavy-duty flexible metal hose is available in large diameters, varying minimum bend radii, and of different materials. Stainless steel tubing for corrosive environments, as an example, is available in 14-in. diam.

## 3.3 Filtration

If the generated dust is efficiently collected and a scrubber or filter is to be roadheader-mounted to improve maneuverability, the following requirements for the scrubber can be specified:

a. Dust collection efficiency must be very high for respirable size dust.

b. Volumetric flow rate should exceed 5000 $ft^3$/min during typical loaded operation, to maintain adequate pickup velocities.

c. A small size is essential so as not to impair the operator's vision.

d. The filter assembly must generate a minimum of noise.

e. Discharge air velocity should be as low as reasonably possible.

f. The unit must be reasonably maintenance-free.

g. Operation must not be affected by tilting the unit.

h. The unit must include warning devices indicating when service is necessary.

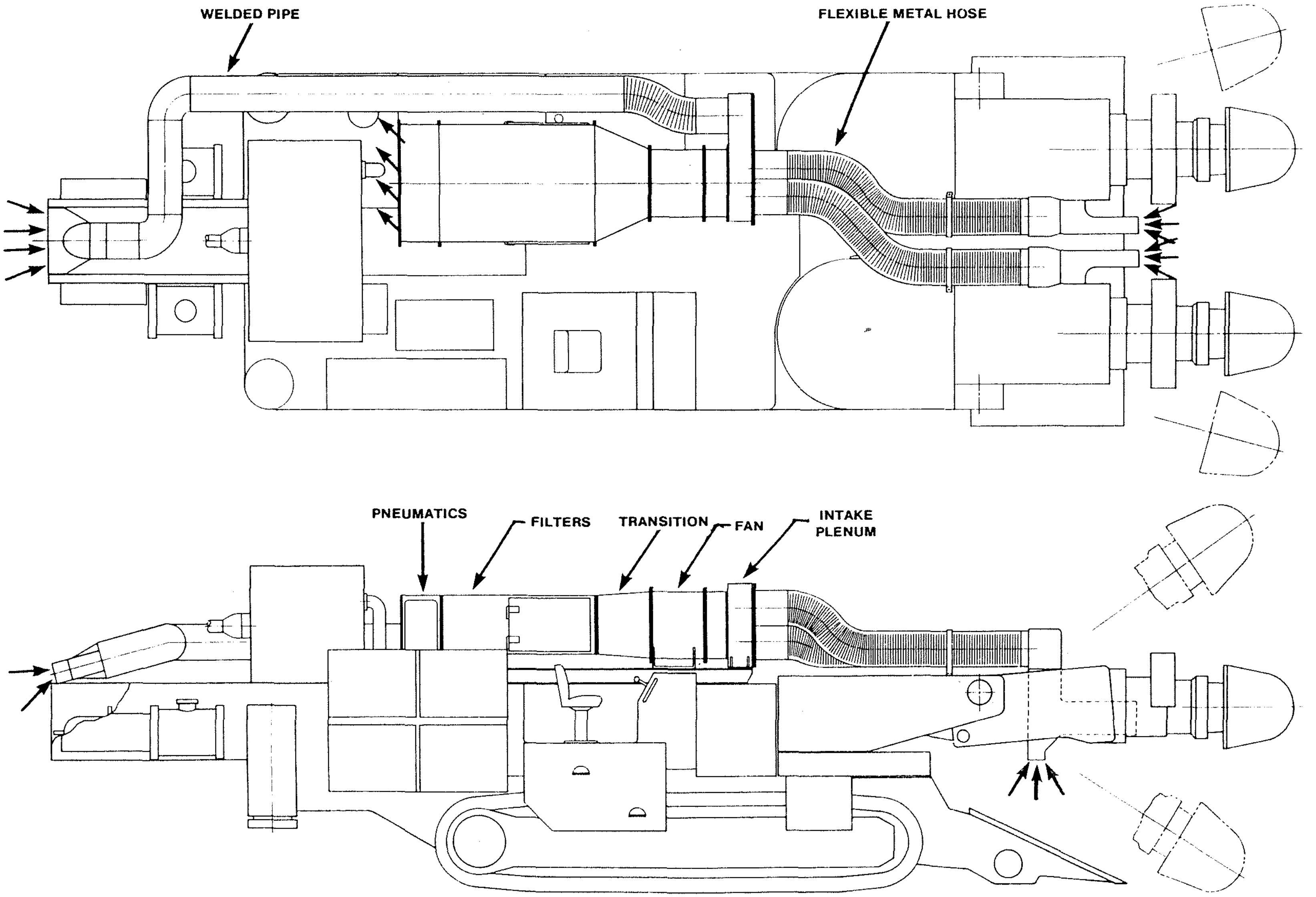



FIGURE 12 . - Suggested retrofit for a twin-boom roadheader.

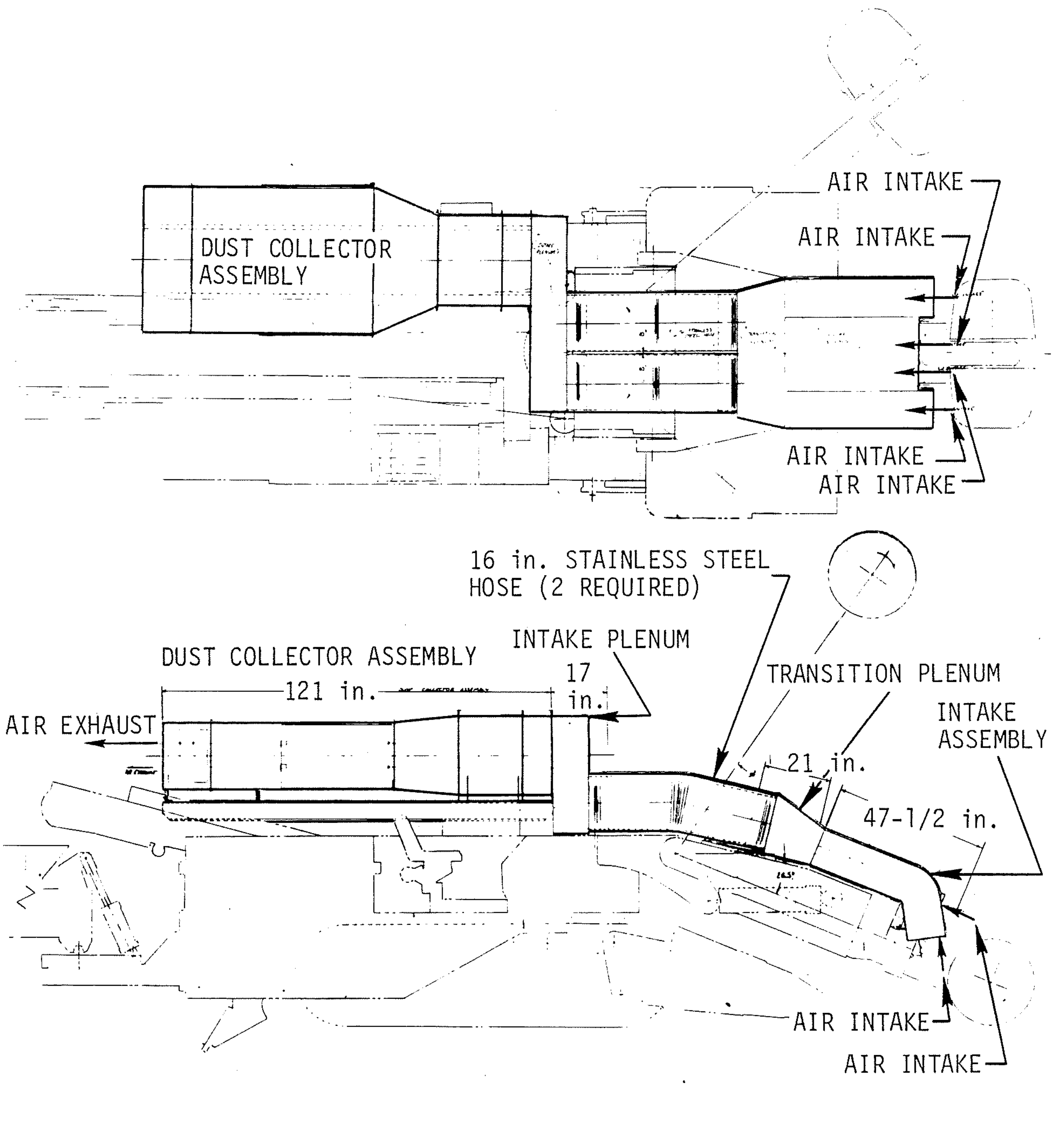



FIGURE 13. - Suggested retrofit for a single-boom roadheader.

i. The system must not create more mine bottom problems and must work in soluble minerals.

After reviewing the operating parameters and size limitations of available collectors, a dry system was identified by FMA as the first candidate if further testing had been done under the contract. Reasons for favoring a dry system included:

a. It offers maximum collection efficiency of any type of system for both total and respirable dust.

b. It requires no water.

c. It can be machine-mounted as a total unit or as modules.

d. The filtration medium can be sized and changed to suit the varying dust size concentration and mineral analysis that are encountered in roadheader operations.

The dry dust collector concept developed under USBM Contract H0395039 "Dry Dust Collector" with Donaldson Co., Inc. (Minneapolis, MN), had several of the features discussed which would enable it to be modified for installation on a roadheader. Figure 14 shows the components of this concept as mounted on a roadheader. Initial results of field tests done by Donaldson* in metal/nonmetal stationary installations indicate that this system will meet or exceed the listed requirements if the filter medium is a pleated synthetic, nonwoven material meeting the specifications shown in Table 7.

TABLE 7. - Specifications for filter medium

| Characteristic | Specification |
|---|---|
| Permeability | 8 $ft^3$/min (2.4 m/min) minimum |
| Dry breaking strength | 3 lb (1.4 kg) minimum in the cross-machine direction |
| Basis weight | 70 lb (31.8 kg) maximum |
| Thickness | 0.025 in. (0.64 mm) maximum |
| Pore size | 24µ (24m) maximum |
| DOP efficiency | 98 percent minimum at 10.5 ft/min (3.2) m/min airflow |

*Reference to specific brands, equipment, or trade names in this report is made to facilitate understanding and does not imply endorsement by the USBM.

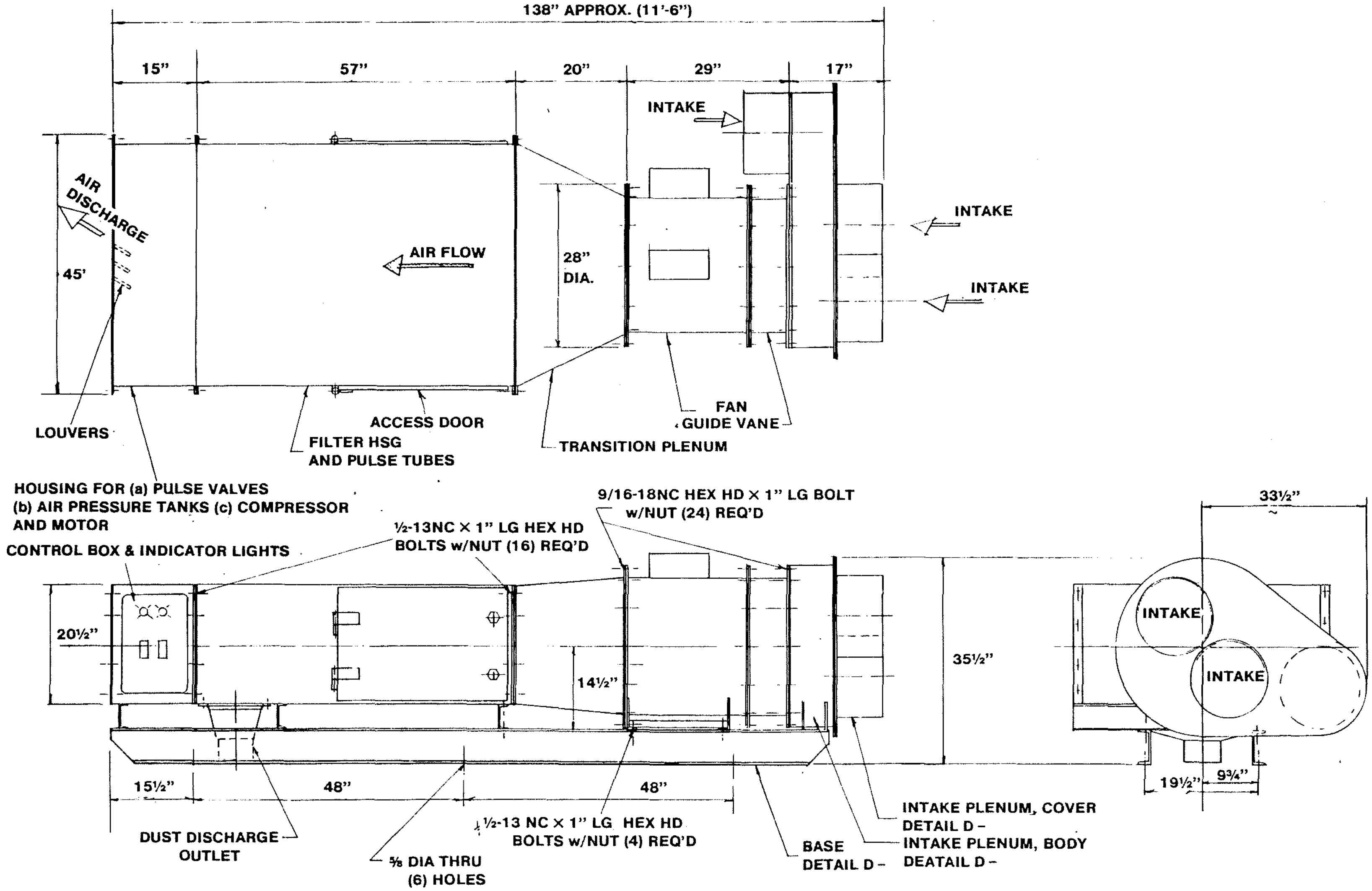



FIGURE 14. - Dry dust collector design for on-board mounting.

The filtration system is essentially automatic. A sensor box measures the dust at a Venturi located in the transition and relays a pressure drop to a pressure switch located in the control box. When a high concentration of dust is detected, the warning light comes on and/or an alarm horn is sounded. When the elements are loaded with dust and pulsing cannot bring them to an acceptable $\Delta P$ level, a second pressure switch is activated and the element change warning system is also activated.

Although such functional systems were not built or tested under the contract, the design specifications indicate that it should provide adequate dust control for roadheaders used in metal and nonmetal mines, providing the mine is reasonably dry.

# 4. FUTURE RESEARCH

Roadheader usage in the United States is currently limited and only one uranium mine is testing the potential utility of a third generation roadheader. The operating conditions measured during this study and documented from previous work indicates that roadheaders are having respirable dust exposure compliance problems. Limited improvements have been noted by the use of:

a. Water sprays

b. Better cutting technology

c. Use of dust collection

d. Improved ventilation.

The use of these techniques individually do not appear to be adequate in bringing a mine into compliance as a matter of routine.

The new heavy-duty third generation roadheaders are being tested in European mines and the manufacturers report that they are being accepted as a viable metal mining alternative. MRDE reports that these new machines cut more material and consequently create more dust. If the roadheader regains its popularity in the United States metal mining community, more directed research in dust control is necessary.

FMA feels that the conceptual design presented in this report, that includes a combination of blowing ventilation with on-board collection with inlet ports close to the dust sources, should be optimized during future research. The key to optimizing the ventilation system combined with collection is in balancing the relative air flows with the location of the collection ports. Although the system could be optimized in a specific underground mine as a retrofit, FMA recommends that the initial research be done in a gallery on the surface.

The simulation of generated dust and the effectiveness of ventilation systems has been demonstrated through the use of tracer gas in a mock-up of a mine entry on the surface. It is recommended that the design concept be simulated in such a mock-up and that the dust collection ports be located in the most effective positions on a manually articulated model of a third generation roadheader. The model should have a boom that simulates the arcing and slewing action of the roadheader so that air flow and collection limitations can be determined in all operating modes of a conventional roadheader in a simulated mine entry.

After the system is optimized in a gallery, detail design, fabrication and field testing can be more effectively accomplished. A cooperating mine using a specific roadheader should be located and the field test and subsequent technology transfer for all types of roadheaders in use will readily be accomplished.

Future research should also include the reduction of dust at its source through the development of improved cutting techniques. Current research by MRDE and the USBM involving improved cutting parameters should be closely monitored and reviewed for its applicability to the use of roadheaders in the United States. If roadheaders regain their popularity in the United States, research into improved cutting techniques would probably have to be accelerated due to the contribution of poor cutting practices to the respirable dust problem.

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