TECHNICAL DUST SUPPRESSION METHODS IN COAL MINES IN THE FEDERAL REPUBLIC OF GERMANY DEPENDING ON THE CONDITIONS OF THE DEPOSITS AND THE MINING DEVELOPMENT

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In the Federal Republic of Germany, mining techniques and dust suppression measures must take into consideration the following important characteristics of the deposits:

- Great depth
- Simultaneous mining in several seams
- Mining in level and inclined formations and the occurrence of rock strata in the seams.

Conditions of the Deposits and of the Mining Technique and Dust Suppression Measures

The average mining depth in West German coal mines in 1986 was 902 m. By the year 2000, an increase in depth to around 980 m is anticipated.

The control of high temperatures requires large volumes of mine air. The results is an increased inlet of dust into the ventilating air current at the dust generation point and hinders dust sedimentation. An important planning principle in all mines is to have both the coal and the ventilating air moving in the same direction (homotropal ventilation) wherever possible. Antitropal ventilation must be avoided.

In order to avoid dust raising in the transport area, transfer points and crushers in particular must be carefully surrounded. Where the belt conveyors have to pass through air locks, covering belts (see Figure 1) are a good method of preventing the dust swirling at these points of high ventilation air velocity.

In some cases, an increasing gas content has been observed with increasing mining depth. In these cases too, large quantities of ventilation air are required in order to keep the CH_4 concentrations within permissible limits. Homotropal ventilation here is an important precondition for preventing dust raising.

Figure 1. Covering belts at air locks.

The depth of the mining operations and the associated overburden pressure demand special measures for roof control at the faces. All faces in level and inclined formations are fitted with shieldtype supports.

Cushions of rock on the shield canopy are the primary causes of dust development at the support and of the dust concentration in the mine air. A further reduction in dust can be achieved with slide bars moving in the same direction (see Figure 2) and dampening of the cushions of rock using water under high pressure (see Figure 3).

A face with a roof which is difficult to control can be effectively improved by a high rate of face advance. All the faces

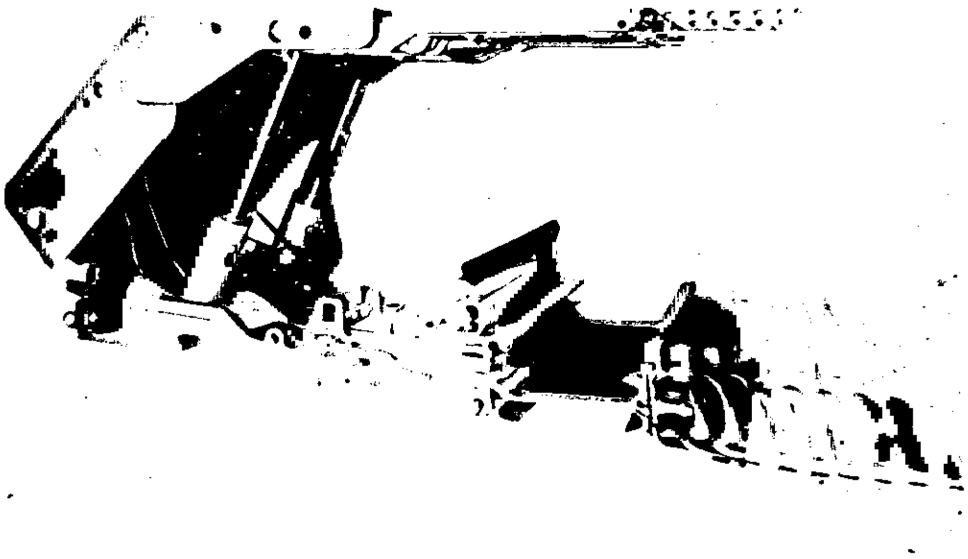

Figure 2. Shield-type support with slide bars.

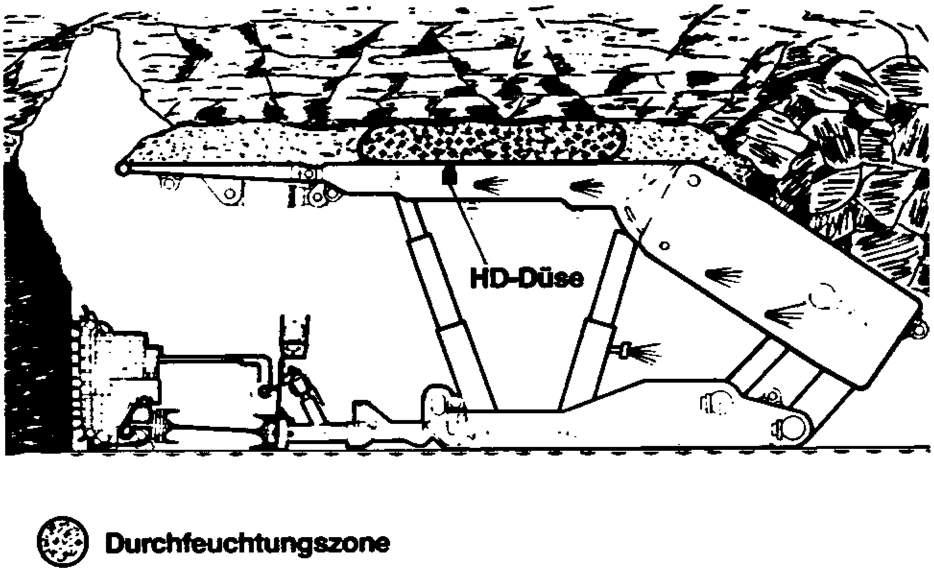

Figure 3. Dampening of the rock cushion with high-pressure water.

are operated in several coaling shifts. This multiple shift mining means, however, that only a limited time is available per night for coal face infusion from the face area, demonstrably the most effective method of dust suppression in West German coal mines. "Longwall face infusion" is therefore becoming more widespread. "Longwall face infusion" can be performed as a process of advance infusion through long boreholes from one or both gate roads. The infusion of 3–4 l/min of water with the necessary pressure is commenced several months before the actual start of mining.

High rates of face advance and the consequent demands for gate roads require a high-performance road heading system. In 1987, 100 cutting head machines and 36 impact rammers were used for this purpose (see Figure 4). The high level of dust created by the cutting head machines necessitates the use of dedusters with high extraction rates.

Mining depth and overburden pressure require special measures to maintain the cross-sections in the gate roads. These measures include back-filling of roadway supports and production of roadside packs using hydraulically bonding materials to increase the strength of the roadway supports on the side of the worked seam. The materials are transported pneumatically in pipelines. Dusts can be created if these materials are sprayed with the incorrect water content. This problem can be avoided, however, by applying the material hydro-mechanically.

These great mining depths and increasing overburden pressures have, however, also resulted in convergence-reducing road heading methods being more widely used. This has led in some cases to a move away from the gate roads being headed in front of the coal face so that the gate roads are now kept with or kept behind the line of the coal face. In 1986, 59 gate roads were kept with and 6 gate roads kept behind the line of advance of the coal face. With this method of road heading, impact rammers (see Figure 5) have proven to be effective, since they show clearly the benefit of reduced cutting into the surrounding rock and thus less dust development. In gate roads headed with the advance of the coal face, face conveyors with supporting sheave curves (see Figure 6) are used. This provides for a sliding transfer of the material conveyed during the deflection through 90°. A free fall of the material from one means of transport to the next is thus avoided.

In the vast majority of pits in West German coal mines, several seams with differing thickness are mined simultaneously in level, gently sloping and sharply sloping formations.

During this multiseam working, the horizontal development is primarily effected by excavations in the surrounding rock of the deposits. In 1986, in addition to the widely practiced heading by blasting, seven full-thickness headers were used for developing hardheads (see Figure 7). During this year, 14 km of roadway were developed. The dust production is controlled by the use of high-performance dedusters.

In the majority of cases, *headings parallel to the face* have to be developed by overcutting and undercutting due to the lack of seam thickness or the non-horizontal position of the seams in the heading area.

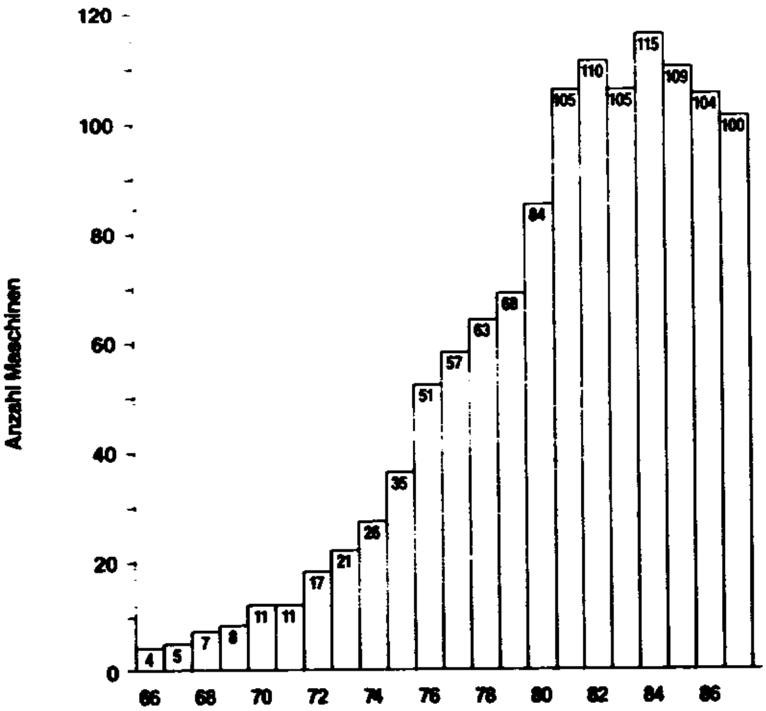

Figure 4. Use of road headers.

Figure 5. Impact rammer.

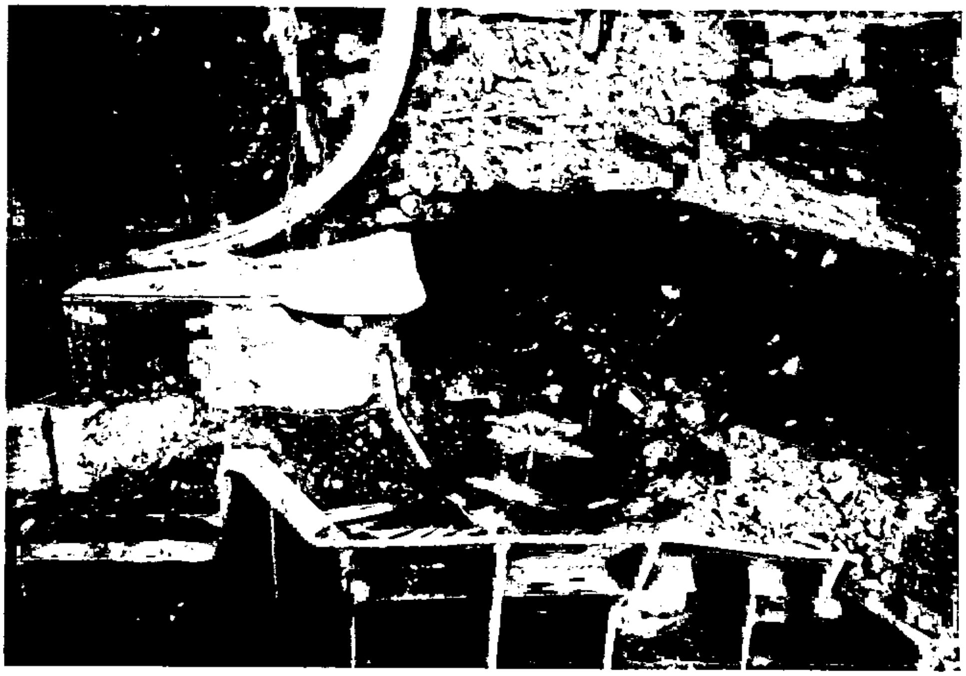

Figure 6. Face conveyor with supporting sheave curvers in the coal haulage road.

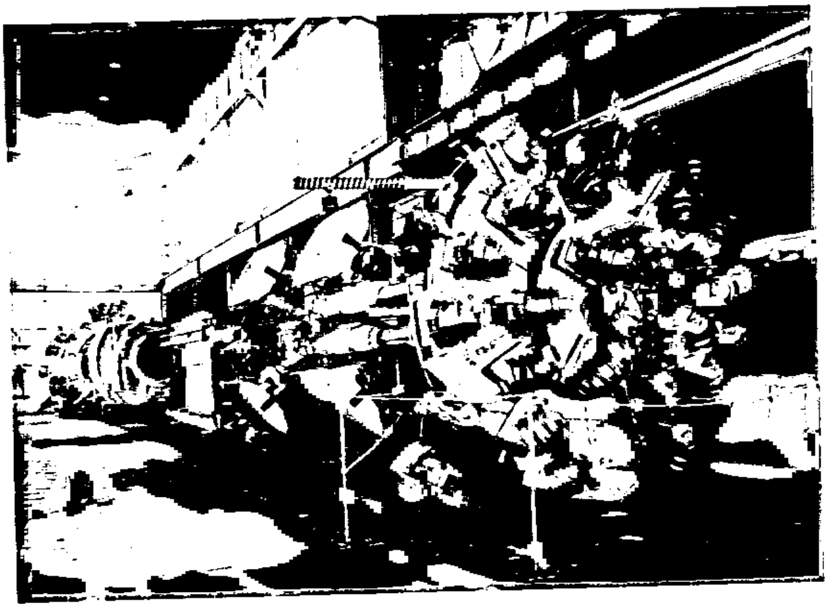

Figure 7. Full-thickness header.

Seams of greater thickness frequently contain intercalated rock materials. Coal dust and rock dust are produced when these intercalations are cut. This creates particular problems for the dust suppression. Since it is not possible to suppress the rock dust separately, the aim must be to make dust suppression so intensive that the total respirable dust content of the mine air is kept as low as possible.

Both plough-type and shearer-type machines are in operation for *mining*. The percentage of the production from 93 faces employing shearer-loader operation in 1986 was approx. 40 million tv = 48%. Shearer operation is used primarily in seams with solid coal with a thickness of greater than 1.90 m. Drum speed and pick lacing, pick length and cutting depth, drum shape, spray jet position and an adequate water distribution to the leading and trailing drums with the necessary pressure are among the most important preconditions for minimizing dust creation.[1] In 1987, good results were obtained during trials using the "coarse grain drum" (see Figure 8).[2]

In mines with gently sloping formations or mines with geological faults and high percentages of surrounding rock which is cut with the coal, no acceptable degree of dust suppression can be achieved using the measures described above. In such cases, the installation of separating elements between the conveyor track and the mining area ("dust flow separation") has proven to be an effective solution.[3,4] An effective deduster for 2/3 of the face air volume in the return air road is necessary.

In seams of lesser thickness and with soft coal, plough operation is employed. In 1986, approx. 37 million tv = approx. 45% of the total coal production came from plough-operated faces. Development of the sliding plough has now made it possible to extend the use of the plough to the tough/hard, thin and gently undulating seams of h.v. bituminous and long-flame coal. At plough-operated faces, sectional plough track spraying has been successfully used under automatic remote control for several years. In two of the mines, trials have been performed with a programmable track spray system which simultaneously monitors the pressure and volume of the spray water.

Optimization of the cutting depth, the number, shape and line of contact of the picks and, of course, the choice of the plough speed are important criteria for minimizing the respirable dust production.[5]

Applying the dust suppression measures described above, a high degree of success has been achieved in West Germany since 1952. The industrial health demands have been regularly increased since the beginning of systematic measurements of the respirable dusts. The annual number of new cases of compensation due to silicosis has decreased noticeably.[6] In order to achieve further successes in the reduction of total respirable dust concentrations, I would like to conclude by formulating a number of demands to be made on future development work on improving technical dust suppression:

1. Increased use of water under high pressure.
2. Planning of all dust suppression facilities as a complete system from the outset.
3. Greater use of remote control systems.
4. Research into the other physical properties of the dusts which would allow the dusts to be bound as a replacement, for the use of water.
5. Research into the surface physics and specific harmfulness of the individual particles.

These new developments in dust suppression measures must be put into practice as soon as possible in order to achieve a further reduction in the total respirable dust content in the mine dusts, and thus to improve the health-related working conditions of the coal miner.

Figure 8. Coarse grain drum.

SUMMARY

In the Federal Republic of Germany, the particular conditions of the deposits—average mining depth of 902 m, high overburden pressures, multiseam mining, sloping formations, developing of roads in the surrounding rock, mining of rock strata in the seam, etc.—and the mining techniques—mining using plough systems, shearer-loaders, use of road heading machines in the coal and in the surrounding rock, use of hydraulically bonding construction materials, etc.—demand intensive efforts in the development of technical dust suppression measures.

Specific planning principles, e.g., ensuring that both the coal and the ventilating air are moving in the same direction, must be observed wherever possible. Effective techniques, e.g., coal face infusion, programmable plough track spraying systems and shearer-loader spraying systems at the face, pick spraying systems on the road heading machines, must be applied.

In research and development, projects are being pursued which are aimed at extending our understanding of the surface characteristics of dust particles. The knowledge of these characteristics can then be used for even more effective dust suppression and for an assessment of the specific harmfulness of the dust particles.

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CHARACTERISTICS OF CHRONICALLY DUSTY LONGWALL MINES IN THE U.S.

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INTRODUCTION

Concentration of respirable coal mine dust in underground mines in the U.S. has been analyzed as industry wide averages and in relation to specific mining technologies.[2,7,12,13] Industry wide averages do not consider important differences between mines and analyses of exposure classified by mining technologies do not consider differences and associations within mines.

The proportion of sections in or out of compliance with the 2.0 mg/m^3 dust standard is also a common method of measuring performance. This type of analysis usually does not consider performance over longer periods of time. Since most lung diseases caused by dust require chronic exposure, it would be more appropriate for the task of disease prevention to assess patterns of violation over longer time periods than is done with measures at one point in time. And since the principal focus of enforcement is a mine, we should analyse performance of mines.

Therefore, the principal analytical unit considered in this paper is individual mines whose performance is assessed over a four year period, from FY 1984–1987. The purpose of this analysis is to describe a method for identifying chronically dusty mines and to consider characteristics of these mines that may provide insight into achieving improved dust control.

Feasible engineering controls for conventional, continuous, and longwall mining methods have been developed and described.[3,6,9] The principal methods for having these controls adopted in mines include enforcement of regulations adopted by the Mine Safety and Health Administration (MSHA), and providing technical assistance by MSHA and the U.S. Bureau of Mines (BOM).

Exposure to respirable dust has been significantly reduced since 1969 when the Federal Coal Mine Health and Safety Act was enacted.[4] However, in recent years, progress in controlling dust exposure in mines, particularly those that use longwall methods, has ceased. (Table I) Therefore, it is appropriate to question what additional opportunities exist or may be created for continuing progress in controlling exposure to dust. This analysis is limited to mines that have one or more longwall sections.

The question remains which mines have the poorest records and what do these mines have in common. The Bureau of Mines has identified some engineering problems at mines with excessive dust concentration.[5] I wish to describe some characteristics that may provide additional opportunities for intervention.

MATERIALS, METHODS

Data were gathered from three sources. First, measurements of dust exposure by mine operators were obtained from MSHA. Operators in the U.S. are required to monitor exposure to respirable dust for five consecutive production shifts six times each year.[11] High exposure personal or quasi-personal samples are taken for specified workers or "designated occupations" at each mechanized mining unit (MMU) or mine section.

The purpose of this monitoring program is to assess compliance with the statutory limit of 2.0 mg/m^3. If the average of five samples exceeds the limit, the operator is issued a citation for non-compliance and is required to continue sampling and make adjustments to reduce exposure.

This sampling program generates approximately 100,000 individual dust samples each year—an exceptionally large data base that can be used to consider a wide variety of issues. This data set includes the mine identification number (including a state code), MMU number, mining method, occupation code, date the sample was taken, and dust concentration.

The dust analysis program at the United Mine Workers of America acquires and analyzes this data on a regular basis in order to identify those mines with the most persistent dust exposure problems. Annual average dust exposure is calculated for each MMU taken at each mine. Those mines that have one or more MMUs with annual averages above 2.0 mg/m^3 are considered "dusty mines." Industry-wide average dust exposure for each mining method and the proportion of mine sections with averages over 2.0 mg/m^3 are also calculated.

Certain mines appear regularly on this list. Chronically dusty mines are those that have appeared on the dusty mines list for at least three out of the past four years.

Second, we acquired additional information about mines with active longwall sections from annual census data published in industry trade publications.[10] This includes the dimensions of longwall panels (length, width, thickness), and number of entries, and the average depth for each mine.

Third, since diesel powered equipment generates respirable

Table I

Percent of Longwall Sections with Annual Average Concentration of Respirable Dust Over 2.0 mg/m^3

FY	%
1982	33.7
1983	35.5
1984	32.8
1985	37.7
1986	32.7
1987	38.4

particulates, it is possible that excess exposure to dust is associated with use of this equipment. At the present time, personal respirable dust sampling units cannot distinguish between diesel particulate and respirable coal mine dust generated by coal cutting and transport.[8] Therefore, we obtained from MSHA a census of diesel powered equipment currently used in underground mines.

None of these data sources is perfect. Operator samples of respirable dust may systematically underestimate concentration.[1] The industry census was incomplete, is dependent on voluntary contributions, and could not be independently confirmed. MSHA's census of diesel equipment also could not be independently confirmed and was a measure only at one point in time.

We compared characteristics of chronically dusty longwall mines with other longwall mines and with the remainder of the industry. Variables examined include geographic distribution, dust exposure at non-longwall sections (Without exception, these are all continuous mining sections) at these mines, number of entries, use of diesel powered equipment, and dimensions of the longwall panels.

RESULTS

Included among all longwall mines are 19 that are chronically dusty. While they occur in most mining regions, they are concentrated in the west. Out of 16 longwall mines in the west (Utah, Colorado, New Mexico, and Wyoming), 9 are chronically dusty. (Table II) Both the proportion and the number of chronically dusty longwall mines is greater than that in the mid-west, northern Appalachia or southern Appalachia.

Chronically dusty mines are somewhat more likely to use diesel powered equipment than not, though the difference is not significant (Table III). They are four to five times more likely to employ two entries for their longwall panel as other mines. This association is highly significant statistically ($p=0.002$) (Table IV).

Use of diesel powered equipment and two-entry mining are also concentrated in the west. (Tables V, VI) These three characteristics—geographic distribution, use of two entries, and use of diesels—are almost completely confounded, making it difficult to separate independent associations.

The length, width and cutting height of chronically dusty longwall panels are slightly but not significantly larger than that of other longwall panels. (Table VII) Moreover, they are also, on average, under deeper cover, especially for mines in the west. (Table VIII) Taken together, these factors may contribute to dust problems. Wider panels and larger cutting height may be associated with dust generation by increasing cutting time per shift and increased contact between cutting bits and the coal seam. Greater depth of cover puts greater pressure on the coal seam which could result in less stability and increased friability.

It is not only longwall sections at these mines that have greater dust exposure; there is greater dust exposure on continuous mining sections at these same mines. Average dust exposure (for FY 1987) and proportion of MMUs with annual averages over 2.0 mg/m^3 at continuous mining sections at chronically dusty mines are both significantly greater than those at other longwall mines and greater than the remainder of continuous mining sections throughout the industry. (Tables IX, X) This is consistent with findings we have reported before.[14]

DISCUSSION

Annual average dust concentrations based on operator samples taken in order to assess compliance is a conservative measure of exposure. Because of institutional incentives, operator samples may underestimate exposure to dust. Furthermore, an annual average based on measurements taken for the purpose of assessing compliance may also underestimate exposure. After a determination of noncompliance, the operator must take additional samples until the average is reduced. In the analysis presented here, we included all measurements, including those taken for the purpose of demonstrating compliance.

By limiting attention to those mines with longwall sections that generate averages over 2.0 mg/m^3 for at least three of the past four years, we miss considering those mines that

Table II

Geographic Distribution of Chronically Dusty Mines

	Number of LW Mines	Chronically Dusty Mines	(%)
West (CO, UT, NM, WY)	16	9	(56)
Mid-West (IL)	5	0	(0)
No. Appalachia (MD, OH, PA)	12	3	(25)
So. Appalachia (AL, KY, VA, WV)	44	7	(16)
Total	77	19	(25)

Table III

Chronically Dusty Mines Classified by Use of Diesel Powered Equipment (percent) 1987

	Number of LW Mines	Chronically Dusty Mines	
Using Diesel Powered Equipment	31	10	(32)
Not Using Diesel Powered Equipment	46	9	(20)
Total	77	19	

Chi Square = 1.61, 1 d.f., NS

Table IV

Chronically Dusty Mines Classified by the Number of Support Entries (percent)

Number of Support Entries	Number of LW Mines	Chronically Dusty Mines
2	6	5 (83)
3	27	7 (26)
4 +	39	6 (15)
Unknown	5	1

*P=0.002 Fisher's Exact Test for 2 entries v. others

Table V

Geographic Distribution of Longwall Mines that Use Diesel Powered Equipment (percent)

	Number of LW Mines	Number Using Diesels	
West (CO , UT, WY)	16	16	(100)
Mid-West (IL)	5	0	(0)
No. Appalachia (MD, OH, PA)	12	1	(8)
So. Appalachia (AL, KY, VA, WV)	44	14	(32)
Total	77	31	(40)

Table VI

Geographic Distribution of Longwall Mines by Number of Support Entries

	Number of Mines by Number of Support Entries			
	2	3	4+	Unknown
West (CO, UT, WY)	6	5	1	1
Mid-West (IL)	0	4	0	0
No. Appalachia (MD, OH, PA)	0	6	8	2
So. Appalachia (AL, KY, VA, WV)	0	12	30	2
Total	6	27	39	5

Table VII

Average (SD) Panel Dimensions and Depth of Longwall Sections

	Chronically Dusty Mines N=19	Others N-58
Cutting Height (inches)	85 (27)	74 (21)
Panel Width (feet)	632 (113)	622 (95)
Panel Length (feet)	5028 (1247)	4949 (1311)
Depth (feet)	1131 (697)	965 (533)

(None of the differences are statistically significant , $p > .05$, t test.)

Table VIII

Average Depth of Longwall Mines Classified by Geographic Location

	Average Depth (feet)	(SD)	N of mines
West (CO, NM, UT)	1492	(704)	16
Mid-West (IL)	620	(60)	5
No. Appalachia (MD, OH, PA)	598	(179)	12
So. Appalachia (AL, KY, VA, WV)	1084	(535)	44

$p < .01$ one-way ANOVA

have only recently developed longwall sections or that have temporarily stopped production. Dust exposure at these mines (the number is unknown and assumed small) may be similar to that of the mines shown here.

It is likely that several factors could contribute, independently or in combination, to the concentration of chronically dusty mines in the west. These include development of two entries, increased depth, and panel dimensions. Assessing the contribution of these factors would require more detailed examination. It is also possible that mine management or regulatory agency practices unique to this area may be contributing factors.

The relatively poor performance in continuous mining sections (in addition to longwall sections) at chronically dusty mines suggests that dust control problems at these mines may be mine-wide rather than confined to any one section or mining method. Excess dust exposure in continuous mining sections shows no geographic association and therefore, no association with any of its correlates—use of diesel powered equipment or two support entries.

We have described and demonstrated a method for identifying mines that exhibit a pattern of excess concentration respirable dust. This method could be employed more efficiently to use resources throughout the industry for the pur-

Table IX

Continuous Mining Sections With Annual Averages Over 2 mg/m^3

	Total Number of Continuous Mining Sections	Number with Annual Averages > 2.0 mg/m3	(%)
Longwall Mines:			
Chronically Dusty	74	8	(11)
Other	281	8	(3)
Non-Longwall Mines	1,659	60	(4)
Total	2,014		

p < .01, Chi Square, 1 d.f., Chronically Dusty Longwall Mines v. all others.

Table X

Average Dust Exposure on Continuous Mining Sections

	Average (SD) (mg/m3)	N of samples
Chronically Dusty Mines	1.38 (1.25)	1,685
Industry-Wide Average	0.98 (1.11)	44,773

pose of achieving better dust control and thereby, to reduce the risk of chronic occupational lung disease.

We have shown that mines in the west have the poorest performance, that chronically excessive dust concentration is associated with use of two entries, and that excessive dust concentration is not limited to longwall sections. Chronic excessive dust concentration is weakly associated with increased panel dimensions and depth of cover.

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MONITORING AND CONTROLLING QUARTZ DUST EXPOSURE IN U.S. COAL MINES: CURRENT MSHA PROGRAM AND EXPERIENCE

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ABSTRACT

On December 1, 1985, the U.S. Department of Labor's Mines Safety and Health Administration (MSHA) implemented a fully computerized, revised quartz exposure monitoring program that among other features, enables coal mine operators to participate for the first time in the coal dust standard-setting process when more than 5 percent quartz is found in active workings. In addition, the improved program also provides for automatic reevaluation of work areas or occupations on a reduced dust standard on a biannual basis.

In the 22 months since its inception, 7418 MSHA, 1349 operator, and 455 operator 6-mo. samples were analyzed for respirable quartz. As a result, 1740 areas or occupations were identified as having excessive quartz dust and thus were required to comply with a reduced respirable dust standard. An additional 304 operations on reduced respirable dust standards continued to operate under stricter dust standards because of quartz reevaluations.

During this period, approximately 42 percent of the coal mining operations given the opportunity to participate in the dust standard-setting process elected to do so. Despite the lower than expected participation rate, the improved program has enabled more effective identification and more frequent monitoring of areas or occupations experiencing high levels of quartz dust exposure.

This paper will discuss the key features of the improved MSHA quartz dust exposure monitoring program, how reduced respirable dust standards are currently set, and the performance of the program since its inception.

INTRODUCTION

During the seventeen years following passage of the Federal Coal Mine Health and Safety Act of 1969, exposure to airborne quartz dust has been controlled by reducing the allowable dust standard when coal mine dust contains more than 5 percent quartz. One of the significant milestones in the Federal quartz enforcement process occurred in early 1981, when MSHA began to use the low-temperature ashing, infrared (IR) method for the determination of quartz in coal mine dust samples.

Unlike the earlier direct IR procedure, which required a number of samples to be combined to obtain a sample containing sufficient dust for analysis,[1,2] the upgraded IR method allows individual samples weighing as little as 0.5 mg to be analyzed for quartz. By using this method, the number of quartz determinations per year increased dramatically as illustrated in Table I. Consequently, this has resulted in a corresponding rise in the number of designated entities on a reduced respirable dust standard (entities that are required to be sampled bimonthly by coal mine operators), from 155 in 1980 to over 1360 in 1985.

The increase in the number of reduced standards, especially on roof bolters, coupled with growing operator concern about MSHA's longstanding policy of establishing a dust standard based on the analysis of a single inspector sample prompted the agency to reexamine its quartz enforcement strategy. In December of 1985, MSHA instituted the current quartz program, one that not only provides for more frequent monitoring of quartz dust exposure, but, for the very first time, enables coal mine operators to participate in the dust standard-setting process.

Table I
History of Inspector Coal Mine Dust Samples Analyzed for Quartz, FY 1978–FY 1987

Fiscal Year	Number of Analyses	Number with >5% Quartz
1978*	876	311
1979*	1257	528
1980*	1619	721
1981*	3937	2188
1982*	4342	1881
1983	4774	1896
1984	5134	2135
1985	4380	1712
1986	4484	1482
1987	3848	1181

* Calendar Year

MSHA's CURRENT QUARTZ PROGRAM

The implementation of the revised quartz enforcement program marked the successful culmination of three years of effort to make the dust standard-setting process more effective. Its aim was to expand the level of health protection of the miner through more frequent monitoring and timely dust-standard adjustments.

Specific Features

The current quartz enforcement program was designed to achieve these objectives:

1. Consider day-to-day variations in environmental quartz levels.
2. Allow use of limited number of operator dust samples to set the dust standard when over 5 percent quartz is found.
3. Provide for subsequent monitoring of entities (i.e., jobs, areas, or work positions) placed on a reduced standard.
4. Provide for automatic biannual reevaluation of entities placed on a reduced standard.

As before, the sample that triggers the dust standard-setting process is an MSHA sample. However, the resulting dust standard is now based on up to three samples, a combination of MSHA and operator samples. The background and development of this dust standard-setting strategy will not be discussed as it is beyond the scope of the paper.[3,4]

Adjusting a Dust Exposure Standard

The specific procedures for setting a respirable dust standard differ somewhat depending on whether an entity is (a) on the normal 2.0 milligrams per cu. meter of air (mg/m^3) dust standard; (b) already on a reduced respirable dust standard; or (c) on a reduced standard and being automatically reevaluated.

Entities on the Normal Dust Standard

Whenever an MSHA dust sample from an entity is found to contain over 5 percent quartz (or more than 10 percent quartz from a Part 90 miner already on a 1.0 mg/m^3 dust standard), the mine operator is notified by computer message of the option to collect a sample from the entity in question and submit it to MSHA for quartz analysis within a prescribed time frame. Since optional samples require minimum weight of 0.5 mg for analysis, dust collection over several shifts is permitted to obtain the required weight gain. These optional samples are used for quartz analysis only—not for compliance determination.

If the percentage of quartz found in the optional sample is within ±2% of the MSHA sample, the two values are averaged, and the result is used to determine the allowable standard by dividing it into the number 10. Should the percentage of quartz differ by more than 2%, the operator is asked to collect a second sample. The three quartz values, MSHA plus two operator, are then averaged, and the result determines the standard for the entity. All quartz percentages are truncated to a whole percent. If the hundredths position in the calculated standard is greater than 0, the standard is raised to the next highest 0.1 mg.

In the event the operator fails to submit an optional sample containing enough dust for analysis within the prescribed time frame, the standard is based on the MSHA sample alone. If the first optional sample is sent in, but not the second, the sample with the highest quartz percentage—be it MSHA's or the operator's—is used to set the standard.

Entities on a Reduced Respirable Dust Standard

When an MSHA sample is collected from an entity already on a reduced respirable dust standard, the percentage of quartz in the MSHA sample is compared to the quartz value that was used to set the standard currently in place. If the two values differ by 2% or less, they are averaged and the standard adjusted accordingly. If the difference exceeds ±2%, the operator is notified of the option to collect a sample from the entity in question. The same procedures used for entities on a normal dust standard are then followed.

Whenever a second optional sample is requested, submitted, and utilized, the preestablished quartz value is no longer used; only the three most recent samples (MSHA's plus two operator samples) are used to determine the average percentage of quartz and the applicable standard.

Automatic Reevaluations

Once an entity is placed on a reduced respirable dust standard, approximately every six months the Information System Center's computer, in Denver, CO, selects the first valid operator bimonthly sample taken on that entity. The entity, however, must be in compliance, and the sample must have sufficient weight for quartz analysis. If no valid sample can be found, the computer continues searching the incoming bimonthly samples until it finds one. This sample is retrieved and analyzed for quartz.

If the percentage of quartz in this sample is within ±2% of the quartz value used to set the current standard, the two values are averaged and the standard adjusted accordingly. If the difference exceeds 2%, the operator is notified of the option to collect another sample; the three values are then averaged to determine the standard. Should the operator not submit an optional sample with sufficient dust for analysis, the previously established standard stays in effect until the next automatic reevaluation or until an MSHA sample is submitted for quartz analysis.

Once a dust standard has been established, the operator is notified about whether bimonthly sampling will be required, the date of the first sampling cycle, and the applicable dust standard for the entity.

PROGRAM STATUS

As of the end of FY 1987 (Sept. 30, 1987), 7418 MSHA, 1349 operator optional and 455 operator 6-month samples have been analyzed for respirable quartz dust. Thirty-three percent of the MSHA, 36% of the operator optional, and 31% of the 6-month samples were found to contain more than 5 percent quartz. Roof bolter and surface highwall drill operators continue to have the highest quartz exposure. Over 23% of the roof bolter and 55% of the highwall drill samples that were submitted for analysis contained more than 10 percent quartz. Some 22% of the highwall drill samples had more than 20 percent quartz.

Of the entities given the opportunity to submit the first optional sample, only 42% elected to do so. The data appear to suggest that the operator's decision may be influenced, in part, by the amount of quartz found in the MSHA sample. This is most apparent when the MSHA sample contains less than 8 percent quartz, a level below which an operator, if given the option, is less likely to participate in the program. The data also show that, when submitted, 33% of the samples where found to contain insufficient weight for analysis and, therefore, had to be voided. As a result, the majority of the reduced dust standards established during this period were solely based on the quartz content of the MSHA samples.

Some 1740 separate entities were required to comply with more stringent standards during part of the period. An additional 304 established entities already on a reduced standard continued to operate under such standards as a result of biannual reevaluations. Of the 2044 entities, 42% were roof bolters. At the end of FY 1987, there were 1526 or 12% more established entities (in producing status) on a reduced standard than in FY 1985, before the current program took effect. However, the number of standards at or below 1.0 mg/m^3 declined by 18%, while the mean of the reduced standards remained relatively unchanged at 1.2 mg/m^3 (Table II).

Table II

Number and (Pct) of Producing Entities on Reduced Standard

Fiscal Year	Range of Reduced Standards, mg/m³				Avg
	1.8-1.5	1.4-1.1	1.0-0.7	0.6-0.1	
1985	227 (31)	218 (30)	199 (27)	90 (12)	1.1
1987	304 (42)	180 (25)	186 (26)	50 (7)	1.2

According to the quartz data, over 70% of the time the MSHA samples contained more quartz than operator first-optional samples for the same entity. And only in 31% of the instances, the quartz content of first-optional samples was within ±2% of the MSHA value (Table III). This is considerably lower than the 58% found in an earlier study which looked only at operator samples.[4]

In 74% of the biannual reevaluations, the quartz content of the 6-month sample was lower than the previous quartz percentage used to set the standard. The difference in % quartz between the previous value and the 6-month sample exceeded 5 percent 38% of the time. As shown in Table IV, only 25% of the 6-month samples were found to contain percentage of quartz that was within ±2% of the previous quartz value.

Finally, to determine the level of impact, if any, of operator participation in the program, a comparison was made of the percentage quartz in the MSHA sample and the final quartz value used to set the allowable dust standard. These show (Table V) that 77% of final quartz values were within ±2% of the MSHA value. Specifically, 56% of the time the two values were found to be equal, 31% of the time the MSHA quartz value was greater, and 13% of the time it was less than the value used to set the standard. This appears to suggest that selective operator participation can influence the final outcome of the dust standard-setting process.

Table III

Cumulative Distribution of Differences in % Quartz: MSHA* vs. Operator 1st Optional Samples

Diff. (±) % Quartz	Cumulative % ≤ Stated Diff.
0	5
1	17
2	31
3	41
4	53
5	62
>5	100

* 71% of the time MSHA samples contained more quartz.

Table IV

Cumulative Distribution of Differences in % Quartz: Previous Value* vs. 6-Month Samples

Diff. (±) % Quartz	Cumulative % ≤ Stated Diff.
0	7
1	17
2	25
3	38
4	47
5	56
>5	100

* 74% of the time Previous quartz value exceeds the 6-mo. value.

Table V

Cumulative Distribution of Differences in % Quartz: MSHA* vs. Final Value Used to Set Std.

Diff. (±) % Quartz	Cumulative % ≤ Stated Diff.
0	56
1	73
2	77
3	82
4	87
5	90
>5	100

* MSHA % quartz vs. Final % value
(=) 56% of the time
(>) 31% of the time
(<) 13% of the time

SUMMARY

Since early 1970, exposure to airborne quartz dust has been controlled by reducing the allowable dust standard when coal mine dust contains more than 5 percent.

The rise in the number of reduced standards, especially on roof bolters, and operator concerns about the use of a single MSHA sample to adjust the standard has led to the development and implementation on December 1, 1985, of a fully computerized, revised quartz enforcement program. The program not only speeds up the dust standard-setting process to control exposure to quartz dust, but enables coal mine operators to be actively involved in this important process.

During the first 22 months of the program's operation, only 42% of the coal mining operations elected to participate in the standard-setting process. As a result, the reduced standards on the majority of the 2044 separate entities, that were found to contain more than 5 percent quartz during this period, were established based on the quartz content of the MSHA sample only.

When operator samples were submitted, over 70% of the time MSHA samples contained more quartz, and only 31% of the samples had a quartz content that was within ±2% of the MSHA value. In 74% of the biannual reevaluations, the quartz content of the 6-month sample was lower than the previous quartz percentage used to set the standard.

A comparison of the percentage quartz in the MSHA sample and the final quartz value used to set the allowable standard, revealed that in 56% of the instances the values are equal, in 31% the inspector quartz value was greater, and in 13% the inspector quartz value was less. This appears to suggest that the final outcome of the standard-setting process may be influenced by selective operator participation.

Through more frequent monitoring of exposure to airborne quartz dust, the current quartz enforcement program has had a positive impact on enhancing the level of health protection of U.S. coal miners.

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THE CHANGING FOCUS OF THE U.S. BUREAU OF MINES RESPIRABLE DUST CONTROL RESEARCH PROGRAM

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ABSTRACT

Since it was established in 1910, the Bureau of Mines, U.S. Department of the Interior, has been concerned with the problems of dust in mines. Early research focused on the explosion hazard of coal dust. Following the passage of the Federal Coal Mine Health and Safety Act of 1969 (amended by the Federal Mine Safety and Health Act of 1977) research has also focused on controlling the respirable-sized coal dust that contributes to lung diseases. Research accomplishments, along with the cooperation of the mining industry, have provided the technology and procedures that have resulted in mines in the United States being among the least dusty operations in the world.

The Bureau's dust control research has experienced three major thrusts since 1969. From 1969 to 1976, emphasis was on developing technology to comply with the newly enacted Federal dust standard of 2.0 mg/m^3. With the increasing trend in extracting coal by longwall methods, emphasis from 1976 to 1983 was on controlling the dust in these operations. Since 1983 emphasis has been on technology to reduce the silica dust component of the respirable-sized dust. Current Federal standards are based on the amount of silica dust found in the mine air. The standard becomes more stringent (less than 2.0 mg/m^3) when silica is present in the mine atmosphere.

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REDUCING QUARTZ DUST WITH FLOODED-BED SCRUBBER SYSTEMS ON CONTINUOUS MINERS

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ABSTRACT

The use of scrubber systems for respirable dust control in continuous mining sections has been found to be a relatively effective approach over the last few years. However, with the implementation of more stringent dust standards due to quartz, the efficacy of some of these systems has been found to be less than optimal. In response, the Bureau of Mines has undertaken field studies to characterize quartz dust, and to determine the effectiveness of scrubber systems on quartz dust.

One underground evaluation for quartz dust suppression involved the doubling of scrubber panel to capture the quartz particles entrained in the ventilation system. The second evaluation consisted of modifying the mining sequence to include a curtain at the end of a blowing tube. Results of these tests indicate that the median diameter of quartz dust is likely to be smaller than that of coal dust. Results also indicate that quartz dust can be suppressed as effectively as coal dust by the doubling of the scrubber panel. A modified mining sequence will help to reduce the operator's exposure to quartz dust. Modified control techniques such as these will be required in mine sections where more stringent dust standards are in effect.

INTRODUCTION

One of the important methods of dust suppression in coal mine sections using blowing face ventilation is the use of machine-mounted scrubbers. They are usually of the flooded bed type, with a capacity of 5,000 to 7,000 cfm, and utilize 6 to 8 gpm of water. Differences exist in the number and location of nozzles upwind of the scrubber panel. The dust reduction efficiency at the machine operator location also varies, and for any scrubber system, depends on face air quantity blowing towards the machine. The operator exposure to dust also depends on whether a tube or a brattice is used to deliver the air to the face. Most scrubber systems do an adequate job of suppressing the dust, so that most of the coal mines using them are in compliance with the 2-mg/m^3 standard for respirable dust exposure. However, some continuous miner sections with scrubber systems are on more stringent quartz standards. It is, therefore, necessary to identify the reasons for the high quartz levels at the machine operator location, and to develop techniques that are more effective on respirable quartz dust.

To achieve the objective of quartz dust control, a knowledge of the source and character of respirable quartz in mine dust is necessary. Taylor et al.[1] indicate that the major source of quartz dust is the continuous miner mining the roof, floor, or middleman (a rockband in the middle of the coal seam). Laboratory testing by Conoco[2] indicates that approximately 65 pct of the respirable dust from a sandstone block (cut by bits on a shaping machine) was less than 2 μm in size. Stobbe et al.[3] have investigated dust from the return of a continuous miner face for size fractions. The results indicate that about 40 pct of respirable quartz dust is between 1 and 3 μm in size.

This paper deals with the nature of quartz dust and explains the methods to suppress it in sections using machine-mounted scrubbers. Quartz size and percentage evaluation was carried out in a mine with a rockband near the top of the coal seam. Evaluation for dust suppression took place in a mine that utilized two panels, instead of one, to capture the quartz particles in the scrubber system. The second evaluation for dust suppression was completed in a mine that used a modified mining sequence with a curtain at the end of the blowing tube.

EVALUATION OF CONTINUOUS MINER DUST FOR SIZE AND QUARTZ PERCENTAGE

Experimental Procedure

The procedure consisted of collecting respirable dust samples using a 10-mm nylon cyclone* and a 2-lpm Dupont* pump. The samples were collected from the face return of a continuous miner in a three-entry section in Virginia. The sampling location selected was approximately 40 ft from the face, in the dust cloud raised by the continuous miner while cutting the coal seam and roof rock. An impaction device and filter cassette sampled the same dust cloud at the same location for a different size fraction. Figure 1 shows the impaction device and cassette filter arrangement.

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*Reference to specific products does not imply endorsement by the Bureau of Mines.

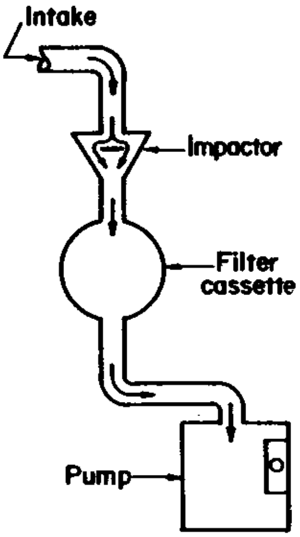


Figure 1. Collection of dust sample through an impactor.

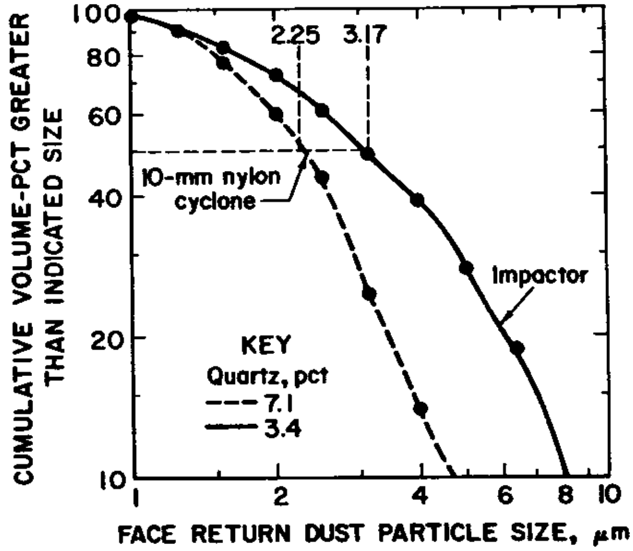


Figure 2. Results of particle size analysis for cyclone and impactor samples.

Analysis Results

The analytical method used to determine quartz content was the standard P-7 method approved by MSHA for these types of samples. Table I shows results of quartz analysis for the two sets of samples. The size distribution of the samples was determined by a Coulter Counter. Table II shows results of particle analysis, and Figure 2 compares the impactor and cyclone results graphically. It can be seen that the median particle size for the regular respirable sample was 2.25 µm, while that for the impactor was 3.17 µm. This means that, in general, the impactor sample consisted of larger size particles than the cyclone sample. However, the quartz percentage in the regular cyclone sample was almost twice that of the impactor sample. This indicates that there is more quartz dust in the smaller size fraction (cyclone sample) of the dust in the face return of the continuous miner. It can also be interpreted that the quartz dust, in general, is finer than coal dust.

CONTROL OF QUARTZ DUST AT A CONTINUOUS MINER SECTION IN MINE *A*

The first underground test was carried out in a coal mine section in Illinois. Two Joy 14 CM continuous miners with flooded bed scrubbers were operating in a 6.5-ft-high coal seam. Electric shuttle cars hauled away approximately 1,200 tons of coal every shift. The entries were 16 ft wide, and a 20-ft cut was usually taken. Face airflow was 8,000 cfm through a blowing curtain. The scrubber airflow was approximately 5,000 cfm, and the miner was equipped with a conventional water spray system. Twenty hollow-cone nozzles, each discharging about 0.7 gpm at 100 psi, were being used. No wetting agent was in use at the mine. Figure 3 shows the ventilation layout and sampling points for scrubber evaluation.

Experimental Procedure

Filter samples were primarily taken to identify the fraction of quartz in the samples, while the light-scattering instruments were used to determine where in the mining cycle dust was being generated. Filter samples were collected using MSA filter holders and compliance-type cassette filters. A 10-mm nylon cyclone sized dust into the respirable range, and air was sampled at a rate of 2 lpm using a flow-controlled Dupont pump. Filters were pre- and post-weighed at Bruceton, PA. Filter samples were collected in packages of three or four, and results were averaged to minimize sampling errors. Filter packages were located as follows:

1. Intake: Located in the last open crosscut and hung from a roof bolt to a distance of 12 to 18 in. from roof.
2. Return: Located in the immediate return of the entry being mined, approximately 80 ft from the face. This was hung 6 to 18 in. from the roof, such that it was representative of face return.
3. Hinge point: Located less than 24 in. from the right rear side of the scrubber inlet, on top of the miner frame. It was protected by a steel enclosure to prevent it from being damaged by falling coal or rock.
4. Operator: Located in the cab, 12 to 18 in. to the left side, and about the same height as the operator's head.

All filter samples were taken only during a portion of the shift and do not represent full-shift samples.

Sampling procedure for scrubber efficiency consisted of drawing air into cans, as shown in Figure 4. One isokinetic probe was introduced into the airstream to sample the dirty air in the intake duct, and another probe to sample clean air coming out of the scrubber fan. The velocity of the air, in inlet and discharge of duct, was measured using a pitot tube.

Table I

Results of Quartz Analysis

Sample No.	Sample type	Dust weight micrograms	Quartz weight micrograms	Quartz pct
1.....	Cyclone	1,220	85	6.9
2.....	Cyclone	1,305	102	7.8
3.....	Cyclone	2,773	187	6.7
4.....	Impactor	2,586	72	2.8
5.....	Impactor	3,006	120	4.0

Table II

Results of Subsieve Particle Size Analysis on Dust Samples

Size in micrometers	Cumulative vol pct > indicated size	
	Impactor	Cyclone
0.79.......	100.0	100.0
1.00.......	95.9	95.8
1.26.......	90.3	88.6
1.59:......	83.3	78.6
2.00.......	74.1	63.5
2.52.......	62.8	43.8
3.17.......	50.8	25.5
4.00.......	39.8	14.2
5.04.......	28.7	8.8
6.35.......	8.5	5.9
8.00.......	9.3	4.2
10.08......	4.5	2.8
12.70......	1.5	2.0
16.00......	.0	1.2

To determine the efficiency of a double panel, a second single panel was placed next to the existing one. No cutting or welding was necessary to install the second panel.

Results of Testing

To determine the total efficiency of the system from the face area to the face return, dust concentrations and quartz percentages were determined, as shown in Table III. There was a reduction in total respirable dust of about 40 pct between the face area and face return. However, there was only a 15-pct reduction in the quartz fraction of respirable dust, with the result that the percentage of quartz dust in the sample increased. In other words, the water sprays and dust collection system on the continuous miner selectively suppressed the coal dust in preference to the quartz dust. Isokinetic sampling to determine the efficiency of the scrubber (single filter panel) showed that there was a total reduction of 50 pct in respirable dust when the downstream sample was compared to the upstream sample. However, there was virtually no reduction in quartz dust, indicating that the scrubber let the quartz dust through. Table IV shows the results.

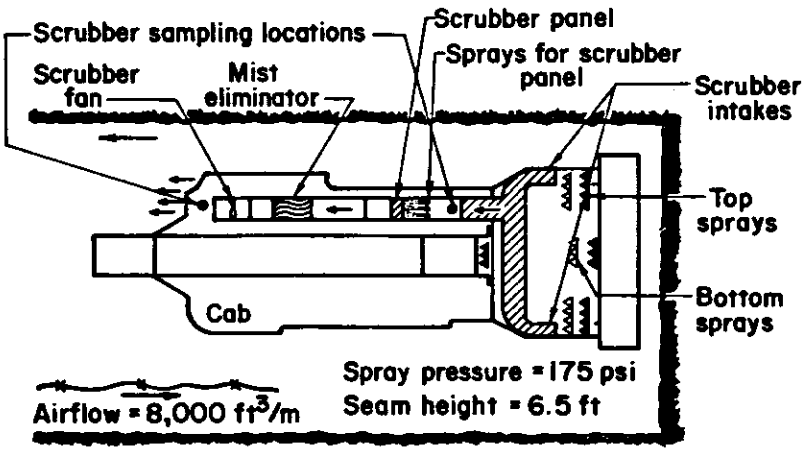
When the double filter was used, the collection efficiency was found to be 72 pct for all respirable dust. The same collection efficiency was found for quartz dust also. This indicates that the double filter scrubber panel was equally efficient on coal and quartz dust. Table V shows the results.

Discussion of Filter Performance

The flooded-bed panel has the advantage of a constant dust collection efficiency and pressure drop during service because dust particles are continuously flushed away from the cleaning elements. It operates very well at about 4 gpm of water and 2,000 fpm face velocity. Normally, there are 20 double layers of stainless steel mesh. Pressure drop is about 4 to 5 in. W.G. across the panel. Pressure drop in the ducting is 7 to 8 in. W.G.

An important requirement for using a flooded bed scrubber panel is that it must be, at all times, wetted with evenly distributed water sprays. Although some mines use just one spray nozzle upwind of the panel to wash out the dust, a minimum of two nozzles is necessary to cover the entire surface area of the panel. The spray patterns should preferably be of solid cone type, and each nozzle should discharge about 1.3 gpm of water. Increasing the water flow rate will increase dust collection efficiency marginally, but will overload the scrubber fan and mist eliminator. The fan may begin to stall, and performance will deteriorate rapidly.

Once during each shift the panels should also be removed, washed down with water, and allowed to dry out over a warm place. The dried-out dust particles can be vacuumed, and the filter put back in service. A few spare panels should be available at all times. The mist eliminator acts as a trap for water droplets carried with the airstream and is very efficient at about 2,000 fpm velocity. Some dust particles are also knocked down, making it a second scrubber. The mist eliminator should be cleaned once a week for optimum performance.



PLAN VIEW

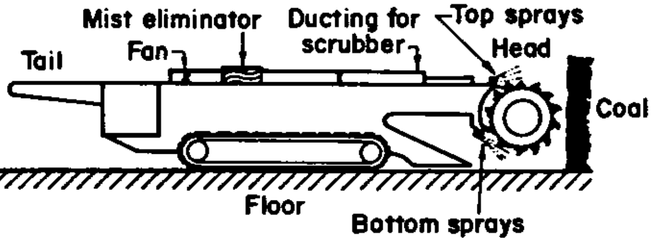


Figure 3. Face ventilation layout and scrubber sampling locations.

Table III
Behavior of Quartz Dust in Face Area

Location	Time, min	Dust mass, mg	Dust conc., mg/m3	Quartz mass, µg	Quartz, pct
Face intake..	311	0.21	0.34	82	12.3
	311	.22	.35		
	311	.23	.36		
Face return..	311	1.26	2.03	219	15.7
	311	1.32	2.12		
	311	1.40	2.24		
Face area left hinge..	321	2.44	3.80	274	11.0
	321	2.51	3.91		
	321	2.45	3.81		
Face area right hinge.	319	1.58	2.47	183	11.6
	319	1.88	2.95		
	319	1.74	2.73		

Table IV
Scrubber Efficiency Results—Single Filter Panel

Location	Time, min	Dust mass, mg	Dust conc., mg/m3	Quartz mass, µg (composite)	Quartz, pct
Intake can...	51	0.832	8.16		
	51	.861	8.44		
	51	1.121	10.99	288	10.2
Return can...	51	.263	2.58		
	51	.809	7.93		
	51	.314	3.08	275	19.9

Table V
Scrubber Efficiency Results—Double Filter Panel

Location	Time, min	Dust mass, mg	Dust conc., mg/m3	Quartz mass, µg (composite)	Quartz, pct
Intake can...	103	0.672	3.26		
	103	.836	4.06		
	103	.977	4.74	311	12.5
Return can...	102	.205	1.00		
	102	.283	1.39		
	102	.226	1.11	87	12.2

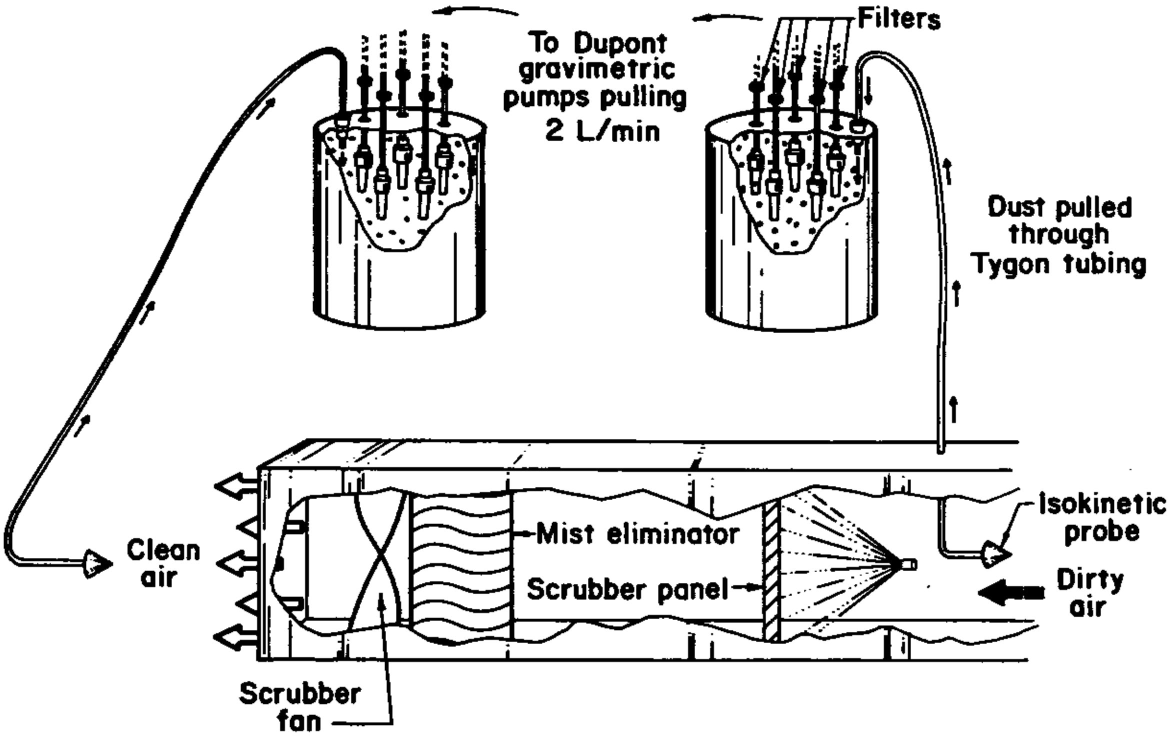


Figure 4. Sampling diagram to determine scrubber efficiency.

CONTROL OF QUARTZ DUST AT A CONTINUOUS MINER SECTION IN MINE *B*

The second underground test was carried out in a mine in Utah. One Joy 12CM continuous miner, equipped with a flooded-bed scrubber, was operating in an 8.5-ft-high coal seam. Diesel ram cars hauled away the coal, as shown in Figure 5. The entries were 18 ft wide, and a 20-ft cut was usually taken. Face airflow of 7,500 cfm was through a blowing tube with a diffuser. The scrubber airflow was about 5,000 cfm, and the airflow in the last open crosscut was 12,000 cfm. One point that should be made here is that the air in the last open crosscut did not go towards the face, but went directly to the face return. The face was totally supplied by the blowing tube, and this air quantity ranged from 6,000 to 10,000 cfm, depending on the length of the tube from the fans located far away from the face. Water spray pressure was approximately 145 psi, and scrubber nozzles operated at 60 psi. A jet pump pumped the slurry from the scrubber discharge on to the coal conveyor. The water pressure at the jet pump was also 60 psi. The mine did not use any wetting agent in the water supply. Section intake had an airflow of 43,500 cfm.

Sampling Procedure

This was similar to the one conducted at Mine *A* where filter samples were primarily taken to identify the fraction of quartz in the samples, while the light scattering instruments, called Real-time Aerosol Monitors, were used to determine short-term fluctuations in dust concentrations. The Real-time Aerosol Monitors (RAM-1's) are manufactured by Monitoring Instruments for the Environment, Inc., at Bedford, MA. The RAM-l's were connected to DL 331 data loggers (Metrosonic Co., Rochester, NY), which stored the data signal from the RAM 1 at 10-s intervals. At the end of each day, data were transferred from the logger to a personal computer and stored on floppy discs for further analysis. All data were time-synchronized with digital watches, and voice tape recorders were used to record mining activities in detail.

Air quantity was determined from velocity measurements taken with a vane anemometer. The collapsible tubing had a diameter of 24 in. when operating. The end of the tubing was initially set at a distance of 15 ft from the face and was not advanced along with mining. Water pressure for the sprays was measured on a gauge located in the operator's cab.

Procedure for Testing

Preliminary tests with the scrubber indicated that the scrubber fan was operating under a significant pressure drop and would not handle any increased resistance through the scrubber circuit. If any additional resistance is added, aerodynamic stall will occur. The addition of a second panel will not, therefore, improve the dust concentration at the operator location because of increased resistance to airflow and greatly decreased capture efficiency.

A modified cutting sequence, in which the operator would sump at about 6 in. from the floor and shear upwards,

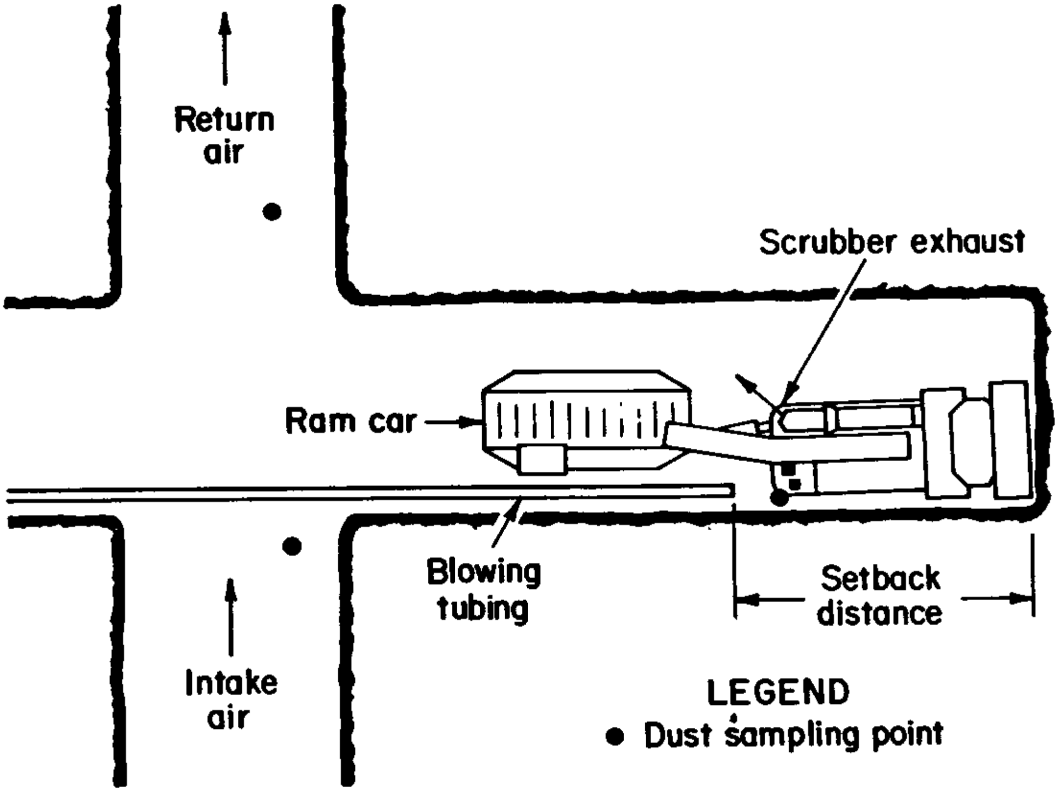


Figure 5. Mining plan with blowing ventilation tube.

was adopted. This eliminated the grinding of the sandstone floor, which was the main source of high quartz levels. Visual inspection of the dust cloud indicated that the dust capture efficiency of the scrubber system was much greater during the box cut. During the box cut, the mining machine prevented the main airflow from reaching the face by blocking the entry. The scrubber inlets, being located near the dust source, were thus able to vacuum a highly concentrated dust cloud before it was diluted by the main airstream.

During the slab cut, however, the large open volume created by the box cut provided an outlet for the dust to disperse and significantly reduced the dust capture efficiency. To eliminate this effect, a curtain was hung to the right side of the machine from the last set of roof bolts when the machine was taking a slab cut. The curtain isolated the dust source from the main airflow and let the scrubber inlets operate effectively on the dust cloud. The curtain layout is shown in Figure 6.

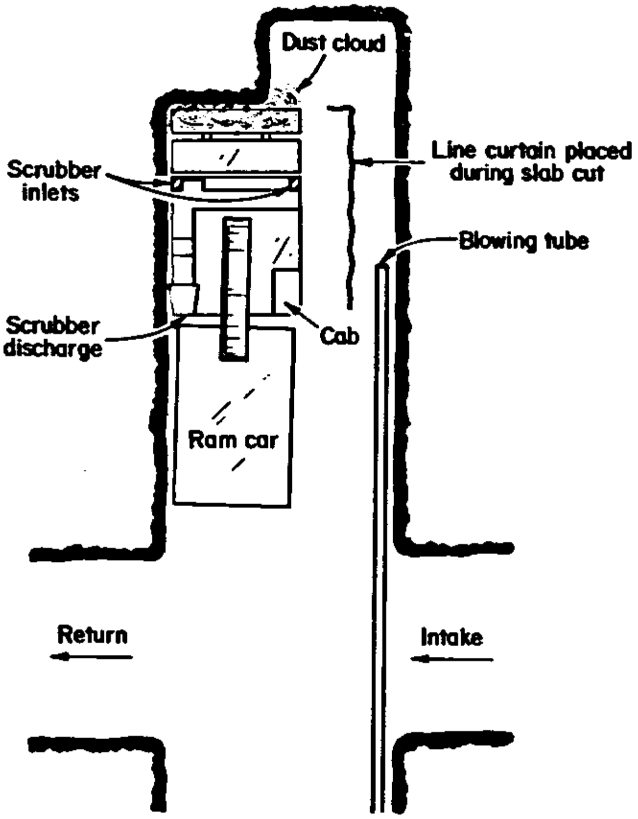


Figure 6. Curtain layout for mining during a slab cut.

Results of Testing

The respirable dust concentrations with and without the modified cutting sequence (together with curtain) are shown in Figure 7. There is a reduction of approximately 50 pct in respirable dust concentrations at the operator location and in the face return. Quartz percentages were also determined to see if there is any reduction at the operator's position. Figure 8 shows that there was a reduction of 60 pct in the quartz content due to the modified operation.

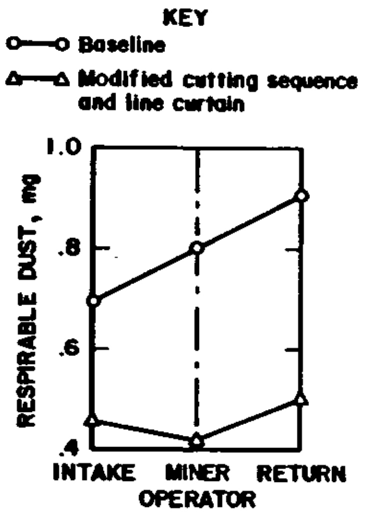


Figure 7. Respirable dust concentrations with and without modified cutting sequence.

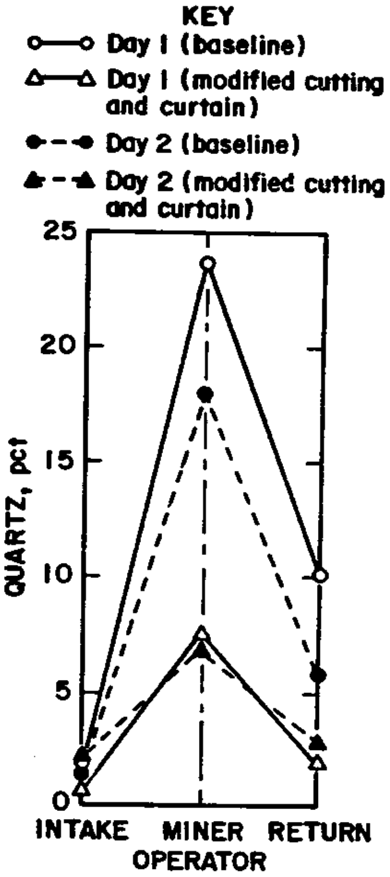


Figure 8. Quartz percentage with and without modified cutting sequence.

CONCLUSIONS

1. The quartz percentage for samples collected by a 10-mm nylon cyclone (median diameter 2.25 μm) was higher than for samples collected by an impactor with a cutoff of 3.7 μm. This leads us to believe that the median diameter for the quartz dust is smaller than that of coal dust. This will affect the planning for dust control technology in coal mines.
2. The results of underground testing show that a machine-mounted scrubber system can be used to reduce the respirable dust, as well as its quartz content, by doubling the scrubber panel.
3. Research indicates that a modified cutting sequence will reduce the operator's exposure to quartz dust.

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RESPIRABLE DUST TRENDS IN COAL MINES WITH LONGWALL OR CONTINUOUS MINER SECTIONS

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INTRODUCTION

In 1970 a mandatory respirable dust standard of 3.0 mg/m^3 was established for underground Coal mines under the Federal Coal Mine Health and Safety Act of 1969. This standard was lowered in 1972 to 2.0 mg/m^3. Mandatory dust standards for surface work areas of underground coal mines and surface mines also became effective in 1972. These regulations were continued under the Federal Mine Safety and Health Act of 1977,[6] which amended the 1969 act and merged coal and noncoal regulations into one law. In the 1969 act, "concentration of respirable dust" was defined as a measurement made with a Mining Research Establishment (MRE, Casella 113A) instrument or such equivalent concentration measured with another device. The 1977 act changed the definition of "concentration of respirable dust" to be the "average concentration of respirable dust measured with a device approved by the Secretary and the Secretary of HEW." The device approved for measuring respirable dust uses a Dorr-Oliver 10-mm nylon cyclone to remove the nonrespirable fraction of dust sampled. Measurements made with this device are converted to equivalent MRE concentrations by multiplying by a constant factor of 1.38.[3] A more rigorous standard is used if the sample contains more than 5 pct quartz. Specific regulations detailing the collection of respirable dust samples by mine operators are found in the Code of Federal Regulations, Title 30.[5]

Since 1970 more than 6.5 million respirable dust samples have been collected by coal mine operators and Mine Safety and Health Administration (MSHA) inspectors to determine compliance with the 2.0 mg/m^3 standard, or with the more rigorous standard due to the presence of excessive levels of quartz. Each year MSHA provides the Bureau with copies of these records to update the Mine Inspection Data Analysis System (MIDAS). MIDAS is a computerized, industrial hygiene data base developed by the Bureau with the assistance of MSHA to statistically analyze environmental compliance data collected by MSHA inspectors and coal mine operators.[7-8] These analyses provide information that is used to determine trends in exposure, to prioritize problem areas requiring special emphasis, and to evaluate the impact of proposed standards. Data are stored on the Bureau's mainframe computer in Denver, Colorado, but portions of the data base may be analyzed on personal computers. MIDAS is available, on-line, via the Bureau's telecommunications network to Bureau, MSHA, and National Institute of Occupational Safety and Health personnel involved in mining research.

Each record of coal mine respirable dust exposure stored in MIDAS contains coded information which identifies the state, mine, type of mine, sample date, occupation code, tons of coal mined, dust concentration, and other information. These records are edited, sorted, stored, and statistically analyzed using software developed by the Bureau.

It was previously reported[8] that the highest mean concentrations of respirable coal dust reported by MSHA inspectors were measured in coal mine sections with longwalls. These sections also had the greatest percentage of samples exceeding the 2.0-mg/m^3 standard (35 pct). Many more samples were collected at mines using continuous rippers, with 11 pct of the samples exceeding the Federal standard. However, a single sample exceeding the 2.0-mg/m^3 standard does not place a mine section out of compliance with the Federal standard. A mine is only out of compliance if the arithmetic average of five operator respirable dust samples collected over consecutive normal production shifts exceeds the standard, or if the average of two or more MSHA inspector samples exceeds statistically determined levels.

MSHA inspectors and coal mine operators regularly sample miners or areas known to have high dust exposure, but mine operators collect many more samples. In underground mines, certain occupations are referred to as designated occupation (DO) and are sampled bimonthly by coal mine operators and annually by MSHA inspectors. Examples of DO's include the continuous miner operator and the longwall shearer operator.

The objective of this paper is to summarize the recent trends in respirable dust levels in sections using longwalls or continuous ripper miners. The analysis includes the large amount of compliance data collected by coal mine operators and MSHA inspectors. Recent data will be compared to data reported for FY 78 to determine the changes that have occurred in dust levels and coal production. Data from mines using both methods of mining will also be compared. In addition, operator data will be compared to inspector data to determine if different trends exist.

Continuous Mining

Continuous mining is a system that allows coal to be ripped from a seam and loaded in the same operation. It was developed in the 1940's to replace the conventional mining cycle of undercutting, drilling, shooting, and loading. Continuous rippers are commonly found in room-and-pillar mines. In these mines, multiple entries are cut parallel to the main haulage lane and reached by cross tunnels, resulting in a checkerboard of alternating rooms and pillars. Pillars are left to support the mine roof; as mining is extended to greater depths, larger pillars must be left behind. This results in reduced mining efficiency.[1]

Longwall Mining

Longwall mining is the most recently introduced mechanized method of mining. Coal is cut by either a shear or a plow from a coal face that is typically 350 to 600 ft in width and 1,000 to 6,000 ft in length. Cut coal drops onto a chain conveyor that lies along the bottom of the face and is hauled to one end. Here it is transferred to the stage loader, which loads it onto a conveyor belt. The roof is supported by hydraulic roof supports which extend support over the walkway, thus creating space for mining to take place. As the coal is cut, the roof supports move forward to cover the newly exposed face, allowing the unsupported roof to fall behind and eliminating the need for permanent roof supports or pillars. Longwall sections are generally developed by continuous ripper miners,[4] and most longwalls operating in the United States are retreat operations using three or more entries on either side of the longwall panel.[2] Though fairly new to the United States, longwall mining has been used in Europe for many years, because mines there have reached greater depths, making it safer and more efficient to use longwall roof-support methods.

RESULTS OF ANALYSIS

From FY 83 through FY 87, mine operators collected 260,370 respirable coal dust samples on continuous miner operators. These samples had a mean dust concentration of 1.0 mg/m^3, with 12.2 pct of the samples exceeding the standard. This compares to 12,622 samples collected on longwall operators on the tailgate side, which had a mean concentration of 2.0 mg/m^3, with 36.8 pct of the samples exceeding the standard.

FY 87 MSHA data show that more than 65 pct of the mine sections in the United States use continuous ripper machines (about 1,750 sections). This mining method typically produces between 300 and 400 tons of coal per shift (Figure 1). Ripper sections have had a small increase in production since FY 78. Table I shows the trends in FY respirable coal dust mean concentrations for continuous ripper operators. The 0.4-mg/m^3 reduction in mean dust concentration from FY 78 to FY 87 is statistically significant and is accompanied by 11.8 pct fewer samples exceeding the 2.0-mg/m^3 standard. In FY 87, 439 ripper sections were cited for noncompliance once, and 120 were cited two or more times.

There were about 128 longwall sections operating in the United States in FY 87. This is approximately a 30-pct increase in the number of longwalls since 1978. However, only about 85 to 90 longwalls are in operational status at any given time. Most of these sections use longwall shearers, primarily of the double drum type. Since FY 78, longwall operators have experienced increases in median production from 500 tons/shift to 2,200 tons/shift, as shown in Figure 1. At the same time, respirable dust levels have also changed, as evidenced by Table II, which shows the trends in respirable coal dust mean concentration for tailgate side shearer operators. The 0.5-mg/m^3 reduction in mean dust concentration from FY 78 to FY 87 is statistically significant and is accompanied by 13.0 pct fewer samples exceeding the 2.0-mg/m^3 standard. In FY 87, 58 longwall sections were cited for noncompliance once, and 31 were cited two or more times.

Table I

Respirable Coal Dust Trends for Continuous Ripper Operators[1]

FY	N	Concentration, mg/m^3		
		Pct of N >2.0	AM	ASD
78	78,765	23.5	1.4	1.5
83	56,742	13.5	1.1	1.3
84	60,273	12.8	1.1	1.3
85	49,716	11.6	1.0	1.1
86	48,996	11.3	1.0	1.1
87	44,643	11.7	1.0	1.1

FY fiscal year. N number of samples.
AM arithmetic mean.
ASD arithmetic standard deviation.
[1] Data collected by coal mine operators

Table II

Respirable Coal Dust Trends for Longwall Operators, Tailgate Side[1]

FY	N	Concentration, mg/m^3		
		Pct of N >2.0	AM	ASD
78	2,747	51.6	2.5	1.9
83	2,392	33.7	2.0	2.0
84	2,782	37.1	2.1	2.0
85	2,234	36.5	2.0	1.6
86	2,668	38.0	2.0	1.5
87	2,546	38.6	2.0	1.5

FY fiscal year. N number of samples.
AM arithmetic mean.
ASD arithmetic standard deviation.
[1] Data collected by coal mine operators

Mines With Both Longwall and Ripper Sections

Respirable coal dust concentrations may be compared at mines having both longwall and ripper sections. The comparison was made by selecting the 10 mines with the greatest number of operator coal dust samples for the continuous miner and longwall operator on the tailgate side covering the period FY 83 through FY 87. These mines are identified as mines A through J in Table III, which summarizes the respirable coal dust concentrations. One mine is in Virginia, two mines each in Alabama, Ohio, and Pennsylvania, and the remaining three mines are in West Virginia.

The mine average respirable coal dust concentrations for the continuous miner and longwall operator samples in Table III are 1.2 and 2.1 mg/m^3, respectively. These means approximate the overall means for the two occupations over the same time period, which were 1.0 and 2.0 mg/m^3, respectively. Mines C, D, E, and J had the highest mean respirable coal dust concentrations for both the continuous miner operator and the longwall operator on the tailgate side. Mine H had the highest median longwall production (2,230 tons/shift) and the second lowest mean longwall operator dust concentration (1.4 mg/m^3).

Comparison of Mine Operator and MSHA Inspector Data

Figures 2 through 4 compare data collected by mine operators to data collected by MSHA inspectors on continuous miner operators and longwall operators on the tailgate side. The arithmetic mean (Figure 2), the percent of samples <0.2 mg/m^3 (Figure 3), and the percent of samples >2.0 mg/m^3 (Figure 4) are used because these measures cover a wide range of exposure. The only measure of the three to show a remarkable trend is the percent of samples <0.2 mg/m^3 (Figure 3), which clearly shows that operators are more likely to submit a sample with a low dust concentration. Approximately 27.4 pct of the operator samples collected on continuous miner operators had concentrations <0.2 mg/m^3, compared to approximately 16.1 pct of the MSHA samples. The trend is also apparent for samples collected on the tailgate side longwall operator, where 6.6 pct of the operator samples and only 1.5 pct of the inspector samples are <0.2 mg/m^3. Possible explanations for this difference are that operators collect five samples over consecutive work shifts during which operating conditions may change and affect dust levels, and since operators sample far more frequently, there is a

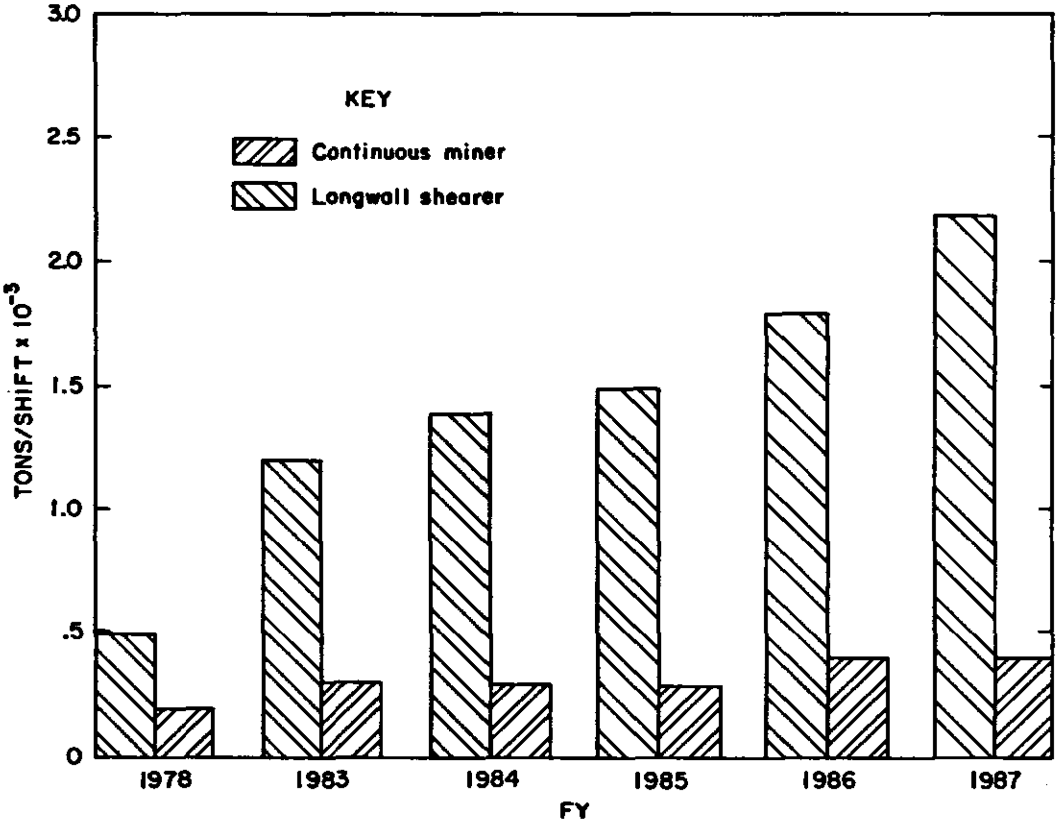

Figure 1. Underground median production as reported by mine operators for longwall shearers and continuous miners.

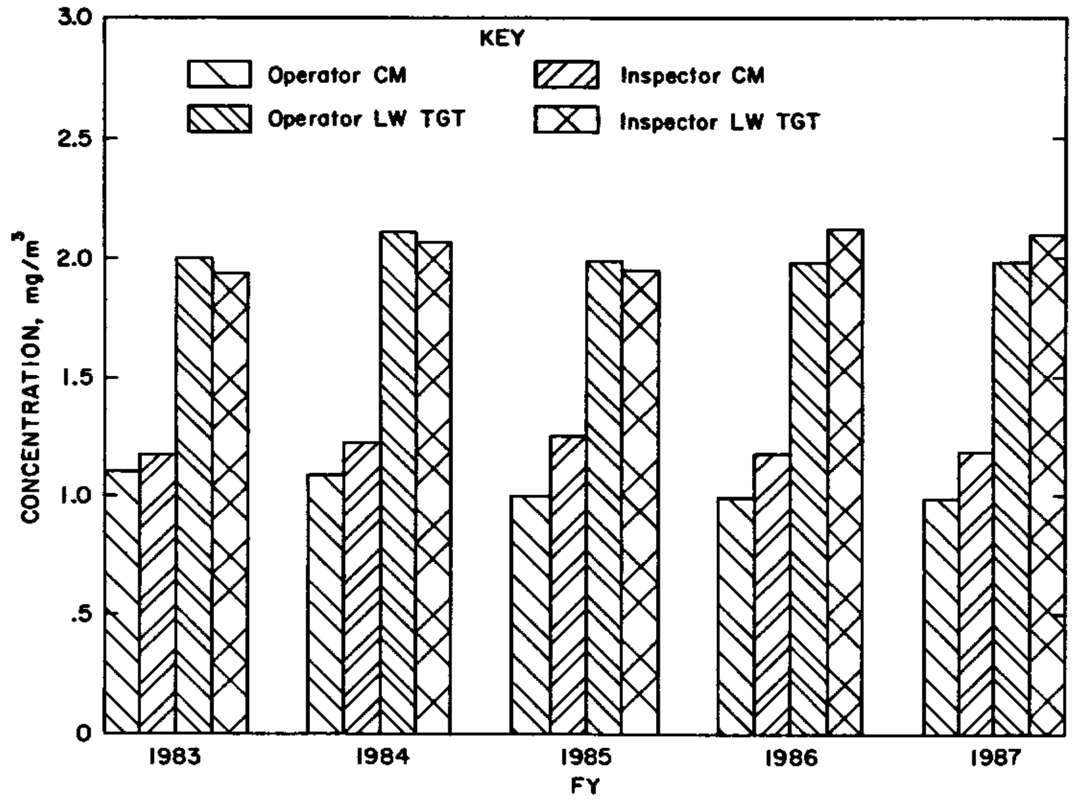

Figure 2. Arithmetic mean concentration for operator and inspector samples collected on continuous miner and tailgate side longwall operators.

Table III

Respirable Coal Dust Concentration, mg/m³ at Mines Using Continuous Rippers and Longwalls[1]

Mine	Continuous miner operator			Longwall operator tailgate side		
	N	AM	ASD	N	AM	ASD
A	970	1.0	1.0	464	2.1	1.8
B	1,222	1.0	0.7	371	2.0	1.5
C	1,437	1.8	1.8	566	2.7	2.1
D	1,172	1.7	1.7	573	2.5	1.8
E	870	1.3	1.1	201	2.6	1.7
F	1,369	0.5	0.7	165	1.8	1.3
G	517	1.0	0.7	139	1.4	1.3
H	681	1.1	1.1	289	1.4	1.2
I	966	0.9	0.9	338	1.3	1.0
J	902	1.4	1.7	173	3.1	2.9

N number of samples. AM arithmetic mean.
ASD arithmetic standard deviation.
[1] Data collected by coal mine operators.

greater chance of collecting samples with low dust concentrations. In addition, MSHA results could be higher because no prior announcement of arrival is given to the mine operator; thus, these samples may be indicative of truer day-to-day conditions.

SUMMARY

Over the past 5 years, operators of longwall shearer sections reported increases in median production from 1,200 to 2,200 tons/shift. This increase in production was accompanied by a continuing problem with respirable dust despite the significant decrease in mean dust levels that has occurred since FY 78. A number of longwall sections still experience difficulty in maintaining continuous compliance with the Federal standard. Longwall sections have arithmetic mean respirable dust concentrations that are more than double the concentrations reported by continuous ripper sections (2.0 mg/m³ vs. 1.0 mg/m³). In FY 87, 45 pct (58) of the longwall sections were found to be in noncompliance once, and an additional 24 pct (31) were cited two or more times. Thus, 69 pct of the longwall sections in operation during FY 87 experienced compliance problems. It is evident from these data that dust problems continue to plague longwall mining operations as longwall production continues to rise. If more high-producing longwalls are to be brought on-line to realize the full potential of this mining method, additional effective dust

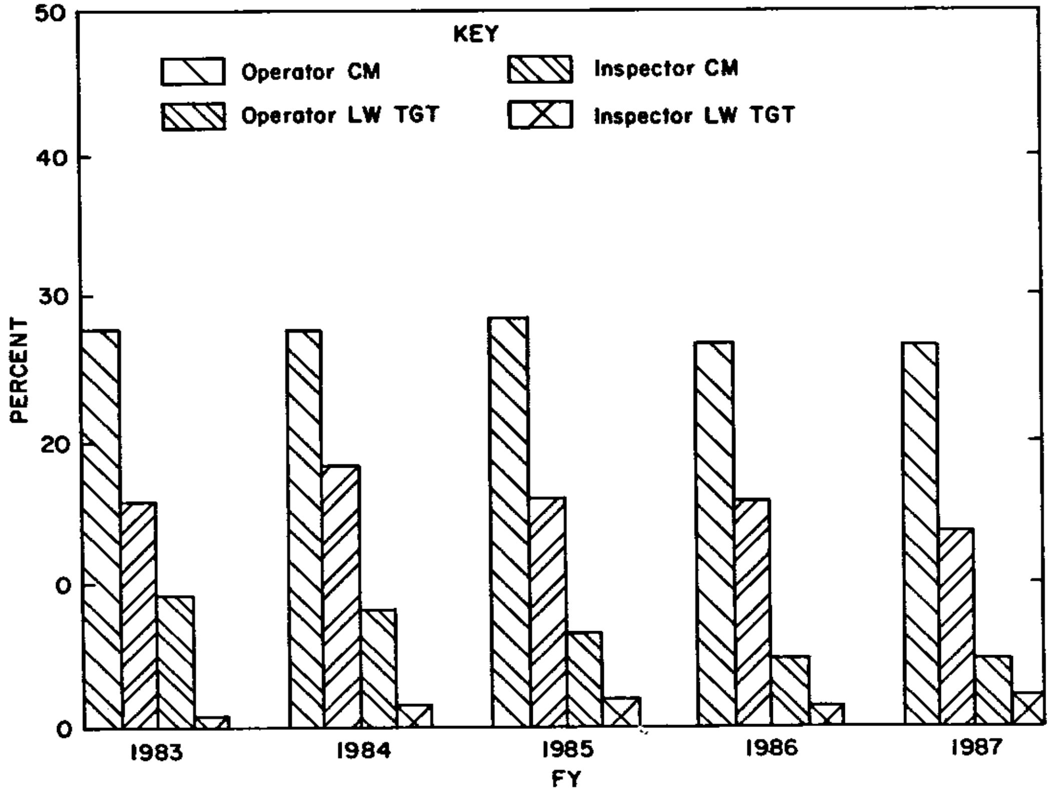

Figure 3. Percent of samples <0.2 mg/m^3 for operator and inspector samples collected on the continuous miner and tailgate operator.

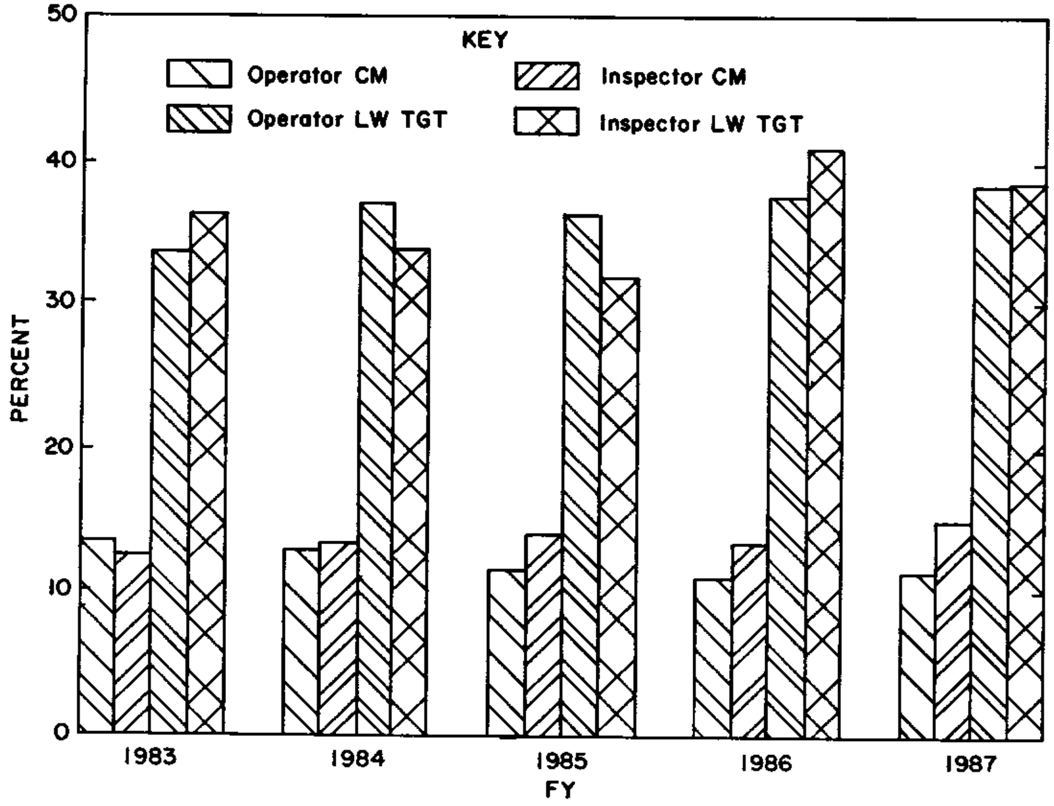

Figure 4. Percent of samples >2.0 mg/m^3 for operator and inspector samples collected on the continuous miner and tailgate side longwall operator.

control measures must be put into place and maintained to more consistently control dust levels on a continuous basis.

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