POLYMER-AUGMENTED AQUEOUS FOAMS FOR SUPPRESSION OF RESPIRABLE COAL DUST *

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INTRODUCTION

Coal dust of 5-micron size and smaller is now generally recognized as the cause of miner's pneumoconiosis, or black lung disease. Among other corrective measures, foams have been suggested and tested in the past as a means of suppressing the respirable coal dust in coal mines.[1] The tests that have been conducted, predominately in actual mines, have involved the use of foam-generating equipment and water/surfactant foams in conjunction with mining machinery. The results were not clear-cut. In some cases, foam appeared to be beneficial; in others, the results were borderline. The complexities of the mining operations and environment militated against an unambiguous case for or against the effectiveness of foam.

The work described here was a laboratory study aimed at developing a water/surfactant/polymer-augmented high-expansion foam capable of suppressing coal dust. The objective was to demonstrate the effectiveness of such a foam in laboratory-scale tests. A high-expansion foam is one in which the ratio of the volume of foam generated to the volume of liquid used is from 50:1 to as much as 1000:1. Foams with the higher expansion factors are regularly used for fire extinguishing application. They are very light, fluffy foams and are relatively dry. They move readily in a stream of air and can even become airborne. Foams with lower expansion factors (50 to about 200:1) are wet and cling well to the surfaces they are applied to.

Monsanto Research Corporation has had considerable experience in developing high expansion foams for a variety of applications. Most of these foams have included varying amounts of water-soluble polymers. These polymers add strength, toughness, and permanence to the foams. The polymer used in many of these earlier foams was gelatin. Foams prepared from gelatin are usually quite permanent. Gelatin solutions go through a sol-gel transition at 30–35°C. Foams prepared from warm gelatin solutions (<35°C) go through this transition as they cool and the foam is stabilized. Such foams lose water to the air but retain their dimensions indefinitely if not chemically or mechanically degraded. They have been maintained in the dry form for as long as two years.

The rationale for use of a foam in coal dust suppression is based on the high expansion factor of foam. A relatively small volume of water incorporated

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in foam will effectively fill a given space. In contrast, if the same volume of water is sprayed into the same space using a spray or fog nozzle, the area will not be effectively occupied by the water. Large spaces will exist between the individual water droplets. Dust in these spaces will not be contacted and captured by a water droplet. Since foam will fill the area more effectively, it is more likely to insure the capture of particles within it.

High-expansion foams make it possible to generate continuously a large-volume, lightweight matrix that, when applied to the mine face and the mining machine's picks, entraps the coal dust particles as they are generated (born). The stability of the foam is controlled, so that it continually collapses and drains to the floor of the mine as a dense, low-volume solution. The polymer in the foam solution acts as an effective binder to keep the dust encapsulated to prevent reaerosolization of the dust particles, even after the water evaporates.

To be acceptable for dust suppression, a foam should have a high expansion factor and the capability of wetting and binding coal dust particles; it should require only simple and structurally rugged generating equipment. It should be nontoxic and nonflammable, and it should not hamper the miner's visibility of the working face. It should have a rapid collapse rate, so that the mine entry does not fill with foam, and it should present no slipping hazard. Finally, it should be inexpensive to produce.

If the foam were to fill the space adjacent to the mine working face completely, the capture of all dust particles would be ensured. This approach is impractical, however, because extremely large volumes of foam would be required and visibility at the working face would be impaired drastically. Indeed, it is probably not possible to fill the cross section of the mine completely, because open areas around the mass of foam must exist to provide for the escape of air in front of the advancing foam. These open areas would provide pathways for the escape of airborne dust.

A more practical approach would be to apply foam directly to the cutters of a mining machine. The foam could trap the dust as it was generated by the cutter and before it became airborne. It was believed that if the dust ever became airborne, the chances of trapping the particles would be very low. But if foam were applied directly to the cutters, it would coat the cutter picks and, in turn, the dust particles as they are formed.

Our initial task was to prepare a foaming solution that contained a water-soluble polymer and had the ability to wet coal. Four constituents initially appeared necessary to prepare such a solution. They were (1) water—the principal component; (2) surfactant/wetting agent—a substance capable of wetting coal rapidly and effectively; (3) a foaming agent—necessary to produce a foam of the desired volume and durability; (4) a water-soluble polymer—to toughen and strengthen the foam and to serve as a binder for the dust.

Experimental

It was anticipated that water would comprise 95–99% of the total foam formulation. To be of practical use in a mine, the formulation had to include water of variable quality. Initial work was done using water from the Dayton, Ohio, municipal water supply system.

Surfactant Testing

A surfactant (surface-active agent) is a material that affects (usually reduces) the surface tension when dissolved in a solvent (usually water) or that tends to reduce the interfacial tension between two materials. Thus, a surfactant may cause water to penetrate more easily into the surface of another material (like coal) or to spread over it. In this case, the surfactant serves as a wetting agent.

Forty surfactants of all types (anionic, cationic, nonionic, and ampholytic) were evaluated in this study. Their compatibility with water and their wetting action on coal was investigated first. Three of the forty surfactants were eliminated because of poor compatibility with water. The ability of dilute aqueous solutions of the remaining surfactants to wet coal was determined by the measurement of the contact angle of a drop of the solution on a coal surface

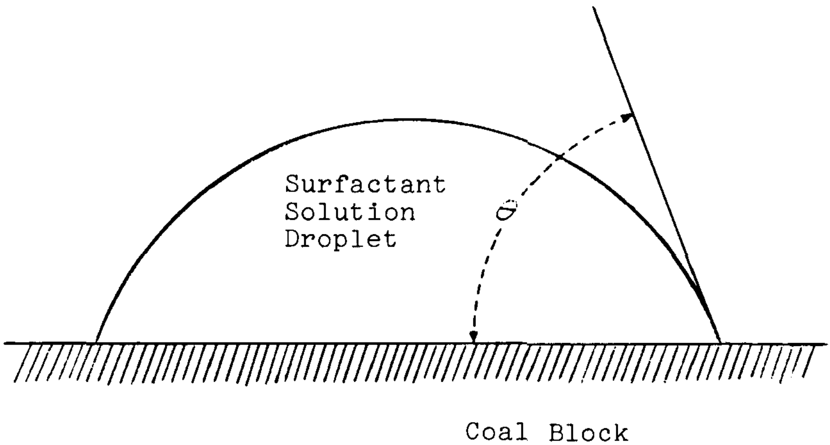

FIGURE 1. Contact angle (θ).

(see FIGURE 1). The contact angle (θ) defines the wettability. When the surfactant solution wets the coal completely and spreads freely over the surface, the contact angle equals, or approaches, zero.

The contact angle was measured using a goniometer eyepiece attached to a telescope (see FIGURE 2). Coal slabs approximately 1¼ in. × ¾ in. × 7⁄16 in. were cut from a large lump of bituminous coal from West Virginia. They were polished before use. The slab was placed horizontally between the telescope and a diffused light source. A drop of surfactant solution was placed on the surface of the coal slab by means of a syringe. A fresh surface was used for each test. The contact angle was measured three minutes after the drop was placed on the coal. Most of the surfactants were mixed with water in three surfactant/water proportions: 1/900, 1/1200, and 1/1500. As a result of this preliminary screening, fifteen surfactants were selected for further study. The aqueous solutions of these materials gave contact angles of 10° or less when applied to coal.

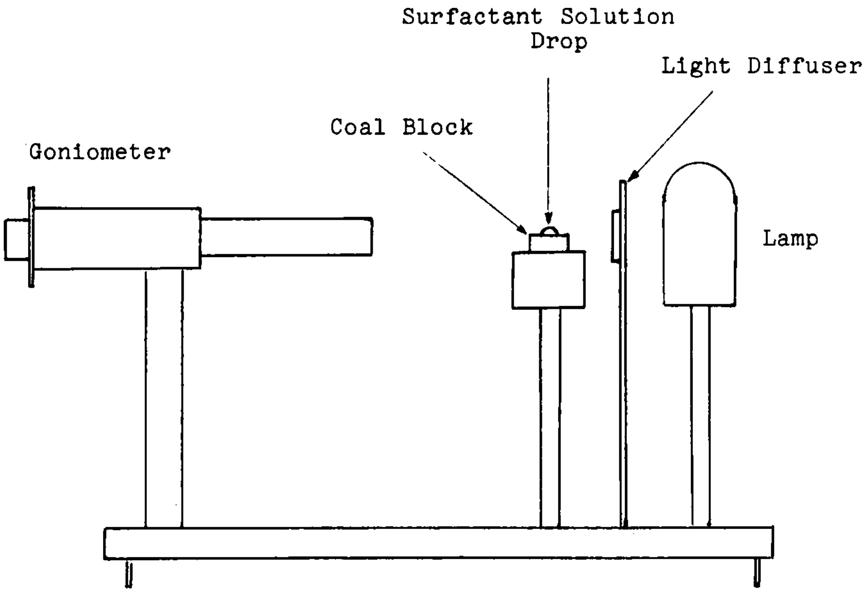

FIGURE 2. Contact angle measuring apparatus.

The selected surfactants were tested along with possible foaming agents and water-soluble polymers for their ability to form solutions capable of wetting coal and of producing forms.

Polymer Evaluation (Screening)

Three kinds of water-soluble polymers were considered possible candidates for use in the foam formulation. They were gelatin, polyvinyl alcohol, and water-soluble polyelectrolytes. Although gelatin had been used successfully in previous work on limited stability foams, it did possess one disadvantage for use in coal mines. Because it is a protein, it is subject to putrefaction when wet. The resulting odors would be objectionable in the mine environment. Thus, it would have been a prime candidate only if no other water-soluble polymer could be found.

Foams made from solutions containing polyvinyl alcohol of various molecular weights and degrees of hydrolysis were tested. The polyvinyl alcohol foams had low expansion factors (50 to 100:1), and the foams were weak and unstable.

Polyacrylic acid (Goodrich's Goodrite K-702) and copolymers of ethylene and maleic anhydride (Monsanto Company's EMA copolymers) were evaluated as examples of water soluble polyelectrolytes. Foams containing polyacrylic acid had high expansion factors, but the foams were very unstable. The sodium salt of the lightly crosslinked copolymer of ethylene and maleic anhydride (Monsanto Company EMA-54) was evaluated as a possible additive to foams. A 0.5% aqueous solution of EMA, as subsequently used in foams, has a viscosity of 93 cps at 29°C. A 0.2% solution of this polymer along with 1.5% by volume of ~30% solution of the sulfate of the ethylene oxide adduct of lauric acid (Kidde Corporation's Hi-EX 15AE + 35) was sprayed to produce foam with an expansion of 250:1 and reasonable stability. On the basis of preliminary foaming tests, EMA-54 was a likely candidate for use in dust suppression foam.

All foam formulation experiments were run using a laboratory foam generator based on a design obtained from the Walter Kidde Company. This apparatus is shown schematically in FIGURE 3. It consists of a blower that blows a stream of air through a cloth screen. Foam solution is sprayed over the upstream side of the screen. Bubbles of foam are formed at the openings in the cloth.

As a result of foaming experiments, it was found that a polyethoxyethyl aliphatic ether containing approximately 9 moles of ethylene oxide (Poly-Tergent J-300), a polyoxyethylene thioether (Sterox AJ), and a trimethylnonyl ether of polyethylene glycol containing 6 moles of ethylene oxide (Tergitol TMN) each combined the functions of a coal wetting agent and a foaming agent. This finding presented the possibility of combining the wetting and foaming function in a single ingredient, resulting in a simpler and more economical foam solution.

Foam Formulation Development

Foam generation and coal wetting tests were conducted on solutions containing Poly-Tergent J-300, Sterox AJ, and Tergitol TMN as surfactants; and gelatin, polyvinyl alcohol, polyacrylic acid, and ethylene/maleic anhydrides as water-soluble polymers. This work is summarized in TABLES 1 and 2.

Based on foam stability, wetting ability, and expansion factor, a foam formulation based on Tergitol TMN and EMA-54 was developed as follows: water—99.0 parts; Tergitol TMN—0.5 part; EMA-54—0.5 part. This formula was tested in water of various types and of various pH's (4.0–10.0). It performed well both in wetting coal and in producing foam.

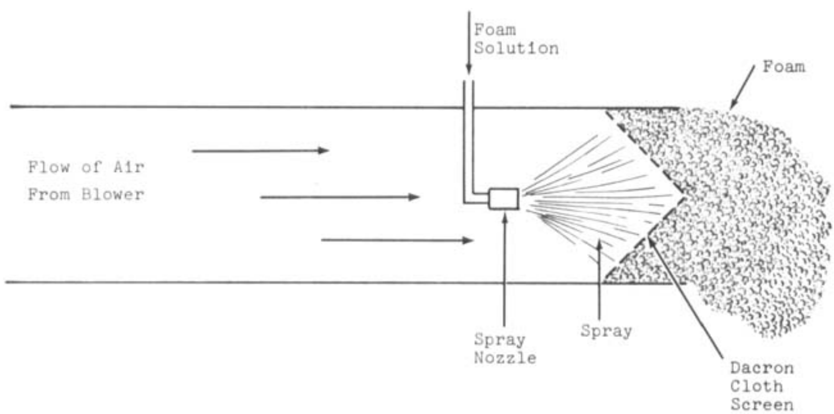

FIGURE 3. Schematic of laboratory foam generator.

TABLE 1

CONTACT ANGLES OF SURFACTANT POLYMER SOLUTIONS AND COAL AND THEIR EXPANSION FACTORS

Surfactant	Polymer Solution	Contact Angle with Coal ($\theta°$)	Foam Expansion Factors
Poly-Tergent J-300	Gelatin (5%)	0	296
	Polyvinyl Alcohol (5%)	10.3	208
	Polyacrylic Acid (5%)	0.7	270
	Ethylene/Maleic Anhydride (1%)	1.3	81
	Ethylene/Maleic Anhydride (0.2%)	0	—
Sterox AJ	Gelatin (5%)	0	296
	Polyvinyl Alcohol (5%)	8.7	183
	Polyacrylic Acid (5%)	7.0	248
	Ethylene/Maleic Anhydride (1%)	4.7	53
	Ethylene/Maleic Anhydride (0.2%)	0	—
Tergitol TMN	Gelatin (5%)	0	337
	Polyvinyl Alcohol (5%)	9.5	120
	Polyacrylic Acid (5%)	4.7	243
	Ethylene/Maleic Anhydride (1%)	0	81
	Ethylene/Maleic Anhydride (0.2%)	0	310

The concentration of EMA-54 in the solution could be varied from 0.1–1%. Tergitol TMN was used as a wetting agent and as a foaming agent. To each 100 parts by volume of polymer solution, 0.5 parts of Tergitol TMN was added. The expansion factor of the foam produced from this formulation could be adjusted over the range of 22–400 × by varying the EMA-54 concentration and the spraying conditions (feeding rate of the solution and air blower speed).

Laboratory Procedure for Dust Generation and Test of Dust Suppression

The selection of a meaningful laboratory test to demonstrate the effectiveness of foam in suppressing airborne respirable coal dust was difficult. Our approach to this problem was based on the following considerations:

TABLE 2

EXPANSION FACTORS OF FOAMS FROM EMA-54 SOLUTIONS OF VARIOUS CONCENTRATIONS

	EMA-54 Solution (100 parts)/Surfactant (0.5 part) Foam Expansion Factors at Various EMA-54 Conc.			
Surfactant	1%	0.75%	0.5%	0.2%
Poly-Tergent J-300	81×	120×	182×	—
Sterox AJ	53×	71×	116×	—
Tergitol TMN	81×	131×	206×	310×

1. It was believed that, to be effective, the foam must trap the dust particle as it is formed by fracture of the coal. If the dust particle ever becomes airborne, it would probably be very difficult for the foam to trap it. Because the particle is very light, it would probably be displaced by the foam front and remain airborne.

2. The coal dust should be freshly formed at the time it is trapped by the foam. Because ground coal dust has a very large surface area, it would be subject to rapid oxidative attack and would thus differ chemically from the freshly fractured surface.

3. The laboratory-scale method of forming the coal dust should simulate as nearly as possible the cutting action of a continuous miner or other coal cutting machine.

Several methods of producing coal dust were considered, namely: (1) a grinding wheel working against the face of a block of coal; (2) a chain saw cutting through a block of coal; and (3) a horizontal boring mill using a fly

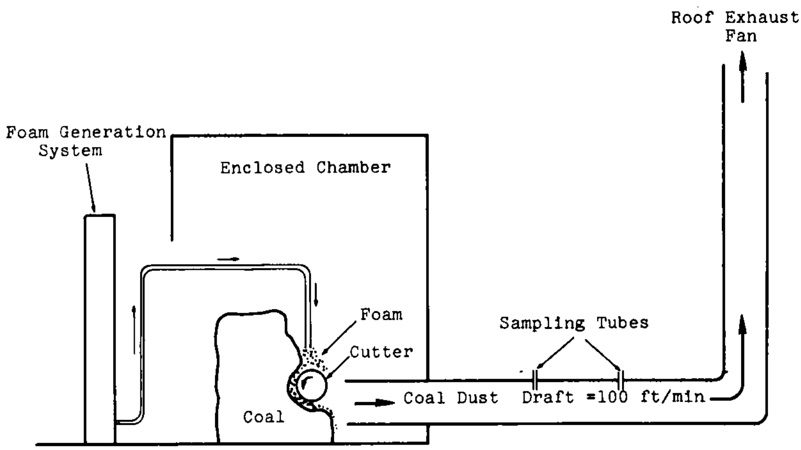

FIGURE 4. Schematic layout of the laboratory coal mining model.

cutter to simulate the action of a continuous miner's picks. This approach offered the possibility of controlling the rate of cutting and the depth of cut taken. The blades of the fly cutter simulate to some degree the action of the picks of the continuous miner. The cutter blades, however, have a shaving or cutting action, as opposed to the gouging or digging action of the picks of the miner.

After considering the alternatives, it was decided that the use of a horizontal boring mill offered the best chance of simulating, on a miniature scale, the action of a continuous miner.

The laboratory coal mining model is illustrated schematically in FIGURE 4. A 3-in. horizontal boring machine was employed as the coal dust generator. A six-blade fly cutter was attached to the shaft of the machine and revolved counterclockwise against a large lump of coal clamped onto the table of the machine. This arrangement simulated coal mining by a "miniature" continuous miner (see FIGURES 5 & 6).

Dust Sampling Procedure

The coal dust sampling system consisted of a partly enclosed chamber surrounding the coal and the cutter. Inside this chamber a duct opening (4 in. × 12 in.) served as the intake for the coal dust exhaust. The position of this duct inlet was adjustable relative to the coal face. Two sampling tubes were mounted in the duct. One was 60 inches and the other 80 inches downstream from the face. Both tubes were mounted so that their inlets were on

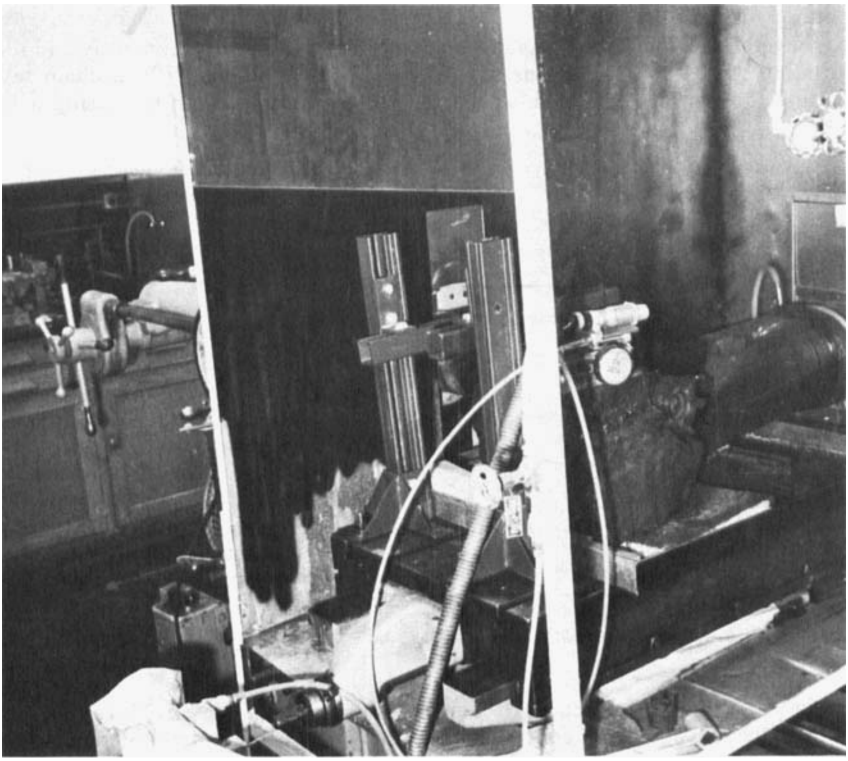

FIGURE 5. Horizontal boring machine set up to cut coal.

the center line of the duct. The draft within the duct was induced by a roof fan. The air velocity at the center of the duct was adjusted to give an air velocity of 100 ft/min as measured by an Alnor Velometer. Initial experiments using a 0.04-in. depth of cut and rate of traverse of 1⅛-in./min of the cutter across the coal face, produced 1×10^7 particles per ft^3. These results were encouraging, but it was felt a higher rate of dust production was desirable.

The amount of dust produced by varying the cutting conditions was measured. The results are summarized in TABLE 3 and in FIGURE 7. The maximum amount of dust was produced at a cutting depth of 0.08 in. and a

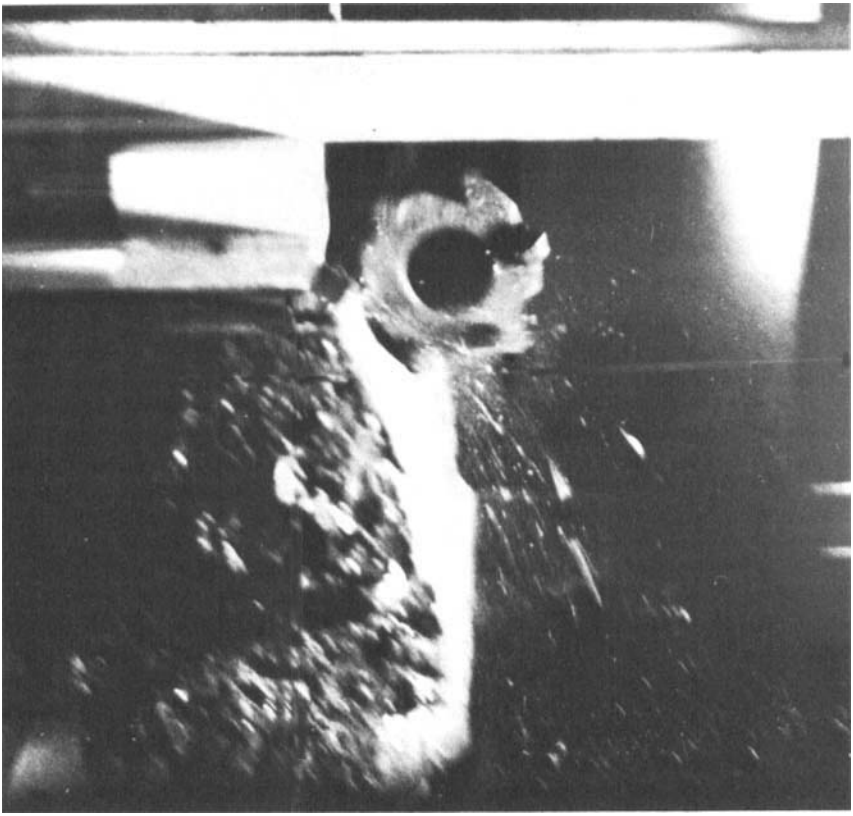

FIGURE 6. Coal cutting using a fly cutter.

TABLE 3
DUST PRODUCTION UNDER VARIOUS CONDITIONS

Speed of Cutter (rpm)	Traverse Speed (in./min)	Depth of Cut (in.)	Airborne Particle (mppcf *)
60	1–⅛	0.04	2.96
180	1–⅛	0.04	8.80
180	1–⅛	0.02	6.00
180	14	0.02	17.60
180	14	0.04	38.86
180	14	0.06	56.00
180	14	0.08	70.44
180	14	0.09	63.48
180	14	0.10	62.96

* mppcf—million particles per ft^3.

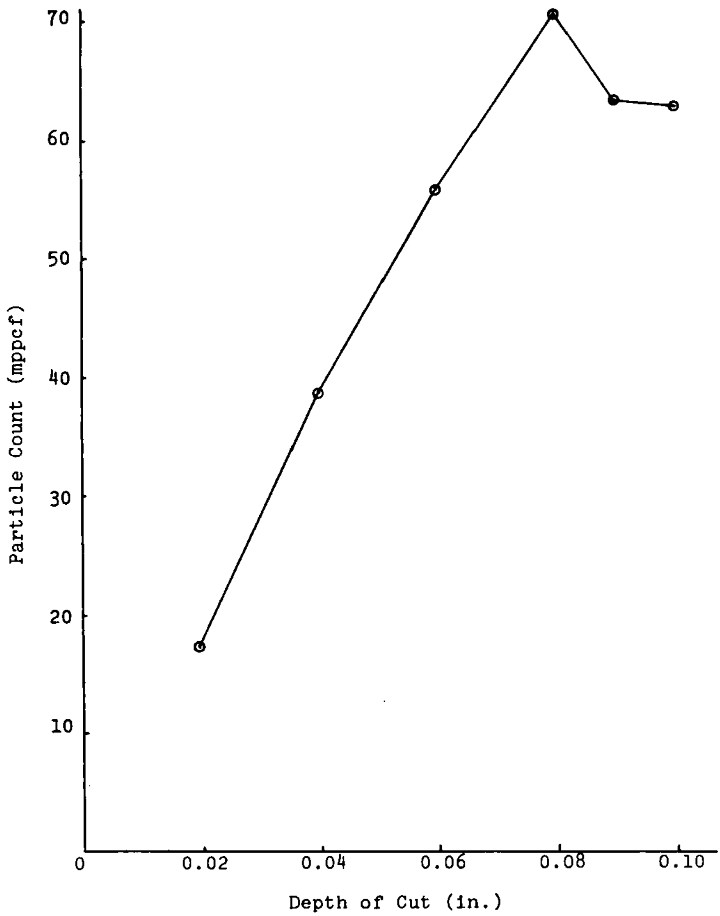

FIGURE 7. Depth of coal cut versus particle count.

traverse of 14 in./min. At greater depths of cut, the amount of airborne dust decreased slightly and the production of large pieces increased.

Coal dust samples were collected from the exhaust duct, using a Mine Safety Appliance Midget Impinger. Initially, suction was applied using a hand-powered pump. In later work, a motor-driven vacuum pump was used to apply 12 in. of water suction to the impinger. The sampling system is shown schematically in FIGURE 8.

A general procedure was established for coal dust sampling. *n*-propanol was filtered with Millipore 0.25-micron, 47 mm-diameter, UGWP 04700 filter paper. The solvent-resistant filter paper was mounted in a Millipore XX1004700 Pyrex filter holder. The impinger units were cleaned successively with water, deionized water, and filtered *n*-propanol. Next, 10 ml of filtered *n*-propanol was added to each impinger unit. After the coal dust sampling system was properly connected, the cutter was positioned and prepared to cut coal. As soon as the cutter touched the coal, the vacuum pump was turned on. Air from the exhaust duct was bubbled through the *n*-propanol in the impinger. Usually, a 5-minute sample was taken. The sample was transferred to a 30-ml bottle that had been carefully cleaned.

Laboratory-Scale Foam Generator

In evaluating the expansion factors and quality of the foam solutions, a laboratory generator capable of producing from 10–20 ft^3 foam/min was used. This rate of foam production was too great for use with the boring machine/fly cutter combination. Foam in this quantity would have flooded the cutter and chamber surrounding it, creating an unrealistic condition.

Thus, prior to actual dust generation and suppression experiments, it was necessary to develop a miniature foam generator, which consisted of a Spraying Systems, Inc. foam jet nozzle (No. 11259-U, Type 1/4 TT). An orifice disk having 0.037-in.-diameter opening was used. This nozzle was mounted in a 1¼-in. pipe. The after end of the pipe was connected to a Variac-controlled blower, capable of delivering 125 cfm at full speed. The forward end contained a nylon knit screen. Expansion factors of 50–400 times the solution volume could be obtained by adjusting the solution supply and the blower speed.

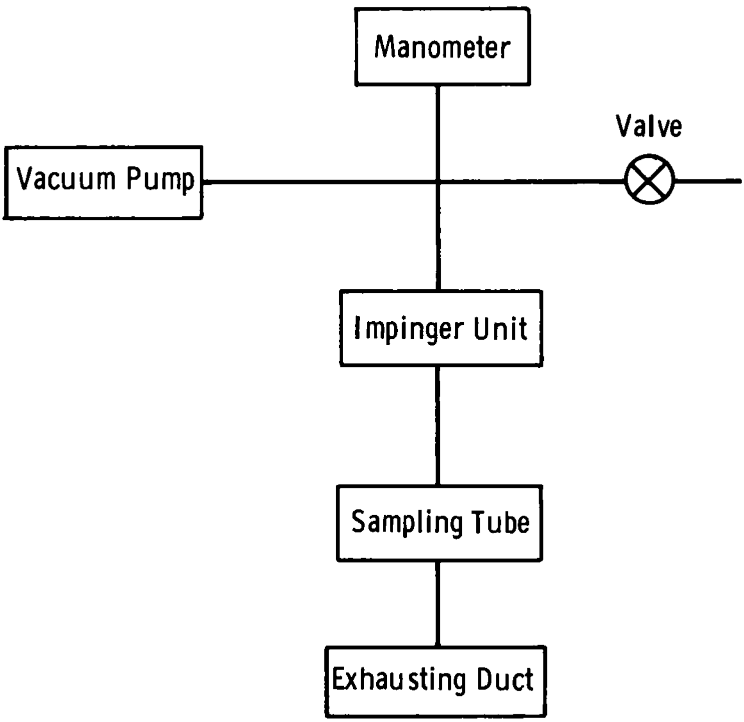

FIGURE 8. Schematic of the vacuum pump dust sampling system.

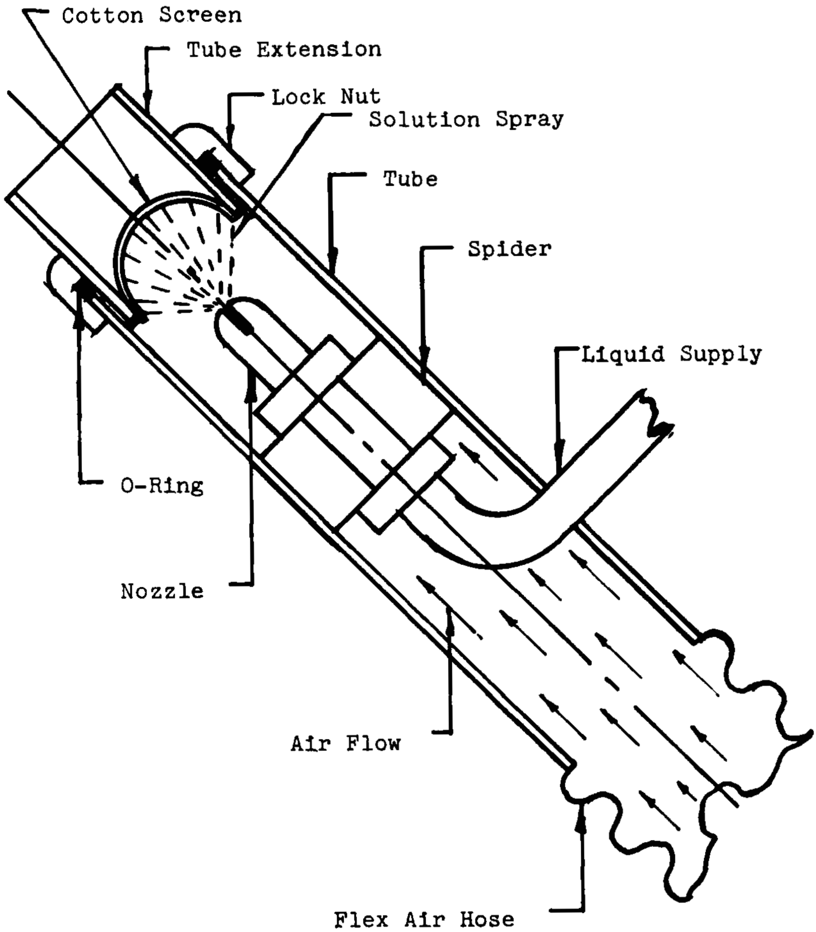

FIGURE 9. Miniature foam generator.

During dust suppression tests, the foam stream was adjusted to keep the fly cutter covered with foam, with a small amount of run-off down the face of the coal. FIGURE 9 shows the details of this generator. FIGURE 10 is a photograph of the miniature generator in use.

Tests for Dust Suppression

The first dust suppression tests using foam were qualitative. The cutter was driven at 180 rpm with a rate of traverse of 1⅛ in./min. The depth of cut was 0.04 in. Visual observations were made and television tapes taken for evaluation of the results. The dust cloud visible in transmitted light was most effectively reduced, it was found, when foam was deposited on the cutter just before it contacted the coal and when depositing was continued during the actual cutting. Samples of the airborne dust were taken before and during foam application. The material collected in the midget impinger was collected on filter paper. Examination of the paper showed definite evidence of a substantial reduction of dust when foam was used. FIGURE 11 shows this effect.

To determine if foams are more effective in suppressing dust than surfactant/water and water-only sprays, a set of comparative experiments was performed. The cutter speed was 180 rpm, rate of traverse 1⅛ in., and depth of cut 0.04 in. The dust concentrations in the air of the duct without foam, with water/Tergitol TMN/EMA 54 foam, with water/Tergitol TMN foam,

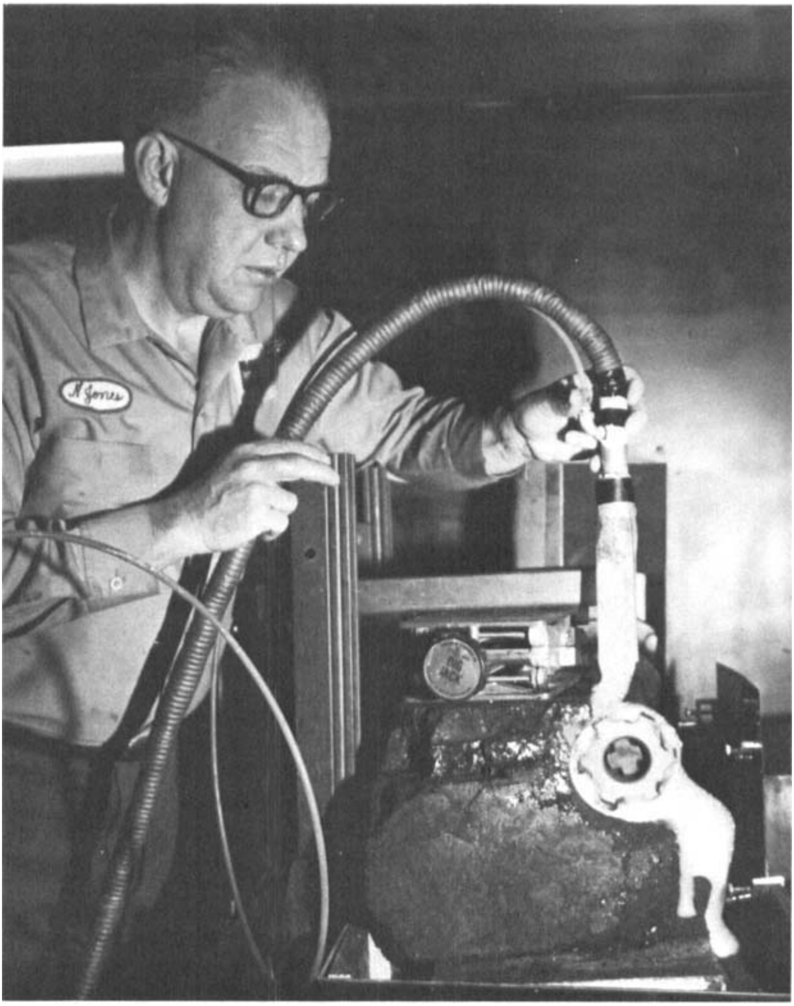

FIGURE 10. Miniature foam generator in use.

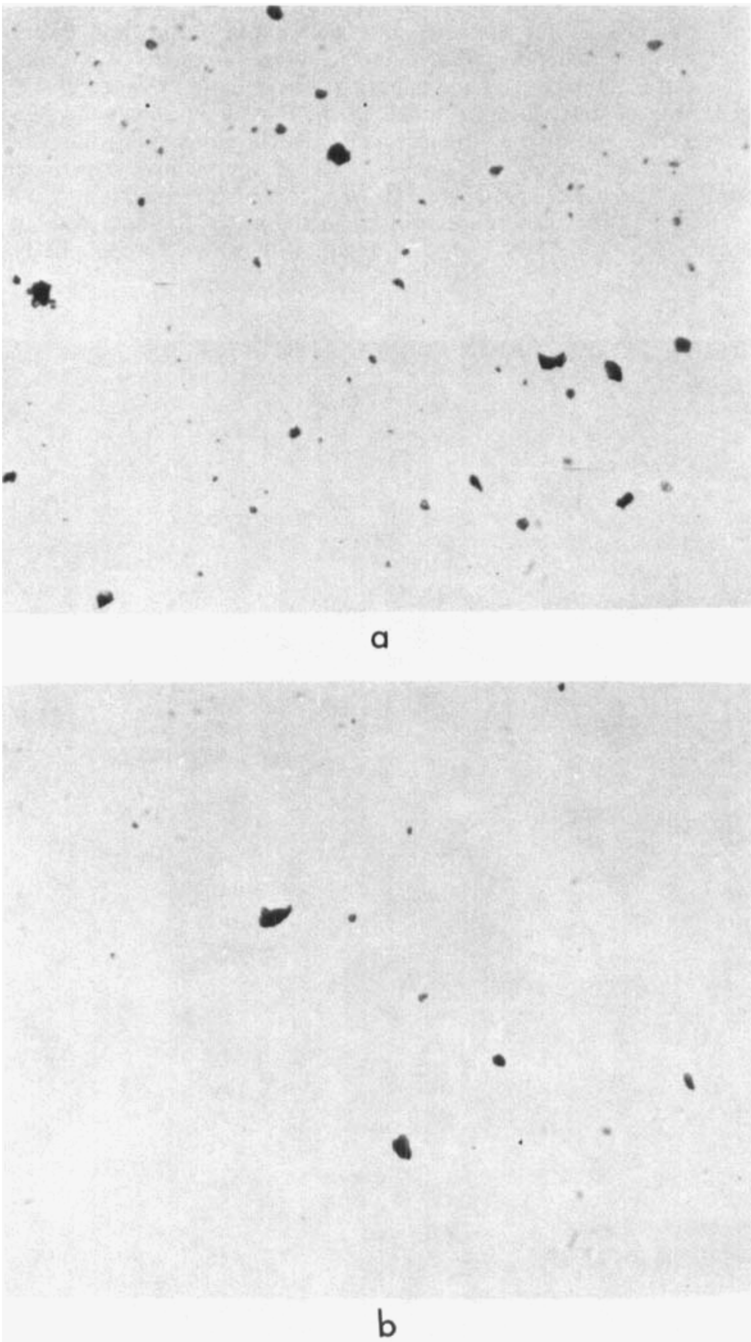

FIGURE 11. Photomicrographs of coal dust samples collected by vacuum pump method (a) before and (b) during foam application.

TABLE 4

COAL DUST SUPPRESSION USING DIFFERENT SOLUTIONS

Dust Suppression Means	Run	Particle Count (mppcf *) 1	2	3
Blank (on reagents and filters)		0.24	—	—
Coal cut with water/Tergitol/EMA 54 † foam application		<0.32	0.32	0.80
Coal cut with water/Tergitol foam ‡ application		0.32	0.64	0.96
Coal cut with water/Tergitol spray ‡ application		2.40	0.64	2.80
Coal cut with water spray application		1.60	5.50	3.40
Coal cut without foam or spray application		7.40	10.40	8.20

* Million particles per ft^3
† 1000 ml of 0.5% (by wt) EMA-54 in water solution plus 5 ml Tergitol TMN.
‡ 1000 ml of water plus 5 ml Tergitol TMN.

with water/Tergitol TMN spray, and with water spray were compared in this series of experiments. The water sprays used in this work were very fine, almost like fog. The coal dust samples were taken during a 5-min period. The results of this work are given in TABLE 4. The amounts of dust suppressed by foam with and without EMA-54 were almost identical. The foam containing EMA-54 suppressed 94.5% of the dust and that without EMA-54 suppressed 92.7% of the dust. The polymer additive in the foam, however, performs two functions that are vital to the successful operation of the system: first, the polymer additive effectively binds the dust on drying (to prevent reaerosolization); second, it provides collapse times of the required duration. If foam collapse times are too long, the working space tends to fill with foam. If the collapse time is too short, the effectiveness of the foam in suppressing dust would be reduced. Water sprays both with and without surfactant are not nearly so effective. With surfactant present, only 78% of the dust is suppressed. Plain water sprays reduce the airborne dust by only 50%.

The dust suppression ability of the Tergitol TMN/EMA-54/water (5 parts/ 5 parts/996 parts) at higher rates of dust production—using the same amount of foam—was also determined. The results are given in TABLE 5. The increase in dust suppressed at the higher rates of dust production is anomalous. Repeti-

TABLE 5

DUST SUPPRESSION AT HIGHER RATES OF DUST PRODUCTION

Dust Concentration Without Foam Application (mppcf *)	Dust Concentration During Foam Application (mppcf *)	% Reduction
38.9	4.8	88
56.0	1.6	97
70.4	0.5	99

* Million particles per ft^3.

TABLE 6

EFFECT OF VARYING THE AMOUNT OF FOAM SOLUTION ON THE DEGREE OF DUST SUPPRESSED *

Foam Solution Used (ml)	Airborne Dust During Foam Application (mppcf)	% of Coal Dust Particles Suppressed
35	11.2	84
110	11.2	84
160	7.9	89
295	3.2	95

* 70.4 million particles per ft^3 (mppcf) produced without foam.

tion of this work did not substantially change the results. The suppression was quite good, however, even at the lower rate of dust production.

The effect of various amounts of foam solution on the degree of dust suppression was investigated. The results are presented in TABLE 6 and in FIGURE 12. At the lowest rate of foam generation (35 ml/min of solution of

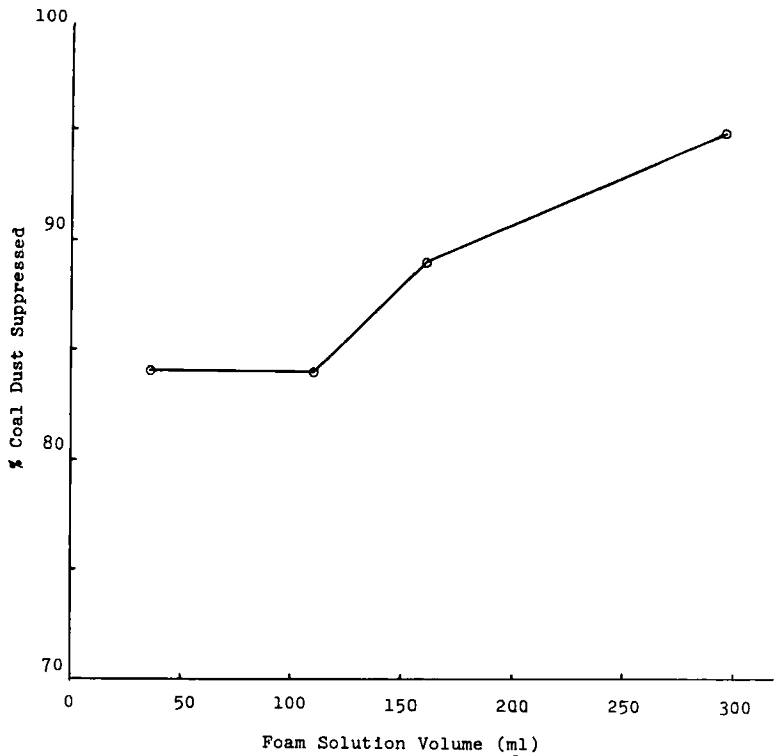

FIGURE 12. Percent coal dust suppressed with various amounts of foam when 70 million particles per ft^3 are being generated.

foam having an expansion ratio of ~200:1), the cutter wheel was practically starved for foam, and yet the degree of dust suppression was quite high (84%). Dust suppression did not improve until the rate of foam solution usage was increased to more than 110 ml.

Tests for Dust Binding with EMA-54

EMA-54 serves as a strengthening or toughening agent in the foam composition. It constitutes the "body" of the water-based foam. It also functions as a binder for coal dust. Once coal dust is wetted down, a cake is formed, so that the dust particle will not be easily reaerosolized. This effect was evidenced by the following tests.

Simple experiments similar to ASTM Standard Method of Test for Oil Absorption (D-1484-60) were carried out. Two grams of coal dust was placed in each of five 50-ml beakers. To each of these beakers was added one of the following: 0.2 ml, 0.4 ml, 0.6 ml, 0.7 ml, and 0.8 ml of the foam solution containing EMA polyelectrolyte binder. The two higher concentrations represent those expected to be achieved in the laboratory scale "mining" operation. The contents of each beaker were "kneaded" into a single lump. After four weeks, only the material in the beaker to which 0.8 ml of solution had been added held together very well and thus prevented reaerosolization of dust. When the beaker was tapped forcefully with a spatula, no coal dust particles separated from the cake. The lower volumes of foam solution provided progressively less binding of the dust, the 0.2 ml and 0.4 ml concentrations being totally ineffective.

A similar experiment was also done with a mixture of water/Tergitol TMN (1000 parts/5 parts). When the beaker with 0.8 ml of this mixture and 2 g of coal dust was tapped, coal dust particles came off the kneaded lump immediately, thus showing ineffective binding of the dust.

Dust Particle Size Measurements

The coal dust samples were analyzed for the number of particles and particle size distribution. The coal dust concentration was expressed as particles per ft^3. Since the sampling time in this laboratory work (5 minutes or less) was much less than the sampling time in coal mine tests, the total dust collected was also less. Thus, it was not necessary to dilute the samples taken from the coal dust suppression tests to give a practical sample for counting and sizing.

The procedure used for particle counting essentially followed the methods of Anderson,[2] except that a Metals Research Corporation Quantimet, a quantitative television microscope (QTM), was used in place of a microprojector. In the QTM,[3] a microscope projects an image onto the screen of a television camera. The electrical output from this camera passes into a closed-circuit television monitor to provide a television image and also into a detector unit, where signals from the camera emanating from the features that need to be measured are discriminated and selected from the rest of the signal. The output from the detector, consisting of pulses from the detected features, can be fed into the monitor, so that the operator can see which features he has detected, and into the computer, which can be set to measure the percentage area, the number of detected features, their total projection, and their size distribution. All these measurements are read out on the meter on the front of the instrument.

For the coal dust measurements, the microscope was fitted with a 10 ×, 0.25 N.A. objective and a 1.3 N.A. Abbe condenser. Kâhler illumination was used, with the iris diaphragm closed to produce sufficient contrast for the small particles to be seen. The measuring field of the QTM was adjusted to 0.25 mm × 0.20 mm, to produce a measuring area of 0.05 mm². A Sedgewick-Rafter counting cell was filled with a representative portion of the sample

TABLE 7

AMOUNT AND DISTRIBUTION OF AIRBORNE COAL DUST WITH AND WITHOUT FOAM

Conditions 0.08 in. cut 14 in. Traverse 180 RPM	Without Foam	With Foam
Airborne Dust Concentration (mppcf *)	70	0.5
Particle Size Distributions (micron)	Total Airborne Particles %	Total Airborne Particles %
0–0.5	20.3	13.2
0.5–1.0	30.5	27.8
1.0–2.0	20.3	18.7
2.0–3.5	10.8	13.2
3.5–5.5	7.3	12.3
5.5–2.0	5.2	6.4
8.0–11.0	3.5	1.2
11.0–14.5	0.9	3.2
14.5–18.5	0.4	2.0
18.5–23.0	0.4	1.2
>23.0	0.4	1.2

* Millions of dust particles per ft³ of air computed from air sampling and Midget Impinger data.

from the midget impinger. The particles were allowed to settle for 10 minutes. At the end of this time, only the particles on the bottom of the cell were measured. All the particles were counted in five 0.05 mm² fields taken near each corner and at the center of the Sedgewick-Rafter cell.

Effectiveness of Foam in Suppressing Various Size Dust Particles

To demonstrate that foam was effective in reducing airborne dust in a range of sizes, the airborne particle size distribution was determined with and without foam application. The results are given in TABLE 7. Approximately equal numbers of particles were counted from the samples obtained under both conditions. These data showed that the particle size distribution of airborne dust that escaped capture by the foam is approximately equivalent to that of untreated dust. The conclusions are based on a limited number of determinations and are preliminary in nature. It is hoped that additional work now in progress will confirm that foam is effective over a wide range of dust particle sizes (including respirable dust) in actual mining operations.

Conclusions

This work has developed foam solutions containing a surfactant and a water-soluble polymer that are capable of trapping or suppressing 90–95% of the airborne dust generated in laboratory coal cutting experiments. A suitable laboratory method for generating coal dust using a horizontal boring mill and a fly cutter was developed. Miniature high-expansion foam generators were developed for use in foam suppression tests.

Status

At this time, work is being conducted to develop foam application equipment and demonstrate the effectiveness of foam in an actual coal mine test. This work consists of developing pumping and metering equipment to proportion a foam concentrate into a water stream and move it to suitable foam nozzles. These nozzles will distribute foam over the cutting drum of a Joy 10 CM continuous miner.

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