FIELD TESTS OF A FOAM DUST-SUPPRESSION SYSTEM WITH LONGWALL SHEARERS

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INTRODUCTION

Dust exposure for machine operators on longwall shearer faces is generally higher than those experienced by operators of other types of face machinery. A study by the Mine Safety and Health Administration (Nesbit, 1978) found that less than 50 percent of operating longwalls surveyed were in compliance with the federal dust standard of 2 mg/m^3. In the case of double-drum shearers, only 10 out of 32 were found to be in compliance. The study also noted that most of the longwall sections in compliance used cutting sequences which did not fully exploit the productive potential of the shearers. Hence there is an exigency to develop more effective methods of dust suppression. One such technique entails the use of a high expansion foam.

This paper presents the results of two field tests of a foam system for dust control in double-drum longwall shearer sections located in West Virginia and Utah. Initial laboratory experiments (Mukherjee et al, 1984) had established that flushing foam through the shearer drum is feasible and could be a viable technique for dust control on longwall faces. The laboratory investigation indicated that an adequate quantity of foam could be sprayed, either through nozzles located near the cutter bits (pick face foaming) or through nozzles located along the scrolls of the cutter drum. Encouraging results obtained from the laboratory investigation led to the field evaluation of the foam system to determine its effectiveness for dust control under actual operating conditions.

Selection of mine sites for the foam system evaluation was based upon the shearer being the dominant dust generating source, but the willingness of the mine operator to cooperate on this project was also a major factor. Emphasis was placed on flushing a major amount of foam through the cutter drums, thereby suppressing the dust close to its source of origin. The first underground test for determining the effectiveness of foam for dust control was conducted during the month of March 1983 in a mine in West Virginia. A second field test was conducted in a mine in Utah during the month of March 1984.

FOAM SYSTEM EVALUATION IN MINE NO. 1

Mine No. 1 was a large coal mine in northern West Virginia with workings in the Pittsburgh seam. At the time of the evaluation, the mine had two longwall sections and eight continuous mining sections in production. The two longwall sections were equipped with Joy double-drum, Model 1LS, shearers. Panel dimensions were approximately 600 ft x 7,000 ft. The longwalls were operated three shifts a day, five days a week.

Foam System Installation

The operation of the foam system required the use of an air compressor, a metering pump to inject the foaming agent into the existing waterline, a foam block (the only equipment mounted on the shearer itself), hoses, and large-diameter nozzles for foam ejection through the drums. The layout is schematically shown in Figure 1. In this mine, the foam block was installed on the shearer at the surface during overhauling, while the installation of the other pieces of equipment was performed on a weekend, hence these had a minimal effect on production. Figure 2 indicates the foam block location on the shearer.

The air compressor utilized for the field testing of the foam system was a Joy Twist Air Model TA-25. This unit was a rotary screw compressor capable of delivering 103 cfm at a maximum pressure of 125 psi. The unit was base-mounted, with a weight of about 930 lb and dimensions of 55-in. x 35-in. x 38-in. A dual-voltage 25-hp motor operating at 460 volts provided power for the compressor. Since the motor was nonpermissible, the compressor was located over four cross cuts (about 400 ft) from the face. A permissible extension cord provided electricity from the section power center to the compressor. The compressor was connected to midface by a 700-ft long, 1-in.-dia, braided airline, rated at 200 psi. A 330-ft continuous length of 1-in.-dia abrasion-resistant traveling airline, rated at 1,000 psi, was installed from midface to the shearer positioned at the headgate.

Water was provided to the longwall section from a water car, using a sunflow pump, 6,000 ft of 3-in. aluminum pipe, and approximately 800 ft of 2-in. waterline, including the traveling waterline (placed in the shearer cable ough). The water car and sunflow pu were located at the head of the section. Capacity of the sunflow pump was 200 gpm at 700 psi. Normal operating water pressure at the shearer was about 180 psi with water consumption varying from 70-80 gpm. Approximately 10-15 gpm of water was flushed through the cooling jackets of the shearer motors with the remaining water flow utilized for dust suppression.

A Milton Roy metering pump was utilized to transfer the foaming agent from a chemical drum to the section waterline. The pump was located as far as practical from the face but in-bye the roof support emulsion system take-off hydrant. A dual-voltage 1/2-hp motor operating at 1,750 rpm provided power for the pump. The pump was capable of delivering 14.8 gph at 730 psi, and its output was regulated by a micrometer stroke adjustment device. Therefore, the pump could accurately be adjusted to operate from 0 to 100 percent of volume capacity. During testing, the pump was operated at 70 percent of full capacity, that is, approximately 10.5 gph.

Due to the reduced water requirements with the foam system (40 gpm), the water supply was maintained at a slightly higher working pressure than the normal operating condition. This necessitated the installation of a bypass arrangement on the metering pump. Normal operating water pressure with reduced water flow was approximately 500 psi. Water pressure increased to 600 psi when the shearer was shut down; therefore, the bypass system was set to open at 550 psi when the shearer was shut down. The bypass valve permitted the injection of chemical into the waterline at pressures below 550 psi, and directed chemical in the bypass at pressures in excess of 550 psi.

A gage manifold was installed on the hydrant, with a check valve to permit flow in only one direction, and a gate valve to permit disassembly.

The chemical agent line was a high-pressure, 1/2-in.-dia, 1,000 ft long, wire braid hose, connected to the bypass arrangement through the gage arrangement. This line had a pressure rating of 1,200 psi and an abrasion-resistant cover.

The mixing of compressed air with agent and water to produce foam occurred at the foaming block. The block consisted of a venturi with a compressed air inlet. The lead and tail drums along with the "J-bar" sprays were fed with separate foam lines.

Placement of the foam block was based on several factors, including accessibility, serviceability, and protection from hazards.

Foam System Eva ation

The foam system was evaluated against the existing water spray system on the shearer. Dust concentration readings upwind of the shearer and at the head shearer operator position were obtained to determine the relative effectiveness of the foam system over the water spray system.

The average air velocity along the face was about 300 ft/min. Sampling was carried out at two locations, namely at the shearer operator position and upwind of the shearer. Dust concentrations were measured every 20 sec, as the shearer progressed along the face. The dust concentration data were obtained when the shearer was operating at normal haulage speed, while fully sumped into the face, and cutting and loading coal. In total, 18 complete passes were sampled with water sprays, and 15 passes with the foam system in operation.

The dust concentration data measured from tailgate to headgate were averaged over a minute for the two dust suppression systems at intake and shearer operator positions. There appeared to be significant shift-to-shift differences in dust concentrations; also, the data varied more at the shearer operator position than at the intake position. Since extreme values can seriously distort the results, they were rejected using Chauvenet's criterion.

The dust concentration data obtained are graphically depicted in Figure 3. The average total dust at the operator position was found to be 6.53 ± 2.17 mg/m^3 with the water sprays but this dropped to 3.30 ± 1.44 mg/m^3 with the foam -- a reduction of 49 percent. In fact, the average intake dust was also decreased from 1.60 ± 0.53 mg/m^3 with the water sprays to 1.16 ± 0.74 mg/m^3 with the foam (about 28 percent). This was probably because the foam did not disintegrate immediately and blanketed the coal as it entered the crusher at the headgate, on its way out of the mine on the panel belt conveyor. This concentration of intake dust could probably be reduced further if a couple of foam nozzles were mounted directly on the crusher hopper, as well as the outlet from the crusher leading to the gate belt.

If it is assumed that the difference between the dust level at the operator position and that at the intake is all generated by the shearer, this was reduced 56 percent from an average value of 4.93 mg/m^3 to 2.14 mg/m^3. (Independent sampling by the mine personnel gave a drop in dust concentration by 65 percent, that is, the foam was even more effective in reducing shearer generated dust.)

In addition to reducing t… amount of respirable dust produced at the face, the technique cut the use of water by nearly 50 percent (from 80 gpm to 40 gpm). Since relatively large diameter nozzles (11/32-in. dia) were used in the cutter assembly, no clogging problems were experienced.

FOAM SYSTEM EVALUATION IN MINE NO. 2

The second field test was conducted in a mine in Utah working the Blind Canyon seam. The seam height varied between 8 to 10 ft, face length was about 550 ft, with about 300 ft of the 4,400-ft-long panel remaining to be mined. The face utilized a double-drum Eickhoff 350-hp shearer with chainless haulage, DMKF 4-face conveyor, and Hemsheidt 460-ton two-legged shields. Face ventilation was antitropal, with about 30,000 cfm of air provided to the panel. About 8,000 cfm of this air was coursed to the belt entry and the remainder utilized for face and gob ventilation.

The sequence of face operations for coal extraction was modified full-face. From the headgate, the shearer trammed to about shield no. 25 with the tail drum raised, and gradually sumped into the face. The shearer then cut the face up to the tailgate. During this cutting pass, the roof supports were advanced upwind of the shearer. After the shearer reached the tailgate, the drums were reversed, and the shearer began its clean-up pass from the tailgate toward the headgate (up to shield no. 25). During this operation, the face conveyor was advanced downwind of the shearer. From shield no. 25, the shearer cut to the headgate, before the drum positions were reversed again (tail drum up and head drum down). It then cut the coal remaining between the drums and traveled back to the headgate to resume its cycle of operations. The effective cutting web depth was about 32 in.

Foam System Installation

The equipment utilized in this second field test was essentially the same as in Mine No. 1, except for minor differences as briefly described in this section. The layout is presented in Figure 4, and the foam block mounting in Figure 5.

An adequate supply of compressed air was available at the section, hence it was not necessary to install a compressor underground. The air supply was available up to about 200 ft out-bye the face. From this point, a 1-in. airline was established to the shearer.

The water consumption at the face was higher at this mine compared to Mine No. 1 (110 gpm versu… 0 gpm). Therefore, it was necessary … have a second injection pump to supply the additional chemical to the waterline. This second pump was also a Milton Roy pump, which delivered about half the quantity of chemical as the initial pump. In this mine, the injection system (pumps and chemical drums) was set up at the pump house, which was located near the head of the panel. Therefore, the pump assembly did not need to be moved during the entire field testing period.

Since only a limited amount of foam could be flushed through the drums, external foam spray manifolds were mounted on the outrigger arms at each end of the machine to augment foam output. Each manifold contained 8 flat Spraying Systems Company Veejet sprays, with 3/4-in. male connections. The foam generator block and accessories were installed on the shearer during an equipment breakdown and caused no disruption in mine production.

In addition to the spraying system described above, one nozzle was also installed in the feeder-breaker, to reduce the dust generated at this point.

Foam System Evaluation

Gravimetric samplers were hung, in groups of three, near the headgate (shield no. 10) and tailgate (shield no. 110), to sample over each shift. Instantaneous dust concentrations were obtained every 20 sec while the shearer was in operation, with GCA RAM-1 dust monitors. These readings were taken simultaneously at the operator position and 30 ft upwind of the shearer (to obtain the intake concentrations). Dust measurements were taken for 20 passes with the foam, but only 7 passes with the water sprays, which resulted in more scatter in the averages. (Actually data were taken for a considerably greater number of passes in each case, but the data proved to be unusable.) There were a number of equipment breakdowns in this section, resulting in considerable lost time.

The average weight gain in the gravimetric dust sampler filters were 1.059 mg and 6.869 mg for the intake and return locations, when the foam system was in operation. The corresponding values when the water spray system was operating were 1.198 mg and 5.370 mg for the same intake and return locations. Because the variations in water pressure, water consumption, and air velocity were within 10 percent, these factors were not included in the analysis of gravimetric data. There was about a 12 percent reduction in dust at the intake location whereas at the return location, there was an increase in average weight gain when the foam system was operating. This weight gain was probably due to an average 30 percent increase in production during the period that the foam system was in operation (1,917 tons with foam vs 1,473 tons with water sprays). The intake reduction, even though small, could be attributed to better intake dust control because of the installation of a foam nozzle at the headgate crusher.

In addition to the intake dust, the return samples collected dust generated by the shearer, the conveyor, movement of roof supports, and spalling of the face ahead of the shearer. The shearer was the principal source of dust, but the face spalls and roof support movements made significant contributions. When the foam system was in operation, the tonnages mined were considerably higher than when the water spray system was in operation. In fact, the highest production shift (3,007 tons of raw coal), a record for the section, was obtained when the foam system was in operation. The gravimetric data obtained at the return location were normalized on the basis of tonnage to determine if there was any significant change when tonnage is considered. The analysis revealed in this case, that the average weight gained at the intake was 10.88×10^{-4} mg/ton of coal mined with the water sprays, and 6.48×10^{-4} mg/ton with the foam system. At the return location, the respective average weights gained were 44.07×10^{-4} mg/ton and 38.32×10^{-4} mg/ton. On this basis, a 40 percent reduction was computed for the intake and a 13 percent at the return location.

The analysis of the data collected with the RAM-1 dust monitors was performed in a manner similar to that reported for Mine No. 1. The total dust concentration at the operator and intake positions was computed for each minute of shearer operation for each acceptable pass. The results are shown in Figure 6. The average value of the total dust with water sprays was 8.83 ± 1.96 mg/m^3 and that with foam was 7.94 ± 2.13 mg/m^3, that is, a reduction of 10 percent. The corresponding average dust levels at the intake were 3.77 ± 1.57 mg/m^3 and 3.19 ± 1.44 mg/m^3, a decrease of 15 percent. These data represent actual dust concentrations as measured at the mine and do not allow for the fact that on the average there was 30 percent more coal produced when the foam system was used. The percentage drop may also be less than in Mine No. 1, because some of the dust was generated by numerous coal face spalls ahead of the shearer cut and by roof support movement. Further, the foam delivery through the nozzles in the drum was relatively poor. However, if all of the difference in dust concentrations measured at the operator and intake positions were attributed to the shearer, the dust level with the water sprays was 5.06 mg/m^3 and that with the foam 4.75 mg/m^3, a reduction of 6 percent (even with the production increase).

The increased production from the longwall during the use of the foam system along with the reduction in dust concentration (by about 10 percent) was well received by both the mine workers and management. They expressed an interest in continuing the use of the foam system at the face for another month. Unfortunately, project contraints did not allow this extended period of testing. Mine personnel indicated that they would like to install the foam system in six of their longwall panels, if the cost of the chemical foaming agent were reduced.

CONCLUSIONS

These early field tests indicate that the use of foam through the longwall shearer drums offers significant potential for respirable dust suppression at the face. The two tests reported were performed under widely varying conditions. In both cases there were significant reductions in the dust levels at the operator position. In Mine No. 1, the total dust concentrations decreased 49 percent near the operator, compared to 10 percent in the similar location in Mine No. 2, but the coal production in the second mine was 30 percent higher. The second mine also had a significant contribution of dust from roof support movements, and did not have very effective foam delivery from the drum nozzles.

It may be concluded from these tests that the success of foam production at the face depends on the size of the plumbing circuit in the shearer. A minimum of 3/4-in.-dia (19-mm) lines is desirable, to deliver an adequate amount of foam through the drums. Also, even-spaced foam nozzles along the scrolls of the drum are preferable to pick face foaming. The fewer outlets permit a high discharge pressure and reduce the likelihood of clogged nozzles.

The cost of the chemical foaming agent used at these mines was $12.15 per gallon. In the first mine, with an average coal production of 1,200 tons/shift, and a 400:1 water-to-chemical ratio, the cost per ton was about $0.25. In the second mine, with a water-to-chemical ratio of 180:1 and coal production of 1,900 tons/shift, the cost computed to $0.71/ton. In both cases an effective working time of 250 min/shift is assumed. (Of course, in this mine the cost drops to $0.45/ton for the shift that produce 3,000 tons.) In the second mine, however, even if a part of the increased productivity is attributed to the foam, the cost of $0.71/ton may well be tolerated. Further, in both mines the water consumption was significantly reduced -- from 80 gpm to 40 gpm in Mine No. 1, and from 110 gpm to 80 gpm in Mine No. 2. This resulted in a drier coal and hence a higher heating value. Besides, it is safe to state that the chemical agent costs will ·op markedly when it is produced and sold in bulk. The cost given above was that paid for the relatively small quantities used during these two tests.

The mine operators as well as face crews in both mines were enthusiastic about the use of the foam. The workers in the first mine noticed occasional skin irritation, but there were no such complaints at the second mine. However, alternative foams that do not have such effect, will be investigated in future tests.

It may be surmized that although these two tests cannot be claimed to be conclusive, further testing of this system, to optimize the various parameters, is justified. The scheme may not be a panacea for the coal industry's dust problems, but it certainly offers considerable promise.

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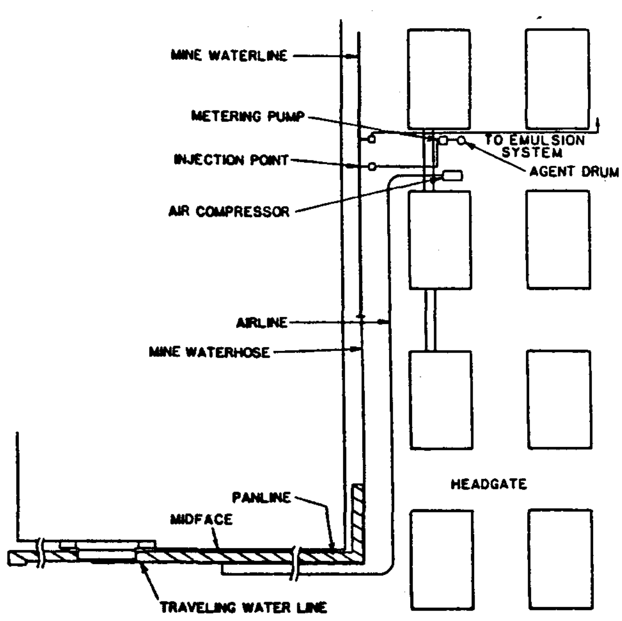

Figure 1. Schematic of Foam System at Mine No. 1

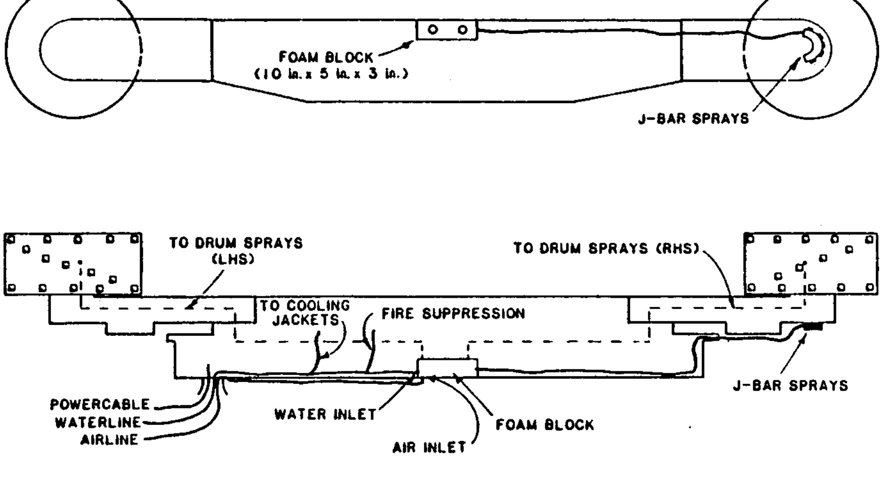

Figure 2. Schematic of Foam System Installation on Joy Shearer, Mine No. 1

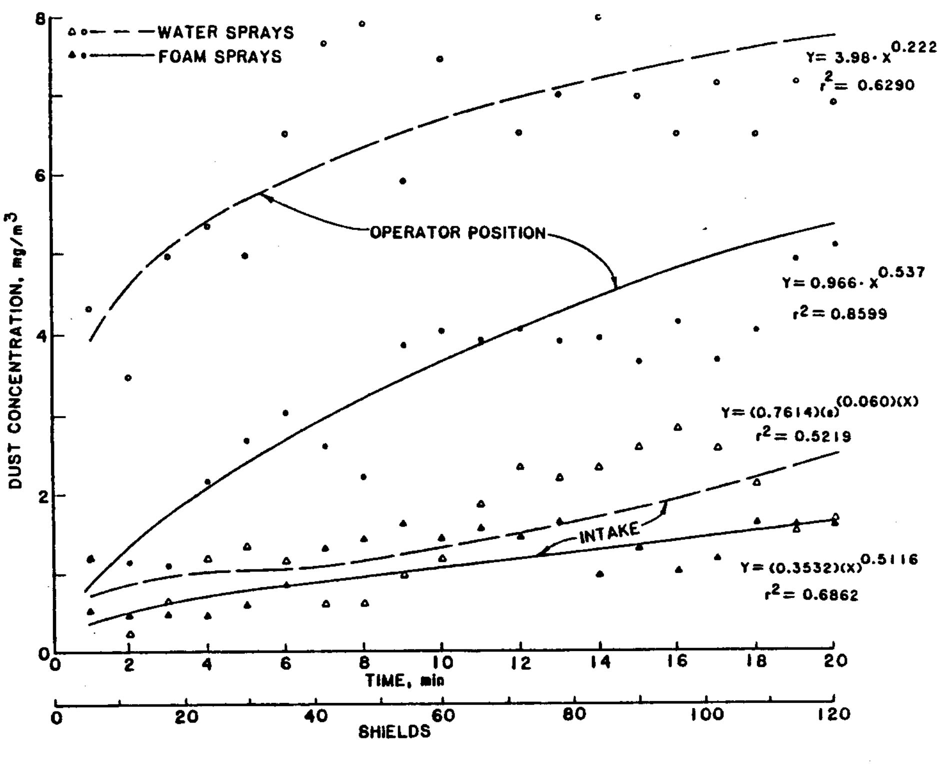

Figure 3. Dust Concentration for Foam and Water Sprays at Mine No. 1

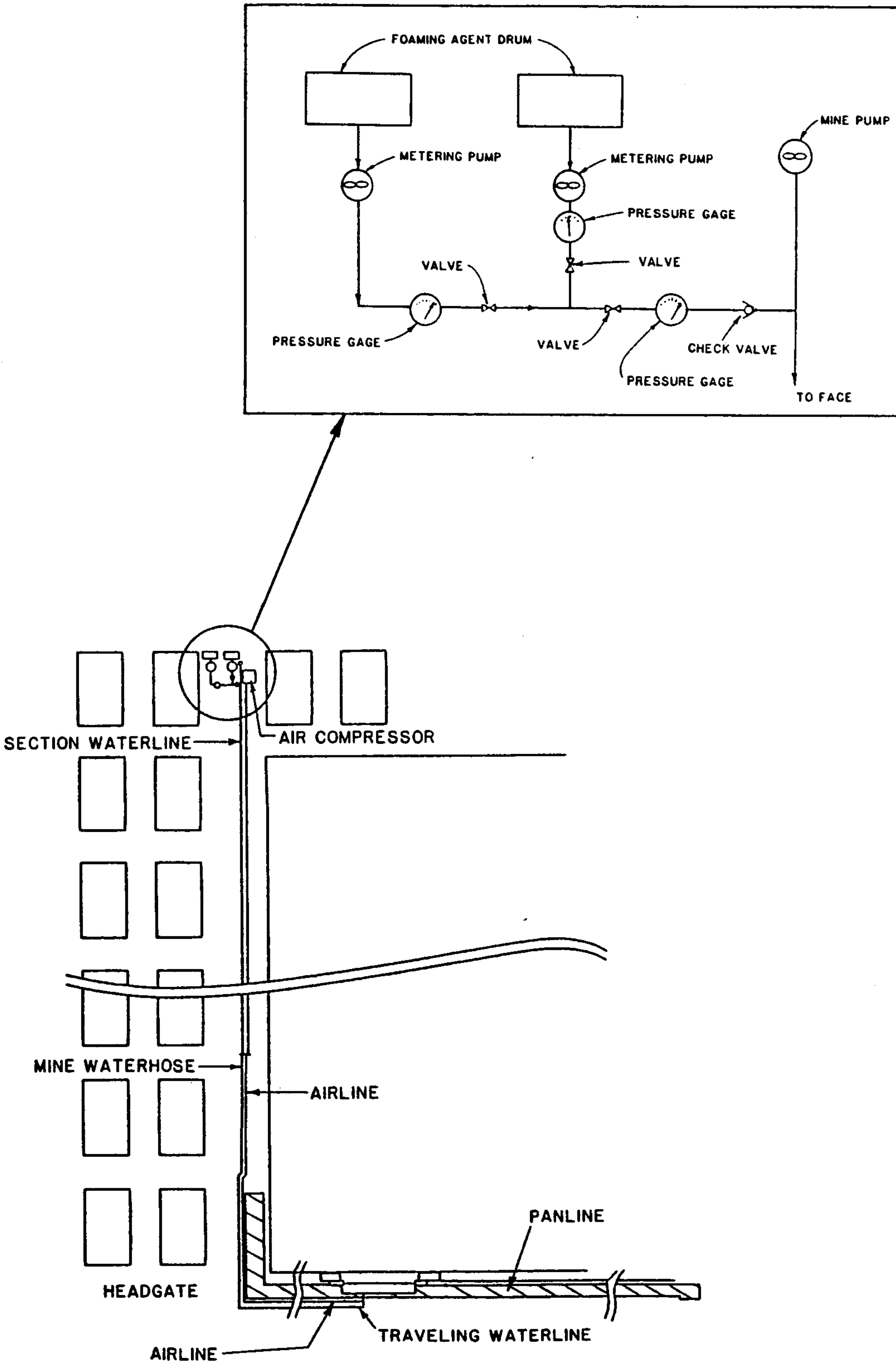

Figure 4. Schematic of Foam System at Mine No. 2

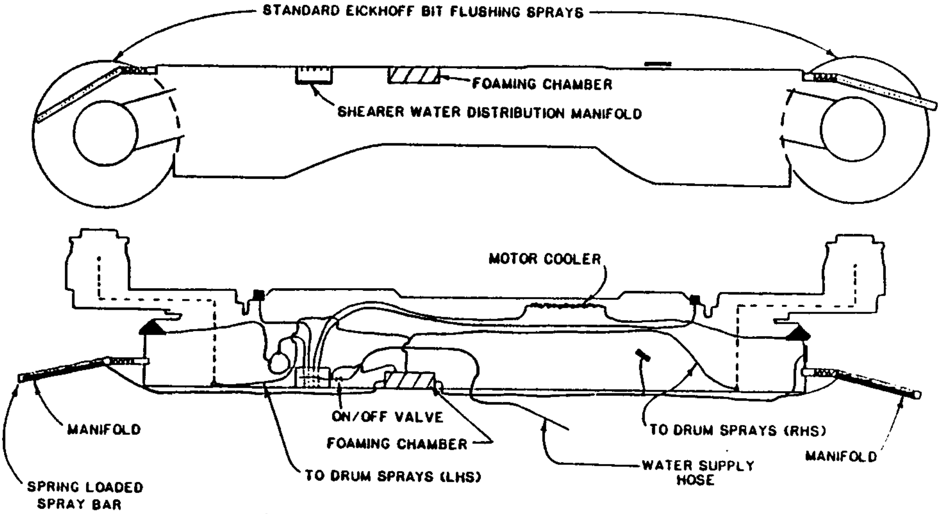

Figure 5. Schematic of Foam Installation on Eickhoff Shearer, Mine No. 2

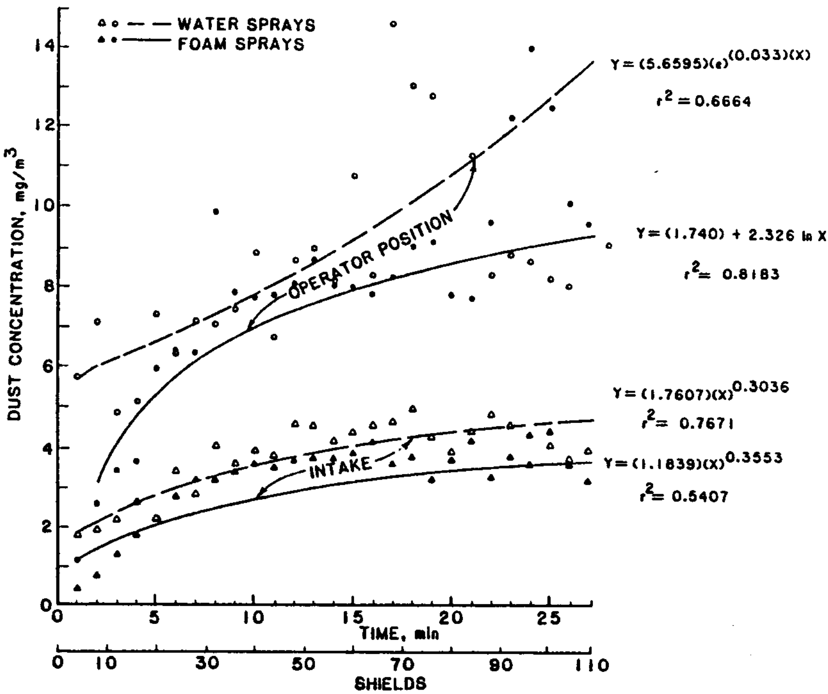

Figure 6. Dust Concentration for Foam and Water Sprays at Mine No. 2