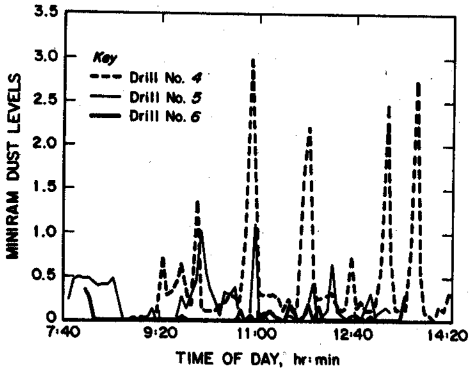

Figure 4. Dust levels inside drill cab

cab. At drill 5, the cab dust levels were steadily elevated for about the first hour of operation (7:52 to 8:49 a.m.), when dust escaped profusely from the large gap underneath the shroud (see Table 3). However, the dust levels were notably lowered next to the shroud (see Table 3) and inside the cab (see Figure 4) after the operator improved the vertical positioning of the drill to eliminate the gap beneath the shroud (after 8:49 a.m.). The spikes in the cab dust levels after this period were likely caused by the occasional dust leakage observed between the drill stem seal and the drill table outside the cab. Drill 6 had very little dust escaping the dust collection system, and the operator consistently kept the cab door closed.

4 OPERATIONAL DUST VARIANCE

Long-term dust sampling was continued for eight months at three drills and three bulldozers operated by Mining Company I in West Virginia. Table 4 shows the daily equipment operator cab dust data during this period and the data summary for each piece of equipment. Figures 5 and 6 show the Box-and-Whisker Plots for the equipment ARD concentrations and silica dust contents, respectively. These Box-and-Whisker Plots display the data frequency distributions in 4 equal areas (25 percent for each box and whisker) around a median, with outliers shown as individual points. Two drills (1 & 2) were alternately used at mine A. Bulldozer no. 2 at mine A was sampled for one day when bulldozer no. 1 was not operated. Drill 3 and bulldozer no. 3 were moved to mine C after mine B ran out of coal reserves.

The long-term data show that enclosed operator cab dust levels tended to be higher and more variable in the drill than in the bulldozer. The data summary in Table 4 shows that two of the highwall drills (drills 1 & 2) had average dust levels more than double the third drill (drill 3) and all the bulldozers (dozers 1, 2, and 3). All the drills also had higher relative dust level variations than the bulldozers. The drills had coefficients of variation (CV = Std. Dev./Average) above 50% while the dozers had CV's below 50%.

Figure 5 shows the median and 25 percentile (boxes and whiskers) ARD data ranges for the three highwall drills and bulldozers. This figure illustrates that drills 1 and 2 had the highest and the widest range of dust levels. A suggested factor for these wide ranges in ARD levels is that the cab doors were observed to be left open occasionally during drilling on some of the sampling shifts. On drill 1, the door was sometimes left open because the cab had no air conditioning filtration system. Drill 2 also had a non-continuous shroud design with a hydraulically activated door on the front of the shroud and this door did not reliably seal the collared hole. Drill 3 had a noticeable improvement in its cab dust levels when the damaged shroud (outlier point in Figure 5) was replaced with a

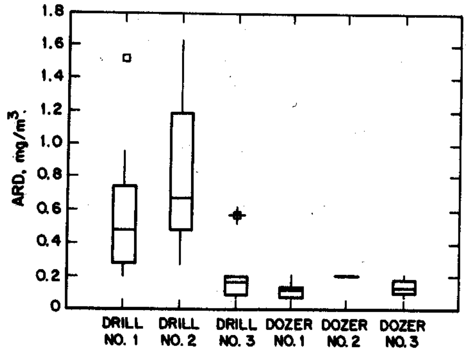

Figure 5. Multiple box-and-whisker plot of drill and dozer dust levels

continuous wrap-around enclosure (see Table 3, discussed earlier). The range of dust levels for drill 3 remained below that of the other two drills with the new shroud. The normal climatic seasons (autumn--dry, winter and spring--wet, and summer--dry) of West Virginia were not observed to have any significant effect on the dust levels inside the enclosed cabs during this study. Dust levels appear to be arbitrary through the climatic seasons of dust sampling in Table 4.

The silica dust sample analyses show that noticeable silica content differences exist between the individual highwall drills and the individual bulldozers sampled, with some conformity evident between the equipment operated at the same mine. More than three-fourths of the ARD samples had reportable silica percentages. Better than two-thirds of these reportable samples contained more than 20% silica. The silica data and the average silica content summaries for the equipment are shown in Table 4.

Figure 6 shows the range of percent silica content in the dust for the equipment sampled. Highwall drills 1 and 2 and bulldozers 1 and 2 were operated at mine A, with the widest range of silica content measurements in the dust. Highwall drill 3 and bulldozer 3 were operated at mines B and C, with the lowest and least variable silica content measurements as compared to the equipment at mine A. Mines B and C were geographically close as compared to their location with mine A.

One unexpected and significant difference in the silica content of the dust was observed between drills 1 and 2 at mine A. The silica content in the dust generated by drill 1 was significantly higher than for drill 2 at the 99% confidence level (one-tailed t-test). This was an unexpected outcome, because the drills were alternately used in close proximity at the mine

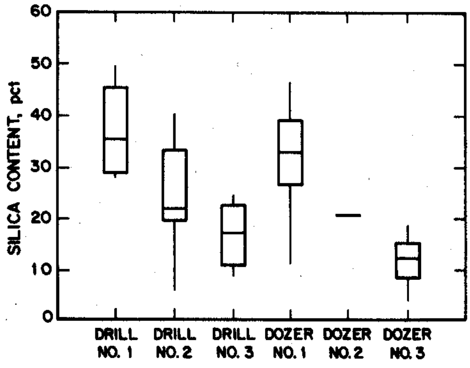

Figure 6. Multiple box-and-whisker plot of drill and dozer silica content

Table 4 - Eight-Month Dust Level History For One Mining Company

Sampling Date	Rotary Rock Drill		Bulldozer	
	Mine,Drill No.	Cab Dust Levels mg/m^3 (SiO_2)	Mine, Dozer No.	Cab Dust Levels mg/m^3 (SiO_2)
11/18/97	B, 3	0.57 (13.2)	B, NS	NS
11/19/97	A, 1	0.29 (42.9)	A, NS	NS
11/20/97	B, 3	0.09 (NS)	B, NS	NS
12/4/97	A, 1	0.54 (29.3)	A, 1	0.11 (38.8)
12/10/97	A, 1	0.20 (29.5)	A, NS	NS
12/17/97	A, 2	1.21 (33.1)	A, 1	0.14 (24.9)
12/30/97	A, 2	0.65 (7.4)	A, NS	NS
1/7/98	A, 2	0.78 (21.1)	A, 1	0.12 (12.6)
1/14/98	A, 2	0.49 (NS)	A, 1	0.14 (NS)
1/21/98	A, 2	1.18 (24.7)	A, 1	0.03 (NS)
1/28/98	A, 1	0.45 (41.0)	A, 1	0.07 (NS)
2/4/98	A, 2	0.28 (20.6)	A, 1	0.03 (NS)
2/11/98	A, 2	1.36 (40.1)	A, 1	0.13 (11.2)
2/18/98	A, 2	0.70 (23.2)	A, 2	0.21 (20.6)
2/25/98	A, 2	1.34 (38.2)	A, 1	0.14 (38.6)
3/4/98	A, 2	0.48 (24.1)	A, 1	0.14 (41.4)
3/11/98	A, 2	0.48 (19.7)	A, 1	0.11 (NS)
3/18/98	A, NS	NS	A, 1	0.13 (32.7)
3/26/98	A, 1	1.51 (48.9)	A, 1	0.17 (28.0)
4/1/98	A, 1	0.51 (47.1)	A, 1	0.04 (NS)
4/8/98	A, 1	0.27 (28.3)	A, 1	0.20 (32.0)
4/15/98	A, 1	0.94 (28.0)	A, 1	0.09 (NS)
4/22/98	A, 2	0.97 (39.5)	A, 1	0.08 (NS)
4/29/98	A, 2	1.62 (37.3)	A, 1	0.06 (NS)
5/6/98	A, 2	0.89 (21.6)	A, 1	0.15 (37.3)
5/13/98	A, NS	NS	A, 1	0.14 (26.6)
5/21/98	C, 3	0.20 (24.1)	C, NS	NS
5/27/98	C, NS	NS	C, 3	0.19 (12.3)
6/3/98	C, NS	NS	C, 3	0.22 (15.1)
6/10/98	C, 3 & A, 2	0.53 (27.3)	C, 3	0.14 (3.8)
6/18/98	A, 2	0.55 (22.0)	A, 1	0.20 (44.6)
6/24/98	C, 3	0.19 (8.7)	A, 1	0.16 (46.1)
7/8/98	A, 2	0.37 (6.0)	A, 1	0.07 (NS)
7/15/98	A, 2	0.35 (8.4)	C, 3	0.09 (NS)
7/22/98	A, 2	0.31 (9.4)	A, 1	0.08 (NS)
7/29/98	C, 3	0.15 (21.4)	C, 3	0.14 (8.6)
8/5/98	C, 3	0.07 (NS)	C, 3	0.11 (18.6)
DATA SUMMARY	A, 1	Average = 0.59 (36.9) Std. Dev. = 0.44 (9.0)	A, 1	Average = 0.11 (31.9) Std. Dev. = 0.05 (11.1)
	A, 2	Average = 0.78 (23.3) Std. Dev. = 0.41 (11.3)	A, 2	Average = 0.21 (20.6) Std. Dev. = NA (NA)
	B & C, 3	Average = 0.21 (16.9) Std. Dev. = 0.18 (7.1)	C, 3	Average = 0.15 (11.7) Std. Dev. = 0.05 (5.7)

NS- *No sample was collected or silica percentage was not reported because of low or high sample weights.*

during the eight-month sampling period. One likely explanation for this silica dust difference is the actual design dissimilarities between these drills. Drill 1 had no air conditioning system for its enclosed cab, less bailing air capacity, less collector capacity, and less-pull down thrust than drill 2. Although the individual effects of these dissimilarities could not be quantified, the overall observation was that drill 1 had more silica dust content in its operator cab than drill 2.

These long-term sampling data indicate that ARD concentrations and silica dust content can be highly variable at surface coal mining operations. The drills had higher dust levels with more variations (0.62 mg/m^3 average with a 0.07 to 1.51 mg/m^3 range) than the bulldozers (0.12 mg/m^3 average with a 0.03 to 0.22 mg/m^3 range). Also, the silica content varied notably at each mine for all the equipment sampled. Thus, accepted dust control methods and good equipment operating procedures must be diligently practiced daily to consistently achieve low ARD and silica dust concentrations.

5 CONCLUSIONS

Results of the surface mine field assessments show that the accepted dust control technologies have the ability to achieve lower silica dust level requirements for highwall drill and bulldozer operators. To achieve these low dust levels, all the engineering controls require quality upkeep with good operating practices followed. The highwall drill was the major and most variable dust source as compared to the bulldozer. The drill's primary dust collector system was observed to have several inherent weaknesses, with dust generation problems evident at four of the drills studied. The most common problem was drill dust containment and capture from under the shrouded drill table. Drill dust commonly escaped through gaps in or around the shroud and through the drill stem seal at the top of the drill table. When containment problems with the shrouded drill table were rectified, significant dust reductions were realized. These containment problems were not always easily corrected, because of uneven drilling surfaces or hard- to-seal areas between the rotating drill stem and fixed drill table surface. Enclosed cab usage on the drills maintained dust levels significantly lower than at the generation source. Dust levels in the operating cabs were more than 90% lower than dust levels next to the drill table shroud. The bulldozers generated dust one order of magnitude lower than the drills, and dust levels inside the enclosed cabs were consistently maintained under 0.2 mg/m^3. Long-term sampling of several of these highwall drills and bulldozers showed that the dust levels in drill cabs were frequently higher than 0.2 mg/m^3 and more variable than in the bulldozers. The bulldozer dust levels infrequently exceeded 0.2 mg/m^3. The higher and more variable dust levels in the drill cabs were likely caused by drill dust collector performance variations and/or occasional opening of cab doors during drilling.

Silica dust was a concern for the equipment operators at these surface mines. Over two-thirds of the dust samples had greater than 20 % silica content. Silica content measured inside the enclosed cabs was noticeably lower than at the source of generation outside the cabs for both the highwall drills and bulldozers. The authors postulate that this difference in silica content may be due to another source of dust generation from inside the cab. Mud and dirt were found on the floor in many of the enclosed operator cabs and were likely entrained into the recirculating airstream of the cab. The long-term silica content in the dust was quite variable between operating shifts, with average silica differences evident between mines, and silica conformity evident between some of the equipment operated at the same mine. One of the most significant differences in percent silica content of the dust was measured between two distinctly different highwall drills operating at the same mine. This result was surprising and suggests that some drill design and operating parameters may affect silica dust generation.

Future research work on silica dust abatement at surface mining operations should focus on improving some of the deficiencies present in the drill's primary dry dust collection system and developing quality control methods to ensure the integrity of enclosed cab protection for equipment operators. The major weakness observed with the drill's primary dry dust collection system is dust containment and capture above the collared hole. The collector inlet is commonly located on a remote side of the shrouded drill table to avoid large drill cuttings from being drawn into the collector. Any gaps underneath or in the shrouded drill table permit the fine dust to escape the remotely located collector inlet, which is multiple-duct diameters away from most of the shrouded volume. Development of an improved shroud and/or a drill cuttings pre-separator collection hood-centrally located over the drill hole, is needed to improve the containment and inlet capture over a greater area under the shroud. Enclosed cab air filtration systems were found to be very effective at maintaining low dust levels, but quality control methods need to be developed to quickly identify when these systems are not being operated under optimal conditions. The essential operating parameters of these cabs must be identified with the development of measuring criteria to reliably optimize their effectiveness.

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