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Coal-Cutting Forces and Primary Dust Generation Using Radial Gage Cutters

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm	centimeter	J/g	joule per gram
cm/min	centimeter per minute	lb/cu ft	pound per cubic foot
cu μm	cubic micrometer	mg/cu m	milligram per cubic meter
cu μm/g	cubic micrometer per gram	mg/ton	milligram per short ton
g	gram	μm	micrometer
in	inch	N	newton
in/min	inch per minute	pct	percent
in sq	inch square		

COAL-CUTTING FORCES AND PRIMARY DUST GENERATION USING RADIAL GAGE CUTTERS

By Wallace W. Roepke[1] and Jon I. Voltz[2]

ABSTRACT

The Bureau of Mines determined coal-cutting forces and primary dust generation of four styles of radial gage bits as used on end rings of continuous mining machines. Direct comparisons for reference were made with two widely used conical plumb-bob types having 60° and 90° (nominal) included tip angles. The cutting forces for all of the gage bits were similar to those of the 60°-tip plumb-bob bit. All bits except the RAD-3 gage bit generated similar amounts of primary total dust at shallow cutting, but during deeper cutting, the amounts varied and the gage bits produced as much as 2-1/2 times the dust produced by the 60° bit. This seems atypical since past experience has always shown differences in dust generation at shallow cutting. The specific energy was more like that found previously with other bits, since the values were spread at shallow cutting but became nearly similar at deeper cuts. The 90° bit and the RAD-3 gage bit are not recommended for use except in extremely difficult cutting conditions where dust and forces are of secondary importance. The choice among the remaining four bits can be made on the basis of dust, energy, forces, or cost, as circumstances dictate.

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INTRODUCTION

The Federal Coal Mine Health and Safety Act of 1969, with revisions in 1977, was enacted to ensure more healthful and safer working conditions for miners. The Bureau of Mines coal-cutting research facility at Twin Cities (MN) is examining fundamental aspects of the cutting system, including generation of primary dust causing pneumoconiosis in miners and ignition of methane by the frictional impact of cutting bits used on continuous mining machines (CMM's). The cutting system is defined as the cutter-mineral interface area with all its variables, e.g., forces, speed, cutter geometry, bit-mounting geometry, and wear. It has become obvious over the past several years that the cutting system directly affects the economics and design of the "total system," which is defined as all areas of the operation, from the mine face to the preparation plant, which support the mineral recovery by cutting tools to obtain a salable product.

Over 2,000 CMM's in use in the United States today account for well over half of our underground coal production. Studies have identified the CMM operators and helpers as those in the "high risk" occupations for dust exposure on continuous sections. Reducing the individual's exposure to levels at or below the mandated 2 mg/cu m by controlling primary dust generation during cutting will substantially reduce dust throughout the mine and improve the environment for thousands of miners. Reduction of the primary dust hazard will also improve secondary dust controls, substantially increasing their usefulness and the economic return, without increasing regulatory control. Long-term solutions to the primary respirable dust problem are not immediately obvious despite a major effort to establish the background knowledge and expertise necessary. The problem, however, is a continuing burden on the mining industry, taxpayers, and miners, which merits corrective action. Between 1970 and 1980, the Federal Government paid over $11.7 billion to more than 470,000 miners and survivors (3).[3]

This report covers one segment of a large, ongoing series of fundamental studies that are aimed at a better understanding of the use and design of coal cutters in a manner that reduces primary dust while increasing the economic return for the operator. In this study, four types of gage-cutting radial bits and two types of conical plumb-bob bits were tested to establish comparisons of orthogonal cutting forces, specific energy, and specific primary airborne respirable dust (ARD). The goal sought was a cutting bit application that afforded maximum coal production with minimum orthogonal force and minimum ARD production.

ACKNOWLEDGMENTS

The authors appreciate the laboratory expertise of Ted Myren, mining engineering technician, Twin Cities Research Center, who ran all of the tests for this research, producing careful, high-quality results. The extensive assistance of Bruce Hanson, physical scientist, and Jeffrey Fritz, mining technician, both of Twin Cities, with data analysis and programing is also appreciated.

GENERAL TEST DESCRIPTION

The bits used for this research (fig. 1) are standard, commercial radial and plumb-bob type cutting tools. Several reports have been published (1, 4-6) on cutting forces and primary dust generation with plumb-bob tools. They are used in this study only as a basis for comparison, since most cutters used in the United States on CMM's are conical plumb-bob type. The radial cutters are

[3]Underlined numbers in parentheses refer to items in the list of references preceding the appendixes.

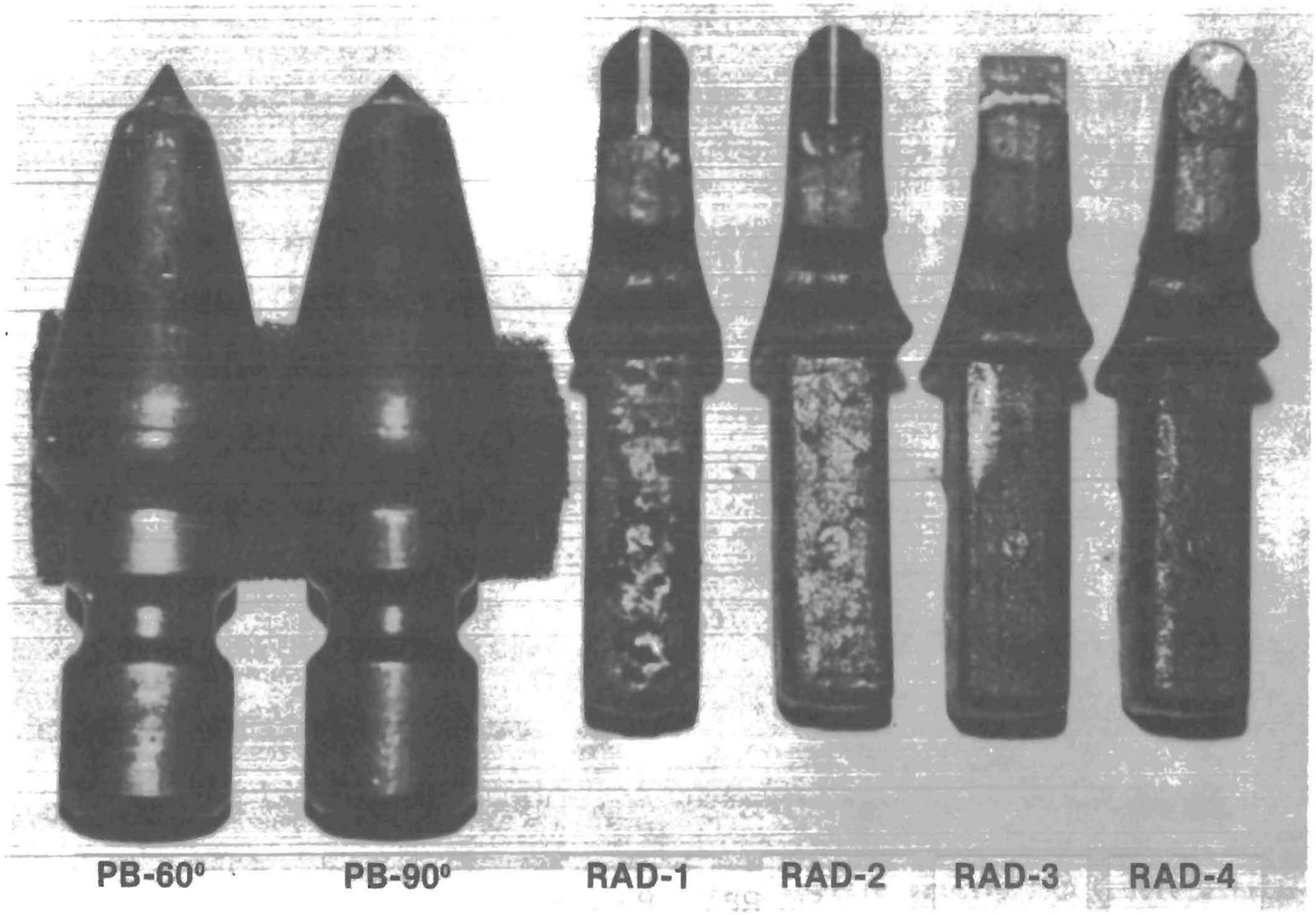

FIGURE 1. Test bits. PB-60 reference bit is 4-7/8 in long.

the type used on CMM's for rock cutting and/or gage cutting. They are also called ring cutters, since they are usually on the end rings of CMM's cutting clearance in the rib. It is this rib- or gage-cutting feature that this report discusses. There are more gage cutters on an end ring per cutting row than any other area of the drum head. Having multiple gage cutters per row on the ends means that they will always be working at less than the maximum depth of the conical bits on the rest of the drum. It is for this reason that a complete review of their operating characteristics is important.

TEST FACILITY

The test equipment has been fully described elsewhere (6), so only a summary is given here. The major equipment is a large, modified planer mill (fig. 2), with a three-axis dynamometer and optical particle sizer. The dust sampler, bit, and the dynamometer are shown in figure 3, with the dust shrouds removed for clarity. The planer mill has been modified by removing the quill head and motor from the overhead rail and replacing them with a rigid mount to support the dynamometer. On top of the dynamometer support is the optical particle sizer with its sampling tube running down into the bit-coal area. The cutter itself is mounted on a 2-in-sq post 10 in long, which is clamped inside the dynamometer assembly. The dynamometer has been calibrated for an X-Y-Z intercept point where the bit tip is 6 in outside the main frame of the dynamometer.

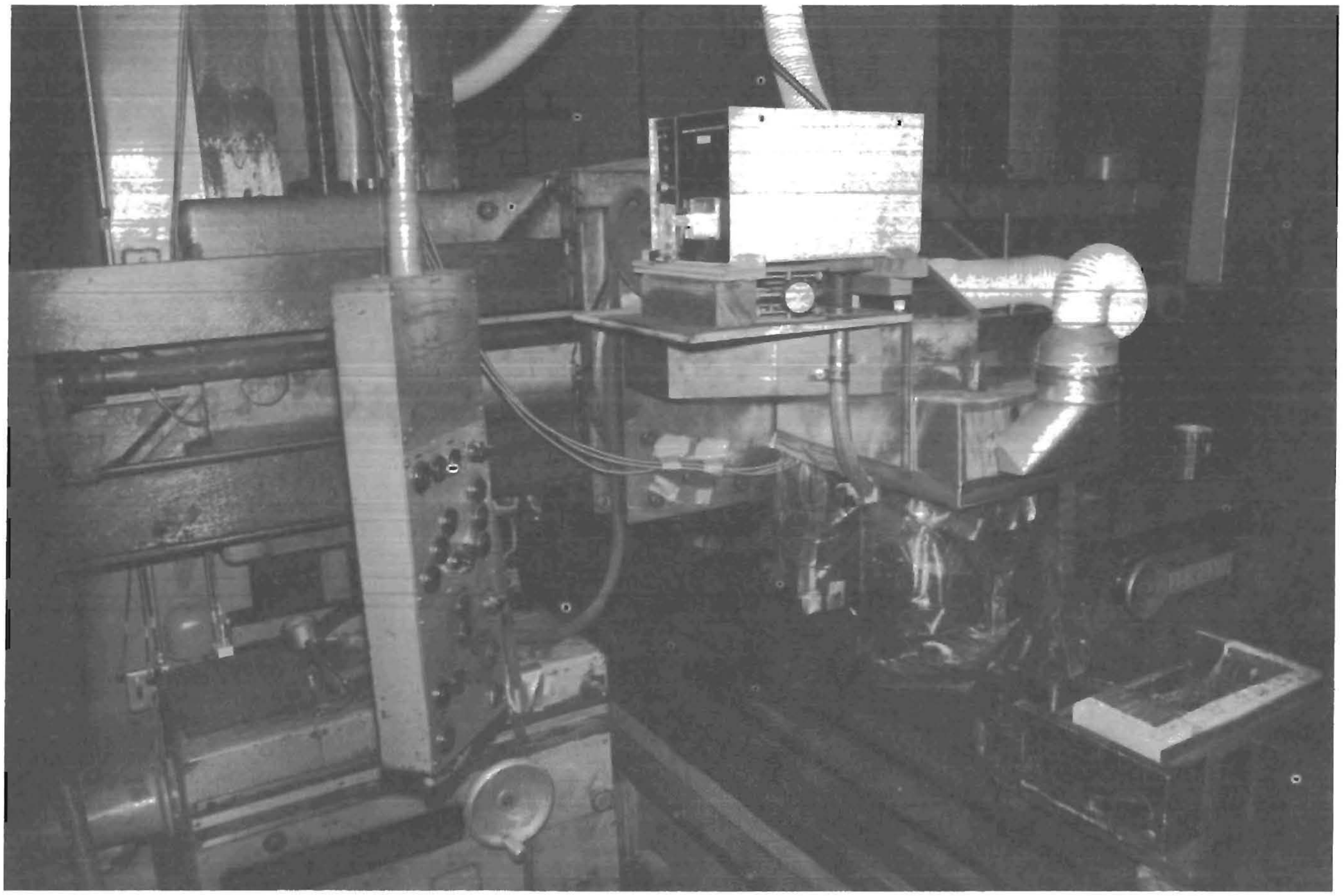

FIGURE 2. - Planer mill.

FIGURE 3. - Dust sampler-bit configuration with shrouds removed.

EXPERIMENTAL DESIGN

All tests were run in an identical manner, using the 60° tip plumb-bob bit as the reference tool. Coal test samples were locked in the holder, which was mounted rigidly to the bed of the test machine. The bed and sample were then moved under the rigidly mounted cutter at a preset depth of cut. One row of cuts was always made on the saw-cut top surface to prepare each block for the actual tests. No data were recorded for the flat, saw-cut first surfaces. Multiple cuts were made in each test block, but clearing cuts were made on the top and at each side to avoid end effects. A complete description of the sample preparation and test method can be found in an earlier report (4).

Test conditions were--

1. Constant spacing of 5.08 cm (2 in) between cuts.

2. A 5.08-cm/min (2-in/min) cutting speed.

3. All cuts perpendicular to bedding planes in Illinois No. 6 coal.

4. Minimum of 15 replications.

5. Total length of cut of 9.84 cm (3.875 in) for all runs (1-15/16-in/min for 2 min).

The independent variables for these tests were--

1. Two conical plumb-bob reference bits (60° and 90° tips) mounted at a 45° attack angle.

2. Four radial gage cutters mounted 90° to cutting direction.

3. Four depths of cut of 0.318 cm (1/8 in), 0.635 cm (1/4 in), 1.270 cm (1/2 in), and 2.540 cm (1 in).

The dependent variable information obtained was--

1. Mean and peak[4] horizontal cutting forces (newtons).

2. Mean and peak normal forces (newtons).

3. Weight of coal removed (grams).

4. Total primary ARD (cubic micrometers per gram).

5. Specific primary ARD (cubic micrometers per gram).

6. Calculated weight of ARD (milligrams per short ton coal).

7. Specific energy (joules per gram).

RESULTS AND DISCUSSION

All dependent variable data are presented in table 1. The data for each parameter are also shown graphically in figures 4 through 10.

CUTTING FORCES

All curves showing average horizontal cutting forces in figure 4 were similar except for the isolated higher level trace made by the 90° conical bit. A moderate divergence of these cutting bit force trajectories was seen at the 2.54-cm (1-in) depth. The RAD-1 bit had the lowest average horizontal force throughout the tests. The 90° plumb bob showed the highest trace for this parameter over the same complete depth range. The average horizontal peak forces, shown in figure 5, were in a different sequence than the corresponding average horizontal forces, shown in figure 4. The horizontal peak forces showed somewhat less convergence at the 0.318-cm (1/8-in) depth than did the average horizontal forces. At depths beyond 0.635 cm (1/4 in), the RAD-3 bit showed the highest horizontal peak force, and the 60° plumb bob showed the lowest.

[4] A peak force is a measure of maximum levels of force.

TABLE 1. - Summary of test results

Bit type	Coal cut, g	Cutting forces, N						Airborne dust			Specific energy, J/g
		Hor. avg.	Hor. peak	Normal avg.	Normal peak	Resultant avg.	Resultant peak	Total, cu µm	Specific, cu µm/g	Weight, mg/ton coal	
					0.318-cm (1/8-in) DEPTH						
PB-60..	6.8	241	952	221	824	328	1,269	1.867E+07	2.993E+06	3,481	3.59
PB-90..	8.0	721	2,729	974	3,413	1,212	4,381	4.011E+07	4.932E+06	5,737	9.36
RAD-1..	8.5	183	847	155	487	241	982	4.914E+07	5.135E+06	5,972	2.14
RAD-2..	7.6	169	800	110	465	203	933	3.657E+07	4.608E+06	5,359	2.20
RAD-3..	9.7	174	955	75	298	189	1,002	9.364E+07	9.438E+06	10,977	1.79
RAD-4..	9.3	269	1,096	349	1,036	442	1,523	3.154E+07	4.044E+06	4,703	3.09
					0.635-cm (1/4-in) DEPTH						
PB-60..	21.9	621	2,300	529	1,738	817	2,889	3.753E+07	1.492E+06	1,735	3.16
PB-90..	25.6	1,417	4,183	1,873	4,567	2,352	6,209	5.099E+07	2.187E+06	2,543	6.07
RAD-1..	19.3	425	1,655	262	639	503	1,786	3.359E+07	1.767E+06	2,055	2.24
RAD-2..	22.7	489	1,971	298	983	574	2,218	3.393E+07	1.527E+06	1,777	2.18
RAD-3..	21.8	434	2,305	154	667	461	2,402	1.339E+08	6.587E+06	7,661	2.00
RAD-4..	18.8	538	2,079	549	1,340	771	2,488	3.741E+07	2.126E+06	2,473	2.97
					1.270-cm (1/2-in) DEPTH						
PB-60..	67.8	1,321	3,827	807	2,044	1,554	4,347	3.581E+07	4.951E+05	576	2.04
PB-90..	64.4	1,953	5,003	2,155	4,890	2,912	7,022	5.092E+07	9.789E+05	1,139	3.29
RAD-1..	66.2	999	3,915	312	896	1,050	4,026	8.377E+07	1.298E+06	1,509	1.59
RAD-2..	64.5	1,108	4,812	395	1,371	1,179	5,025	4.985E+07	7.708E+05	896	1.81
RAD-3..	66.0	1,158	5,927	341	1,481	1,209	6,119	1.681E+08	2.692E+06	3,131	1.80
RAD-4..	55.9	1,137	4,268	774	1,792	1,380	4,664	7.958E+07	1.454E+06	1,691	2.11
					2.540-cm (1.0-in) DEPTH						
PB-60..	166.9	2,140	6,071	998	2,395	2,375	6,546	3.414E+07	2.050E+05	238	1.33
BP-90..	167.3	3,003	8,800	2,492	5,933	3,907	10,656	4.488E+07	2.544E+05	296	1.79
RAD-1..	146.1	1,896	7,117	382	1,057	1,940	7,207	1.317E+08	9.504E+05	1,105	1.39
RAD-2..	190.0	2,759	9,311	591	1,755	2,827	9,502	1.738E+08	9.732E+05	1,132	1.48
RAD-3..	182.3	2,728	9,690	712	2,461	2,821	10,015	1.208E+08	6.725E+05	782	1.48
RAD-4..	169.5	2,279	7,728	786	1,836	2,415	7,957	7.897E+07	4.828E+05	561	1.42

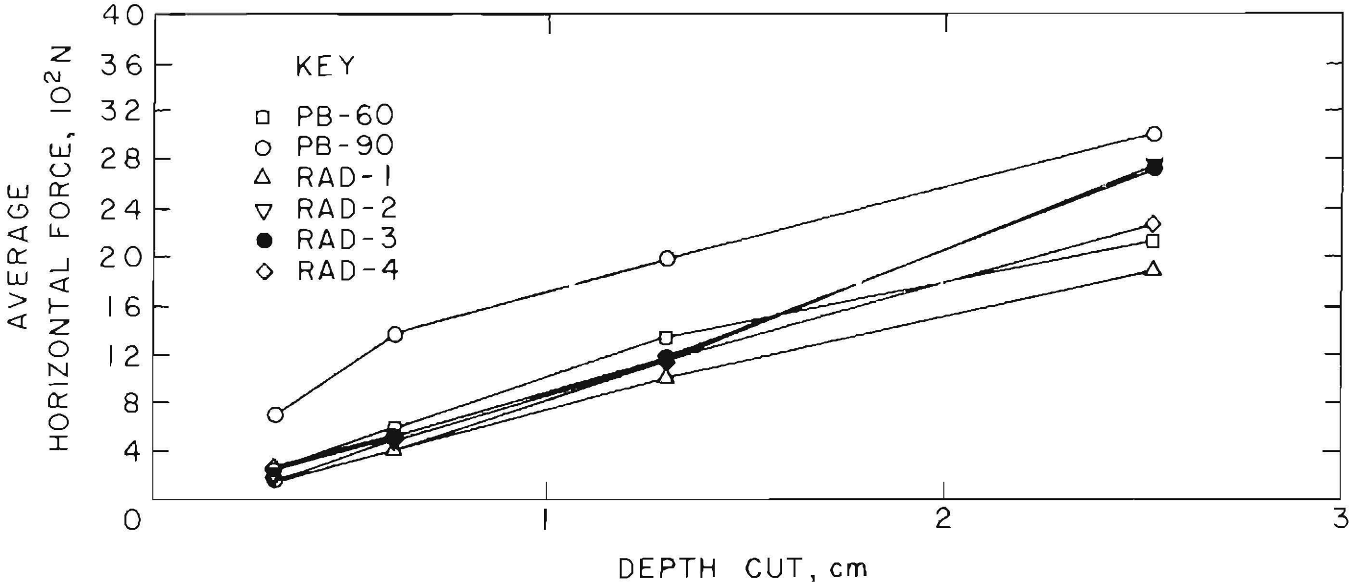

FIGURE 4. - Average horizontal forces.

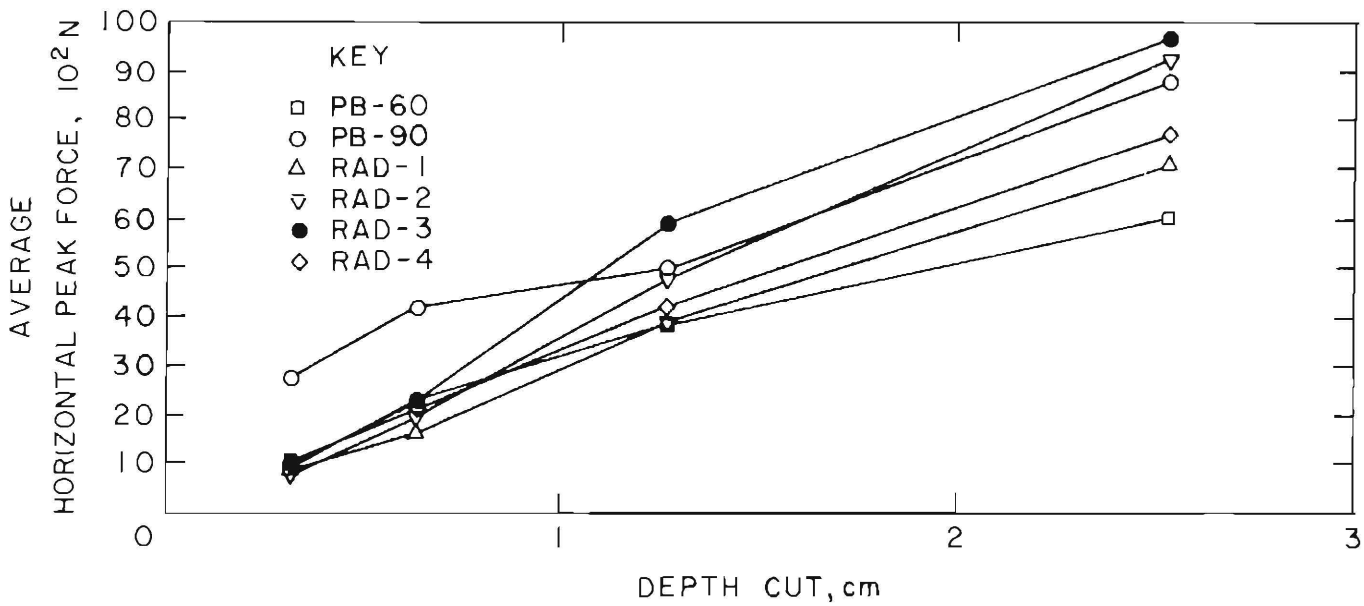

FIGURE 5. Average horizontal peak forces.

The results for average normal forces, in figures 6 and 7, could not be predicted from the corresponding horizontal forces. The only exceptions to this were the relatively higher trace made by the 90° plumb-bob bit and the lowest or next to the lowest level trace made by the RAD-1 bit in both the horizontal and the normal force plots. All of the test bits except for the 90° plumb bob had forces close to that traced by the RAD-1 bit in plots of both types of normal force, at all depths. The radial bits had lower values than did the 60° reference bit.

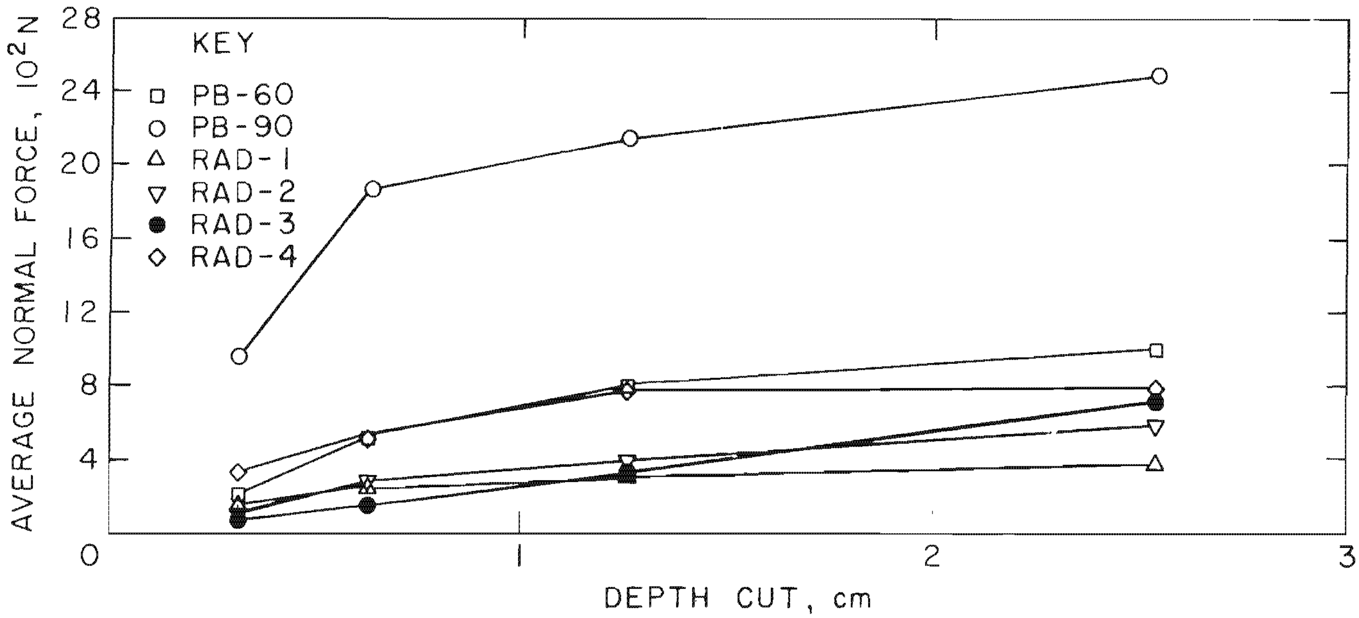

FIGURE 6. Average normal forces

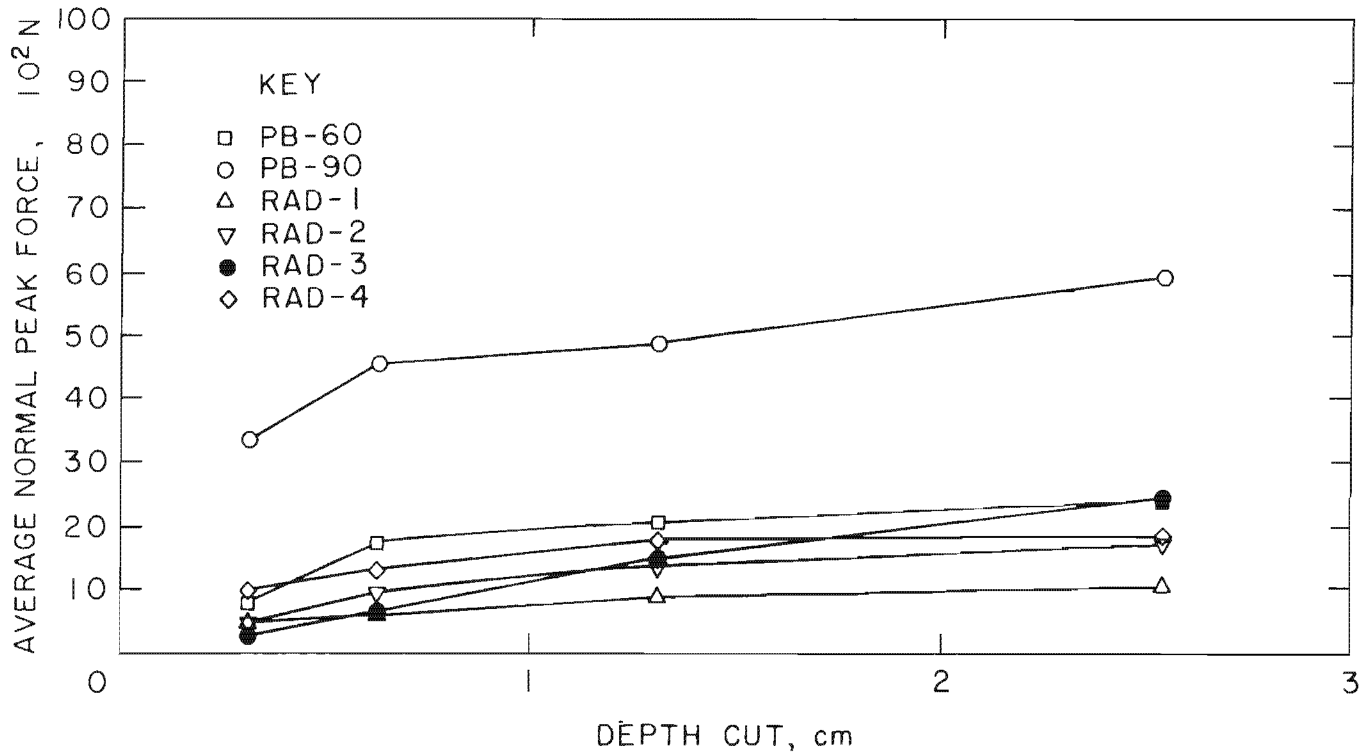

FIGURE 7. - Average normal peak forces.

ENERGY

The general shape of the horizontal specific energy curves in figure 8 agrees with previous research results; i.e., the energy values were highest at shallow cutting, and they dropped and converged at deeper depths. As would be expected,

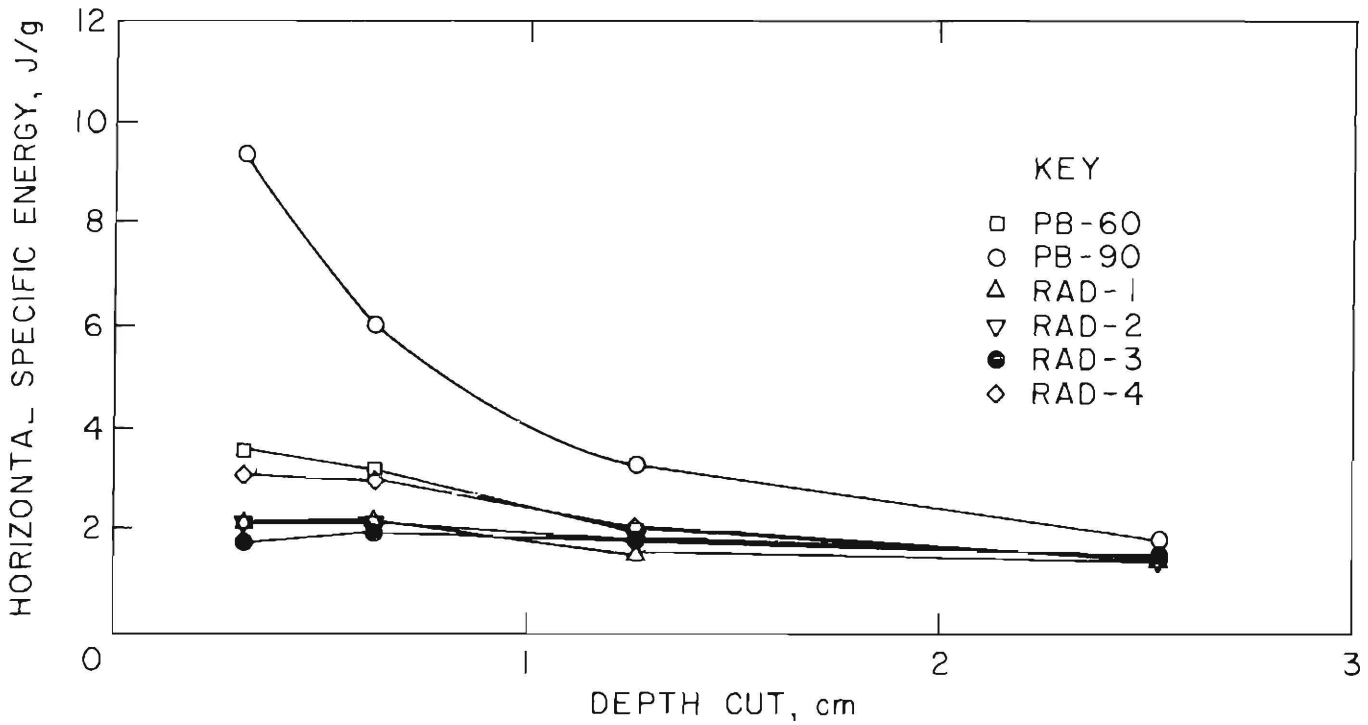

FIGURE 8. Horizontal specific energy.

the shapes of these specific energy curves reflect the data for horizontal average cutting forces in figure 4. Since specific energy is force times distance, divided by cut material weight, the specific energy curves are the reciprocal of the horizontal force curves. They converge and decline at deeper cuts while the reverse is true for both types of horizontal forces. Again, the 90° plumb bob produced traces higher than those made by other bits, and the 60° bit data were between the radial bit data.

DUST GENERATION

The respirable dust curves in figures 9 and 10 do not reflect any of the bit data for force energy. The data for total dust (fig. 10) converged somewhat at shallow cuts but diverged at deeper cuts. This is different from results of previous conical bit tests, which showed divergence at shallow cutting. The specific dust (ARD) data did follow the expected trend, however, showing the highest level of dust at shallow cutting and decreasing dust (and data convergence) as cutting depth increased.

For total dust, at 0.318-cm (1/8-in) and 0.635-cm (1/4-in) cutting depths, all of the bits except RAD-3 produced approximately the same mass of dust; beyond the 0.635-cm (1/4-in) depth, the two conical bits produced the lowest levels of total dust. The 60° reference bit produced the least amount of both types of dust at all depths; the RAD-3 bit produced the greatest amount, except at the 2.540-cm (1-in) depth. The 90° conical bit produced an intermediate level of specific ARD at the 1.270-cm (1/2-in) depth and next to the least level of specific ARD at the 2.540-cm (1-in) depth. Appendix B gives the primary respirable dust distribution between 0.2 and 10 µm in seven class intervals. The calculated value for ARD in milligrams per short ton does not include secondary dust generated by regrinding, gathering head dust, or dust distribution by fanning action.

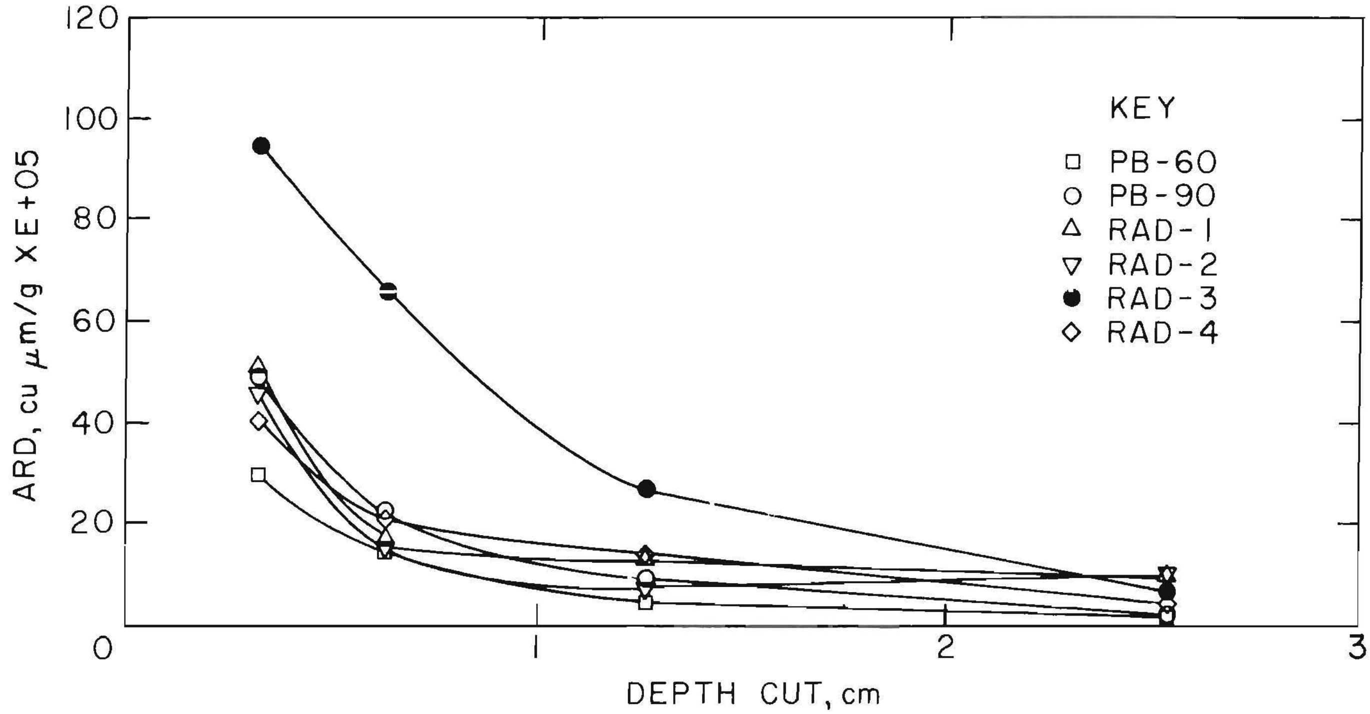

FIGURE 9. Specific primary airborne respirable dust (ARD)

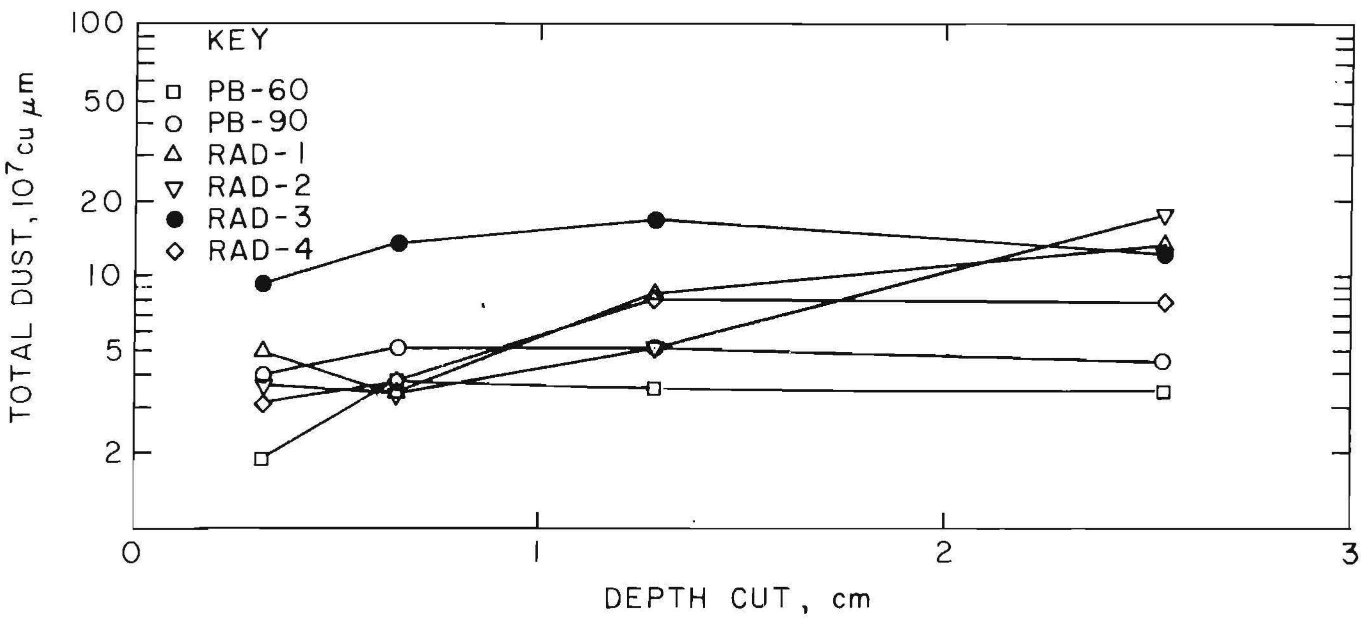

FIGURE 10. Total primary airborne respirable dust.

SUMMARY AND CONCLUSIONS

These data clearly show that no single variable can be a guide to machine design or dust control. For instance, of all bits tested, RAD-1 had close to the lowest specific energy with low peak and average normal and horizontal forces, but it had an undesirably high production of both specific and total respirable dust. It is readily apparent that determining the best system for mineral recovery requires an integrated knowledge of all cutting variables.

Clearly, dust reduction by selection of an optimum cutting tool for the seam being mined is highly desirable and will be economically advantageous since it will reduce both regulatory concerns and needs for secondary control. If, however, the cutting tool is chosen solely on the basis of dust control, it could significantly increase other costs. It may be that a cutter has undesirable characteristics for the seam being mined. The 90° plumb bob, one of the widely used bits, is an excellent example. It has low dust generation (figs. 9-10) but very high normal forces (figs. 6-7), with a high specific energy (fig. 8) and high average horizontal force (fig. 4). These high forces require a larger mainframe mass and greater horsepower to obtain optimum depth of sump to keep cutting deep enough to maintain low dust. The net effect would be either high levels of dust from poor sumping characteristics and poor dust control, or higher capital expense to buy a larger machine.

Based on these test results, two of the bits would not be recommended except in extreme conditions where force and dust are of secondary importance to mineral recovery. This would not include any cutting in coal unless it had large amounts of intrusive materials. The two bits not recommended are the 90° plumb bob, which required unusually high specific energy and both normal forces, and the RAD-3 bit, which generated substantially more dust than all the others except at a 2.54-cm (1-in) depth.

Among the remaining four bits, the choice could be made on economics alone or the operator could optimize his cutting system for the variable of greatest concern. While there is no clear choice, the 60° plumb-bob conical and RAD-1 radial bit had the best overall performance for the two respective styles. The 60° plumb bob required too much specific energy during shallow cutting, and the RAD-1 produced too much dust at deeper cuts. However, a complete review of all data shows that their peak and mean forces are generally the lowest for each style. RAD-1 has the lowest average horizontal and normal forces. The 60° plumb bob has the lowest average peak horizontal forces. Of the bits tested, either the plumb bob with a 60° tip or the RAD-1 style would be a good choice in coal with minimal inclusive material.

Within the limitations and qualifications inherent in this study, the results suggest that the 60° plumb-bob conical bit offers the best performance with minimum dust output and maximum energy economy per unit weight coal recovered when cutting at 2.54 cm (1 in) instead of shallower depths.

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APPENDIX A.--MEAN VALUES FOR EACH TEST

Tables A-1 through A-6 give the mean values for each test with radial gage cutters and include horizontal, normal, and lateral forces, weight of coal cut, respirable dust per gram cut, and total respirable dust. Conversion factors for some of the measurements used in these tables are as follows:

Unit of measure	To convert to--	Multiply by--
cubic micrometer ARD per gram coal	milligrams ARD per short ton coal (where weight of coal = 80 lb/cu ft)	1.163×10^{-3}
joule per gram of coal cut	foot pounds per pound of coal cut	334.9
newton	pounds force	.2248
newton	specific energy, in joules per gram	.09842 and divide by grams of coal cut.

TABLE A-1. - TEST RESULTS FOR PB-60

BLOCK	CUT WEIGHT, G	CUTTING FORCES, N						AIRBORNE DUST		SPECIFIC ENERGY, J/G
		HOR. AVG.	HOR. PEAK	NORMAL AVG.	NORMAL PEAK	RES. AVG.	RES. PEAK	TOTAL, CU µM	SPECIFIC, CU µM/G	
				0.318-CM DEPTH						
1........	8.0	205	600	151	636	254	875	3.912E+06	4.890E+05	2.52
	7.8	249	827	200	845	320	1187	9.329E+06	1.196E+06	3.14
	7.8	280	752	249	818	375	1111	2.969E+07	3.807E+06	3.54
2........	6.2	236	770	205	672	312	1021	9.536E+06	1.538E+06	3.74
	4.7	294	903	325	1027	438	1363	4.407E+07	9.376E+06	6.15
	7.0	294	787	325	725	438	1070	1.231E+07	1.759E+06	4.13
3........	7.4	400	2024	365	1210	542	2358	7.548E+06	1.020E+06	5.32
	9.1	236	1188	169	641	290	1349	1.871E+07	2.056E+06	2.55
	6.3	169	658	125	294	210	721	7.113E+06	1.129E+06	2.64
4........	5.7	267	792	280	912	387	1208	1.876E+07	3.291E+06	4.61
	5.1	151	645	138	645	205	912	1.219E+07	2.390E+06	2.92
	7.1	191	996	173	1032	258	1434	9.812E+06	1.382E+06	2.65
5........	6.4	191	814	187	654	267	1044	2.789E+07	4.358E+06	3.94
	5.9	214	1032	196	850	290	1337	4.742E+07	8.038E+06	3.56
	7.1	245	1491	227	1397	334	2056	2.181E+07	3.072E+06	3.39
AVERAGE..	6.8	241	951	221	824	328	1268	1.867E+07	2.993E+06	3.59
STD. DEV.	1.2	62	374	73	269	93	430	1.335E+07	2.580E+06	1.07
				0.635-CM DEPTH						
1........	24.3	338	1263	302	1245	454	1774	5.254E+06	2.162E+05	1.37
	22.5	498	2971	436	2615	662	3958	6.921E+07	3.076E+06	2.18
	19.2	436	1348	360	1170	566	1785	2.189E+07	1.140E+06	2.23
2........	13.7	418	1699	387	1312	570	2147	5.505E+06	4.018E+05	3.00
	16.2	569	1579	520	1495	771	2174	3.815E+06	2.355E+05	3.46
	17.2	449	2451	396	1566	599	2908	2.320E+06	1.349E+05	2.57
3........	19.8	574	2789	449	1806	729	3323	4.904E+06	2.477E+05	2.65
	14.0	983	3865	934	2491	1356	4598	3.284E+07	2.346E+06	6.91
	25.1	876	2931	747	2188	1152	3658	1.473E+08	5.867E+06	3.44
4........	16.9	814	3421	729	2344	1093	4147	1.178E+07	6.969E+05	4.74
	22.1	756	2304	623	1744	980	2889	4.981E+07	2.254E+06	3.37
	18.0	845	2086	721	2002	1111	2891	2.533E+07	1.407E+06	4.62
5........	56.0	587	1895	369	1299	694	2297	1.485E+08	2.651E+06	1.03
	24.4	538	1850	396	1343	668	2287	1.175E+07	4.816E+05	2.17
	18.5	632	2033	556	1432	841	2487	2.270E+07	1.227E+06	3.36
AVERAGE..	21.9	621	2299	528	1737	816	2888	3.753E+07	1.492E+06	3.15
STD. DEV.	10.1	192	764	184	482	263	879	4.854E+07	1.557E+06	1.46
				1.270-CM DEPTH						
1........	61.2	1112	2985	436	1432	1194	3310	1.571E+07	2.567E+05	1.79
	63.7	974	2678	632	1441	1161	3041	9.300E+06	1.460E+05	1.51
	82.4	1379	3785	858	1966	1624	4265	7.981E+07	9.686E+05	1.65
2........	52.7	1143	3100	858	2122	1430	3757	2.477E+07	4.700E+05	2.14
	44.2	1228	3977	939	2469	1545	4680	9.454E+06	2.134E+05	2.73
	53.5	1139	3692	801	2086	1392	4240	4.589E+06	8.577E+04	2.09
3........	78.5	1414	4555	663	2264	1562	5086	7.753E+06	9.876E+04	1.77
	42.3	2144	5582	1735	3514	2758	6596	1.022E+07	2.417E+05	4.99
	93.7	1495	4586	805	2055	1698	5025	2.280E+07	2.433E+05	1.57
4........	76.6	1659	3398	792	1899	1838	3893	2.431E+07	3.174E+05	2.13
	61.0	1468	3576	890	2113	1716	4154	1.150E+07	1.886E+05	2.37
	79.6	1103	3790	547	1957	1231	4265	4.085E+06	5.132E+04	1.36
5........	75.1	823	2291	463	1223	944	2597	4.280E+07	5.699E+05	1.08
	64.8	867	3501	498	1268	1000	3723	1.190E+08	1.836E+06	1.32
	86.9	1864	5889	1179	2833	2205	6535	1.511E+08	1.739E+06	2.11
AVERAGE..	67.8	1721	3826	806	2043	1553	4345	3.581E+07	4.951E+05	2.04
STD. DEV.	15.5	367	991	327	602	472	1128	4.507E+07	5.737E+05	.93
				2.540-CM DEPTH						
1........	138.5	952	2736	583	1828	1116	3290	1.587E+07	1.146E+05	.68
	295.9	2340	6076	600	1659	2415	6296	1.046E+08	3.536E+05	.78
	165.9	2862	6104	1561	3591	3000	8860	2.870E+07	1.730E+05	1.52
2........	133.1	2349	5404	1130	2091	2606	5795	7.309E+06	5.491E+04	1.74
	158.7	1526	5264	801	2188	1723	5719	1.023E+07	6.444E+04	95
	137.1	2237	6383	1339	2736	2607	6944	3.593E+07	2.621E+05	1.61
3.....	143.3	3883	11249	1810	4737	4284	12206	2.887E+07	2.015E+05	2.67
	218.5	2317	7766	1072	2602	2553	8191	2.978E+07	1.363E+05	1.04
	168.7	2900	7379	1165	2540	3125	7804	4.379E+07	2.596E+05	1.69
4........	171.6	2553	5115	894	2135	2705	5543	4.565E+07	2.660E+05	1.46
	215.2	1908	5226	378	987	1945	5319	1.396E+07	6.489E+04	.87
5........	99.6	1566	5000	1036	1922	1878	5356	4.419E+07	4.437E+05	1.55
	163.6	1125	2762	560	1254	1257	3034	3.941E+07	2.409E+05	.68
	126.4	1735	6472	1032	3269	2018	7251	2.967E+07	2.347E+05	1.35
AVERAGE.	166.9	2139	6068	997	2394	2374	6543	3.414E+07	2.050E+05	1.33
STD. DEV.	49.1	757	2179	402	977	817	2329	2.394E+07	1.134E+05	.54

TABLE A-2. - TEST RESULTS FOR P8-90

BLOCK	CUT WEIGHT, G	CUTTING FORCES, N: HOR. AVG.	HOR. PEAK	NORMAL AVG.	NORMAL PEAK	RES. AVG.	RES. PEAK	AIRBORNE DUST: TOTAL, CU µM	SPECIFIC CU µM/G	SPECIFIC ENERGY, J/G
					0.318-CM DEPTH					
1........	8.8	907	3999	1245	4550	1541	6058	1.544E+07	1.754E+06	10.15
	7.0	396	1761	494	1855	633	2558	3.619E+06	5.170E+05	5.57
	7.4	489	2086	614	2420	785	3195	9.509E+06	1.285E+06	6.51
6........	5.9	645	2197	885	2922	1095	3656	4.285E+07	7.263E+06	10.76
	10.7	1027	4555	1232	4550	1604	6438	1.172E+08	1.095E+07	9.45
	8.7	325	1245	387	1509	505	1956	1.919E+07	2.206E+06	3.67
7........	5.8	885	3007	1302	4488	1579	5402	2.327E+07	4.012E+06	15.02
	6.7	623	2384	850	2962	1053	3803	4.883E+07	7.288E+06	9.15
	8.3	867	4457	1259	4550	1529	6369	6.463E+07	7.787E+06	10.29
8........	10.1	1188	2878	1628	4243	2015	5127	1.139E+08	1.128E+07	11.57
	7.1	876	2829	1205	3870	1490	4794	1.037E+08	1.460E+07	12.15
	5.0	778	2998	1063	4564	1318	5460	9.835E+06	1.967E+06	15.32
9........	5.6	552	1699	734	2415	918	2953	4.216E+06	7.529E+05	9.69
	11.6	707	2451	956	3140	1189	3983	9.550E+06	8.233E+05	6.00
	10.6	547	2366	738	3136	919	2928	1.592E+07	1.502E+06	5.08
AVERAGE..	8.0	72'	2728	973	3412	1212	4379	4.011E+07	4.932E+06	9.36
STD. DEV.	2.1	241	976	345	1065	419	1409	4.092E+07	4.592E+06	3.47
					0.635-CM DEPTH					
1........	26.3	632	1735	645	2095	903	2720	6.996E+06	2.660E+05	2.36
	31.0	729	1953	747	1655	1044	2559	9.994E+06	3.224E+05	2.32
	31.8	1076	3323	1072	3118	1519	4557	1.320E+06	4.150E+04	3.33
6........	38.6	1059	3910	1108	3380	1532	5169	5.304E+07	1.374E+06	2.70
	23.7	1366	6143	1877	5747	2321	8412	1.313E+08	5.540E+06	5.67
	18.2	2513	9141	3656	9114	4437	12908	4.452E+07	2.446E+06	13.59
7........	24.1	1250	3425	1695	4782	2106	5882	1.317E+07	5.463E+05	5.10
	24.5	1094	2162	1575	2722	1917	3476	5.985E+07	2.443E+06	4.40
	28.4	1419	3131	1899	3990	2371	5072	5.282E+07	1.860E+06	4.92
8........	16.9	2655	8140	3723	9897	4573	12814	5.168E+06	3.058E+05	15.47
	25.8	1846	4381	2593	5698	3183	7188	1.618E+07	6.270E+05	7.04
	26.7	1766	5592	2286	5818	2889	8063	2.977E+07	1.115E+06	6.51
9........	21.1	1268	2584	1797	3274	2199	4171	3.013E+08	1.428E+07	5.91
	28.1	1179	3034	1610	3340	1996	4512	2.748E+07	9.780E+05	4.13
	18.1	1392	4070	1806	3643	2280	5598	1.189E+07	6.571E+05	7.57
AVERAGE..	25.6	1416	4181	1873	4565	2351	6207	5.099E+07	2.187E+06	6.07
STD. DEV.	5.8	573	2196	906	2374	1064	3200	7.681E+07	3.623E+06	3.82
					1.270-CM DEPTH					
1........	93.2	489	1130	307	827	578	1400	1.733E+07	1.859E+05	.52
	62.1	1045	2366	1005	2602	1450	3517	1.158E+08	1.865E+06	1.66
	41.0	1895	4804	2028	3781	2776	6113	2.033E+08	4.958E+06	4.55
6........	42.3	2767	6561	3492	7873	4455	10248	9.378E+07	2.217E+06	6.44
	88.8	3047	6792	3189	7014	4411	9764	5.866E+07	6.606E+05	3.38
	96.7	1948	5636	2349	6072	3051	8284	2.863E+07	2.961E+05	1.98
7........	49.0	1753	4346	2073	4425	2714	6209	4.513E+06	9.211E+04	3.52
	64.4	1882	5604	1837	5671	2630	7973	1.358E+07	2.108E+05	2.88
	66.4	1121	3536	1054	1877	1539	4003	3.457E+06	5.207E+04	1.66
8........	44.9	2776	8856	3082	9652	4148	13099	6.609E+07	1.472E+06	6.08
	68.0	3269	8505	3474	7210	4770	11150	1.852E+07	2.724E+05	4.73
	61.5	2522	4114	3122	4719	4014	6261	2.208E+07	3.590E+05	4.04
9........	54.7	1793	4991	2126	4315	2781	6597	5.258E+07	9.613E+05	3.23
	55.5	1815	4559	1988	4626	2692	6495	4.666E+07	8.407E+05	3.22
	78.0	1161	3211	1183	2647	1658	4161	1.877E+07	2.407E+05	1.46
AVERAGE..	64.4	1952	5001	2154	4888	2911	7018	5.092E+07	9.789E+05	3.29
STD. DEV.	17.9	801	2109	981	2408	1256	3141	5.340E+07	1.289E+06	1.70
					2.540-CM DEPTH					
1........	192.0	1899	4391	1570	5080	2464	7121	1.760E+08	9.169E+05	.97
	187.7	3616	8416	2722	6739	4526	10781	4.664E+07	2.485E+05	1.90
6........	103.2	3598	10809	3292	7317	4877	13052	3.125E+07	3.028E+05	3.43
	173.0	3656	12574	3163	8629	4834	15251	2.400E+06	1.387E+04	2.08
	202.3	4177	11685	3647	7584	5545	13930	1.044E+08	5.161E+05	2.03
7........	99.1	1695	4012	1761	3581	2444	5378	4.820E+06	4.864E+04	1.68
	189.2	2842	6103	1975	3634	3461	7103	5.850E+07	3.092E+05	1.48
8........	188.9	4248	11907	3305	7281	5382	13957	4.804E+06	2.543E+04	2.21
	200.7	4799	14145	3594	7473	5996	15997	3.657E+07	1.822E+05	2.35
	172.3	3825	13464	3336	7606	5076	15464	3.008E+07	1.746E+05	2.19
9........	162.6	2242	6628	1748	3603	2843	7544	5.569E+07	3.425E+05	1.36
	132.3	1343	4759	1223	4546	1817	6582	2.229E+07	1.685E+05	1.00
	171.2	1076	4857	1050	4025	1504	6308	9.974E+06	5.826E+04	.62
AVERAGE..	167.3	3001	8796	2491	5931	3905	10651	4.488E+07	2.544E+05	1.79
STD. DEV.	34.6	1224	3742	956	1873	1540	4065	4.853E+07	2.467E+05	.73

TABLE A-3. - TEST RESULTS FOR RAC-1

BLOCK	CUT WEIGHT, G	CUTTING FORCES, N HOR. AVG	HOR. PEAK	NORMAL AVG.	NORMAL PEAK	RES. AVG.	RES. PEAK	AIRBORNE DUST TOTAL, CU µM	SPECIFIC, CU µM/G	SPECIFIC ENERGY, J/G
					0.318-CM DEPTH					
2.......	12.7	111	587	107	320	154	669	9.152E+06	7.206E+05	.86
	6.0	93	512	62	320	112	604	2.908E+07	4.847E+06	1.53
	7.5	125	543	107	356	164	649	8.520E+06	1.136E+06	1.63
6.......	8.5	191	863	169	458	255	977	1.499E+08	1.764E+07	2.21
	7.1	165	801	116	454	201	920	1.496E+07	2.107E+06	2.28
	9.2	267	1174	205	525	336	1286	5.115E+07	5.560E+06	2.86
10	9.0	231	1041	289	787	370	1305	3.452E+07	3.835E+06	2.53
	9.2	187	907	179	596	259	1086	2.430E+07	2.641E+06	2.00
	11.2	222	1081	218	627	311	1250	3.694E+08	3.298E+07	1.95
11.......	9.5	236	1170	156	503	283	1273	7.357E+06	7.744E+05	2.44
	8.7	222	827	160	507	274	970	1.828E+07	2.101E+06	2.52
	8.7	218	898	187	494	287	1025	1.014E+07	1.165E+06	2.47
12.......	9.5	245	1334	187	529	308	1436	4.915E+06	5.174E+05	2.53
	5.3	138	449	129	538	189	701	3.087E+06	5.825E+05	2.56
	5.6	93	507	53	280	108	579	2.330E+06	4.161E+05	1.64
AVERAGE..	8.5	183	846	155	486	241	982	4.914E+07	5.135E+06	2.13
STD. DEV.	2.0	58	280	62	132	81	289	9.594E+07	8.835E+06	.53
					0.635-CM DEPTH					
2.......	18.6	262	1005	191	396	325	1080	5.627E+06	3.025E+05	1.39
	14.6	254	1968	142	356	291	2020	8.332E+06	5.707E+05	1.71
	31.3	338	1103	107	391	355	1170	3.562E+06	1.138E+05	1.06
6........	14.5	423	1446	329	912	536	1709	2.501E+07	1.725E+06	2.87
	13.4	463	1753	374	703	595	1888	1.840E+07	1.373E+06	3.40
	19.5	538	1677	302	654	617	1800	1.857E+07	9.524E+05	2.72
10.......	20.7	494	2558	387	805	627	2681	1.222E+08	5.901E+06	2.35
	16.9	374	1624	285	676	470	1759	8.246E+07	4.879E+06	2.18
	19.0	449	1592	396	752	599	1761	9.276E+07	4.882E+06	2.33
11......	19.9	436	1428	138	369	457	1475	3.425E+07	1.721E+06	2.16
	21.4	449	1632	227	681	503	1769	1.368E+07	6.392E+05	2.07
	25.4	645	3180	325	689	722	3254	5.979E+07	2.354E+06	2.50
12.......	19.8	423	1397	209	707	471	1566	5.603E+06	2.830E+05	2.10
	18.0	347	1179	222	747	412	1396	4.750E+06	2.639E+05	1.90
	16.4	476	1250	294	743	559	1454	8.927E+06	5.443E+05	2.86
AVERAGE..	19.3	425	1654	262	639	503	1795	3.359E+07	1.767E+06	2.24
STD. DEV.	4.5	101	570	93	174	122	555	3.770E+07	1.912E+06	.60
					1.270-CM DEPTH					
2........	63.5	627	3292	218	934	664	3421	1.059E+07	1.667E+05	.97
	70.2	663	2700	240	512	705	2748	1.287E+07	1.833E+05	.93
	77.1	583	2642	133	512	598	2691	7.210E+07	9.352E+05	.74
6........	56.5	1383	5720	578	1917	1499	6033	5.562E+07	9.844E+05	2.41
	54.1	1156	4163	338	694	1205	4221	2.961E+07	5.474E+05	2.10
	103.0	921	4159	289	1268	965	4348	4.988E+07	4.843E+05	.88
10.......	61.0	1116	2936	129	423	1124	2966	3.667E+08	6.012E+06	1.80
	90.4	716	3434	116	396	725	3457	1.183E+08	1.309E+06	.78
	62.2	694	2913	342	1188	774	3146	3.461E+08	5.565E+06	1.10
11......	66.1	1027	4092	387	939	1098	4198	4.589E+07	6.943E+05	1.53
	59.0	1170	5066	383	1156	1231	5197	2.558E+07	4.335E+05	1.95
	61.5	1561	5791	574	1254	1663	5926	6.175E+07	1.004E+06	2.50
12.......	52.2	1156	3968	378	854	1217	4058	1.807E+07	3.462E+05	2.18
	46.4	1148	3122	342	685	1198	3197	2.436E+07	5.250E+05	2.43
	70.0	1059	4706	236	707	1085	4759	1.909E+07	2.727E+05	1.49
AVERAGE..	66.2	999	3914	312	896	1050	4024	8.377E+07	1.298E+06	1.59
STD. DEV.	14.7	291	1042	142	410	311	1083	1.143E+08	1.855E+06	.65
					2.540-CM DEPTH					
2.......	135.7	1343	4960	182	587	1356	4994	3.751E+07	2.764E+05	.97
	165.7	2162	6481	196	654	2171	6514	2.744E+07	1.656E+05	1.28
	194.3	2424	7588	347	818	2449	7632	3.138E+07	1.615E+05	1.23
6.......	45.0	894	4960	351	1050	961	5069	2.182E+07	4.848E+05	1.96
	106.2	1437	4230	342	1054	1477	4359	5.392E+07	5.077E+05	1.33
	179.4	1637	6214	325	961	1669	6288	8.721E+07	4.861E+05	.90
10.......	108.4	3395	8118	898	1721	3502	8298	5.612E+08	5.177E+06	3.07
	196.6	1895	5613	440	1143	1945	5729	1.662E+08	8.455E+05	.95
	187.3	1570	6254	387	1219	1617	6372	3.875E+08	2.069E+06	.83
11.......	124.0	1668	11387	400	1023	1715	11433	7.367E+07	5.941E+05	1.32
	148.9	3581	7740	418	983	3605	7802	3.736E+08	2.509E+06	2.37
	150.7	1481	11387	556	1392	1582	11472	8.132E+07	5.396E+05	.97
12.......	175.1	1437	4559	294	1357	1466	4757	3.787E+07	2.163E+05	.81
	180.9	1512	8723	191	565	1524	8741	2.726E+07	1.507E+05	.82
	93.9	2006	8500	405	1321	2046	8602	6.889E+06	7.337E+04	2.10
AVERAGE..	146.1	1895	7114	382	1057	1939	7204	1.317E+08	9.504E+05	1.39
STD. DEV.	43.7	741	2252	175	321	747	2234	1.692E+08	1.366E+06	.68

TABLE A-4. - TEST RESULTS FOR RAD-2

BLOCK	CUT WEIGHT, G	CUTTING FORCES, N: HOR. AVG.	HOR. PEAK	NORMAL AVG.	NORMAL PEAK	RES. AVG.	RES. PEAK	AIRBORNE DUST: TOTAL, CU µM	SPECIFIC, CU µM/G	SPECIFIC ENERGY, J/G
					0.318-CM DEPTH					
3........	5.6	169	1010	89	427	191	1096	1.835E+07	3.277E+06	2.97
	6.9	138	1032	49	507	146	1150	2.430E+07	3.522E+06	1.97
	6.0	218	907	111	427	245	1003	1.388E+07	2.314E+06	3.58
7........	5.2	107	583	62	236	124	629	3.585E+07	6.895E+06	2.02
	7.2	142	592	67	227	157	634	8.251E+06	1.146E+06	1.95
	8.7	138	703	80	654	159	960	4.096E+07	4.708E+06	1.56
10.......	10.5	196	939	107	400	223	1020	1.022E+08	9.730E+06	1.83
	8.8	182	805	173	614	252	1012	5.489E+07	6.237E+06	2.04
	6.5	151	583	120	423	193	720	4.427E+07	6.811E+06	2.29
13.......	7.2	116	552	93	409	149	687	2.776E+07	3.855E+06	1.58
	6.8	116	734	85	485	143	880	2.007E+07	2.952E+06	1.67
	5.7	120	516	76	307	142	600	4.341E+06	7.615E+05	2.07
14.......	8.8	245	970	173	600	300	1141	3.643E+07	4.140E+06	2.74
	8.5	182	1116	116	423	216	1194	8.594E+07	1.011E+07	2.11
	11.7	307	947	254	841	398	1267	3.109E+07	2.657E+06	2.58
AVERAGE..	7.6	168	799	110	465	203	933	3.657E+07	4.608E+06	2.20
STD. DEV.	1.9	56	202	54	162	74	226	2.723E+07	2.823E+06	.56
					0.635-CM DEPTH					
3........	20.3	378	1841	147	574	406	1929	2.631E+07	1.296E+06	1.83
	17.0	507	1668	249	747	565	1826	2.975E+07	1.750E+06	2.94
	23.3	614	2273	316	1072	690	2513	3.735E+07	1.603E+06	2.59
7........	25.8	658	3367	320	1156	732	3560	5.369E+07	2.081E+06	2.51
	22.2	480	1984	267	943	550	2197	3.439E+07	1.549E+06	2.13
	15.9	342	1446	227	854	411	1679	2.573E+07	1.618E+06	2.12
10.......	24.8	396	2037	254	672	470	2145	2.681E+07	1.081E+06	1.57
	29.7	534	2015	387	1005	659	2252	7.360E+07	2.478E+06	1.77
	21.3	543	2291	351	841	646	2440	3.054E+07	1.434E+06	2.51
13.......	17.8	191	1321	89	685	211	1488	1.374E+07	7.719E+05	1.06
	23.9	418	1766	271	1299	498	2192	6.489E+06	2.715E+05	1.72
	36.6	495	1557	316	1410	579	2100	1.367E+07	3.734E+05	1.30
14.......	17.9	689	2046	507	1361	856	2457	4.638E+07	2.591E+06	3.79
	21.2	512	1646	311	894	593	1673	3.555E+07	1.677E+06	2.37
	23.5	587	2295	449	1219	739	2599	5.492E+07	2.337E+06	2.46
AVERAGE..	22.7	489	1970	297	982	574	2217	3.393E+07	1.527E+06	2.18
STD. DEV.	5.3	130	492	106	264	161	488	1.763E+07	6.982E+05	.69
					1.270-CM DEPTH					
3........	78.2	756	3567	142	885	769	3675	5.063E+07	6.475E+05	.95
	63.4	1148	5867	320	1090	1191	5967	1.633E+07	2.575E+05	1.78
	48.6	1326	6837	512	1583	1421	7018	1.992E+07	4.099E+05	2.68
7........	44.3	1414	10141	538	2291	1513	10397	1.936E+07	4.371E+05	3.14
	51.5	1259	4533	516	1321	1360	4721	2.602E+07	5.053E+05	2.41
	61.8	1174	4181	307	1317	1214	4384	3.939E+07	6.373E+05	1.87
10.......	77.6	947	3163	449	1366	1049	3445	5.378E+07	6.930E+05	1.20
	62.6	1108	3576	471	1334	1204	3817	1.675E+08	2.675E+06	1.74
	56.2	1277	4728	360	1076	1326	4849	8.183E+07	1.456E+06	2.24
13.......	78.1	1032	6209	360	1583	1093	6408	6.807E+07	8.716E+05	1.30
	51.6	1125	4123	445	1677	1210	4451	3.096E+07	6.000E+05	2.15
	62.8	1312	5560	609	1890	1447	5873	3.024E+07	4.816E+05	2.06
14.......	74.6	1019	2807	454	1374	1115	3125	6.547E+07	8.776E+05	1.34
	70.8	1161	3848	276	1139	1193	4012	3.875E+07	5.473E+05	1.61
	85.0	552	3140	156	627	573	3202	3.956E+07	4.654E+05	.64
AVERAGE..	64.5	1107	4819	394	1370	1179	5023	4.985E+07	7.708E+05	1.81
STD. DEV.	12.5	226	1902	136	407	248	1905	3.785E+07	5.969E+05	.67
					2.540-CM DEPTH					
3........	188.2	3234	8505	654	1744	3299	8681	9.118E+07	4.845E+05	1.69
	156.0	2758	10862	485	2344	2800	11112	1.380E+08	8.843E+05	1.74
	202.2	2331	11365	605	1557	2408	11471	3.688E+07	1.824E+05	1.13
7........	224.7	4475	13686	912	3025	4567	14017	2.989E+08	1.330E+06	1.96
	247.3	3714	12165	574	1210	3758	12225	2.255E+08	9.119E+05	1.48
	165.4	3696	13344	712	1646	3764	13445	6.811E+07	4.118E+05	2.20
10.......	192.5	1886	5511	320	1285	1913	5659	3.627E+08	1.884E+06	.96
	169.7	2780	10359	520	1935	2828	10539	3.489E+08	2.065E+06	1.61
	128.6	2317	7344	916	2429	2492	7735	3.495E+08	2.718E+06	1.77
13.......	159.5	1201	7006	209	587	1219	7030	5.555E+07	3.483E+05	.74
	325.3	1864	6458	200	654	1874	6492	1.802E+08	5.540E+05	.56
	183.6	2019	8585	267	778	2037	8620	1.631E+07	8.884E+04	1.08
14.......	163.0	3332	9150	970	2722	3470	9546	8.769E+07	5.380E+05	2.01
	192.9	3269	8651	872	2633	3384	9843	7.222E+07	3.744E+05	1.67
	151.0	2491	6614	641	1766	2572	6846	2.751E+08	1.822E+06	1.62
AVERAGE..	190.0	2758	9307	590	1754	2826	9497	1.738E+08	9.732E+05	1.48
STD. DEV.	47.9	868	2563	260	768	887	2573	1.255E+08	8.018E+05	.48

TABLE A-5. - TEST RESULTS FOR RAD-3

BLOCK	CUT WEIGHT, G	CUTTING FORCES, N HOR. AVG.	HOR. PEAK	NORMAL AVG.	NORMAL PEAK	RES. AVG.	RES. PEAK	AIRBORNE DUST TOTAL, CU µM	SPECIFIC, CU µM/G	SPECIFIC ENERGY, J/G
					0.318-CM DEPTH					
4........	9.9	111	836	40	249	118	873	6.570E+07	6.636E+06	1.11
	11.5	156	823	67	254	169	861	2.272E+08	1.976E+07	1.33
	11.7	187	894	67	258	198	931	2.380E+08	2.034E+07	1.57
8........	12.0	267	1339	111	360	289	1386	8.036E+07	6.697E+06	2.19
	8.3	182	814	80	258	199	854	1.729E+08	2.083E+07	2.16
	12.4	294	1361	129	383	321	1414	1.261E+08	1.017E+07	2.33
11.......	11.6	169	1339	49	280	176	1368	6.020E+07	5.190E+06	1.43
	7.6	267	1250	107	418	287	1318	6.951E+07	9.146E+06	3.46
	6.9	169	885	76	294	185	933	8.811E+07	1.277E+07	2.41
13.......	8.4	138	850	76	391	157	935	1.693E+07	2.015E+06	1.62
	11.5	178	1245	89	289	199	1279	6.385E+07	5.552E+06	1.52
	10.9	142	774	71	307	159	833	1.152E+08	1.057E+07	1.29
15.......	7.0	111	614	53	196	123	644	4.078E+07	5.825E+06	1.56
	10.3	147	796	67	302	161	852	1.267E+07	1.230E+06	1.40
	5.6	85	498	44	231	96	549	2.708E+07	4.835E+06	1.49
AVERAGE..	9.7	173	955	75	298	189	1002	9.364E+07	9.438E+06	1.79
STD. DEV.	2.2	60	278	25	64	65	278	7.057E+07	6.400E+06	.61
					0.635-CM DEPTH					
4........	19.3	391	1846	111	560	407	1929	1.974E+08	1.023E+07	2.00
	18.0	236	2460	71	525	246	2515	2.290E+07	1.272E+06	1.29
	19.8	334	1815	102	636	349	1923	1.984E+08	1.002E+07	1.66
8........	23.0	632	2784	236	667	674	2863	2.962E+08	1.288E+07	2.70
	21.6	267	1761	80	503	279	1832	1.178E+08	5.456E+06	1.22
	21.8	409	2526	142	641	433	2606	7.246E+07	3.324E+06	1.85
11.......	13.1	427	1588	133	396	447	1637	3.097E+08	2.364E+07	3.21
	20.2	516	3216	178	907	546	3341	2.054E+07	1.017E+06	2.51
	25.7	667	3469	222	1174	703	3663	1.824E+08	7.098E+06	2.56
13.......	26.3	734	4555	262	1223	779	4716	5.904E+07	2.245E+06	2.75
	20.8	552	2277	236	663	600	2372	9.033E+07	4.343E+06	2.61
	34.1	334	1512	125	618	356	1634	1.627E+08	4.772E+06	.96
15.......	17.3	254	1672	76	387	265	1717	4.612E+07	2.666E+06	1.44
	18.5	338	1592	160	534	374	1679	8.318E+07	4.496E+06	1.80
	28.0	414	1490	178	560	450	1592	1.495E+08	5.341E+06	1.45
AVERAGE..	21.8	434	2304	154	666	461	2401	1.339E+08	6.587E+06	2.00
STD. DEV.	5.1	155	887	63	249	166	914	9.097E+07	5.827E+06	.68
					1.270-CM DEPTH					
4........	86.8	752	4470	187	1245	775	4640	6.117E+07	7.047E+05	.85
	68.2	747	4177	173	983	767	4291	1.528E+08	2.241E+06	1.08
	64.3	934	6565	280	1539	975	6743	5.218E+07	8.115E+05	1.43
8........	70.3	1997	7370	578	1699	2079	7564	3.049E+08	4.337E+06	2.80
	54.9	1761	11027	538	2091	1842	11223	2.787E+08	5.077E+06	3.16
	60.0	1459	8416	405	1712	1514	8588	3.860E+08	6.434E+06	2.39
11.......	64.3	1228	4630	334	1285	1272	4805	1.498E+08	2.330E+06	1.88
	43.8	983	5680	245	1076	1013	5781	1.335E+08	3.048E+06	2.21
	91.1	1441	5516	276	912	1467	5590	9.520E+07	1.045E+06	1.56
13.......	50.5	1303	6312	431	2246	1373	6700	7.504E+07	1.486E+06	2.54
	74.6	1370	6160	476	2122	1450	6516	2.104E+08	2.821E+06	1.81
	58.2	1108	5213	378	1361	1170	5388	3.676E+08	6.317E+06	1.87
15.......	84.7	676	3567	222	1063	712	3722	1.253E+08	1.479E+06	.79
	46.4	649	3340	267	1294	702	3582	6.069E+07	1.308E+06	1.38
	72.5	956	6423	329	1579	1011	6614	6.858E+07	9.459E+05	1.30
AVERAGE..	66.0	1158	5924	341	1481	1208	6117	1.681E+08	2.692E+06	1.80
STD. DEV.	14.4	402	1982	124	426	416	1995	1.146E+08	1.966E+06	.71
					2.540-CM DEPTH					
4........	215.0	2718	8456	752	2486	2820	8814	2.003E+07	9.320E+04	1.24
	174.8	3274	11387	916	4497	3400	12243	2.727E+08	1.560E+06	1.84
	191.2	3131	8829	858	2673	3247	9225	8.981E+07	4.697E+05	1.61
8........	134.8	2580	9141	805	2478	2703	9470	1.197E+08	8.878E+05	1.88
	223.1	5231	16102	1392	3380	5413	16453	1.658E+08	7.432E+05	2.31
	215.4	2918	19691	805	3892	3027	20072	6.335E+07	2.941E+05	1.33
11.......	130.2	3363	10586	885	3514	3477	11154	9.680E+07	7.435E+05	2.54
	231.9	3011	9319	609	2033	3072	9538	1.435E+08	6.189E+05	1.28
	189.6	3051	7326	867	2113	3172	7624	1.865E+08	9.839E+05	1.58
13.......	157.6	1668	6672	405	1112	1716	6764	1.241E+07	7.876E+04	1.04
	172.5	1775	8229	405	1890	1820	8443	1.054E+08	6.113E+05	1.01
	213.6	3069	9732	756	1824	3161	9902	1.575E+08	7.375E+05	1.41
15.......	106.9	1081	6227	347	1948	1135	6525	8.399E+07	7.857E+05	1.00
	175.7	1454	6049	294	1610	1484	6260	3.324E+07	1.892E+05	.81
	202.1	2580	7539	578	1446	2644	7677	2.609E+08	1.291E+06	1.26
AVERAGE..	182.3	2727	9686	712	2460	2819	10011	1.208E+08	6.725E+05	1.48
STD. DEV.	37.1	996	3725	284	966	1032	3798	7.879E+07	4.186E+05	.49

TABLE A-6. - TEST RESULTS FOR RAD-4

BLOCK	CUT WEIGHT, G	CUTTING FORCES, N HOR. AVG.	HOR. PEAK	NORMAL AVG.	NORMAL PEAK	RES. AVG.	RES. PEAK	AIRBORNE DUST TOTAL, CU µM	SPECIFIC, CU µM/G	SPECIFIC ENERGY, J/G
0.318-CM DEPTH										
5........	10.4	182	1655	160	885	243	1877	7.769E+06	7.470E+05	1.73
	6.8	316	930	342	1019	466	1379	8.119E+06	1.194E+06	4.57
	9.7	218	947	280	712	355	1185	1.967E+07	2.028E+06	2.21
9........	8.8	151	663	142	471	208	813	5.860E+07	6.659E+06	1.69
	8.1	227	725	294	796	371	1077	9.979E+06	1.232E+06	2.76
	6.3	236	1463	249	1237	343	1916	8.681E+07	1.378E+07	3.68
12.......	17.7	254	1463	236	996	346	1770	9.827E+06	5.552E+05	1.41
	10.6	414	1281	543	1081	682	1676	2.833E+06	2.673E+05	3.84
	10.5	325	1192	423	1285	533	1753	9.836E+05	9.368E+04	3.04
14.......	8.0	209	1019	262	1463	336	1783	2.306E+07	2.883E+06	2.57
	11.7	302	1272	427	1152	523	1716	2.545E+07	2.175E+06	2.54
	6.9	454	1392	685	1272	822	1886	1.211E+07	1.755E+06	6.47
15.......	6.1	280	818	480	1294	556	1531	1.404E+07	2.302E+06	4.52
	7.4	245	898	427	1188	492	1489	1.629E+08	2.201E+07	3.25
	10.4	218	707	276	681	352	981	3.095E+07	2.976E+06	2.06
AVERAGE..	9.3	269	1095	348	1035	442	1522	3.154E+07	4.044E+06	3.09
STD. DEV.	2.9	83	315	148	278	164	357	4.292E+07	6.045E+06	1.36
0.635-CM DEPTH										
5........	16.7	218	1441	182	770	284	1634	3.507E+07	2.100E+06	1.28
	14.0	654	1939	676	1454	941	2424	6.279E+07	4.485E+06	4.60
	16.3	756	2945	681	1639	1017	3380	1.299E+08	7.967E+06	4.57
9........	13.4	498	1748	480	1339	692	2202	3.886E+07	2.900E+06	3.66
	26.9	427	2922	356	1125	556	3132	3.906E+07	1.452E+06	1.56
	26.3	445	2282	325	1156	551	2558	4.723E+07	1.796E+06	1.66
12.......	19.8	663	2019	698	1321	963	2413	7.102E+06	3.587E+05	3.29
	20.3	801	2740	707	1446	1068	3098	2.454E+07	1.209E+06	3.88
	15.0	600	2647	712	1779	931	3189	1.772E+07	1.181E+06	3.94
14.......	22.7	200	1361	267	1468	334	2002	4.186E+07	1.844E+06	.87
	16.1	703	1926	778	1495	1049	2438	2.198E+07	1.365E+06	4.30
	21.7	863	2771	898	1788	1246	3298	3.899E+07	1.797E+06	3.91
15.......	17.9	463	2019	529	1188	703	2343	1.829E+07	1.022E+06	2.54
	15.4	431	1232	512	1090	669	1645	3.517E+07	2.284E+06	2.76
	19.7	351	1179	423	1014	550	1555	2.648E+06	1.344E+05	1.76
AVERAGE..	18.8	538	2078	548	1339	770	2487	3.741E+07	2.126E+06	2.97
STD. DEV.	4.2	202	618	208	288	285	621	3.002E+07	1.921E+06	1.28
1.270-CM DEPTH										
5........	63.9	987	2767	489	1139	1102	2992	5.128E+07	8.025E+05	1.52
	52.5	1428	4079	827	1779	1650	4450	1.587E+08	3.023E+06	2.68
	47.9	1312	4946	836	1850	1556	5281	6.079E+07	1.269E+06	2.70
9........	72.1	867	3425	414	1019	961	3573	2.055E+07	2.850E+05	1.18
	60.5	814	3781	409	939	911	3896	2.107E+08	3.482E+06	1.32
	59.5	898	4101	489	974	1023	4215	2.873E+08	4.828E+06	1.49
12.......	41.1	1557	5560	1170	2389	1947	6051	9.708E+07	2.362E+06	3.73
	60.7	1263	6894	952	2024	1582	7185	1.971E+07	3.247E+05	2.05
	46.4	1495	5422	952	1962	1772	5766	2.167E+07	4.670E+05	3.17
14.......	51.9	1419	5311	1165	2206	1836	5751	9.435E+07	1.818E+06	2.69
	54.1	783	2873	725	2331	1067	3700	1.493E+07	2.760E+05	1.42
	46.4	1486	4275	1183	3292	1899	5395	5.188E+07	1.118E+06	3.15
15.......	57.3	1272	3367	854	1646	1532	3748	2.133E+07	3.723E+05	2.19
	59.4	698	3652	574	1557	904	3970	6.427E+07	1.082E+06	1.16
	64.4	765	3541	560	1757	948	3953	1.917E+07	2.977E+05	1.17
AVERAGE..	55.9	1136	4266	773	1791	1379	4662	7.958E+07	1.454E+06	2.11
STD. DEV.	8.3	312	1146	276	635	399	1170	8.059E+07	1.392E+06	.86
2.540-CM DEPTH										
5........	162.8	1566	4234	645	1486	1693	4488	7.310E+07	4.490E+05	.95
	172.2	2206	6694	623	1321	2292	6823	7.126E+07	4.138E+05	1.26
	170.7	4283	8940	1677	3025	4600	9438	1.808E+08	1.059E+06	2.47
9........	111.3	1472	5698	427	1054	1533	5795	1.648E+08	1.481E+06	1.30
	159.3	1810	6405	467	1063	1870	6493	3.540E+07	2.222E+05	1.12
	208.6	1606	5253	516	1063	1687	5360	6.081E+07	2.915E+05	.76
12.......	86.5	2740	13188	1090	2455	2949	13415	9.826E+06	1.136E+05	3.12
	161.8	3874	12708	1374	2958	4111	13048	4.066E+07	2.513E+05	2.36
	173.4	2802	10106	939	2068	2955	10315	4.500E+07	2.595E+05	1.59
14.......	168.2	1406	4234	641	1712	1545	4568	3.964E+07	2.357E+05	.82
	233.8	2482	7682	654	1312	2567	7793	9.249E+07	3.956E+05	1.04
	196.4	2157	6436	614	1855	2243	6698	3.431E+07	1.747E+05	1.08
15.......	212.1	1170	7406	285	1566	1204	7570	1.059E+08	4.993E+05	.54
	130.8	2335	8763	1152	2268	2604	9051	8.332E+07	6.370E+05	1.76
	194.2	2260	8118	676	2322	2359	8443	1.473E+08	7.584E+05	1.15
AVERAGE..	169.5	2278	7724	785	1835	2414	7953	7.897E+07	4.828E+05	1.42
STD. DEV.	38.6	884	2702	385	660	952	2739	5.113E+07	3.725E+05	.72

APPENDIX B.--SUMMARY OF AIRBORNE RESPIRABLE DUST BY CLASS INTERVAL, WITH CALCULATED MILLIGRAMS PER TON

TABLE B-1. - Airborne respirable dust by class interval

Bit type	Cut avg. wt., g	DP, µm	Number	Cum. number	Volume, cu µm Inc. vol.	Cum. vol.	Weight, mg/ton Inc. wt.	Cum. wt.
				0.318-cm (1/8-in) DEPTH				
PB-60.............	6.77	0.94	29,727	29,727	1.2928E+04	1.2928E+04	15.0	15.0
		1.83	15,110	44,837	4.8487E+04	6.1415E+04	56.4	71.5
		2.62	9,713	54,549	9.1461E+04	1.5288E+05	106.5	178.0
		3.63	11,825	66,374	2.9616E+05	4.4903E+05	344.8	522.7
		5.06	9,311	75,685	6.3161E+05	1.0806E+06	735.3	1,258.0
		6.86	11,318	87,003	1.9131E+06	2.9937E+06	2,227.0	3,485.0
		8.51	5,362	92,365	1.7304E+06	4.7241E+06	2,014.3	5,499.3
				0.635-cm (1/4-in) DEPTH				
PB-60.............	21.86	0.94	12,370	12,370	5.3795E+03	5.3795E+03	6.3	6.3
		1.83	6,621	18,991	2.1246E+04	2.6626E+04	24.7	31.0
		2.62	4,289	23,280	4.0387E+04	6.7013E+04	47.0	78.0
		3.63	5,353	28,633	1.3408E+05	2.0109E+05	156.1	234.1
		5.06	4,793	33,426	3.2510E+05	5.2619E+05	378.4	612.5
		6.86	5,690	39,115	9.6172E+05	1.4879E+06	1,119.5	1,732.1
		8.51	2,970	42,085	9.5845E+05	2.4464E+06	1,115.7	2,847.8
				1.270-cm (1/2-in) DEPTH				
PB-60.............	67.75	0.94	4,322	4,322	1.8797E+03	1.8797E+03	2.2	2.2
		1.83	2,208	6,530	7.0843E+03	8.9640E+03	8.2	10.4
		2.62	1,580	8,110	1.4878E+04	2.3842E+04	17.3	27.8
		3.63	1,975	10,085	4.9454E+04	7.3295E+04	57.6	85.3
		5.06	1,655	11,740	1.1227E+05	1.8556E+05	130.7	216.0
		6.86	1,832	13,571	3.0960E+05	4.9516E+05	360.4	576.4
		8.51	1,064	14,635	3.4331E+05	8.3847E+05	399.6	976.1
				2.540-cm (1.0-in) DEPTH				
PB-60.............	162.19	0.94	1,703	1,703	7.4073E+02	7.4073E+02	0.9	0.9
		1.83	891	2,594	2.8587E+03	3.5994E+03	3.3	4.2
		2.62	602	3,196	5.6695E+03	9.2689E+03	6.6	10.8
		3.63	757	3,953	1.8966E+04	2.8235E+04	22.1	32.9
		5.06	651	4,605	4.4166E+04	7.2401E+04	51.4	84.3
		6.86	742	5,347	1.2549E+05	1.9789E+05	146.1	230.4
		8.51	395	5,741	1.2731E+05	3.2520E+05	148.2	378.6
				0.318-cm (1/8-in) DEPTH				
PB-90.............	7.95	0.94	29,921	29,921	1.3012E+04	1.3012E+04	15.1	15.1
		1.83	17,261	47,181	5.5387E+04	6.8399E+04	64.5	79.6
		2.62	11,569	58,751	1.0895E+05	1.7735E+05	126.8	206.4
		3.63	17,014	75,765	4.2611E+05	6.0346E+05	496.0	702.5
		5.06	15,370	91,134	1.0426E+06	1.6460E+06	1,213.7	1,916.2
		6.86	19,453	110,587	3.2882E+06	4.9343E+06	3,827.8	5,744.0
		8.51	13,244	123,832	4.2738E+06	9.2081E+06	4,975.2	10,719.2
				0.635-cm (1/4-in) DEPTH				
PB-90.............	25.55	0.94	10,407	10,407	4.5257E+03	4.5257E+03	5.3	5.3
		1.83	6,854	17,261	2.1995E+04	2.6521E+04	25.6	30.9
		2.62	5,109	22,370	4.8110E+04	7.4630E+04	56.0	86.9
		3.63	7,313	29,683	1.8316E+05	2.5779E+05	213.2	300.1
		5.06	6,965	36,648	4.7248E+05	7.3027E+05	550.0	850.1
		6.86	8,619	45,267	1.4569E+06	2.1871E+06	1,695.9	2,546.0
		8.51	11,699	56,966	3.7752E+06	5.9624E+06	4,394.8	6,940.8
				1.270-cm (1/2-in) DEPTH				
PB-90.............	64.43	0.94	6,829	6,829	2.9701E+03	2.9701E+03	3.5	3.5
		1.83	3,719	10,549	1.1935E+04	1.4905E+04	13.9	17.4
		2.62	2,686	13,234	2.5289E+04	4.0194E+04	29.4	46.8
		3.63	3,529	16,763	8.8381E+04	1.2857E+05	102.9	149.7
		5.06	3,044	19,807	2.0649E+05	3.3507E+05	240.4	390.1
		6.86	3,810	23,617	6.4395E+05	9.7902E+05	749.6	1,139.7
		8.51	2,339	25,956	7.5485E+05	1.7339E+06	878.7	2,018.4

See explanatory notes at end of table.

TABLE B-1. - Airborne respirable dust by class interval--Continued

Bit type	Cut avg. wt., g	DP, μm	Number	Cum. number	Volume, cu μm Int. vol.	Volume, cu μm Cum. vol.	Weight, mg/ton Int. wt.	Weight, mg/ton Cum. wt.
2.540-cm (1.0-in) DEPTH								
PB-90..............	156.46	0.94	1,618	1,618	7.0381E+02	7.0381E+02	0.8	0.8
		1.83	942	2,560	3.0225E+03	3.7263E+03	3.5	4.3
		2.62	646	3,207	6.0856E+03	9.8119E+03	7.1	11.4
		3.63	870	4,077	2.1794E+04	3.1606E+04	25.4	36.8
		5.06	782	4,858	5.3022E+04	8.4628E+04	61.7	98.5
		6.86	1,004	5,863	1.6978E+05	2.5441E+05	197.6	296.2
		8.51	645	6,508	2.0808E+05	4.6249E+05	242.2	538.4
0.318-cm (1/8-in) DEPTH								
RAD-1 (CF radial)..	8.51	0.94	26,922	26,922	1.1708E+04	1.1708E+04	13.6	13.6
		1.83	15,808	42,730	5.0727E+04	6.2435E+04	59.1	72.7
		2.62	11,868	54,598	1.1176E+05	1.7419E+05	130.1	202.8
		3.63	16,703	71,301	4.1832E+05	5.9251E+05	487.0	689.7
		5.06	15,862	87,163	1.0760E+06	1.6685E+06	1,252.6	1,942.3
		6.86	20,395	107,558	3.4774E+06	5.1159E+06	4,013.1	5,955.4
		8.51	13,037	120,595	4.2070E+06	9.3229E+06	4,897.4	10,852.8
0.635-cm (1/8-in) DEPTH								
RAD-1 (CF radial)..	19.29	0.94	7,665	7,665	3.3336E+03	3.3336E+03	3.9	3.9
		1.83	4,604	12,269	1.4772E+04	1.8106E+04	17.2	21.1
		2.62	3,635	15,904	3.4230E+04	5.2336E+04	39.8	60.9
		3.63	5,298	21,202	1.3269E+05	1.8502E+05	154.5	215.4
		5.06	5,268	26,469	3.5732E+05	5.4234E+05	416.0	631.3
		6.86	7,246	33,716	1.2249E+06	1.7672E+06	1,425.9	2,057.2
		8.51	5,558	39,274	1.7934E+06	3.5607E+06	2,087.7	4,145.0
1.270-cm (1/2-in) DEPTH								
RAD-1 (CF radial)..	66.21	0.94	4,347	4,347	1.8904E+03	1.8904E+03	2.2	2.2
		1.83	2,863	7,210	9.1881E+03	1.1079E+04	10.7	12.9
		2.62	2,184	9,394	2.0566E+04	3.1644E+04	23.9	36.8
		3.63	3,333	12,727	8.3464E+04	1.1511E+05	97.2	134.0
		5.06	3,437	16,164	2.3316E+05	3.4827E+05	271.4	405.4
		6.86	4,573	20,737	7.7298E+05	1.1213E+06	899.8	1,305.3
		8.51	3,480	24,217	1.1229E+06	2.2442E+06	1,307.2	2,612.4
2.540-cm (1.0-in) DEPTH								
RAD-1 (CF radial)..	146.14	0.94	2,992	2,992	1.3013E+03	1.3013E+03	1.5	1.5
		1.83	2,102	5,094	6.7444E+03	8.0456E+03	7.9	9.4
		2.62	1,687	6,781	1.5886E+04	2.3931E+04	18.5	27.9
		3.63	2,697	9,478	6.7541E+04	9.1473E+04	78.6	106.5
		5.06	2,856	12,334	1.9373E+05	2.8520E+05	225.5	332.0
		6.86	3,936	16,270	6.6533E+05	9.5053E+05	774.5	1,106.5
		8.51	3,227	19,497	1.0414E+06	1.9919E+06	1,212.3	2,318.8
0.318-cm (1/8-in) DEPTH								
RAD-2 (CP radial)..	7.61	0.94	23,468	23,468	1.0206E+04	1.0206E+04	11.9	11.9
		1.83	14,937	38,405	4.4930E+04	5.8137E+04	55.8	67.7
		2.62	10,583	48,988	9.9657E+04	1.5779E+05	116.0	183.7
		3.63	15,206	64,194	3.8084E+05	5.3863E+05	443.3	627.0
		5.06	14,520	78,715	9.8498E+05	1.5236E+06	1,146.6	1,773.6
		6.86	18,251	96,966	3.0850E+06	4.6086E+06	3,591.3	5,364.9
		8.51	12,187	109,153	3.9327E+06	8.5413E+06	4,578.1	9,943.0
0.635-cm (1/2-in) DEPTH								
RAD-2 (CP radial)..	22.75	0.94	7,942	7,942	3.4539E+03	3.4539E+03	4.0	4.0
		1.83	5,079	13,001	1.6233E+04	1.9687E+04	18.9	22.9
		2.62	3,777	16,778	3.5564E+04	5.5251E+04	41.4	64.3
		3.63	5,052	21,830	1.2653E+05	1.8178E+05	147.3	211.6
		5.06	4,517	26,347	3.0641E+05	4.8819E+05	356.7	568.3
		6.86	6,150	32,497	1.0396E+06	1.5278E+06	1,210.2	1,778.5
		8.51	4,218	36,715	1.3611E+06	2.8888E+06	1,584.4	3,362.9

See explanatory notes at end of table.

TABLE B-1. - Airborne respirable dust by class interval--Continued

Bit type	Cut avg. wt., g	DP, µm	Number	Cum. number	Volume, cu µm Int. vol.	Volume, cu µm Cum. vol.	Weight, mg/ton Int. wt.	Weight, mg/ton Cum. wt.
				1.270-cm (1/2-in) DEPTH				
RAD-2 (CP radial)..	64.47	0.94	2,816	2,816	1.2246E+03	1.2246E+03	1.4	1.4
		1.83	1,936	4,752	6.2135E+03	7.4381E+03	7.2	8.7
		2.62	1,405	6,157	1.3233E+04	2.0671E+04	15.4	24.1
		3.63	2,124	8,281	5.3194E+04	7.3865E+04	61.9	86.0
		5.06	2,222	10,504	1.5076E+05	2.2463E+05	175.5	261.5
		6.86	3,232	13,736	5.4633E+05	7.7095E+05	636.0	897.5
		8.51	2,494	16,230	8.0489E+05	1.5758E+06	937.0	1,834.4
				2.540-cm (1.0-in) DEPTH				
RAD-2 (CP radial)..	189.99	0.94	3,468	3,468	1.5082E+03	1.5082E+03	1.8	1.8
		1.83	2,446	5,914	7.8477E+03	9.3559E+03	9.1	10.9
		2.62	1,954	7,868	1.8400E+04	2.7756E+04	21.4	32.3
		3.63	2,955	10,823	7.4010E+04	1.0177E+05	86.2	118.5
		5.06	2,962	13,785	2.0094E+05	3.0270E+05	233.9	352.4
		6.86	3,991	17,776	6.7461E+05	9.7732E+05	785.3	1,137.7
		8.51	3,047	20,823	9.8340E+05	1.9607E+06	1,144.8	2,282.5
				0.318-cm (1/8-in) DEPTH				
RAD-3 (CC radial)..	9.71	0.94	37,203	37,203	1.6179E+04	1.6179E+04	18.8	18.8
		1.83	24,882	62,085	7.9844E+04	9.6023E+04	92.9	111.8
		2.62	19,004	81,089	1.7896E+05	2.7498E+05	208.3	320.1
		3.63	28,440	109,529	7.1228E+05	9.8726E+05	829.2	1,149.3
		5.06	29,060	138,590	1.9713E+06	2.9586E+06	2,294.8	3,444.1
		6.86	38,348	176,937	6.4820E+06	9.4406E+06	7,545.7	10,989.8
		8.51	29,503	206,440	9.5203E+06	1.8961E+07	11,082.6	22,072.4
				0.635-cm (1/4-in) DEPTH				
RAD-3 (CC radial)..	21.83	0.94	25,862	25,862	1.1247E+04	1.1247E+04	13.1	13.1
		1.83	17,228	43,089	5.5281E+04	6.6528E+04	64.4	77.4
		2.62	13,362	56,451	1.2583E+05	1.9235E+05	146.5	223.9
		3.63	20,089	76,540	5.0313E+05	6.9548E+05	585.7	809.6
		5.06	20,291	96,831	1.3764E+06	2.0719E+06	1,602.3	2,411.9
		6.86	26,716	123,547	4.5159E+06	6.5878E+06	5,257.0	7,668.9
		8.51	20,889	144,436	6.7408E+06	1.3329E+07	7,847.0	15,515.8
				1.270-cm (1/2-in) DEPTH				
RAD-3 (CC radial)..	66.04	0.94	8,479	8,479	3.6875E+03	3.6875E+03	4.3	4.3
		1.83	5,914	14,393	1.8976E+04	2.2663E+04	22.1	26.4
		2.62	4,923	19,316	4.6361E+04	6.9024E+04	54.0	80.4
		3.63	7,495	26,811	1.8771E+05	2.5673E+05	218.5	298.9
		5.06	8,128	34,938	5.5134E+05	8.0807E+05	641.8	940.7
		6.86	11,149	46,087	1.8845E+06	2.6926E+06	2,193.8	3,134.5
		8.51	8,811	54,898	2.8433E+06	5.5359E+06	3,309.8	6,444.3
				2.540-cm (1.0-in) DEPTH				
RAD-3 (CC radial)..	182.29	0.94	2,858	2,858	1.2427E+03	1.2427E+03	1.4	1.4
		1.83	1,906	4,763	6.1154E+03	7.3581E+03	7.1	8.6
		2.62	1,434	6,197	1.3500E+04	2.0858E+04	15.7	24.3
		3.63	2,070	8,267	5.1841E+04	7.2699E+04	60.3	84.6
		5.06	1,959	10,226	1.3289E+05	2.0559E+05	154.7	239.3
		6.86	2,763	12,989	4.6701E+05	6.7260E+05	543.7	783.0
		8.51	1,857	14,846	5.9921E+05	1.2718E+06	697.5	1,480.5
				0.318-cm (1/8-in) DEPTH				
RAD-4 (CR radial)..	9.29	0.94	19,166	19,166	8.3352E+03	8.3352E+03	9.7	9.7
		1.83	12,373	31,539	3.9703E+04	4.8038E+04	46.2	55.9
		2.62	8,944	40,483	8.4225E+04	1.3226E+05	98.0	154.0
		3.63	12,892	53,375	3.2288E+05	4.5515E+05	375.9	529.8
		5.06	11,943	65,319	8.1017E+05	1.2653E+06	943.1	1,473.0
		6.86	16,446	81,764	2.7799E+06	4.0452E+06	3,236.1	4,709.0
		8.51	9,686	91,451	3.1257E+06	7.1709E+06	3,638.7	8,347.7

See explanatory notes at end of table.

TABLE B-1. - Airborne respirable dust by class interval--Continued

Bit type	Cut avg. wt., g	DP, µm	Number	Cum. number	Volume, cu µm		Weight, mg/ton	
					Int. vol.	Cum. vol.	Int. wt.	Cum. wt.
0.635-cm (1/4-in) DEPTH								
RAD-4 (CR radial)..	18.81	0.94	12,701	12,701	5.5234E+03	5.5234E+03	6.4	6.4
		1.83	8,069	20,770	2.5892E+04	3.1416E+04	30.1	36.6
		2.62	5,539	26,309	5.2161E+04	8.3577E+04	60.7	97.3
		3.63	7,530	33,838	1.8858E+05	2.7216E+05	219.5	316.8
		5.06	6,649	40,487	4.5100E+05	7.2316E+05	525.0	841.8
		6.86	8,304	48,791	1.4037E+06	2.1268E+06	1,634.0	2,475.8
		8.51	5,007	53,798	1.6156E+06	3.7424E+06	1,880.7	4,356.6
1.270-cm (1/2-in) DEPTH								
RAD-4 (CR radial)..	55.87	0.94	6,908	6,908	3.0044E+03	3.0044E+03	3.5	3.5
		1.83	4,354	11,263	1.3973E+04	1.6977E+04	16.5	19.8
		2.62	3,240	14,503	3.0512E+04	4.7489E+04	35.5	55.3
		3.63	4,592	19,095	1.1501E+05	1.6250E+05	133.9	189.2
		5.06	4,474	23,569	3.0346E+05	4.6596E+05	353.3	542.4
		6.86	5,845	29,414	9.8801E+05	1.4540E+06	1,150.2	1,692.6
		8.51	4,479	33,892	1.4452E+06	2.8992E+06	1,682.4	3,375.0
2.540-cm (1.0-in) DEPTH								
RAD-4 (CR radial)..	169.47	0.94	2,233	2,233	9.7097E+02	9.7097E+02	1.1	1.1
		1.83	1,382	3,615	4.4341E+03	5.4051E+03	5.2	6.3
		2.62	1,055	4,669	9.9341E+03	1.5339E+04	11.6	17.9
		3.63	1,438	6,107	3.6012E+04	5.1351E+04	41.9	59.8
		5.06	1,442	7,550	9.7836E+04	1.4919E+05	113.9	173.7
		6.86	1,974	9,524	3.3369E+05	4.8288E+05	388.4	562.1
		8.51	1,448	10,972	4.6728E+05	9.5015E+05	544.0	1,106.1

Column descriptions:

DP = Mean size value for each class interval.

Number = Number of particle counts in class interval.
Cum. number = Cumulative particle count.

Int. vol. = Volume of airborne respirable dust per class interval.
Cum. vol. = Cumulative volume of all sizes of respirable dust.

Weight = Calculated weight of dust per short ton coal, using 80-lb/cu ft density.

Int. wt. = Weight of dust per class interval.
Cum.wt. = Cumulative weight of dust per ton.

APPENDIX C.--STUDENT'S T-VALUES OF PAIRED DATA[1]

$$T = \frac{(\bar{y}_2 - \bar{y}_1) - D_o}{\sqrt{\frac{(n_2 - 1)\, s_2^2 + (n_1 - 1)\, s_1^2}{(n_2 + n_1 - 2)} \times \frac{1}{n_2} + \frac{1}{n_1}}},$$

where T = calculated paired Student's t-value indicating statistically significant differences between two given arithmetic average comparisons if this calculated t-value is not less than the handbook t-value for the same paired degrees of freedom at a given percent confidence level;

D_o = null hypothesis set to zero for computing Student's t-value under the conditions described above;

$\bar{y}$ = arithmetic average of given column of data; subscripts 1 and 2 indicate the first and second data columns being compared;

n = number of digits in a given data column;

$(n_2 + n_1 - 2)$ = degrees of freedom of a given pair of data columns;

and s = standard deviation for a given data column:

$$s = \sqrt{\frac{\Sigma xi^2 - (\Sigma xi)^2/n}{n - 1}},$$

where Σxi^2 = result of squaring each digit, then totaling up values;

and $(\Sigma xi)^2$ = result of totaling up all digits, then squaring the sum.

[1]From Mendenhall (2, pp. 26-27) and Weast (7, p. A-161). The list of references precedes appendix A.

TABLE C-1. - Student's t-values of significance of paired specific energy averages

Depth of cut....	0.318 cm (1/8 in)	0.635 cm (1/4 in)	1.270 cm (1/2 in)	2.540 cm (1 in)
PB-90, PB-60....	6.154[a]	2.756[a]	2.498[a]	1.858[a]
RAD-2, RAD-1....	.301	-.254	.913	.419
RAD-4, RAD-3....	3.378[a]	2.592[a]	1.077[c]	-.267
RAD-2, RAD-3....	1.918[a]	.720	.040	.000
RAD-4, RAD-1....	2.521[a]	2.00[a]	1.868[a]	.117
RAD-4, RAD-2....	2.344[a]	2.104[a]	1.066[c]	-.269
RAD-1, RAD-3....	1.677[b]	1.025	-.845	-.416
PB-90, RAD-1....	7.966[a]	3.836[a]	3.618[a]	1.500[b]
PB-90, RAD-2....	7.889[a]	3.881[a]	3.137[a]	1.345[b]
PB-90, RAD-3....	8.322[a]	4.063[a]	3.132[a]	1.336[b]
PB-90, RAD-4....	6.516[a]	2.980[a]	2.399[a]	1.347[b]
PB-60, RAD-1....	4.703[a]	2.257[a]	1.536[b]	-.260
PB-60, RAD-2....	4.458[a]	2.350[a]	.777	-.784
PB-60, RAD-3....	5.660[a]	2.789[a]	.794	-.777
PB-60, RAD-4....	1.119[c]	.379	-.214	-.376

[a]≥90-pct confidence level. [b]≥80-pct confidence level. [c]≥70-pct confidence level.

TABLE C-2. - Student's t-values of significance of paired specific dust averages

Depth of cut....	0.318 cm (1/8 in)	0.635 cm (1/4 in)	1.270 cm (1/2 in)	2.540 cm (1 in)
PB-90, PB-60....	1.426[b]	0.683	1.328[b]	0.677
RAD-2, RAD-1....	-.220	-.457	-1.048	.056
RAD-4, RAD-3....	-2.373[a]	-2.816[a]	-1.990[a]	-1.311[c]
RAD-2, RAD-3....	-2.674[a]	-3.339[a]	-3.621[a]	1.288[c]
RAD-4, RAD-1....	-.395	.513	.261	-1.279[c]
RAD-4, RAD-2....	-.327	1.135[c]	1.747[a]	-2.148[a]
RAD-1, RAD-3....	-1.528[b]	-3.044[a]	-1.997[a]	.753
PB-90, RAD-1....	-.079	.397	-.547	-1.807[a]
PB-90, RAD-2....	.233	.693	.567	-3.101[a]
PB-90, RAD-3....	-2.216[a]	-2.484[a]	-2.822[a]	-3.153[a]
PB-90, RAD-4....	.453	.058	-.970	-1.880[a]
PB-60, RAD-1....	-.901	-.432	-1.602[b]	-2.033[a]
PB-60, RAD-2....	-1.636[b]	-.079	-1.290[c]	-3.548[a]
PB-60, RAD-3....	-3.617[a]	-3.272[a]	-4.155[a]	-4.038[a]
PB-60, RAD-4....	-.619	-.993	-2.467[a]	-2.674[a]

[a]≥90-pct confidence level. [b]≥80-pct confidence level. [c]≥70-pct confidence level.

TABLE C-3. - Student's t-values of significance of paired tangential force averages

Depth of cut....	0.318 cm (1/8 in)	0.635 cm (1/4 in)	1.270 cm (1/2 in)	2.540 cm (1 in)
PB-90, PB-60....	7.471[a]	5.101[a]	2.778[a]	2.220[a]
RAD-2, RAD-1....	-.673	1.506[b]	1.146[c]	2.927[a]
RAD-4, RAD-3....	3.593[a]	1.582[b]	-.160	-1.306[c]
RAD-2, RAD-3....	-.236	1.053	-.420	.091
RAD-4, RAD-1....	3.289[a]	1.938[a]	1.251[c]	1.285[c]
RAD-4, RAD-2....	3.868	.790	.291	-1.501
RAD-1, RAD-3....	.418	-.188	-1.241[c]	-2.594[a]
PB-90, RAD-1....	8.406[a]	6.603[a]	4.336[a]	2.937[a]
PB-90, RAD-2....	8.641[a]	6.117[a]	3.932[a]	.614
PB-90, RAD-3....	8.530[a]	6.414[a]	3.436[a]	.655
PB-90, RAD-4....	6.868[a]	5.603[a]	3.675[a]	1.811[a]
PB-60, RAD-1....	2.646[a]	3.499[a]	2.663[a]	.876
PB-60, RAD-2....	3.338[a]	2.205[a]	1.914[a]	-2.039
PB-60, RAD-3....	3.008[a]	2.935[a]	1.160[c]	-1.779[a]
PB-60, RAD-4....	-1.047	-1.153[c]	1.477[b]	-.453

[a]≥90-pct confidence level. [b]≥80-pct confidence level. [c]≥70-pct confidence level.

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