FLOAT DUST DEPOSITS IN RETURN AIRWAYS IN AMERICAN COAL MINES

By Edward M. Kawenski, Edwin M. Murphy,
and R. Ward Stahl

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FLOAT DUST DEPOSITS IN RETURN AIRWAYS IN AMERICAN COAL MINES[1]

by

Edward M. Kawenski,[2] Edwin M. Murphy,[3] and R. Ward Stahl[4]

SUMMARY AND INTRODUCTION

Float dust deposits in return airways in bituminous coal and lignite mines present a special explosion hazard. Research is in progress at the Bureau of Mines experimental coal mine to evaluate the degree of the hazard and to develop measures for preventing dissemination of dust into the ventilating air current. To determine the extent of this hazard prevailing in operating coal mines, 711 dust samples were collected in 50 mines located in the major coal fields of the United States. The mean quantity of coal and the incombustible content of the dust in the samples were determined.

The term "float dust" is used to designate particles smaller than 74 microns in diameter (particles passing a No. 200 sieve) which have settled from the air current. Dust usually found in roadways and in working places is coarser than float dust, and is termed "coarse dust" (particles passing a No. 20 sieve). Variations in amount and incombustible content of coarse dust in a midwestern mine were studied previously.[5]

The mean quantity of fine coal or float dust on the mine surfaces in the return airways is equivalent to 0.02 ounce per cubic foot of entry volume; the respective parts on the floor and rib-roof surfaces are 73 and 27 percent.

The mean incombustible content of the float dust in return airways is 89 percent. Although this is high, 20 percent of the skim and 46 percent of the

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[5]Hartmann, Irving, Nagy, John, and Rauschenberger, John K., Lessons from Intensive Dust Sampling of a Coal Mine: Bureau of Mines Rept. of Inv. 5054, 1954, 12 pp.

1-inch floor samples contained less than 65 percent incombustible content. In belt entries, 7 of 10 samples collected contained less than 65 percent incombustible content.

Preliminary results from research on the explosion hazard indicate that the quantity of the float-coal dust is a primary factor affecting the incombustible requirement for arresting an explosion.[6] The hazard might not be neutralized by maintaining 65 percent incombustible content as provided in the Federal Mine Safety Code.[7]

SAMPLING PROCEDURES

The sampling procedures for collecting dust in the operating mines were those used in research on the explosion hazards of float-coal in the experimental coal mine. In the explosion tests, controlled quantities of coal and limestone dusts are dispersed into the ventilating air, and deposition on mine surfaces is measured by collecting samples from the mine floor, rib, and roof. Experience showed that lightly brushing the dust into a collecting tray is a satisfactory method for collection, provided the air velocity is less than 300 feet per minute. The samples collected in the current survey in operating mines consisted of the following:

1. Skim sample--the surficial layer of floor dust not more than 1/8-inch deep, collected from a 6-inch-wide strip by brushing into a collecting pan (fig. 1).

2. Rib sample--the loose dust on the rib surfaces in a 6-inch-wide strip. The dust was collected from both ribs and combined into a single sample.

3. Roof sample--the loose dust on the roof surface brushed from a 6-inch-wide strip into a pan.

4. 1-inch floor--the floor dust 1 inch deep, collected by the brush-pan method.

Combination of the 1-inch floor sample with the rib and roof samples can be considered equivalent to the perimeter or band sample normally collected for evaluating the rock dust conditions of a mine. In this report the float coal in the skim sample is assumed to be surficial; this is not entirely true as appreciable quantities of fine coal dust are present in the 1-inch samples.

Large quantities of dust collected from the floor during sampling were quartered to reduce bulk. The dust samples were screened through a No. 10

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[6] Mitchell, Donald W., Nagy, John, Kawenski, Edward M., Murphy, Edwin M., and Stahl, R. Ward, The Explosion Hazard of Float Dust Deposits: Paper No. 14, Internat. Conf. of Directors of Safety in Mines Research, Warsaw, Poland, Oct. 16-24, 1961, 11 pp.

[7] Federal Mine Safety Code for Bituminous-Coal and Lignite Mines of the United States. Pt. I--Underground Mines, Oct. 8, 1953, 86 pp.

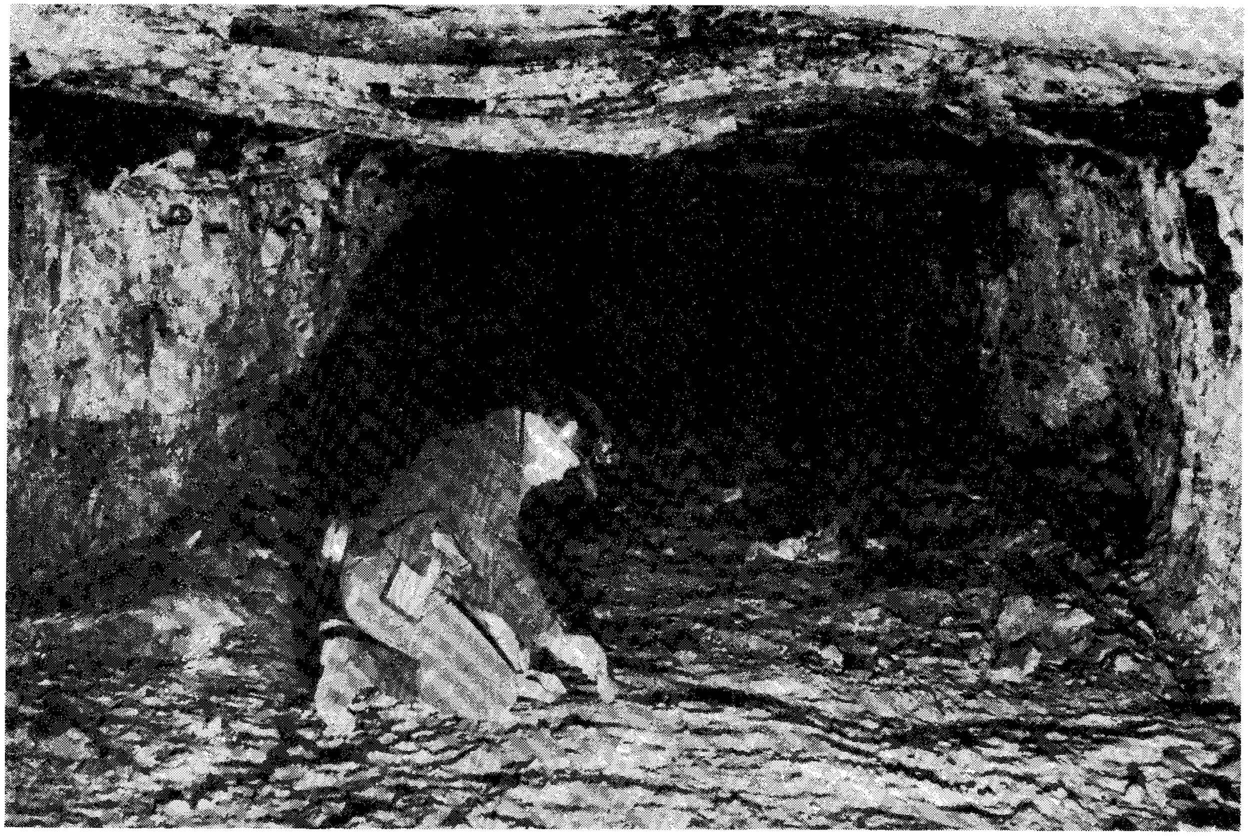

FIGURE 1. - Collection of Skim Sample From Mine Floor.

sieve at the sampling location, and the oversize portion was discarded. In the laboratory, samples of dust were screened first through a No. 20 sieve and then through a No. 200 sieve; the respective weights were obtained and the incombustible contents were determined by chemical analysis. From these data the incombustible content of dust through a No. 20 sieve was calculated.

As shown in table 1, samples were collected in 50 coal mines operating in 25 coal seams having volatile ratios (ash and moisture free) ranging from 0.191 to 0.502. The mines are located in 11 states and encompass the major coal producing areas of the United States; the average productions ranged from 215 to 25,000 tons per day. The thickness of the coal seams ranged from 3 to 10.5 feet; the widths of the airways ranged from 11 to 28 feet. On the average, 13 samples were collected from each mine; 80 return airways were studied. At some sampling locations all types of samples were not collected because of wetness, compacted dust, or height of roof. The samples were collected where visual inspection (blackness of deposit) indicated heavy deposits of coal dust. In several instances samples were collected in a given entry at increasing distances from a working face. Continuous mining machines were used in 27, and conventional equipment in 17 of the mines visited; in 5 mines both types of equipment were used. At one mine the coal was hand-loaded. The age of the airways ranged from less than 1 to more than 36 months. A few samples were collected in belt entries and from the tops of rockfalls where contamination was at a minimum.

TABLE 1. - Bituminous coal mines surveyed for float-coal deposits

No.	Location: State	Location: County	Mining equipment	Entry width, ft.	Production, tons per day	Coal seam: Name of bed	Coal seam: Thickness, ft.	Coal seam: Volatile ratio,[1] $\frac{VM}{VM + FC}$	Entries investigated	Number of samples: Floor: Skim	Number of samples: Floor: 1 in.	Number of samples: Rib	Number of samples: Roof
1	Alabama	Jefferson	Conventional	22.0	5,000	Pratt	5.5	0.296	1	5	4	5	4
2	do	do	do	24.0	2,400	Mary Lee	6.5	.310	1	5	0	4	4
3	do	do	do	20.0	5,300	do	7.5	.253	2	3	0	2	1
4	do	Walker	do	28.0	6,400	do	4.75	.409	1	4	0	3	2
5	do	do	Continuous	28.0	7,000	America	4.0	.400	1	4	0	1	1
6	Colorado	Las Animas	do	15.0	6,000	Main	7.0	.446	2	10	7	8	6
7	do	Pitkin	Conventional	22.0	1,750	Carbondale	7.0	.251	1	6	5	6	5
8	do	do	Handloading	14.0	750	Anderson	8.0	.366	1	9	4	9	3
9	Illinois	Franklin	Continuous	12.0	15,000	No. 6	9.0	.407	1	0	0	2	2
10	do	Jefferson	do	11.0	14,000	No. 6	6.25	.427	1	0	4	4	2
11	do	Williamson	do	16.0	6,000	No. 6	7.0	.400	1	0	2	2	0
12	Indiana	Gibson	Conventional	12.5	3,300	No. 5	6.0	.440	1	1	1	2	0
13	do	Sullivan	Conventional and continuous.	15.0	3,000	No. 6	5.25	.482	2	3	4	3	2
14	do	Vigo	Continuous	15.0	2,400	No. 5	4.0	.493	3	3	4	3	2
15	Kentucky	Harlan	Conventional	20.0	4,000	Ky. No. 6	3.0	.409	1	5	5	3	0
16	do	Hopkins	do	23.0	5,000	Ky. No. 11	5.0	.451	1	1	2	2	0
17	do	do	do	15.5	3,700	Ky. No. 11	7.5	.502	2	1	1	2	0
18	do	Pike	Continuous	15.0	4,000	Low. Elkhorn	3.5	.354	1	6	6	2	0
19	do	Union	Conventional	15.0	5,500	Ky. No. 9	4.5	.441	1	2	2	1	0
20	New Mexico	Colfax	Continuous	24.0	1,600	Raton	9.5	.447	1	5	5	5	0
21	do	do	do	18.0	215	do	9.5	.455	1	5	5	5	0
22	Ohio	Harrison	do	14.0	5,500	Mid. Kittanning	5.0	.419	1	2	1	2	2
23	Pennsylvania	Cambria	Conventional	16.0	3,000	Lower Kittanning	4.0	.225	2	5	4	3	3
24	do	do	Continuous	17.0	2,000	do	4.0	.191	2	3	3	1	1
25	do	do	Conventional and continuous.	16.0	3,500	do	3.5	.217	2	2	1	2	2
26	do	do	Continuous	18.0	6,000	do	3.5	.240	1	1	1	1	1
27	do	Green	do	22.0	7,500	Pittsburgh	6.0	.409	2	4	4	4	0
28	do	do	do	11.5	6,500	do	7.0	.384	1	2	1	2	1
29	do	do	do	14.0	8,000	do	7.0	.410	2	4	4	4	4
30	do	do	do	16.0	8,000	do	6.5	.410	2	3	3	3	3
31	do	do	do	15.0	8,000	do	6.0	.410	1	2	2	2	2
32	do	do	do	12.5	6,600	do	6.5	.384	1	1	1	1	1
33	do	Indiana	Conventional	21.0	4,200	Lower Freeport	6.5	.354	2	5	4	3	2
34	do	do	do	20.0	4,750	Upper Freeport	5.8	.335	2	4	2	2	2
35	do	Washington	do	16.0	10,000	Pittsburgh	6.5	.404	3	4	1	3	0
36	do	do	Conventional and continuous.	16.0	5,300	do	5.8	.427	2	11	2	7	3
37	Utah	Carbon	Continuous	24.0	1,500	"C"	9.0	.472	1	9	7	8	2
38	do	Sunnyside	do	20.0	3,000	Lower Sunnyside	6.0	.409	1	7	6	7	7
39	do	do	do	17.0	4,700	Sunnyside	9.5	.446	1	9	9	9	0
40	Virginia	Russell	do	20.0	25,000	Tiller	10.5	.302	2	11	10	5	0
41	do	Tazewell	do	21.0	7,000	Pocahontas #3	6.0	.237	1	4	4	4	2
42	do	Wise	do	21.0	2,300	Taggert	4.0	.362	2	5	5	3	0
43	do	do	Conventional	16.0	3,300	Imboden	5.5	.386	1	7	3	3	1
44	do	do	do	20.0	2,500	Taggert	4.5	.363	5	8	5	6	0
45	W. Virginia	Fayette	Conventional and continuous.	16.0	4,300	No. 2 Gas	4.0	.417	3	5	4	4	4
46	do	McDowell	Continuous	18.0	6,500	Pocahontas #3	8.0	.203	2	5	5	5	1
47	do	Monongalia	Conventional	17.0	6,000	Pittsburgh	7.0	.403	2	5	1	5	5
48	do	do	Conventional and continuous.	17.0	7,500	do	7.0	.394	2	10	8	9	9
49	do	Raleigh	Continuous	17.0	1,500	No. 2 Gas	4.5	.344	1	4	1	3	1
50	do	Wyoming	do	24.0	600	do	3.5	.192	3	4	2	2	2

[1]Meaning of VM is volatile matter; FC, fixed carbon.

CONCLUSIONS AND DISCUSSION

In the following discussions the term "quantity of coal" is used to indicate the combustible portion of the dust; these data are reported as ounces of combustible per cubic foot of entry volume; presumption is made that should a disturbance or local explosion occur, all of the dust would be thrown into suspension. By use of the ratio of the dust weight to unit volume of entry, compensation is made for differences in entry cross section.

A brief summary of the results of the survey is given in the following paragraphs with details of the statistical analyses. The mean quantities of coal dust and the percent incombustible in the dust in return airways are summarized in table 2.

TABLE 2. - Mean quantity of coal and incombustible content in mine dust samples

Type of sample	Quantity coal, oz./cu. ft.	Incombustible content, percent
Float dust:		
Skim......................	0.016	87.1
Rib.......................	.005	89.8
Roof......................	.001	92.2
Perimeter.................	.022	88.6
Skim-belt entry[1]	.077	58.7
Skim-nonbelt entry[1]	.011	88.5
Coarse dust:		
1-inch....................	.242	76.2
Skim......................	.040	82.2

[1]Data from nine coal mines.

The data show the mean quantity of float coal at a sampling location is equivalent to 0.022 oz./cu. ft., except in belt entries where 0.077 oz./cu. ft. of coal is present. More than three quarters of the float coal is on the floor. Approximately 6 percent of the samples contained more than 0.1 oz./cu. ft. of float coal. The mean incombustible in the surficial dust in return airways is 88.6 percent; the differences in incombustible content among the floor, rib, and roof locations are slight. Although the average value is high, 20, 13, and 12 percent of the floor, rib, and roof samples, respectively, contained less than 65 percent incombustible.

Data given in table 2 show that the mean amount of coarse coal dust (through a No. 20 sieve) in the 1-inch sample is equivalent to 0.242 oz./cu. ft. Previous research in the experimental coal mine showed that this quantity of coal dust is about optimum with regard to explosion propagation. Data included in table 2 for the coarse coal in the skim sample show the quantity to be 0.040 oz./cu. ft., or about one-sixth of that in the 1-inch sample; this ratio of 1 to 6 could be expected from the relative depths of the two samples. The mean incombustible content of the 1-inch samples is 76.2 percent; however, 46 percent of these samples contained less than 65 percent incombustible.

Statistical comparison showed that the quantity of coal and the incombustible content did not differ significantly in samples collected from mines using conventional or continuous mining equipment. Similarly, no significant differences in amount of coal or incombustible content were observed between entries having a low or a high velocity ventilating air current, between mines working in coal seams having a low or a high volatile content, between mines located in eastern or western States, and between sampling locations adjacent to or remote from the working face.

The quantity of float coal was independent of mine size (production less or greater than 4,990 tons per day), but the average incombustible content was significantly less in the low production than in the high production mines (78.1 vs. 89.6 percent).

Ten samples of skim-float dust were collected in nine mines where coal was conveyed by belt. The float-coal concentration in the belt entries is seven times higher than that in the nonbelt entries in these mines (0.077 vs. 0.011 oz./cu. ft.). The mean incombustible content in the belt entries is 58.7 percent as compared with 88.5 percent for the nonbelt entries.[8] The incombustible content was less than 65 percent in 7 of the 10 belt samples. These limited data indicate that the potential dust explosion hazard in belt entries is critical; not only is the quantity of float coal excessive, but the incombustible content is low.

Analysis of the particle size of the float skim samples shows that on the average 46 percent of the combustible passes a No. 200 sieve; the range for 95 percent of the samples is 35 to 55 percent through the No. 200 sieve.

The survey of dust conditions in return airways in 50 coal mines in the United States shows that on the average the incombustible percentage in the float dust is high, and the quantity of float coal is low; unfortunately, average values are not satisfactory for assessing the potential hazard of coal-dust explosions. The back entries should be rock-dusted for at least 1,000 feet outby the junction with the first active entry. Where float coal deposits exist, somewhat higher percentages of incombustible may be required to neutralize the dust explosion hazard. It could be expected that the frequency distributions for incombustible would show truncation at 65 percent, the minimum value provided by the Federal Mine Safety Code for Bituminous-Coal and Lignite Mines of the United States. Data from the present investigation, show this is not true. In the operating mines studied, 46 percent of the 1-inch coarse, 20 percent of the skim float, 13 percent of the rib, and 12 percent of the roof samples contained less than 65 percent incombustible content. Using 80 percent incombustible as a tentative criterion for protection against explosion propagation where light float dust deposits are present in return airways, the sampling locations deficient in incombustible in the 1-inch coarse, skim float, rib, and roof-float samples are 65, 40, 26 and 28 percent, respectively. These values indicate that a deficiency exists in current rock dust practices.

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[8] The belt entries constitute a separate sample population from the nonbelt entries; details of this statistical analysis are given in the appendix.

Research on the explosion hazards of float coal deposits has not progressed sufficiently to establish a limiting quantity of float coal above which normal rock dusting procedures may become inadequate for protection against explosion propagation. Assuming a tentative value of 0.10 oz./cu. ft. of float coal dust as a critical value, the survey shows that 6 percent of the perimeter samples had higher quantities. In these mines, methods of protection to supplement normal rock dusting must be provided, or means for decreasing the quantity of float dust must be developed.

Data from limited samples indicate that belt entries present a serious dust explosion hazard when judged from the existing criterion of 65 percent incombustible content without considering the special hazard arising where surficial coal exists. The data show that 70 percent of the belt entries contained less than 65 percent incombustible content, and 80 percent contained less than 80 percent incombustible content. The mean quantity of skim-float coal present in the belt entries is 0.077 oz./cu. ft. or seven times higher than that for return airways in those mines.

The survey data show that the logarithms of the quantity of coal and of the combustible in the dust collected from the 50 mines are distributed approximately normal. This permits statistical treatment of the data with confidence. The data reported in 1954 from an intensive dust sampling program in a single coal mine indicate the incombustible content in the band and 1-inch samples approximate normal distributions, and the rib-roof samples approximate lognormal (Ln) distribution.[9]

STATISTICAL ANALYSIS

The quantity of coal and the incombustible content in the dust samples exhibited lognormal distribution as shown in the histograms, figures 3 through 13. This distribution is proven with 95 percent confidence by the chi-square test for all data except that shown on figures 8 and 10.

In a few instances, distributions are truncated or deviate from normal by inclusion of excessive numbers of samples of pure rock dust. These latter samples are considered nonrepresentative and are not used in calculations; dashed lines indicate an assumed frequency for calculation.

The deviation, d', around the mean for the normal distribution is shown at the top of each histogram. The average quantity of coal and percent incombustible are shown as the "mean of samples" and are expressed as the antilog of

[9]Work cited in footnote 5.

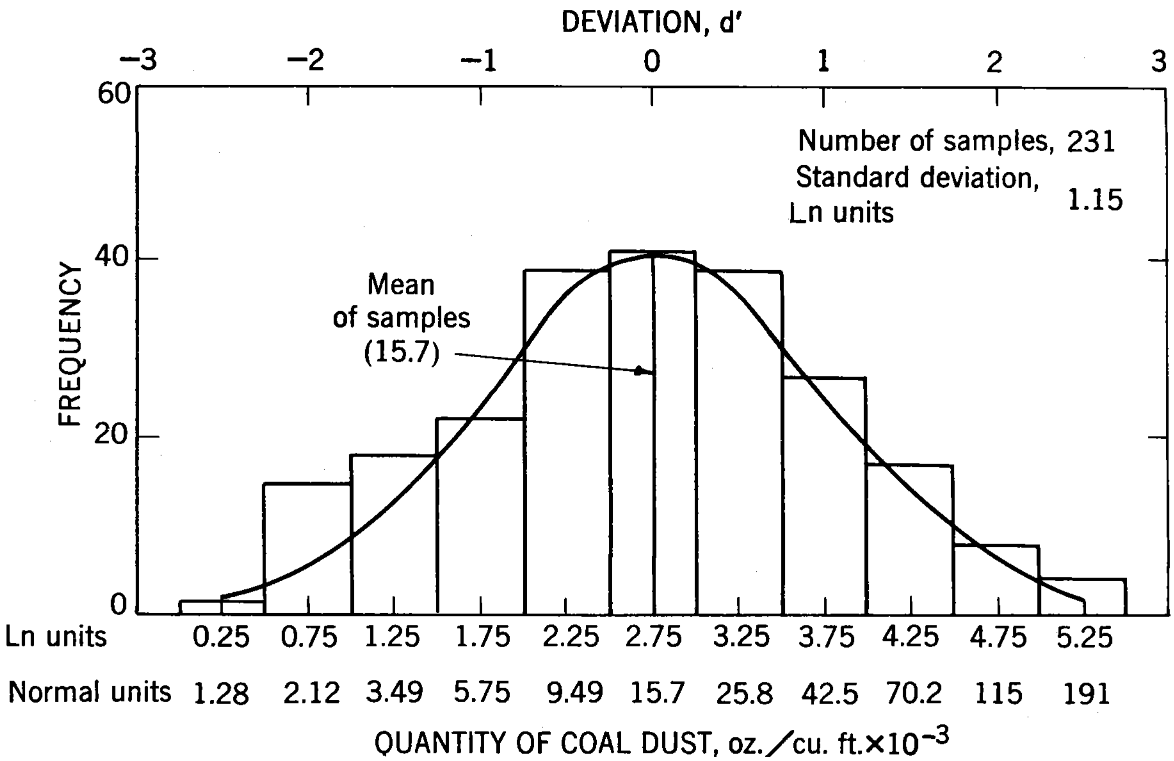

FIGURE 2. - Distribution of Float-Coal Dust Concentration in Skim Samples.

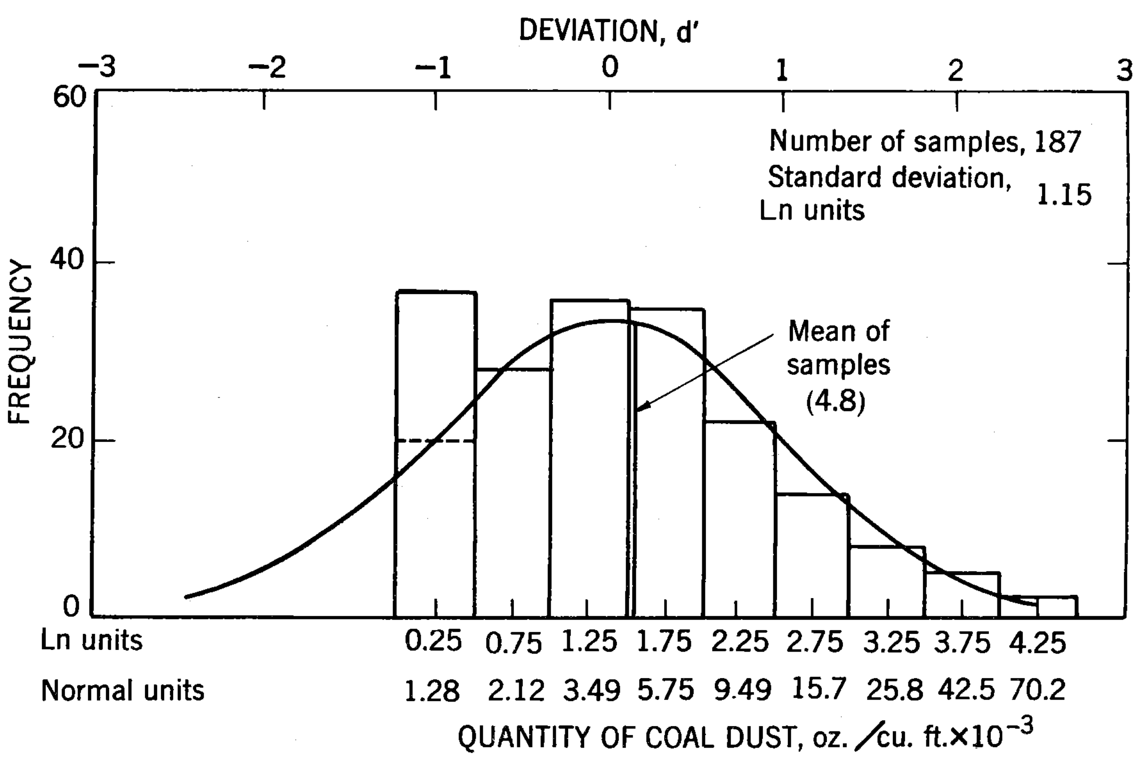

FIGURE 3. - Distribution of Float-Coal Concentration in Rib Samples.

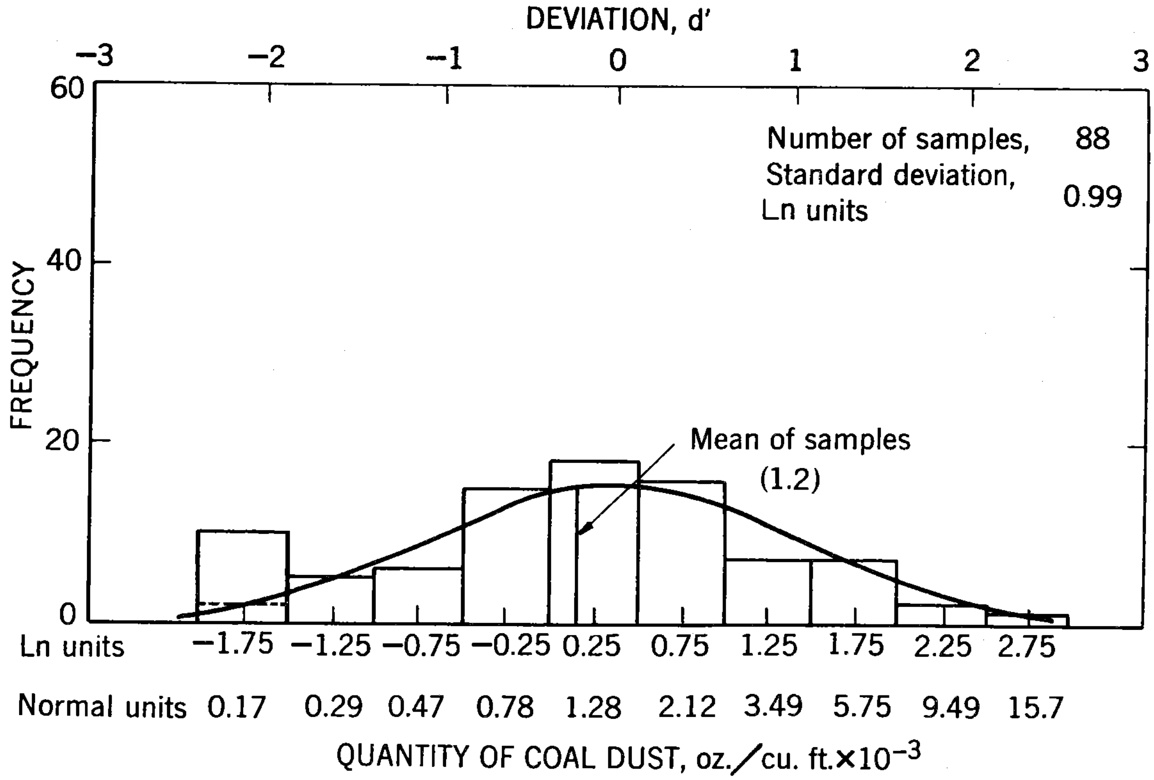

FIGURE 4. - Distribution of Float-Coal Concentration in Roof Samples.

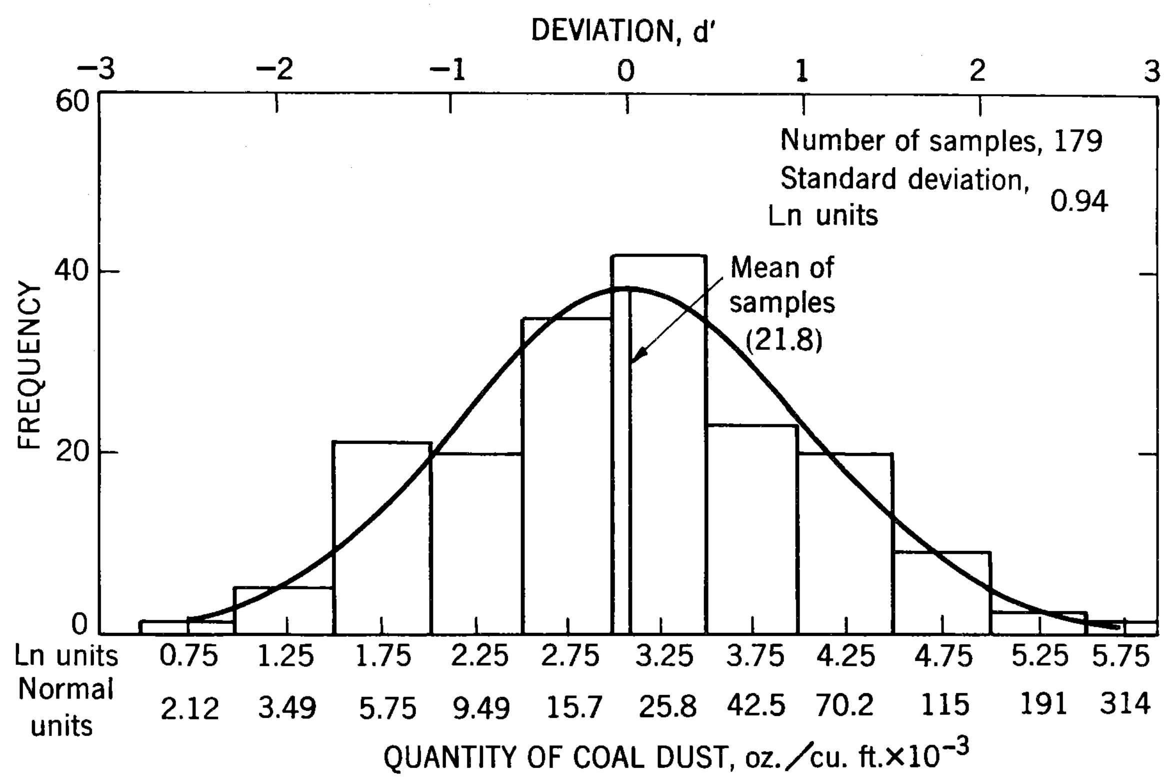

FIGURE 5. - Distribution of Float-Coal Concentration in Rib-Roof-Skim Samples.

the geometric mean.[10] Conclusions from statistical calculations are made in accordance with accepted procedures.[11]

As shown in figures 2, 3 and 4, the mean quantity of float coal on the floor, ribs and roof in the samples collected are 15.7, 4.8 and 1.2 oz./cu. ft. x 10^{-3} respectively, or a total of 0.022 oz./cu. ft. Data from the composite floor-rib-roof or floor-rib samples at specific locations (fig. 5) also show the average to be 0.022 oz./cu. ft. Approximately 72.7 percent of the float coal is on the floor, 22.7 percent is on the ribs, and 4.6 percent is on the roof surfaces. From figure 5 it can be estimated that 94 percent of the samples contain 0.10 oz./cu. ft. or less float coal. The data for the roof samples (fig. 4) are approximate, as 40 samples contained insufficient dust for analysis, and 70 samples were not collected because of wetness or high roof.

Incombustible Content in Float Samples

Although the term "float dust" implies coal dust overlaying a rock-dusted surface, the dust collected from the mine surfaces contained appreciable inert dust. The frequency distributions of the incombustible contents of the floor (skim), rib- and roof-float samples are shown in figures 6, 7 and 8;[12] the mean incombustible contents are 87.1, 89.8 and 92.2 percent respectively. A composite frequency distribution is shown in figure 9 prepared from data where floor-rib-roof or floor-rib samples were collected at a given location; the mean incombustible of the composite float dust sample is 88.6 percent.

The frequency distribution of the incombustible content in the skim samples shows an excessive number containing pure rock dust; truncation occurs at low incombustible percentages where the dust is essentially pure coal. Not enough samples were collected from the roof for determination of a frequency distribution; however, the limited data indicate a bimodal distribution having peaks at high incombustible (pure rock dust) and at 70 percent incombustible.

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[10] Geometric means are used rather than arithmetic because the sample populations have log normal distribution. The geometric mean is the "n"th root of the product of "n" samples.

[11] Becker, R. M., and Hazen, Scott, W., Jr., Particle Statistics of Infinite Populations as Applied to Mine Sampling: Bureau of Mines Rept. of Investigations 5669, 1961, 79 pp.

Brownlee, K. A., Industrial Experimentation; Chemical Pub. Co., New York, N.Y., 1953, 194 pp.

Hazen, Scott, W., Jr., A Comparative Study of Statistical Analysis and Other Methods of Computing Ore Reserves, Utilizing Analytical Data from Maggie Canyon Manganese Deposit, Artillery Mountains Region, Mohave County, Ariz.: Bureau of Mines Rept. of Investigations 5375, 1958, 188 pp.

Hold, A., Statistical Theory with Engineering Applications. John Wiley & Sons, New York, N.Y., 1952, 783 pp.

[12] These and the other histograms for incombustible content of mine dusts show data for the logarithm of 100 minus the percent incombustible, as the logarithms of percent combustible have normal distribution.

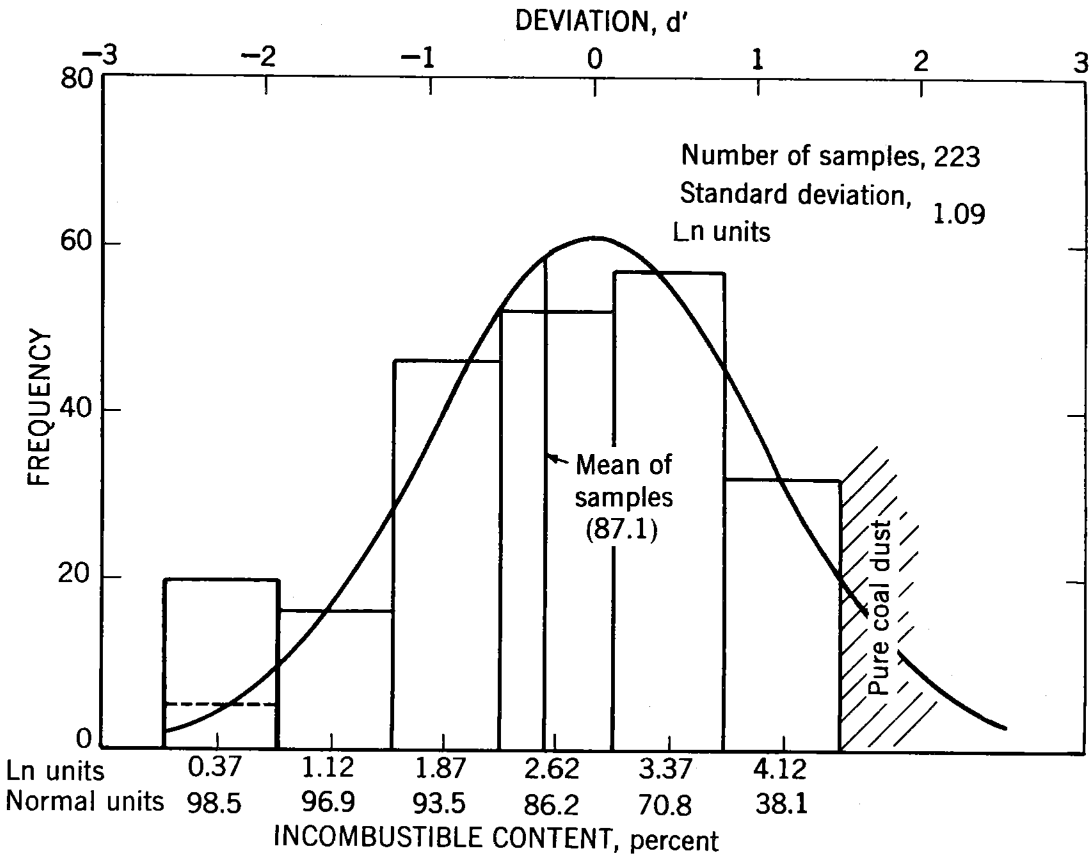

FIGURE 6. - Distribution of Incombustible Contents of Float Dust in Skim Samples.

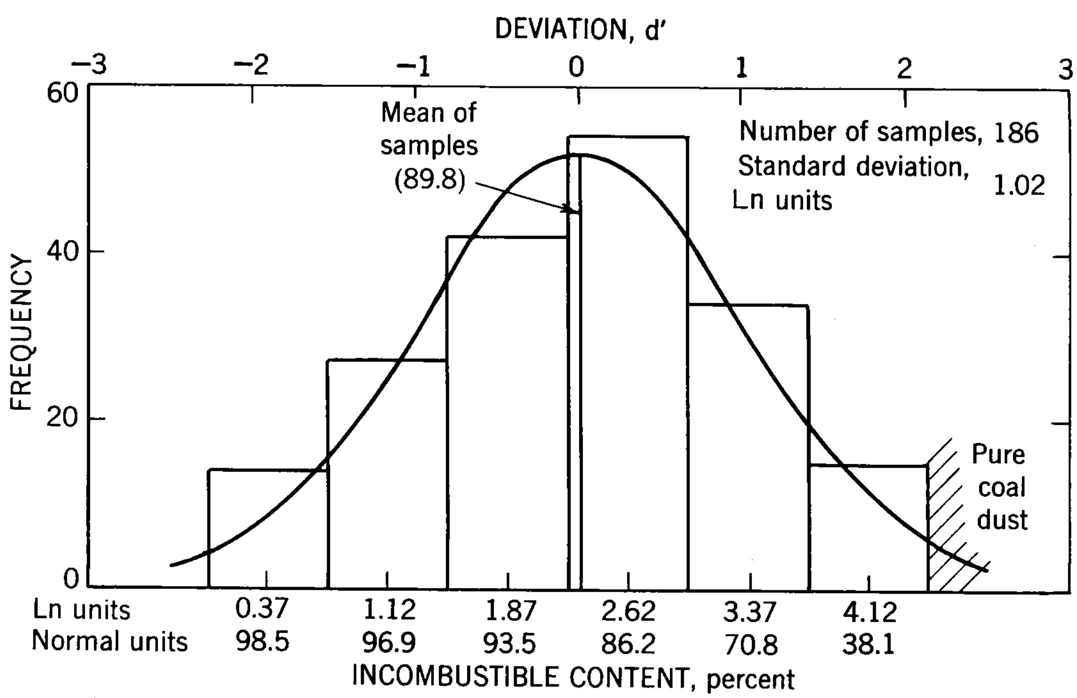

FIGURE 7. - Distribution of Incombustible Contents of Float Dust in Rib Samples.

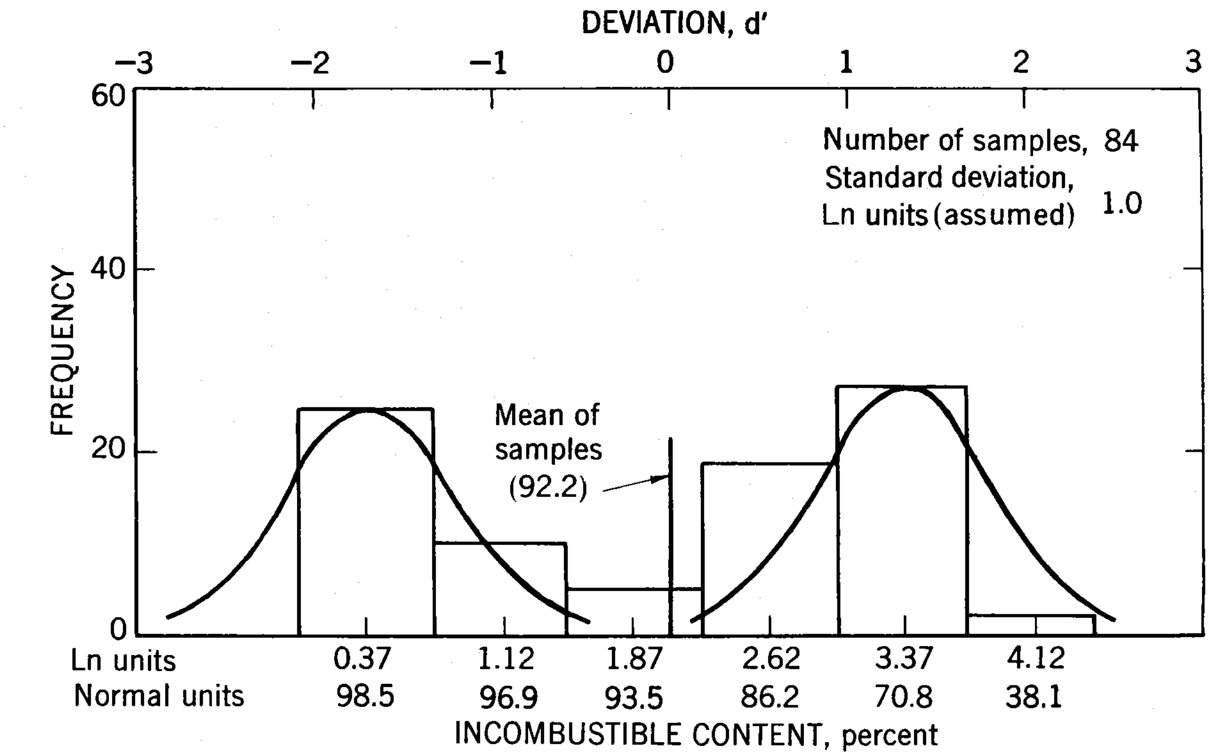

FIGURE 8. - Distribution of Incombustible Contents of Float Dust in Roof Samples.

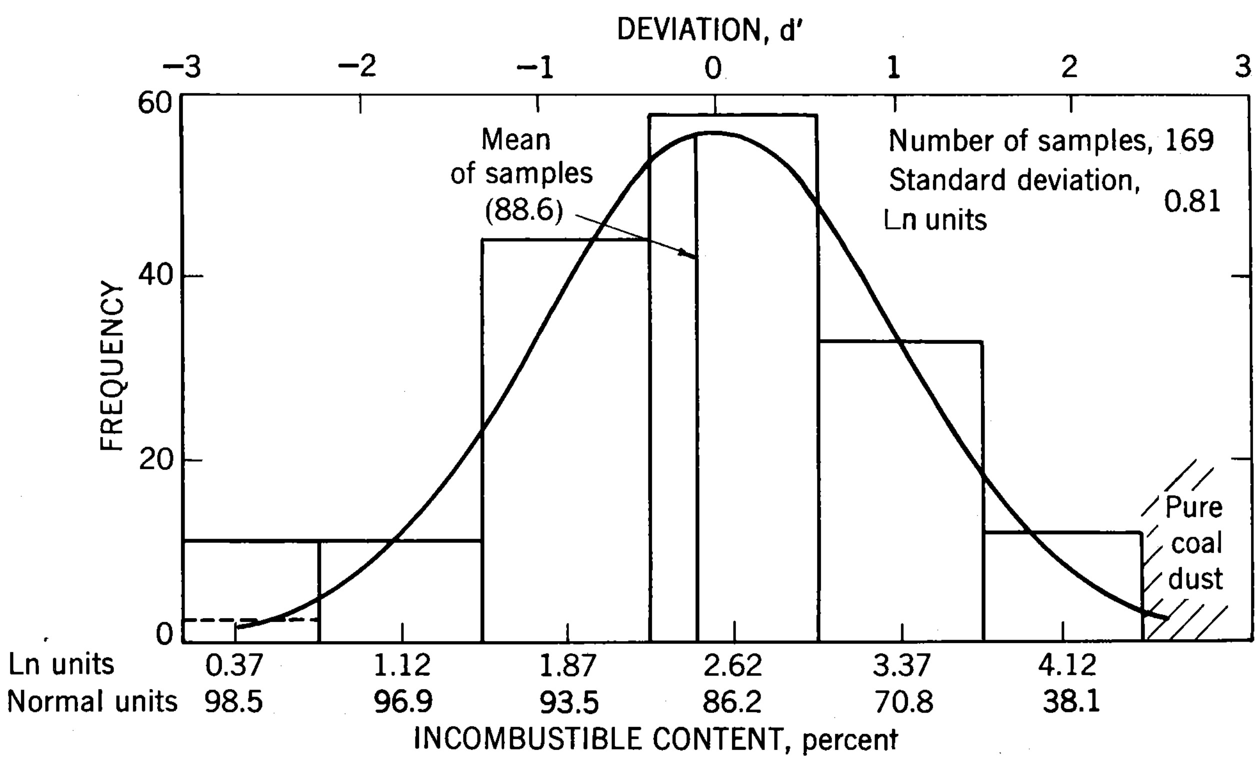

FIGURE 9. - Distribution of Incombustible Contents of Float Dust in Rib-Roof-Skim Samples.

Quantity of Coarse Coal Dust

The frequency distribution of the quantity of coarse coal dust (through No. 20 sieve) in the 1-inch as well as the skim floor samples are approximately lognormal (figs. 10 and 11). The quantity of coarse coal dust in the 1-inch samples ranged from 0.008 to 2.02 with an average value of 0.242 oz./cu. ft. The mean quantity of coarse coal dust in the skim samples is 0.040 oz./cu. ft., or 2.5 times more than the quantity of coal in the float skim samples.

Incombustible Content of Coarse Dust

The incombustible contents of the coarse dust in the 1-inch and skim floor samples is 76.2 and 82.2 percent, respectively (figs. 12 and 13). The lognormal frequency distributions for both types of samples appear to be truncated at about 10 percent incombustible (pure coal dust). From analysis of paired samples, the incombustible in the skim sample was determined to be 4.4 percentage points higher than that in the 1-inch sample.[13] As large variations in difference in the incombustible exist between the paired samples, skim sampling cannot be substituted for 1-inch sampling with reliability. The difference between the two types may be as much as 4.4 ± 21.3 percent incombustible (mean plus or minus 1.96 times the standard deviation) for 95 percent of the samples.

ACCURACY OF EVALUATION OF THE QUANTITY AND INCOMBUSTIBLE CONTENT OF MINE DUSTS

Information on the accuracy of evaluation of the quantity of coal dust and the incombustible content at a given location in a mine entry was obtained from 10 adjacent replicate samples collected in mine No. 36. These data indicate the overall accuracy in the sampling technique, local variation in dust deposit, and laboratory determination. Table 3 shows that for the quantity of dust and incombustible content, the range to include 95 percent of the samples is relatively small. Therefore, the combination of sampling technique, analysis, and local variation at a station permit relatively accurace assessment of the quantity of coal and incombustible content at the station.

TABLE 3. - Variation of quantity of coal and incombustible content of 10 replicate dust samples from mine No. 36

Type of sample	95 percent confidence interval[1]	
	Quantity of coal, oz./cu. ft.	Incombustible, percent
Skim float....................	0.004 ± 0.0043	96.7 ± 2.2
Rib float.....................	.002 ± .0013	92.3 ± 4.6
Skim coarse...................	.005 ± .0067	97.6 ± 3.6
1-inch coarse.................	.046 ± .068	97.3 ± 2.8

[1]Mean ± 1.96 times standard deviation.

[13]This difference was calculated in arithmetical rather than logarithmical units in this instance, as the difference between paired samples is considered rather than the difference between the means. Table 2 shows the difference in the mean to be 6.0 percentage points.

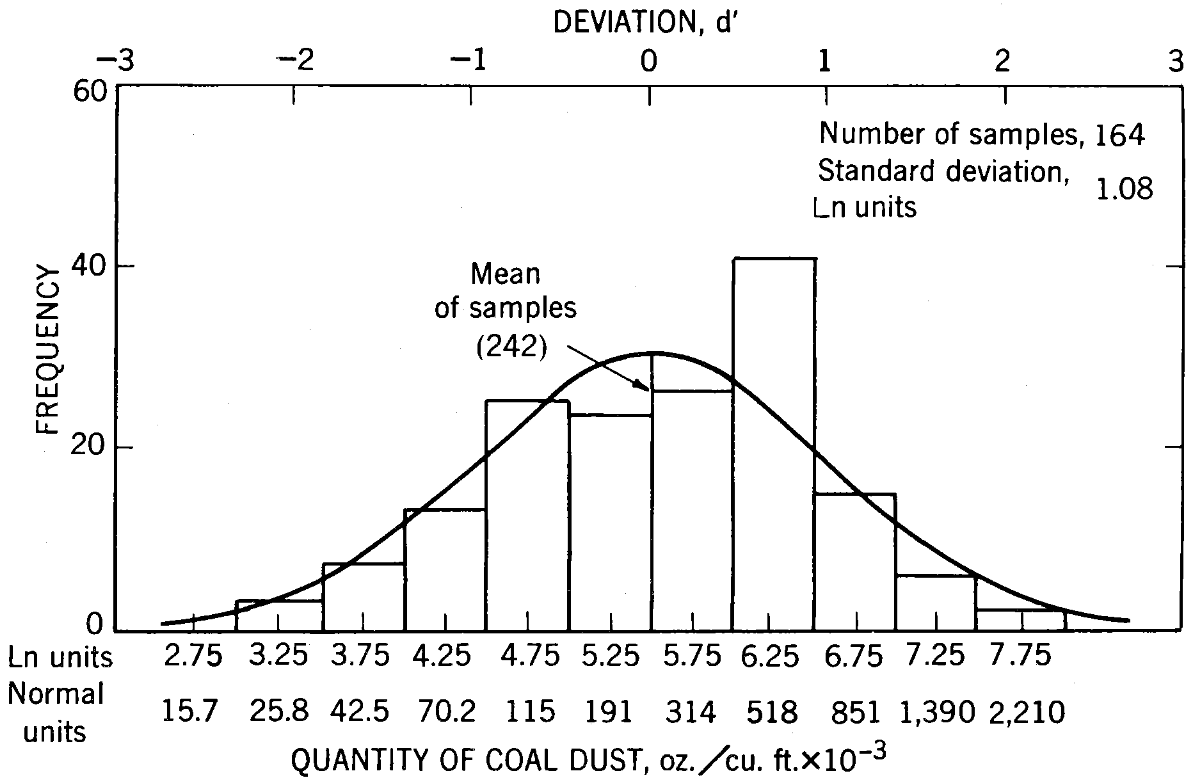

FIGURE 10. - Distribution of Coarse Coal Dust Concentration in 1-Inch Samples.

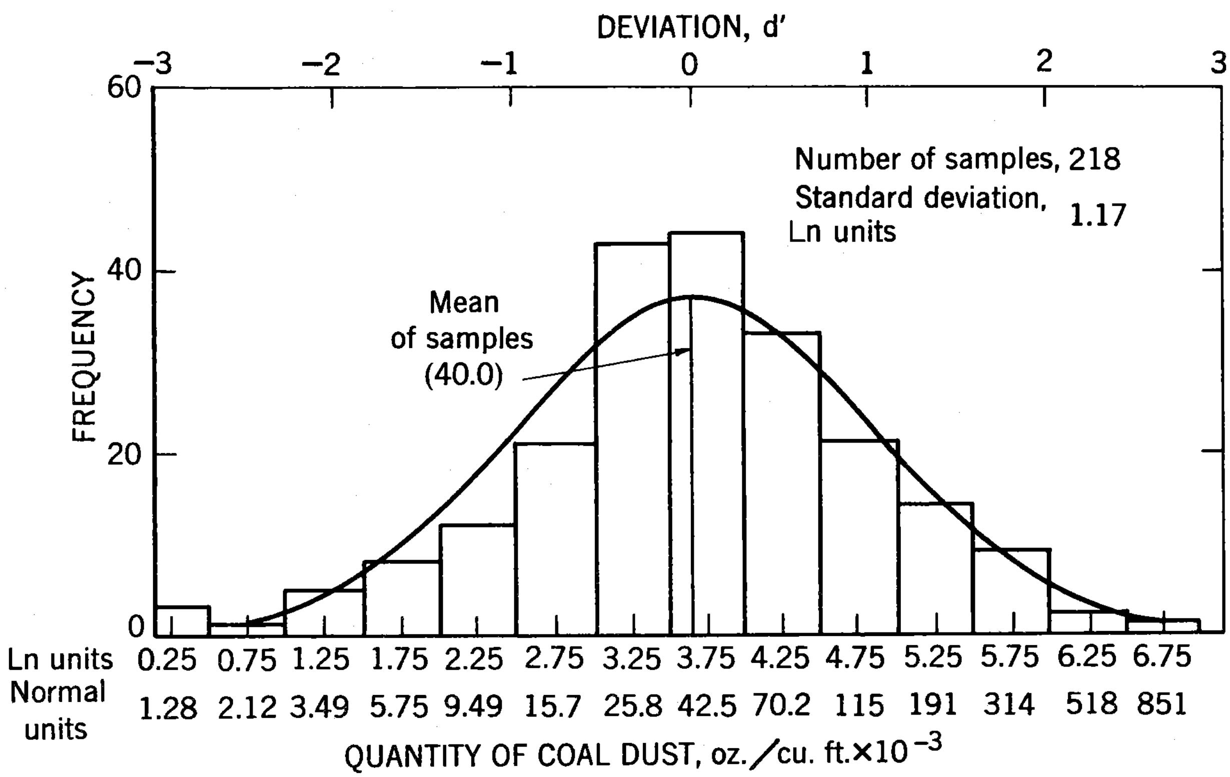

FIGURE 11. - Distribution of Coarse Coal Dust Concentration in Skim Samples.

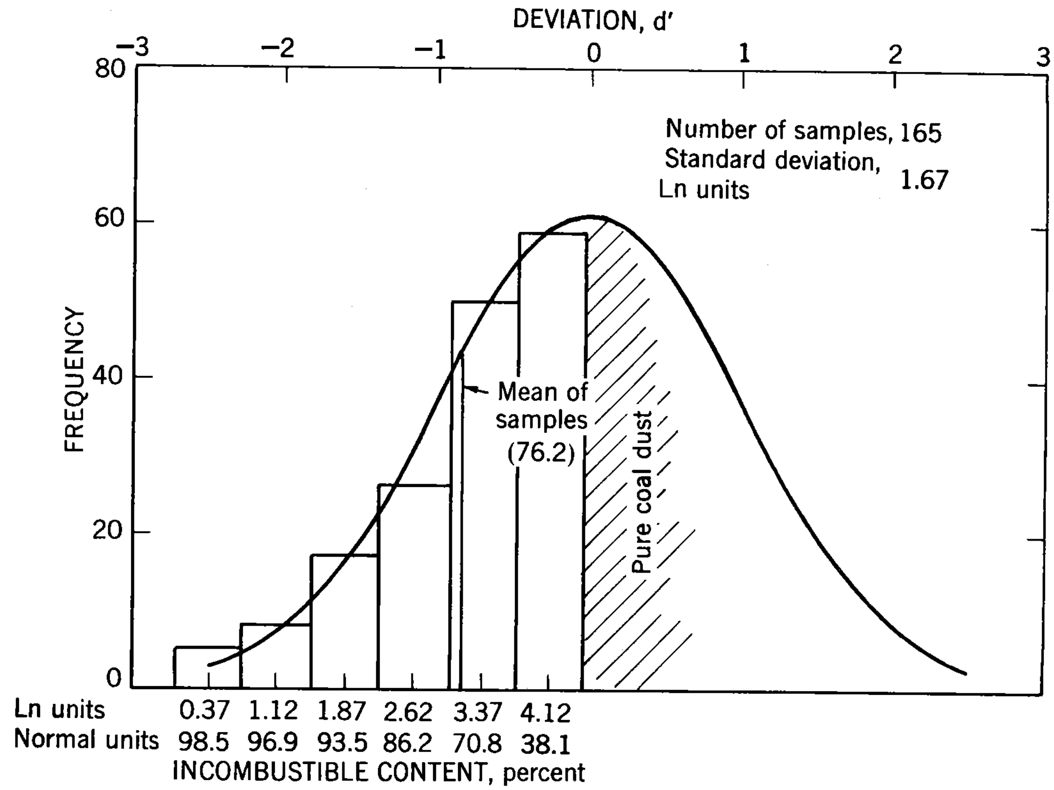

FIGURE 12. - Distribution of Incombustible Contents of Coarse Dust in 1-Inch Samples.

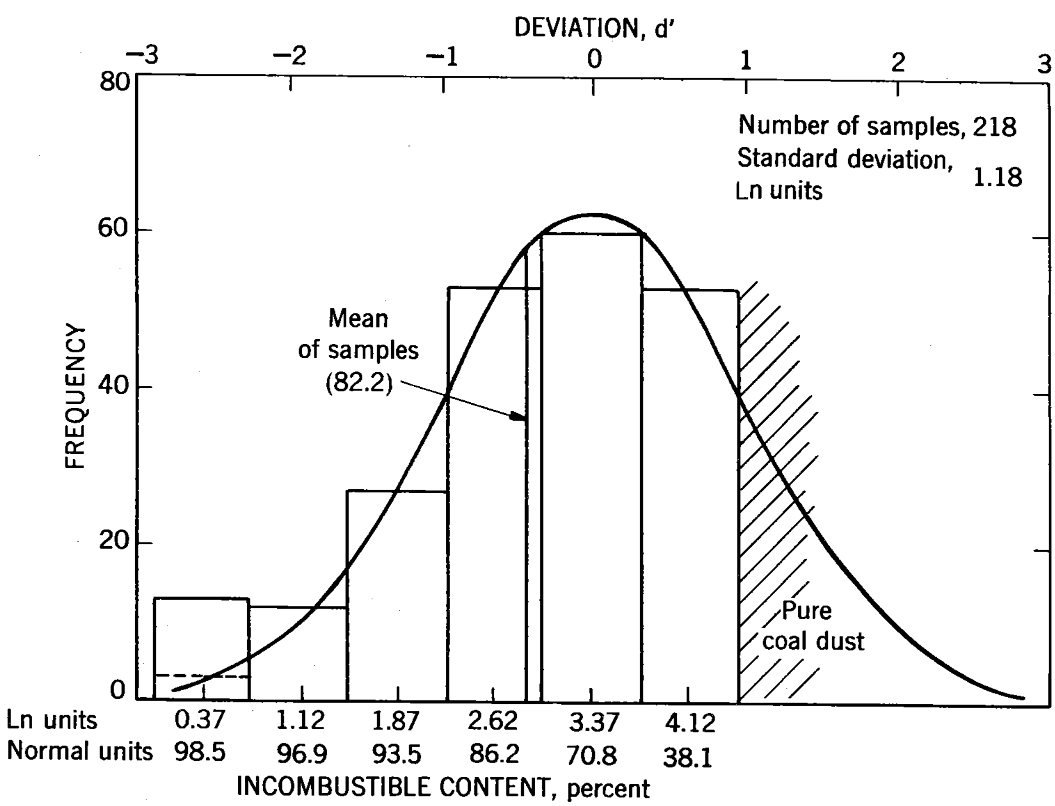

FIGURE 13. - Distribution of Incombustible Contents of Coarse Dust in Skim Samples.

FIGURE 14. - Collection of Special Skim Sample From Flat Surface.

The variation in quantity (table 4) of skim- and rib-float coal dust is about 10 times greater for random samples than for the replicate samples collected in mine No. 36. The variation in the incombustible content for the random samples is three to six times greater than that for the replicate samples.[14]

Information on the adequacy of assessment of the quantity of coal and incombustible content of the dust in the return airways was further provided from 13 special samples. In 10 mines special skim samples were collected from smooth surfaces on top of fallen rock (fig. 14) where the whole depth of dust deposit could be easily brushed into the collecting pan. The data in table 5 show that the quantity of skim-float coal and incombustible content of the

[14]Analysis of the variances and means indicates the two types of samples are from two different populations. Comparison of the random samples in mine No. 36 with the samples from 50 mines indicates that the means are significantly different, but not the variances.

dust collected from the smooth rock surfaces are equivalent to those of the skim samples collected from the mine floor.[15]

TABLE 4. - Comparison of quantity of coal and incombustible content in random and replicate dust samples from mine No. 36

Sample		95 percent confidence interval[1]	
Type	Number	Quantity of coal, oz./cu. ft.	Incombustible, percent
Skim float:			
Random..............	11	0.012 ± 0.034	93.4 ± 14.0
Replicate...........	10	.004 ± .0043	96.7 ± 2.2
Rib float:			
Random..............	7	0.011 ± 0.019	84.0 ± 14.3
Replicate...........	10	.002 ± .0013	92.3 ± 4.6

[1]Mean ± 1.96 times standard deviation.

TABLE 5. - Comparison of quantity of coal and incombustible content of skim float dust collected from smooth rock and from normal floor surfaces

	Type of sample		
	Skim samples from all mines	Skim samples from 10 mines	Special rock surface sample from 10 mines
Quantity of float coal:			
Number of samples..............	231	10	10
Mean (Ln units)[1]	2.82	2.59	2.83
Mean, oz./cu. ft...............	.017	.013	.017
Standard deviation (Ln units)..	1.15	.65	1.41
Incombustible content:			
Number of samples..............	223	10	10
Mean (Ln units)[2]	2.56	2.25	2.14
Mean, percentage...............	87.1	90.5	91.5
Standard deviation (Ln units)..	1.09	.77	1.37

[1]Natural logarithm (Ln) of 1,000 times the dust concentration in ounce per cubic foot.
[2]Natural logarithm of 100 minus the incombustible percentage.

[15]Analysis of the variances and means indicates that the special rock samples are from the same population as all samples collected.

APPENDIX

Comparison of nonbelt and belt entries in nine mines (skim samples)

Mine No.	Incombustible content				Quantity of combustible			
	Nonbelt		Belt		Nonbelt		Belt	
	Pct.	Ln (100 minus pct.)	Pct.	Ln (100 minus pct.)	Oz./cu. ft.	Ln (1000 times oz./cu. ft.)	Oz./cu. ft.	Ln (1000 times oz./cu. ft.)
4	97.5	0.916	83.5	2.803	0.002	0.693	0.047	3.850
	97.0	1.099			.004	1.386		
	91.0	2.197			.005	1.609		
13	71.5	3.350	45.0	4.007	.043	3.761	.176	5.170
	92.0	2.079			.009	2.197		
	85.0	2.708			.017	2.833		
33	77.0	3.135	59.0	3.714	.014	2.639	.062	4.127
	49.0	3.932			.023	3.136		
	93.0	1.946			.004	1.386		
	95.0	1.609			.004	1.386		
34	75.5	3.199	39.5	4.103	.020	2.996	.124	4.820
	89.0	2.398			.012	2.485		
	90.5	2.251			.033	3.497		
42	53.0	3.850	33.0	4.205	.007	1.946	.041	3.714
	30.0	4.249	33.5	4.197	.007	1.946	.014	2.639
	77.0	3.135			.006	1.792		
45	86.5	2.603	63.0	3.611	.010	2.303	.040	3.689
	96.0	1.386			.006	1.792		
	49.0	3.932			.021	3.046		
	94.0	1.792			.004	1.386		
47	94.5	1.705	76.3	3.157	.010	2.303	.030	3.401
	82.0	2.890			.014	2.639		
	75.0	3.219			.015	2.708		
	84.5	2.741			.012	2.485		
48	98.5	.405	81.0	2.944	.005	1.609	.231	5.442
	88.0	2.485			.008	2.079		
	95.5	1.504			.011	2.398		
	99.0	.000			.002	0.693		
	61.0	3.663			.002	0.693		
	98.0	.693			.022	3.091		
	95.0	1.609			.022	3.091		
	95.0	1.609			.012	2.485		
	90.0	2.302			.017	2.833		
50	36.0	4.159	13.0	4.466	.139	4.934	.725	6.586
	83.5	2.803			.013	2.565		
	15.0	4.443			.036	3.583		

Analysis of Variance

Number of samples	36	10	36	10
Σx (Ln units)	87.996	37.207	84.403	43.438
Σx^2	259.5450	141.4564	226.9733	200.7403
$(\Sigma x)^2$	7743.2960	1384.3608	7123.8664	1886.8598
$\Sigma x/n$	2.4443	3.7207	2.3445	4.3438
$(\Sigma x)^2/n$	215.0916	138.4361	197.8852	188.6860
$\Sigma x/n$ (normal units)	88.5	58.7	0.011	0.077

$$S^2 = \frac{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}{n - 1}$$

Incombustible content [Ln (100 minus percent combustible)][1]

$$S^2_{NB} = \frac{259.5450 - 215.0916}{35} = 1.2701$$

$$S^2_B = \frac{141.4564 - 138.4361}{9} = 0.3356$$

$$F = \frac{S^2_{NB}}{S^2_B} = F^{35}_{9} = \frac{1.2701}{.3356} = 3.785$$

Critical value of ${}^{35}_{9}F_{.025} = 3.53$.

As the calculated F exceeds the critical value at the 95 percent confidence level, the variances are statistically different, indicating different populations.

Quantity of float dust [Ln (1,000 times oz./cu. ft.)]

$$S^2_{NB} = \frac{226.9733 - 197.8852}{35} = 0.8311$$

$$S^2_B = \frac{200.7403 - 188.6860}{9} = 1.3394$$

$$F = \frac{S^2_B}{S^2_{NB}} = F^{9}_{35} = \frac{1.3394}{.8311} = 1.612$$

Critical value of ${}^{9}_{35}F_{.025} = 2.51$.

Calculated F does not exceed critical F value, the variances are not statistically different.

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[1] The following abbreviations are used:

NB = non-belt samples. $\overline{NB}$ = mean of samples in nonbelt entries.

B = belt samples $\overline{B}$ = mean of samples in belt entries.

Assuming the sample variances are a valid measure of the population variances it follows that the "t" and "t′" tests must be applied to determine the difference between the means of the nonbelt and belt entries.

Incombustible $\quad (S^2_{NB} \neq S^2_B)$

$$t' = \frac{\overline{B} - \overline{NB}}{\sqrt{\frac{S^2_B}{n_B} + \frac{S^2_{NB}}{n_{NB}}}} = \frac{3.7207 - 2.4443}{\sqrt{\frac{0.3356}{10} + \frac{1.2701}{36}}} = 4.864$$

$$\phi = \frac{\left[\frac{S^2_B}{n_B} + \frac{S^2_{NB}}{n_{NB}}\right]^2}{\frac{\left[\frac{S^2_B}{n_B}\right]^2}{n_B + 1} + \frac{\left[\frac{S^2_{NB}}{n_{NB}}\right]^2}{n_{NB} + 1}} - 2 = \frac{(0.3356 + 1.2701)^2}{\frac{\left[\frac{0.3356}{10}\right]^2}{11} + \frac{\left[\frac{1.2701}{36}\right]^2}{37}} - 2 = 33$$

$t' = 4.864 \qquad$ critical $t'_{.025,\ 33} = 2.03$

Calculated $t' >$ critical t' $\therefore$ sample population means are significantly different at 95 percent confidence level.

Combustible $\quad (S^2_{NB} = S^2_B)$

$$t = \frac{\overline{B} - \overline{NB}}{\sqrt{\left[\frac{1}{n_B} + \frac{1}{n_{NB}}\right]\left[\frac{S^2_B(n_B - 1) + S^2_{NB}(n_{NB} - 1)}{n_B + n_{NB} - 2}\right]}}$$

$$= \frac{4.3438 - 2.3445}{\sqrt{\left[\frac{1}{10} + \frac{1}{36}\right]\left[\frac{9(1.3394) + 35(0.8311)}{10 + 36 - 2}\right]}}$$

$t = 5.78 \qquad t_{.025,\ 44} = 2.02$

$t = 5.78 > t_{.025,\ 44} = 2.02$ $\therefore$ sample population means are significantly different at 95 percent confidence level.