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Peak Methane Concentrations During Coal Mining

An Analysis

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNITED STATES DEPARTMENT OF THE INTERIOR
Rogers C. B. Morton, Secretary

BUREAU OF MINES
Thomas V. Falkie, Director

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PEAK METHANE CONCENTRATIONS DURING COAL MINING

An Analysis

by

Fred N. Kissell,[1] J. L. Banfield, Jr.,[2] R. W. Dalzell,[3] and M. G. Zabetakis[4]

ABSTRACT

Methane concentration peaks were measured by the Bureau of Mines at coal mine working faces during entry development. The statistical distribution of peaks was found to be normal or log normal depending on how well the methane was being mixed into the ventilation airstream. A normal distribution indicated good mixing, whereas a log-normal distribution indicated that mixing was poor. In addition, the "highest" peaks over selected intervals were found to fit a type I extreme-value distribution, a result similar to that obtained while mining longwall faces.

INTRODUCTION

Since its establishment in 1910, the Bureau of Mines has been actively concerned with decreasing the hazards associated with the presence of methane in coal mines. In practice, a methane ignition is most likely to occur near the working face, where a continuous miner releases methane into the mine atmosphere as it breaks coal. If the cutter picks strike a hard surface such as sandstone, an ignition by frictional spark may result.

The maximum allowable methane concentration in the working place as measured not less than 12 inches from the roof, face, or rib must be less than 1 volume-percent (12)[5] whereas the lower explosive limit is 5 percent. Although this difference theoretically provides a safety factor, in practice face ignitions are not uncommon in U.S. coal mines. The vast majority of such ignitions do no harm to the men working nearby; however, in some cases injuries and death result. When an ignition occurs at the face the possibility of a major disaster is always present, particularly if the burning methane ignites coal dust.

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[2] Mining engineer.
[3] Chief, Ventilation Group.
[4] Supervisory research chemist.
[5] Underlined numbers in parentheses refer to items in the list of references at the end of this report.

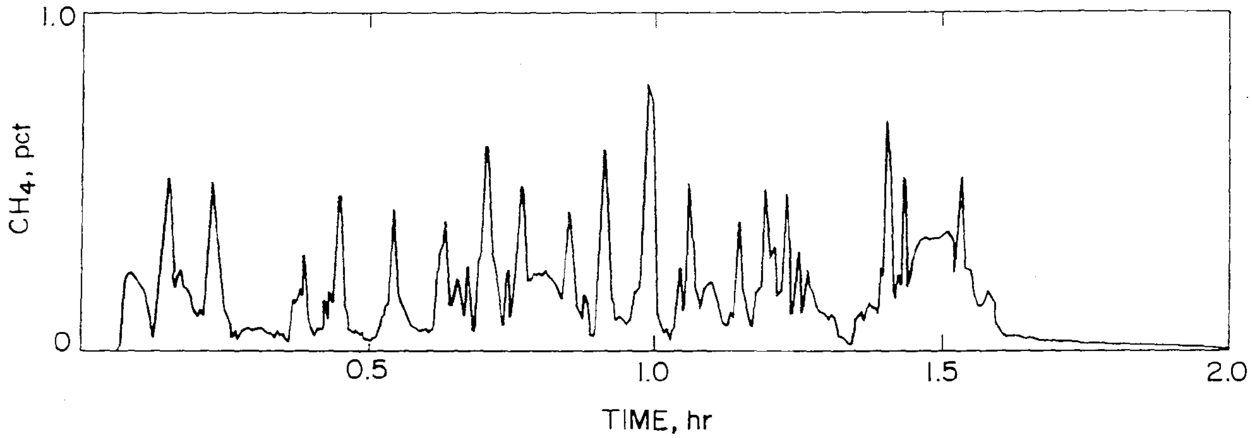

FIGURE 1. - Recorder chart from methane monitor located near working face.

Methane emission at the immediate working face varies substantially, generally increasing as the mining machine cuts into the solid coal and then dropping to some background value as the machine backs away in preparation for another cut. A typical recorder chart from a methane monitor located near the working face is shown in figure 1. Each peak corresponds to one complete shear, which in this case involves sumping in about 2 feet, raking the cutter head down, and loading the coal. The peak methane concentrations are several times higher than the average. In practice, if the working face is not adequately ventilated, these peaks may exceed the lower explosive limit even when the average concentration is satisfactory (10).

High peak concentrations of methane also occur during longwall mining. Lavtsevich (5) has found that the statistical distribution of "highest" concentrations at a longwall face is given by the first or second type limiting distribution (extreme value) laws:

$$\Phi_1(x) = \exp\left[-e^{-\alpha(x-\mu)}\right],$$

and

$$\Phi_2(x) = \Phi_1(\ln x),$$

where $\Phi(x)$ is the probability that a given maximum value of a random variate (CH_4 concentration) is less than x, and α and μ are parameters related to the slope and intercept of extreme probability plots.

The purpose of this investigation was to examine the distribution of methane concentration peaks obtained during entry development in room-and-pillar mining. Given the proper distribution of peaks within the legal limit, it might be possible to predict with the extreme-value laws the probability of surpassing this limit, and perhaps the explosive limit, within a given time interval.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance given by Bureau of Mines engineers of the Technical Support Center, Pittsburgh, Pa., who have participated in the collection and evaluation of data: J. D. Hadden, R. A. Haney, S. M. Hoover, H. Schade, A. Reisz, and E. J. Miller.

EXPERIMENTAL WORK

Face emission data were collected by the Bureau of Mines Technical Support Center as part of a study of the effect of integral machine-mounted dust scrubbers on methane distribution in the working place. Face area methane concentrations were monitored in two mines called A and B in the Illinois No. 6 coalbed and one in the Pittsburgh coalbed called mine C. Two-step and fullface continuous miners were used; both inside and outside entries were mined. Face ventilation was supplied by auxiliary tubing (blowing or exhaust) or line brattice (blowing). Intake air quantities at the inby end of the tubing or brattice ranged from 3,300 to 8,500 cfm; the distance between the face and the tubing (or brattice) end ranged from 5 to 25 feet. In every case, the mining machine was equipped with a dust scrubber. The scrubber air inlet was between and below the cutter booms, directly above the shovel, and was 7-1/2 feet outby the face. The exhaust was approximately 12 feet outby and varied as illustrated in figures 2-3. All entries were in development sections. With the two-step miner, only methane emission data obtained with box cuts were used because this yielded results that were comparable with those obtained with a fullface miner where every major cut is a box cut. Data taken during the mining of crosscuts were not used.

Methane monitors were located on the body of the machine, in the intake, and in the return (figs. 2-3). At least three locations were monitored. The intake (A), the scrubber exhaust (D), and the return (F). In most instances monitors were also located on the corner of the machine directly behind the right bit (B), and the left bit (C), and at the diffuser fan (E).

Monitoring was conducted over intervals ranging from several days to 2 weeks. A mining engineer was always present to record the progress of mining, to mark recorder charts, and to determine the ventilation air quantity and tubing-to-face distance. Otherwise, mining proceeded normally.

During each series of measurements, methane peak heights were recorded on charts similar to that in table 1. In general, peaks occurred almost simultaneously at all locations outby the face. A separate line appears in table 1 for each sump cut. Thus (table 1), three cuts were made in the various entries of the working section with a face-to-tube distance of 8 feet, two cuts with a face-to-tube distance of 9 feet, etc. Typically, each set of data had about 80 sump cuts.

TABLE 1. - Peak methane concentrations from mine C, Pittsburgh coalbed

Distance of tube from face, ft	Intake A	Right bit B	Left bit C	Scrubber D	Diffuser fan E	Return F	Air quantity in tubing, cfm
8	0.08	0.29	0.64	0.27	0.24	0.32	7,600
	.04	.31	.43	.25	.24	.32	7,600
	.07	.29	.53	.46	.18	.36	7,100
9	.04	.35	.58	.41	.15	.39	7,600
	.07	.31	.43	.50	.17	.38	7,200
10	.08	.31	.54	.36	.09	.36	7,600
	.08	.28	.43	.30	.17	.30	7,600
	.07	.29	.53	.46	.15	.40	7,200
	.07	.26	.43	.38	.15	.35	7,200
	.07	.28	.70	.53	.28	.40	7,100
11	.04	.35	.64	.39	.28	.40	7,600
	.04	.23	.51	.27	.12	.34	7,200
	.07	.31	.45	.43	.19	.36	7,100
12	.04	.25	.33	.23	.10	.29	7,200
	.07	.28	.53	.43	.19	.38	7,100
	.07	.29	.50	.46	.24	.34	7,100
14	.04	.28	.59	.39	.13	.36	7,600
	.07	.32	.56	.46	.22	.43	7,200
	.07	.35	.60	.50	.20	.42	7,200

RESULTS AND DISCUSSION

All Methane Peaks

Peak concentration data of the sort listed in table 1 were ranked[6] and then plotted on probability paper (4). Data points from each mining location were plotted separately with no initial attempt to determine or separate the effect of brattice or tube-to-face distance or the particular entry mined.

[6] Ranking was done as follows: (1) Rank the peak heights x from the smallest to the largest. Thus, $x_1 \leq x_2 \leq x_3 \leq x_n$. (2) Plot the x's versus $(i-1/2)\frac{100}{n}$ on the probability paper. (i = 1, 2, 3, ...n). Thus the lowest peak is plotted at $(1/2)\frac{100}{n}$; the second at $(3/2)\frac{100}{n}$; and so on (4). As an example, suppose there are 50 peaks. Then n = 50 and the lowest peak is plotted at 1 percent, the next highest at 3 percent and so on until the highest peak is plotted at 99 percent.

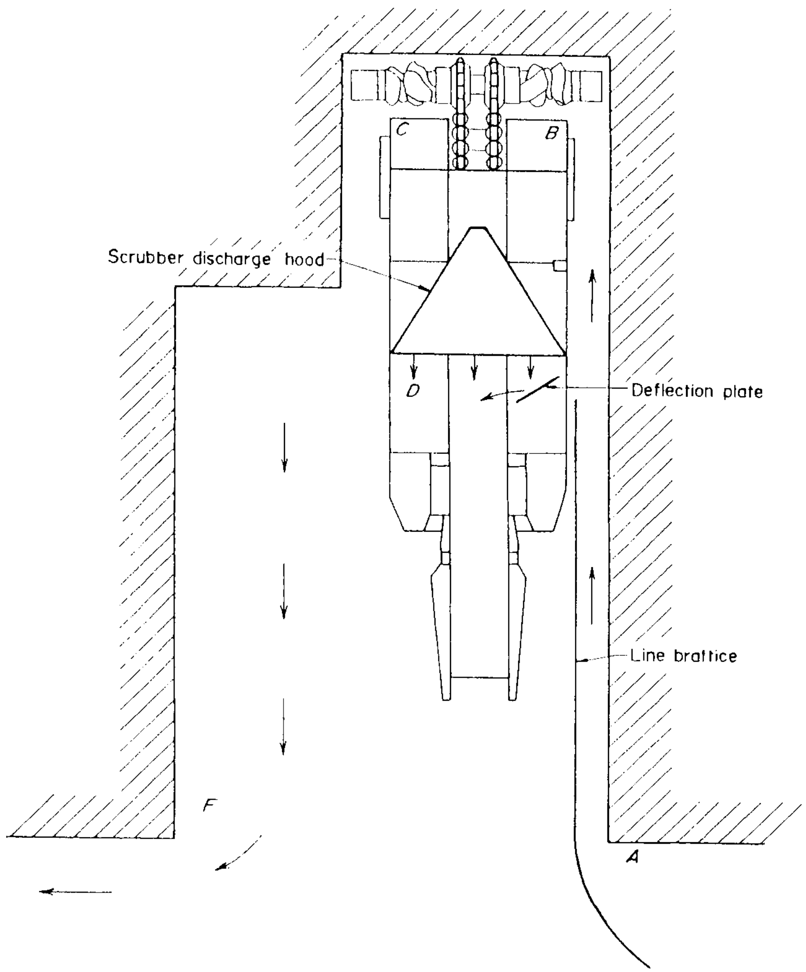

FIGURE 2. - Scrubber exhaust toward rear of machine.

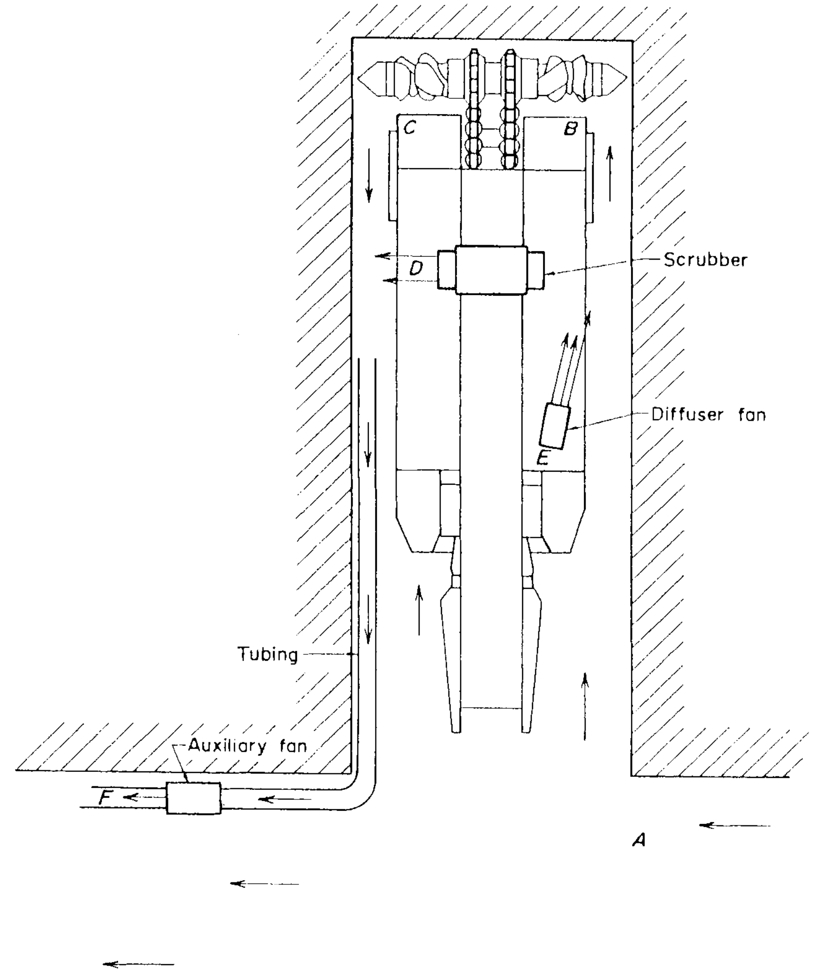

FIGURE 3. - Scrubber exhaust toward side of machine.

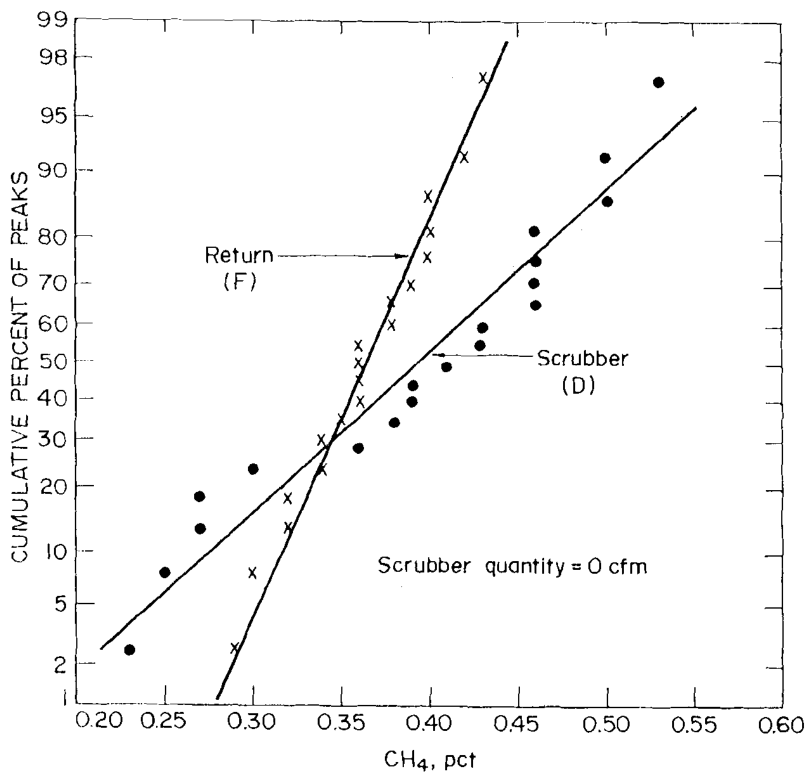

FIGURE 4. - Peak methane concentrations from table 1 plotted on normal probability paper, mine C, Pittsburgh coalbed.

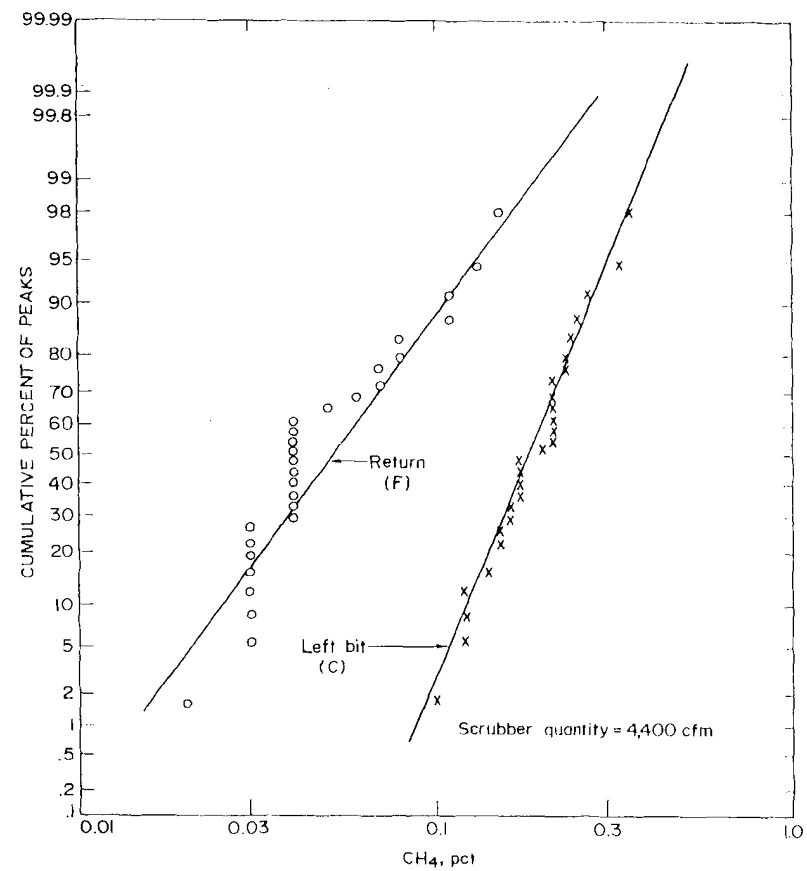

FIGURE 5. - Peak methane concentrations plotted on log-normal probability paper, mine A, Illinois No. 6 coalbed.

Thus, figure 4 shows the peak methane concentrations from table 1 at the scrubber (location D) and at the return (location F) for all entries and for tube-to-face distances of 8 to 14 feet plotted on normal probability paper. The trend line through the plotted points indicates that in this case, the peak heights at the scrubber and return locations are normally distributed.

Examination of the available data showed that the peaks for any one set were either normally (fig. 4) or log normally (fig. 5) distributed. A total of 43 sets of emission peaks similar to those shown in table 1 were ranked and plotted on normal or log-normal probability paper to find which distribution fit best. Table 2 summarizes the pertinent results obtained. Column 5 gives a measure of the scatter (84.13 percent value minus the median), which is actually the standard deviation (S) for a normal distribution; column 6 gives the ratio S:median, which is the coefficient of variation for a normal distribution.

Upon examining table 2, several conclusions can be drawn:

1. For a given test, not all the locations gave similar distributions. For instance, in the test listed as mine A--scrubber 4,400 cfm--entries less than 40 feet in depth, the scrubber and right bit peaks were normally distributed, but the left bit and return peak concentrations were log normally distributed. Different locations will give different concentrations and different distributions.

2. If the ratio S:median was less than 0.3, the peak heights in most cases followed a normal distribution. If the ratio was greater than 0.3, the peak heights in most cases followed a log-normal distribution.

3. If the peaks were normally distributed the ratio scrubber median:return median tended to be below 2; whereas a log-normal distribution was generally accompanied by a ratio of scrubber/return medians greater than 2.

Table 3 lists the ratio S:median in increasing order, with an indication of the type of distribution (normal or log normal) and values for the ratio scrubber median:return median.

Environmental air pollution samples are known to be log normally distributed (6), but why coal mine emission peaks should be normally distributed in some instances and log normally in others has not been explained. However, in coal mines the type of distribution could be determined by the degree of mixing of methane with the ventilation air. A normal distribution would indicate rapid and complete mixing, whereas a log-normal distribution would indicate that mixing (at that location) is incomplete.

TABLE 2. - Summary of results from mines A, B, and C

Scrubber quantity, cfm	Sample location	Median peak,[1] pct CH_4	84.13 pct value, pct CH_4	S,[2] pct CH_4	S / median[3]	Scrubber median / return median	Distribution	Comments
MINE A, NOVEMBER 1972[4]								
0	Return...........	0.033	0.06	0.027	0.818	5.15	Log normal..	Entries <40 ft.
	Scrubber..........	.17	.23	.060	.353		.....do.....	Do.
	Left bit..........	.26	.34	.080	.308		.....do.....	Do.
	Right bit.........	.19	.28	.090	.474		.....do.....	Do.
4,400	Return...........	.052	.090	.038	.731	4.15	Log normal..	Entries <40 ft.
	Scrubber..........	.216	.275	.059	.273		Normal......	Do.
	Left bit..........	.180	.250	.070	.388		Log normal..	Do.
	Right bit.........	.210	.305	.095	.452		Normal......	Do.
0	Return...........	.060	.086	.028	.47	2.75	Log normal..	Entries >40 ft.
	Scrubber..........	.165	.213	.050	.30		.....do.....	Do.
	Left bit..........	.220	.295	.075	.34		.....do.....	Do.
	Right bit.........	.165	.270	.105	.636		.....do.....	Do.
4,400	Return...........	.084	.110	.026	.31	3.10	Log normal..	Entries >40 ft.
	Scrubber..........	.26	.335	.075	.39		Normal......	Do.
	Left bit..........	.245	.324	.079	.32		Not clear...	Do.
	Right bit.........	.255	.360	.105	.412		Normal......	Do.
MINE B, AUGUST 1972[5]								
4,600	Return, left side.	0.320	0.343	0.023	0.072	1.25	Log normal..	
	Return, right side.	.35	.327	.022	.072		Normal......	
	Scrubber..........	.40	.43	.030	.075		.....do.....	
MINE B, JULY 1972[6]								
6,400	Return, left side.	0.225	0.275	0.050	0.222	1.02	Normal......	Return sensors in immediate return behind miner.
	Return, right side.	.218	.255	.037	.170		.....do.....	
	Scrubber..........	.225	.275	.050	.222		.....do.....	Data from July 18.
6,400	Return, left side.	.304	.336	.032	.105	1.09	Normal......	Return sensors in immediate return behind miner.
	Return, right side.	.310	.348	.038	.123		.....do.....	
	Scrubber..........	.314	.353	.039	.124		.....do.....	Data from July 20.

MINE B, JULY 1972[6]--CONTINUED								
6,400	Return, behind miner.	0.336	0.361	0.025	0.074	1.71	Normal......	Data from July 21.
	Return, nearest crosscut.	.255	.275	.020	.073		Log normal..	
	Scrubber..........	.435	.465	.030	.069		Normal......	
MINE C, DECEMBER 1972[7]								
0	Return............	0.362	0.400	0.038	0.104	1.06	Normal......	
	Scrubber..........	.390	.484	.094	.241		.....do.....	
	Left bit..........	.520	.610	.090	.173		.....do.....	
	Right bit.........	.296	.330	.034	.114		.....do.....	
3,300	Return............	.320	.385	.065	.203	1.03	Normal......	
	Scrubber..........	.330	.510	.180	.545		Log normal..	
	Left bit..........	.455	.563	.108	.237		Not clear...	
	Right bit.........	.290	.360	.070	.241		Normal......	
5,200	Return............	.365	.475	.110	.301	1.43	Normal......	
	Scrubber..........	.525	.655	.130	.248		.....do.....	
	Left bit..........	.475	.615	.140	.294		.....do.....	
	Right bit.........	.310	.430	.120	.387		.....do.....	
MINE C, SEPTEMBER 1972[8]								
5,200	Return............	0.270	0.325	0.055	0.20	220	Log normal..	
	Scrubber..........	.595	.665	.070	.118		.....do.....	

[1] The median peak is the 50 percent value.

[2] S equals the 84.13 percent value minus the median peak value. This is the standard deviation if the distribution is normal.

[3] The quantity $\frac{S}{\text{median}}$ is the coefficient of variation if the distribution is normal.

[4] November 1972; blowing line brattice on right side; brattice-to-face distance, 7 to 25 ft (average 17.1 ft); air quantity, 4,000 to 6,700 cfm; two-step ripper.

[5] August 1972; blowing tubing; tube-to-face distance, 14 to 22 ft (average 19.2 ft); air quantity, 4,400 to 6,200 cfm; fullface miner; 8 right off west mains.

[6] July 1972; blowing tubing; tube-to-face distance, 10 to 25 ft (average 18.7 ft); air quantity, 3,300 to 4,300 cfm; fullface miner; 8 right off west mains.

[7] December 1972; exhaust tubing on right side; tube-to-face distance, 5 to 14 ft (average 10.7 ft); air quantity, 6,200 to 8,500 cfm; diffuser fan, 2,000 cfm; fullface miner; 5 north off west mains.

[8] September 1972; exhaust tubing on right side; tube-to-face distance, 12.5 ft only; air quantity, 7,000 to 8,600 cfm; diffuser fan, 2,000 cfm; fullface miner; 5 north off west mains.

TABLE 3. - Ratio S:median, type of distribution, and ratio scrubber median:return median[1]

S/median	Normal	Not clear	Log normal	S/median	Normal	Not clear	Log normal
0.069	(1.71)			0.248	(1.43)		
.072	(1.25)			.273	(4.15)		
.072			(1.25)	.290	(3.10)		
.074			(1.71)	.294	(1.43)		
.075	(1.25)			.300			(2.75)
.078	(1.71)			.301	(1.43)		
.104	(1.06)			.308			(5.15)
.105	(1.09)			.310			(3.10)
.114	(1.06)			.320		(3.10)	
.118			(2.20)	.340			(2.75)
.123	(1.09)			.353			(5.15)
.124	(1.09)			.387	(1.43)		
.170	(1.02)			.388			(4.15)
.173	(1.06)			.412	(3.10)		
.200			(2.20)	.452	(4.15)		
.203	(1.03)			.470			(2.75)
.222	(1.02)			.474			(5.15)
.222	(1.02)			.545			(1.03)
.237		(1.03)		.636			(2.75)
.241	(1.03)			.731			(4.15)
.241	(1.06)			.818			(5.15)

[1]Values in parentheses are $\frac{\text{scrubber median}}{\text{return median}}$.

For instance, if mixing in the face area were complete, that is, if all the ventilation air swept the face and the methane was immediately mixed into that air, the methane concentration at every point in time would be identical at every location. The ratio scrubber median:return median would always be 1.0. The fact that higher values of this ratio are generally accompanied by a log-normal distribution suggests incomplete mixing.

Further support of this explanation comes from examining the face ventilation system in each of the three mines studied. In mine B, blowing tubing was used for face ventilation. The airflow was 3,300 to 6,200 cfm, and the exit velocity from the tubing was between 25 and 47 ft/sec. A blowing tubing with a high exit velocity is generally regarded as the best way to insure that the airstream reaches the face (1, 8-9). Mixing was good, and the peak distributions were generally normal.

Face mixing at mine C was almost as good as at mine B. At mine C exhaust tubing was used. The airflow was about 7,500 cfm, and mixing was enhanced by means of a machine-mounted 2,000-cfm diffuser fan (1, 8, 11). Exhaust ventilation alone is not as effective as blowing ventilation with comparable air quantities and velocities; however, the diffuser fan considerably improved mixing in the immediate face area. In most instances the peak distribution was normal (table 2).

At mine A, a blowing line brattice was used. The airflow varied between 4,000 and 6,700 cfm, but as the area behind the line brattice averaged about 20 ft^2, the exit velocity was only between 3.3 and 5.6 ft/sec. Luxner (7) found that a blowing line brattice with an exit velocity of 12.8 ft/sec provided an adequate sweep of the face in an empty heading; however, with a lower exit velocity of 6.4 ft/sec, the primary airstream in most instances did not reach the face.[7] It seems likely that the 3.3 to 5.6 ft/sec velocity observed at mine A provided poor face mixing especially since the heading was crowded with machinery. Thus it follows that in all of the tests with the scrubber off the peak distribution should be, and was, log normal. This was in spite of the fact that mine A had the lowest average return methane concentration of all three mines. With the scrubber on, mixing was improved somewhat; peak distributions became normal in about half the cases (table 2).

These results from the three mines indicated that the kind of face ventilation used determined the distribution of methane peaks, and also possibly that the scrubber had some effect. Another important variable in face ventilation is known to be the line brattice position; that is, the line brattice-to-face distance (7). Accordingly, it seemed worthwhile to see whether the peak distribution was different at shorter brattice distances than it was at longer brattice distances.

Since mine A had the poorest methane-air mixing, these data were re-examined first. In the initial ranking, all line brattice positions were lumped together; however, the methane peaks were now separated into two categories--those obtained when the line brattice distances was ≦15 feet and those obtained at >15 feet--and each category was ranked separately.

In practice, when the line brattice is moved close to the face, ventilation improves and the average methane content of the air close to the face sharply drops (7). It is likely that mixing is also improved, and therefore it is possible that peaks ranked in the ≦15-foot category were more likely to stay as normal distributions. This was found to be the case. For instance, the first four distributions in table 2 are log normal (mine A, scrubber quantity 0 cfm, entries <40 feet). When the peaks were separated into the two categories and reranked, the ≦15-foot peaks more closely fit a normal distribution, whereas the >15-foot peaks retained a log-normal distribution.[8] The

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[7] Luxner interpreted his results in terms of "tight rib distance" instead of velocity. This is the distance between the line brattice and the nearest rib. For a given airflow quantity, a decrease in tight rib distance means a velocity increase. Luxner had concluded that at 10,000 cfm, a tight rib distance of 2 feet provided better ventilation than a distance of 4 feet. The entry was 6.5 feet high, and so the rib distances of 2 feet and 4 feet have been interpreted as corresponding to velocities of 12.8 ft/sec and 6.4 ft/sec, respectively.

[8] The 15-foot value was selected because this provided enough peaks, both above and below, for an accurate ranking.

same effect was observed with the other mine A log-normal distributions. The closer the line brattice, the better the mixing, and so the greater the chance of a normal distribution.

This effect was not so pronounced in the case of mines B and C especially since mixing at all observed tubing distances was generally good and few log-normal distributions were obtained. In the case of mine B, not enough peaks were measured at distances less than 15 feet to make an accurate ranking, and so 19 feet was used instead. When the two log-normal distributions were reranked for ≦19 feet, they more closely fit a normal distribution, similar to mine A. For mine C, December 1972, reranking for shorter tubing distances had no effect on the one log-normal distribution. For mine C, September 1972, reranking was not possible because all peaks were obtained at the same tubing distance of 12.5 feet.

Extreme Values

In the previous section, the distribution of all peaks within a given data set were examined and found to be normal or log normal. On the other hand, if one considers only the highest peak (extreme value) in a given interval, then a distribution of highest peaks may be obtained for a number of such intervals. As an example, if measurements are made over 50 half-hour intervals, the distribution of the 50 peaks may be plotted if the highest peak in each half-hour is taken.

This distribution of "highest" peaks is known as an "extreme value" distribution; the statistical theory of extreme values has been studied most extensively by E. J. Gumbel (2). Extreme-value theory has been applied successfully to a wide variety of natural phenomena (3). As noted previously, Lavtsevich (5) has found that the distribution of the extreme values (highest methane concentrations) at a longwall face was given by the extreme-value laws.

To evaluate a given series of extreme values (highest peaks), these data are first ranked and the values plotted in a fashion somewhat similar to that used in studying peak values. However, extreme-value probability paper was now used rather than the normal or log-normal paper. If the plotted points followed a straight line, the data fitted an extreme-value distribution.

The quantity of data required for an extreme-value probability plot is quite large; the most that Lavtsevich presents are 16 highest (or extreme value) points. Of the three mines in table 2, only mine A, which was monitored for 2 weeks, yielded enough emission data for an extreme value plot.

Before an extreme-value plot can be made, an interval has to be selected from which each highest peak is taken. Lavtsevich used 1/2 hour for one set of data, and one shift for another set of data. It was found convenient to select the mining of one entry between crosscuts as the interval. Methane concentration data of the type shown in figure 1 were grouped on an entry-by-entry basis. When a series of cuts were made in a given entry, the highest box-cut emission peak was determined. Then the highest peak was determined in the next entry between crosscuts, as so on. In the course of 2 weeks of

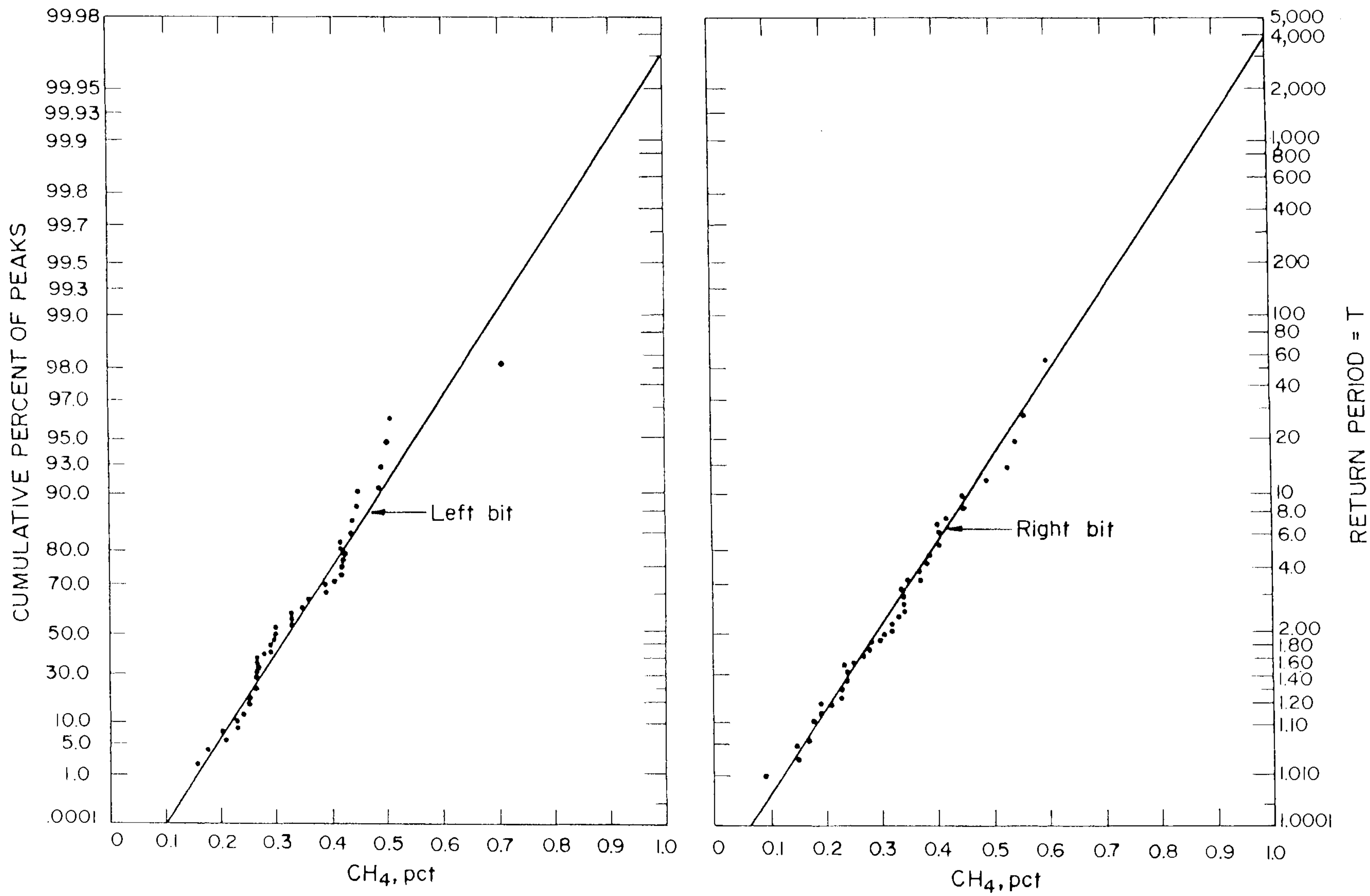

FIGURE 6. - Highest peak methane concentrations at right bit and left bit plotted on type I extreme-value probability paper.

methane monitoring in a working section, 56 such peaks were obtained. Extreme-value plots for the left bit and right bit locations are shown in figure 6, and extreme value plots for the scrubber location are shown in figure 7. The existence of straight lines through the plotted points indicates that these data fit the first (type I) limiting distribution law:

$$\Phi_1(x) = \exp\left[-e^{-\alpha(x-\mu)}\right].$$

This is the expected distribution for the highest values if the initial distribution is normal or log normal.

According to Lavtsevich, for large fluctuations of the concentration (standard deviation $\geq$0.30), the highest values will follow the second limiting law of distribution:

$$\Phi_2(x) = \Phi_1(\ln x).$$

Since the largest standard deviation observed in any test was 0.18 (mine C, December 1972, 3,300 cfm, scrubber), it is likely that the highest peaks from mines B and C would also fit an extreme-value distribution of the first type rather than the second.

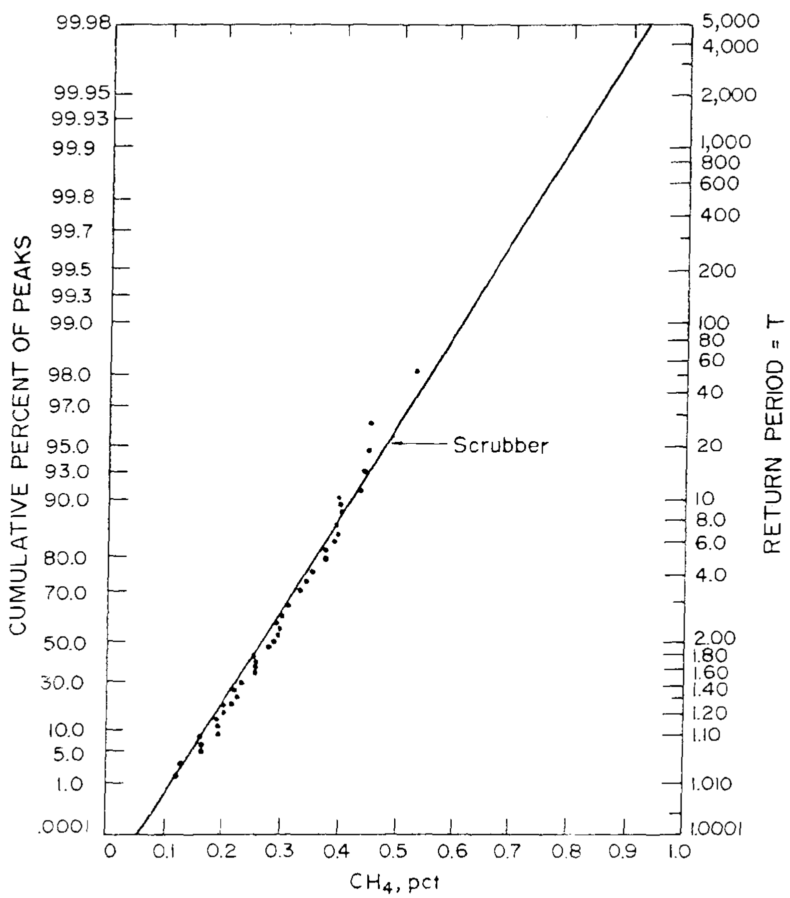

FIGURE 7. - Highest peak methane concentrations at scrubber plotted on type I extreme-value probability paper.

Although the highest peak concentration shown in figure 6 is 0.71 percent methane, extrapolation of the plotted points can yield the probability of higher concentrations. For instance, extrapolation of the "left bit" values to 1.0 percent methane gives 0.99967 for the probability of values less than 1.0 percent. This means that the probability of achieving 1.0 percent or more in any given entry in mine A is 1.0 -0.99967 = 0.00033.

The extrapolation in figures 6-7 also gives an indication of the "return period." This is the reciprocal of the 1.0 percent or greater methane probability, which also means it is the average number of observations necessary for the methane concentration to assume a value of more than 1 percent on one occasion. For the "left bit" values, the return period is about 3,000, meaning that in mine A a concentration of 1 percent or more is reached at the left bit only once in mining 3,000 entries between crosscuts. The return period for the right bit extreme values is 4,000 for 1.0 percent or more methane and, as expected, the return period is even greater for the scrubber.

A similar extrapolation could be made to higher percentages of methane and the return period determined. However, for the mine A data the return period would be extremely high, and the probability of reaching 5 percent methane, for instance, would be minuscule.

Not enough data are available to obtain return periods or probabilities for mines B and C; however, it is likely that these have a much greater probability of reaching 1 percent or more methane. Table 2 shows the median return concentrations in mine A were always below 0.1 percent, whereas those of mines B and C were generally above 0.3 percent.

These probability predictions assumed that mining conditions do not change appreciably from those that existed when the data were gathered; however, as it is quite possible that the conditions imposed by this restriction are difficult to meet, the practical value of such predictions for the long range is limited. For instance, when it is assumed that "conditions do not change appreciably," it is assumed the following all remain the same: (1) The amount of methane in the coal; (2) the characteristics of the coalbed that affect gas flow to the face; (3) the rate of advance of the mining machine; (4) the ventilation air quantity; (5) the manner in which the tubing or brattice is advanced.

It is known that over the long range many of these factors will change. For instance, mining in a virgin area of the coalbed will produce more methane than mining in an area that has been degassed. The rate of advance of the mining machine will be influenced by the available haulage. The ventilation air quantity may fall considerably below the range of quantities used while data was taken. Because of these factors, it seems unlikely that probability prediction would have long-range application or that data obtained in one part of a mine would apply to other parts of the mine. However, probability predictions may find some utility for short-range forecasting in a given working section. Additional research is needed.

CONCLUSIONS

Peak methane emissions measured at the working face during development room-and-pillar mining are normally or log normally distributed. The difference is attributed to the extent to which methane and air are adequately mixed in the immediate face area. A normal distribution indicates complete mixing, whereas log-normal distribution indicates incomplete mixing.

In mine A, the highest peaks fit a type I extreme-value distribution. Extrapolation of the plotted points on type I extreme-value probability paper shows a return period of 3,000 or more for 1.0 percent or greater methane concentrations. This means that 1.0 percent or greater methane concentrations are achieved, on the average, only once in mining 3,000 entries provided mining conditions do not change appreciably. Mines B and C have a greater probability of reaching 1.0 percent or more methane.

Probability plotting may be a powerful technique for predicting dangerous methane concentrations. Additional research is needed to establish its applicability for use underground.

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