RI 8392

Bureau of Mines Report of Investigations/1979

Forecasting Methane Hazards in Metal and Nonmetal Mines

By Edward D. Thimons, Robert P. Vinson, and Fred N. Kissell

UNITED STATES DEPARTMENT OF THE INTERIOR

Report of Investigations 8392

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UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary

BUREAU OF MINES
Lindsay D. Norman, Acting Director

This publication has been cataloged as follows:

Thimons, Edward D

Forecasting methane hazards in metal and nonmetal mines.

(Report of investigations ; 8392)

Bibliography: p. 9.

1. Mine gases. 2. Methane. 3. Mine safety. I. Vinson, Robert P., joint author. II. Kissell, Fred N., joint author. III. Title. IV. Series: United States. Bureau of Mines. Report of investigations ; 8392.

TN23.U43 no. 8392 [TN305] 622'.08s [622'.42'028] 79-15652

PREFACE

Shortly before this report was to be printed, five men were killed in a methane gas mine explosion that tragically underscored the need for reliable methods of forecasting methane hazards in mines.

The explosion occurred on June 9, 1979, in a Louisiana salt mine. As a result of the explosion, this mine and three other salt mines have now been reclassified as gassy by the Mine Safety and Health Administration. The mine where the explosion occurred is shown in table 1 of this report as mine number 48. Also reclassified as a result of this explosion was mine number 50, shown in the same table.

The return air methane concentration for mine number 48 was 90 ppm. Use of the 100-ppm guideline as an indication of a methane hazard, as suggested in this paper, would have indicated that a potential methane hazard might exist in this mine. Mine number 50, with a return air methane concentration of 165 ppm, was the only mine in the study that was not previously classified as gassy having concentration above 100 ppm.

The new information and reclassifications that resulted from this explosion have led the authors to suggest that a guideline of about 70 ppm might be more appropriate, since every mine in this study having a return air methane concentration of more than 70 ppm is now classified as gassy. New analyses are now needed to establish the most appropriate concentration for use as a guideline. In the meantime, this paper shows that methane concentration is potentially valuable as an indicator of methane hazards in mines.

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FORECASTING METHANE HAZARDS IN METAL AND NONMETAL MINES

by

Edward D. Thimons,[1] Robert P. Vinson,[2] and Fred N. Kissell[3]

ABSTRACT

Because of the high number of accidental methane gas ignitions in metal and nonmetal mines, the Bureau of Mines searched for a simple guideline that would allow mine personnel to evaluate the methane hazard in a given mine. Air samples were collected by the Bureau in 53 metal and nonmetal mines and analyzed for trace evidence of methane gas. Samples were collected in the returns and at the working faces.

Those mines classified as gassy by the Mine Safety and Health Administration had a significantly higher average methane concentration than those classified as nongassy. Of the 9 gassy mines sampled, 7 had methane concentrations above 100 ppm, whereas only 1 of the 44 nongassy mines had a concentration above 100 ppm. The 100-ppm concentration may be used as a simple and convenient guideline for forecasting the methane hazard in a mine, whether or not the mine is classified as gassy.

There was no consistent correlation between commodity mined and methane concentration, nor was there a correlation between mine depth and methane concentration. Neither of these factors can be considered a guideline for predicting methane hazards.

INTRODUCTION

Methane, although usually associated with underground coal mines, also occurs in significant concentrations in some metal and nonmetal mines. It is found in mines that penetrate carbonaceous shales or in mines that are located near rock formations containing carbonaceous materials (1, 3).[4] Hundreds of miners' lives have been lost as a result of unexpected methane gas explosions.

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[4] Underlined numbers in parentheses refer to items in the bibliography at the end of this report.

Furthermore, the occurrence of methane in metal and nonmetal mines is not confined to the United States. Methane ignitions and explosions have also occurred in European and South African mines. In Poland, almost all salt mines are classified as gassy (2), and in some Polish mines, large quantities of methane are released in conjunction with rock salt outbursts. Also, numerous ore mines in Canada and the U.S.S.R. experience methane gas problems (6).

The Mine Safety and Health Administration (MSHA) of the U.S. Department of Labor classifies U.S. metal and nonmetal mines as either gassy or nongassy. A mine that meets any one of the following four criteria is classified as gassy and so must comply with certain safety standards. These criteria, as set forth in the Code of Federal Regulations, 30 CFR 57.21-1 (5), are--

a. The State in which the mine is located classifies the mine as gassy; or

b. Flammable gas emanating from the orebody or the strata surrounding the orebody has been ignited in the mine; or

c. A concentration of 0.25 pct or more, by air analysis, of flammable gas, emanating only from the orebody or the strata surrounding the orebody, has been detected not less than 12 inches from the back, face, or ribs in any open workings; or

d. The mine is connected to a gassy mine.

Approximately 10 U.S. mines are classified as gassy because they fit one or more of these criteria. However, an ignition occasionally occurs in a mine not previously classified as gassy, and where no gas hazard was suspected. For this reason, the Bureau of Mines undertook an in-mine study to determine if trace methane gas measurements made in the working areas or air returns of metal and nonmetal mines could be used by mine operators to predict potential methane hazards. An attempt was made to establish a correlation between the methane concentrations found in noncoal mines classified as gassy and those in mines listed as nongassy. Correlations were also sought between the methane concentration measured in a mine and the depth of the mine, or between the methane concentration and the commodity mined.

SAMPLING AND ANALYSIS

Gas samples were collected by the Bureau of Mines in 53 metal and nonmetal mines selected to represent a wide variety of commodities mined, mining methods, age, size, and depth of operation. Nine of these mines were classified as gassy by MSHA.[5] At each mine, samples were taken in the return airways, and in most of the mines, samples were also taken from the working areas. Surface samples were taken at most of the mine sites for use as base readings to compare underground samples against. Samples were collected in 10-ml evacuated bottles and analyzed on a chromatograph in the Bureau's analytical laboratory at Bruceton, Pa. Methane concentrations were determined in parts per million (table 1).

[5] Two of the 53 mines used for this study have been reclassified by MSHA as gassy, following a Louisiana salt mine explosion which occurred after this report was written. As a result, two more of the mines tested are now classified as gassy than are shown in this report. See "Preface."

TABLE 1. - Methane concentrations found in mines

Mine No.	Commodity mined	Methane concentration, ppm			Mine classification
		Return air	Working area	Surface air	
1	Lead and zinc	10	8	2	N
2	...do	6	NA	4	N
3	...do	7	9	3	N
4	...do	6	7	3	N
5	...do	4	3	1	N
6	Gold and silver	4	9	4	N
7	...do	10	10	2	N
8	...do	7	7	1	N
9	...do	10	9	2	N
10	Copper	4	NA	2	N
11	...do	5	NA	1	G
12	...do	10	7	2	N
13	...do	9	9	4	N
14	Tungsten	2	2	4	N
15	Molybdenum	1	0	0	N
16	...do	3	3	2	N
17	Iron	30	27	2	N
18	Gypsum	2	2	3	N
19	...do	9	3	1	N
20	Silicates	6	8	1	N
21	Marble	9	4	3	N
22	Uranium	4	3	2	N
23	...do	3	3	2	N
24	...do	3	2	2	N
25	...do	110	35	NA	G
26	...do	5	5	NA	N
27	...do	9	9	2	N
28	Limestone	3	2	2	N
29	...do	783	NA	13	G
30	...do	41	43	NA	N
31	...do	7	11	2	N
32	...do	1	NA	1	N
33	...do	54	64	18	N
34	...do	10	8	2	N
35	...do	10	6	NA	N
36	...do	10	8	2	N
37	...do	5	5	NA	N
38	...do	31	49	NA	N
39	Oil shale	10	40	NA	N
40	Oil[1]	115	85	2	G
41	Trona	1,000	NA	NA	G
42	...do	61	NA	2	G
43	...do	340	700	2	G
44	...do	2,000	NA	NA	G
45	Salt	70	70	2	N
46	...do	30	NA	NA	N
47	...do	4	NA	NA	N
48[2]	...do	90	NA	NA	N
49	...do	19	NA	NA	N
50[2]	...do	165	19	2	N
51	...do	200	130	3	G
52	...do	2	2	3	N
53	...do	2	2	3	N

G Gassy. N Nongassy. NA Not analyzed.

[1] This oil mine consists of a 1,000-foot-long adit sloping 15° from horizontal. At the bottom of the adit, a room is mined out and long horizontal holes are drilled into the oil-bearing strata. Oil flows from the holes into a sump.

[2] As a result of an explosion June 9, 1979, at the mine shown here as number 48, the mines numbered in this table as 48 and 50 have been reclassified as gassy by MSHA. The explosion occurred after this research was completed. See "Preface."

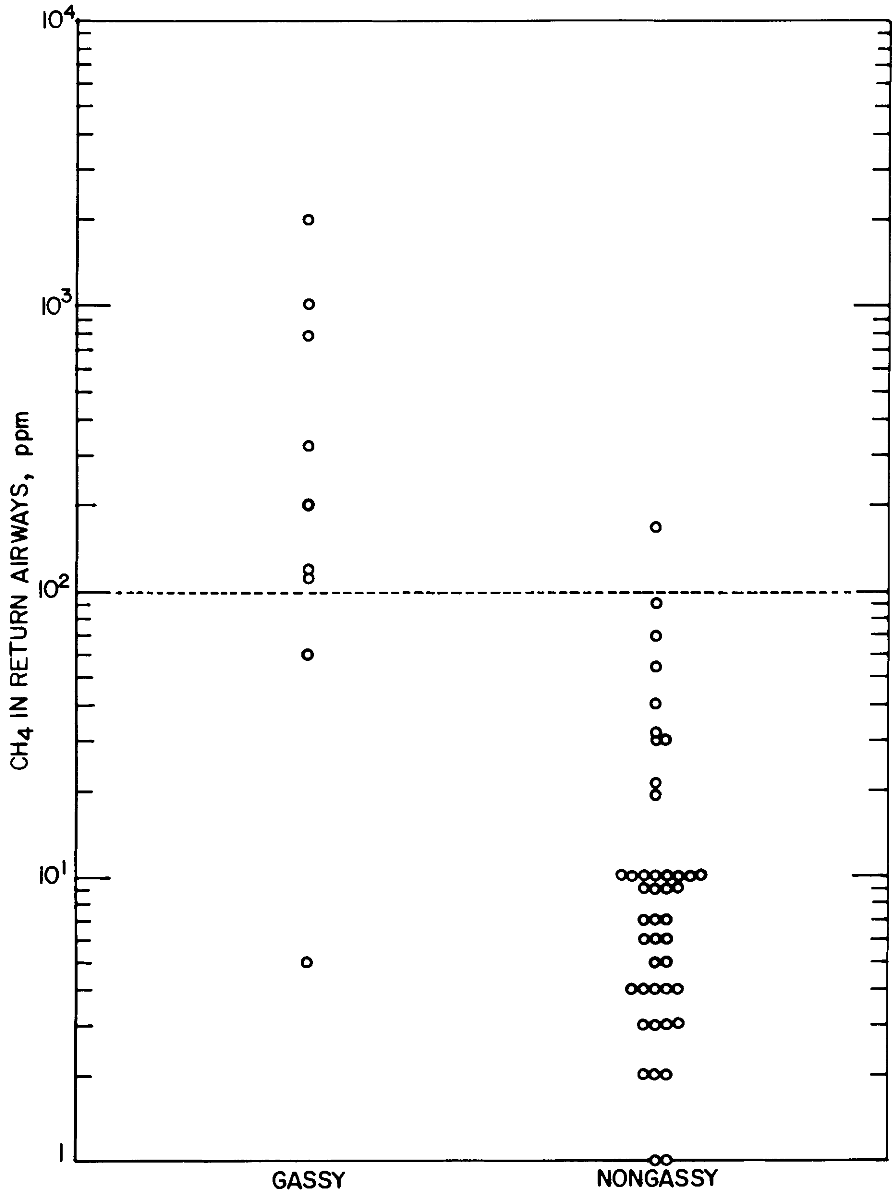

FIGURE 1. - Semi-logarithmic chart of methane concentrations found in returns of mines sampled. With only three exceptions, the broken line separates concentrations found in gassy mines from those found in nongassy mines. This line is at 100 ppm, the simple guideline determined by this investigation for identification of a methane hazard.

Table 1 shows that for those mines where working area samples were taken there is usually a close correlation between methane concentrations in the returns and at the working areas. If the concentration in the returns is high, the working area concentration is also high. For almost every mine, the surface air samples had very low methane concentrations, indicating that no significant amounts of methane were entering the mines with the intake air.

A semi-logarithmic chart (fig. 1) of the methane concentrations found in the returns of both the gassy and nongassy mines shows a very obvious trend. Of the 44 nongassy mines, 43 have return methane concentrations below 100 ppm; But for the gassy mines, 7 out of 9 have return methane concentrations above 100 ppm.

The average methane concentration in return airways of the 44 nongassy mines was about 17 ppm, and the average for the 9 gassy mines was about 512 ppm.

DISCUSSION

An analysis of the data obtained from this study shows that certain general trends exist. Before discussing these trends, the following point should be made. It can be logically argued that the methane concentration in any mine is a function of the mine's ventilation. When more fresh air reaches the working areas, lower methane concentration can be expected in these areas and in the returns. It might therefore be assumed that mines having high methane concentrations are poorly ventilated. But in fact, it is generally true that the mines with high methane concentrations are better ventilated than those with lower concentrations. This is because the mines having the highest concentrations are classified as gassy, and therefore must meet the more rigid MSHA ventilation standards for gassy mines (5).

In this study, mine airflows were not taken into account for three reasons:

1. MSHA classification standards for gassy mines are based solely on methane concentration and do not take airflow rates into account.

2. Concentration data can both reveal a high methane release rate and also indicate whether or not current ventilation is adequate for that rate of methane release. Therefore, the concentration figure may be considered a reasonable indicator of the true hazard at the time of measurement without allowance for airflow.

3. Airflow measurements in many metal/nonmetal mines are sometimes difficult to measure accurately because of large airway sizes and changes in the airflow rate.

THE 100-PPM GUIDELINE

As noted earlier, 43 of the 44 nongassy mines had return air methane concentrations less than 100 ppm, and 7 of the 9 gassy mines had return air concentrations greater than 100 ppm. One mine, a copper mine classified as gassy by MSHA, had a return air methane concentration of only 5 ppm. A discussion with MSHA inspectors from that district revealed that a gas ignition occurred in this mine over 20 years ago, but no significant methane concentrations have been measured since. The inspectors feel that the mine should not be classified as gassy. Therefore, it is more realistic to state that seven out of eight mines had concentrations above 100 ppm. The only gassy mine below this level was a trona mine with a return air methane concentration of 61 ppm, which is still substantially above the average for the nongassy mines. These findings suggest that 100 ppm may be used as a simple guideline for determining if potential methane hazards exist in metal and nonmetal mines.[6]

COMMODITY MINED AND DEPTH AS GUIDELINES

The first 17 mines in table 1 produce materials chemically classified as the transition elements and their neighbors and commonly referred to as metals. All 17 of these mines have low methane concentrations, averaging about 8 ppm. Limestone and salt mines tend to have higher methane concentrations, although only a few are classified as gassy. The 11 limestone mines sampled had an average return air concentration of 87 ppm. However, if the one mine classified as gassy is excepted, the average concentration drops to about 17 ppm. The nine salt mines had an average concentration of 67 ppm. The oil mine and four trona mines all had high methane concentrations, and all are classified as gassy. Five of the uranium mines sampled had low methane concentrations. The sixth mine, which is classified as gassy, had more than 100 ppm.

Table 2 presents the average methane concentrations in returns for the various types of mines. While some general trends do exist between commodity mined and methane concentration, this study indicated that no reliable guideline could be established on the basis of commodity.

[6] As a result of a mine explosion and subsequent reclassification of several mines by MSHA, which occurred after this report was written, the authors suggest that the guideline be set at a lower concentration. A more appropriate concentration might be 70 ppm, the authors suggest, in light of this new information. See "Preface."

TABLE 2. - Average return air methane concentrations for various types of mines sampled

Type of mine	Number of mines sampled	Number of gassy mines	Average methane concentration, ppm		
			Gassy and nongassy mines	Nongassy mines only	Gassy mines only
Transition elements and neighbors..............	17	1	8	8	5
Uranium.................	6	1	22	5	110
Limestone...............	11	1	87	17	783
Salt....................	9	1	67	50	200
Oil.....................	1	1	115	G	115
Trona...................	4	4	850	G	850
Other[1]	5	0	7	7	0

G Gassy mines.
[1] Gypsum, silicates, marble, and oil shale.

It is a commonly known fact that deeper coal mines generally have more methane gas problems than those of lesser depth, and one objective of this study was to determine if this is also true for metal and nonmetal mines. Depth information was obtained for 35 of the mines sampled in this study. For the remaining mines, depth varied from location to location so much that a meaningful value could not be obtained. A graph of methane concentration versus mine depth (fig. 2) shows no obvious relationship between methane concentration and depth. Many mines having high methane concentrations are quite shallow, while several deep mines have low concentrations. Thus, depth alone cannot serve as an indicator of the gas hazard.

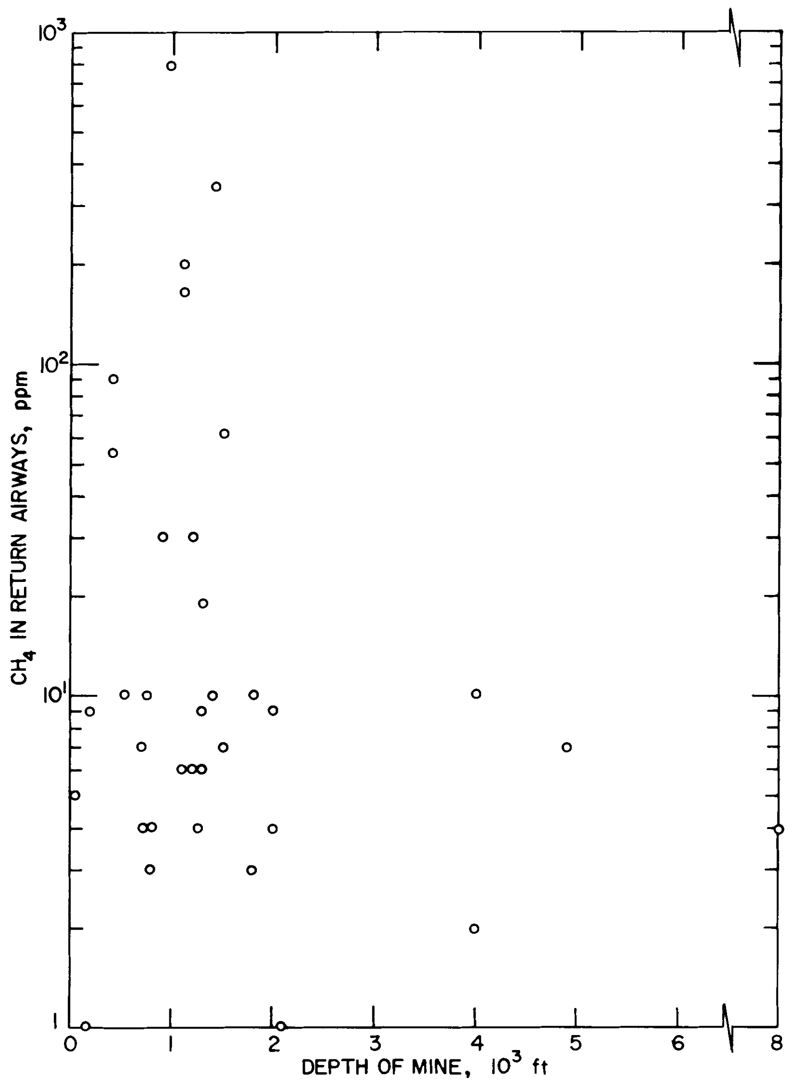

FIGURE 2. - Methane concentration versus depth of mine.

CONCLUSIONS

Since only 1 of 44 nongassy mines and 7 of 9 gassy mines had methane concentrations greater than 100 ppm, this level of concentration may be considered a simple guideline for metal and nonmetal mine personnel to use in evaluating the potential methane hazard in a mine.[7]

Although some general trends do exist, this study indicates that no reliable guideline for predicting methane hazards can be based upon the correlation between commodity mined and methane concentration. Furthermore, no correlation whatsoever was found between mine depth and methane concentration.

In general, metal and nonmetal mines classified as gassy by MSHA have significantly higher methane concentrations at their workings areas and in their returns than do nongassy mines. The average return air methane concentration was 512 ppm for the 9 gassy mines sampled, and only 17 ppm for the 44 nongassy mines.

[7] See footnote 6.

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[8] Titles enclosed in parentheses are translations from the language in which the item was published.

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