RI 9295

REPORT OF INVESTIGATIONS/1990

Analysis of Acoustic Responses of Domal Salt Mine Samples

By Roy H. Grau III and Thomas E. Marshall

1910 ★ 80 YEARS ★ 1990

BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR

Mission: As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.

Report of Investigations 9295

Analysis of Acoustic Responses of Domal Salt Mine Samples

By Roy H. Grau III and Thomas E. Marshall

UNITED STATES DEPARTMENT OF THE INTERIOR
Manuel Lujan, Jr., Secretary

BUREAU OF MINES
T S Ary, Director

Library of Congress Cataloging in Publication Data:

Grau, Roy H.

Analysis of acoustic responses of domal salt mine samples / by Roy H. Grau III and Thomas E. Marshall.

p. cm. – (Report of investigations / United States Department of the Interior, Bureau of Mines); 9295

Includes bibliographical references.

Supt. of Docs. no.: I 28.23:9295.

1. Rock-salt–Testing. 2. Methane–Analysis. 3. Noise–Measurement. I. Marshall, Thomas E. II. Title. III. Series: Report of investigations (United States. Bureau of Mines); 9295.

TN23.U43 [TN900] 622 s–dc20 [622'.82] 89-600275 CIP

CONTENTS

ILLUSTRATIONS

TABLES

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

atm	atmosphere, standard	kg	kilogram
cm	centimeter	mL	milliliter
cm^3	cubic centimeter	min	minute
dB	decibel	oz	ounce
ft	foot	pct	percent
g	gram	s	second
Hz	hertz	V	volt
in	inch		

ANALYSIS OF ACOUSTIC RESPONSES OF DOMAL SALT MINE SAMPLES

By Roy H. Grau III[1] and Thomas E. Marshall[2]

ABSTRACT

The U.S. Bureau of Mines has developed an acoustic test for determining if a rock salt sample is from a "normal" nongassy salt face or from a gassy face where an outburst has the potential to occur. The test is based on the observation that a salt sample taken near an outburst-prone zone produces an audible popping sound when it is dissolved in water. The sound is produced when pressurized gas that is trapped in salt samples is released. In the acoustic test, the sound is electronically measured, digitized, and transmitted to a microcomputer; the output is an average decibel value that classifies the sample as "normal" or "outburst." The acoustic test procedure and equipment are described, and raw test results and data analysis are shown. Results are also shown for several salt samples that were analyzed using a laser Raman microprobe.

[1]Mining engineer.
[2]Engineering technician.
Pittsburgh Research Center, U.S. Bureau of Mines, Pittsburgh, PA.

INTRODUCTION

Methane gas (CH_4) has long been recognized as a hazard in coal mining. In recent years, sporadic methane occurrences have been encountered in the domal salt mining industry (*9,11*).[3] Salt domes and coalbeds differ in that salt domes do not have regular macroscopic fractures that transport methane throughout the whole ore body; gas occurs in isolated zones because of the impermeable nature of salt.

In domal salt mines, the standard drill-and-blast method is used to form a room-and-pillar configuration. Large methane gas volumes are liberated in only a small percentage of blasted faces (*2*). The methane may be accompanied by a violent expulsion of salt from the mine roof and/or wall. The expulsion of salt and methane creates cone-shaped voids in the roof or rib termed "outburst cones." Since salt is relatively impermeable, a small hand-size sample from a gassy zone may contain and hold a measurable quantity of methane many months after mining; evidence of this can be seen as small suspended trapped bubbles within the salt crystals.

The U.S. Bureau of Mines, in previous studies, has found that the occluded methane gas and higher hydrocarbons in a rock salt sample can be measured using a laboratory dissolution test, which involves dissolving a rock salt sample in water and collecting the gas for gas chromatograph analysis (*3,10*). The gas volume can then be normalized to the rock salt mass. This report describes acoustical response of pressurized gas being released when rock salt samples are dissolved in water. With the addition of this acoustical information, the test could be an indicator of the outburst potential for the particular face.

It must be kept in mind that while methane under pressure appears necessary for outburst occurrence in the gulf coast domal salt mines, this is not the only factor that may contribute to outburst formation. Factors such as strata weakening due to folding or shearing and mechanically weakened salt due to undersized pillar overloading may create areas that are susceptible to outbursts in high gas pressure zones (*7*).

The dissolution test by itself has been used primarily as a research tool; it has not been accepted by the salt mining industry for daily use because of several inherent problems. It is a relatively lengthy procedure and requires the use of selective equipment, including a gas chromatograph. Also, methane gas content values for normal and outburst salt tend to overlap (*10*).

The samples used for the acoustic test were classified as "outburst" or "normal" prior to testing. Samples were considered outburst if they were within about 100 ft from an outburst that already occurred. Values for normal salt range from less than 0.0003 to 0.31 cm^3 CH_4 per 100 g NaCl, while outburst salt values range from 0.014 to 7.4 cm^3 CH_4 per 100 g NaCl (*10*). A previous investigator has indicated that domal salt may contain large quantities of CO_2 (*1*) that may not be detected by the dissolution test alone because CO_2 is exsolved from the brine solution as the salinity increases. If some outbursts are caused by high-pressure CO_2 and face samples contain CO_2, the dissolution test alone may not reveal the gas. This indicates that a test that could easily determine if a sample contained any type of high-pressure gas would be helpful in predicting conditions that might precipitate an outburst. In at least two instances, the acoustic test has identified samples containing gas prior to mining into gassy salt zones in a U.S. gulf coast domal salt mine (*5*). The test provides no indication of the gas composition; it only records the acoustic emission of gas escaping under excessive pressure.

During dissolution tests, it was noted that gases are consistently liberated with a series of loud "pops" attributed to the pressures under which the gases are occluded in the salt. Initially, a dosimeter connected to a strip chart recorder confirmed the magnitudes of the pops (*4*); however, this method allowed operator error in analyzing the strip chart. Subsequent tests by the Bureau, resulting in the acoustical-dissolution test, which uses a dosimeter-data logger and a microcomputer, have refined the method. The equipment records and analyzes the sound level of the pops during dissolution. This provides a concrete numeric amplitude value for each salt sample, which can then be classified as "normal" or "outburst." This methodology is being used by at least one domal salt mine operator as standard operating procedures for checking faces before blasts. The results show that the test is a reliable method for differentiating between the two salt types.

One important part of the Bureau's overall mission is to develop technology that provides for a safer work environment. This work was performed with the cooperation of personnel at the Cote Blanche Mine, Domtar Industries Inc., New Iberia, LA; Weeks Island Mine, Morton Salt Co., New Iberia, LA; and Avery Island Mine, International Salt Co., Avery Island, LA.

ACKNOWLEDGMENTS

The authors thank Timothy McCue, production supervisor, Cote Blanche Mine for his efforts in identifying gassy faces and outburst-prone areas. Also, thanks go to Patricia Olivier, chemist, Cote Blanche Mine, who ran the acoustic test response at the minesite and provided the results.

[3]Italic numbers in parentheses refer to items in the list of references preceding the appendix at the end of this report.

THEORY AND BACKGROUND

Sound is energy transmitted by longitudinal waves; it is measured in terms of amplitude, frequency, and time. Amplitude represents the energy's strength, which can be called loudness. The loudness is actually the quantity of energy flowing through a given area in a given time, which is power. The conventional units used to express this power are decibels. Decibels are related to the ratio of the intensity of power of one sound versus that of another sound. A conventional baseline reference point is at a frequency of 1,000 Hz and an amplitude of 0 dB. Forty decibels is not 40 times the standard but is actually 10^4 times. Likewise, the sound amplitude of 50 dB is actually 10 times 40 dB.

An accurate representation of noise sampling requires a statistical approach. In order to adequately describe the actual noise levels of the event, many noise samples must be taken. The sound produced during the acoustical-dissolution test is measured at a time frequency of four times per second. Measurements at this time frequency for a 2-min period give an accurate description of the sound produced by the dissolving salt. During testing, the data are digitized and electronically transmitted to a microcomputer for processing.

ACOUSTICAL-DISSOLUTION TEST

The test is a fairly simple procedure that could be incorporated as standard operating procedure for analyzing face salt samples. Since it is simple, the individual assigned to do the testing requires little training. The acoustical responses from random salt samples used in the tests ranged from 40 to 80 dB, with most samples producing less than 50 dB. Since an average work environment may have ambient noise levels as high as 40 dB, a quiet room or inactive area of the mine should be used as the test area; even in a quiet area, a soundproof chamber enhances the accuracy of the results.

TEST APPARATUS

The instrumentation used for the tests was originally designed for measuring occupational noise exposure; it was modified slightly for use with the dissolution test. It consists of a small sensitive microphone, a dosimeter-data logger (*6*), a microcomputer, a soundproof chamber, and associated hardware for dissolving the salt sample. All equipment, except the dosimeter-data logger and the microcomputer, are inside the soundproof chamber. The 2- by 2- by 2-ft chamber (inside dimension) reduces ambient noise levels. It provides ample space for the needed equipment (fig. 1). An instrument panel, equipped with receptacles, is on the chamber's side with the microphone outputs. Permanently attached inside the chamber is a round aluminum canister (not shown in figure 1), which serves two purposes: It provides an additional sound shield from ambient noise and it acts as an amplifier for the noise emitted by the dissolving salt. The canister has a removable cover to provide easy access when the salt is added. Inside the aluminum canister is a 2,000-mL glass beaker filled with 1,800 mL of normal tap water and an inverted 250-mL beaker that holds the test samples. The microphone picks up the sound of the dissolving salt, and the information is measured, processed, and stored by the dosimeter-data logger at a rate of four times per second. This device then computes the average decibel level for each 10-s interval and for the entire test period (usually 2 min). The information is then electronically transferred to the microcomputer, which provides printouts of sound levels and time history data analysis. Using this information, the sample is classified as "normal" or "outburst" salt. Provided with this information, the mine engineer can take suitable precautions during blasting. This methodology is now standard operating procedure at at least one of the Louisiana domal salt mines.

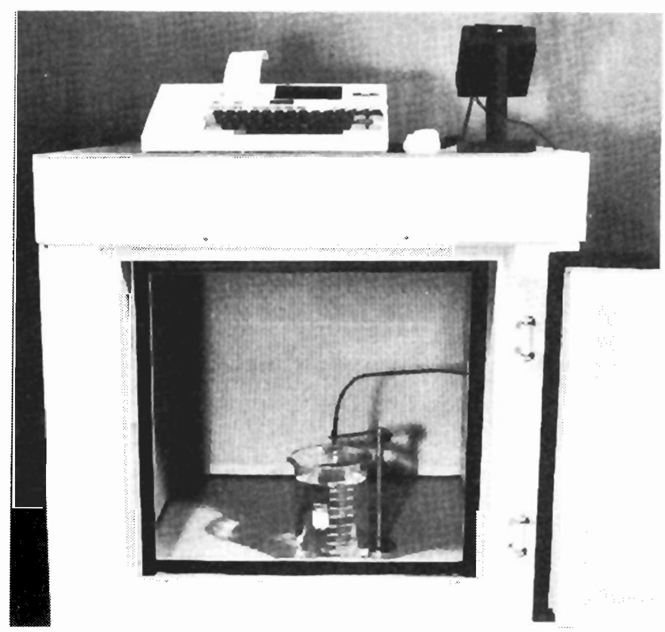

Figure 1.-Experimental apparatus for conducting acoustic test.

TEST PROCEDURE

The standard test procedure developed for measuring acoustic levels of dissolving domal rock salt is as follows:

1. A salt sample weighing about 50 g is selected and placed in the beaker of water inside the soundproof chamber. Although tests have shown that reliable results can be obtained for a sample that varies by 40 g, the sample size should be kept as uniform as possible (*4*).
2. The dosimeter-data logger test switch is moved from the standby to the test position. Verification of test startup is then confirmed by observing the indicator lights on the bottom of the dosimeter; a red light should flash four times per second as sampling takes place.
3. The timing device is activated and the test is run for 2 min.
4. After the test is run, the microcomputer is connected to the dosimeter-data logger and the digital sound levels are transferred to the computer memory. A commercially available software package immediately performs all the averaging functions, with the results provided via a printout.

Figure 2 shows typical computer-generated results for a normal salt sample (0.0028 cm^3 CH_4 per 100 g) and for an outburst sample (2.1079 cm^3 CH_4 per 100 g). The average sound produced (shown in the last line of figure 2) when the normal salt sample was dissolved was 40.1 dB; the outburst salt sample averaged 68.4 dB. The first four lines of the printout provide user programmable information. Information such as heading, title, mine name, and possibly a short note is helpful here. Line 5 identifies which particular dosimeter was used, and line 6 provides the serial number of the software package used. The

```
     Normal Salt
US BUREAU OF MINES
SALT/SOUND STUDY
MINE SALTY

V1.1              S/N:7047
dB-301/14         S/N:5428
DYNAMIC RANGE: 40-103dB
TEST NUMBER: 248
LOCATION: 8BNE
DATE: 02/06/85
METHANE LEVEL: 0.0028
RUN TIME:   2: 3
AVERAGING PERIOD: 10 sec
PERIODS COMPLETED: 12

   TIME HISTORY

PERIOD
NUMBER--LEVEL (dB)
     1 - 40.0
     2 - 40.0
     3 - 40.0
     4 - 40.0
     5 - 40.0
     6 - 40.0
     7 - 40.0
     8 - 40.0
     9 - 40.0
    10 - 40.0
    11 - 41.0
    12 - 40.0

LEQ CURRENT:   40.1
```

```
     Outburst Salt
US BUREAU OF MINES
SALT/SOUND STUDY
MINE SALTY

V1.1              S/N:7047
dB-301/14         S/N:5428
DYNAMIC RANGE: 40-103dB
TEST NUMBER: 229
LOCATION: 31FNN
DATE: 06/07/85
METHANE LEVEL: 2.1079
RUN TIME:   2: 4
AVERAGING PERIOD: 10 sec
PERIODS COMPLETED: 12

   TIME HISTORY

PERIOD
NUMBER--LEVEL (dB)
     1 - 65.0
     2 - 69.0
     3 - 66.0
     4 - 70.0
     5 - 72.0
     6 - 69.0
     7 - 66.0
     8 - 67.0
     9 - 69.0
    10 - 68.0
    11 - 67.0
    12 - 67.0

LEQ CURRENT:   68.4
```

Figure 2.-Examples of microcomputer printouts of acoustical test results for normal salt (right) and methane-enriched salt (left).

seventh line shows the "DYNAMIC RANGE," which is the decibel range that can be recorded. The "TEST NUMBER" and "LOCATION" are supplied by the user, but the "DATE" is provided by the computer's battery-operated clock. The "METHANE LEVEL" is the gas content (cubic centimeters per 100 grams) of the sample, if known. The test duration is automatically shown as "RUN TIME" and is in minutes and seconds. "AVERAGING PERIOD" denotes the time increments in seconds that will be averaged to produce the time history file, and "PERIODS COMPLETED" shows how many time increments were averaged. The actual "TIME HISTORY" profile shows two events: First, "PERIOD NUMBER" represents the 10-s blocks of time that the samples are averaged; second, "LEVEL (dB)" gives the average decibel level for the 40 measurements taken during that 10-s period. The decibel levels for all of the periods are then averaged to produce the "LEQ CURRENT." The LEQ is called the average sound level. It is defined as the constant sound level in a given situation and time period that conveys the same sound energy as does an actual time-varying sound during the same time period. This is used to determine the relationship between decibel levels and gas emitted.

DATA ANALYSIS

One hundred and seventy-three salt samples were analyzed. The samples were obtained from ribs and faces of known location at two mines identified as "mine A" (108 samples) and "mine B" (65 samples). These samples had been stored in a Bureau salt sample library, accumulated from this and other studies. The samples do not represent a true ratio of normal-to-outburst samples that would be taken from a random minewide sampling program. The ratio of normal-to-outburst samples present is probably higher than what mine operators would expect from daily sample collections at the mined faces. For example, of the 173 samples tested, 25 were outburst. This does not imply that, for every 173 faces sampled during normal salt production, there are 25 outburst faces. The data are useful, however, because they give a relative range of sound level output for normal and outburst-related salt.

Distribution of all samples from both mines is shown in table 1, by salt type (normal or outburst) and by the range of decibels for the specified salt type. From mine A, 84 pct of all normal salt samples were at a decibel range of 40 to 65 dB. The remaining 16 pct of normal samples were widely distributed above 65 dB. This suggests that, while normal salt may produce as much noise as outburst salt, 84 pct of normal salt samples in mine A had low-noise outputs.

Test results of mine B samples show that all normal samples had acoustic levels below 55 dB, and outburst samples all had levels above 55 dB. Assuming the sound levels are related to gas pressures, this could be a significant finding. Depending upon factors previously mentioned, different pressures may be required to precipitate an outburst. This could explain why noise levels for outburst samples vary between mines but are reliably constant within each particular mine. These results show general guidelines that a salt mining enterprise could use in expanding its own data base concerning salt type and acoustic test results. If the methodology were accepted by the mining enterprise, a detailed data base could easily be formed.

Table 1.–Distribution of salt samples tested for gas content and noise

	Mine A			Mine B		
Range . . dB . .	40-65	65-85	Total	40-55	55-85	Total
Normal samples	79	15	94	54	0	54
Outburst samples	0	14	14	0	11	11
Total	79	29	108	54	11	65

Tests were conducted by the Bureau to determine if a relationship existed between the gas content and the sound emitted of salt samples. Each sample was divided into two equal parts; one-half was tested using the original gas dissolution test, and the other half by the acoustical-dissolution test. Figure 3 shows a graphic comparison of the data from mines A and B. The values are in increments of 5 dB, with the corresponding average gas content. The data are also shown in tables A-1 and A-2 in the appendix, sorted by sound emitted. A large increase in gas content from both mines occurs at 55 to 65 dB. The diagram proves only relative relationships between the sound and the gas content exist. Variances do exist and may be due to a number of reasons, including the presence of CO_2 in the sample, the inhomogeneous nature of gas occlusions in the sample, and varying gas pressure. A numerical value for CO_2 contents from the dissolution test lacks meaning, since CO_2 is exsolved from the brine in the dissolution chamber as its salinity increased.

The acoustic test results proved to be a good indicator of a potential outburst face. However, several questions remained. Why did samples from the two mines differ? Is the difference in the frequency of pops caused by inclusions distributed in a nonhomogeneous manner? Was the loudness of the pops caused by one large inclusion or many small ones together? Could differences in results be attributed to higher levels of CO_2?

To answer these questions, tests were conducted on seven samples (four outburst, three normal) from the two mines, using a laser Raman microprobe. The Raman microprobe can determine the total internal gas pressures

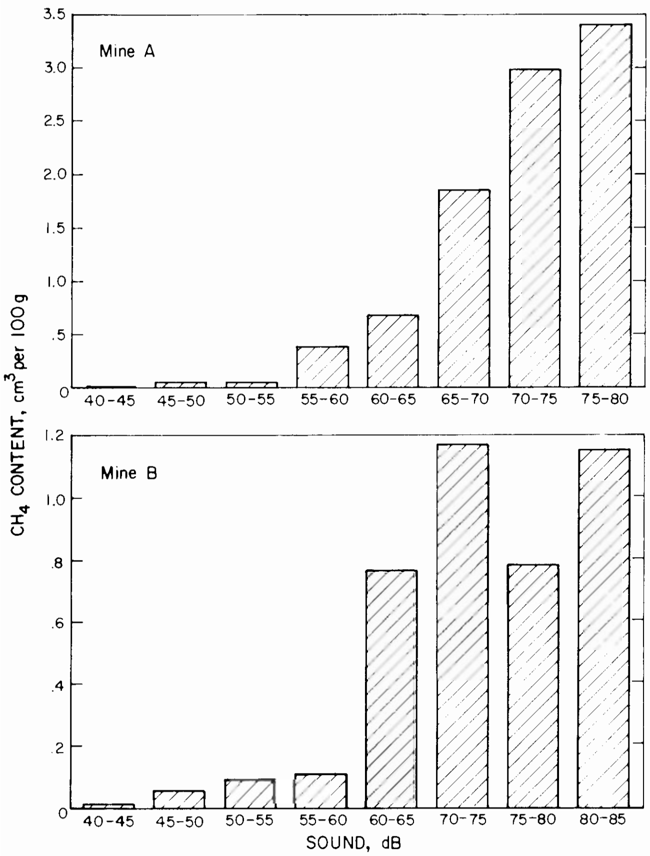

Figure 3.-Relationship between average gas content data and average noise levels for two domal salt mines.

of individual methane-bearing fluid inclusions and the pressure differences among CO_2-bearing fluid inclusions. Also, various covalently bonded gas species have been identified using this method (*8*). The results of the laser Raman microprobe analysis of salt inclusions from the seven samples are shown in table 2. During these tests, fluid inclusions were found to be nonhomogenously distributed throughout the samples. Inclusions observed in the samples could be classed in three types: (1) methane bubbles that frequently occur in trails, (2) brine inclusions that appear in thin tubules, and (3) anhydrite crystals that seem to be abundant in all samples. Mixtures of all three inclusion types were present, and some of the brine inclusions contained huge vapor bubbles, possibly indicating brine-methane mixtures. Initially, analysis was conducted for CO_2, CO, H_2, N_2, CH_4, and H_2S. However, since only CH_4 and CO_2 were found, analysis for the other gases was discontinued. Samples 1, 2, 3, and 6 were outburst. They had the highest sound levels, pressures, and methane content. Samples 1, 2, and 3 had CO_2 concentrations ranging from 2.5 to 3.4 pct, with the remaining gas being methane. Generally, inclusions could not be found in the low-methane-content samples and are therefore listed as not detected. It would be inaccurate to conclude that these seven samples represent all samples from all mines. However, results from the laser Raman tests lead to several hypothetical conclusions: (1) The acoustic noise is related to the gas content and the gas pressures, (2) gas inclusions are fairly inhomogenously distributed through the samples; this could be why there is a variation between the acoustic test and the gas content results of outburst samples, (3) no methane inclusions are present in low-gas-content salt, and (4) CO_2 appears insignificant within the inclusions themselves, but this does not rule out the presence of CO_2 in fractures within the salt mass itself. The CO_2 within inclusions could be an indicator of such a condition.

Table 2.-Results of tests performed on salt samples using laser Raman microprobe

Mine and sample	CH_4 content, cm^3 per 100 g	Average pressure, atm	Peak pressure, atm	CO_2 content, pct	Sample type	Average sound, dB
Mine A:						
1	8.6	145	155	2.5	O	74.2
2	8.2	70	90	3.4	O	74.1
3	7.5	103	110	2.5	O	75.5
4	.003	ND	ND	ND	N	40.0
5	.001	ND	ND	ND	N	41.3
Mine B:						
6	2.4	161	200	ND	O	77.9
7	.008	ND	ND	ND	N	40.0

N Normal.
ND Not detected.
O Outburst.

SUMMARY

One hundred and seventy-three salt samples from two different mines were analyzed for methane gas content and noise output. Results showed that for mine A, 84% of low-gas salt samples produced a decibel range of 40 to 65. The remaining 16% of normal salt samples produced noise levels that were widely distributed above 65 dB. All outburst samples from mine A produced a noise greater than 67 dB. All normal salt samples from mine B produced noise levels below 55 dB, and all outburst samples had levels above 55 dB.

In order to determine why the samples produced a range of acoustic noise, tests were performed on seven samples using the laser Raman microprobe. Results from these tests lead to several hypothetical conclusions: (1) The acoustic noise level is related to the gas content and the gas pressures, (2) gas inclusions are not homogeneously distributed through the samples, (3) no methane inclusions are present in low-gas-content salt, and (4) CO_2 appears insignificant within the inclusions themselves.

Gas inclusions are not homogeneously distributed through the salt; this could explain why there is a variation between results of the acoustic test and the dissolution test on outburst samples. Also, although the CO_2 appears insignificant within the inclusions themselves, the CO_2 within inclusions could be an indicator of the presence of CO_2 in large fractures within the salt mass itself.

REFERENCES

1. Cybulski, W., C. Gorol, T. Gotkowski, and J. Sobala. Charakterystyka Zagrozenia Metanowega w Polskich Kopalniach Soli (Characteristic Features of Methane Hazard in Polish Salt Mines). Pr. G1. Inst. Gorn., Komun., No. 567, 1972, 20 pp. Saf. Mines Res. Establ. Trans. 6344.

2. Grau, R. H. III., T. E. Marshall, and G. L. Finfinger. Evaluation of Methane Liberations From Production Blasts in Domal Salt Mines. Paper in Proceedings of Fourth International Mine Ventilation Congress, Brisbane, Australia, July 3-6, 1988. Australas. Inst. Min. and Metall., 1988, pp. 229-234.

3. Hyman, D. M. Methodology for Determining Occluded Gas Contents in Domal Rock Salt. BuMines RI 8700, 1982, 11 pp.

4. Marshall, T. E., and G. L. Finfinger. Gas Content Determinations of Salt Samples Using Acoustic Responses. BuMines RI 9113, 1987, 10 pp.

5. McCue, T. (production supervisor, Cote Blanche Mine). Private communication, 1986; available upon request from T. Marshall, BuMines, Pittsburgh, PA.

6. Metronics, Inc. Metrologger Instruction Handbook dB-301/301P. Undated, 35 pp.

7. Molinda, G. M. Investigation of Methane Occurrence and Outbursts in the Cote Blanche Domal Salt Mine, Louisiana. BuMines RI 9186, 1988, 21 pp.

8. Pasteris, J. (associate professor, Dep. Earth and Planetary Sci., WA Univ.). Private communication, 1987; available upon request from G. Molinda, BuMines, Pittsburgh, PA.

9. Plimpton, H. G., R. K. Foster, J. S. Risbeck, R. P. Rutherford, F. King, G. L. Buffington, and W. C. Traweek. Final Report of Mine Explosion Disaster, Belle Isle Mine, Cargill, Inc., Franklin, St. Mary Parish, Louisiana. MSHA Accident Invest. Rep., 1980, 156 pp.

10. Schatzel, S. J., and D. M. Hyman. Methane Content of Gulf Coast Domal Rock Salt. BuMines RI 8889, 1984, 18 pp.

11. Thoms, R. L., and J. D. Martinez. Blowouts in Domal Salt. Paper in Fifth Symposium of Salt (Hamburg, Federal Republic of Germany, May 29-June 1, 1978). North. OH Geol. Soc., Cleveland, OH, v. 1, 1980, pp. 119-134.

APPENDIX.–SALT SAMPLE DATA

Table A-1.–Average gas content and decibel levels of salt samples at mine A

Sample	Salt type	CH_4 content, cm^3 per 100 g	Sound, dB	Sample	Salt type	CH_4 content, cm^3 per 100 g	Sound, dB	Sample	Salt type	CH_4 content, cm^3 per 100 g	Sound, dB
1	N	0.0000	40.0	37 ...	N	0.0057	40.1	73 ...	N	0.0816	60.1
2	N	.0000	40.0	38 ...	N	.0073	40.1	74 ...	N	.8728	61.8
3	N	.0000	40.0	39 ...	N	.0163	40.1	75 ...	N	2.0069	63.2
4	N	.0000	40.0	40 ...	N	.0037	40.2	76 ...	N	.2968	63.5
5	N	.0000	40.0	41 ...	N	.0049	40.2	77 ...	N	.3404	63.6
6	N	.0000	40.0	42 ...	N	.0060	40.2	78 ...	N	.6256	63.8
7	N	.0010	40.0	43 ...	N	.0296	40.2	79 ...	N	.5579	64.1
8	N	.0011	40.0	44 ...	N	.0000	40.3	80 ...	N	.3143	65.1
9	N	.0012	40.0	45 ...	N	.0000	40.3	81 ...	N	.7156	65.3
10 ...	N	.0021	40.0	46 ...	N	.0013	40.3	82 ...	N	1.5795	65.5
11 ...	N	.0021	40.0	47 ...	N	.0022	40.3	83 ...	N	2.0482	66.0
12 ...	N	.0024	40.0	48 ...	N	.0027	40.3	84 ...	O	.1235	67.1
13 ...	N	.0026	40.0	49 ...	N	.0034	40.3	85 ...	O	1.4107	67.4
14 ...	N	.0028	40.0	50 ...	N	.0040	40.3	86 ...	N	2.0294	68.0
15 ...	N	.0028	40.0	51 ...	N	.0042	40.3	87 ...	N	1.5116	68.2
16 ...	N	.0030	40.0	52 ...	N	.0049	40.3	88 ...	O	6.5021	68.9
17 ...	N	.0031	40.0	53 ...	N	.0055	40.3	89 ...	N	.6684	69.0
18 ...	N	.0031	40.0	54 ...	N	.0067	40.3	90 ...	O	3.4708	69.9
19 ...	N	.0034	40.0	55 ...	N	.0085	40.3	91 ...	N	.9953	70.4
20 ...	N	.0035	40.0	56 ...	N	.0103	40.3	92 ...	N	8.7837	70.4
21 ...	N	.0036	40.0	57 ...	N	.0130	40.3	93 ...	N	.0622	71.3
22 ...	N	.0037	40.0	58 ...	N	.0134	40.3	94 ...	N	.9665	72.2
23 ...	N	.0039	40.0	59 ...	N	.0152	40.3	95 ...	N	1.6197	72.3
24 ...	N	.0040	40.0	60 ...	N	.0159	40.4	96 ...	O	2.0288	72.3
25 ...	N	.0045	40.0	61 ...	N	.0045	40.5	97 ...	O	1.2414	72.5
26 ...	N	.0047	40.0	62 ...	N	.0033	40.6	98 ...	O	3.5953	72.8
27 ...	N	.0056	40.0	63 ...	N	.0101	40.7	99 ...	O	3.2307	73.2
28 ...	N	.0062	40.0	64 ...	N	.0150	40.7	100 ..	O	4.6632	74.8
29 ...	N	.0063	40.0	65 ...	N	.0102	41.7	101 ..	N	5.6358	74.9
30 ...	N	.0085	40.0	66 ...	N	.0364	43.2	102 ..	O	6.1282	75.4
31 ...	N	.0096	40.0	67 ...	N	.0138	44.2	103 ..	O	5.7197	76.0
32 ...	N	.0096	40.0	68 ...	N	.0158	44.2	104 ..	O	7.4248	76.2
33 ...	N	.0117	40.0	69 ...	N	.0475	49.5	105 ..	O	.2401	76.5
34 ...	N	.0136	40.0	70 ...	N	.0366	50.1	106 ..	N	2.6580	77.4
35 ...	N	.0443	40.0	71 ...	N	.0618	51.6	107 ..	N	1.1500	77.8
36 ...	N	.0028	40.1	72 ...	N	.3910	57.6	108 ..	O	2.3798	77.9

N Normal.
O Outburst.

Table A-2.–Average gas content and decibel levels of salt samples at mine B

Sample	Salt type	CH_4 content, cm^3 per 100 g	Sound, dB	Sample	Salt type	CH_4 content, cm^3 per 100 g	Sound, dB
1	N	0.0000	40.0	34 ...	N	0.0165	40.0
2	N	.0000	40.0	35 ...	N	.0116	40.5
3	N	.0000	40.0	36 ...	N	.0064	40.7
4	N	.0041	40.0	37 ...	N	.0049	40.8
5	N	.0053	40.0	38 ...	N	.0448	40.9
6	N	.0054	40.0	39 ...	N	.0047	41.0
7	N	.0068	40.0	40 ...	N	.0103	41.0
8	N	.0071	40.0	41 ...	N	.0199	41.0
9	N	.0077	40.0	42 ...	N	.0492	41.0
10 ...	N	.0082	40.0	43 ...	N	.0126	41.1
11 ...	N	.0083	40.0	44 ...	N	.0356	41.3
12 ...	N	.0091	40.0	45 ...	N	.0072	42.0
13 ...	N	.0104	40.0	46 ...	N	.0240	42.0
14 ...	N	.0135	40.0	47 ...	N	.0190	42.8
15 ...	N	.0143	40.0	48 ...	N	.0033	43.0
16 ...	N	.0151	40.0	49 ...	N	.0303	43.0
17 ...	N	.0172	40.0	50 ...	N	.0575	43.0
18 ...	N	.0036	40.1	51 ...	N	.0351	44.0
19 ...	N	.0048	40.1	52 ...	N	,0029	44.2
20 ...	N	.0022	40.2	53 ...	N	.0608	45.3
21 ...	N	.0045	40.2	54 ...	N	.0979	51.4
22 ...	N	.0068	40.2	55 ...	O	.0976	55.3
23 ...	N	.0091	40.2	56 ...	O	.1243	59.4
24 ...	N	.0153	40.2	57 ...	O	1.4776	60.4
25 ...	N	.0186	40.2	58 ...	O	.1597	61.6
26 ...	N	.0233	40.2	59 ...	O	.3274	63.5
27 ...	N	.0293	40.2	60 ...	O	1.1082	63.5
28 ...	N	.0347	40.2	61 ...	O	.6164	71.4
29 ...	N	.0023	40.3	62 ...	O	1.7289	73.1
30 ...	N	.0114	40.3	63 ...	O	1.2749	76.5
31 ...	N	.0065	40.4	64 ...	O	.2960	79.3
32 ...	N	.0089	40.4	65 ...	O	1.1543	83.6
33 ...	N	.0118	40.4				

N Normal.
O Outburst.

INT.BU.OF MINES,PGH.,PA 29070