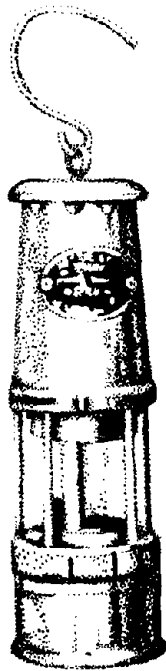


**A mining research contract report
JANUARY 1983**

DEVELOP DATA FOR REVIEW OF METAL AND NON-METAL MINE METHANE HAZARD CLASSIFICATION



Contract J0100060
Golder Associates, Inc.

Bureau of Mines Open File Report 158-83

**BUREAU OF MINES
UNITED STATES DEPARTMENT OF THE INTERIOR**



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The authors have endeavored to present the information in this document as factually and objectively as possible. By its nature, however, some of the information may unavoidably be influenced by the opinions of those who supplied it.

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17. Document Analysis a. Descriptors Mining <table border="0"> <tr> <td>Flammable gas</td> <td>Nitrogen</td> <td>Classification</td> <td>Blowers</td> <td>Monitoring</td> </tr> <tr> <td>Methane</td> <td>Firedamp</td> <td>Regulations</td> <td>Methanometry</td> <td>Detection</td> </tr> <tr> <td>Carbon dioxide</td> <td>Blackdamp</td> <td>Outbursts</td> <td>Safety thresholds</td> <td>Ignitions</td> </tr> </table> b. Identifiers/Open-Ended Terms Gassy mines c. COSATI Field/Group 081					Flammable gas	Nitrogen	Classification	Blowers	Monitoring	Methane	Firedamp	Regulations	Methanometry	Detection	Carbon dioxide	Blackdamp	Outbursts	Safety thresholds	Ignitions
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FOREWORD

This report was prepared by Golder Associates under United States Bureau of Mines Contract Number JO100060. The contract was initiated under the Minerals Health and Safety Technology Program. It was administered under the direction of the Pittsburgh Research Center, with Mr. Ed Thimons as Technical Project Officer and Mr. H.R. Eveland as Contracting Officer for the Bureau of Mines.

This report describes the work completed under the terms of the contract during the period July 1980 - August 1982. It was submitted in September 1982 and contains no patentable features.

The information is presented as being, to the best of our knowledge, factual; some of it, however, was obtained by word of mouth and although the information is presented as objectively as possible it may occasionally be subject to certain personal bias. The information has also been in large part obtained by translating foreign language documents and conversations. Exact translations are frequently not possible without some distortion of the meaning, with the result that the authors have frequently had to exercise discretionary judgement in order to arrive at the most probable meanings of phrases and sentences.

A study of this type could not have been successfully completed without the assistance of a great many people.

We wish, therefore, to gratefully acknowledge the assistance of the following people, companies, and organizations, and thank them for their cooperation, and for permission to present the information contained in this report.

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1.0

PREFACE

During recent years an awareness has evolved that the phenomena of occurrences of flammable and toxic gases in underground openings are complex and not always well understood. This is particularly true of violent gas outbursts, which, despite considerable research in a number of countries, remain largely unpredictable in both frequency and magnitude.

With the advent of the increased use, outside of the coal mining industry, of high extraction mining methods such as longwalling, and the interest in mining commodities such as oil shale by conventional underground methods, there has come a need to assess the efficacy of the existing gassy mine standards for metal/non-metal mines in the United States. For example, the large scale of certain operations such as some domal salt mines creates a special problem in that some of the heavy equipment in everyday use in these mines may not be available in a permissible form. Again, the use of flame-proof equipment may not, in itself, contribute significantly to safety in mines which are prone to violent outbursts of gas and rock, but which are at other times free of gas. Also, under certain circumstances such a mine may at present escape a gassy classification, the extreme danger notwithstanding, until a disaster actually occurs.

The intention of the present study has been to examine the ways in which certain foreign countries classify and regulate metal and non-metal mines which are experiencing measurable occurrences of flammable and/or noxious gases. This report documents the information which was obtained and offers comments where these are deemed appropriate. It does not offer opinions on, or make recommendations concerning the existing gassy mine standards in the United States. A body of information is presented as objectively as possible, from which the reader may draw his or her own conclusions. A section of the report is devoted to a discussion of certain mines in the U.S. which are presently

classified gassy. This section is included in order that the reader may more readily be able to make comparisons between mines of similar types operating in the United States and in foreign countries.

The information has been obtained in a variety of ways. Meetings and discussions have been held with mine operators, mine inspectors, government officials, and members of the academic community in a number of countries, including at least two eastern bloc countries. Wherever possible copies of mining codes have been obtained and (where necessary) translated. Selected excerpts from foreign mining codes are included as appendices. Wide ranging literature searches were initiated to obtain historical background information, and the results of research concerning gas ignitions and violent outbursts around the world. No study of quite this type had previously been undertaken so that major effort was required during the initial stages to identify, and to establish dialogue with, sources of accurate, useful information in other countries.

Since it has been the purpose of the study to examine the regulatory processes rather than the exact nature of gas occurrences, the contents of the report are only concerned with technical matters to the extent that they are relevant. That is to say, in cases where the nature of the gas occurrence affects technical considerations or is of technical interest in itself.

In certain instances however, an efficient set of safeguards can only be achieved after a certain level of understanding of all the technical aspects of the particular problem has been developed. Violent outbursts of gas and rock come into this category, and for this reason an appendix has been attached in which some of the established results of research into these phenomena are briefly discussed. The information presented does not purport to be the sum of that available. Constraints imposed by considerations of budget and time, and the need to translate

much of the information from other languages, prevented a more detailed pursuit of the subject. These dangerous events are a common threat to mine safety in a number of countries, in some of which research into their causes, effects, and predictability is being actively pursued. It is to be hoped that the results of these researches may become available in the United States, where violent outbursts have occurred with sometimes disastrous consequences (2).

The study has indicated worthwhile avenues for further research, and it is to be hoped that in due course some of these will be followed as a logical extension of the present work. These are briefly discussed in a final section which summarizes the study results. It is hoped that this information will be of practical interest to both the metal/non-metal mining industry at large, and to those charged with the responsibility for mines inspection and regulation.

1.1 TERMINOLOGY

Throughout this report the terms "flammable gas", "firedamp", and "methane" are used. Methane (CH_4) almost never occurs in a mine in significant volumes as a pure gas. "Firedamp" is a traditional coal-miners term for flammable gas; British Standard 3618 defines "firedamp" as "a flammable gas consisting mainly of methane, found naturally in mines". The statutes of many countries use the term "firedamp", others "flammable gas". Since methane is the main constituent of firedamp, the reader may consider the use of any of these three terms throughout the report to mean the same thing.

In researching occurrences of methane in mines, it is inevitable that some overlap with other types of gas hazards will occur. For example, methane often occurs in association with hydrogen sulfide, nitrogen, carbon dioxide, and other hydrocarbons. For this reason the use of the word "gas" in this report should not

automatically be construed to mean "flammable gas". Rather, the word "gas" will generally refer to a mixture of gases, some of which may or may not be flammable. =

In discussing mining equipment, generic names only are used for the most part. Exceptions have been made in those instances wherein the manufacturer's name and the model have been relevant to the question of whether or not the machine is available in (or may readily be converted to) permissible form.

Contract Scope of Work

which have been criticized on the grounds that they do not always enhance safety, and that they lack flexibility. The 1979 disaster at the Belle Isle Mine in Louisiana, in which five men died in an explosion of methane gas (2), undoubtedly provided impetus to those who felt that the present gassy mine standards for metal/non-metal mines should be reviewed. This mine, operating in domal salt, had a history of violent outbursts of gas and salt previous to this disaster (2), yet was not classified as a gassy mine until after the explosion. The disaster itself was caused by a large-scale release of methane in the form of a violent outburst immediately following a scheduled production blast. The violence of the outburst and the quantity of gas released were in themselves sufficient to inundate parts of the mine with gas, severely damage equipment, and endanger life, without ignition occurring. When the gas ignited ten minutes later, after reaching parts of the mine quite distant from the site of the outburst, the men who were trying to flee were killed, and others who were adjacent to the main shaft waiting to be hoisted to the surface were very fortunate to escape asphyxiation (2). This disaster, and some other, less dramatic gas-related events, notably at the Lisbon Mine in Utah (3), contributed directly to the initiation, early in 1980, of this study.

2.2 TERMS OF REFERENCE

The terms of the original contract required that a body of information be assembled, but specifically excluded the contractor from making recommendations concerning changes in the existing gassy mine standards. The work was to be divided into three main phases and a number of sub-tasks, with all work to be completed within 24 months of commencement. Work began in August, 1980.

2.2.1 Phase I

The requirement of the Phase I work under the original contract was to gather information detailing the metal and nonmetal mine

2.0

CONTRACT SCOPE OF WORK

2.1 HISTORICAL PERSPECTIVE

The Mine Safety and Health Administration (MSHA) of the United States Department of Labor presently classifies all underground non-coal mines in the United States only as being either gassy or non-gassy. The established classification system does not define varying degrees of gassiness, nor does it permit classifying only a part of a mine as gassy (1). It takes no account of the situation wherein a mine which is free of gas is nevertheless operating in a potentially gassy geological environment, and it does not address the special problems of mines wherein gas occurs only in the form of violent outbursts of gas and rock. The criteria used to classify gassy mines in the U.S. are:

"A mine shall be deemed gassy, and thereafter operated as a gassy mine, if:

- 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 percent 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."

These criteria seem to many people to overlook some of the variables which are associated with gas occurrences in non-coal mines. They are accompanied by an explicit set of regulations

methane-hazard classification systems used in other countries and to:

- a. List all classification criteria in current use
- b. Determine whether different levels of classification exist, and if so, ascertain how and why these levels are derived
- c. Determine whether special classification systems apply to multilevel mines, and if so, how they work
- d. Determine how classification criteria are applied and how any associated safety regulations are enforced.

The contract called for a minimum of 20 countries to be studied.

The Phase I work was divided into three tasks. Task I consisted of selecting a number of foreign countries considered suitable for study, by virtue of their present mining activity and past experience with methane gas. Task II consisted of obtaining the pertinent information (wherever possible) from the selected countries. Task III consisted of summarizing and evaluating the information received from all the sources, and preparing an interim report.

2.2.2 Phase II

The Phase II work, as originally stipulated, was to consist of two tasks, to be performed in parallel. These were:

- (i) To perform an economic analysis of the cost differential between implementing regulations applying to mines which have been classified as gassy in the United States, and those applying to similarly classified mines in foreign countries.

- (ii) To perform a hazard analysis which would examine the incremental improvements in safety resulting from the implementation of regulations in use in mines classified as gassy in the United States and in foreign countries.

2.2.3 Phase III

The requirement in Phase III was to select 12 metal/non-metal mines in the United States, of which it was stipulated that six were to be currently classified gassy by the MSHA, and six non-gassy (but with the potential to be gassy). It was further stipulated that the six gassy mines should include:

- at least one salt mine
- one uranium mine
- one limestone mine
- one trona mine.

The six non-gassy mines were to include:

- at least two salt mines
- at least one uranium mine.

For each of the twelve mines selected all necessary data was to be collected from which to determine how each of them would be classified under the classification criteria of the 20 foreign countries studied during Phase I. These data were to be obtained from mine and MSHA records, and (where possible) mine tests.

2.3 CONTRACT MODIFICATIONS

As a result of information obtained during the Phase I work, it became apparent that some of the original concepts of Phases II and III ought to be modified in order to best serve the original intent of the contract. By mutual agreement between the Bureau

of Mines and its contractor, Golder Associates Inc., the scope and intent of Phases II and III were modified in a number of ways.

As originally conceived, the scope and intent of the Phases II and III work were predicated on the assumption that other countries used an approach similar to that in use in the U.S. in classifying metal/non-metal mines with respect to gas. The investigations performed during Phase I revealed that this is not the case. It was therefore proposed and agreed to that the Phases II and III work should consist, broadly speaking, of a comparative analysis based upon a case-by-case study of selected foreign gassy mines. The intent has been, in each case, to:

- (i) define the exact nature of the gas problem
- (ii) determine how the mine operators safeguard the operation, and
- (iii) examine how (i) and (ii) affect the operation, overall.

For each mine a case history was compiled, based upon the above considerations. The Phase III work then consisted of a similar exercise using gassy mines in the U.S., and drawing whatever conclusions that validly could be drawn from a comparison of these mines with foreign ones. Direct comparisons were difficult to make, because of widely differing socio-economic and labor conditions, as well as for historical reasons. Qualified comparisons were made on the basis of:

- (i) the type of mine (potash, salt, etc.)
- (ii) the mining method (conventional room-and-pillar, longwall, etc.)
- (iii) type and origin of gas and mode of occurrence (violent outbursts, steady emissions, blowers), and

- (iv) geological and structural conditions which would directly affect (i), (ii) and (iii).

The Phase I Work

3.0

THE PHASE I WORK

3.1 CANDIDATE COUNTRIES

In order to compile a preliminary list of countries which would be potentially worth studying, a literature search was initiated. This concentrated first on identifying the minerals being mined, other than coal, with which methane emissions were most frequently associated. Countries where these commodities were being mined by underground methods were then identified (4) (5).

3.1.1 Commodities Associated with Methane Occurrences

Occurrences of methane have been observed at one time or another in almost every type of underground mine. Outside the United States it appears that, except for coal mines, historically, methane has most frequently been noted in those operations mining salt, potash, limestone, uranium, silver, lead, zinc, mercury, and in deep gold mines. The preliminary selection process therefore consisted of compiling a list of those countries which produce these commodities from underground mines.

The literature pertaining to gas occurrences in non-coal mines is frequently concerned with emissions of carbon dioxide, carbon monoxide, nitrogen, and hydrogen sulfide, as much as with methane. This literature also is often out-dated, so that the mine or mines referred to are no longer operating.

Because of these problems, identifying 20 countries with experience potentially useful to the study proved to be a time consuming task involving painstaking research.

3.1.2 Experience, Economic Importance, and Political Stability

Only countries which have a well established mining industry, and in which mining is a reasonably important part of the national

economy, were considered for study. Another important factor in the selection process was the degree of political stability prevailing in any given country. It was felt that an unstable political situation could make it difficult to obtain the required information. For these reasons a number of countries in which there is considerable mining activity were not included in the study.

3.1.3 Selection of Countries for Study

The terms of the contract required a minimum of five foreign countries to be visited, out of the total of approximately twenty selected for study. In all cases, the initial problem was to identify the appropriate organizations to be approached for information. In countries such as Australia, South Africa, and the United Kingdom where no foreign language is involved, this was relatively easy. In other countries such as Spain and India, mining companies were able to render assistance in identifying regulatory agencies, and individuals within those agencies. In all other countries the initial approach was through academic institutions (correspondence established with Mining Schools and Universities) and/or commercial/economic attaches at United States embassies. In all but five cases these methods led to useful contact being established with the appropriate authority. In one of the five remaining cases (the Soviet Union) successful contact was established through their consular representatives.

The countries selected for study are listed below:

*Australia	Mexico
Canada	Pakistan
Chile	*Poland
Czechoslovakia	Romania
Finland	*Rep. of South Africa
*France	Soviet Union
East Germany	*Spain
*West Germany	Sweden
India	*United Kingdom
*Italy	*Yugoslavia

3.1.4 Problems Encountered

Obtaining information by correspondence has proved to be either very slow or apparently impossible. For example, it was not until February 1981 that replies were received from Poland and Romania to letters that were sent there in August 1980. Replies were not received until March 1981 to letters sent to Czechoslovakia in October 1980. In the case of the Soviet Union an affirmative reply was received to our request to visit that country to obtain information, but since the visit was cancelled (at the request of the USBM) the Soviets have not responded to written requests for information. This is unfortunate because the information which we have been able to obtain from secondary sources indicates that the Soviets have a great deal of experience in dealing with methane, particularly in the form of violent outbursts (13).

Unexpected difficulty has been experienced in a number of cases in obtaining copies of official mining codes. Presumably in most

* Countries to which visits were made during the study.

cases this is due to the fact that such volumes are only published in limited numbers by government printers and are therefore not always in print. In other cases, however, Czechoslovakia being an example, there appears to be some reluctance on the part of officials to making such information available. Hence, in spite of assurances that the information would be supplied in due course, some countries have not supplied copies of official mining regulations.

The matter of translating material obtained from non-English-speaking countries has proved to be much more time-consuming and expensive than originally anticipated. This arises from the fact that in no country so far studied has it been found that a separate, concise gas classification system exists for metal-liferrous mines. Therefore, because the relevant sections on gassy conditions have usually been contained in the coal mining code (or codes) of that country it has sometimes been necessary to translate relatively large volumes of material, at least in summarized form, to obtain all the required information.

3.2 EVALUATION OF COUNTRIES

3.2.1 Introduction

The following sections consist of general summaries, which contain the basic information obtained from each country. The countries are presented in alphabetical order. Pertinent extracts from the regulations of each country are attached as Appendices in all cases where they are available and seem useful. Some of these extracts have been translated from foreign languages couched in formal, somewhat legalistic terminology, difficult to translate exactly. The authors have sometimes had to rely on their own knowledge of the subject matter in order to arrive at the most probable meaning in English.

3.2.2 Australia

3.2.2.1 General

Australia was visited for a period of approximately two weeks, and discussions were held with representatives of mining companies, universities, government regulatory agencies, and Chambers of Mines.

There is no single Federal Government regulatory agency responsible for the imposition of mine regulations for underground mines in Australia. Regulations governing safety are laid down in individual Mining Acts enacted by each State Government, and are enforced by the Mines Department of that State. Partial uniformity of mine safety regulations between the various States has, however, been achieved by agreement on a common code of safety for metalliferous mines and quarries.

The law requires mine managers to hold a Certificate of Competency, granted by the Mines Inspectorate, and requires the certification of certain individuals, in particular, locomotive drivers. Individuals may be held legally responsible for safety infractions, along with the mine manager and the mine owner (for a typical description of the system, see the New South Wales Mines Inspection Act, 1901, 1972, relevant paragraphs from which are reproduced in Appendix I). Mine Inspectors are required to hold mine manager certification and/or a degree in mining engineering. Electrical and mechanical inspectors must hold recognized degrees in electrical and/or mechanical engineering (see Appendix I).

Emissions of methane are not unknown in metal and non-metal mines in Australia, but at the time of preparing this report there are no underground mines operating in Australia (other than coal mines) which are classified as gassy. We were informed that

historically, methane gas has never occurred in metal and non-metal mines in Australia in concentrations sufficient to constitute a real or potential threat to mine safety, and no special legislation has ever been enacted. For the same reasons, no separate system exists for the classification of metal and non-metal mines with respect to methane or other gas in Australia. In the Mines Regulation Acts of certain States, standards are set for the quality of air breathed in or about mines, but these do not make direct reference to methane. They generally specify a minimum allowable oxygen level, and a maximum allowable level for gases such as carbon dioxide, carbon monoxide, hydrogen sulfide, oxides of nitrogen, and aldehydes.

3.2.2.2 New South Wales

Although methane gas occurrences in metal and non-metal mines in Australia are not at present considered significant, minor, sporadic emissions are nevertheless occasionally seen, and certain mines which are prone to these emissions monitor for methane quite rigorously. For example, at the Broken Hill South Mine of the Zinc Corporation (New Broken Hill Consolidated Mines, Ltd.) methane is occasionally seen in minute, barely identifiable amounts, bubbling from water in depressed drill holes in development headings. The gas, which is in quantities so small that it cannot usually be identified in the return ventilation air, is thought to emanate from a carbonaceous formation underlying the orebody. Nevertheless, the drillers working in development headings are equipped with methanometers, and are required to take daily readings for methane. Forced ventilation is used in all development headings.

The Broken Hill North Mine of ConZinc Rio Tinto has also experienced very minor, sporadic inflows of methane from boreholes in development headings. We were informed unofficially that on one occasion several years ago, in an isolated and undocumented episode, gas issuing from a borehole in a heading was ignited by

a drill crew, and apparently flamed off for several minutes. Since that time methane has occurred on rare occasions of short duration only, in barely identifiable amounts. Drill crews in development headings are equipped with methanometers, as at the South Mine.

In both the North and South Broken Hill Mines very slight traces of methane have occasionally been detected in old workings, and these are thought to be emanating from old timber sets which have been immersed in water for long periods. In both mines regular checks for methane are carried out, but in neither is it regarded as an operating hazard warranting any special safety procedures.

The office of the State Mining Engineer for the State of New South Wales had no record of any significant methane occurrence in non-coal mines in that State.

3.2.2.3 West Australia

In the Annual Report of the West Australian Mines Department for the year of 1951 a brief accident report describes a gas explosion which occurred at the 2,650 foot level on the Great Boulder, Kalgoorlie. The gas was encountered in a depressed diamond drill hole which had been drilled for a distance of 1,665 feet. Analysis confirmed the gas as methane. Two drillers later died as a result of injuries sustained in the explosion.

We were advised, unofficially, of other instances of methane emissions in Kalgoorlie mines, including instances of gas from boreholes being flamed off to avoid dangerous accumulations, and one instance of gas from a borehole being piped to an exhaust airflow. Although these events may be documented in old mine records we did not have the opportunity to further research them.

The principal host rocks for the Kalgoorlie gold lodes consist of two series of basic igneous rocks known as the older and younger

greenstone series, or quartz dolerite greenstone. This is a tightly folded, faulted structure, and includes a bed of slate associated with a porphyry dike. Areas of graphitic slates have been encountered in mining and drilling operations, and these probably give rise to some methane gas emissions. The 1979 Annual Report of the Western Australian Department of Mines contains a one-paragraph reference to diamond-drilling encountering "pockets of gas occurring naturally in the rock," on three occasions. These were underground, at Kambalda Nickel Mines and at Kalgoorlie State Battery Reserve, but were evidently very minor events. Apart from the one serious accident in 1951, methane gas has not presented a hazard to mining in Western Australia. No special legislation exists pertaining to methane in non-coal mines in the State of Western Australia, and at the time of our enquiries (1981) no underground metal/non-metal mines were employing any special safeguards against flammable gas.

3.2.2.4 Queensland

Discussions held with the State Mining Engineer of the State of Queensland disclosed the fact that there are no recorded instances of methane emissions in non-coal mines in that state. Safety clauses in the Queensland Mines Regulation Act 1964-1979 (for metalliferous mines) do not specifically refer to methane, but set out procedures to deal with "noxious or flammable gas in any part of a mine, . . . "

In the State of Queensland, however, methane gas is causing complex problems in underground coal mines, where it occurs in large volumes, and frequently in the form of violent outbursts. Even in the coal mines, however, where rigorous rules are laid down regarding air quality and flammable gas, there is no general system of classification for gassy and non-gassy mines. Mr. B.J. Cox, the Queensland State Mining Engineer, stated that, with reference to coal mines (letter to Golder Associates, 2/5/81).

"Where a methane emission problem exists, a Code of Practice is developed jointly by Mine Management - Coal Mines Inspectorate - Unions, to cope with the problem. It is not considered practical to design regulations for dealing with the problem in coal mines generally. A Code of Practice is developed only after much research, and the resulting safeguards are not necessarily transferable from one mine to another."

3.2.2.5 Victoria

Discussions were held with representatives of the State Mines Department of Victoria who stated that there are no operating gassy mines (including coal mines, which are all surface operations) in that State, and that, historically there were no documented methane occurrences. None of the deep underground gold mines in Victoria are still operating.

3.2.2.6 Tasmania

Correspondence with an official of the Department of Mines in Tasmania revealed that methane occurrences in the mines in that state have never warranted concern or special legislation.

3.2.2.7 Summary

Methane occurrences in metal and non-metal mines in Australia, although by no means unknown, have never been considered to constitute a serious hazard. Where methane has been detected, common sense monitoring is routinely carried out, but no operating mine in Australia at the present time, other than coal mines, experiences methane on a scale that would warrant any special operating precautions beyond routine monitoring. No system exists in any Australian State for the classification of gassy and non-gassy mines except that which applies to coal mines. Wide discretionary powers are vested in the Mines Inspectorates with regard to the implementation of rules, or the

making of special rules (Mines Inspection Act of New South Wales, 1979, Division 2, Section 58). Some underground coal mines in New South Wales and Queensland are experiencing severe and complex problems due to violent outbursts of methane gas. The tendency is for individual mines to develop Codes of Practice which are designed to best safeguard the particular operation. Because such codes are worked out in collaboration with the Mines Inspectorates, they have the force of law once they are implemented. The severity and nature of the methane occurrences in the coal mines is providing the impetus for considerable research on the parts of both government and industry to try to develop reliable methods of predicting violent gas outbursts. One of the recommendations arising from the official enquiry into a 1979 explosion at the Appin Colliery was that collieries "be graded in terms of gassiness . . ."(6).

It is likely that this recommendation will soon be implemented, in New South Wales, at least. The Mines Inspectorate is presently examining this and other recommendations to determine what advantages, if any, would accrue from their being adopted.

3.2.3 Canada

3.2.3.1 General

The Canadian situation is in some respects analagous to that in Australia insofar as each Canadian Province is directly responsible for devising and implementing mine safety regulations within its own boundaries. The Province of Ontario has probably experienced more methane emissions in metal mines than any other Province in Canada. Methane commonly occurs in a relatively minor way in the Precambrian rocks which cover most of Ontario, so that historically there have been many instances of methane being encountered in diamond drillholes, raises, and shafts. An ignition of methane occurred in a shaft at the Central Patricia Mine (prior to 1950), and in Ontario a number of fatalities and

injuries have resulted from ignitions of methane in metal mines (7). In general, however, although methane has occasionally been detected at many metal mines throughout Canada, the emissions have been minor and of short duration. At the time of preparing this report there are no operating metal or non-metal mines in Canada which are classified as gassy.

The regulations and procedures in the various Provinces are basically similar (the regulations of all Provinces were reviewed). There is no classification system in Canada which is used to define metal and non-metal mines as being either gassy or non-gassy. References to gas in the mining regulations for metalliferous mines do not specifically refer to methane, but rather to gas in general. Where methane gas is involved it appears that mine management is permitted to exercise quite a high degree of discretion in dealing with the problem. In general, where methane is encountered in measurable quantities, the coal mining safety regulations are used as guidelines in all mines. These set specific threshold limit values and rigorously define permissible procedures, equipment types, and explosive types. Once the threshold limit values of methane are exceeded, then such procedures as shutdown of all equipment and withdrawal of personnel are mandatory. As noted earlier, however, below these levels, and depending on the particular circumstances, mine operators may, with the knowledge and consent of the Mines Inspectorate, exercise considerable discretion. In all Provinces it is mandatory to notify the Mines Inspector for the area within twenty-four hours of any flammable gas having been detected in any part of a mine, even though no accident has occurred and the gas is not in dangerous concentrations. In such cases, prescribed areas within a mine may be declared "fire hazard areas", either by the Mines Inspector, or the mine management, without necessarily affecting the entire mine. To quote from the Mine Regulations for the Province of Quebec, which has no coal mines and therefore only one set of regulations, "part or parts" of a mine may be designated as a "fire hazard area." The Act goes on

to state that "No person shall smoke or be allowed to smoke, use or have in his possession open flame lamps, matches or other means of producing heat or fire in such areas, without the permission of the Inspector of Mines, and under such conditions as he may deem proper. Such 'fire hazard areas' shall be properly indicated by suitable signs. The Operator shall cause such signs to be installed and maintained as long as the area is so designated". In other provinces the definition of a "fire hazard area" is the same, and mine operators may apply such a designation to a part or parts of their mines at their own discretion. As noted earlier, it is, however, mandatory to inform the Mines Inspector of the conditions which made such designation necessary or desirable.

The generally accepted threshold limit values for "flammable gas" (methane is not specified) in Canadian mines are as follows:

one and one-quarter percent in the general body of air in the vicinity of any operating electrical machinery requires the immediate cutting off of electrical power to the affected area; and two and one-half percent in the general body of air in any part of the mine requires the immediate withdrawal of all persons from the "affected area".

"The affected area" is defined as being that part of the mine that appears (to the person in charge of the general area of the mine in which the high flammable gas level was noted) to be affected. In other words, it is to some extent a discretionary matter. In addition, most Provinces require regular (mandatory) measurements to be made for flammable gas, usually at least weekly, once levels well short of these limits have been reached. For example, in New Brunswick, if flammable gas levels in the atmosphere in haulageways exceed 0.75 percent it is mandatory for a qualified person to test the atmosphere at least once a week. In the British Columbian regulations, if air in a main return

airway is found to contain one percent or more of flammable gas the mine manager is required to notify the Mines Inspector within 24 hours, and take immediate steps to improve the ventilation.

In Nova Scotia most of the mines have experienced what the Mines Inspector termed "nuisance occurrences of methane." This was defined as meaning barely detectable quantities of methane appearing from time to time, usually associated with diamond drilling. The most frequent occurrences have been at the Canadian Rock Salt Mine at Pugwash, where diamond drill rigs in development headings are fitted with continuous methane monitoring equipment which will emit an audible warning when methane is detected. (At the time of preparing this report we had not been able to ascertain the level of methane in the atmosphere which would trigger the alarm.) Drillers have standing orders to suspend drilling when methane is detected until such time as the gas has been dissipated. The Mines Inspector has stipulated that all sites in underground mines in Nova Scotia where diamond drilling is taking place be designated fire hazard areas (as previously defined).

3.2.3.2 Summary

In Canada there is no one Federal Government regulatory body responsible for mine safety. The responsibility for drawing up and enforcing mine safety statutes for operations within the Provinces is vested in the individual Provincial Governments. There is no system in use anywhere in Canada for officially classifying metal and non-metal mines as gassy or non-gassy, nor are there any operating non-coal mines in Canada which are classified as gassy by the application of the coal mining regulations which pertain to methane.

Methane occurrences in non-coal mines have not historically been serious or persistent enough to warrant legislation. The mining codes for non-coal mines do not in general single out methane,

but refer rather to "flammable gas," and stipulate safety measures to be adopted where this is encountered. The usual practice is to designate part or parts of the mine as "fire hazard areas" until the gas is diluted or removed (by enhanced ventilation, cessation of the gas inflow, or both). In a designated fire hazard area it is forbidden to smoke, possess open flame lamps, matches, or any other means of producing heat or fire. Threshold limit values are defined for flammable gases, and where these are approached or exceeded then the safety regulations which apply to coal mines are invoked. The safety codes which apply once threshold limit values are approached or exceeded are much more rigorous, and explicitly define procedures, permissible equipment types, and chains of responsibility. Thus, individuals from blasting foreman up to mine manager are certified, to ensure that certain safety procedures are followed, and these individuals may be held legally accountable if they are not. Excerpts from the British Columbia Mining Regulations, and Coal Mining Regulations, which are typical, will be found in Appendix II.

3.2.4 Chile

3.2.4.1 General

In Chile there are no operating mines other than coal mines which are classified as gassy, nor is there any official system of classifying mines with respect to gassiness. The only regulations which refer to "firedamp" are the Coal Mining Regulations, which define standards for equipment types, explosive types, air quality, and operating procedures.

The Mine Safety and Policing Regulations apparently cover all types of mining in Chile, both surface and underground, as well as miscellaneous mines and quarries, and including coal mines. The responsible government regulatory agency is the Servicio De Minas Del Estado. A summary of the relevant sections

of the Reglamento De Policia Y Seguridad Minera (Mine Safety and Policing Regulations) of Chile are contained in Appendix III.

3.2.5 Czechoslovakia

3.2.5.1 Introduction

Enquiries directed to academic institutions and government agencies in Czechoslovakia have met with very limited response. We have had to rely to a large extent, therefore, in compiling information concerning that country, on the personal knowledge of a Czech expatriate, who was trained as a mining engineer in Czechoslovakia, and on his translations of available Czechoslovak mining literature. This has consisted of Mining Standards issued by the District Mining Bureau in Ostrava. The mines of the Ostrava-Karvina coal basin experience severe methane blowout problems; safety regulations, as well as being comprehensive, are strictly enforced. These standards pertain to coal mines. The only response we have received from Czechoslovakia, a letter from the Chairman of the Czech Mine Bureau, informs us that there are no operating non-coal mines in Czechoslovakia classed as gassy with regard to methane.

3.2.5.2 General

The Czechoslovak mining industry is organized on a national basis under the general control of the Federal Ministry of Fuel and Power, located in Prague. On a regional basis mining is under the jurisdiction of the Slovak and Czech Mining Bureaus, located in Bratislava and Prague respectively. The country is further divided into a number of mining districts which come under the direct jurisdiction of District Mining Bureaus (DMB), and it is the DMB personnel who impose and enforce mine safety regulations.

With respect to the presence of methane, two general categories of mines have been established in Czechoslovakia. These are (a) mines free of explosive gases (non-gaseous mines), and (b) mines with explosive gases (gaseous mines). Non-gaseous mines are defined as being those wherein the methane content in the general body of air in any underground working place does not exceed 0.1%, and wherein, after ventilation has been shut down for a period of 24 hours, the methane content in the general body of air in the underground working areas does not exceed 1.0%.

Gaseous mines are by definition all those which do not come into the above category, and are further divided into three sub-categories. These are:

1. Mines subject to sudden outbursts of coal and gases
2. "Second Class of Danger" mines, . . . this category includes all the mines located in the Ostrava-Karvina coal district.
3. "First Class of Danger" mines, which category includes all gaseous mines not belonging to the first two categories.

The information available to us does not define what constitutes a "First Class of Danger" or a "Second Class of Danger" mine.

3.2.5.3 Summary

It has not been possible to obtain complete information from Czechoslovakia concerning the gassy mine standards of that country. The information that has been obtained confirms that a classification system does exist with respect to methane gas in coal mines, and that this system defines more than one category of gassiness. The classification system may declare only part of

a mine gassy under certain circumstances, or may assign different categories of gassiness to different parts of the same mine.

There are no operating gaseous non-coal mines in Czechoslovakia, and no separate system for classifying such mines exists. The approach being used seems to be that a new mine is potentially gassy until proven otherwise.

Translated material from the Mining Standards issued by the DMB in Ostrava will be found in Appendix IV.

3.2.6 Finland

3.2.6.1 General

Our sources of information concerning methane gas occurrences in Finland were the Mining Inspection Office of the Ministry of Trade and Industry, and ventilation engineers from the staff of Outokumpu Oy, a leading Finnish mining and engineering company.

The history of methane emissions in Finnish metal mines consists of minor occurrences during diamond drilling and shaft sinking. At the Kotalahti Mine (nickel) in 1962 a driller lost consciousness (but subsequently recovered) when he was overcome by an outrush of gas under pressure from a surface borehole. Analysis showed the gas (which was almost odorless) to be methane with some hydrogen sulfide. The gas flow was apparently of fairly short duration although this is not documented. Later, when the main shaft was being sunk at the same mine, methane was again encountered for a short time in the vicinity of the 400 m level. Methane is occasionally noted in trace amounts at Kotalahti Mine and mine personnel carry out routine checks with methanometers at least monthly throughout the mine, and more frequently in areas where methane has been detected at any time. These checks may be as often as daily if methane is actually detectable. The concentrations of gas have been so slight, however, that the mine

engineers do not consider them as a practical problem of mine ventilation or mine safety. Apart from very minor occurrences of the type being experienced at Kotalahti Mine the mining industry in Finland has not encountered problems attributable to methane gas.

In Finland, Mine Safety Statutes are laid down by the Ministry of Trade and Industry. In addition, mines have to comply with Safety Instructions laid down by the Ministry of Labor and Health, and the inspectors of this Ministry, as well as the Mines Inspector, have authority to enforce safety laws and rules. In certain situations the mining companies may impose safety rules of their own. At each mine a safety engineer on the staff of the mining company is locally responsible for ensuring that safety rules and laws are known to and observed by all operating personnel. The Finnish Mine Safety Regulations do not contain any special references to methane, and in fact refer specifically only to pyrite dust and radon in discussing gas or explosion hazards.

3.2.7 France

3.2.7.1 General

In France we were informed that the only mines, other than coal mines, which experience methane emissions are the potash mines of Alsace, which are operated by Mines de Potasse d'Alsace (MDPA). The government agency with overall responsibility for the formulation and imposition of mine safety regulations is the Ministerie de l'Industrie, with central authority located in Paris. There are regional offices at Strasbourg in the Bas Rhin province with local authority over Mines de Potasse d'Alsace, and in November 1980, meetings were held in Strasbourg with representatives of the Ministerie.

Copies of the printed regulations were not available at that time, and we have subsequently determined from the publishers that the general regulations are out of print. The following comments are therefore based only on our discussions.

There is no formal system of mine classification with regard to gas, and where flammable gas is considered to be a problem, the coal mining safety codes are applied. If flammable gas is detectable in a mine then the mine may be declared gassy in whole or in part, depending on the physical layout of the mine, the concentration of the gas, the mode of its occurrence, and other variables. Any such declaration seems to be at the discretion of the Mines Inspectorate, rather than a result of some specified methane concentration.

Safety regulations are actually imposed by the Direction Interdepart de l'Industrie with effective authority located in Strasbourg. Two engineers from this organization are located in Mulhouse, and are directly responsible for the day to day operations of the Mines d'Alsace. They are assisted by ten union representatives who serve three year terms on assignment to the Direction Interdepart de l'Industrie. In addition, each mine has its own safety department responsible for day to day safety in the mines so that, traditionally, there has been close cooperation between the union, mine management, and the branch of government involved in mine safety.

Regulations are applied and enforced by the Direction Interdepart de l'Industrie. However, mine management may request that specific regulations be adopted to suit unique local conditions, and these, in order to have the force of law, must be countersigned by the government safety engineer. Also, by the same method, management may seek variance from rules already in force.

The Alsace potash mines have worked two seams 70 feet apart at a depth of 1400 to 3500 feet. The hanging and footwalls of the seams are rocksalt containing shale and anhydrite beds, and the shale beds contain both methane and carbon dioxide. The dominant mining method used is advancing longwall with complete caving. Two phenomena are observed:

- (i) gas and rock outbursts in the footwall,
- (ii) gas outflows.

The outbursts, which generally occur without warning, are accompanied by large gas emissions which can amount to several tens of thousands of cubic meters. The gas flow tends to diminish fairly quickly, suggesting that it may be contained in localized zones even though it is associated with the shale strata. Large gas flows are also observed where the shale beds are intersected by mine openings or drill holes. Again, these flows tend to diminish with time but may continue for several days. The dominant gas is usually methane in both types of occurrences, but the relative proportion of methane to other gases was not determined during our discussions.

There have not been any reported gas ignitions in any of the currently operating potash mines. No diesel equipment is used near the working face, and all electrical equipment is flame-proof.

A detailed description of the Amelie Potash Mine is included in a later section of the report; this mine experiences violent outbursts of methane, as well as continuous emissions.

3.2.7.2 Summary

In France, regular methane emissions are encountered in the potash mines of Alsace. France does not have a separate system

for classifying metal and non-metal mines with respect to gassiness. When methane occurs it is dealt with as the particular situation demands. There are no categories of gassiness defined and part or parts of a mine may be declared gassy depending on the concentration of methane, either temporarily or permanently. In any mine, or part of a mine, that is declared gassy, the same safety regulations that apply in coal mines may be enforced. Considerable discretion can be used, however, in applying the regulatory process.

3.2.8 East Germany

No replies have been received to enquiries sent to that country, therefore no first-hand information has been received. Published information, however, indicates that the East Germans have considerable experience in dealing with gas outbursts (13). The literature contains several references to outbursts of salt and gas in the Werra area (among others) of the German Democratic Republic (8)(9)(13). It is evident that violent gas outbursts have been the subject of a considerable amount of research in East Germany (13), and most of the information which is summarized in Appendix XIII is derived from East German sources. (The authors were told by West German sources that exchanges of technical mining information between East and West Germany are now almost non-existent because of political considerations).

3.2.9 West Germany

3.2.9.1 General

In November 1980 a visit was made to Oberbergamt-Clausthal-Zellerfeld, which is the headquarters of the Mining District for the State of Lower Saxony. Much of the potash mining presently being done in West Germany is carried on in this area; the region contains six operating potash mines and one salt mine. Three additional potash mines are operating in the Hessen Mining

District further to the south, with headquarters in Weisbaden. Safety regulations are administered through the central office of each mining district and its associated local branch offices. Each mining district has a considerable degree of autonomy and can establish, as required, regulations needed to control local conditions. The inspection and enforcement of regulations is carried out by the local offices.

Information obtained from Oberbergamt-Clausthal-Zellerfeld, and from the German Mining Association, indicates that methane gas occurrences in potash and salt mines have not been sufficient to create a safety problem. Far more serious problems have been caused by carbon dioxide. A later section of the report deals with this in some detail.

Large methane outflows were reported during the early development of some of the Lower Saxony salt mines. These were encountered during shaft-sinking and also during subsequent operations, and were on a scale sufficiently large to warrant some of these old mines being declared "firedamp excavations". A "firedamp excavation" had to comply with the established safety regulations corresponding to that designation. We have been unable to obtain a clear definition of a "firedamp excavation" or to find out what safety regulations were imposed on any mine once it had been so defined. Little or no documentation of these particulars seems to be extant. In any event, none of these mines are still in operation.

In the salt and potash mines operating in Germany today, methane occurs only occasionally, usually in minor amounts, and usually in association with hydrogen and hydrogen sulfide. In other types of mines, such as iron and metal ore mines generally, methane is not encountered at the present time, and there is no record of it having been encountered in the past. The methane emissions in the salt and potash mines are almost always associated with exploration diamond drilling, and specific safety

regulations developed to cover diamond drilling activities are presently being revised. A complete set of mine regulations has been obtained, and relevant parts have been translated, and this material will be found in Appendix V. A full translation was not made because there are few direct references to methane contained in the general mine regulations.

3.2.9.2 Summary

In West Germany, no system of classification exists for metal and non-metal mines with respect to methane gas. The potash and salt mines of Lower Saxony experience occasional very minor inflows, mainly from diamond drill holes, but are not generally required to use permissible diesels or flameproof electrical equipment. In metal ore mines, methane is not encountered in West Germany. The main problems arising from the presence of gas in non-coal mines in West Germany are those due to carbon dioxide, which has frequently occurred in the form of blowouts in the potash mines of the Hessen district. Special precautions are employed against this gas in these mines, and these are to be discussed in detail in a later section of the report.

3.2.10 India

3.2.10.1 General

There are references to methane gas occurrences in Indian metal mines in the literature, but documented accounts of specific events could not be found. The deep gold mines of the Kolar gold fields are mentioned as having experienced methane inflows, but the extent and duration of these inflows could not be determined. Apparently there have been no ignitions or other significant accidents in these or other Indian metal mines due to methane gas.

The Metalliferous Mines Regulations, 1961, under which all Indian mines other than those mining coal or oil operate, make no

mention of any system whereby mines are classified with respect to flammable or other gases. However, from the wording of the statute, it seems that a form of classification does exist, in that operations are suspended and operating personnel are withdrawn from any part of a mine in which flammable gas has been "found or detected". Being "found or detected" is defined in the statute as follows, (Regulation 141): "For the purpose of this regulation, inflammable (sic) gas should be deemed to have been found or detected when it is indicated by the lowered flame of a flame safety lamp or, where methane indicators are used, they indicate one and a quarter percent or more of inflammable gas." Other regulations then go on to state that in ventilation districts where flammable gas has been found (by the above definition) only flameproof equipment and permissible explosives shall be used. There is no definite statement made as to what constitutes a gassy mine, but the term "gassy mines" is used (Regulation 142) and from the wording of this statute one may infer that any mine (or part of a mine) in which flammable gas has been found (as defined in Regulation 141) is considered gassy.

The regulations which apply to the use of explosives, types of permissible equipment, ventilation, and safety procedures in general for gassy mines are rigorous and comprehensive. The Indian Coal Mines Regulations assign three categories of gassiness to coal seams, referring to them as gassy seams of the first, second, and third degree. A gassy seam of the first degree is one in which the percentage of flammable gas in the general body of air does not exceed 0.1, and the rate of emission of such gas does not exceed $1 \text{ m}^3/\text{tonne}$ of coal produced. For seams of the second and third degrees these figures become $>0.1\%$, $>1 \text{ m}^3/\text{tonne}$; and $>0.1\%$, $>10 \text{ m}^3/\text{tonne}$, respectively.

3.2.10.2 Summary

There appears to be one classification of gassiness in metalliferous mines in India under criteria laid down in Regulation 142 of The Metalliferous Mines Regulations of 1961. From this statute we infer that a gassy mine or place is:

1. A mine in which an explosion or ignition of flammable gas has occurred.
2. A ventilating district in which flammable gas has been found.
3. Any place in which, in the opinion of the Regional Inspector, flammable gas is likely to be present in such quantities as to render the use of naked lights dangerous.

In this context the word "found" refers to those levels of methane ordinarily detectable with a safety flame lamp, i.e., approximately 1.25 percent of the general air body. A copy of the Indian Metalliferous Mines Regulations 141, 142, 165, and 171-(2) will be found in Appendix VI.

Indian mining codes assign responsibility for certain specified tasks to particular individuals, who are required to be certified by law before being allowed to perform those tasks (e.g., blasting). Non-certified persons performing unauthorized tasks, or certified persons neglecting their assigned responsibilities may be prosecuted and punished by law.

3.2.11 Italy

3.2.11.1 General

Responsibility for the overall control and regulation of the Italian mining industry lies with the Directorate General for

Mines of the Ministry of Industry and Commerce in Rome. In November 1980, a useful meeting was held in Rome with officials of the Ministry, with the result that the following information was obtained.

The Ministry's Directorate supervises the 20 or more Mining Districts into which Italy is divided, each one of which has a Superintendent of Mines who is responsible for the proper application of mining rules and laws within that particular district. Italy, with a tradition of mining limestone, mercury, and more recently, potash, has developed sophisticated regulations to deal with noxious, toxic, and flammable gases in non-coal mines, as well as with explosive dusts.

The regulations appear to allow a high degree of discretion on the part of mine management and the local Superintendent of Mines as to when, and to what extent the regulations should be applied. The regulations themselves, however, are rigorous, specifying air quality, acceptable levels of methane, ventilation criteria, permissible explosives and equipment and, occasionally, mining modifications. In mines suspected of being subject to "firedamp" (and other gases), by virtue of the nature of the deposit and the geological environment generally, it is mandatory to monitor the operation after notifying the Superintendent of Mines. It appears to be left to the judgement of the chief mine engineer to a large extent, however, as to whether the mine is in fact suspect or not. Also, from the wording of the relevant statute, it would seem to be a matter, at least to some extent, for decision by the chief mine engineer as to whether the specified monitoring ought to be followed by safety measures. The statute clearly states that the mine engineer will, when he considers safety measures necessary, and after consulting with the Superintendent of Mines, establish which of the security measures prescribed by law ought to be adopted in all or parts of the mine, and set a deadline for action.

The Italian system defines two categories of gassiness by which a mine may be classified after a monitoring period of two years maximum duration. In certain exceptional circumstances this period may be extended by one year at the request of the chief mine engineer. Again, the chief engineer may classify the mine during the established monitoring period when the firedamp, or other gas being monitored, continues to appear or increases in concentration. Results of all monitoring tests have to be made known to the Superintendent of Mines, however, as well as the precise limits of the underground area being monitored, and also information concerning the conduct of operations in the area in question. A special category of classification is defined for mines subject to sudden outbursts of firedamp.

A translation of the relevant Articles (389-399, 401, 402, 444, 445) from the Italian Mine Regulations will be found in Appendix VII.

3.2.11.2 Summary

The basic Italian mining legislation defines two main categories of gassy mines, the second one of which includes a number of sub-categories. Briefly, these two main categories are defined as:

1. First Category, or slight firedamp hazard, wherein detectable firedamp concentration has never exceeded 0.3% by volume of the general airflow during the required monitoring period.
2. Second Category, or definite firedamp hazard, wherein the concentration of firedamp in some places has been found to be in excess of 0.3% by volume of the general airflow.

The second category also includes any mine or part of a mine in which (a) an accumulation of firedamp has been noticed under

conditions of normal ventilation, and/or (b) the release of firedamp per metric ton of ore produced in normal production during a 24-hour period exceeds 4 m³, and/or (c) an accumulation of firedamp is noted underground within one hour of a deliberate shutdown of the main ventilation. (An accumulation of firedamp is defined as a percentage volume equal to or greater than 1%). Elaboration of these categories and sub-categories will be found in Appendix VII.

In addition to the two categories defined already, there is a special categorization for mines subject to sudden outbursts of firedamp (see Articles 401, 402, Appendix VII). In all cases the classifications are decided by the chief engineer in consultation with the Superintendent of Mines.

Records of gas occurrences, mine accidents and so on are not stored at any one central location in Italy, but are stored in the files of the various Mining District offices. We have not been able to ascertain with certainty whether there are at the present time any non-coal mines operating in Italy under any of the above classifications.

3.2.12 Mexico

Response to enquiries directed to Mexican sources has not resulted in any useful information being received.

3.2.13 Pakistan

Requests for information sent to sources in Pakistan have met with no response. We surmise, however, that the mining laws of Pakistan will be found to be very similar to those of India since at the time the basic Indian legislation was introduced, and of subsequent amendments (1901, 1923, 1935-1941, 1946) India and Pakistan were linked by British Colonial Rule.

3.2.14 Poland

3.2.14.1 General

During the performance of the Phase I work it was not possible to arrange a visit to Poland within the time allotted for the completion of the work. A literature search had revealed that Poland does in fact have a system of classifying gassy metal/non-metal mines (10), and that several Polish salt mines experience serious problems due to methane. Several of these mines are in domal salt geologically similar to the salt domes of the Louisiana Gulf coast (11). A visit to Poland therefore seemed very worthwhile, but could not be arranged quickly enough to be included in Phase I. A visit was eventually made to Poland during the Phase II work. During that visit a meeting was held in Katowice with the President of the Polish High Inspectorate for Mining, at which time the classification and regulatory procedures were discussed. It has not been possible to obtain a copy of the Polish Mining Codes as they are out of print and the author was told that copies are scarce. All the information obtained was by word-of-mouth, and some details may be lacking because of language difficulties.

Even though this and other Polish meetings took place during the Phase II work, it is appropriate to the form of the report that the information concerning mine classification be included here. Information obtained during other meetings, and mine visits in Poland will be found in a later section.

Katowice is one of the principal centers of mining technology in Poland, located in the province of Silesia, which is the heartland of the Polish mining industry. In addition to being the headquarters of the Mines Inspectorate, Katowice is also the location of the Central Mining Institute (an organization analogous to the United States Bureau of Mines) and of the Safety in Mines Institute. At the meeting with the Chief Mines Inspector the following points were established.

- (1) The overall mining regulations of Poland, which apply to all mines, are devised by the Prime Minister's Department, and are very general. These are not specifically designed to meet the problems of any particular type of mine, but rather to provide guidelines, although they do have separate sections for coal and noncoal mines. In Poland there are a number of mining ministries, each responsible for the mining of certain commodities. Originally there were 18 of these, but the number has been reduced, and at the time of this meeting (November, 1981) re-organization was underway to reduce the number still further. The commodities are grouped under ministries with titles such as Chemical (salt, sulfur, potash, etc.), Heavy Industry (Zn, Pb, Cu, etc.), Coal, and so on. Detailed mining regulations governing safety and other matters are worked out for each ministry in consultation with the Mines Inspectorate.
- (2) The Mines Inspectorate, which is responsible for the enforcement of regulations, comes under the jurisdiction of the Prime Minister's Department. The Central Mining Institute (CMI) in Katowice, is primarily a research and development organization, but has direct control over the Safety in Mines Institute. The Safety in Mines Institute has the responsibility for the formulation of safety regulations in mines where special problems exist (e.g., gas). The CMI is a separate government department which interfaces with the various mining ministries as well as the Mines Inspectorate, recommending mining methods and, through the affiliated Safety Institute, appropriate regulations. The CMI is involved with all new mining operations from the outset, and is responsible for engineering studies, recommending mining methods, and all technical mining matters. The Safety in Mines Institute recommends the category under which any given mine should be classified where gas is present and helps to work out appropriate operating safeguards. In general, the Mines Inspectorate

adopts the recommendations of the Safety Institute. The matter of who would have ultimate authority in the event of disagreement was "under discussion", the author was told.

- (3) In Poland there are separate systems for the classification of coal mines and non-coal mines with regard to the degree of hazard due to methane gas. Four categories of gassiness are defined for coal mines, and two for non-coal mines. However (at least in the case of non-coal mines) these classifications, when they are imposed, are not automatically accompanied by a complete set of regulations corresponding to that particular classification. The system seems designed more to characterize the type of gas occurrence and the gas levels which are typically noted. Basic safety thresholds for all mine gases are established fairly uniformly throughout the industry worldwide. The nature and extent of regulation which is imposed is therefore worked out after a study of the particular problem, the objective of course being to try to ensure that hazard thresholds will not be exceeded in any part of the mine workings. The two basic categories of gassiness are:

- (i) mines in which $\geq 0.1\%$ CH_4 by volume is measurable anywhere in any part of the workings.
- (ii) mines in which violent outbursts of CH_4 have occurred.

The four categories of gassiness defined for coal mines were not discussed since the problem of CH_4 in coal mines is beyond the scope of the contract.

- (4) A system of certification exists in Poland whereby certain key mining personnel are required to be licensed by the Mines Inspector. These include all mine supervisors and engineers, as well as foremen and blasters. The Mines Inspector issues these licenses, which are mine-specific.

Upon transfer to another mine, the individual may be re-licensed for the new mine by having an interview with the Mine Inspector, or he may have to take a written examination, depending on the particular circumstances. The license may be revoked for incompetence, and in the case of a serious dereliction, much more severe penalties may result, such as a heavy fine, or even a jail term.

- (5) Once a mine has been classified the mine operators, mine safety people (i.e., officials of the Safety in Mines Institute), and the Mines Inspector may confer and decide upon appropriate regulations. In the case of gas occurring in an operating mine with no previous history of gas, the problem would be studied over a period of time before binding regulations were imposed. In the interim, monitoring would be routine, and appropriate precautions would be taken during operations until the problem was defined.

3.2.14.2 Summary

In Poland two categories of gassy non-coal mines are defined under a classification system separate from that applying to coal mines. Safety regulations are devised by the Mines Inspectorate in each mining district in consultation with the mining ministry concerned. There are several mining ministries responsible for the mining of commodities which are grouped under headings such as Chemical, Heavy Industry, and so on. In technical and safety matters the mining ministries come under the overall jurisdiction of the Central Mining Institute, which recommends both the classification which should apply to any given mine and the corresponding safety regulations (there is no complete, all-encompassing set of regulations which automatically applies when a mine is classified). The CMI is involved, through its Safety in Mines Institute, with all mining activities, including preliminary drilling and startup, throughout Poland. The Mines Inspectorate comes within the jurisdiction of the Prime

Minister's Department, which lays down broad guidelines for the more detailed regulations worked out by the mining ministries. The Mines Inspectorate has ultimate responsibility for enforcing mine regulations once they are implemented.

3.2.15 Romania

According to information received from the Romanian Ministry of Mines in Bucharest there is not, at the time of this investigation, any serious methane problem in non-coal mines in Romania. Officials of the ministry stated that gas does occur in some Romanian salt mines, but that the problem is "a small one". They stated that "no special technology" (which presumably includes mining machinery and special standards) has been developed for use in these mines. They accordingly expressed doubt concerning the likely usefulness of a visit to their salt mines, but also expresses willingness to arrange a tour. A potash mine is in the planning stage, but is not yet operational.

Officials of the Labor Safety Department of the Romanian Ministry of Mines, Petroleum and Geology, through the good offices of the Science Attache at the United States Embassy in Bucharest, supplied us with copies of the Romanian Mining Codes. Pertinent extracts from these have (with some difficulty) been translated, and are attached as Appendix IX.

Six categories of gassy mines are defined, and it would appear that these may be used to categorize all mines, regardless of the commodity, but that they have been derived mainly from coal mining experience. The categories are numbered 0 through V (see Table 2, Appendix IX). Category 0 may not apply to salt or coal mines, apparently, and Category V applies only to mines experiencing violent outbursts. Categories I through IV are all based on the volume of methane produced per ton of ore over a 24-hour period, suggesting that these categories are primarily intended for coal mines (it will be noted that almost all the regulations

refer to coal or to rocks in the vicinity of coal seams). It is noteworthy that Romania assigns a special category to mines experiencing violent blowouts (as do several other countries) and sets out special operating precautions for mines of this type.

There are two other categories, 'A' and 'B', which seem to be designated for non-coal mines, notwithstanding the fact that we were told by Romanian mining officials that "no special technology" had been developed. It is not clear exactly what types of mines these two categories are intended to cover, but it is true that the regulations which accompany them are very similar to those applying to coal mines. Translation of the Romanian codes proved to be particularly difficult; the authors had to spend a great deal of time with the translator (who had no knowledge of mining) in order to arrive at an acceptable translation. Where assumptions have been made concerning the meaning of words or phrases which do not translate readily into English, explanatory footnotes are provided.

3.2.16 Republic of South Africa

3.2.16.1 General

In South Africa a gassy mine is designated by the term "fiery mine," and this is defined in the South African Mines and Works Act and Regulations in the following way.

"The Inspector of Mines, with the approval of the Government Mining Engineer, may declare any mine to be a fiery mine by reason of the danger from inflammable gas in the mine. Such declaration shall be by written notice to the manager".

All coal mines in South Africa are designated fiery; a number of non-coal mines, including several gold mines in the Orange Free State, experience gas emissions and some specified regulations for the operation of fiery mines are enforced as determined by

the Mines Inspectorate. No categories of fieriness are defined, rather, it is a matter of judgement on the part of the mine management and/or the Mines Inspectorate. For example, a mine (non-coal) may be recognized as having local emissions of flammable gas, yet will not be classified as fiery. In a case like this, a number of the established fiery mine regulations, as specified by the Mines Inspector and approved by the Government Mining Engineer, may be enforced. This is done on a case-by-case basis, and those rules applied to one such mine may not necessarily be applied to another which is experiencing similar gas levels. When gas is detected, however, a rigorous system of monitoring and reporting (to the Mines Inspectorate) is adopted, together with specified procedures to be followed, and these procedures are all covered by the mine regulations.

The South African regulations relating to methane emissions are based upon the use of the flame safety lamp as the statutory means of detecting the gas. This is presently under review, with the object of introducing the use of methanometers as the statutory procedure and methanometers are, in fact, in use in the South African mines. At the time of preparing this report, however, the latest edition of printed regulations is still based on the use of the flame safety lamp. Even a very experienced operator using a flame safety lamp cannot accurately determine methane concentrations of less than 1.25% by volume of the general body of air in which it is placed. This means that, as far as South African regulations are concerned, "detectable" levels of methane are actually levels of 1.25% or more, a relatively high concentration.

Permissible quantities of gas in the general body of air at any place where persons are required to work or travel, as stipulated in the regulations, are, with regard to flammable gas, required to be "insufficient to show a distinct cap on the reduced flame of a safety lamp." This implies that at methane concentrations of approximately 1.25% or more work will stop. The regulations

further state that, "The manager shall immediately notify the Inspector of Mines of the presence of inflammable gas detectable by a flame safety lamp in any ventilation district of the mine if inflammable gas has not been detected therein within the previous three months." Once gas has been detected it is then the responsibility of certain specified individuals to take whatever action is necessary to dilute the gas to safe levels. The ultimate responsibility for gas removal lies with the mine overseer, shiftboss, or ventilation engineer, but not with anyone below this rank. While flammable gas is present in detectable quantities, no workmen are permitted in the mine area except those under the direct supervision of a suitably qualified ganger, who may be required to erect brattice, or perform other work necessary for the clearing away of gas.

When flammable gas reaches detectable levels it is mandatory to shut off all electrical equipment other than approved types of electric safety lamps. Because of this requirement flame-proof electrical equipment is not in general use. Instead, it is mandatory to test for flammable gas in all development headings at the beginning of each shift in all controlled mines. (A controlled mine is any mine coming under the Occupational Diseases in Mines and Works Act of 1973.) Fans are required to be installed in fresh air, and any exception to this, such as the installation of an auxiliary fan in the return airway from a ventilating district cannot be made without the permission of the Mines Inspector.

When flammable gas has been detected in a mine, whether it is declared a fiery mine, either permanently or temporarily, wholly or in part, is a matter for the discretion of the Mines Inspector, in consultation with the mine management and the Government Mining Engineer. In a mine which is designated fiery, only permitted explosives are used, and although flameproof fan motors are not required, strict regulations involving testing for methane apply to their shutdown and startup. Diesel equipment

used in fiery mines must be of a design approved by the Mines Inspector.

The mine safety code requires Certificates of Competency to be held by individuals before they are allowed to perform specific tasks. Some of these Certificates require a written examination, others are granted only after a requisite minimum of practical experience (usually a specified number of shifts worked under the supervision of a certified person) followed by examination by a Commission of Examiners. Individuals require certification to perform blasting, lamp inspection and repair; drive locomotives or other equipment; perform surveying, assaying, gas detection; to be mine managers, overseers, or ventilation engineers; to operate winding engines; and attend boilers and stationary engines. Any of these individuals, once certified, may be held responsible under law for safety infractions. In some instances, as for example in the case of blasters' certification, a special certification is required in order to legally entitle the individual to be responsible for blasting in a fiery mine. Chapter 28 of the South African "Mines and Works Act and Regulations" deals with Certificates of Competency. This chapter is reproduced in its entirety in Appendix VIII.

3.2.16.2 Summary

No formal system of classification of gassy mines exists in South Africa. If methane is detectable in a mine by the use of a flame safety lamp, that part of the mine where it is located is shut down until appropriate steps have been taken to clear the gas. The gas concentration is then reduced to a level that is no longer detectable by the lowered flame on a safety lamp in any part of the affected workings before it is deemed safe to allow workmen to re-enter the mine. When flammable gas has been so detected, the Mines Inspector may, in consultation with the Government Mining Engineer and the mine management, at his discretion, declare the mine fiery. All, or part of a mine may

be declared fiery, and one such mine, Western Deep Levels gold mine, is operating under a partial classification at present. Alternatively, the mine may not be officially declared fiery, but may, again at the discretion of the Mines Inspector, be required to adopt some of the safety measures which are mandatory in fiery (gassy) mines.

In all controlled mines it is mandatory for a certified person to check the mine workings for flammable gas at the commencement of each shift. Certification is required of all persons who are responsible for certain high risk activities, such as blasting or operating heavy equipment underground, and safety-related matters such as ventilation and gas/dust monitoring. These persons, who range in rank from mine manager to foremen and gangers, may be held accountable by law for breaches of regulations. In some cases certification requires the passing of a written examination prepared by a Commission of Examiners, and in all cases a specified minimum of practical experience under the direct supervision of a certified person is mandatory. Extracts from the pertinent South African regulations will be found in Appendix VIII.

3.2.17 Soviet Union

3.2.17.1 General

Reference to methane occurrences in available Soviet technical literature, and information received from colleagues who have visited the Soviet Union, has led us to believe that the Soviets have experience in dealing with methane in non-coal mines. A formal request to be allowed to visit the Soviet Union and discuss these matters at first hand was made, and accepted by the Russian authorities, but at the request of the USBM we were obliged to cancel it. Subsequent attempts to obtain technical information from Russia by letter and telex, and through Soviet technical liaison groups in the United States, have been completely unsuccessful.

We are therefore unfortunately in the position of not being able to present any information concerning Russian mining codes and practices.

3.2.18 Spain

3.2.18.1 General

During November 1980 a visit was made to Spain and discussions were held with mining experts in government and industry. Spain has a relatively sophisticated system of classifying all mines with respect to methane hazard, but does not have a separate system for the classification of metal and non-metal mines. Thus coal and non-coal mines are subject to the same set of regulations, and in fact the regulations apply to all underground works in general. The only distinction made between coal and non-coal mines is that coal mines are classified with regard to gassiness before they go into production, whereas other mines are classified only after the presence of methane has been established and a study of the particular mine has determined the appropriate type of classification. At the time of our visit to Spain there was at least one operating non-coal mine in the country, a potash mine near Pamplona, classified as a gassy mine.

The Spanish classification system defines four categories of mines with respect to "firedamp". These are:

1. Mines without "firedamp": those in which the presence of this gas has not been established.
2. Mines with little "firedamp": those in which this gas occurs in concentrations of less than 0.3% in the return air currents.
3. Mines with considerable "firedamp": those in which this gas occurs in concentrations exceeding 0.3% in the return air currents.

4. Mines with sudden "firedamp" inflow: these are emissions which suddenly invade a heading or erupt from a working face, and cause cracking, caving, or a blow out of rock.

With reference to the fourth category, above, this may be placed into a higher, sub-category classified as "very gassy" if the inflows occur "regularly and abundantly". This is defined as a situation wherein explosive concentrations of gas may be attained within one hour of a ventilation shutdown, or one in which, due to the spalling or breakage of weak rock, "firedamp" may be suddenly liberated in quantities sufficient to produce concentrations of 2.5% or more.

Each category of gassiness is associated with a corresponding set of regulations which are formulated by the Ministry of Industry and Energy. The actual classification of mines (and other underground works) however, is the responsibility of what is known as the Provincial Delegation in each of the Spanish provinces. The Provincial Delegation will classify a mine only after receiving a mandatory report from the Firedamp and Mining Safety Commission, whose responsibilities are analogous to those of a Mines Inspectorate.

All new underground excavations are classified by the Provincial Delegation on the basis of the geological environment, the history of other excavations in the area, the nature of the mineral being extracted, and other relevant factors. This classification is imposed before production commences, and is temporary, but it remains in effect until work has progressed to a point where a definitive classification is possible. Where coal mines are concerned this pre-production classification with regard to methane hazard is mandatory. In all other cases the initial classification is temporary, and to some extent discretionary. For example, even though the initial classification is in the first category (no "firedamp") the Provincial Delegation

may still order additional test work during the temporary period to permit a more definitive classification. This, when imposed, may apply to the whole mine, or only to part or parts of it. Once imposed, the classification can only be changed or lifted by the mine manager submitting a written request, supported by data obtained in the mine over a one year period, to the Provincial Delegation. The Provincial Delegate may order additional tests such as shutting down the mine ventilation for a prescribed period and testing for methane, before making a decision. For mines in the fourth category wishing to change classification, the supporting data must cover a two-year period.

A summary of the rules which apply to mines of the fourth category (mines prone to sudden outbursts) will be found in Appendix X. From our discussions with Spanish experts, and from examining the mining codes, it is apparent that, as in other countries we have studied, considerable discretion may be exercised by the Provincial Delegation in the imposition of safety regulations. Certain basic rules, however, such as the use of flameproof equipment; ban on fire, sparks, or flame underground; gas monitoring and recording; and the education and informing of personnel in safety and rescue matters, are mandatory.

The gassy potash mine referred to earlier has been the subject of a detailed investigation as part of this study. It is a Category 2 gassy mine, and is described in considerable detail in a later section of the report. This mine is the only operating gassy potash mine in Spain, and special rules were devised to meet its particular problems. To some extent, at least, this seems to be the norm; in Spain the statutory requirements seem to establish procedural guidelines, and mandatory reporting and monitoring requirements for the various categories of gassiness. The actual operating safeguards are worked out by the Provincial Delegate and the operators, working together.

3.2.18.2 Summary

In Spain no distinction is made between coal and metal and non-metal mines with regard to methane gas hazard classification. A system of classification has been developed which applies without exception to all underground works, including activities other than mining. Four categories of gassiness are defined, and at least one operating non-coal mine in Spain is classed as a gassy mine under this system. A translation of the Spanish classification criteria and the way in which the system is applied will be found in Appendix X.

3.2.19 Sweden

The literature contains a number of references to methane inflows in Swedish ore mines, in the Dannemora region and elsewhere. However, when we approached the Mining Section of the Swedish Occupational Safety and Health Board (Arbetarskyddsstyrelsen) we were informed that the methane hazard in mines is "non-existent in Sweden". Letters and other enquiries directed to mining companies elicited no response.

3.2.20 The United Kingdom

3.2.20.1 General

Historically, sporadic occurrences of methane gas have been known to occur in the U.K. in some of the old Cornish tin mines, and in the iron mines of central Scotland. Most of the mines wherein these occurrences took place are no longer operating, and among those that are still operating none are experiencing any real problems due to methane gas. Apart from the coal mines, the only mine operating in the U.K. at the present time which is experiencing significant occurrences of methane is a potash mine in northern England.

In the U.K. all mines except coal mines, and certain others which are specified, operate under the Law Relating to Safety and Health in Mines and Quarries, Miscellaneous Mines. This is contained in Part 3 of a three volume set which contains the regulations applying to mines of coal, stratified ironstone, shale, and fireclay as well. (These four types of mines are the only ones which do not come under the Miscellaneous Mine regulations). No separate regulations exist in the U.K. for the classification or control of hazard due to methane (or other flammable gases) in non-coal mines. In the case of the potash operation the coal mine regulations were used as the basis for a set of regulations (mining procedures) formulated by the mine engineers in consultation with the Inspectorate. These were based upon the nature of the problem, the experience gained by the operators, and the needs of the operation. When agreed upon between the mine management and the Mines Inspector (who operates under the Health and Safety Executive of the Department of Trade and Industry) and signed by the Mines Inspector, they have the force of law even though they are not so legislated by Act of Parliament.

The emphasis of these regulations is on mining geology and tight control of mining procedures, so as to fully utilize the predictive capability which has been developed with regard to intrushes of methane and other gases. A summary of the regulations and gas monitoring practices is included in Appendix XI. A detailed description of the mine itself is to be found later in the report.

The official regulations covering Miscellaneous Mines do not refer to methane gas specifically, but deal with precautions against fire and intrushes of liquid or gas. With reference to explosives, there is a short section which states that in any mine in which it is unlawful to use lights other than permitted lights, then only blasting materials or devices which are "in accordance with special regulations applicable to that mine"

shall be used. These "special regulations" are explained in detail in the section on explosives in the Coal Mines Regulations. Other sections of the Coal Mines Regulations deal with flammable dusts, "firedamp" drainage, electrical equipment, "dangerous occurrences", intrushes, fire and rescue, smoking materials, safety lamps, and other safety matters related to fire and explosions. These statutes are all contained within the Health and Safety at Work Act, 1974, and the Mines and Quarries Act, 1954-71, and govern all mines of every type in the U.K.

The regulations pertaining to methane contained in the above-mentioned Acts have been excellently summarized by the Mining Department of the National Coal Board in a 1979 publication which they have prepared, entitled "Ventilation in Coal Mines: A Handbook for Colliery Ventilation Officers." With the permission of the National Coal Board we have reproduced pertinent extracts from this book and have included them in Appendix XI.

3.2.20.2 Summary

There is no system for classifying mines with regard to gassiness in the United Kingdom. Hazardous levels of methane and other gases are laid down by statute, and when methane appears in any mine, coal or other, the same regulations (or some variant of them which has been agreed to by the Mines Inspectorate) shall apply to all mines. There is only one operating non-coal mine in the U.K. at present, a potash mine, which experiences operating problems due to methane emissions. In this mine the regulations in force to contain the methane hazard have been worked out by the mine management, and are a variation of the basic statutory regulations designed to meet the particular needs of the operation. These have been agreed to by the Health and Safety Executive (Mines Inspectorate) of the Department of Trade and Industry.

3.2.21 Yugoslavia

3.2.21.1 General

In November 1980 a meeting was held in Belgrade with mine ventilation experts at the Rudarski Institut, which is the body responsible for the formulation of mine safety regulations in Yugoslavia. The staff of the Institut were very cooperative and informative.

Historically, all the underground coal mines of Yugoslavia, and a number of non-coal mines, have experienced severe problems due to methane. Since 1965 three major disasters due to methane ignition have occurred, resulting in the loss, between them, of a total of 203 miners lives.* Although these disasters all occurred in coal mines, what makes them relevant is that all three occurred in mines low in "firedamp". We were told that, in fact, this was a contributing factor, in that the rate of "firedamp" formation was rated as very low, and thus strict controls which were supposedly in effect were not maintained in practice. Thus, in parts of the workings ventilation standards were not maintained, and we were told that in some so-called "low firedamp" mines, smoking, open lights, and the use of non-permissible explosives had been permitted. As a result of these disasters and the apparent carelessness which contributed to them, new classification systems were devised to regulate mine safety. Apparently one of the problems with the old classification system arose from the fact that the degree of firedamp hazard was defined, at least in part, by the potential which existed for firedamp formation in part or parts of a mine, based on the partial pressure of methane in the coal and its rate of

* Figures provided by the Rudarski Institut.

desorption*. This system did not take sufficient account of the effect of, among other things, interruptions or changes to the ventilation, changes in the character of the coal, and the possible effects of structural features.

The Rudarski Institut was responsible for the formulation of the new regulations, which include a system for classifying the firedamp hazard in coal mines. These regulations, which were brought into being between 1970 and 1975, include all mines except the rock salt mine, Tusanj, for which special regulations were devised, again by the staff of the Rudarski Institut.

The main reasons for the distinction made in applying gas hazard controls to the salt mine are that it is the only operating gassy mine in Yugoslavia that is not a coal mine, and it employs room and pillar mining whereas the dominant coal mining method now is longwall. Also, ventilation in this mine posed special technical problems due to the presence of hygroscopic host rock materials (marls) accompanied by high dry-bulb temperatures. Thus a set of regulations was devised for this mine which (as has been noted to be the case in most other countries we have studied) take into account the mining method, the commodity being mined, and the particular circumstances of the operation in general.

The Tusanj rock salt mine is exploiting a seam at an approximate depth of 400 m. During exploratory drilling, methane inflows were noted, so that the need for safety measures against flammable gas in the subsequent mining operation was anticipated. Methane is emitted into the mine more or less constantly in a steady state type of emission from the salt itself. Desorption tests performed on salt samples from the seam being mined have shown a methane content in the range $0.04 - 1.74 \text{ m}^3/\text{metric ton}$; no ignitions or blowouts have occurred in this mine. (The gas

* Rate of desorption is evidently still the basis of the Romanian classification system.

quantities computed from desorption tests on core have been confirmed by operating experience). During the design of the ventilation system, fresh air quantities required to safely dilute the methane in all parts of the mine were computed on the basis of measured gas flow and pressure in boreholes, as well as on the results of the desorption tests.

With regard to methane levels in the mine, the standards adopted were taken from the coal mining regulations. These require that the following methane levels are not to be exceeded:

- <0.5% in intake air being supplied to any room or working face

- <1.0% at working faces and in secondary returns

- <0.75% in the main return air

- <1.5% at any longwall tailgate

Portable methanometers are used to check the working faces and the ventilation return air streams at the beginning of every shift, and before and after every blast. These measurements are the responsibility of the mine ventilation section under the direction of the chief mine engineer, who in turn reports the data to the mines inspectorate. All diesel equipment at Tusanj is flameproof, all electrical equipment is explosion proof, and only methane-safe explosives are used.

At the time of our discussions in Belgrade new mine regulations were under discussion (for coal and fireclay mines as well as Tusanj) which would require continuous monitoring of methane. These were being held up for economic reasons, but will come into effect eventually. The existing regulations (and also reports on the disasters referred to earlier) are only available in the Serbo-Croat language. The Rudarski Institut has translated relevant sections of these and they are attached as Appendix XII.

With regard to the system for classifying methane hazard, mentioned earlier, which is included in the Yugoslavian coal mining regulations, three categories of what they call "firedamp hazard" are defined. Of these, Category I is assigned to areas of the lowest hazard level, and Category III to the highest. These categories also apply to mines other than coal, such as Tusanj, and different parts of a mine may be assigned different categories. Details of these categories are given in Appendix XII.

3.2.21.2 Summary

In Yugoslavia, the firedamp hazard in all mines is defined and regulated by the coal mining regulations. Three categories of firedamp hazard are defined, and these may be used to classify all or only part of a mine. Also, different categories may be assigned to different parts of a mine. There is one major non-coal mine operating under gassy classification in Yugoslavia at the present time. This is the Tusanj Rock Salt Mine for which special safety regulations have been formulated. These regulations, however, are designed to maintain safe firedamp concentrations as defined in the coal mining laws. No separate gas hazard classification system exists for non-coal mines in Yugoslavia.

European and South African Mine Visits

4.0

EUROPEAN AND SOUTH AFRICAN
MINE VISITSOctober/November, 1981

4.1 INTRODUCTION

A number of European and South African mine operators with experience of methane, and other gases, in metal/non-metal mines agreed to assist with the study. Accordingly, visits were arranged to operating gassy mines in five European countries, and in the Republic of South Africa. In all cases the intention was to compile the most detailed body of information possible about each individual mine. This entailed an examination of the type and mode of occurrence of the gas or gases; the degree of hazard created by the gas; the manner in which the operations are safeguarded; the technical and economic impact of the gas occurrences; the statutory safety requirements; and the ways in which mine managements and the official regulatory agencies interact in the various countries.

Although occasionally beset by communications problems due to language differences a substantial body of information has been obtained. Section 4 presents the results of these foreign mine visits.

4.2 AMELIE MINE, MULHOUSE, ALSACE, FRANCE

4.2.1 Introduction

On October 7, 1981, a visit was paid to the Amelie Mine, operated by Mines de Potasse d'Alsace, at Mulhouse, France. Several hours were spent underground, visiting the working faces and inspecting ventilation and automated gas-monitoring systems. The writer was escorted through the underground workings by M. Godefroy, the Mine Manager, and M. Bonte, of the Engineering Studies Division with Mines de Potasse d'Alsace in Mulhouse. The underground visit was followed by a meeting in M. Bonte's office in Mulhouse, at which the methane problem was discussed in detail.

Mulhouse is in the Haut-Rhin Department of France, some 30 km north of the Swiss city of Basel, and some 11 km east of the River Rhine, on the south-east flank of the Vosges. Amelie Mine is about 7 km west of the city of Mulhouse. Potasse d'Alsace operate two other potash mines in the area, both of which experience occurrences of methane gas.

Combined ore production from the three mines is approximately 50,000 metric tons/day. Amelie produces 16,000 tonnes/day with an overall productivity running at around 30 metric tons per man-shift. Until 10 years ago, Amelie was mined by room-and-pillar, which permitted a maximum panel productivity of 60 tonnes per man-shift. In order to improve this it would have been necessary to enhance the underground transportation system by purchasing larger LHD units. This in turn would have meant enlarging the roadways over considerable distances (some of the working faces are more than 10 km from the main hoisting shaft). This alternative was considered unacceptable for financial reasons. Accordingly, room-and-pillar was finally phased out 3 years ago in favor of longwall mining and conveyor transport (which could utilize existing roadways). Longwall shearers, each rated at 800 kw, are now operating on three 250-meter faces.

These shearers are capable of mining a seam up to 3.6 meters thick; as a result, panel productivity is now 100 metric tons per man-shift.

4.2.2 Geology and the Gas Problem

The geological environment is that of a typical evaporite deposit. The basin in which Amelie Mine is situated contains some 20 km² of rock salt, with two main seams of sylvite at approximately 900 m depth below the surface. These seams of sylvite are on average 25 m apart, and 2.5 to 3.5 m in thickness. Anhydrites and shale stringers intersperse the salt and the sylvite more or less uniformly.

The sylvite seams themselves are very uniform in thickness and grade; the upper seam averages about 20-25 percent K₂O, and the lower 15-20 percent K₂O. Both seams are being mined by retreat longwalling. Rock temperatures in the longwall panels are high, in the range 42-55 degrees Celsius.

Methane is continuously present in this mine at relatively high concentrations, average levels typically being in the range 0.7 - 0.8 percent of the mine air at the downstream end of a working face. Methane is present in both the salt and the sylvite, and these gas levels are a result of steady emissions, most of which emanate from the caved and caving material behind the longwall machines. In addition, however, violent blowouts have occurred, causing inundation of parts of the mine with methane. These blowouts have on occasion released as much as 30,000 m³ of CH₄ into the workings in as short a period as 10 seconds, sufficient to overwhelm the ventilation and cause a temporary reversal of flow. The dominant gas in both continuous emissions and violent outbursts is methane, although other hydrocarbons are occasionally seen. The writer was told that the source of the gas was not well understood, particularly the outbursts, and that no set

of conditions which would permit these to be predicted has so far been identified.

4.2.3 Safety Measures

4.2.3.1 Statutory Requirements

In France there is no system of classifying gassy mines and the only laws which apply to flammable gases in mines are those designed for the coal mines. Thus, in non-coal mines permissible levels of flammable and other dangerous gases are defined by statute, but specific safety regulations are not laid down.

The government regulation for non-coal mines has a chapter which says "Mines with a special risk such as flammable or noxious gas, rockbursts or gas outbursts..., must have special regulations. These regulations will be edicted by the Head of the Department after approval of the government."

At Amelie Mine two sets of general mining regulations apply; those of the French Government and those of the Department of Haut-Rhin. The actual enforcing agency is the French Bureau of Mines, which is responsible for mines inspection, and for the approval of any proposed safety procedures.

4.2.3.2 Safety Measures at Amelie

The local and detailed safety regulations which are in effect as a result of application of the government rules at Amelie Mine were devised by the mine operators, but required the signed approval of the French Bureau of Mines before they could be put into effect. With this approval, the regulations became law. The writer was told that the labor unions are represented when decisions affecting safety are being made, and that in general the unions, which are very strong, cooperate in safety matters.

This mine experiences levels of methane at all times during its normal operations which would be considered dangerous by any country's standards. (For example, during the writer's visit underground, continuous monitoring units just downstream in the main returns from the three longwall faces were showing steady readings of 0.8% CH₄.) Therefore the safeguards are elaborate.

The ventilation system is designed as a negative-pressure system, with 3 main axial-flow fans situated underground at the bottom of the main up-cast shafts. The overall ventilation capacity is 400 m³/sec, which is rather high for a mine of this size (400 m³/sec approximately equals 847,000 cfm). The ventilation capacity was designed more to meet the problem of high rock temperatures than to dilute the methane. The actual network, however, was designed to dilute gas with the maximum effect (rock temperatures at the longwall faces are consistently in the range 42-55 degrees Celsius, creating a major climate control problem). Fans of sufficient horsepower to move the required quantity of air create a temperature increase of 4-5 degrees Celsius in the air exhausting from the fan. For this reason, a forced-air ventilation system would be undesirable in a mine with climate problems of this order. Also, a negative-pressure system tends to inhibit gas build up if a main fan goes down, because the pressure of the mine atmosphere will then tend to rise, to some extent counter-acting gas emission from the formation. All fans are flameproof, and the three main fans are independent of the main mine grid, so as to keep running when all other electrical equipment in the mine automatically trips out.

The methanometry at Amelie is automated. Continuously monitoring methanometers give strip-chart read-out of methane in the air in the main returns from longwall faces, and in the up-cast shaft(s). The strip-chart recorders are located in the main engineering office on the surface; each sensor read-out unit is fitted with a meter which shows the level of CH₄ as a percentage by volume of the air passing over the sensor, so that it may be

directly read. These units, which are flameproof, are tied into the main mine electrical grid, and are set to trigger safety switches and alarms when methane levels reach 2 percent. At 2 percent CH_4 , all electrical equipment in the mine is automatically shut down, including the methanometers themselves. Only the three main fans continue running, and one remotely-read methanometer in the exhausting air in the main up-cast shaft. The writer was informed that the methanometers currently in use throughout the mine are being phased out in favor of smaller, intrinsically safe units. The methanometers continuously monitoring the working panels are located at the highest points available, downstream in the returns from the longwall faces.

Safety enforcement is rigorous; all equipment throughout the mine, including fans, motors, diesels, circuits and switching gear, is permissible. The men are checked at the cage before going underground and are not allowed to take any flame or spark-producing device into the mine. Even battery-operated wrist watches are forbidden. Repair of equipment, and any spark or flame-producing activity such as welding, is only permitted in designated areas, in fresh air districts.

Certain equipment operators and blasters require licenses in order to perform their duties. These licenses are not a certification system such as that in effect in countries of the British Commonwealth and South Africa. They do not, therefore, automatically carry with them certain legal responsibilities but are meant to ensure that persons who perform certain specified tasks are competent to do so. In short, licenses are issued by employers, and indicate competence, but they are not a statutory requirement (there is no statutory certification of mining personnel in France).

All explosives used in the mine are of the permissible type. Blasting is only used during development work, but is being phased out in favor of using continuous miners. All haulage ways

are mined in the rock salt because it provides better mining and ground conditions than the ore seams do. Under-cut, drilling and blasting is used in mining the haulage ways, and in developing galleries. A modified coal cutter is used to under-cut the face which is then drilled and blasted. The average pull per round is 2.5 meters. At the time of the writer's visit to Amelie the mine owned four continuous miners, and three more of these machines were on order. (The writer has since been informed by the mine operators that two more mining machines have been ordered and are expected to be in service before the end of 1982.)

The only diesel-powered units in use underground at Amelie are man-haulage and maintenance vehicles, all of which are equipped with flameproof engines. The mining machines are coal-mining type continuous miners, which are routinely produced in flame-proof form, but those in service at Amelie have specially reinforced shearers and more powerful engines than the standard models, to deal with the hard rock.

4.2.3.3 Impact on the Mining Operation

The main impact of the gas problem is in the area of operating costs. The cost of operating and maintaining permissible equipment at Amelie is approximately three times that of standard equipment. The purchase price of permissible equipment is about 20% more than that of standard equipment. In addition, special repair shops are maintained because welding is forbidden and specialized workers are employed in maintenance and inspection roles. Maintenance of the methane monitoring system is a significant cost.

It was deemed necessary to use permissible equipment throughout the mine because of the danger of violent outbursts. These have occurred with sufficient force to inundate the ventilation throughout extensive sections of the mine. Historically, they

have proved to be unpredictable and random, so that no part of the mine may be considered safe from their effects.

The ventilation system at Amelie was designed to deal with very high rock temperatures and thus serves a climate-control as well as a ventilation function. For this reason the ventilation has capacity which is more than adequate to safely dilute the methane which is ordinarily present in the mine. To design a ventilation system capable of preventing the occasional inundations due to violent outbursts would be impracticable, and would at best result in an over-designed system. Because of the methane problem, however, the ventilation network is more rigorously designed than it would otherwise need to be. This has injected an additional real cost into the operation, but compared to the maintenance and capital cost associated with permissible diesels it is not considered significant.

4.2.4 Summary

At Amelie mine, methane is continuously present in the workings in potentially dangerous concentrations, due to the steady emission of gas from the formation. Occasional violent outbursts of gas and rock also occur, releasing large volumes of methane with explosive force such that the ventilation flow may be temporarily reversed and large areas of the mine are inundated with gas. No set of conditions which would permit these events to be predicted has so far been identified; the reasons for their occurrence are not well understood.

No classification system exists with respect to flammable gases in non-coal mines in France. At Amelie the rigorous safety measures which are in effect are based upon special government rules edicted by the Department of Haut-Rhin and approved by the Bureau des Mines. The local and specific safety measures taken in the application of these rules were devised by the mine operators, in consultation with the concerned labor unions. To become

legally binding, and before the mine could operate under these or any other safety measures proposed, the written approval of the French Bureau of Mines had to be obtained.

The higher costs associated with the purchase and maintenance of permissible equipment have been largely offset by increasing productivity. This has been achieved by a transition from room-and-pillar to longwall mining, phased in over a seven-year period, and by a reduced dependence on blasting brought about by the increased use of mining machines in development work.

4.3 KALIWERK HATTORF PHILLIPSTHAL, WEST GERMANY

4.3.1 Introduction

On October 12, 1981, a visit was made to the Hattorf Works of Kali und Salz AG, at Phillipsthal, West Germany. Kali und Salz operate an underground mine there (Kaliwerk Hattorf) which experiences serious problems due to carbon dioxide (there are no gassy mines, other than coal mines, experiencing methane occurrences in West Germany. Several potash mines, however, experience serious gas problems due to CO_2 and N_2).

A morning meeting was held with the Chief Mine Engineer, M. Boning, followed by a tour of the underground workings, which included an inspection of the site of a very recent violent outburst. This was followed by a visit to the central control room to observe shift-end blasting being carried out. A further discussion with Mr. Boning was held in the afternoon when he answered specific questions about safety matters and how they affected the operation of the mine.

Although Kaliwerk Hattorf does not experience methane gas occurrences, the problems encountered at this mine with CO_2 and the steps taken to safeguard the men and equipment are of great interest to the study. This is because there is a good deal of similarity in the ways in which violent outbursts of CO_2 and CH_4 occur, and in the counter-measures required to provide a safeguard against these events. There are marked similarities between the CO_2 occurrences at Kaliwerk Hattorf and the CH_4 occurrences at Klodawa, in Poland (13).

Kaliwerk Hattorf is a potash mine which recovers both sylvite and carnallite, with carnallite grade averaging 15% K_2O , and sylvite grade averaging 10-11% K_2O . Mine production is approximately 26,000 metric tons/day, with productivity averaging 80 metric

tons/man-shift. Mining method is room-and-pillar, and the extraction ratio averages 50-60 percent, depending on grade. Underground transport of ore is by conveyor belt, of which there are 26 km.

The potash seams being exploited are in the so-called Kali-Werra district which lies astride the border between East and West Germany, in the valley of the River Werra. The River Werra rises in the Thuringen Wald of East Germany, crosses into West Germany at Phillipsthal, and enters the River Weser at Munden.

4.3.2 Geology and the Gas Problem

There are two seams of potash containing both carnallite and sylvite ($\text{KMgCl}_3 \cdot 6\text{H}_2\text{O}$ and KCl), each of which is exploited commercially. The potash seams are overlain by sandstones. During the Permian era the evaporites containing the potash seams were intruded by volcanics, forming dikes which intersect the orebody at regular intervals (~ 600 m apart). These volcanics are the source of the gas.

Two types of gas occurrence are common; free emissions, and violent outbursts of explosive force. The free emissions are not considered dangerous because they are generally low-volume affairs and they do not eject large amounts of solid material. The violent outbursts are extremely dangerous, on the other hand, because they happen with extreme rapidity and usually eject large volumes (≤ 800 metric tons) of highly fragmented material. This may be distributed through the working areas for a considerable distance and those parts of the mine in the vicinity of the outburst may be completely inundated with gas.

The low-volume emissions usually occur during exploratory drilling, the purpose of which is to locate volcanic dikes. These gas emissions usually result from the drill-hole intersecting gas-filled cracks, allowing the free gas to escape along the bore-

hole. The violent outbursts usually occur in areas close to the volcanic dikes. The underlying purpose of the exploratory holes is therefore to give warning when the mine workings are about to enter an area known to be outburst-prone (i.e., the vicinity of a dike). Unfortunately however, outbursts have frequently occurred in areas far from the intrusives so that proximity to, or distance from a dike, does not provide a reliable basis for assessing the probability of their occurrence. In fact, in this mine no effective way of predicting outbursts has been devised. Operating safety procedures are therefore enforced on the assumption that an outburst could occur at any time during certain routine operations. These precautions apply in particular to all drilling operations, and to blasting.

The violent outbursts of gas at Kaliwerk Hattorf are essentially a rock mechanics phenomenon. There is no free gas under pressure involved. Rather, the gas is thought to be adsorbed on to the crystal surfaces of the salt in very large volumes (up to 90% of the total). The remaining 10% is thought to be contained interstitially within the crystal lattice (13). When the approach of mining activity alters the stress field in the vicinity of a zone which is saturated with gas in this way, a shear stress may develop in the direction of the free surface. Cracking results, permitting the mobilization of the potential energy of the gas. A high-speed salt/gas stream forms, splintered salt being ejected by pneumatic force such that a cavity develops at an extremely rapid rate. A chain reaction is initiated whereby an increasing volume of gas escapes as the free surface inside the cavity grows. The speed of propagation of the cavity may be as high as 3m/sec creating an opening with final dimensions of 30 or more meters in depth and up to 10 meters wide. These cavities may be contorted in their final form. For a more detailed description of violent outburst phenomena, the reader is referred to Appendix XIII.

4.3.3 Safety Measures

4.3.3.1 Statutory Requirements

In West Germany there is no system of classifying metal/non-metal mines with respect to gassiness. Although the mining regulations define permissible levels for various gases in mines, actual operating safeguards against gases are not specified by statute. Therefore in non-coal mines safety regulations are devised on a mine-by-mine basis.

Legal responsibility for safety matters is defined by statute and certain key personnel are certified by the Mines Inspectorate. For example, blasters are required to hold mines inspectorate certification, and only those possessing such certification are permitted to even purchase explosives (usually the mine manager has such certification; explosives may be accepted on delivery by non-certified persons). Legal responsibility for safety begins at the face, but the mining company, through the mine manager, is responsible for the training of all operators in safety matters.

4.3.3.2 Safety at Kaliwerk Hattorf

The mining method at Kaliwerk Hattorf is room-and-pillar/drilling and blasting. The blasting is by burn-cut, with an average advance of 7 meters; the blasting agent used is ANFO. The violent gas outbursts usually occur either immediately after blasting as a secondary blast, or during face-drilling in preparation for blasting. Therefore special procedures are followed in carrying out these particular operations.

Kali und Salz, who operate Kaliwerk Hattorf, operate 8 potash mines and one rock salt mine in West Germany. Of these mines, at least three experience severe gas problems. In the non-gassy mines the shot-holes drilled in the center of the burn are 420 mm

in diameter. At Kaliwerk Hattorf the maximum hole diameter permitted in the center of the burn is 280 mm. Holes of larger diameter than this can cause changes in the local stress field sufficient to initiate cracking and splintering of the kind known to be associated with high-speed gas liberation and the occurrence of violent outbursts. Two large-diameter holes are usually drilled at the center of the burn, and these are drilled by remote control, using auger bits. A two-drill jumbo is positioned at the face but does not commence drilling until the drill crew have left the area. The machine can be shut-off or restarted remotely from a safe control room where the drill crew wait while drilling is actually in progress. The rig is equipped with a limit switch which enables it to withdraw the augers from the holes when it has drilled to a pre-determined depth, and then shut itself off. This activity is monitored in the control room. During the drilling of the large-diameter center burn holes, signs are posted to warn people not to enter the area where the drilling is in progress, (See Appendix V).

In addition to being able to remotely control and monitor the drill-rig, the crew can also monitor gas levels in the heading from the control room (this information is also transmitted automatically to a control room on the surface). The level of CO_2 is not monitored directly; rather, oxygen levels are continuously monitored in all the headings. Flame safety lamps placed at strategic locations in the working places and electronic oxygen monitors are both used to send an alarm signal to the surface control room. The lamps are remotely monitored by using the heat from the flame to balance a known resistance in a bridge circuit. Thus if a lamp goes out a green light goes out on the control panel at the surface and is replaced by a red one.

Because these lamps may occasionally go out for reasons other than the presence of CO_2 , e.g., concussion from blasting, they are not, in themselves, considered to be 100% reliable as gas indicators when remotely stationed and read in this manner. The

fans each have capacities of $4,000 \text{ m}^3/\text{min}$ ($\approx 141,160 \text{ cfm}$). There is one back-up main fan on the surface, at the top of the upcast airshaft. Under normal conditions only the main fan underground is operating.

4.3.4 Summary

Kaliwerk Hattorf is a good example of the approach typically used in West Germany to deal with a gas problem in a non-coal mine. Although the gas causing the safety problem is CO_2 its' mode of occurrence and the way in which it impacts the mining operation show many similarities to the occurrences of CH_4 at Klodawa, Poland (I3).

In fact, the history of mining experience in the salt deposits of northern Europe shows that violent blowouts of methane, nitrogen, and carbon dioxide are all fairly common, sometimes in the same mine, as at Klodawa. Appendix XIII contains a description of the gas blowout phenomena associated with this region; this has been translated from an East German source, and was given to the writer by the mine engineering staff at Kaliwerk Hattorf. Because of the nature of these occurrences remedial measures often show many similarities, irrespective of the gas type. At Kaliwerk Hattorf safety procedures were formulated by the mine operators and labor union representatives. These procedures were then submitted to the Mines Inspectorate for approval before being finally adopted. This approach seems to be the norm in West German non-coal mines; although permissible concentrations of gas in the mine atmosphere are defined by statute, actual procedures, equipment types, and mining methods are not. Appendix V is a translation of some of the operating procedures which are in effect at Kaliwerk Hattorf at the present time.

system is, however, inexpensive and by complementing the oxygen monitor network becomes a component in a very reliable system. The third component in the gas detection network is audio. Microphones are placed in all headings and are connected to the surface control room. These are used to listen for violent outbursts and/or blowers of gas during face drilling and immediately after blasting.

All blasting is done from the surface at the end of each shift. There are certain exceptions to this, but in these cases extraordinary rules apply (see Appendix V). All personnel are withdrawn from the mine, and after this has been confirmed the round(s) are fired from the central control room on the surface (see Appendix V). This is the responsibility of the Blasting Engineer. The blast is followed by a waiting period of 45 minutes during which CO₂ levels are monitored before anyone is permitted to re-enter the mine.

In the event that gas is detected, either following a blast, or during the regular course of a shift, strict rules mandate the sequence of precautions that go into immediate effect (see Appendix V, Section E). Accumulations of gas are purged into the main ventilation return air by the use of portable auxiliary fans, of which the mine has several hundred. These are skid-mounted, relatively small fans which can be positioned quickly and easily to deal with local gas accumulations. A major advantage of these movable fans is that they are not, during non-use, exposed to damage from violent gas outbursts in the same way that permanently installed auxiliary fans would be (the explosive force of these occurrences is capable of severely damaging mine equipment).

The ventilation system consists of one main fan underground, one main booster fan, and ten smaller booster fans. The main fan capacity is 25,000 m³/min (~882,250 cfm), that of the main booster fan 10,000 m³/min (~352,900 cfm), and the smaller booster

4.4 POTASH MINE, SPAIN

4.4.1 Introduction

On October 15, 1981, a visit was made to a large underground potash mine in the province of Navarra, Spain, and a meeting took place between the writer and members of the engineering staff. This mine has been experiencing methane inflows since development work began in 1961, and is officially classified as a gassy mine. Carnallite and sylvite are both exploited by longwalling; production averages 10,000 metric tons per day, and a total of approximately 1000 men are employed underground, including all maintenance and mining personnel. Eight longwall faces are being worked, but actual productivity figures were not available. The writer was told, however, that this is a "difficult mine" owing to variations in seam thickness and in the dip of the orebody. Productivity here is probably lower than in the longwall potash operations in Alsace, France.

4.4.2 Geology and the Gas Problem

The geology is that of a typical evaporite deposit which has undergone some tilting and folding corresponding in time to tectonic activity in the Pyrenees Mountains, which are nearby. Eight seams of carnallite, each averaging 0.5 - 1.0 meter in thickness, and one sylvite seam, averaging 2.0 - 2.5 meters in thickness, are being exploited. The sylvite was laid down first in the depositional sequence, and is separated from the bottom of the carnallite sequence by a band of rock salt mixed with marls. The carnallite seams are separated by thinly bedded salt with marl stringers, and are overlain by about 120 meters of the same material. Above the salt and marl the overburden consists primarily of sandstone. Below the sylvite there is a band of compacted rock salt which varies in thickness from 1 - 25 meters. Beneath this lie marls which are the source of the methane in the

mine. The gas is generally found in salt near these marls, usually during road building.

The generally accepted theory is that solidification of the marls which contain organic gas-bearing materials has caused gas to migrate into the salt. The gas usually occurs as blowers during drilling, which suggests that free gas under pressure is trapped in cracks and fissures within the salt rather than adsorbed within microscopic intercrystalline spaces. The gas encountered is dominantly composed of CH_4 , but often contains significant amounts of H_2 . Some blowers have released extremely large volumes of gas into the mine. The most serious of these occurred in 1978 when the mine ventilation was overwhelmed and the workings were inundated for three days before the gas flow ceased. Typically, though, the emissions are small events of short duration, giving readings of CH_4 of one or two percent at the emission point, with no measurable CH_4 at points a few meters away. It is noteworthy that even though, historically, gas has been encountered in this mine throughout its' life, it was not officially classified as a gassy mine until the large volume blower occurred in 1978.

4.4.3 Safety Measures

4.4.3.1 Statutory Requirements

In Spain mines (and in fact, all underground excavations) are classified with respect to gassiness. Four categories of gassiness are defined, ranging from Category I (no detectable methane) to Category IV (prone to violent outbursts of gas and rock). These classifications apply to coal and non-coal mines alike, and are outlined in detail in Appendix X (see Article 54). To a degree, each category of gassiness carries with it a set of regulations, but these apply for the most part to gas monitoring and reporting requirements rather than mandating mine operating procedures and equipment types. Standards are set for the

education and information of personnel concerning the risks associated with methane, and for the provision of first aid and rescue equipment and the training of teams in its' use. Such things as the use (in non-coal mines) of flameproof equipment, and modifications to ventilation and mining methods are not specifically addressed by statute, but air quality standards are defined.

Records of gas occurrences and all data concerning gas levels have to be reported regularly to the Spanish Government Department of Mines in Madrid, which is the ultimate enforcement authority. However, the Province of Navarra is responsible for mine inspection, and safety enforcement at the mine (mines inspection is normally a provincial responsibility in Spain).

4.4.3.2 Safety Measures in Effect

Special safety regulations were devised for this mine; it is the only gassy potash mine in Spain, and the only gassy mine in the Province of Navarra. There was consequently no precedent from which to derive guidelines, and it was the mine operators, working with the Provincial authorities, who devised the safety regulations which are now in effect.

Gas had been detected in this mine right from the beginning, but only in very small concentrations so that apart from regularly checking for gas no special precautions were in effect. After the 1978 inundation occurred however, the mine was officially designated a Category II gassy mine and rather stringent safety measures went into effect.

In matters pertaining to safety the miners have a representative who participates directly in all decision-making by mine management. This man cannot independently take direct action in the mine but can, without consulting his own management, make recommendations to the Mines Inspectorate. There is also a mine

safety committee composed entirely of miners who can demand a study of any matter affecting safety, and who can also demand that the Mines Inspectorate be represented on this study.

Because of the danger of sudden unpredictable inundation, all equipment used underground is permissible. The ventilation was initially designed to dilute possibly dangerous concentrations of CH_4 because of the fact that gas has always been detectable under certain conditions.

The main fans are underground, designed to provide a minimum of 40 liters of air per second for every man underground. The ventilation system has a designed capacity sufficient to dilute CH_4 to a maintained concentration of less than 0.8% of the main return air current by volume (this would be in the event of local inundation within a development heading or longwall panel).

The ventilation is an exhausting system, with 1 upcast and 5 downcast shafts. The main collector fans are at the foot of the upcast shaft; there are three main fans, at least one of which, and usually 2, are in reserve. There are 2 booster fans servicing each of the two main groups of longwall faces. No personnel are allowed to work in any return air, and all return airways are inclined upwards (the permitted gradients on these are not available). The system is designed to dilute gas to 1.5% CH_4 in the auxiliary returns in the event of a gas occurrence. If no electrical equipment is present, 2.5% CH_4 is allowable in closed headings, but no personnel are permitted to enter such an area under these conditions.

In all main roadways the minimum permitted air flow rate is 0.25 m/sec, and in all closed headings wherein personnel are working the minimum permissible fresh air volumes and flow rates are 5 m³/sec and 0.25 m/sec respectively.

When manual methanometry is used permissible maximum levels of methane under which work may proceed are:

- 1% at a longwall face, downstream (at the tailgate)
- 1% in the main return air

(Spanish government statutes do not require shutdown of electrical equipment until CH_4 levels reach 1.5%). Where methanometry is by permanently installed, fixed methanometers, these maximum permissible levels become:

- 1% in the main return
- 1.5% at a longwall face, downstream (longwall tailgate)
- 2.0% in a secondary (bleeder) return

(At the time of the visit, no fixed methanometers were actually in use at this mine).

When methane concentration reaches these levels all equipment is shutdown; personnel may remain in the mine, but if CH_4 concentrations exceed these levels in any of the locations, personnel are immediately withdrawn to the surface.

Blasting is used very little (mainly during development work) but the explosives that are used are permissible. Blasting is used mainly in the construction of raises, chutes, and ore passes, and occasionally to induce caving behind longwall machines. Actual numbers were not obtained, but we were told that only "very small amounts" of explosives are used.

The only diesel equipment used underground is for the transport of maintenance crews and parts for equipment. Thus, only small jeeps and trucks are in use underground; these diesels are flameproof. Man transport to the working places is by chairlift.

Methane readings are taken at the start of every shift in all work places, and once every hour throughout the shift. Readings are taken at the faces, in the roadways, and in all development headings, according to a specified procedure, details of which unfortunately were not made clear because of communications difficulties. Essentially, however, locations for the taking of readings relative to faces, roofs, borehole collars, etc., are specified. These readings are sent to the surface and logged hourly. All foremen carry methanometers, and it is the foremen who are responsible for taking and reporting the readings. Miners and equipment operators do not normally carry methanometers. A record of all CH₄ readings has to be kept for the Spanish Government Department of Mines in Madrid (although the actual inspection of the mine is the responsibility of the Province of Navarra).

Exploratory drill holes are put in ahead of road-making operations in areas where gas is deemed likely to be present (i.e., in salt adjacent to the marls and in disturbed zones near the marls). The road-making is done with Joy continuous mining machines and in potentially gassy zones drill holes are maintained a minimum 2 - 3 meters ahead of these machines at all times.

4.4.3.3 Impact of the Mining Operation

This mine was known to have the potential to be gassy right from start-up, therefore rigorous methane checks were always carried out as a matter of routine. Because of the known gas potential the ventilation too, was designed to have more capacity than would ordinarily have been deemed necessary. Therefore the imposition of the Category II gassy classification in 1978 did not significantly impact staffing or ventilation. The main effect was felt in the area of changing over to the 100% use of permissible equipment underground, the increased use of continuous miners in road-making, and the corresponding reduction in the use of explosives. The operators told the writer that this had

approximately doubled their total equipment purchasing, maintenance, and operating costs.

Some modest cost increases have resulted from the need to drill exploratory boreholes ahead of development works, and the use of permissible explosives, but the operators do not regard these as significant.

4.4.4 Summary

Methane gas has historically been present in trace amounts in the underground ever since the start-up of the mine. Therefore some precautions, especially gas monitoring, have always been in effect. Low volume emissions from boreholes have given readings close to the points of emission as high as 2% CH₄, but a few meters away no CH₄ would usually be detectable. Even so, electrical equipment in the area would be shut down until the gas flow ceased. One large volume emission in 1978 inundated the mine with CH₄ and caused it to be reclassified as a gassy mine, Category II. The safeguards now in effect are largely an enhancement of measures which were being taken prior to this event, with the one exception of the introduction of flameproof, permissible equipment throughout the mine. Methane monitoring and reporting requirements have been up-graded, as has been the education and representation of miners in safety matters. No precedent existed from which to draw safety guidelines as this is the only gassy potash mine in Spain. The mine operators themselves therefore, in consultation with the Province of Navarra Mines Inspectorate, designed and proposed the safety procedures now in effect. When these were approved in writing by the Provincial Delegation they became law.

4.5 BOULBY MINE, CLEVELAND POTASH LTD. CLEVELAND, ENGLAND

4.5.1 Introduction

On October 22, 1981 a visit was made to Boulby Mine, and a long meeting was held with the Ventilation Engineer, Mr. G. Robinson, who was very informative. Boulby Mine is operated by Cleveland Potash Ltd., and is situated in the County of Cleveland just south of the town of Guisborough. The mine lies within the boundary of a National Park, and within two miles of the ocean, and therefore has had to meet exacting environmental impact criteria. It has, throughout its life, experienced severe technical problems of climate control, rock mechanics, and flammable gas outbursts, and has been the subject of numerous studies.

Boulby Mine produces potash from a sylvite seam approximately 3600' below the surface. Only one seam, which varies in thickness from one up to twenty meters, is being exploited. The mining method is room-and-pillar, using continuous miners, with ore transport by conveyors. The seam being exploited is not amenable to longwall mining because of the danger of consequent subsidence disturbing water-bearing sandstone overlying the workings, and the unacceptable dilution that would be caused by the extreme variations in the thickness of the seam (this was described as resembling a "lumpy quilt").

4.5.2 Geology and the Gas Problem

The evaporites, which include the sylvite being exploited, as well as salt, anhydrite, dolomites, and carnallite marls, are Permian. These are overlain by mudstone, sandstone, and more marls, in this order, of Triassic age. Above these lie shales, ironstone, and clays of the Jurassic. The sandstone, known as Bunter Sandstone, is approximately 900' thick and heavily water-bearing. The carnallite marl, which appears in the roof beds of

the potash seam, is very hygroscopic and "weathers" rapidly whenever it is exposed. This has caused some severe stability problems in permanent roadways which unavoidably intersect the roof marl. The K_2O grade in the sylvite varies from 17% up to 75%; the carnallite is barren.

Gas was first noted in this area of England in 1952, in ironstone mines (now closed down) close to the site of Boulby Mine (25) (26). At Boulby gas was first noted in exploratory boreholes, and was encountered in the upper dolomite layer during the sinking of the Number 1 Shaft (this is the rock shaft). The gas has some features typical of gas originating in oil-bearing shales, and differs from that commonly encountered in coal mines in that it often contains nitrogen and higher hydrocarbons as well as methane.

The source of the gas at Boulby is not known with certainty but is thought to be the magnesium limestone (dolomite) which has been a target for gas exploration in the area, and which, offshore, is a source of North Sea natural gas. These dolomites underlie the orebody and are occasionally encountered during mining in disturbed zones. Gas is also thought to originate in coal measures beneath the limestone, and some gas may have been generated during the deposition of the potash seam itself. The gas detected in the mine usually has a significant nitrogen content, sometimes as high as 80% (25). The hydrocarbon content of the gas encountered in the seam is usually composed of about 50% CH_4 , 25% ethane, and 25% other hydrocarbons. The gas found in the magnesium limestone usually has a hydrocarbon content of about 90% methane and 10% higher hydrocarbons, including ethane (C_2H_6).

The gas occurrences at Boulby are in the form of violent outbursts, some of which have been large-scale, releasing large volumes of gas causing local inundations. In one such event the operator of a mining machine was killed, and the machine and its'

attendant shuttlecar were severely damaged. No ignitions have occurred however.

During the early life of the mine, when gas had been seen during shaft-sinking and occasionally encountered in boreholes but no blowouts had occurred, no flame-proof equipment was in use at Boulby. Gas checks were carried out regularly, however, as a matter of routine. Because no flameproof equipment was in use the mine manager at that time designated 0.2% as the concentration of CH_4 at which all equipment would be shut down. When violent outbursts began to occur flameproof equipment was introduced, but only after some study and negotiation with the Mines Inspectorate was agreement finally reached regarding the category of flameproof equipment to be used, and the extent to which it would be used.

Gas outbursts at Boulby at first appeared to be totally unpredictable and occurred at very irregular intervals. The only factor common to all these occurrences was noticed to be the presence of black shale (25). Shale stringers are seen in the potash in disturbed zones and/or areas containing lower grade ore. Tests have shown that where the shale content reaches 9% or more of the seam content, CH_4 is usually encountered. (The figure of 9% is an average from studies performed on ore samples at Nottingham University and at the Royal School of Mines. The mine geologists conduct surveys daily by taking samples from the drill cuttings, muck piles, and production lines). Experience has shown that zones of higher shale content are likely to be gas-bearing, with gas adsorbed within the crystalline structure of the seam. In undisturbed ground the gas is in equilibrium with the surrounding strata, but when a heading approaches such a zone equilibrium is lost as the local stress field becomes destabilized (25). The resultant propagation of microfractures permits the potential energy of the gas to mobilize in the direction of the free surface, resulting in a chain reaction type of high speed desorption. An extremely high-energy pneumatic

stream of gas and rock fragments is formed, causing large volumes of gas and rock to be ejected into the heading with explosive force. It is thought that free gas under pressure may form within the seam immediately prior to the occurrence of a blowout. Because of its' fissile character the shale develops micro-fractures before the seam rock, thus releasing free gas which eventually develops pressure sufficient to overcome the strength of the containing rock as the heading advances (25). At this point the explosive event described above is initiated.

Roof blowouts during roadmaking and development work have on occasion led to major support problems by exposing hygroscopic, degenerative carnallite marl. These areas are supported by steel sets and shotcrete impregnated with wood shavings.

4.5.3 Safety Measures

4.5.3.1 Statutory Requirements

In the United Kingdom mines such as Boulby come under the general regulations applying to Miscellaneous Mines. These regulations do not classify mines with respect to gassiness, and therefore do not stipulate conditions under which mines will use flameproof equipment or permissible explosives. This, and the allocation of responsibility for safety is at the discretion of the Mines Inspector, who operates under the Health and Safety Executive of the Department of Trade and Industry.

The statutes refer to flammable gas in a very general way, stating only that in any part of an underground mine in which flammable gas "may occur in a quantity sufficient to indicate danger, no electrical apparatus shall be used other than apparatus approved. . . for use in such conditions" (27). Danger levels of flammable gases are not specifically defined in the Miscellaneous Mines Regulations; those used are the ones devised for Coal Mines. Reporting requirements are spelled out in a sec-

tion on "Notification of Dangerous Occurrences", which includes any inrush of noxious or flammable gas. The regulations state that shot-firers have to be "competent" persons, appointed by the mine manager, and may not be less than 21 years old. Only permitted explosives may be used in any mine, "in any part of which the use of other than permitted lights is unlawful" (27). The UK Coal Mine Regulations require that mine managers, and specified engineers, foremen, equipment operators, shot-firers, and miners, have to hold legal certification in order to do their jobs. Under Miscellaneous Mine regulations this is not the case; mine managers are not legally required to be trained mining engineers, but are responsible for seeing that the people who perform certain critical tasks (mining and hoisting equipment operators, blasters, ventilation and safety officers, for example) are competent to do so. In practice the Coal Mining Regulations, which set out criteria for the determination of competence, are used as a basis for appointing people to these duties (the first general manager at Boulby was a chemical engineer).

The regulations grant the Chief Inspector of Mines the discretionary power to grant exceptions to part or all of the regulations in cases where individual circumstances warrant such exceptions. In a section dealing with precautions against the inrush of liquid and gas, operating procedures are rigorously defined with respect to the permitted dimensions of development works, and the requirement to maintain exploratory holes in the roof and floor, and similar holes of specified length ahead of the advancing face (27).

"Approved" equipment and explosives referred to in these regulations are defined and listed in a separate publication from the Department of Trade and Industry.

4.5.3.2 Safety at Boulby Mine

The regulations in effect at Boulby were devised using the Coal Mine Regulations as a basis for setting hazard threshold values for gas concentration (see Appendix XI) and for selecting equipment. Operating procedures, and the degree to which permissible equipment has been introduced, are a function of experience in the mine and agreement between the operators and the Inspectorate.

4.5.3.2.1 Equipment

Class I flameproof equipment is in use at Boulby; this is, under British standards, the lowest flameproof category. Originally the Mines Inspectorate had pressed for the use of Class II equipment on the ground that ethane and other higher hydrocarbons such as pentane are constituents in the mine gas. Class II equipment is designed to operate in the presence of these gases. The mine operators successfully argued against the Class II equipment because the higher hydrocarbons are only occasionally seen, and because the costs involved would have made the operation questionable in economic terms. The fact that no ignitions have occurred in the mine would appear to vindicate the operators' position.

All electrical equipment (flameproof) is in fresh air; the only exceptions to this are the unattended flameproof motors on the ore conveyor belts. All diesels are fitted with flame traps on the air intakes and exhausts. On the exhaust system a conditioner box (which is essentially a water trap) takes out soluble nitrous fumes and cools the exhaust gases. (This arrangement also reduces the effective horsepower of the unit by some 15%.)

4.5.3.2.2 Ventilation & Mine Layout

Essentially the mine is on a forced ventilation system, with two main fans passing a combined airflow of 330 m³/sec (700,000 cfm). An emergency main fan is kept in reserve at the head of the upcast (No. 1) shaft.

The ventilation system was originally designed to deal with high rock temperatures and dust rather than gas; virgin rock temperature (VRT) at seam depth is 42°C, with approximate humidity at 40% (28). No significant changes have been made to the ventilation capacity or circulation to deal with gas, but changes are planned for the summer of 1982. These changes are being planned to improve the efficiency of the existing ventilation system, and are not specifically associated with gas occurrences.

The two main fans, which are underground, are being moved to the surface in 1982, to reduce pressure differentials, reduce friction losses in the two shafts, and alleviate other disadvantages of the present set-up (25). Gas control is not a factor in this decision.*

The fan capacity is not being increased; the ventilation capacity is already large, but is constrained by the size and length of the shafts and the materials through which they and the mine roads pass (25). The design of the ventilation system at Boulby has had to take account of high dry-bulb temperatures in the workings, and hygroscopic minerals which rapidly absorb water and "weather" if the vapor pressure of the mine air exceeds their own. Thus it has been designed to supply large volumes of cool, dry air (25), and the existing capacity is adequate to dilute gas entering the mine, even from a violent outburst.

*In August 1982, two new main fans were being run up on surface, utilizing the motors and transformers formerly used underground.

Because the gas occurs in isolated areas and is held within the crystalline structure of the rock matrix in a state of equilibrium with the surrounding strata, gas drainage from the formation ahead of mining is not feasible (25). Therefore good ventilation is of vital importance in effective gas dilution. Drainage of gas from the headings after an outburst of gas has occurred is achieved by extending a forced-air ventilation column towards the face in stages. This permits dilution of the gas before it enters the return but requires very good control of the network.

Early attempts to control gas outbursts by altering mine layout were unsuccessful (25). The intention was to alter stress distributions around mine openings, the assumption being that the outbursts of gas and rock were a purely stress-related phenomenon. These efforts at control were not particularly effective; the outbursts continued in a random and apparently unpredictable manner (25).

4.5.3.2.3 Mining Methods

The normal method of mining at Boulby is room-and-pillar, using continuous mining machines, but in areas which are recognized as being potentially gas-bearing (i.e., areas in which black shale is noted) undercutting, drilling, and blasting is employed.

Experience has shown that gas blowouts almost always occur immediately after blasting, more or less as a secondary blast. The change from mechanical to cyclic mining in areas containing black shale is therefore a safety measure, with the two-fold purpose of inducing any potential gas blowout and protecting personnel and machinery. Prior to blasting, personnel are removed from the immediate district and blasting takes place from the intake roadways. It is not considered necessary to evacuate the mine before blasting.

Other precautions taken against gas outbursts are the drilling of exploration holes ahead of the advancing faces, and vertical probe holes in the roof and floor of all headings. These holes are not drain holes (the gas, because of the manner of its' inclusion, is not amenable to being drained from the formation) but are a device to provide precise geological control. The pilot holes drilled ahead of the workings faces are 26 m and 13 m long, and are drilled at an upward angle which is determined by the local geology. In general, the 13 m holes are collared 0.5 m below the roof, and are drilled at 12° and 6° above the horizontal (see Appendix XI). These drill holes are a routine procedure to identify potential gas-bearing zones ahead of mining advance.

Blasting is performed with permissible explosives, types P4 and P5. These are approved explosives for use in methane environments; the 'P' means that the explosive is of a permissible type, and the number signifies the strength of the cooling salts in which the explosive is sheathed (the larger the number, the stronger the cooling salts, and the weaker the explosive).

The cyclic mining method employed in gas-bearing (or potentially gas-bearing) zones is as follows; an undercut is made with a Joy RU 16 jib coal-cutter. The face above the undercut is then drilled with 1 3/4" (44 mm) diameter shot-holes to a length of approximately 10 feet (3 m). Average advance is approximately 8 ft. (2.5 m). It has been found that undercutting results in a cleaner break at the face than using alternative methods such as a center burn-cut or top-slicing.

This variation in mining method in gas-bearing zones is probably the most important single safety measure against gas outbursts in effect at Boulby.

4.5.3.2.4 Impact on the Operation

Apart from the variations in mining methods described in the previous section, the main impact has been in the capital and maintenance costs associated with the use of permissible equipment. The operators claim, in fact, that had they not successfully argued against the use of the higher category Class II flameproof equipment, the mine could have been forced to shut down. They estimate that the use of flameproof diesels and flameproof electrical equipment (including underground auxiliary bifurcated fans) has doubled their equipment capital costs. Maintenance costs are correspondingly increased; mechanics who carry out repairs to permissible equipment must be legally certified to do so, and the repair and maintenance times are longer than for standard equipment because of the more rigorous re-certification requirements.

4.5.3.2.5 Methanometry

Both automatic and manual instrumentation is employed at Boulby. The continuous mining machines are equipped with automatic sensors to detect methane and other hydrocarbons. A light situated close to the operator flashes at 15-second intervals. Should the gas level in the heading reach a pre-determined danger threshold (for CH_4 this is 1%) the light begins to flash once every second. These alarms do not, however, automatically shut down the equipment. These sensors read up to 3% concentration of gas.

Manual methanometers capable of reading up to 5% concentrations are used by shot-firers, foremen, ventilation engineers, and safety officers. Readings are taken before and after blasting, and at regular intervals during each shift.

A third type of sensor, also capable of reading methane concentrations up to 3%, is located in the main return from each

working panel. These are fixed installations which are remotely read. The sensor is attached to a read-out unit located in the intake roadway; the read-out indicates the gas concentration on a meter, and also records the continuous readings on a chart-recorder.

4.5.4 Summary

Gas was first noted at Boulby Mine during shaft-sinking operations, but it was not until panel development began that the first violent outbursts of gas and rock occurred. At first these outbursts seemed random and totally unpredictable (25), but experience showed them to have a common factor, the presence of black shale and secondary ore. Even so, the presence of black shale does not always presage a gas occurrence; to this extent the outbursts remain unpredictable. The safeguarding of personnel and equipment is achieved through close control of mine geology to identify potential danger zones, changing to cyclic mining methods in potentially gas-bearing zones, rigorous manual and automatic methanometry, and efficient ventilation. The lowest category of flameproof equipment is used throughout the mine, and only permissible explosives are used.

4.6 POLAND, NOVEMBER 1 THROUGH 5, 1981

4.6.1 Introduction

During the period November 1 through November 5, 1981, meetings were held in Katowice and Krakow, Poland, during which the occurrence of methane gas in non-coal mines in Poland was discussed with mine operators, research engineers and officials of the regulatory agencies. These meetings were arranged by Dr. Pawel Krystolik, the Director of the Central Mining Institute and the Safety in Mines Institute in Katowice. Dr. Krystolik had arranged a program of meetings over three days, in Katowice and Krakow. This program consisted of a meeting in Katowice with Dr. Naglik, the President of the Polish Mines Inspectorate; a visit to the gassy Pomorzany Mine (lead/zinc) at Olkusz; a visit to the Mining Union of Chemical Raw Materials in Krakow; and a visit to the experimental mine "Barbara" at Katowice. The round of meetings began with a visit to Dr. Naglik at the headquarters of the Polish Mines Inspectorate in Katowice, the principal city in the mining province of Silesia. The results of this meeting have been discussed in Section 3.2.14 and will not be described therefore; the following sections deal with Pomorzany and Klodawa Mines in detail, and briefly describe some of the research going on at the experimental mine "Barbara."

4.6.2 Meeting at Olkusz Mine, 11/03/81

Olkusz Mine is one of three Pb/Zn mines operated as a group some 30 kilometers southeast of Katowice, on the northern flank of the Carpathian Mountains. One of these three mines, Pomorzany, is a gassy mine, and this was the main topic at the meeting. The meeting was held at Olkusz rather than at Pomorzany itself because this is the location of the main engineering office for the three mines, which are in close proximity to each other. Present at the meeting were Mr. F. Swiergot (who acted as interpreter), Mr. Jan Borowski, and the chief ventilation engineer for

the three mines, Mr. M. Polak. The discussion, which was long and detailed, centered around the geology, the origin and nature of the methane problem in the mine, and its effect on the mining operation.

4.6.2.1 Geology

The orebody is in a formation of Triassic age, overlying coal measures of Devonian age (these coal measures are not being exploited). The lower part of the Triassic formation is composed of mineralized dolomites varying in thickness from 0 to 20 meters. The mineralization is sphalerite (ZnS) and galena (PbS) with average grades of 5% Zn and 1% Pb. The average depth of the workings is 100 to 200 meters below surface, and in places the Zn grades have been as high as 25%.

Two schools of thought prevail concerning the mineralization, one being that it occurred during the sedimentation process, and the other being that it occurred during subsequent tectonic activity. The dolomite seams are overlain by calcite layers, which are in turn overlain by impermeable clays. Due to erosion processes these clays are not always present, and in these areas surface water may penetrate into the formation and reach the orebody. Water also penetrates the formation through a number of faults which intersect the calcites and dolomites. These faults are heavily mineralized, and the percolation of groundwater has formed large caverns in the carbonates. The carbonate seams formerly contained large quantities of potable water, and in earlier times wells in the area were used to provide water to the city of Katowice. In fact, part of Katowice is still supplied with water from wells in this area.

4.6.2.2 The Methane Problem

Pomorzany has been mined, more or less continuously, since medieval times. During the early life of the mine, and in fact

until 1977, methane gas had never been detected in the workings.

During the development of a crosscut off a recently-driven inclined raise in 1977, large inflows of water, in the order of 20 m³/min, were encountered. This eventually shrank to a steady-state flow rate of 8 m³/min which has continued to the present time. At the lower end of the raise a weir was constructed from which the water, which was high quality and potable, was pumped out of the mine. With time it was noted that the water had begun to develop an unpleasant taste, and upon heating it became malodorous, with gas boiling off. The gas was identified as methane.

No methane was detectable in the mine atmosphere at this time, even in the raise from which the gas-contaminated water was flowing. The methane was apparently all dissolved in the water, and the source was thought to be submerged wooden sets in the partially flooded workings adjacent to the weir. It was decided to replace the wooden sets with steel, therefore, and during this work an ignition occurred, killing a welder and badly injuring another worker. (Interestingly, the ignition did not occur while welding was actually in progress, and is thought to have been caused by a workman smoking.) Following the ignition, air samples were taken in all headings, and at points up to 500 meters from the ignition site methane levels as high as 5% were noted. In the immediate vicinity, due to recharge with fresh air, levels were lower, but in the crosscut above the raise, which was the original source of the water entering the mine, levels were again $\geq 5\%$ CH₄. An adjacent heading in which miners had been working prior to the ignition was sealed off 50 meters from the face. Three sample points were established inside the sealed off area by the insertion of pipes of differing lengths. Until the CH₄ level reached equilibrium throughout the heading, the central monitoring point gave the highest readings with concentration of methane reaching 9% (men had been working in this area!).

4.6.2.3 Source of the Methane

Tests on rock samples (dolomite and calcite) and brown coal specimens (there are small inclusions of brown coal in the formation) showed them to be gas-free. Air and water samples from within the mine, on the other hand, established a directly proportional relationship between the volume of CH_4 in the mine atmosphere and the CH_4 content of the water entering the mine workings. Tests on the water showed 70 milliliters CH_4 /liter H_2O at 2 atm partial pressure CH_4 , with very significant CO_2 . Combined CO_2/CH_4 partial pressure was as high as 7 atm in some cases. The water was therefore confirmed as the transport mechanism bringing methane into the mine.

The source of the methane in the water was not so easily established. Approximately 3 kilometers northeast of the part of the mine workings in which the water inflow occurred, there is a large pulp mill which has been operating since 1930. Waste water from this plant became a prime suspect as the methane source.

Tests on the mill waste water showed that it contained up to 40 kilograms (dry weight) of organic salts per metric ton. Carbon dating of the methane showed it to be of very recent origin, and test borings in the vicinity of the tailings impoundment yielded gas outflows containing up to 70% methane. The theory which is now generally accepted is that mill waste water has seeped through permeable, clay-free zones, and contaminated the ground water. When the high volume discharge of ground water into the mine began, the contaminated water began to flow through the formation until eventually it too began to enter the mine, bringing with it the methane and other gases. Since the contamination has probably been going on for more than 40 years, disseminating an estimated 150,000 tonnes of organic waste throughout the formation there seems little hope that the situation will change in the foreseeable future. Moreover, it is not technically feasible to prevent the contaminated water from entering the mine, or to

seal off that part of the workings. The mine is now classified as a Category I gassy mine, and safety measures are in effect.

4.6.2.4 Impact of the Operation

The part of the mine operation most severely affected by the inflow of methane was the ventilation system. Previously, ventilation capacity had been governed by two downcast shafts and one upcast, all situated behind the working faces. The first step in enhancing the ventilation was to increase the upcast capacity. Accordingly, an additional shaft was sunk in advance of the working faces and headings were developed to connect this shaft to the main system. The addition of the extra shaft increased the exhaust capacity of the ventilation system by 7000 m³/min (~250,000 cfm). Total main fan capacity was also increased, from 12,000 to 15,000 m³/min. At the time of the Olkusz meeting (Nov. 1981) another upcast shaft was being sunk ahead of the mine workings. When this is completed, the more southerly of the two existing upcast shafts (the direction of advance is to the north) will be changed to downcast. The main fans are on the surface at the upcast shafts, thus the ventilation is an exhausting, negative pressure system.

A dewatering program was introduced to drain the formation ahead of mining. Dewatering is in the order of 300,000 m³/day, and this removes large volumes of dissolved methane from the strata.

A study of the gas concentrations throughout the mine resulted in its being classified overall as a Category I gassy mine. Within this category, three subcategories have been defined: A, B, and C. Panels are individually classified under these designations, which are defined as follows:

- A defines panels experiencing 0 - 0.3% CH₄
- B defines panels experiencing 0.3 - 0.5% CH₄
- C defines panels experiencing $\geq$ 0.5% CH₄

In Pomorzany Mine all three subcategories exist. They are not sealed off from each other, nor are they required to be, but old, disused working areas are sealed off.

Under the "A" subclassification, standard equipment may be used and only manual methanometry (hand-held methanometers) is required. Under "B" and "C", methanometry is automatic with alarm signal threshold set at 0.5% CH₄. All equipment is flameproof except for diesel engines. Methane sensors are placed at the working faces, and at levels of 0.5% CH₄ these will activate warning signs in other areas so as to prevent operators of nonflameproof diesels from unwittingly bringing their equipment into the affected area.

Blasting throughout the mine is with permissible explosives only. No blasting is allowed in any area wherein methane levels are 0.3% or more.

Ore transport from the working faces is by diesel-powered, rubber-tired LHD units dumping into ore-passes, then by diesel-powered rail units to a primary crusher at the foot of the main hoisting shaft. LHD bucket capacity is 4 m³ (5.25 yd³).

Mandatory shut-down level for all equipment in the mine is 1.0% CH₄. (Shut-down is manual but in a coal mine it would be automatic.)

Man removal to a fresh air place is at 0.5% CH₄ in zones B and C, but is mandatory at 0.3% in zone A. This is because there is no flameproof equipment of any kind in zone A.

4.6.2.5 Summary of Pomorzany Mine Experience

Pomorzany lead/zinc mine was for many years a gas-free mine, but began to experience methane gas in extremely dangerous concentrations ($\leq$ 9.0%) after groundwater contaminated with organic

salts from a pulp mill tailings impoundment began to enter the mine in large volumes. An ignition occurred which resulted in the death of a welder, and in a miner being severely injured. A major study was undertaken to identify the gas source, define the gas problem, and plan remedial measures.

The remedial program consisted of; a major upgrading of the ventilation system, involving additional shafts and increased fan capacity; the initiation of an extensive dewatering program to remove gas dissolved in groundwater ahead of the working faces; and the classification of the mine overall as a Category I gassy mine. Three sub-categories of gassiness were defined to designate the gas hazard which actually exists in different parts of the mine. Varying degrees of regulation designed to meet the safety requirements of these particular zones apply within them.

4.6.3 Meetings in Krakow, 11/04/81

On November 4 a meeting took place at the Mining Union of Chemical Raw Materials in Krakow, some 80 kilometers southeast of Katowice. Present at this meeting were Dr. Kazimierz Slizowski (Director); Zbigniew Kobiela, of the Central Mining Institute in Katowice, who is an expert on violent gas blowouts; Adam Wyroba, a mining engineer with the Union who specializes in salt and sulfur mining; Stanislaw Branka, a senior geologist with responsibility for mine geology at Klodawa Mine; and Andrzej Kurdziel, who acted as interpreter.

4.6.3.1 General Geology of Salt Deposits

The meeting began with some general discussion of the Polish salt deposits, of which there are two of major importance; the northern and the southern. The northern deposit extends into East and West Germany, part of France, and under the North Sea. The Polish part of this deposit is an extensive basin, the central part of which is covered by up to 7 kilometers of

overburden. The salt itself is about 1 kilometer in vertical thickness, except where domes have formed (in domes it is 5 or more kilometers thick). Domes have formed where static overburden pressure has caused the salt to flow, forcing domes up through the younger (Mesozoic) overlying deposits (the salt is Permian).

There are four major seams of salt, separated by anhydrites, clays, shales, and potash (the latter is not commercially significant). The deposits were laid down during four cyclotherms, with each sequence consisting of:

1. clay
2. carbonates (mostly dolomites)
3. anhydrites
4. chlorides of salt.

Mixed with and bounded by the dolomites, are layers of bituminous shale; these materials were originally saturated with hydrocarbons.

The southern salt deposits are geologically younger (Miocene), much closer to the surface, and not as thick as the northern ones. These have not formed domes, but rather, have formed diapiric folds caused by lateral plate movement from south to north as the Carpathian Mountains rose.

Both of these major salt formations are exploited commercially at a number of locations. Mines are located in the diapiric folds of the southern formation, and in the domes of the northern. All are in tectonically active regions; the Carpathian Mountains are still rising, as are the domes of the northern formation. One of these mines, Klodawa, which is situated in the northern formation was discussed in detail.

4.6.3.2 Klodawa Mine

Klodawa is prone to violent outbursts of gas, and is therefore classified as a Category II gassy mine. It has been described as the most dangerous mine in Poland. The salt seams are separated, as was noted in the previous section, by clays, carbonates, and anhydrites. The lower part of the carbonates often contains a layer of bituminous shale, bounded by dolomites. These materials are the source of the gas, which is composed mainly of methane, but other hydrocarbons (mainly ethane) are sometimes noted, as well as H_2S and CO_2 .

4.6.3.2.1 The Gas Problem: At Klodawa three main gases occur.

(i) Methane, which may eject 800 metric tons of salt in one outburst. Methane outbursts occur where bituminous impurities in the salt are noted. These often include brines and oil products too. Usually, outbursts happen in areas of vertical or near-vertical stratification (90° - 70°). Typical cavities caused by blowouts are 2 x 10 x 20-30 meters. Methane blowouts are usually of higher intensity than those of other gases, and the salt ejected has usually been secondarily-crystallized.

(ii) Nitrogen blowouts are usually of lower intensity than those of methane, typically ejecting ≥ 100 tonnes in one outburst. The nitrogen blowouts characteristically occur in salt containing clay impurities and/or anhydrites

(iii) Methane/Hydrogen Sulfide occurrences, although typically of lower intensity than either (i) or (ii), usually ejecting ≤ 100 metric tons of rock, are regarded as the most dangerous. The H_2S content may be as high as "several" percent, but this has never been accurately determined. After one blowout 47% H_2S was measured in the cavern created by the blowout (in Poland the permissible level of H_2S is .007%).

The dome in which Klodawa is situated is tectonically active; due to plastic flow the bituminous shale and other gas-bearing materials have become dislocated and intrude upon the salt beds in places. The gas blowouts are considered to be related to metamorphism and tectonic activity, and occur wherever evidence of this is greatest. Two forms of gas inclusions occur. In one type the methane from the gas-bearing intrusives is thought to adsorb onto the coarse, secondarily-crystallized, impure salt in large volumes, creating localized zones of very high gas content. Gas is also contained in significant quantities interstitially within the salt crystals. This is the type of inclusion which causes violent outbursts. When the stress distribution within and around such areas is disturbed by mining activity, liberation of gas can occur with explosive rapidity along cracks forming towards a free surface, causing a violent ejection of gas and salt. In this type of inclusion there are no pockets of free gas; the outburst is a result of an extremely rapid chain reaction, and free gas under pressure is not initially a factor. In the other type of gas inclusion, free gas is trapped under pressure in cracks and fissures within monolithic salt. Oils and brines are often present also. The majority of inclusions of this type contain N_2 , and will occasionally blow during drilling. Flows of gas from such inclusions may continue for days or weeks, and although very large volumes and pressures (<90 bars estimated) have sometimes been noted, these outflows do not normally eject large amounts of salt.

4.6.3.2.2 Operations at Klodawa

During the normal course of events gas is not detectable in the mine. When it is detectable it is usually only after blasting or after an outburst (outbursts almost always follow blasting). During blasting, therefore, all personnel are withdrawn to a Safety Room adjacent to the main shaft. The area is ventilated for one hour after the blast, after which only certified personnel re-enter the working areas to make gas checks. The miners

may only re-enter the working areas after these have been certified as gas-free.

There are known gas-free zones in which mining may proceed without the likelihood of gas being detected, and in these zones safety regulations are less stringent. Emphasis throughout the mine is on detecting potentially gassy zones ahead of time. Location of potential gas zones is determined by drilling horizontal test holes 300m ahead of the working faces. Development work is forbidden without such test holes.

Areas which are suspected of being gassy are not exploited because of (a) safety considerations, and (b) the poor quality of the salt. Headings are therefore driven through these zones.

The normal blasting advance is 1-2 m; test-holes of larger diameter than the shot-holes are 1 m over-drilled. In danger (gas-prone) zones, the drilling pattern is the same, but shot-holes are 50% overloaded to induce potential outbursts. During drilling gas checks are made, and the test holes are drilled (100mm diam.) using a packer system to prevent blowouts. The shot-holes themselves are 42 mm diam., and the round is fired electrically with caps at hole bottom (reverse priming). An important feature is that face drilling is only carried on in one location at a time in danger zones. Gas emissions have occurred during drilling, but have never exceeded 20 l/min, and are most often predominantly composed of N_2 . No violent outburst has ever taken place during drilling. No flameproof equipment is used in gas-prone areas, and methanometry is manual.

It is important to note that even after prolonged ventilation shutdown no gas is detectable in this mine; it is only present after an outburst has occurred. The underlying philosophy of the precautions taken to combat the gas problem is therefore preventive. The gas is either briefly present in hazardous concentrations, or not at all; the approach to the problem is

based on experience of the conditions under which the gas may occur, and common sense.

Due to lack of time, communications difficulties, and the fact that there was no opportunity to actually visit Klodawa Mine, some questions were not dealt with in as much depth as might have been hoped for. Complete details of the ventilation system were not obtained, and more details concerning mining method, blasting, production rates, and transportation systems would have been of interest. Of particular interest is the question of how gas blowers (gas flowing from drill-holes, sometimes for quite long periods) are dealt with. These are not common, and are not seen as a problem, but since no flameproof or intrinsically safe equipment is used in the mine, a method of dealing with such a gas flow must obviously exist. Presumably the gas is either piped to a safe place until the flow ceases, or the ventilation has sufficient capacity to dilute it to an acceptable level of concentration in the return air. In view of the small scale of the flows recorded when these blowers occur, and the fact that they are usually N_2 , the latter seems most probable. The information obtained was, in spite of these deficiencies, of great interest, and covered the main topics in considerable detail.

4.6.4 Experimental Mine "Barbara"

The experimental mine "Barbara" is situated at Mikolow, roughly 7 km from Katowice, and is a research facility operated by the Safety in Mines Institute and the Central Mining Institute. A small scale experimental underground mine is in fact operated, as well as a number of laboratories in which research and development of explosives and safety equipment is carried on. Permissible explosives are developed and tested, as well as flame-proof and intrinsically safe equipment. Complete machine shops and electronics workshops manufacture prototype systems which undergo extensive testing under simulated gassy mine conditions. Research

is ongoing to improve the efficiency of permissible explosives, flameproof motors, and electrical systems. Intrinsically safe power sources have been developed to remotely energize automatic methanometry systems, and miniaturized intrinsically safe circuits have been brought to a high level of efficiency and reliability. The institute's work in this area must be regarded as state-of-the-art, and researchers there export technology to, and maintain dialogue with, a number of western countries, including Australia, the United Kingdom, the United States, and W. Germany. The international caliber of the engineers at "Barbara" is impressive. A number of them have made several visits to Western Europe, the U.K., and the U.S., to exchange technical information, and they are well informed regarding mining technology around the world.

In addition to the safety-related research which is carried on at this facility, the Central Mining Institute performs a full range of mine engineering studies. It is directly involved in all aspects of feasibility studies for new mining projects. The time available only permitted a visit to the Safety in Mines Institute's laboratories, however.

As a final note of interest, the mine is named "Barbara" for Saint Barbara, who is the patron saint of Polish miners.

4.6.5 Summary of Polish Meetings

The meetings in Katowice, Krakow, and at Olkusz established that in Poland two separate systems exist for classifying gassy coal and non-coal mines. These classifications, however, seem designed to characterize the gas problem rather than to be a regulatory device. Operating safeguards are designed on a mine-specific basis after detailed study of the problems of that particular mine. The two mines examined in detail, Pomorzany and Klodawa, clearly illustrated the diversity both of the ways in which mine gases can occur, and of the operating safeguards which

may be best suited to meet the problem. The Polish engineers had no hesitation in rating Klodawa as a much more dangerous mine than Pomorzany even though the latter has methane continuously present in the workings and the former does not. At Klodawa, the safeguards take the form of strictly-adhered-to operating procedures, using standard equipment, and mining methods (room-and-pillar, drilling and blasting). It is the procedures which provide the safeguards, an option that is made possible by the nature of the problem, and by the fact that the problem has been studied in detail and is well understood. At Pomorzany the problem is very different and the safeguards which have been developed clearly reflect this.

The approach to the problem of dangerous mine gases in Poland recognizes that under different geological and structural conditions methane gas may be expected to occur in a number of reasonably predictable ways. These are amenable to classification according to the mode(s) of occurrence and the gas concentrations encountered. It also recognizes that wide variation in the actual danger level may occur within each category, the main variables being:

- (i) violence and frequency (outbursts)
- (ii) volume, pressure, and duration (blowers)
- (iii) peak concentrations (emissions)
- (iv) source of the gas or gases.

These in turn are influenced by other variables such as the mining method (room-and-pillar vs. longwall, for example), the size and depth of the mine (dimensions of shafts, roadways, working faces), and structural and hydrogeological conditions. The Polish authorities seem to adopt the premise that to formulate rigid rules which would correspond automatically to any given classification would be inappropriate. Such rules, in order to be effective, would have to be designed so as to be

adequate to deal with a worst-possible-case situation. Clearly, this would often result in over-regulation.

To a degree, a state-owned and operated mining industry enjoys an advantage in matters pertaining to safety. The system allows those responsible for the formulation and enforcement of regulations to have unrestricted access to the mines at all times. Although not without disagreement on occasion, in general the full cooperation of the mine operators is assured. However, it seems apparent that the main reason for cooperation by the mine operators is the practical approach which is taken toward the imposition of any regulations which could impose unwelcome burdens on the operation. Although the profit incentive does not apply as it does in a free-enterprise system, production targets still have to be met. The overall impression made by these meetings was that Polish mining engineers are very competent; very experienced; and have developed sophisticated but highly practical methods of defining and controlling problems due to flammable and other gases in non-coal mines.

4.7 REPUBLIC OF SOUTH AFRICA, NOVEMBER 1981

4.7.1 Introduction

A four day visit was made to Welkom, located in the Orange Free State (O.F.S.) Goldfields in South Africa, in November, 1981 when discussions were held with the district Chief Inspector of Mines and Mining, and ventilation and geological department staff members of three mining companies. An underground trip was also made at one of the mines.

The mines visited, all of which experience methane occurrences, were recommended by the Government Mining Engineer, Mr. V. Barnes, following discussions held during a previous visit in November 1980 and subsequent correspondence. Several companies operate mines in the O.F.S. Goldfields, and one operation was selected from each of the following organizations:

- (i) Anglo-Transvaal Consolidated Investment Company Ltd.
- (ii) General Mining and Finance Corp. Ltd./Union Corp. Ltd.
- (iii) Anglo American Corporation of South Africa Ltd.

This approach was taken to assess how practices designed to safeguard an operation against methane might vary within the overall framework of a common mining law and regulatory system. It was discovered, however, that variation between operations is confined to minor differences and much that is described in the text that follows is common to all operating gold mines in the O.F.S. goldfields.

Where a distinction is necessary, the operations visited will be referred to as Mine A, Mine B and Mine C.

4.7.2 Background Information

The O.F.S. Goldfields form the southwestern tip of the Witwatersrand Basin, south of the Far West Rand Goldfields, and are centered around the city of Welkom located some 225 km southwest of Johannesburg. The O.F.S. Goldfields extend from Allanridge, in the north, approximately 50 km to Virginia, in the south. The mines in this area have been in operation since the late nineteen forties.

The main minerals produced are gold and silver, with other minerals such as uranium and osmiridium produced in lesser quantities. The ore occurs in thin conglomerate horizons, or reefs, and generally two or more reefs are mined depending on local geological conditions and the assay value of the reef (measured in cg/ton). Ore production at the three mining operations is in the range of 2 to 3 Mty, and the ore is treated by flotation, cyanidation and acid leaching processes. The geological structure is described in detail in a later section.

The depth of mining varies throughout the O.F.S. Goldfields due to structural dip trends and major faulting but is typically in the range 1200 m to 2500 m below surface. Each mine is serviced by a varying number of vertical shafts (5-Mine A, 9-Mine B, 3-Mine C). Underground haulage is either by rail (Mine A and Mine B), using diesel and electric locomotives, or by rail/conveyor belt combination (Mine C).

The mines are mainly worked by open stoping methods, although some use is made of sublevel caving in steeply dipping areas (Mine A). The application of the method can vary from one mine to another, depending on local conditions, but can generally be described as follows. The orebody is accessed by crosscuts and reef drives developed from main level haulages. Stopes are then developed laterally from reef raises mined up-dip along the reef horizon between levels. Since the reef pay zone is generally

only several centimeters thick, the stope height is kept as small as can be worked, to minimize the tonnage of waste rock broken. Blast holes are drilled with hand-held, air-powered, jackleg drills, are charged with ANFEX*, and are detonated electrically. The blasted ore is mucked to a boxhole using an electric powered winch and slusher bucket.

The mines typically employ 8,000 to 10,000 workers, composed of both white South Africans and expatriates, and black, native Bantus from a number of different tribal groups. The black workers largely comprise the basic labor force in the mine. The whites comprise the first line operators, the operating supervisors, and the management staff.

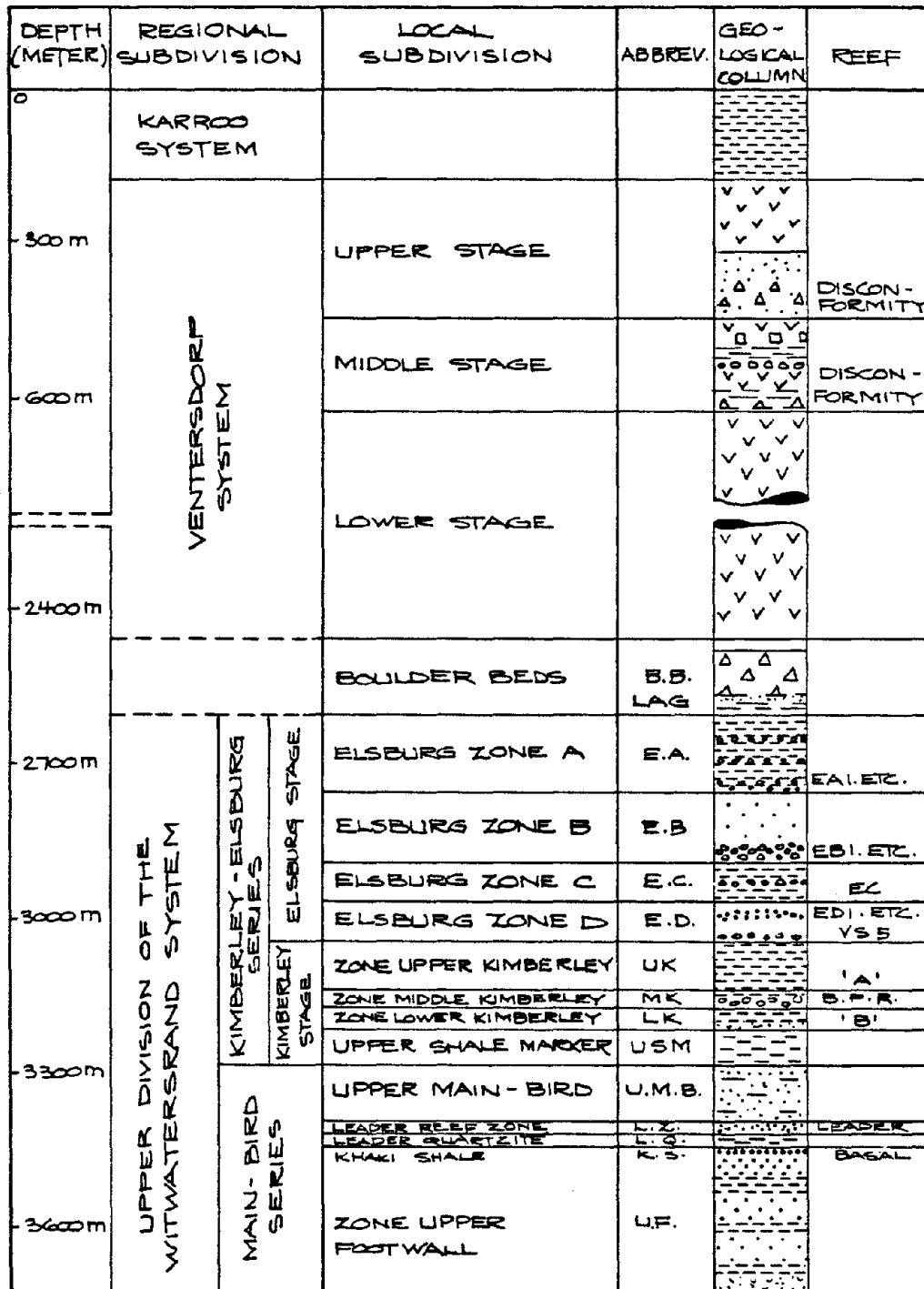
4.7.3 Geology

The geological structure of the Orange Free State Goldfields consists of a major North-South syncline of Lower and Upper Witwatersrand rocks overlain conformably by Ventersdorp sediments and lavas, covered by horizontal Karroo sediments of which the Eccra Series contain coal measures. Above the coal measures the sediments are mostly impervious shales, while the footwall is predominantly sandstone. All the reefs mined at the three mines visited are found within the Upper Division, Witwatersrand System. A stratigraphic section from the surface to below the Basal reef is shown on Figure 1.

The tectonic history of the area is complex and is not described here. It is believed that the source of the gold reefs was from mountains rising to the west of the area, and sediments were deposited as alluvial fans east of a basin peripheral fault and spread by floods. During a stable period the Boulder Beds were deposited, followed by the Ventersdorp volcanic activity.

* Ammonium nitrate fuel-oil explosive (ANFO).

GENERALIZED GEOLOGIC SECTION-O.F.S. GOLDFIELDS Figure 1



LEGEND



SHALES



QUARTZITES



CONGLOMERATES



VOLCANICS



PYROCLASTICS



BOULDERS

Several periods of faulting are recorded throughout the O.F.S. Goldfields, summarized as:

- a. Witwatersrand Age
 - North-south trending thrust faults found in restricted areas only.
- b. Pre-Middle Ventersdorp Age
 - East-west trending thrust faults which preceded a regional westerly tilting era.
 - North-south trending normal faults, mainly associated with the regional westerly tilting, displacing the former thrust faults
- c. Pre-Upper Ventersdorp Age
 - Transverse NE-SW faults, displacing the N-S trending faults.
- d. Post-Ventersdorp Age
 - Nearly vertical NW and NE trending faults with prominent horizontal slip.

In the Odendaalsrus/Welkom area, structural dislocations in the mineralized area are dominated by three north-south trending faults, the Dagbreek, the Arrarat and the De Brons, which persist for at least 12,000 meters along strike. The area is also characterized by intrusions of dikes and sills of various ages, the most recent of which were intruded into the Karroo system (see Figure 2).

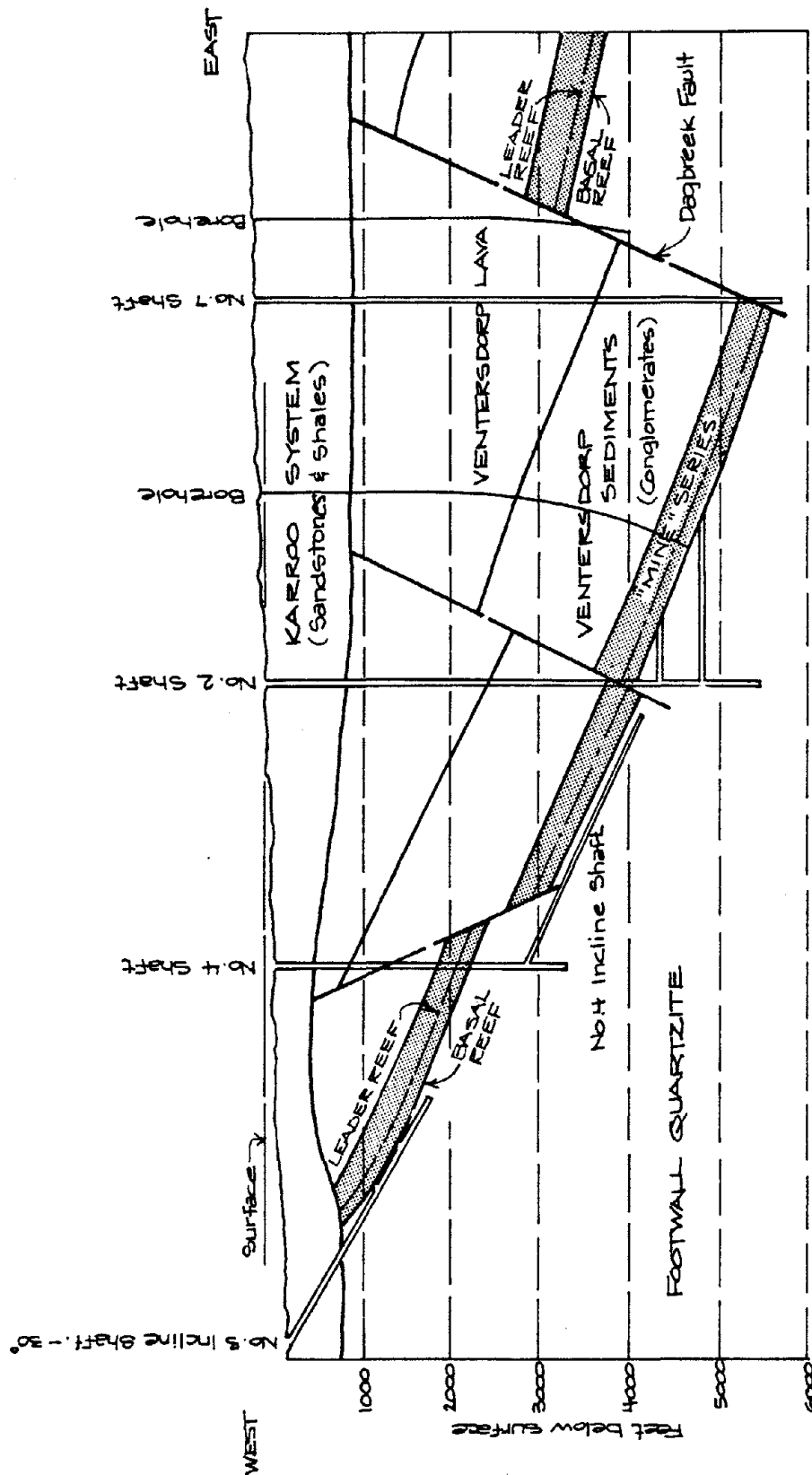
4.7.4 Occurrence of Gas

4.7.4.1 Sources

Methane is believed to originate from the Eccra Series coal seams in the Karroo sediments, formed by destructive distillation during periods of dike and sill intrusions. The overlying shales being impervious, the methane was trapped below them and was dissolved in the water contained in the porous sandstone below the

TYPICAL GEOLOGIC CROSS SECTION - MINE B

Figure 2



coal. The water containing dissolved methane percolated downwards gradually, along interformational contacts, faults, older dikes, bedding planes and fractures, into older rocks. Although there is an increase in temperature downwards, the stability of the solution was preserved by the increase of pressure. When a development end or underground borehole intersects a water-bearing fissure the sudden reduction to atmospheric pressure releases the methane from solution and it bubbles freely from the water. In some of the O.F.S. goldmines, methane is found mixed with hydrogen sulfide and/or hydrogen, reinforcing the belief that the gas originated in the overlying coals.

In recent years, more dry fissures (carrying methane) have been encountered in the upper levels of the O.F.S gold mines. This is thought to result from the lowering of the water table by pumping, allowing methane released from solution to flow up into the dry fractures. Recent experience tends to confirm this, as quantities of methane associated with water have decreased. However, methane is still being encountered in water-bearing fissures in the lower levels of mines and, in many instances, is associated with helium gas (up to 3%), and small quantities of argon. It is postulated that the argon and helium are derived from radioactive decay, and that some of the methane originates directly from within the conglomerates deposited during the Witwatersrand era. The presence of these trace gases was not recorded until 1958.

4.7.4.2 Occurrence of Methane in Underground Workings

The volume of flammable gas emissions is generally quite small, with notable exceptions (e.g., Virginia Mine). Typical flows recorded at Mine B are 80 cfm maximum at one location with a mine total of 1000 cfm. Methane emissions are generally encountered at the contacts of dikes, faults, fissures or cleavage planes which form natural paths for both water and gas. The emission of methane is not always localized to a fissure as the rock is often shattered by blasting, or may be naturally fractured with the

result that the methane is "made" at various indeterminate points in a development end. Emission from dry fissures has been far more serious than that from boreholes, and is becoming an increasingly more difficult problem as the water table is lowered.

Areas of a mine where methane is first intersected may frequently become gas-free, even though methane continues to be encountered in water-bearing fissures at depth. This suggests that the "methane table" will rise over a period of time. The most likely locations for gas concentrations therefore appear to be the shallower portions of the mines where fissures, related perhaps to faulting or folding, that can provide reservoir volume may exist.

The occurrence of methane in the gold mines is now fairly well understood, based on many years of experience, and locations where gas is likely to be found are generally well documented.

4.7.4.3 Gas Composition

It is not possible to provide gas composition data for all known occurrences, but the information in Table I is included for the sake of interest. The data represents irregular sampling over an eight year period, from four surface boreholes and at three underground locations at Mine B. The mean value is the arithmetic mean. Oxygen, argon, and carbon dioxide content were not determined in all the samples.

Table I

Gas	Dry Fissure U/G		Surface Borehole	
	Mean %	Range %	Mean %	Range %
Methane	78.8	68.0 - 85.3	84.0	74.0 - 92.0
Oxygen	0.3	0.08 - 0.58	0.5	0.23 - 1.20
Nitrogen	13.3	8.1 - 24.0	9.4	3.8 - 11.3
Helium	7.8	N/A	6.0	N/A
Argon	0.5	N/A	0.3	N/A
Carbon Dioxide	<u>0.1</u>	N/A	<u>0.1</u>	N/A
	100.8		100.3	

4.7.4.4 Methane Drainage

Attempts to drain even relatively localized fissures have generally not been successful, and methane drainage is not considered feasible for the relatively small quantities encountered. Even where large volumes of gas are potentially available, it must be pumped to obtain satisfactory drainage.

4.7.5 Safety Measures

4.7.5.1 Mine Classification

The mines of South Africa are operated under the Mines and Works Act #27 (1956) and Regulations, which permit a mine to be declared as either fiery (gassy) or non-fiery, as specified in the Regulations. Pertinent extracts of these are reproduced in Appendix VIII.

None of the metalliferous mines (including all gold mines) are presently declared fiery, even though methane gas is found in most of them in various quantities. For each of these mines, however, specific regulations applicable to fiery mines are

generally enforced, on an individual basis (see Regulation 3.18.2, Appendix VIII).

Directions issued under Regulation 3.18.2 are generally qualified by written permissions and exemptions (Reg. 3.15.1) relating to specific regulations. Exemptions may also be withdrawn (Reg. 3.15.2) where necessary to maintain health and safety standards.

The procedure established above allows specific fiery mine regulations that are considered essential to be applied to a mine experiencing limited methane gas emissions without imposing the full force of the Fiery Mine regulations. The procedure relies on the combined judgement and experience of the mines' Management, the Inspector of Mines, and the Government Mining Engineer, and satisfactory enforcement requires:

- a. Established procedures for the detection, monitoring, and reporting of gas emissions.
- b. Discipline with respect to posting and enforcement of the regulations.
- c. Certification of all mine personnel.
- d. Penalties for infraction of regulations by individuals.

This approach has evolved, regarding the O.F.S. Goldfields, since the first mines were opened, when it was stated that the declaration of these mines as fiery would be against the best interests of the industry. During the early years of operation, certain mines that experienced methane explosions were declared fiery (Mine C, 1950-1956), but such declarations were subsequently withdrawn. Directions concerning the application of fiery mine regulations to the individual gold mines, together with permissions and exemptions, have been periodically re-issued as necessary.

4.7.5.2 Methane Codes of Practice

Each mine is required to issue written instructions concerning the fiery mine regulations, permissions, and exemptions that are imposed. Formerly this was done by issuing a memorandum to key operating personnel. However, mine managements found that effective enforcement of the regulations could not be achieved unless a clear and concise summary of the application of the regulations was provided to all mine employees, down to the ganger (miner).

This has led to the publication by individual mines of documents such as "Methane Precautions and Instructions" and in later years a "Methane Code of Practice." These documents, published independently by each mine, generally include most of the following topics:

- a. Methane.
- b. Flame safety lamp and methanometers (use of).
- c. Testing for methane, and procedures to follow when it is detected and/or the ventilation system fails.
- d. Clearing of methane and potential methane traps.
- e. Ventilation standards.
- f. Stopped ends or stopes.
- g. Regulations regarding methane.
- h. Persons competent to take action.
- i. Diamond drilling and cementation procedures.
- j. Blasting procedures and open flames.
- k. Electrical machinery and installations.

A typical Code of Practice is included in Appendix VIII.

4.7.5.3 "Methane in Metal Mines" Code of Practice

In the early nineteen sixties, an investigation was undertaken by the Orange Free State Branch of the Association of Mine Managers

of South Africa to study all existing practices with respect to methane in the O.F.S. gold mines, and also the knowledge available in other countries. This resulted in the publication in 1964 of the report "Methane in Metal Mines," which was written to conform with the Fiery Mine Regulations made applicable to mines in that District by the O.F.S. Inspector of Mines (30).

This is a comprehensive document that is issued to, and used extensively by, the operating mines' staffs. In fact, it addresses the requirements of the applicable Fiery Mine Regulations so well that it has been used as the vehicle by which the Regulations are enforced in the mines, and from which exemptions are requested by mine Management.

The intent of the document was to provide guidance to mine operators in combating the dangers arising from the presence of methane in mines. It is considered a living document, and copies are updated (by inserts or deletions) at each mine as modifications to the applicable Fiery Mine Regulations and Exemptions are made.

In 1973, a second report was prepared by the Orange Free State Branch of the Association of Mine Managers entitled "A Guide to Managers to Assist in Combating Methane in Metal Mines." The content of this report is similar to the 1964 publication, which it updates, but apparently it has not been accepted as a direct replacement for the latter document, which is still in common use.

4.7.5.4 Classification for Smoking

The Inspector of Mines has classified the O.F.S. gold mines into two groups, defined as follows:

Group I - Smoking permitted underground except
in restricted areas.

Group II - Smoking not permitted underground.

Restricted areas are defined as sections in a mine where methane occurrences are common, and notices are posted underground at points of entry to such areas. These areas are also identified on specific plans by the Ventilation Officer.

In practice, the enforcement of no-smoking regulations in restricted areas in Group I mines has proved to be cumbersome, and in some of these cases mine Managements have elected to adopt the Group II regulations despite the less rigorous classification of their operation by the Inspector of Mines. The two classifications are identified by appropriate Exemptions to the Regulation concerning the taking of smoking materials, or appliances of any kind for striking a light, into the mine.

4.7.6 Detection

Methane testing is required by law in all working places and this is presently done by means of the flame safety lamp. In areas where methane is likely to be present, the flame safety lamp must be equipped with a probe to allow proper sampling of inaccessible areas of the back, and boreholes or fractures. The Ventilation Departments at the mines also use electronic, intrinsically safe, methanometers for routine surveys (methane patrols).

All responsible officials, including shift bosses and gangers, are issued with flame safety lamps. Procedures have been established in the Regulations which address the requirements for entry into working places at the start of shift, and monitoring for gas during the shift. All new occurrences of methane are reported to the Mine Management in writing on the Mine Overseers' Daily Report, and to the Ventilation Officer by means of the Ventilation Daily Report. When this occurs, a senior ventilation assistant visits the place to accurately determine the volume of methane and the percentages in the intake and return air of the

working place, and in the main ventilation current. This information is reported in writing to the mine Management with the department's recommendations, and instructions for dealing with the occurrence are issued after full discussion by senior staff.

The mine Manager is required to notify the Inspector of Mines, immediately, of the presence of inflammable gas detectable by a flame safety lamp in any ventilating district of the mine if such gas has not been detected within the previous three months. This notification must be confirmed in writing (Regulation 10.6.8, Appendix VIII).

In the general body of the air where persons are required to work or travel, under normal working conditions, strict criteria are applied concerning permissible gas levels (see Regulation 10.6.6, Appendix VIII). This Regulation states, among other things, that "the amount of inflammable gas shall be insufficient to show a distinct cap on the reduced flame of a safety lamp".

The absolute minimum quantity of methane that can be detected by this means is 1-1/4% under ideal conditions but may be as much as 2-1/2%. For this reason, strong recommendations have been made by the mining industry to adopt an improved standard for monitoring methane on a routine basis.

It was stated that a potentially more serious hazard arising from methane emissions concerns the danger of asphyxiation rather than ignitions. Asphyxiation is a particular hazard in raises, along the upper faces of stopes where inadequate ventilation may occur, or along infrequently travelled ways.

4.7.7 Prevention of Accumulations of Methane

4.7.7.1 Allowable Quantities of Gas

Areas where methane is likely to occur are reasonably well known in the established mines, and areas in the mine most likely to encounter gas have been defined to try to guarantee minimum safe standards of ventilation and flame-proofing. These are called "Restricted Areas." Presently only those areas in a mine which are ventilated by means of auxiliary fans are restricted.

The 1973 publication referred to in Section 4.7.5.3 defines a "Methane Stress Area" as an area in the mine, designated by the Manager, in which methane is likely to be present in the general atmosphere in detectable amounts. "Detectable amounts" means detectable by means of "detecting instruments" (not necessarily the flame safety lamp). A "methane stress area" is considered safe to work in, if not more than 1% methane is present in the general air stream. Regulation 9.29 states that no blasting may take place if a distinct cap is visible on the reduced flame of a flame safety lamp, and this is generally interpreted to be equivalent to a 1-1/2% concentration of methane. Regulations 9.27 and 9.30 are also concerned with blasting and the use of permitted explosives (see Appendix VIII).

4.7.7.2 Ventilation

Large volumes of air are circulated to prevent gas build-up and to ensure dilution. The system is flexible so that sufficient air may be coursed to a methane area by stopping and sealing other areas when necessary.

Return airways are monitored on a monthly basis to determine the volume of methane flowing. All main fans are equipped with isolation doors and are installed in pairs, where possible, to

prevent a reversal of the main ventilation current in the event of a power failure to one fan.

Development ends are ventilated by both the force system and force-exhaust overlap system. The dependence on auxiliary fans is kept to a minimum by effecting holings as quickly as possible between adjacent levels. In some cases, long and single development ends have to be blasted for exploratory purposes and these are invariably ventilated by the exhaust-overlap system to allow multi-shift development. Short-circuiting of air at fan intakes is prevented by not allowing a fan to draw more than 50 percent of the available through-ventilation.

The geological structure of a mine often necessitates reef stoping above the normal strike airways. This results in inverted U-tube mining conditions where special attention is required to ensure satisfactory ventilation.

4.7.7.3 Cementation of Methane Fissures

The mines predominantly have ascensional ventilation systems. This entails having to allow methane mixtures to flow through working places above the source of the gas. If dilution by the available air is insufficient to ensure safe conditions in the return of a methane emission, the source fissure has to be cemented. Mixtures of pure cement and water in a ratio of such that high penetration is assured are used for this purpose. (the mixture has been found oozing out of the rock up to a hundred meters from the point of injection).

4.7.7.4 Prevention of Methane Ignition

In addition to testing for gas with approved equipment, prevention of methane ignitions is aided by specific requirements for mine machinery and installations, and by training and discipline

of the mine labor force. A brief summary of main features is provided.

(1) Training of Personnel

All new persons employed are trained to be cautious of methane. Every black worker in a supervisory category is trained in the use of the safety lamp, including winch and machine operators. All white employees also undergo training.

(2) Blasting

All production blasting is normally detonated electrically from surface after all persons have been removed from underground. Some isolated multi-blast ends are shot from approved blasting points during the shift. The points are indicated by notices, must be situated in through-ventilation, and should not be in the direct line of the blast. Permission to blast working places more than once in 24 hours must be obtained in writing from the Inspector of Mines. These permissions are accompanied by specific conditions laid out concerning minimum ventilation quantities and reentry times. Quarterly returns, showing development ends worked under multi-blast or double-shift conditions, are submitted to the Inspector of Mines.

(3) Electrical Installations

All main fans have duplicate feeders to prevent shutdown in case of cable failure. If electric equipment is installed in a restricted area, it has to comply with flame-proofing requirements. When such equipment has been installed, an electrical official checks it monthly and records the results.

(4) Static Electricity

All compressed air-driven equipment is grounded as for electrical equipment. Compressed air hoses may not be used

to blow out methane concentrations.

(5) Diesel Locomotives

The writer was informed that tests have proven that methane is unlikely to be ignited solely by the heat from diesel engines. Flame-proofing of locomotives is maintained by an underground fitter on all units which operate in restricted areas.

(6) Battery Locomotives

Battery-operated locomotives are not permitted to enter restricted areas.

4.7.7.5 Clearing Methane-Filled Areas

A summary of the recommended procedure used on the O.F.S. mines to clear gas from methane-filled areas is provided here.

- (i) All working places on the route which the gas will take are barricaded and guarded to ensure that no persons can enter. All electrical gear on this route is checked to guarantee flame-proofing.
- (ii) A fan is installed (flame-proof, if possible), in fresh air, close to the footwall and at such a distance that the ventilation from the fan will just blow into the methane-filled area.
- (iii) The ventilation column is slowly extended in 3-meter lengths, taking care that the methane concentration in the return air remains at a harmless percentage.
- (iv) The entire operation is supervised by a senior ventilation official.

4.7.8 Training and Certification

An essential part of the safety measures taken by the South African mining industry is the training and certification of all

personnel. On the mine, two types of certificates are issued to persons working underground, the Clearance Certificate and the Certificate of Proficiency in Methane Testing. The following descriptions were adopted from the 1973 publication by the Chamber of Mines (31).

(1) Clearance Certificates

The purpose of the clearance certificate is to provide management with physical proof that every man working underground has been made aware of the dangers of inflammable gas and whether a man working underground has received all relevant managerial instructions appertaining to his occupation. The certificate should clearly state what instructions the man has received and should be signed by the holder of the certificate and by the man giving the instructions.

All holders of valid Pneumoconiosis Bureau certificates who may be permitted or are required to work underground, should be issued with a clearance certificate before they are allowed to work underground.

At any mine where explosive gas is likely to occur, a system should be devised whereby all underground employees are instructed in the necessary safety precautions to be taken. Clearance certificates fulfill this purpose; a record of all clearance certificates should be kept.

(2) Certificate of Proficiency in Methane Testing

The function of the Certificate of Proficiency is to provide management with physical proof that the holder of the certificate has received the necessary instructions and training in testing for methane. The following persons are required to be the holders of current valid Certificates of Proficiency in methane testing:

- a. All holders of blasting certificates.
- b. All cementation and diamond drilling personnel.
- c. Pumpmen.
- d. All persons who are required to use an "open flame", such as underground boilermakers, electricians, haulage construction timbermen, etc..
- e. Ventilation department staff.
- f. Any scheduled person required to take charge of other persons or of a working place underground.
- g. Any other persons required to carry out methane gas tests in their normal function underground, such as development or stoping bosses, winch drivers, etc., referred to (in the Regulations) as "competent persons."

Holders of Certificates of Proficiency in methane testing are re-examined periodically; the period between re-examination is not to be greater than one year.

The training should include the following points:

- (i) the extreme dangers of inflammable gas,
- (ii) the care and operation of the detecting instruments in routine use for testing for inflammable gas,
- (iii) the procedure for testing for gas,
- (iv) the precautions and procedures to be taken when gas is detected.

These certificates should be numbered and a record maintained of all certificates issued.

Copies of the examination syllabus for the methane proficiency certificate, and examinations for shift bosses, electricians, diamond drilling personnel and persons using welding, cutting or burning torches are contained in Appendix VIII.

In addition to these certificates, the Regulations require that individuals holding key positions in the mine should be examined and certified by the Inspector of Mines. This has been referred to in an earlier section of the report; a complete description of the system is given in Appendix VIII.

Certification is a prerequisite to employment in many positions. The Mine Manager's certificate is awarded for three separate categories of mining operation, and is not interchangeable. These are:

- (i) coal mines (including both fiery and non-fiery mines)
- (ii) metal mines (with more than 1000 men)
- (iii) other.

In practice, a Mine Manager responsible for a gold mine to which fiery mine regulations have been applied would be advised to have a coal Mine Manager's certificate.

4.7.9 Mines Inspectorate

The Orange Free State Goldfield is divided into two Districts, Welkom and Virginia, and each is under a separate branch of the Inspectorate. The mines visited within the context of this study were located in the Welkom District, which comprises the following mines:

Welkom Gold Mining Company Limited,
 St. Helena Gold Mines Limited,
 Loraine Gold Mines Limited,
 Free State Geduld,
 Western Holdings.

The staffing of the Welkom District Inspectorate office is based in part on the total labor working at the mines within the

District. In Welkom, the total labor force is some 60,000 to 70,000 persons.

A major part of the work of the District staff is associated with inspections, exemption requirements and processing, and accident investigations. Underground visits, mostly concerning accidents, are generally made as follows:

Subinspector - 4 to 5 days/week,
 Assistant Inspector - 2 to 3 days/week,
 Inspector - 1 to 2 days/week.

Statistics indicate that there are approximately 60 to 90 deaths per year in the District, from all causes, the majority of which are due to falls of ground and accidents associated with trucks and tramming operations.

The qualification requirements for positions within the Inspectorate are high, and some difficulty is experienced in obtaining staff in competition with the mining companies, who can generally pay higher salaries for similar experience. Required minimum qualifications are:

Subinspector -	permanent blasting certificate,
Assistant Inspector -	mine overseers certificate, high school diploma (Grade 12), and experience
Inspector -	University Degree or mine manager's certificate, 6 mo/1 yr as mine overseer, manager, or assistant inspector.

4.7.10 Impact on Mining

4.7.10.1 Ventilation

Good ventilation practices are an essential part of controlling the methane concentrations in the gold mines of the Orange Free State. These mines have high-capacity ventilation systems, designed to deal with high dry-bulb temperatures in the workings, as well as to effectively sweep all the working faces with high volumes of air to minimize gas build-up. Some details of the ventilation operations, typical of the O.F.S. mines, are provided below.

I Mine A

The mining method in use at this mine is primarily standard reef stoping. In the steeply dipping areas of the mine, sublevel caving is being used, but has been associated with several drawbacks, the more important of which are:

- (i) potential buildup of methane in the broken rock behind the drawpoints;
- (ii) reduced ventilation flow;
- (iii) loss of control of the ventilation system.

The virgin rock temperature (VRT) at the current working depth is 52.3°C and the mine operates at an average wet-bulb temperature of 29.2°C (84.6°F), and plans to operate at 31°C (87.8°F). Working conditions are monitored using a kata* (alcohol) thermometer.

The mine uses a combination of main fans on the surface and underground booster fans; total ventilation capacity is 990

* The kata thermometer measures the cooling power of the air in which it is placed.

m³/sec (2.1 million cfm). Booster fans are of both the axial (with adjustable-pitch blades) and centrifugal types.

The Ventilation Department consists of a chief Ventilation Engineer, three Assistants, and six observers. This department undertakes routine surveys of all working places.

II Mine B

The mining method at Mine B is standard reef stoping. Pillar recovery is practiced, and this creates some difficult conditions in terms of both rock stress and potential methane emission and control.

The present weighted mean rock breaking depth of the mine is 1401 meters below surface, at a virgin rock temperature of 39,7°C (103.5°F). The maximum working depth is 1800 m.

The main ventilation fans are located on surface and these exhaust air at a rate of 1000 m³/sec (2.1 million cfm). The system has been developed using high-volume, centrifugal high-pressure fans located on existing small-diameter shafts, and the maximum air velocity in the shafts is 3600 ft/min (18 m/sec). The main ventilation fans are supplemented with 75 hp booster fans located in the mine.

The ventilation system downcasts air to the lowermost levels, with return ventilation coursed through old stoping areas to reduce the pressure losses on the exhaust side. This also has the effect of reducing methane build-up in old working areas.

The Ventilation Department consists of nine staff and six observers. Surveys of all working places are carried out monthly and the work schedule is 11 days out of 14, up to 2 shifts per day. The installation of fans, seals, etc., is under the supervision

of the ventilation department. (This is not true of all mines, including Mine A.)

4.7.10.1a Stope Ventilation

A schematic stope plan is shown in Figure 3. The lower end of the stope is accessed by a raise driven from a stub crosscut off the main strike drive. The upper end of the stope is accessed by developing up-dip on the reef, then via a winze to a crosscut off the strike drive on an upper level. Stope faces are developed en echelon along strike. The broken rock is mucked, using a winch and slusher bucket, both along strike gullies and down-dip along the face, to boxholes leading to the lower level haulage.

The ventilation flow is up-dip and the air flow is controlled by extensible strike curtains (Klingseal) and the blasting barricades. Rubber brattice strips are used to prevent flow along the scraper gullies. This system provides a positive flow of air past all the working faces where methane emissions are likely to occur. The minimum required velocity at the stope face is 0.25 m/sec (50 ft/min), but a velocity of at least 0.5 m/sec to 1.0 m/sec is considered desirable by mine ventilation personnel to ensure adequate methane dilution.

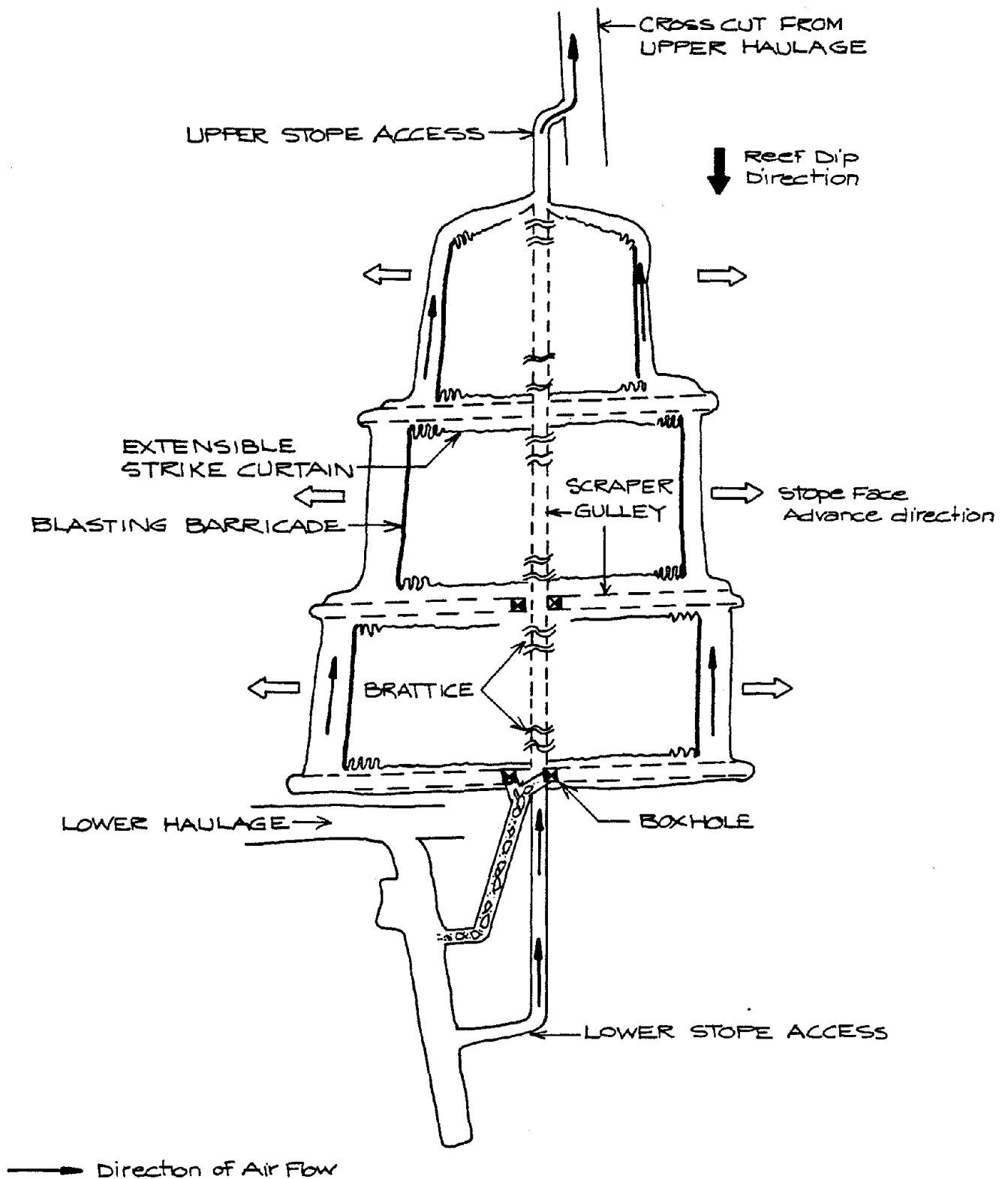
All old stopes not used for return ventilation airways are sealed off, using concrete brick walls with a core of vermiculite bricks. There is some advantage, the writer was told, to keeping stopes open where significant methane emissions are likely to occur for long periods of time. This provides an opportunity for dilution of the gas and helps prevent accumulations.

4.7.10.1b Heading Development

There is no statutory restriction on the length of single heading development, and ventilation is done by booster fans and fan bags, in accordance with written practice to avoid unplanned

TYPICAL STOPE VENTILATION LAYOUT

Figure 3



recirculation of exhaust air and possible methane build-up. A schematic development plan is shown in Figure 4. This shows development typical in a stoping area: the main strike haulage; main return airway; crosscuts to stopes, and reef raises. The detailed requirements for the positioning and operation of development fans are provided in the two references cited, published by the Chamber of Mines (30) (31).

The technique of controlled recirculation is being tried experimentally, to improve local conditions near a methane emission. This is a means of circulating, over a limited zone, an air quantity greater than the primary quantity available. This is achieved by operating a forcing fan (with a limited length of ventilation tubing) in opposition to the main air flow. The quantity and velocity in the airway is then effectively doubled along the length of the fan column. It is emphasized that the primary air quantity must be sufficient to dilute the total methane emission to below 0.5% as the finally diluted concentration will enter the fan. The purpose of this is to dissipate methane closer to its source.

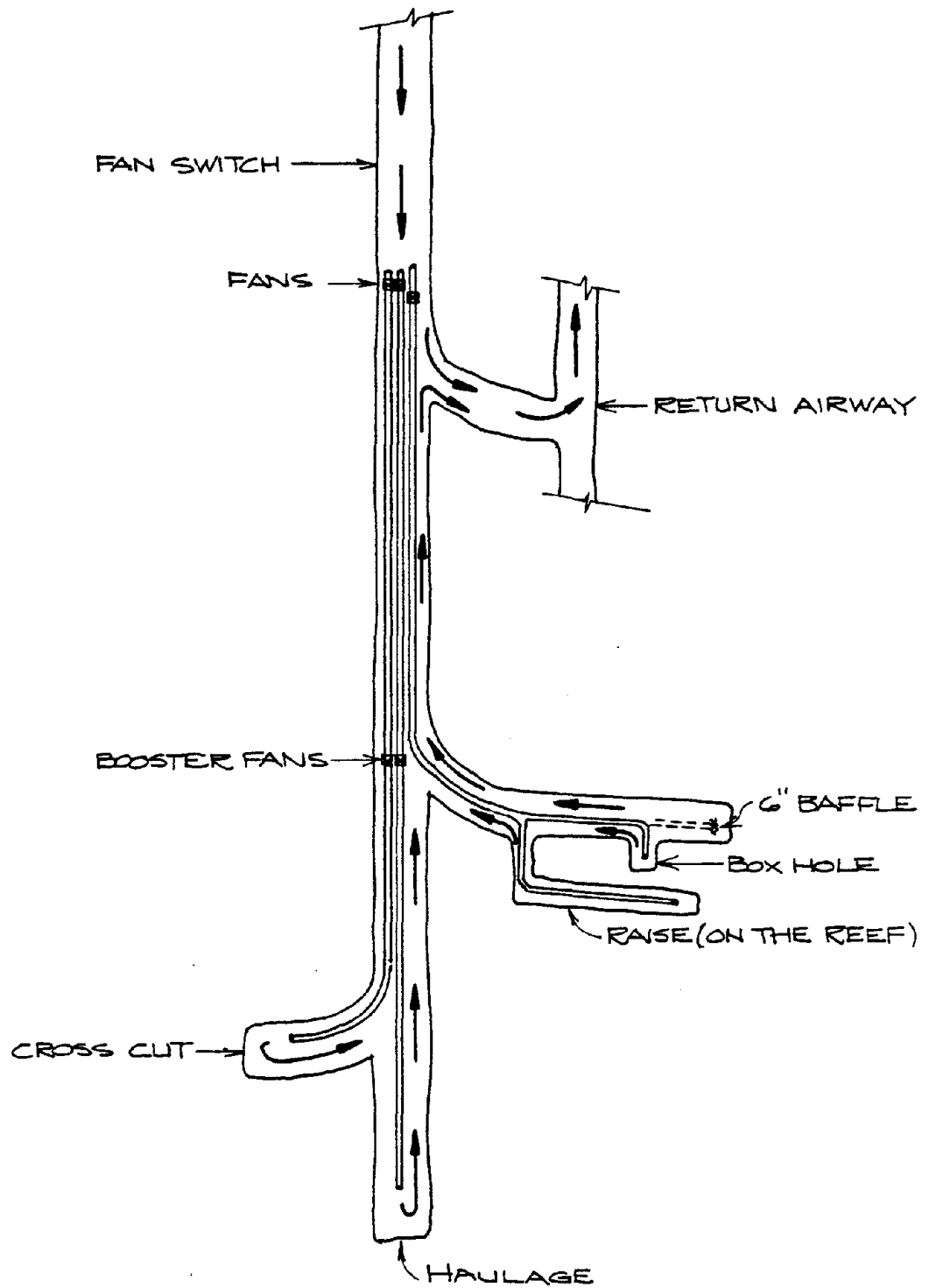
Methane sources in headings are normally dealt with by a forced system of ventilation, or a combination of force and exhaust with a brisk velocity across the face. Simple exhaust systems are not used. Where a system with an overlap is used, the overlap zone is checked regularly for methane, as this zone has the lowest velocity in the system.

4.7.11 Reporting and Monitoring

A reliable system of monitoring and reporting the appearance of methane is mandatory. The mines use a number of reporting procedures, all of which require the signature of several of the mine officials responsible for a given area. Examples of the various types of reports are:

TYPICAL STOPE DEVELOPMENT VENTILATION

Figure 4



→ Direction of flow

- a. Development Methane Report.
- b. Temporary/Permanent Stoppage of Development and/or Stope.
- c. Quarterly Abandoned End/Methane Trap Report.
- d. Methane Trap Report.

The Ventilation Department staffs use methanometers for measuring reported gas emissions. Methanometers are regularly checked and calibrated to ensure proper functioning.

Restricted areas (methane stress areas) are clearly marked on a plan kept in the Ventilation Department, and warning notices are placed underground at points of entry to these areas. Additional checks are required in restricted areas. These are at the following locations:

- (i) in each pilot hole in development headings;
- (ii) at all faults, dikes;
- (iii) in pilot holes in stope development;
- (iv) during and after ventilation failures.

Automatic methanometry employing alarms and automatic shutdown of equipment is not generally used in these mines, except in critical locations such as pump stations, sumps, around shafts, or in vulnerable headings or tunnel boring projects.

Routine mine environmental observations include regular monitoring for flammable gases by means of approved electronic methanometers in conjunction with the safety lamp, as required by law. Regular checks on methane levels in return airways and at known methane points are conducted by the Ventilation Department staff. Miners are required to make checks for methane at specified regular intervals during their shifts.

Hydrogen is known to occur with methane, and because of its low specific gravity, is even more liable than methane to form layers

in slow moving air currents. Hydrogen determination is performed by taking air samples for laboratory analysis.

4.7.12 Blasting

Production blasting is normally carried out once every 24 hours, at end of shift. The mine is required to report to the Inspector of Mines a list of all development ends where multi-blasting (more than once in 24 hours) is being carried out.

The blasting agent is normally ANFEX, using safety fuse and igniter cord. The igniter cord is fired electrically, by means of either an approved shot-firer from an authorized blasting position, or by the centralized blasting system. Normal production blasting is done using the centralized blasting system after all employees are out of the mine.

4.7.13 Pilot Headings

All development is preceded by pilot drilling, primarily to detect water intersections. As drainage water frequently contains methane, special drainage provisions are provided, including:

- (i) color-coded pipes to identify methane-bearing water;
- (ii) adequate ventilation volume and velocity at sumps where gas-bearing water is collected.

Advance headings into virgin rock are covered by extending diamond drill holes ahead of the advancing face. Water and gas emissions from these holes are recorded. In addition, four pilot holes are drilled to a depth of approximately 3 m in four directions before the 2 m shot-holes are drilled. This ensures that the round will not expose a dangerous accumulation of gas or water. Structural information is very helpful in identifying potentially gassy zones, since disturbed or faulted ground often

provides structural pathways for the migration of gas-bearing water.

4.7.14 Discretionary Options Available to Management Versus Statutory Requirements.

The Regulations as written are strictly enforced in the interest of the safety of workers. However, where conditions prevail such that full imposition of the Fiery Mine Regulations would create an undue burden, application is made to the Inspector of Mines, who may grant, with the permission of the Government Mining Engineer, such exemptions as are allowable without endangering workers and equipment. Where these exemptions apply, regular evaluation of the environmental conditions is made and the exemptions may be extended or removed at any time. Flexibility of the law regarding flammable gas is not at the discretion of the Mine Management alone.

**Gassy Metal/Non-Metal Mines
Within the United States**

GASSY METAL/NON-METAL MINES
WITHIN THE UNITED STATES

5.0

INTRODUCTION

The owners and/or operators of eight mines within the United States provided considerable assistance to Golder Associates during both the Phase II and the Phase III work. The commodities being mined in these eight operations include trona, potash, limestone, massive sulfides, uranium, and salt. Of the eight mines contributing to the study, seven are presently classified as gassy by the Mine Safety and Health Administration (MSHA).

The information in the following sections, in which the seven gassy mines are discussed individually, was obtained by various means. Meetings were held with mine operators, and a number of the mines were visited. In addition, MSHA records were examined so as to obtain more complete historical information concerning the events which led to some of the gassy classifications. Many informal discussions have been held as well with mine inspectors who had (or have) the responsibility of inspecting some of the mines under consideration. Thus we have endeavoured to present the information as factually and objectively as possible. Given that much of it was obtained by word of mouth, however, it may sometimes unavoidably be influenced somewhat by the personal opinions of those whom we interviewed.

The information which has emerged will, we believe, permit certain valid comparisons to be made concerning the relative merits and/or effectiveness of U.S. gassy metal/non-metal mine standards as opposed to the approach used in certain foreign countries. Any comparisons must, however, be drawn with some caution because, for example, what may be economically acceptable in one country or situation may not even be feasible in another. As well as the many technical variables which may affect this issue (grade of

ore, ease of mining, and so on), there are socio-economic variables (partly or wholly State-owned operations, militant labor unions, to name two of the more obvious ones) which make direct comparisons misleading. The information obtained will, however, provide the reader with a wider base from which to evaluate the present system of classification and regulation of gassy mines in the United States.

5.1 MISSISSIPPI CHEMICAL CORPORATION, POTASH MINE,
CARLSBAD, NEW MEXICO

5.1.1 Historical and General Overview

Mississippi Chemical corporation operates a potash mining facility near Carlsbad, New Mexico which recovers sylvite on a single horizon approximately 800 to 900 feet below the surface.

The first shaft was sunk at this mine during 1931 after exploratory drilling in the area for oil and gas had revealed the presence of potash in commercial quantities in the basin. This shaft (the No. 1), in use today as the down-cast shaft for main mine ventilation intake air, was followed by a second, sunk during 1931-32. These shafts were respectively sunk to depths of 1062' and 950' from surface. The mine has operated more or less constantly from this time to the present, with fluctuating but generally steadily increasing production.

In November of 1980 this mine was officially classified as a gassy mine by the MSHA after analysis of a single sample of air taken in the mine on August 18 of that year. The percentage of methane in this sample was given as 0.976; that of oxygen as being 5.89. By the time the analysis results became available, some eleven weeks after the sample was collected, the area in which it had been taken was no longer accessible; it was by then mined-out and had caved.

This sample was collected during a rigorous testing program initiated by the South Central District (Dallas, TX) of the MSHA in the aftermath of the 1979 disaster at the Belle Isle Mine. By November access was limited because of mining activity subsequent to the August sampling, and it was impossible to approach nearer than a point one thousand feet from the site at which the sample had been taken. Analysis of samples taken in the main returns and at other locations in the mine prior to August 1980 had

revealed only trace amounts of methane, with a high reading of 0.186% on August 30, 1979.

Historically the mine has no record of accidents, ignitions, or dangerous occurrences attributable to the presence of methane in the mine atmosphere. Tests in the mine since November 1980 have not revealed methane in greater than trace amounts. This (among other reasons) has caused the mine operators to challenge the imposition of the gassy classification on their operation. They are concerned at the delay which ensued following the taking of the August 1980 bistable ("cricket") sample before the results of its analysis became available (apparently 11 weeks), and are of the opinion that the analysis results are moot. They are particularly concerned by the apparent low oxygen reading (in an atmosphere in which men had been working without displaying symptoms of oxygen deprivation) and argue that no other test, either by the MSHA or the operators themselves, has ever indicated the presence of methane in hazardous or potentially hazardous concentrations.

5.1.2 Geological Environment

The potash mines of the Carlsbad area are all located within the same marine evaporite basin. The geology of the basin is well documented, (14)(15)(16) and will be discussed briefly here only insofar as it is relevant to a discussion of this particular mine.

The potash deposits are in the form of lenses within a sequence of beds of anhydrites and rock salt. This evaporite sequence is in some places as much as 3000 feet thick, but in others may be only 1000 feet thick. The potash lenses occur in what is locally known as the McNutt Potash Member, which is in the upper part of the evaporite sequence, and is of Permian Age. This member averages 300'-500' in thickness. The evaporite sequence is underlain by beds of sandstone and porous carbonates that have in the past

been targets for oil and gas exploration. The presence of structural pathways which might transport gas upwards into the orebody from these underlying formations has not been established. A basaltic dike of Tertiary age intersects the evaporites within the mining district but it has not been demonstrated that this structural feature is in any way associated with gas transport. This dike has not been encountered within the Mississippi Chemical mine workings in any case. The evaporite beds are for all intents and purposes horizontal and uniform, with the potash seams bounded above and below by more or less pure halite. The upper boundary between the sylvite and halite is marked by a weak layer of banded salt and mud, varying in thickness from one to two feet. The McNutt Member itself is bounded above by a marker bed composed of mudstone, and below by a bed of polyhalite (a hydrated sulfate of potassium, calcium, and magnesium). Above and below these marker beds lie beds of halite, known respectively as the Upper and Lower Salado Members. The halite in these beds is known to contain narrow mudstone seams and some clays, but is regarded as being essentially impermeable. The halite in the Upper Salado averages 500' in thickness while that in the Lower is approximately in the range >400', <1500'.

5.1.3 Formation Gases

Gases are encountered within the McNutt Member, the dominant one being nitrogen, which is thought to originate in the mud seams. The operators of the Mississippi Chemical Corporations potash mine informed us that they regard N_2 as much more of a problem than CH_4 . This gas enters the mine from caved areas where subsidence has ruptured gas-bearing mud seams and has thereby provided pathways by which the liberated gas may enter the workings. Methane usually either cannot be detected in the mine atmosphere, we were informed, or is measurable in trace amounts only (usually < 0.01% by volume). Nitrogen in the mine atmosphere does not usually exceed the levels normally present in air; historically, however, we were informed there have been occasions when nitrogen

blowing from pressure-relief holes has caused local concentrations high enough to warrant the temporary removal of personnel from the area. None of these events are recent, however.

Pressure-relief holes are drilled vertically upwards at all intersections as roadways and entries are developed, to relieve possible gas pressure, and to help to prevent possible roof falls. In addition, three such holes are drilled in each 50' x 400' room. These holes, which are of 1 5/8" diameter, are drilled upwards until they intersect a clay seam in the halite, 25 to 30 feet above the orebody. This clay seam is thought to be the source of any gas which may flow from the borehole. The operators informed us that less than 25% of these holes ever yield any gas. Typically, when there is a gas flow, it is a low-volume affair of only a few minutes duration before ceasing altogether. Very occasionally the gas will flow from the hole with sufficient force to create a draft discernible to a person standing beneath the collar of the hole. This, however, is rare, we were told, and there has never been a gas flow of sufficient volume or duration to necessitate piping the gas into the return air, or the removal of personnel for more than a few minutes. Analysis of gas samples taken from within these holes shows average concentrations of N_2 to be over 90%; those of CH_4 to be generally less than 5% (although one high reading of 6.37% is on record); CO_2 is generally less than 5%, and CO is generally less than 1%.

The mine has no history of violent outbursts of gas and particulate matter.

5.1.4 Mine Ventilation

The ventilation is by a negative-pressure system with two main fans located underground, one of which is held in reserve. The reserve fan is located at the foot of the down-cast shaft, and the operating collector fan is at the foot of the up-cast shaft.

The ventilation system total capacity is ~140,000 cfm; the mine ventilation is by series, and the volume of air is constrained by the existing shaft capacity. There are only two main-shafts, one down-cast and one up-cast. The operators claim that this provides sufficient air in each panel to transport dust from the working face, and that the distance between panels allows time for any dust in transport to settle.

5.1.5 Mining Method

The mining method was originally conventional room-and-pillar, but in 1975 the operators began converting to a modified retreatting longwall method, using continuous mining machines. At the present time this is the mining method employed. Transport from the panels to the shaft is by conveyor. Shuttle-cars supported by rubber-tired dozers (the latter are used to clean up) are used to transport ore from the continuous miners to the conveyor belts. Approximately 90% extraction is being achieved, with complete caving. Three entries are developed down the center of the panel for its full length, with the middle entry being used for ore transport. On both sides of these entries rooms 50' wide x 400' long are cut, leaving 8' pillars between the rooms. The seam being exploited averages 4' in thickness, dipping ~3 degrees, and mining height is dictated by seam thickness. The mine is designed to produce 6,200 tpd at an operating factor of 90%.

Mining is now carried on entirely on the 850' level. A raise, connecting the 5th level (850') to the 6th level, is used as a chute down which muck is passed to a feeder on the lower level. The 6th level is now mined-out but the loading pocket below the 6th level is still used to hoist ore to the surface.

Development entries are 6 1/2' high, and are taken, regardless of grade. Overlying the ore seam there is a layer of weak, banded salt and insoluble bentonitic mud. This material is too weak to stand in the back unsupported. To avoid roof falls therefore, a

practice has been adopted of always mining to the salt above this layer. The technique used is to mine out the potash seam as far ahead as the mining machine can reach, leaving a "brow" composed of the weak salt/mud layer. This is done so that the mining machine operator is never beneath the brow. When the cutter can no longer recover ore without placing the machine operator under the brow the salt/mud layer is secondarily mined (or "gobbed") as waste, into an adjacent mined-out room.

Production blasting has been phased out since the introduction of the modified longwall method of mining. The only blasting now performed in the mine is to clear occasional hang-ups in the mucking raise. Production mining is carried out entirely by continuous mining machines, of which the operation employs 7 Marietta 3080's and 1 Joy 14 PM (this is a modified type to handle potash mining).

5.1.6 Impact of Gassy Mine Citation

At the time of preparing this report the impact due to the gassy mine citation served on Mississippi Chemical Corporation in November 1980 is more potential than actual. The company has sought legal counsel and is disputing the matter. The MSHA have not forced the adoption of all gassy mine standards and the mine is operating under interim safety codes until the matter is resolved. No permissible equipment is presently in use, and for the very limited amount of blasting being done, standard explosives and caps with standard delays are used. The conveyors are in return air, and at the time of preparing this report these are standard, non-flameproof belts and motors.

The Marietta 3080 mining machines in current use are available in permissible form, therefore a conversion would not greatly affect productivity. Conversion of existing mining machines, support equipment, and conveyors to flameproof type would, however, be

required. The main area of potential impact concerns the ventilation system. To fully comply with the gassy mine standards would require a very considerable increase in the capacity of the system, necessitating additional shaft capacity and extensive modification of the network. At least one additional up-cast shaft would be required, and underground, bulkheaded booster fans, control bulkheads, and auxiliary fans would be necessary. An additional main fan (on surface) would also be required to provide the necessary airflow, and the main fans which are at present underground would have to be moved to the surface. All of this would represent considerable capital outlay.

5.1.7 Summary

The potash facility operated by the Mississippi Chemical Corporation in the Carlsbad area of New Mexico has been in continuous production since 1931 when the first shaft was sunk. Throughout the life of the mine the operators have noted the presence of gas in the mud/clay seams which are present in the formation. One of these shows as a marker bed in the roof/hanging-wall, and another as part of the evaporite sequence overlying the orebody. The gas has historically always been composed of >90% nitrogen, with the remaining percentage composed about equally of oxygen and methane, with trace amounts of carbon dioxide. These gases have never been considered a problem; the flows are low-volume, short-duration affairs, and the mine has never experienced a gas-related accident or ignition. As a routine procedure, pressure-relief holes are drilled upwards from rooms and intersections, to drain gas from an overlying clay seam which is prone to dislocation when mined-out panels cave. Typically, these relief holes yield only minor gas, and in the majority of cases no gas at all.

In November 1980 the MSHA classified the mine gassy on the basis of a single bistable sample collected in panel 210 in August of that year. This sample indicated a concentration of 0.976% methane, 0.05% ethane, and 5.89% oxygen. The mine is currently

operating under interim, partial standards, pending the outcome of legal proceedings which the operators have initiated, contesting the validity of the gassy citation.

5.2 COTE BLANCHE MINE, ST. MARY'S PARISH, LOUISIANA

5.2.1 Historical Overview

The Cote Blanche Mine is operated by Domtar Industries, Inc., a wholly owned subsidiary of Domtar Inc. The mine has been operating since 1964, and recovers salt from a domal structure on the coast of the Gulf of Mexico, southeast of New Iberia, Louisiana. The mining method is conventional room-and-pillar, with production averaging approximately one million tons per year. The mine was declared by the MSHA to be a gassy mine after methane levels in excess of 0.25% were recorded in July, 1979. These methane readings were obtained during the so-called Operation Salt Dome, a period of intensive inspection instituted by the South Central District office of the MSHA in the aftermath of the June 1979 disaster at the Belle Isle mine. At the time of preparing this report the mine is still in the process of being modified to comply with gassy mine standards. By agreement with MSHA, Cote Blanche has been operating under partial standards only since 1979.

5.2.2 Geological Environment

The geology of the deposit is that of a typical domal salt piercement structure, and will not be discussed in detail. For a complete discussion of the mine geology of the Cote Blanche operation, the reader is referred to an earlier Golder report, prepared for the Gulf Interstate Engineering Co. (16)

The mining activity is not permitted to approach the periphery of the salt dome but is carried on as nearly as possible in monolithic salt, and the mining level was chosen to coincide with a zone of high salt purity at depths ranging between 1300 and 1400 feet below the surface. A summary of the mine geology, taken from the above referenced Golder Report, is as follows:

- As part of the formation of the dome, the originally bedded salt has flowed into complicated fold patterns with steeply dipping axes. This layering appears as light and dark bands of variable widths and spacing in the roof of the mine.
- The layering is aligned in a general north-south direction although there are many tight twists, turns and complicated folds throughout.
- Two distinct foreign inclusion types were identified in the mine, the first being a yellow to orange coloration and the second a darker reddish-brown to dark brown coloration. These inclusions contained potash minerals (sylvite, kieserite) and sediment particles. In some cases the yellow to orange inclusions were in a distinct vertical to subvertical bed up to 18 inches thick which parallels the layering direction. These beds pinch out and re-appear over a number of headings. In other cases the only evidence was a yellow to orange staining. The darker inclusions generally occurred in thin bands exactly following the layering and contained round inclusions of fine-grained sediment. The yellow/orange inclusions are difficult to mine through because of their hardness.
- The inclusions were evidenced in most sections of the mine although the darker inclusions were only noted in the southern part of the mine. The darker inclusions had a higher aluminum content than the yellow/orange inclusions.
- Only minor petroleum leaks have been identified in the mine and no leaks were noted during the present mapping program.

- There was very little evidence of water in the mine. The accumulation at the base of the service shaft results from condensation of moisture from the intake ventilation air. Two small pools of water and an area with a small amount of dripping water were noted in other parts of the mine. The origin of this water is not known, but it is associated with potash-containing bands.

5.2.3 Formation Gases

Methane gas is present in the mine, as a constituent in hydrocarbon gases similar in composition to the natural gas which occurs in the oil and gas-bearing formations of the Gulf of Mexico. With regard to the occurrence of methane the operators of this mine stated (Statement Submitted by Domtar Inc. on behalf of Domtar Industries, Inc., Gassy Mine Conference, May 4, 1982, New Orleans, Louisiana),..."Methane occurs in the Cote Blanche Mine. Typically it occurs in the intragranular interstices in crystalline (*sic*) salt and in the phenomenon known as 'blowouts' (local nomenclature peculiar to the Southern salt mines). On the crystalline portions of the deposit, some 25% in the known areas of the mine, the amount of interstitial methane is so low as to be difficult to detect with normal monitoring equipment".

In 1977 Golder Associates performed a complete geotechnical study of the Cote Blanche mine for the Gulf Interstate Engineering Co. (The mine was at that time under consideration as a potential underground oil storage reservoir). The Golder Associates report (17) states,...

- At two locations in the mine, large openings termed pressure pockets have developed. The mechanism by which these form is not known but they seem to be invariably associated with gas emissions. It is not

possible to predict at this stage when and where pressure pockets will develop.

- Common characteristics of pressure pockets are as follows:

- (a) Most are observed in the roof of the mine with a smaller number in the walls.
- (b) None have been identified in the floor.
- (c) All have developed at the time of blasting.
- (d) Most have a conical shape with a round to oval opening at the salt face.
- (e) Near the peak of the pressure pocket, the jointing results in a distinct target appearance with concentric rings spaced two to three inches apart.
- (f) Closely spaced parallel jointing (one inch spacing) is often present at the mouth of the pressure pocket. These have the appearance of closely spaced exfoliation joints.
- (g) Pressure pockets are often associated with tight folding and inclusions.
- (h) Their orientation does not appear to be related to the layering direction.
- (i) The pressure pockets contain medium to coarse grained salt prior to their actual formation.

- The largest pressure pocket at Cote Blanche mine is estimated to extend 60 ft. above the roof of the mine.

- The core obtained from one of the holes drilled into the line of pressure pockets consisted of relatively porous salt, and gas was given off from the hole. It seems likely (although unconfirmed) that the salt within the pressure pockets is also quite porous.

Whilst pressure pockets have not been located in the floor, zones of more porous salt may exist.

- Pressure pockets in excess of 120 ft. high have developed in other salt dome mines in southern Louisiana. Pressure pockets in other mines are more prominent at depths greater than 700 ft. below surface.

It is apparent from this, and from information given to us by the mine operators, that Cote Blanche is prone to outbursts of gas and rock, but that during the intervals between these events the mine is relatively free of gas. The frequency with which these blowouts occur (or have occurred) could not be established since they are not documented. The MSHA records of Cote Blanche refer only to recorded gas levels since the mine was declared gassy in 1979, and contain no reference to the mode of occurrence. In any event, we were informed by the mine operators that there had been no more than 12 or 13 outbursts during the life of the mine, and that the quantity of gas released and its composition on release is not known. The information which we have obtained indicates that, aside from the question of outbursts of gas and rock, other emissions of methane into the mine workings are small, but that they do occur. It seems reasonable to suggest that the greatest threat to safety in this mine comes from the possibility of unpredictable violent outbursts of gas and rock on a large scale.

The mine was declared gassy on the basis of readings taken with hand-held methanometers on July 7, 1979. A reading of 0.4% was recorded by the mine production foreman, on top of a muck pile after a scheduled blast. Later the same day, and in the same area of the mine, a MSHA inspector (also using a hand-held methanometer) obtained legal readings of 0.3%, 0.5%, and 1.2% methane (the last was obtained on top of the same muck pile). According to the inspector's notes the area was "poorly ventilated" at the time,...there is no elaboration. Air analysis of samples taken in the same area indicate rather high methane

(<0.94%), and MSHA records do in general show that methane is randomly present in trace amounts (<0.1%) in almost every part of the mine.

The source of the gas at Cote Blanche has not been the subject of serious study apparently, and is therefore not well understood. Gas desorption tests have not, as far as we have been able to determine, been done on core samples of impure and/or crystalline salt, and little is known about the gas content of the formation or the potential for violent outbursts. The observed nature of the cavities formed by the blowouts which have occurred (the "pressure pockets" referred to above, see previous Golder Report (17)) shows a similarity to those observed and documented in East and West Germany, Poland, and elsewhere (see Appendix XIII). Zones of impure salt exist within the orebody; these are of two types and both appear to be possibly gas-bearing. The more important of these are occasional bands of sandy potash, 5-6 feet thick; the other consists of zones of crystalline, discolored salt which has been intruded by brines and is possibly secondarily crystallized. It is not known whether the potential for a large-scale, possibly catastrophic blowout of gas and rock exists, but the possibility of such an event occurring should not be ignored.

5.2.4 Mine Ventilation

The mine operators informed us that they regard the existing ventilation at Cote Blanche as being marginal.

The mine is serviced by two main shafts, one of which is a production shaft of 14' diameter, and the other is a service shaft of 8' diameter. The 8' diameter shaft serves as the ventilation downcast shaft, and 2 main fans are located underground at the bottom of this shaft. The ventilation is thus a forcing system. This 8' diameter shaft limits the overall capacity of the system, which is approximately 125,000 cfm. The underground network is

augmented by approximately a dozen auxiliary fans, and is regulated by stoppings and brattice lines.

In the absence of gas the main contaminants in the mine atmosphere are diesel fumes, and fumes and dust from blasting (the mine is very dry, which tends to create a rather dusty environment, under normal operating conditions).

5.2.5 Mining Method

As mentioned previously, the mining method is conventional self-developing room-and-pillar, with room dimensions 50' x 50' on 150' centers. The mining level is 1360' below the ground surface. Ore extraction is by undercutting, drilling, and blasting in two lifts. A top heading of 25' x 50'-55' is undercut and blasted, with a normal advance of 12 1/2' per round. A 55' high bench is then blasted, using vertical shot holes over a basal undercut; normal bench advance is 15' per round, and bench mining may follow top heading development by anything from a few months to a few years.

Ore transport is a conventional load-haul-dump operation, utilizing Caterpillar 769C trucks and 988B loaders. Underground haulage distances may be as much as 1200 yards, and crushing, screening, and beneficiation of the salt is performed underground. There is underground capacity for the stockpiling of approximately 20,000 tons of ore and finished product to absorb process fluctuations.

Finished product is hoisted to surface and shipped from the facility by barge.

5.2.6 Impact of Gassy Mine Citation

The operators of Cote Blanche have estimated that it will necessitate an initial capital outlay of \$2.2 million, and

increased operating costs of \$400,000 per year, to make the mine conform to MSHA gassy mine standards for metal/nonmetal mines.* At the time of this writing the operation has not been fully modified to conform to all the standards, but is operating under certain safety-oriented strictures which were not in effect prior to the 1979 citation. These are:

1. All primary blasting is now done from the surface, at shift-change, with all personnel evacuated from the mine. (Blasting agent is ANFO, electrically detonated, using indirect priming, millisecond delay caps, and no stemming).
2. No smoking is permitted in the mine.
3. Three continuously-monitoring methane sensors have been installed in the workings at points decreed by the MSHA. Of these, at least two are required to be in-by advance face blasting (in return air from blasting points).

In addition, complete conformity with the gassy mine standards will require that the following changes be effected.

1. The main fans shall be removed from their underground location to the surface (estimated cost \$750,000).
2. The ventilation network underground will be modified to permit the complete separation of intake and return air. This will necessitate installing bulkheads, brattice lines, and permissible auxiliary fans. Estimated cost of these changes is approximately \$450,000 without including the cost of new, permissible fans.

* These figures, and all other cost estimates, are in 1982 dollars and were supplied by the parent company, Domtar Inc. They are preliminary estimates and include only major items.

3. Seismic/acoustic monitoring capability will be installed to monitor all blasting, and to permit the detection of secondary blasts caused by possible outbursts of gas and rock (estimated cost approximately \$40,000).
4. Comprehensive, remotely-read methane detecting capability will be installed to cover key points in the mine workings. The estimated capital cost of this is \$150,000.
5. Underground electrical circuitry and lighting will all be converted to permissible type, at an estimated cost of \$160,000.
6. Existing permissible equipment (purchased from the beginning of 1979 onwards, in anticipation of the gassy classification) must be up-graded. Preliminary estimates indicate a cost of about \$200,000 to do this.

The ventilation capacity can be increased by about 40% using the existing shafts. Should it be necessary to increase capacity to the point where an additional shaft is required then the costs would increase considerably. Because of water-bearing members overlying the salt, ground-freezing would be necessary in order to keep water out of the mine during shaft-sinking. Some 500 vertical feet of ground would have to be frozen. To take a shaft of 18' x 21' dimensions from surface to 1360' below surface (the level of the mine) is tentatively estimated to cost \$7.5 million.

Other ongoing costs are those arising from pre-shift examination of the workings for gas. Pre-shift examinations would necessitate paying a hoist-man and the two men carrying out the examination for an undetermined amount of extra time, and could cause

up to three hours per day of down-time for the main underground work force.

5.2.7 Summary

Cote Blanche Mine has experienced minor levels of methane gas due to small-scale, random and discontinuous emissions from the formation throughout the life of the mine. These emissions have seldom resulted in more than trace amounts of hydrocarbon gases entering the mine, with methane levels typically less than 0.1% of the general body of air. More importantly, the mine, which commenced operation in 1964, has, throughout its life, experienced an undetermined number of outbursts of gas and rock. These events are not documented as such, but apparently have always been associated with blasting, and there have been no recorded accidents or ignitions attributable to them. This, and the fact that they would have taken place at shift-change and so would not apparently have interfered with production or endangered personnel, may explain the lack of documentation. In these circumstances there would be no mandatory reporting requirement. In any event the volume of gas released into the mine by outbursts of this kind is unknown, and the phenomena do not appear to be well understood. The mine was declared gassy on the basis of readings taken with a manually operated methanometer in July of 1979. Air samples taken in the same part of the mine at that time confirmed the presence of methane in a concentration greater than 0.25% (the air samples contained up to 0.94% methane). It is noteworthy that the known potential for this mine to experience outbursts of gas and rock, and the known dangers associated with the occurrence of these phenomena around the world, played no ostensible part in classifying the mine as gassy.

5.3 LISBON MINE, RIO ALGOM CORPORATION, MOAB, UTAH

5.3.1 Historical and General Overview

Lisbon Mine is located south and east of Moab, in southeastern Utah and is owned and operated by the Rio Algom Corporation. The mine has been producing uranium from an underground, room-and-pillar operation since June, 1972. At the time of this writing however, mining activity is restricted to pillar extraction due to depressed market conditions. The mine was issued a gassy citation in April 1973, after an ignition of flammable gas occurred in a roof cavity in a blind heading. The roof cavity had been created during development work approximately 3000 feet below surface preparatory to raise-boring. The ignition occurred when a welder climbed up into the roof cavity to use an oxy-acetylene cutting torch. The welder received burns, but no fatalities occurred, and there were no other injuries; the ignition was confined to the immediate area of the raise.

Since that time the mine has operated under the gassy mine standards applicable to metal/non-metal mines, with certain modifications. No serious accidents or fatalities which are attributable to flammable gas have occurred in the mine, although there have been several occurrences of gas containing significant amounts of methane. The most important of these occurred early in 1979 when three separate outbursts of gas (which contained at least some methane) and rock occurred, between March 29 and May 17. The largest of these ejected an estimated 250 tons of fragmented rock into the adjacent cross-cut and drift (3).

5.3.2 Geological Environment

The Lisbon Mine orebody is a sedimentary-type uranium deposit of the primary peneconcordant type, on the down-throw side of the Lisbon Valley Fault. The uranium is disseminated in fluviatile sandstone in the lower part of the Moss Back Member of the Chinle

Formation (of Triassic Age), and occasionally on the erosional unconformity cutting into the underlying Cutler Formation, which is Permian. For a detailed discussion of the genesis of the uranium orebodies of the Lisbon Valley in particular, and of the Colorado Plateau in general, the reader is referred to Wood, Adler, and others (18)(19)(20). The subject is complex, and goes beyond the scope of this report. The Lisbon orebody lies reasonably flat, and the pay zone is of an approximate average thickness of 3 feet. The host rocks are all sandstones and shales, and the mining level is approximately 2500 feet below ground surface. The mine experiences relatively large inflows of water on occasion, and some mined-out areas of the workings are now flooded.

5.3.3 Formation Gases

The uranium orebodies of the Colorado Plateau are commonly associated with shales and cherts, and not infrequently contain coalified plant remains (19). It is reasonable to assume that these formations have the potential to produce gases when they are disturbed by mining activity.

At Lisbon, traces of methane gas were encountered during shaft-sinking; the gas did not appear in serious concentrations and did not create a problem. Later, in April 1973, the ignition referred to in 5.3.1 occurred; this ignition, which occurred in a blind heading, resulted in the mine being certified as gassy by the MSHA. The mine operators contend that the ignition may have resulted from gas (acetylene) leaking from a defective welding kit cylinder, and that it was not clearly established that it was due to naturally occurring flammable gas (the specific gravity of air is 1.0; that of methane, 0.55; that of acetylene, 0.91). The gas was identified as a hydrocarbon. This was, and is, the only recorded ignition of gas in the mine workings.

In the early part of 1979, between March 29 and May 17, three outbursts of gas and rock occurred in the mine (3). The gas involved in these events was confirmed as having a methane content (3), but the MSHA report shows some discrepancy concerning the times at which the methane readings were taken. Bistable ("cricket") samples taken in 342 drift, and at other locations in the mine on April 2, 1979, show a range of methane concentrations between 0.23% and 0.66%, with an average of 0.40% (MSHA records). During the almost seven years of operations prior to these events there were no outbursts recorded, however, and their causes remain unexplained. All three immediately followed a scheduled production blast, and after the first one the blasting crew, upon re-entering the area, obtained a reading of 3.5% methane on a hand-held methanometer in the 137 drift, at a site approximately 100 feet out-by the site (3). MSHA records (3) indicate levels of approximately 1% methane in the area of the outburst two hours after it had occurred.

Readings of methane (derived from samples taken in the main returns) by air analyses since these outburst events have been extraordinarily low (0.02%, 09/25/79; and 0.007%, 02/16/82). From MSHA records, the average methane concentration in samples from the main returns appears to be in the vicinity of 100,000 ft³ CH₄/24-hour period. This represents a percentage concentration of about 0.02 in the general mine atmosphere.

In Panel No. 3 during May and June 1978, methane levels in excess of 5.0% were recorded by mine personnel (hand-held methanometers capable of reading up to 5.0% concentration were pegged at full-scale deflection). These readings were not considered representative of the mine atmosphere, however, since the gas was apparently emanating from adjacent mined-out and previously sealed-off areas which had flooded (at the same time mine personnel recorded hydrogen sulfide concentrations of up to 15 ppm). Other similarly high methane readings have from time to time been recorded by mine personnel (1973, 1974) inside probe holes which were bleed-

ing some gas at various locations. On occasions high methane levels in probe holes have caused the temporary cessation of work (ordered by the operators) in those parts of the mine wherein the particular holes were located.

The source of the methane which apparently enters the mine atmosphere in varying concentrations more or less continuously is not well understood. The evidence suggests that the gas emanates from within the orebody; the host sandstone contains shale stringers, and possibly both the shale and the sandstone contain carbonaceous materials of organic origin. No tests have been performed on core to try to determine gas content. The mine is on a reduced schedule at the time of this writing, with activity confined to pillar extraction. Almost complete caving is being induced but no significant methane is being detected in the working areas.

5.3.4 Mine Ventilation

The ventilation was originally designed with high capacity to deal with radon daughters; when the mine was in full production (prior to 1981) ventilation capacity averaged approximately 322,500 cfm of air. As of February 1982, due to reduced mining, capacity has been cut back to approximately 220,000 cfm.

The system consists of 4 main fans on surface (one of these is permanently shut down because of reduced mining). The system is negative-pressure, the fans being located at the top of the up-cast shaft (there are two main shafts). All work areas are on a separate split of air, with permissible auxiliary fans underground (there are two of these in current use). No booster fans are used.

5.3.5 Mining Method

The mining method is conventional room-and-pillar with sublevel haulage. Mining is accomplished by conventional drill-and-blast, with average pull per round in the range 8 feet - 10 feet. Main haulage is by rail 60 feet below the working level. Haulage to ore-passes is by rubber-tired diesel LHD units. The mine work force is about 50% unionized, and contract mining is carried on (i.e., a majority of the underground work force is paid production incentive bonuses). The blasting agent used is ANFO, using electric detonators.

5.3.6 Impact of Gassy Mine Citation

The mine operators drill pilot holes ahead of all development headings and working faces. These holes are required to be 20 feet long, but we were informed by the operators that they frequently drill pilot holes up to 500 feet ahead of development works, probing for water which they regard as more of a problem than gas (it is noteworthy that the company had instituted a pilot-hole drilling program prior to the 1979 violent outburst events).

Lisbon Mine continues to operate under only partial gassy mine standards. Variance from the standards has been allowed in the continued use of ANFO as a blasting agent, and blasting is permitted with personnel underground. The ANFO is detonated electrically, using millisecond delay caps, bottom priming, and sand stemming. The operators contend that the use of millisecond-delay caps causes them a maintenance and operating problem in that the use of these caps generates undesirable quantities of fly-rock. The variance was granted on the ground that permissible explosives are not strong enough to be economical in production blasting in this mine due to the strength of the rock.

The diesel LHD units are Schedule 24 type (not permissible). Five Schedule 31 (permissible) units were purchased but were found to be expensive to maintain and "unreliable", we were told. The company has applied for variance on this issue and the Schedule 24 machines remain in use (Eimco 911's with Deutz air-cooled diesel engines). The ventilation system, because of its large design capacity, has not required modification, but auxiliary fans operating underground are of permissible type.

Variance has been granted on crosscuts; these are spaced up to 250 feet apart instead of the 100 feet called for in the gassy mine standards. Since mining is being performed on one level, only the matter of crosscut frequency has not been as critical as it would be in a multi-level mine. Electrical circuitry underground is of permissible type. The operators were not asked to make an exact assessment of the cost burden imposed by their present level of compliance with gassy mine standards, but stated that full compliance in the market conditions of 1982 would force them to close the mine.

5.3.7 Summary

The Lisbon Mine, operated by the Rio Algom Corporation, southeast of Moab, Utah, is the only operating uranium mine in the United States which is classified gassy. The mine commenced operations in 1972, and was classified gassy after an ignition of flammable gas occurred in a blind heading roof cavity during development work in April 1973. Between 1973 and 1980 when the mine was in full production methane was detectable in the mine in usually very low (less than 0.1%) concentrations. Mine personnel occasionally (1973, 1974, 1978) recorded dangerous methane concentrations (5%+) in probe holes in isolated areas of the mine, causing them to temporarily suspend work in those areas until the gas had ceased to bleed from the holes. In the period March-May 1979 three outbursts of gas and rock were reported by the mine operators; a methane content was confirmed in the gas in all

three events. Since going on to a reduced production regime in 1980, methane in the mine has become almost non-existent (no new development work is presently being done), with concentrations in the main returns typically less than 0.02%. The mine continues to operate under modified standards only, and since 1973 no ignitions, injuries, or fatalities attributable to mine gases have occurred.

5.4 WEEKS ISLAND MINE, MORTON SALT COMPANY NEW IBERIA, IBERIA PARISH, LOUISIANA

5.4.1 Historical and General Overview

The Weeks Island salt mine is located at Weeks Island, Louisiana, on the coast of the Gulf of Mexico, just south of the city of New Iberia. The mine is owned and operated by the Morton Salt Company, who took over the operation from the Myles Salt Company in the late 1940's. The original mine (referred to as the "old" mine by the operators) was requisitioned by the Department of Energy in September 1979, and is now used for underground oil storage. The mine currently being operated has not yet reached full production, having only commenced operating in 1981. The operators finally vacated the old mine in September 1981. The mines are adjacent, within the same domal salt structure, but are not in any way connected. The new mine operates on a single level approximately 1240 feet below the surface; the old mine operated on two levels, 370 feet and 700 feet below surface respectively, and had been operating at least since 1901.

The old mine was classified gassy by the MSHA on the basis of a sample taken on July 3, 1979 in E-3-Left Room. Methane concentrations greater than 0.25% by air analysis were obtained in this area from bistable samples after a hand-held methanometer gave methane readings approaching 1.5% in the vicinity of (but not inside) an undercut. Methanometer readings legally taken in the area at that time range from 0.3% to 1.45% (MSHA records). We were informed that independent analysis of samples taken in the same locations by the operators have shown considerably lower methane concentrations than this, however.

Production in the old mine prior to its closure was about 1.2 million tons/year. In July 1982, production in the new mine is running at a level approximately equivalent to 1.2 million tons per year.

The new mine was classified gassy shortly after it commenced operating when a 1% methane concentration was noted in a closed heading in the western part of the mine. The information available to us at this writing does not make clear whether this methane level was obtained by air sample analysis or by a reading on a methanometer. Neither mine has ever experienced a gas-related accident, although in the old mine relatively small scale outbursts of gas and salt had been known to occur.

5.4.2 Geological Environment

The Weeks Island salt mine is located within a typical Gulf Coast piercement domal structure which does not significantly differ geologically from those being exploited at Belle Isle, Cote Blanche, and Avery Island. Piercement domes are formed when salt at great depth undergoes plastic deformation due to the static pressure of overburden and moves upwards by displacing unconsolidated sediments and/or by following structural pathways along faults. For a detailed discussion of the formation of salt domes along the Gulf Coast, and of the Weeks Island dome in particular, the reader is referred to Hanna (21)(22) and Kupfer (23), respectively. Typically, as domes of this type rise, they cause complex faulting of the overlying sediments. Frequently the salt will be intruded by anhydrites, brines, and other impurities. It is not uncommon to encounter zones of discolored, secondarily crystalized salt, particularly in the vicinity of the periphery of the dome. The salt encountered in mining operations at Weeks Island is for the most part monolithic, but contains finely disseminated sandstone. The operators informed us that the mine is in "good ground" and that they do not experience problems related to ground control. Sediments enclosing the dome are marked by radial fault patterns, and bands of anhydrite are noted within the salt.

5.4.3 Formation Gases

The Weeks Island mine was originally classified gassy on the basis of a methane reading in excess of 0.25% obtained in E-3-Left Room of the old mine on July 3, 1979. Strangely, the inspector's notes concerning this, although specific concerning the exact time, place, and sampling point, do not give the value of the methane reading itself!

Bistable ("cricket") samples taken during the period 7/9/79 to 7/26/79 show methane levels ranging from 0.01% to 1.038% with five samples out of a total of 21 showing methane concentrations greater than 0.27%. All of this occurred in the old mine.

We were informed by the mine operators that (and again, this information applies only to the old mine) methane was detectable in the mine in minor concentrations from time to time, but never created a threat to safety. The situation was routinely monitored by the operators, who performed methanometer checks in all the working areas at the beginning of every shift, and after blasting. The gas occurred occasionally as low-pressure outflows from drillholes, and in newly cut or broken material, typical concentrations being $\leq 2.0\%$ (obtained with a methanometer) inside the mouth of a hole or in a fresh cut. These flows were typically of low volume and short duration, we were told. The gas content usually was dominantly methane, but there was often significant CO_2 and N_2 (i.e., significant as a percentage of the total gas flow). These outflows were only observed in the western part of the mine. In other areas methane appeared only in trace amounts, with concentrations being in the order of 0.006% in the main returns.

The source of the gas was never really identified with certainty, but it was noticed that areas in which outflows occurred were occasionally associated with a higher-than-usual concentration of disseminated sandstone in the salt. We are not aware of any

tests ever having been performed on salt samples to establish gas desorption rates, or to try to identify a gas source. The reason for this omission is probably the fact that the gas never caused any problems to the operators.

The old mine experienced occasional outbursts of gas; these are not documented, but were described as being "comparatively minor", and without exception they followed blasting. No ignitions, or accidents of any other kind, were ever associated with these events.

In the new mine, which commenced operations in 1981, small gas outflows from drillholes are occasionally noted in the western part of the workings. No outbursts have so far occurred in the new mine, which was not initially classified gassy and only became so after an MSHA inspector obtained a reading of approximately 1.0% methane in a closed heading. In this particular area, small amounts of water enter the mine, and the operators do not consider the area to be representative of the mine in general.

Documentation of gas levels in both the old and the new mines by MSHA show very minor concentrations for the most part. The gas levels definitely identified by MSHA inspectors as being legal samples (and/or readings) lie for the most part in the range 0 to 0.1% methane. The mine was subjected to intensive investigation by the MSHA during July 1979 as part of the so-called Operation Salt-Dome, referred to in previous sections.

5.4.4 Mine Ventilation

At the time of this writing (July 1982), the ventilation capacity of the mine is 166,000 cfm, with one main fan on the surface. Capacity of the fan is actually (and was formerly) 254,000 cfm, but the capacity has been down-graded to fit the needs of the much smaller new mine. This down-grading was achieved by

changing down from a 400 hp to a 250 hp motor on the main fan. There are 10 auxiliary fans underground; these were not apparently all in operation when the MSHA inspector was making the inspection which resulted in the new mine being classified gassy. The mine is operating with two 18-foot shafts, for air, hoisting, and service.

5.4.5 Mining Method

The mining method at Weeks Island is room-and-pillar, using undercutting, drilling and blasting, with production running at approximately 100,000 tons per month. Haulage is by rubber-tired 35-ton end-dump trucks from the face to an underground stockpile. Mucking and loading is by 955 (Fiat-Allis) front-end loader. Mining and haulage is all on one level, 1240 feet below ground surface. Salt is crushed and screened underground, and is fed to the crusher from the stockpile by conveyor belt. Rooms are approximately 70 feet by 90 feet high; crosscuts and entries are 70 feet wide. Rooms are developed by taking a top-slice 25 feet high by 70 feet wide, and then benching down to give a final room height of 90 feet.

The face undercut is made with a coal-cutter; the blasting agent used is ANFO; extraction ratio is about 55 percent.

5.4.6 Impact of Gassy Mine Citation

The operators have made a preliminary estimate of between \$800,000 and \$1,250,000 as being the cost of what they see as a feasible level of compliance with the gassy mine standards, but stress the fact that until the required level of compliance is defined by the MSHA, it is very difficult to quantify this figure. This is their estimate of the cost of upgrading the ventilation, and installing permissible electrical circuitry and lighting underground. The cost is held down by the fact that much of the equipment in use underground was of a permissible

type before the issuance of the gassy mine citation (permissible equipment of certain types was already in use in the old mine). For example, the auxiliary fans are all of permissible type, as are the cutters. A problem arises with the load-haul-dump element of the operation, however, because the equipment in current use (955 front-end loaders and 35-ton end-dumps) is not available in permissible form from the manufacturers. The operators claim that if they are not granted variance from the standards with regard to these machines, and are forced to adopt the use of smaller, permissible types of equipment, the resulting loss of productivity could be critical (the capital cost, they claim, although considerable, would not be as significant). The ventilation could be up-graded by reverting to the use of a larger motor on the main fan (the 400 hp motor previously in use is still serviceable and in reserve). The existing shaft capacity is seen as being adequate for all ventilation needs.

The gas monitoring program has been up-graded. This is for the most part voluntary on the part of the operators. Each foreman carries out a pre-shift check for methane, carbon dioxide, carbon monoxide, and oxides of nitrogen. These checks are made at all working faces, as well as in the main intake and return air.

In addition, checks are made for methane in the immediate vicinity before and after every blast. These checks are all made with methanometers, and the procedure results in an average of four to six checks for gas every day.

Bottle samples of mine air are taken weekly in order to verify methanometer readings, and as a check on MSHA findings. These samples are taken in the main returns after production blasting, and in the vicinity of the working faces before and after blasting; after face drilling; and after undercutting.

5.4.7 Summary

The Weeks Island salt dome has been continuously mined since the beginning of the century but the present mine has only been operating since 1981. The old mine was requisitioned by the Department of Energy in 1979, and is now used for the underground storage of oil.

Throughout the history of the Weeks Island operation, methane has occurred in the mine in relatively minor concentrations, as blowers from drillholes, and occasionally as outbursts immediately following production blasting. Methane concentrations have ranged from 0 to $\leq 0.1\%$, on average, in the main returns and in the working areas of the mine. No accidents, injuries, or ignitions attributable to methane have occurred since the operation has been in the hands of the present operators (more than 30 years). The outburst events are not documented, but apparently have never released significant volumes of gas.

The mine was classified gassy by the MSHA in July 1979, when a methane concentration of greater than 0.25% was detected in one area of the workings. This operation closed down in 1981 and the new mine commenced operating the same year. The new mine, although not initially classified so, was classified gassy shortly after it commenced operating when a methane concentration of approximately 1.0% was detected in a blind heading. The mine uses some permissible equipment, transferred from the old mine, and continues to operate using standard non-permissible diesel equipment underground.

5.5 CALLOWAY MINE, CITIES SERVICE COMPANY COPPERHILL, TENNESSEE

5.5.1 Historical and General Overview

Calloway Mine is located at Copperhill in southeastern Tennessee, due east of Chattanooga, and close to the point where the states of Georgia, Tennessee, and North Carolina all meet. The mine recovers copper and sulfur ore from an underground operation which exploits a massive sulfide deposit. It is now owned and operated by the Cities Service Company; prior to 1970 the mine was operated by the Tennessee Copper Company. The first shaft was sunk in 1942. In 1958, during development work in a hand raise, an ignition of flammable gas occurred resulting in the death of a miner. In 1971 the mine was classified gassy, based, apparently, on the historical assumption that the 1958 ignition had been caused by a naturally occurring flammable gas, probably composed mainly of methane.

Mine production is approximately 400,000 tons per year from two production shifts per day, working a five-day week.

5.5.2 Geological Environment

The orebody is a steeply dipping (70°) typical massive sulfide deposit, located in an over-thrust fault zone which thrusts west over coal measures lying at great depth (20,000 or more feet below surface). Seismic surveys performed during oil and gas exploration indicate that rocks overlying the deeper sedimentary deposits may have been transported 80-100 miles, indicating major thrust-faulting. The host rocks in the area consist of tightly folded, interbedded schists, and graywacke, with the schists increasing at depth, showing chlorite and biotite. Although there are believed to be gas and oil-bearing sediments at depth, and the area is faulted, no potentially gas-bearing rock is seen in the mine.

The mineralization is 60% sulfides of iron, copper, and zinc (pyrrhotite, pyrites, sphalerite, magnetite, and chalcopyrite).

Occasional foul-smelling water is encountered, but the mine is generally dry. Analysis of the water shows no methane and the gases responsible for the smell are thought to be sulfurous.

5.5.3 Formation Gases

The mine was declared gassy under Standard 57.21-1 (b), which states that a mine shall be deemed gassy and thereafter operated as a gassy mine if ... "Flammable gas emanating from the orebody or the strata surrounding the orebody has been ignited in the mine;" ...

The ignition which occurred in 1958 was a serious event which resulted in the death of one man, and injured another. Prior to this event, comparatively minor, and (as far as could be determined) undocumented occurrences of flammable gas were apparently by no means uncommon in the workings. Miners who were employed in the mine during the forties and fifties have informed us that they recall occasions when gas bleeding from the drill-holes was burned off "to get rid of it". No record of any analyses of the gas or gases causing these events could be located so that their composition remains unknown. These events were first noted apparently during the early 1950's; we were informed by the operators that since the mine has been operated by the Cities Service Company no methane or other flammable gas has been detected. This claim is supported by MSHA records; analyses of bottle samples taken in the general mine atmosphere on a regular basis by the MSHA have never revealed the presence of methane in other than trace amounts. No outbursts have ever been recorded.

The mine is now some 800 feet deeper than it was during the period when gas was encountered bleeding from drill-holes. The source of the gas which caused these events remains unknown;

since they have not occurred in the deeper parts of the mine and have not occurred for several years one may speculate that the source or sources were small and localized. The reason for the mine not being classified gassy until 13 years after the fatal ignition could not be determined with much certainty. One MSHA spokesman speculated that, prior to 1970, flammable gas was not historically associated with metal/non-metal mines in the United States, and that standards pertaining to gas were not therefore clearly defined or rigorously enforced in non-coal mines.

5.5.4 Mine Ventilation

The ventilation at Calloway Mine is a negative-pressure system, with two main exhausting fans on surface; system capacity is approximately 300,000 cfm. Three shafts extend to the lower level, approximately 3000' below surface; of these one is down-cast and two are up-cast. One booster fan is in use underground, and all work places are on a separate split of air. The booster fan is permissible; there are 6 permissible auxiliary fans underground, of which three are usually operating.

5.5.5 Mining Method

The mining method is sub-level open stoping with draw-point loading. Productivity averages about 30 tons per man-shift, working two production shifts per day, 5 days per week, to give an annual production rate of 400,000 tons.

Transport of ore from stope areas to the hoisting shaft is by rail haulage. Stopping is being done on 20, 22, and 24 levels, and main haulage is on the 32 level. The basic procedure is to develop stopes by driving along-strike in the footwall, then drifting into the orebody. Headings are developed alongstrike from which drill-holes are fanned upwards to generate a stope with a trough in the lower part. The stope is developed by underhand mining to a point where it can be blasted with shotholes drilled in a ring

pattern from a sublevel drift above the main level. Broken rock is hauled from the stope draw-point by front-end loader, to ore passes connecting to the main tramming level.

One stope is developed at a time, and each is designed to produce approximately 500,000 tons of ore; a stope thus has a working life of somewhat more than year. This, as will be seen in the next section, requires that development and production drilling be carried on in the stoping areas; the effect of the gassy classification is to significantly increase the cost of drilling by lowering drill-rig availability. Development drilling is done with trackless Gardner-Denver 2-boom articulated jumbos; blast-holes are drilled with a sled-mounted Atlas Copco ring-drill with a CF123 drifter. Recovery is about 60%; although there are plans to backfill worked-out areas in the future, at present this is not being done. Transverse and rib pillars are left in the stope areas.

5.5.6 Impact of Gassy Mine Citation

Calloway mine operates under a number of variances from the gassy mine standards, and we were informed that these variances are critical to the viability of the operation. Even so, productivity at Calloway is only a little more than 80% of that at Cherokee Mine (which is also operated by Cities Service Company in the same area, but which is not gassy). The most important variance is that which permits the operators to drive development works, and particularly exploratory adits, 800' beyond the last open crosscut. This variance is contingent upon 10,000 cfm of fresh air being maintained in the adit. Since the mine is being worked on several levels in a steeply dipping seam, this concession is of particular importance in mine planning and grade control.

New levels and stopes are developed by driving along-strike in the footwall; drill-holes from these drives block out the ore-body. The operators informed us that they would welcome a vari-

ance that would permit them to extend the drive up to 2000 feet beyond the last open crosscut. The cost of connecting the drives by raises between levels would clearly be very high. The operators estimate the cost of development work at approximately \$200 per foot.

Blasting is performed with ANFO (which is not a permissible-type explosive); primary (production) blasting is performed with standard-delay caps, but with all personnel evacuated from the mine, and is therefore performed at shift-change only. Secondary blasting is allowed with personnel underground, but the use of permissible detonating circuitry and caps is mandatory.

Standard (non-permissible) loaders of small capacity ($<2 \text{ yd}^3$ bucket capacity) are allowed 800' beyond the last open cross-cut. For production haulage from stopes to chutes a mix of Schedule 31 (permissible) and Schedule 24 (non-permissible) equipment is used. Two loaders are standard, Schedule 24 type, but these are of a kind that can be converted to permissible-type (Eimco, 3-yard). Schedule 31 equipment in use underground includes 1 battery-operated locomotive (used for main haulage on the tramming level) and 2 auxiliary fans.

The operators estimate the average increase in cost overall to be about 10%, but stress that this is a very difficult figure to quantify. The main cost impact is seen, as mentioned earlier, in lowered productivity. This is attributed to several things, the most important of which, according to the operators, is lack of efficient utilization of production drill-rigs. Blast-holes can only be drilled during non-production shifts; this is because under the gassy mine standards drilling cannot be done in exhaust air from production areas for fear of an ignition. Because the stopes are developed from the main levels by underhand mining, the locations on sub-levels from which ring patterns for blasting are drilled are technically in return air when production mining

is going on. Therefore blast-holes can only be drilled on day-shift. We were informed that because of this 4 drill rigs are maintained at Calloway Mine to perform an equal rate of blasthole drilling as is achieved at neighbouring Cherokee Mine by 2 rigs.

Foremen take readings for methane at the start of every shift; readings must be taken at every location in which men are working. Unless a fan is down, or some other abnormal situation has arisen, these inspections are performed with the workforce underground. Welders (or anyone using a flame-producing device) must be certified in the use of methanometers, and must take a methane reading before using the equipment. No smoking materials are allowed underground.

5.5.7 Summary

The Calloway Mine, now operated by Cities Service Company, but prior to 1970 operated by the Tennessee Copper Company, recovers copper, sulfur, and zinc from the underground exploitation of a steeply dipping massive sulfide deposit. The host rocks are graywacke and tightly folded schists. During the early life of the mine occasional flows of gas were noted from blast holes and exploratory drill-holes. These flows are not documented, but were apparently small in volume and duration, and were sometimes burned off by the miners. In 1958 a serious ignition of flammable gas occurred in a hand raise, resulting in the death of one miner, and injury to another. On the basis of this event the mine was classified as a gassy mine in 1971 when enforcement of safety standards pertaining to gas in non-coal mines became more rigorous. No flammable gas has been recorded in the mine in greater than trace amounts, and no gas flows from drill-holes have been noted since Cities Service Company took over the operation. The mine operates under partial gassy mine standards with a number of variances granted by the MSHA. The operators

consider that even this partial compliance with the gassy standards is responsible for a drop in mine productivity of approximately twenty percent.

5.6 ALLIED CHEMICAL COMPANY, GREEN RIVER OPERATION, ALCHEM MINE, GREEN RIVER, WYOMING

5.6.1 Historical and General Overview

The Allied Chemical Company owns and operates a large underground trona mining facility at Green River in southwestern Wyoming. Green River is some 110 miles east and somewhat north of Salt Lake City, and there are a number of trona mines in the area. Trona is a comparatively rare hydrous carbonate of sodium which is found in saline lake deposits. The concentrate produced is soda ash, used extensively (among other things) in the manufacture of detergents.

Historically trona was (and in some other parts of the world still is) produced synthetically, but with the advent of stricter environmental laws most such facilities in the United States closed down (the process generates atmospheric pollution from fine dust particles). Because of this, mining natural deposits of trona became economically attractive, and the trona mining industry of Wyoming came into existence during the years after World War II.

The Alchem facility is one of the largest of the trona mines, producing approximately 3.5 million tons of ore per year. The mine was classified gassy by the State of Wyoming from the outset, and is therefore automatically classified gassy by the MSHA under Standard 57.21-1(a). It has been in production since 1968, and employs about 120 men underground on any given production shift. The first shaft was bottomed-out in 1966, and between 1966 and 1968 a pre-production pilot plant was operated.

5.6.2 Geological Environment

The trona seam being exploited, which is about 1600 feet below surface, lies in a sedimentary basin which in places contains up

to 25 seams (not all necessarily of ore grade). It is underlain by oil shales, some of which are probably of commercial grade, but the mine operators state that their exploratory drilling indicates that there is not sufficient ore to make its recovery economical above or below the presently-mined seam. The overburden is non-uniform; the orebody is overlain by green shale, which in some areas approaches being a mudstone, and in others a commercial grade oil shale. The only distinctive overburden feature is a bed of sandstone, averaging 120 to 200 feet in thickness, lying between 800 and 1000 feet below the ground surface. Above this lie more mudstones; the sequence is typical of a marine sedimentary deposit.

5.6.3 Formation Gases

According to the mine operators, the beds both above and below the orebody are sources of gas. Significant concentrations of gas are present more or less continuously in certain parts of the mine (mainly in the bleeder returns from one panel which is being mined by a longwall shearer). The gas is mainly composed of methane, with very minor carbon monoxide (the latter is usually present in trace amounts only). A methane monitor is permanently located at the longwall tailgate, and a typical reading from this unit would be $\sim 0.5\%$. MSHA records indicate that the mine as a whole generates more than 1,000,000 ft³ of methane in a 24-hour period; because of this the MSHA inspects the mine every five days. One ignition occurred, in which one or two miners sustained minor injuries, in 1977. This event, caused by a defective machine cable, occurred during pillar extraction when a cave knocked out a ventilation curtain and short-circuited the air supply to the area.

The trona itself is not regarded as a source of flammable gas, but rather the shales above and below the pay zone. This would appear to be substantiated by the fact that the longwall panel generates larger volumes of gas than do other areas of the mine

where recovery rates are lower and caving of the overburden does not occur. Violent outbursts and blowers of gas have not been encountered; rather, gas enters the mine by steady-state emission from the formation. Most of the gas is believed to emanate from the roof.

In all areas of the mine other than the longwall panel (i.e., in all areas of the mine where caving does not occur), gas drain holes are drilled into the roof. These are drilled at all intersections, midway between intersections, and at 100-foot intervals in every entry; the holes are vertical, 1-3/8 inch in diameter, and 20 feet long. Occasionally these will release sufficient free gas to give a 1% reading on a methanometer 20 feet from the collar of the hole, but usually they do not release measurable methane or other gases.

The operators informed us that in the so-called conventionally mined areas of the mine (i.e., areas other than the longwall panel) gas levels are very low. Occasionally methane levels in the main returns may reach 0.1%, sometimes slightly higher, but this is regarded as being higher than usual, and is usually attributable to some abnormal circumstance such as a major roof fall, or a main fan going down. When a main fan is shut down for routine maintenance, methane buildup occurs in the mine as a whole, typically to approximately 0.5%.

In bleeder returns from the longwall panel, methane levels are typically in the range of 1% to 2%. Because the gas is being generated by the caving of overburden, these methane levels may persist in the bleeder returns for as much as 36 hours after the longwall shearer is shut down.

5.6.4 Mine Ventilation

The mine ventilation is an exhausting (negative-pressure) system with four main fans on surface. Auxiliary fans are used under-

ground for face ventilatoin; there are no booster fans. Current air flow is approximately 1,100,000 cfm, but total system capacity is approximately 1,350,000 cfm. The four main fans are in continuous operation; fan maintenance is carried out on days when the mine is idle, usually once each week, at which time one fan only is shut down. We were told that this, however, is dependent on gas conditions in the mine; gas build-up does occur at these times, as noted in the previous section.

In the longwall panel, 50-60,000 cfm of fresh air is delivered to the panel as a whole, with approximately 25,000 cfm maintained across the face. The air is split at the tailgate, with 10-15,000 cfm going down the secondary return, and the rest going into the gob bleeder system.

Although trona is hygroscopic, we were informed that this has not created any particular problems in ventilating the mine.

There are four main shafts, of which one is a main down-cast air shaft, two are up-cast, and one (the men and materials hoisting shaft) is combined up-cast/down-cast.

5.6.5 Mining Method

Three mining methods are in use at the Alchem facility; one panel is being mined by longwall shearer, as mentioned in previous sections, and room-and-pillar mining is carried on in the other areas of the mine by two methods. These are by conventional drilling-and-blasting, and by using mining machines. The various methods account for the following percentages of total production; longwall shearer, 10%; continuous mining machines, 40%; conventional drill-and-blast, 50%.

Total mine production is approximately 3.5 million tons of ore per year; one ton of concentrate (soda ash) is produced from 1.8 tons of ore.

We were told that the longwall method of mining is to be phased out because of high maintenance costs. Although the longwall shearer achieves a 70% recovery rate compared to 50% recovery in other parts of the mine, it is not profitable because of poor overall availability. The longwall panel is estimated to generate possibly as much as 95% of the methane measured in the mine, but this was not stated as a reason for the phase-out of this mining method. The continuous miners apparently operate more successfully in the harder host rocks encountered during mining (the company operates nine such machines). The seam being mined is eight to 12 feet thick, and fairly horizontal. The operators stated that to mine a seam less than eight feet thick with the equipment being used is not practical because the machinery is not of the low-profile, coal-mining type.

Haulage is by conveyor belts directly from the longwall panel; in the case of the conventional panels, and those in which continuous mining machines are being used, electric shuttle-cars are used to haul from the face to the conveyors. Distances involved are in the order 300-400 feet.

The only diesel equipment used underground is for hauling men, equipment, and supplies, and there are eleven diesel ANFO wagons (ANFO is the explosive used in production blasting), and two diesel generators.

In the room-and-pillar areas of the mine there is partial pillar extraction, but not on a scale large enough to induce caving of the overburden. Mined-out areas are sealed off with seals made of wood (double-stopping) with trona dust placed between them.

5.6.6 Impact of Gassy Mine Citation

Alchem Mine has operated as a gassy mine from the outset, and therefore has not been "impacted" in quite the same way as would

an operation which had formerly operated as non-gassy. Significant concentrations of methane are regularly observed in the workings and the operators take appropriate precautions.

Permanent methane monitors are located at the longwall tailgate, and on all continuous mining machines. These are set to automatically de-energize the machines at a methane threshold level of 1.0%. Threshold levels at other key locations are:

- (i) 1.0% in secondary returns (equipment shutdown)
- (ii) 1.5% in secondary returns (withdraw personnel)
- (iii) 2.0% in longwall bleeder returns (equipment shutdown and personnel withdrawal).

We were informed that (iii) may happen even when methane at the longwall tailgate is within permitted levels because the source of the CH₄ in the bleeder returns is the caved rock in the gob, not the working face. In allowing the mine to operate with up to 2% methane in the bleeder returns the MSHA have granted a variance (the usual level mandated by the gassy mine standards for both equipment shutdown and withdrawal of personnel is 1.5%). Methane checks are made manually in the bleeder returns once during every shift, and more often if methane levels seem to be approaching 2.0%.

All equipment used, and all electrical circuitry, beyond the last open crosscuts is of permissible type.

The blasting agent in use is ANFO (the use of this explosive is also a variance from the gassy mine standards). It is used under certain stipulated conditions, which are:

- (i) the use of grounded loading,
- (ii) methane checks must be made of the area both before and after shooting,
- (iii) electric detonation must be used with permissible caps,

(iv) the use of water for stemming is mandatory.

With these provisions, production blasting is permitted during the shift, with the work force underground. All personnel must be moved to a designated safe place and accounted for before a round is fired.

Shot-fires must be legally certified (this is a State of Wyoming, not a Federal MSHA requirement) to perform their duties.

Safety programs for the education of miners specifically address the gas problem beyond the standards required by MSHA, we were told. The work force is unionized, and the company conducts regular safety education programs in which the hazard due to flammable gas in the mine is of major importance.

The operators consider that phasing out longwall mining will greatly diminish the volume of methane entering the mine (by as much as 95%, it was suggested).

Since the mine has been recording significant methane in the workings throughout its life, and has operated under the gassy standards since production began, the question of the financial impact of the gassy citation seemed hypothetical and was not discussed.

5.6.7 Summary

The Alchem Mine, at Green River, Wyoming, was certified gassy by the State of Wyoming prior to the initiation of commercial production in 1968. It is a large-scale operation producing trona from a sedimentary basin containing gas and oil-bearing shales. Three methods of mining (longwall, conventional room-and-pillar, and room-and-pillar using mining machines) are employed. Significant volumes of methane enter the workings, and these are thought to emanate from shales above and below the orebody.

Variances from the MSHA gassy mine standards apply to blasting and methane threshold levels for withdrawal of the underground work force (ANFO is used for blasting, and methane levels may reach 2.0% in the bleeder returns from the longwall panel before personnel are withdrawn). During accidental reduction to the fresh air supply in the area, an ignition occurred during pillar extraction in 1977. The ignition was initiated by a faulty machine cable, and no fatalities or serious injuries resulted. This mine has an excellent safety record, despite significant and continuous gas levels.

5.7 THE WARNER COMPANY, BELLE MINE BELLEFONTE, PENNSYLVANIA

5.7.1 Historial and General Overview

The Belle Mine is located at Bellefonte in central Pennsylvania, and recovers limestone from an underground facility. It is owned and operated by the Warner Company, and has been a producing mine since 1921.

In 1975, an ignition of flammable gas occurred in a blind raise. This event took place approximately 1-1/2 hours after the beginning of a shift, and some 16 hours after a production blast had been set off. The miners apparently failed to purge the raise effectively before re-entering it after the blast, and the ignition was sparked by one of the men lighting a cigarette lighter.

As a result of this episode, the mine was declared gassy by the MSHA and has since operated under gassy mine standards with some variances.

5.7.2 Geological Environment

The geology of this particular orebody is not well documented, and the mine operators were not able to identify a potential source of gas within the formation. The seam being exploited is the so-called Valentine limestone, a steeply-dipping (70° - 89°) calcium carbonate which outcrops at the mine office. The main men-and-materials shaft follows the dip angle (+70° at surface and increasing with depth) down to the working level, approximately 960 feet below the surface. The limestone is very pure, containing on average less than 1% silica (one ton of rock mined yields 1000 pounds of high-grade metallurgical lime). The mine is very dry, and in "good ground"; roof support and ground control problems are minimal.

For more complete information concerning the geology of the area the reader is referred to Butts and Moore (29).

5.7.3 Formation Gases

Historically there have been four ignitions of flammable gas in the mine (including the 1975 event). All have occurred in blind raises after blasting, and all, in the opinion of the operators, were due to human carelessness. We were informed that the circumstances were almost identical in every case; a blind raise was not purged before re-entering after a blast because the air "looked clear" when the beam of a miner's lamp was directed into the raise.

Air samples collected in the raise after the 1975 event confirmed the presence of methane (concentration was not made available by MSHA, and was not on record at the mine office). This resulted in the mine being classified as gassy. Since then no further ignitions have occurred.

No set of conditions has been identified which can be positively associated with gas of any kind; the source of the methane in the four ignition events remains speculative. According to the operators, tests performed on rock samples have not revealed the presence of methane within the limestone itself, and there are no known coal measures or other carbonaceous rocks in the orebody host rocks. There are dolomites in the area, and dolomites have, in other parts of the world, been a major source of natural gas (e.g., the North Sea gas fields), but there is no evidence, we were told, that the Bellefonte area dolomites are gas-bearing.

In the normal course of events, methane is not detectable anywhere in the mine; the plot on chart recorders attached to permanent methane monitors in a number of key locations is a straight line showing zero. One may speculate that there are, within the orebody, zones which contain some methane, either within the

crystal lattice, or in pockets or fissures. When such a zone is blasted, the small amount of methane released could reach an explosive concentration in a roof cavity if the area was not thoroughly purged with fresh air. This has been the apparent sequence of events in all of the ignitions which have occurred and, at least in the case of the 1975 occurrence, the main ventilation had been down prior to the ignition.

Fortunately, none of the ignitions have resulted in death or serious injury; the events were very local and only affected the immediate vicinity of the raises in which they occurred.

5.7.4 Mine Ventilation

The ventilation is a forcing system, with two main fans on the surface. Total system capacity is 142,000 cfm, utilizing one down-cast and one up-cast shaft (a third shaft is maintained as an escapeway only, and is shut out of the ventilation circuit by air doors). There is only one main drift, 960 feet below surface, used for ore tramming and man transport, so that the air cannot be split by a line brattice. There are five auxiliary fans operating underground. A secondary drift connects the main shafts, 600 feet below surface; fresh air courses along this and the main drift, and is forced into the stopes by auxiliary fans.

5.7.5 Mining Method

The mining method is along-strike, by sub-level long-hole stoping, with drawpoint loading; only one main level is being worked. Ore transport is on the main 960-foot level, by a rail system powered by a diesel locomotive.

Raises are developed from the main drift, at 380-foot intervals, and slot raises and drawpoints are established between the man-raises. These are connected by a secondary drift which is mainly

an airway. Completed stopes are 300 feet high. Loading at the drawpoints is by diesel-powered, rubber-tired front-end loader.

Production blasting is done from the surface at shift-change; the blasting agent used is ANFO. Each production round takes an 8-foot slice, and breaks approximately 4000 tons of rock. Mine production averages approximately 470,000 tons of ore per year.

5.7.6 Impact of Gassy Mine Citation

The operators stated that the gassy mine classification does not affect the operation very much; a number of variances have been permitted, and these are crucial. The operators stated that if the mine "was really gassy", they could not operate. They are of the opinion that the present mining methods would not be possible in "a truly gassy" environment, but that they are necessary "to get the rock out."

The most important variance applies to the frequency of cross-cuts. Raises are put in every 380 feet instead of every 100 feet as required by the gassy mine standards. No Schedule 31 (permissible) diesel equipment is in use underground, and no permissible explosives are used for production blasting (rock strength precludes their use in any case). Primary blasting is, however, done from the surface with no personnel in the mine. Secondary blasting may be carried out with the workforce underground, and for this permissible explosives are used.

A permanent methane monitoring system is in place, with four sensor units at key locations specified by the MSHA. These units monitor continuously and their output is plotted on a strip-chart recorder. They are checked and calibrated every 30 days by the mine electricians (this is seen as a reasonably significant cost item as it involves having two electricians and a hoistman work at least one extra shift each month).

The sensors are located as follows:

- 1 in fresh air in the secondary drift on the 600-foot level;
- 1 in secondary return air on the 600-foot level;
- 2 in primary return air on the 960-foot level.

The ventilation system also operates under one major variance: auxiliary fans operating underground are of permissible type, but there is no separate split of air to the work places. Thus the stopes, as well as shops on the main drift level, are basically ventilated in a series; some of these areas could be described therefore as being, at least in a technical sense, in return air.

Electrical circuitry and switching gear used in blind headings and raises is of permissible type.

The mine operators state that without the variances which have been permitted they could not continue to mine this particular orebody, as much because of technical considerations as for any economic reason. They do not feel that the present level of compliance imposes any significant financial burden, but the initial capital costs associated with setting up the methane-monitoring system and purchasing permissible fans and circuitry were significant.

5.7.7 Summary

The Belle Mine, operated by the Warner Company, exploits a steeply dipping limestone bed near Bellefonte, Pennsylvania. The mine, which produces about 470,000 tons of limestone ore per year, has been operating since 1921. In 1975 an ignition of flammable gas occurred in a blind raise after a production blast had apparently liberated some methane, and miners re-entered the raise before thorough purging of the atmosphere had taken place. As a result of this event, the mine was classified gassy. Previous to this,

three other ignitions had occurred under similar circumstances, but none of these events caused death or serious injury. The source of the flammable gas in these episodes remains unknown, and in the normal course of events methane is not detectable in the mine atmosphere (which is continuously monitored). A number of variances from the gassy mine standards have been permitted by the MSHA. The operators maintain that the operation would be neither technically nor economically feasible if they were forced to fully comply with the MSHA gassy mine standards.

Summary of Study Results

6.0

SUMMARY OF STUDY RESULTS

6.1 GENERAL COMMENTS

The results of the study show that of all the countries from which reasonably complete information has been received, only two have a separate and distinct system for the classification of methane hazard in metal and non-metal mines. These two are Poland and Romania. Of the twenty countries approached during the study, sixteen responded, and of these only seven have any system by which a mine may be formally classified as gassy or non-gassy under prescribed criteria laid down by statute. These countries are Yugoslavia, Italy, Spain, India, Czechoslovakia, Poland and Romania. With the exceptions of Poland and Romania, the classification systems in use apply to all underground mines equally, no matter what commodity is being mined. India defines only one category of gassiness; the others define two or more, with the lower categories usually being applied to mines (or parts of mines) wherein gas concentration does not approach the generally accepted safety threshold value of 1-1/4%, but is nevertheless present in detectable amounts. The higher categories of gassiness are used to subdivide mines which experience gas in varying concentrations by grouping those which experience similar levels of concentration, and those with sudden outbursts of gas and rock. These last are usually assigned to a separate category based on the mode of occurrence, regardless of the gas concentration (or type).

The most significant result to emerge from this study is an apparent difference of emphasis, between the United States and other countries, in the approach to the problem of ensuring safety in gassy mines. This will become more apparent in the following sections. In the United States, once a mine is classified gassy, regulation of mining procedures, equipment types, and blasting procedures is comprehensive and automatic. The onus is then on the mine operator to demonstrate that any

exceptions to the codes should be permitted. In those foreign countries covered by the study, the situation is rather different. The recognition of a gas problem does not in itself necessarily mean the imposition of a comprehensive set of pre-determined rules. The maintenance of air quality and safety is mandatory, of course, and danger levels of gas and dust concentrations are defined by statute. The intent of the statutes is to mandate safety guidelines within which the specific details of how a mine will be safeguarded are then worked out on a mine-by-mine basis. This apparent lack of specifics in the safety regulations is offset to a degree by the fact that in the majority of countries the statutes are very specific concerning the standard of training, education, and experience required of people who work in underground mines. This is particularly true concerning those persons who are in supervisory positions or those responsible for safety, or who are operating heavy equipment.

6.2 THRESHOLD VALUES

All countries studied, whether they have a formal system of classifying gassy mines or not, use similar standards to define danger thresholds for concentrations of methane whenever and wherever it occurs. In all cases, even though methanometers are now widely used, the generally accepted upper limit of methane concentration for safe operations is the lowest concentration detectable by the use of a flame safety lamp. This is approximately 1-1/4% of the general body of air. Equipment shut-down is mandatory at concentrations that range from a low of 1% to a high of 1.5%. It appears to be fairly standard also to withdraw other than certain specified personnel (who may be required to remain underground to take remedial action) from all underground workings when methane concentrations reach a maximum value of 2 1/2% of the general mine atmosphere (or half the lower limit of methane concentration in the explosive range for a methane/air mixture). In some cases withdrawal of personnel is required at a

concentration of 1.5%, in others 2%. Blasting is generally not permitted in mine atmospheres containing 1% or more of methane by volume.

6.3 RESPONSIBILITY FOR SAFETY

A number of countries, notably Australia, South Africa, India, Canada, the United Kingdom, and Yugoslavia employ a system which establishes a chain of responsibility in mine operations, extending from mine manager through engineering and surveying staff, to foremen and gangers. Under these systems, individuals performing certain tasks such as blasting or operating certain types of equipment, or who are responsible for certain areas of operations such as ventilation or gas monitoring, must be certified to do so. In the case of mine managers, mine inspectors, surveyors, or ventilation engineers, certification is usually mandatory, and requires the appropriate degree or diploma, a specified amount of practical experience, and a written examination. Certification of miners or gangers usually requires serving a specified number of shifts under the supervision of a certified person, and may or may not, depending on the certification, require a written examination. In these countries, certified personnel may be held accountable under law for breaches of regulations, and the chain of responsibility for dealing with emergencies is laid down by statute.

Appendix VIII contains details of the South African system of personnel certification. Similar, if slightly less comprehensive systems are in effect in Yugoslavia, Australia, Canada, and India. Note that certification in these countries applies to mine inspectors also.

Some other countries (notably Poland) certify personnel on the basis of education and experience on a mine-specific basis. That is, a person transferring from one mine to another must renew his or her certification.

6.4 PHILOSOPHY OF MINE REGULATION AND CLASSIFICATION

In all countries with or without a system for the formal classification of gassy mines, a great deal more emphasis is placed on regulation than on classification. The hazardous levels of methane are well established, as are the means of detecting and measuring the concentration of this gas with some precision. The philosophy is that methane may represent a hazard wherever it occurs, and clearing it from a salt mine is not especially different from clearing it from a coal mine. The application of regulations in all countries is subject to some discretion, and is a function of the mining method, the geological environment, and the mode of occurrence and distribution of the methane. In other words, the regulations are applied so as to best ensure the safety of the particular mine, and the designation of the mine as being gassy or non-gassy as such is not considered paramount. The study results indicate that the general application of a classification governed by a more or less standard set of rules would be regarded by most of the people with whom we discussed this question as over-simplification of a very complex problem. It would seem that a formal classification system is more useful, (and is more often intended) to categorize the type rather than the degree of hazard. (For example, without exception, those countries which have multi-category classification systems assign a special category to mines which experience violent outbursts of gas and rock). The intent of any regulatory or classification process ought clearly to be to enhance mine safety. It is arguable that to classify a mine merely as gassy, and to simultaneously apply a set of predetermined rules may not always be the best way to achieve this end.

In a non-coal mining situation, because of the variables involved, the usefulness of any gas hazard classification system which is based on measured gas levels rather than on the type of occurrence is questionable. The special case of violent blowouts of gas and rock is a good illustration of this point. In mines

where these occur (Klodawa Mine in Poland, Boulby Mine in the United Kingdom, for example) no methane (or other dangerous gases) may be detectable in the workings for weeks or months. When a blowout occurs, however, the event itself is liable to be dangerous, and it may release flammable gas in large, potentially explosive concentrations. In dealing with a situation such as this, classifying the mine as gassy and mandating the use of permissible equipment may not be the most effective way of meeting the problem. Safety may be better served by gaining an understanding of the causes and mechanisms of the events so as to better predict or control their occurrence. Experience at Boulby, Klodawa, at Hattorf Werken, and in East Germany, (13) suggests that an understanding of the causes of violent outbursts, and a prudent choice of mining method can achieve a high degree of control, and therefore greatly improve safety. These events will always pose a special danger to operations wherein they occur, and their complexity is such that any set of predetermined regulations designed to provide safeguards against them would almost certainly result in over-regulation in some individual cases. Again, a classification system based only upon observed gas levels during regular mine inspections might lead to a situation wherein a mine prone only to outbursts could escape a gassy classification altogether until after a catastrophe has occurred.

The system of classifying only parts of mines, or assigning varying categories of gassiness to different areas of a mine, is permitted in a number of countries. A variant of the same idea, which is seen in South Africa, is to impose only certain gassy mine regulations without actually classifying the mine as gassy (or fiery, in the case of South Africa). This is a practical compromise which endeavours to impose the least burden on the mine operators consistent with upholding the required standards of safety. The philosophy is simple: first define the problem and then impose only that degree of regulation required to effect

safeguards, rather than impose blanket regulations and then work backwards to determine which ones may not be warranted.

The information obtained during this study has drawn us to the conclusion that the control of methane hazard in mines is just as effective in countries which do not possess formal systems of classifying the problem as it is in those countries that do (we have noted that lack of formal classification does not necessarily indicate that no problem exists). In countries where classification systems are in effect it is nevertheless customary to study the problem of where the gas originates, and how it enters the mine, in some detail before imposing final regulations. Usually both the Mines Inspectorate and the mine operators participate in this process, in recognition of the fact that the more clearly the problem is defined the more effectively it can be regulated.

A mine operating under gassy mine regulations may have such regulations lifted under certain conditions. This may occur (as it does in Spain, for example) after a specified period during which thorough monitoring has failed to detect methane in dangerous, or potentially dangerous concentrations. In Spain the specified period is one year, during which methane monitoring will be closely documented, and will include measurements taken with the mine ventilation system shut down for 24-hour periods. Any revision of a mine's classification remains at the discretion of the Mines Inspectorate, however, and any submissions made by mine operators to support reclassification are subject to confirmation by the responsible authorities. Equally, a reclassification may assign a mine (or part of a mine) into a higher category of danger should change occur in the type or volume of gas occurrences (see Appendix X).

The emphasis of the regulatory process in most of the countries studied seems to be to ensure vigilance. Reporting and documentation requirements are usually strict, with the result that

comprehensive and specific regulations can be designed to achieve maximum effectiveness without over-regulation.

6.5 CONCLUSIONS

The study has succeeded in its main purpose, which has been to obtain a comprehensive body of information on foreign methods of classifying and regulating non-coal mines with respect to hazards due to naturally occurring gases, flammable and otherwise. From an objective assessment of these data, it is possible to draw a number of conclusions which may affect the future course of gassy mine regulation for metal/non-metal mines in the United States. Certain fundamental differences have been noted between the approach used in the classification and regulation of gassy metal/non-metal mines in the United States and that prevailing in most foreign countries studied. The most notable difference is one of emphasis.

In no case that has been seen outside the United States during the course of this study has the main emphasis of statutory requirements for gassy mines been placed upon such detailed safety matters as prescribing the use of certain mining methods, equipment types, or explosive types. Rather, the emphasis falls on the two main areas of:

- (i) ensuring the adequate training and experience of the people who work in the mining industry (including those charged with inspection and law enforcement), and
- (ii) the immediate reporting of, and subsequent documentation of all occurrences of flammable or toxic, naturally-occurring gases.

The first of these automatically has a far-reaching effect, in that it acknowledges the fact that underground mining is an inherently dangerous business. Particular emphasis is placed on the legal requirement that those in supervisory, managerial, and

rule-enforcement positions shall have adequate training and experience within the mining industry. Guaranteeing (insofar as such a thing is possible) that those charged with running the mines shall be competent to do so would seem to be a logical and necessary element in any regulatory process designed to ensure adequate safety standards.

The second area of emphasis acknowledges the fundamental truism that a problem can be more effectively solved when it is better understood. Thus the requirement to report and document all gas occurrences, regardless of type or scale, contributes to the processes of determining whether a problem exists, and (if one does) of devising effective safeguards.

The argument has been advanced that the individual, mine-by-mine approach to the regulation of gassy mines favored in other countries is unwieldy, and would not work in the United States. This argument contends that such a system would cause inspectors to become disproportionately involved in examining the problems of a mine (or mines) experiencing gas occurrences at the expense of other responsibilities. The net result (so the argument goes) would be a staffing problem within the MSHA, and a general lowering of standards. Throughout this study we have seen no evidence of anything which would support such a proposition. Rather, the opposite appears to be true in fact.

It has been our observation that within the United States a certain adversariness prevails between some of the operators of gassy mines and the MSHA. We have not seen the equivalent of this in any foreign country, and it seems reasonable to conclude that mine operators in those countries are reasonably content with the ways in which their operations are regulated. It would not be true to conclude from this, however, that the regulation of mines in those countries is more lax than it is in the United States. In fact, we have seen no evidence that underground mines in the United States are safer in general than those of other

countries. This state of adversariness has caused litigation, and has entailed numerous applications for variances on the part of mine operators who have received gassy citations. Such a state of affairs must be costly and time-consuming for all concerned, and could perhaps be largely avoided in a more harmonious and less cumbersome situation.

While it is true that in most foreign countries the operators of a gassy mine may participate directly in decisions concerning the details of how their operation will be regulated, it is not true to interpret this as self-regulation. Air quality and worker safety standards are clearly mandated as a rule; what may appear to be some degree of self-regulation arises solely from the fact that reasonable discretionary powers are usually vested in the local enforcement authority. The result of this is a certain flexibility within the frame of which the mine inspector(s) and the mine management will usually confer. Against this should be weighed the fact that in granting some degree of discretion and flexibility the law usually also mandates a certain level of training and experience for all mine inspectors, mine managers, and many others engaged in the industry.

There is no doubt that the training and education of workers can contribute significantly to safety in the environment of an underground mine, by creating a greater awareness of the dangers associated with natural events, such as gas intrushes, and with careless operating practices such as smoking in the presence of flammable gases. In some countries the practice of legally certifying certain personnel in order that they may perform specified tasks in the mine is seen as a means of guaranteeing the competence and responsibility of those occupying critical positions in the work-force. It is argued that by thus fixing legal responsibility for the proper performance of a given task on the individual who is certified to perform that task, the legal certification of workers contributes directly to training, good practice, and thereby to safety. Legal certification

usually provides for the imposition of penalties on certified workers who are guilty of derelictions, but this does not usually automatically absolve others higher up the chain of responsibility (e.g., the mine manager) from blame. In fact, the South African regulations state quite explicitly that the delegation of responsibility shall in no way relieve the manager of responsibility under the law. In those countries (such as the United Kingdom) where coal mining is the only branch of mining requiring legal certification of managers and others, the law usually requires the appointment of "competent" persons. In practice in those cases the coal mining laws are used to define what is meant by a "competent" person, and the effect is the same as if a system of certification existed. It is difficult to see how such a system, applying at least to those in positions of authority, would not contribute to technical excellence and thus to safety.

From the foregoing it will be seen that the approach to safety in underground mines in foreign countries, particularly those in which mines were actually visited, is composed of a number of elements. Among those, the more universal of which have been discussed above, the classification of mines with respect to gassiness does not assume particular importance. In those countries which employ some form of classification, it is used to identify and (in cases where a multi-category system is in effect) to define a problem. The matter of regulation is kept separate, and is based upon established air quality and gas danger threshold criteria. The results of this study have given no indication that mine safety is necessarily served by gas hazard classification as such. Certainly, we have found no reasons to conclude that underground mine safety is any better in countries that do classify gassy metal/non-metal mines (Poland, Spain, Yugoslavia) than it is in those that do not (South Africa, West Germany, France, the United Kingdom).

The main function of classification where it is used is to direct attention to a problem. It must be emphasized that it is not

seen as a final regulatory device in any country whose system we have studied; it is regulatory only to the extent that its' imposition usually mandates strict gas monitoring and reporting. Mandatory safety guidelines are then followed until the problem is defined, and such detailed regulations as are required can be imposed. The matter of reporting gas occurrences, regardless of their severity, is an important element in the safety codes of most countries. The Spanish system is an interesting example under which all underground excavations are held to be potentially gassy until a period of gas monitoring shows them to be gas-free. This is probably the most effective way of using a classification system in that it automatically ensures an initial period of gas monitoring, whether gas is actually present or not.

The matter of reporting assumes key importance in a mine prone to violent outbursts of gas and rock. These events pose a special danger because in mines affected by them there is usually no reliable way of predicting either their frequency or magnitude. Between outbursts such mines may be completely free of gas for months or weeks, such as is the case at Boulby, Hattorf, and Klodawa. The only defense against the possibility of disaster in such a situation is vigilance, combined with the best possible understanding of the outburst mechanism and the source of the gas. The classification of such a mine as gassy without taking into account the uniquely dangerous nature of the gas events is merely an exercise in semantics. Historically, violent outbursts of gas show an extreme range in magnitude, with a high degree of unpredictability. Although statistically the majority of these events are relatively small-scale, it has been shown that in formations which are prone to them extremely large-scale events may occur randomly (13)(24)(25). Experts with whom we discussed these events in Australia, West Germany, Poland, and the United Kingdom, were agreed that while under certain conditions the outbursts themselves may be to some extent predictable, their magnitude is not. The immediate reporting of their occurrence,

regardless of magnitude, to management and to the Inspectorate, is considered very important. The MSHA standards are less rigorous on this particular matter, and require (50.1 Purpose and Scope) that operators immediately notify MSHA of accidents. "Accident" is defined (50.2 Definitions) as,..."(4) An unplanned inundation of a mine by a liquid or gas;" and,..."(9) A coal or rock outburst that causes withdrawal of miners or which disrupts regular mining activity for more than one hour;"... .

In summary then, it can be said that the main purpose of gassy mine classification in those countries in which we have observed its use, is to focus attention on the fact that special hazards exist in a particular mine (or parts thereof), and that special precautions and extra vigilance are therefore needed. The precautions take the form of working within mandated safety guidelines, and extra vigilance is employed in checking and defining the gas problem. Detailed regulations appropriate to the problem are then devised to ensure the safety of the operation, and those regulations are usually worked out by the mine management and the Mines Inspectorate in consultation. The Mines Inspectorate, however, has ultimate authority in all cases that we have seen. Mine classification does not usually mean the automatic imposition of a mandatory set of detailed, comprehensive regulations.

The statutory regulations of every country that we have seen spell out air quality standards and gas hazard thresholds that may not be violated under the law. They do not, in general, go into detail about the methods by which these standards are to be maintained, and it is in this area that mine managements and mine inspectors are usually permitted some discretion. The specifics of the regulations apply for the most part to guaranteeing the technical competence of those who are engaged in both the regulation and the operation of the mines, and to addressing the matter of mine safety in general, aside from the question of gas. Within this context gas, flammable or otherwise, is seen as a

special problem requiring special rules; the latter are not usually defined.

The adversariness noted earlier, between some U.S. mine operators whose mines have been classified gassy, and the MSHA, arises from the fact that these operators feel that the classifications of their operations are unreasonable. It is not the classification, but the regulation, that is significant, and it is difficult to see how, under the existing U.S. system, such adversariness, with its attendant problems will not persist. The Mine Safety and Health Administration should examine the existing gassy mine standards with a view to making them more acceptable to industry, and more effective in enhancing mine safety. The matters of violent blowouts, documentation and reporting of gas events, and the training and education of both mining and enforcement personnel, should receive particular attention.

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Appendices

APPENDIX I
AUSTRALIA

Excerpts from the Mines Inspection Act, 1901, No. 75
(Reprinted as of 10th, July, 1979,
by authority, D. West, Government Printer).

State of New South Wales

MANAGERS AND ENGINE DRIVERS

DIVISION 1 - MANAGERS

(3) Subject to the provisions hereinafter mentioned, a person shall not be qualified to be a manager of a mine unless he is registered as the holder of a certificate of competency as manager granted under this Act, or of a certificate approved by the board of examiners of managers, or of a certificate of service as manager granted under this Act, being in each case a certificate that relates to a class of mine of which the mine is a member.

DIVISION 2 - ENGINE DRIVERS

(1) Any person -

- (a) who is not registered as the holder of a certificate of competency as an engine-driver granted under this Act or of a certificate approved by the board of examiners of engine-drivers; or
- (b) who (whether or not the holder of a certificate as afore said) by reason of deafness, total or partial, or defective sight or being subject to fits, giddiness or any other infirmity is unable to discharge his duties efficiently,

and who is in charge of machinery, of a class or description prescribed for the purposes of section 13 (2)(g), in use at any mine in which steam, water, electricity, gas, oil, or air, or any two or more of them are used as motive power (except water power used for pumping) and any other person who, knowing that such person is not registered as the holder of such certificate, or that he is subject to such defect or infirmity, employs any such person as aforesaid, shall be guilty of an offence against this Act.

- (2) Any person who being registered as the holder of a certificate as aforesaid is in charge of any such machinery in use at any mine, and such machinery is not of the class or description of machinery of which he may be in charge or have the management under the authority of such certificate, shall be guilty of an offence against this Act.

DIVISION 2 - SPECIAL RULES

58. (1) The Governor may make such rules (referred to in this Act as special rules) for the conduct and guidance of the persons acting in the management of any mine or employed in or about the mine as, under the particular state and circumstances of such mine, may appear best calculated to prevent dangerous accidents, and to provide for the safety, convenience, and proper discipline of the persons employed in or about the mine.

(1A) A provision of a special rule may -

- (a) apply generally or be limited in its application by reference to specified exceptions or factors;
- (b) apply differently according to different factors of a specified kind; or

(c) authorize any matter or thing to be from time to time determined, applied or regulated by any specified person or body, or may do any combination of those things.

(1B) Subject to subsection (4), section 41 of the Interpretation Act, 1897, applies in respect of a special rule made under this section as if this Act had been passed after the commencement of the Interpretation (Amendment) Act, 1969.

(2) All special rules shall be observed in and about the mine to which they refer (including any extension thereof) in the same manner as if they were enacted in this Act.

(3) If any person who is bound to observe the special rules for any mine acts in contravention of or fails to comply with any of them, he shall be guilty of an offence against this Act, and also the owner and manager of such mine shall each be guilty of an offence against this Act, unless he proves that he has taken all reasonable means, by publishing and to the best of his power enforcing the rules as regulations for the working of the mine, so as to prevent such contravention or noncompliance.

(4) Any special rules in force immediately before the commencement of the Mines Inspection (Amendment) Act, 1967 -

(a) shall continue in force notwithstanding any amendments made by that Act;

- (b) shall be deemed to have been made by the Governor under this section as amended by that Act; and
- (c) may be amended, substituted or repealed by the Governor under this section, as so amended.

66. Every person who pulls down, injures, or defaces any abstract, notice, proposed special rules, or special rules, when posted up in pursuance of this Act, or any notice posted up in pursuance of the special rules, shall be guilty of an offence against this Act.

PART VII

LEGAL PROCEEDINGS AND MISCELLANEOUS

DIVISION 1 - LEGAL PROCEEDINGS

67. (1) Every person employed in or about a mine other than an owner, or manager, who is guilty of any act or omission, which in the case of an owner or manager would be an offence against this Act, shall be deemed to be guilty of an offence against this Act.
- (2) Every person who is guilty of an offence against this Act for which a penalty is not expressly prescribed shall be liable to a fine not exceeding, if he is an owner or manager, \$500, and if he is any other person, \$200 for each offence; and if an inspector has given written notice of any such offence, to a further fine not exceeding \$100 for every day after such notice that such offence continues to be committed.
- (3) The penalty for an offence against this Act relating to the storage or use of explosives in or about a mine is a fine not exceeding \$1,000.

68. Where an owner, or manager of, or a person employed in or about, a mine is guilty of any offence against this Act which, in the opinion of the Court that tries the case, is one which was reasonably calculated to endanger the safety of the persons employed in or about the mine, or to cause serious personal injury to any of such persons, or to cause a dangerous accident, and was committed wilfully by the personal act, personal default, or personal negligence of the person accused, such person shall be liable, if the Court is of opinion that a fine will not meet the circumstances of the case, to imprisonment for a period not exceeding three months.
69. (1) Proceedings for an offence against this Act, section 24 excepted, may be taken before a court of petty sessions held before a stipendiary magistrate sitting alone or before the Supreme Court in its summary jurisdiction.
- (2) If proceedings in respect of an offence against this Act are brought in a court of petty sessions held before a stipendiary magistrate the maximum penalty that the court may impose in respect of the offence is, notwithstanding any other provision of this Act, \$2,000 (including any daily penalty) or the maximum penalty provided by this Act in respect of the offence, whichever is the lesser.
- (3) If proceedings in respect of an offence against this Act are brought in the Supreme Court in its summary jurisdiction, the Supreme Court may impose a penalty not exceeding the maximum penalty provided by this Act in respect of the offence.

- (4) Proceedings in the Supreme Court in its summary jurisdiction in respect of an offence against this Act may be commenced only within 6 months after the offence was committed.
71. (1) Where an offence has been committed, for which the owner or manager of a mine is liable under this Act, but which has not personally been committed by such owner or manager, no proceedings for such offence shall be instituted against such owner or manager except by an inspector or with the consent in writing of the Minister.
- (2) An inspector shall not institute any prosecution under this Act against the owner or manager or an employee of a mine if satisfied that he had taken all reasonable means to prevent the commission of the offence.
- (3) Proceedings for an offence referred to in section 37A (4) shall not be instituted except with the consent of the Minister.
72. Where the owner or manager of a mine has taken proceedings under this Act against any person employed in or about a mine in respect of an offence committed under this Act, he shall within 21 days after the hearing of the case report the result thereof to an inspector.
73. (1) Nothing in this Act shall prevent any person from being indicted or liable under any other Act or otherwise to any other or higher penalty or punishment than is provided for any offence by this Act; provided that no person shall be punished twice for the same offence.

- (2) If the court before whom a person is charged with an offence under this Act thinks that proceedings ought to be taken against such person for such offence under any other Act or otherwise, it may adjourn the case to enable such proceedings to be taken.

74. Where a fine is imposed under this Act for neglecting to send a notice of any explosion or accident, or for any offence against this Act which has occasioned loss of life or personal injury, the Minister may direct such fine to be paid to or distributed among the persons injured, and the relatives of any person whose death may have been occasioned by the explosion, accident, or offence, or among some of them; provided that -

- (a) such persons did not in his opinion occasion or contribute to occasion the explosion or accident, and did not commit and were not parties to committing the offence;
- (b) the fact of the payment or distribution shall not in any way affect or be receivable as evidence in any legal proceeding relative to or consequential on the explosion, accident, or offence.

Save as aforesaid all fines recovered under this Act shall be paid into the Treasury and carried to the Consolidated Revenue Fund.

75. All notices and documents required by this Act to be served or sent by or to an inspector may be either delivered personally, or served or sent by post by a registered letter.

APPENDIX II

CANADA

BRITISH COLUMBIA MINE REGULATIONS

9. Notice to Inspector of dangerous occurrences.

Where in or about a mine there is a dangerous occurrence involving:

- (a) overwinding of a cage, skip, elevator, or bucket;
- (b) breakage of a rope used for hoisting men;
- (c) inrush of water;
- (d) fire underground;
- (e) premature or unexpected explosion of explosives or gas;
- (f) inflow of explosive or other dangerous gases;
- (g) breakdown of main ventilation system;
- (h) vehicles out of control; or
- (i) any other unusual occurrence,

and where notice thereof is not required to be given under section 8, the owner, agent, or manager shall, within 24 hours after the occurrence, mail a notice in writing to the Inspector, Chief Inspector, and the local union or safety committee, and shall furnish such particulars as may assist the Inspector in making inquiry into the occurrence.

Ventilation shut down for four hours.

If the main system of ventilation is shut down for more than four hours, ventilation shall be restored for at least four hours or other suitable intervals before any person enters the mine.

Men to be withdrawn if fan stopped.

If the main system of ventilation is stopped, other than through momentary interruption of the power supply, and a hazard to workmen would exist because of this stoppage, all

persons shall be immediately withdrawn from the mine, and there shall be no re-entry of persons until the ventilation has been restored and the workings inspected and pronounced safe by an authorized person.

Rule 92. Unused workings to be tested for gas.

- (a) Underground workings, especially raises, shafts, and sumps, that have been in disuse for some time shall be examined before being used again, in order to ascertain whether air deficient in oxygen or containing dangerous gases has accumulated therein; and
- (b) Only authorized persons as may be necessary to make the examination shall be allowed to proceed to such places.

Rule 313. Where there exists danger of ignition of inflammable gases or material, no part of the equipment of a mine electrical system shall be opened or taken apart for examination, removal, or repair unless that part of the system has been disconnected from its supply and made dead.

BRITISH COLUMBIA COAL MINE REGULATIONS

Rule 28. Shot-firing and flammable gas.

Charging and firing of shot-holes.

In no case shall shot-holes be charged or shots fired where the presence of flammable gas exceeds one per centum as determined by a flame safety lamp or approved appliance.

Rule 29(b). Charging and firing of shot-holes.

Before the hole is charged, the shot-lighter shall examine the area contiguous to it within a radius of 75

feet, and shall ascertain that it has been adequately treated for coal dust, that the ventilation is normal, and that no flammable gas exceeding one per centum as determined by a flame safety lamp or approved appliance is present.

Rule 30. Use of explosives where outbursts occur.

Where large volumes of flammable gas may be given off by the seam unexpectedly, no explosives shall be used in the mine or part of the mine subject to such outbursts, except upon approval in writing of the Inspector, such approval stipulating the conditions under which the use of explosives is thus permitted.

Rule 85(d). Men to be withdrawn if fan stopped.

If the main system of ventilation is stopped, other than through momentary interruption of the power supply, and a hazard to workmen would exist because of this stoppage, all persons shall be immediately withdrawn from the mine, and there shall be no re-entry of persons until the ventilation has been restored and the workings inspected and pronounced safe by an authorized person holding a first-, second-, or third-class certificate under this Act.

(d) Construction and location of fans and housing.

All fans and all structures containing fans shall be of fireproof construction and, except in case of auxiliary or development fans, shall be installed at the surface and shall be reversible.

Rule 89(a)(iv) Combustible matter to decrease with methane present.

The permissible percentage of combustible matter in the dust found in any underground roadway shall be further

decreased by one for each increment of one-tenth part of one percent in the methane content of the mine air beyond a quarter of one percent.

Rule 91. Inspector may order interval between shifts.

If, in the opinion of the inspector, owing to the quantity of flammable gas given off or the quantity of dust created by working, or for any other reason, it is unsafe to work two shifts in close succession in the rooms or stalls, he may require that there be such interval as he thinks necessary between the finishing of work by one shift and the beginning of work by the next, and he shall give notice in writing thereof to the agent, owner, or manager of the mine in the form and manner set out in section 6.

Rule 95(ii)(b) Use of diesel engines underground.

- (B) All mobile diesel-powered equipment shall be equipped with suitable lights, sound-warning devices, fire-extinguishers, flame traps, exhaust-conditions, and all shall be kept in working order.
- (C) The flame traps fitted to the diesel engine shall be detached and replaced by traps in clean condition at least once in every 24 hours.

Rule 96. Main fan.

- (a) Fans used for ventilating underground shall be offset not less than 15 feet from the nearest side of the mine opening, equipped with fireproof air ducts, provided with explosion doors or a weakwall, and operated from a separate power circuit, but a fan may be located directly in front of or over a mine opening, provided that such opening is not in

direct line with possible forces coming out of the mine if an explosion occurs, and provided further that there is another opening having a weakwall stopping or explosion doors that would be in direct line with the forces coming out of the mine, such opening to be not less than 15 feet or more than 100 feet from the fan opening.

- (b) Main fans shall be provided with a pressure-recording gauge or water gauge and, unless the fan is attended constantly, an automatic device to give alarm when the fan slows down or stops. Such alarm shall be placed that it shall be seen or heard by a responsible person.

Rule 101. Abandoned workings.

All worked-out or abandoned parts of a mine in operation shall be kept free from dangerous accumulations of flammable gas or shall be sealed with substantial seals.

Rule 102. Flammable gas detection.

- (a) At any time where the Inspector is of the opinion there is a hazard due to the presence of flammable gas, he may require the manager to provide a sufficient number of appliances approved by the chief inspector for the determination of lower percentages of flammable gas than can be detected with a safety lamp.
- (b) The inspector may require the manager to appoint a competent person holding a first-, second-, or third-class certificate of competency under this Act to make regular determinations of the content of flammable gas in the mine air at such points and

at such time intervals as the Inspector may prescribe, and a record shall be kept of such determinations.

- (c) Where electrically powered machinery is employed at the coal face or at any other point where the inspector is of the opinion that a hazard exists by reason of the presence of flammable gas, the Inspector may require the manager to provide an appliance of a type approved by the Chief Inspector which may be set to give an audible or visible warning when a predetermined percentage of flammable gas is present in the mine.

Rule 103. Reporting of flammable gas.

If the air immediately returning from a split that ventilates any group of active workings, or if the air in the main return airway is found to contain more than one percent of flammable gas as determined with a permissible flame safety lamp, air analysis, or other approved means of detection, the person who detected the same shall report his finding forthwith to the manager. The manager shall within 24 hours mail a notice of the condition in writing to the Inspector, and shall take immediate steps to improve the ventilation.

Rule 104. Flammable-gas content of return air.

If the general body of the air in the vicinity of any operating electrical machinery is found to contain in excess of one and one-quarter percent of flammable gas as determined by means of a permissible flame safety lamp or other approved means of detection, the electrical power shall be cut off from the machinery until such time as the ventilation has been improved

and the person in charge of that part of the mine has, after examination of the place, given permission for the electric power to be switched on.

Rule 105. Withdrawal of persons.

- (a) If at any time it is found that the general body of the air in a place in a mine contains two and one-half percent or more of flammable gas, the person in charge of that part of the mine in which the place is situated shall comply with the following requirements, namely:
 - (i) He shall forthwith cause all persons employed in so much of that part of the mine as appears to him to be affected (hereinafter referred to as the "affected area") to leave it;
 - (ii) Unless he is the manager of the mine, he shall without delay inform his immediate supervisor;
 - (iii) Inasmuch as it is possible to do so without undue risk, he shall himself ascertain or cause some competent person to ascertain the condition of the affected area and the measures necessary to render it safe.
- (b) No person shall be readmitted to the affected area until the person in charge of that part of the mine or a competent person appointed for the purpose has examined the area and reported it to be safe, but nothing in this clause shall prohibit a person entering the affected area for the purpose of saving life or rendering the area safe.
- (c) Where persons have been caused to leave an affected area by the foregoing provisions of this rule, the person who caused them to leave shall record in a book, to be provided for that purpose and kept at

the mine, particulars of the reason for causing them to leave, and the person who carries out the examination required in subrule (b) of this rule shall report the results of his examination in the aforesaid book.

Rule 106. Care of safety lamps.

No lamp or light other than a locked safety lamp of a pattern approved by the Chief Inspector shall be allowed or used underground in a mine; and a competent person or persons shall be appointed by the owner, agent, or manager for the purpose of examining and shall examine every safety lamp immediately before it is taken into any mine, and ascertain it to be secure and securely locked.

Rule 107. Lamps to be examined.

No safety lamp shall be taken into a mine unless it has been examined and found secure, nor shall any safety lamp be unlocked except in a lamp-room on the surface.

Rule 108. Maintenance of flammable-gas detectors.

The owner, agent, or manager shall appoint a competent person to examine and maintain in safe and efficient working order all appliances used in or about the mine for the detection of methane.

Rule 109. Single-gauze lamp prohibited.

No single-gauze safety lamp shall be allowed in a mine.

Rule 110. Safety lamps to be submitted to mechanical air test.

Every flame safety lamp shall be submitted to a mechanical air test whenever assembled after being

taken apart; and if shown by such test to be imperfect or ineffective, its use shall not be permitted; and every colliery using safety lamps shall be equipped with apparatus for making such tests as are approved of by the chief inspector.

Rule 111. Relighting flame safety lamp.

A person having a flame safety lamp with a self-contained relighting device shall not -

- (1) attempt to relight the lamp unless he has examined it and found it to be undamaged;
- (2) attempt to relight the lamp if he has reason to suspect the presence of flammable gas.

Rule 112. Care of safety lamp.

- (a) A person who carries a safety lamp in a mine shall take all reasonable precautions to prevent the lamp being damaged and shall not leave the lamp unattended.
- (b) If any safety lamp is damaged in a mine, the person using it shall carefully extinguish the light.

Rule 113. Testing of safety lamps.

Every flame safety lamp so in use shall be tested in an explosive mixture of gas and air at least once every week; and if the glass, washers, gauze, or any of the essential parts of such lamp have been renewed after a lamp has been so tested, then such lamp shall be again tested; and any lamp that is shown by such test to be imperfect or ineffective shall not be allowed in a mine until such imperfection or ineffectiveness has been remedied and the lamp has passed a satisfactory test.

Rule 114. Articles prohibited underground.

- (a) No person shall have in his possession in a mine any match or apparatus of any kind for striking a light, except a relighting device enclosed within the tube of an approved flame safety lamp, or any pipe for smoking tobacco, or any tobacco or smoking mixture for smoking, either as cigars, cigarettes, or in any other form.
- (b) The owner, agent, or manager shall appoint a competent person to search any underground employee for any article prohibited by this rule, and the Inspector may order a search for such purpose of any employee whenever he deems it necessary, and any person refusing to submit to such search shall be deemed to be a source of danger to other persons in the mine, and shall be immediately removed from the mine by order of the person appointed to make the search or by order of the Inspector, and such refusal shall be a violation of this Act.
- (c) Nothing in this rule shall be so interpreted as to prevent the use of a shot-igniter, electric firer, or other appliance for such purpose if of a pattern approved and permitted by the Chief Inspector.

Rule 220. Restriction of electric lighting.

- (a) No part of an electric-lighting system shall be extended into any part of a mine where permissible equipment is required or where there is danger of explosion from flammable gas or coal dust unless such equipment is of an approved type.

APPENDIX III
CHILE

Excerpts from Mine Safety and Policing Regulations

EXPLOSIVES IN MINES AND QUARRIES

<u>Paragraph 1</u>	Acquisition and Transportation of Explosives
<u>Paragraph 2</u>	Storage of Explosives
<u>Paragraph 3</u>	General Statements Regarding Use of Explosives
<u>Paragraph 4</u>	Blasting in General

Art. 153 In coal mines, the holes bored will be loaded with cartridges having a physical diameter with a maximum ease of 6mm.

Art. 163 In coal mines where the risk of a sudden release of firedamp exists, the trigger or switch will be located at a distance of at least 170 meters from the blast area, in such a way that the person triggering it, and anyone else that may be affected, are away from the straight trajectory of the explosive, unless suitable refuges or booths exist, provided with fresh air independent from the ventilating circuit at the blasting location.

Art. 166 In coal mines, electric detonators and installations will comply with the intrinsic safety rules defined in Article 284. whenever there is a firedamp hazard.

<u>Paragraph 5</u>	Primary Blasting
<u>Paragraph 6</u>	Secondary Blasting
<u>Paragraph 7</u>	Explosives in Underground Mining

Art. 186 In coal mines where flammable gases have been detected, it will be compulsory to use safety explosives, also known as "permissible" explosives.

Art. 187 Use of explosives in coal mines that have firedamp will be subject to the following conditions:

1. Safety explosives will be those approved by the Instituto de Investigaciones y Control del Ejercito, and recommended by the Service.
2. They will only be used at one specific location and at those times when there is less circulation in nearby works, and only after checking lamp flames to ensure that there are no flammable gases present. This checking must be done before fire is

applied to any explosive-filled hole (before shooting the round).

3. No more than one loaded hole will be fired at a time in each work, unless several shots are simultaneously electrically detonated.

4. Explosives allowed in coal mines will be tested in a stainless steel gallery with an internal sheath of reinforced concrete and a 1.60m vacuum.

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Explosives to be used in coal fronts or fronts where a firedamp danger exists will pass the two tests of slotted blocks with lateral slots.

It is up to the experimenter to determine how many tests will be made; however, each test will have at least 5 trials, both with firedamp and with dusts.

7. When testing with firedamp, the gas used will have the same composition as the one in the mine, and it will be at maximum explosive concentrations, meaning between 8 and 10%.

For tests with dusts, the coal used will have the maximum amount of volatile material content found in the mine, or it will have at least a 30% volatile material content, passing through a 00 Tyler sieve.

The loaded hole will be prepared in the presence of a preformed cloud.

8. The load limit to be used in coal fronts where firedamp is a danger will be 2800 g.

Paragraph 8 Rules regarding the storage and handling of ammonium nitrate and the preparation and use of explosives from mixtures of nitrate and petroleum.

Art. 238 The use of ANFO (mixtures of nitrates and petroleum) is prohibited in coal mines where it cannot be guaranteed that ignition of the coal can be prevented.

TITLE X
ELECTRICITY IN UNDERGROUND MINES

Paragraph 1 General Provisions

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Art. 284 No current from lighting or power circuits will be used to cause electrical triggering where there are flammable gases in the air.

Equipment and circuits to be used where an explosion of firedamp may occur, will be flameproof. This means that it can operate without igniting a control mixture placed in a test tunnel, composed of 16% oxygen, 64% nitrogen, 14% hydrogen, and 6% methane, and in an atmosphere of 80% compressed air and 20% mixture, 70% hydrogen, and 30% methane or liquid gas.

The current used in testing electrical detonators will be at least 50 milliamperes. This condition is known as "intrinsic electric safety."

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TITLE XI SPECIAL RULES

Paragraph 1 Ventilation

Art. 291 Paragraphs I, II and III of Title IX and all the rules in Title V will apply except where they conflict with this title.

Art. 292 The entrance of the ventilating current in coal mines will be so situated that coal dusts will not be sucked in.

The coal deposit area must be located far enough away from the mouth of the mine that the smoke would not enter the mine if the stored coal were to ignite.

Art. 293 A barometer will be placed on the surface of a coal mine, next to the pressure gauge in the ventilating fan. In mines where explosive gases have been found, it is forbidden to ventilate exploitation fronts by a descending air current.

Paragraph 2 Lighting

Art. 294 In coal mines, lighting will be by safety lamps and it is forbidden to open them inside the mine. If it is necessary to relight them, this operation shall only be performed by authorized personnel at the locations indicated by the Administration of the mine. The use of other types of lamps will only be permitted if the Administration so determines, and if approved by the Service.

Safety lamps must be equipped with locks or other safety features to prevent fatal accidents.

- Art. 295 Anyone employed in the mine, whose safety lamp is defective in any way, must immediately turn it off and inform the superintendent of his reasons for doing so.
- Art. 296 In coal mines where a firedamp hazard exists, works must be inspected each time working is resumed, by employees appointed by the Administration. These inspectors will also be in charge of overseeing the ventilation in mine works and will evacuate them if there is any danger due to concentrations that exceed the minimums established in Article 272 above. Work can only be resumed when the air is back to normal. Each time firedamp accumulates, in whatever amount, this fact will be recorded in the book kept by the superintendent of the section.

APPENDIX IV
CZECHOSLOVAKIA
DIVISION OF MINES

1. From a ventilation perspective, with respect to the presence of methane in mines, two categories have been established:
 - a. Mines free of explosive gases (non-gaseous mines)
 - b. Mines with explosive gases (gaseous mines)
2. Non-gaseous mines are those wherein any ventilated underground working the methane content does not exceed 0.1%. In addition, upon cessation of ventilation fans for a period of 24 hours, the methane content should not exceed 1.0%. Gaseous components stemming from mining fires are not considered in the classification.
3. Only mines designated and classified by the District Mining Board (DMB) belong to the non-gassy category.
4. All gassy mines are classified in accordance with the amount of outflowing methane and mode of methane emission detailed as follows:
 - a. Mines subjected to a sudden outburst of coal and gases. This category includes all mines where the methane emissions have already occurred or have been classified and designated by the DMB (based on the geological environment and other conditions ascertained and supposed within the actual or adjoining mine).
 - b. "Second Class of Danger" Mines--This category contains all mines located within the Ostrava-Karvina coal

district and any other mines so classified by the DMB.

- c. "First Class of Danger" Mines--This category includes all other gaseous mines.
- 5. If the mine is divided into several separate explosion proof isolated ventilated panels (departments), the DMB can classify the panel (department served with independent down and upcast air shafts) to a separate category or other class of danger from the remainder of the mine.
- 6. The DMB must be notified by the mine management about all significant discoveries and information that might influence the classification of the mine into a different category or class of danger.

In gaseous mines the following procedures are mandatory:

- a. On a monthly basis, air in the primary upcast shaft must be measured with respect to quantity, temperature, and moisture. An air sample analysis must also be taken.
- b. On a monthly basis, upcast air from the collection point of every individual air network compartment must be measured for quantity, temperature, and moisture. The air must also be analyzed. If the analysis shows that the air current contains more than 1.0% of methane, 1.0% of carbon dioxide, or 0.001% of carbon monoxide, additional samples must be taken. It is important to localize the sources of damp*, and appropriate measures must be taken and recorded.

* *Firedamp, blackdamp*

- c. Upcast air flows in the vicinity of every working stope, separately ventilated underground working, and haulage roads (either with diesel or electric locomotives) must be measured, sampled, and analyzed for methane, carbon monoxide, and carbon dioxide content on a monthly schedule. Air velocity must be measured in all faces monthly.
 - d. Finally, at least once a month all air flow near electric equipment must be sampled and analyzed for methane content. If electric devices are situated in the same air current next to each other, it is sufficient to sample the air near one particular electric device where the conditions for methane accumulation are presumed most favorable.
- 7. Air sampling and analysis for oxygen, carbon monoxide, and carbon dioxide content is required in underground workings where:
 - a. Blasting operations are taking place (nitrogen gases are also monitored).
 - b. Combustion engines are used in haulage, or immediately after their introduction, and
 - c. In situations where substantial changes in working or ventilating conditions occur.
- 8. At every essential change in working and ventilating conditions the air in possible accumulation areas must be sampled at a time which is considered most favorable for detection of combustible gases.

9. Procedures and analyses prescribed in 1-4 can be omitted and substituted by the results rendered from gas detectors. Gas detectors may be used only in applications determined by the Czech Mining Bureau (CMB) decree.
10. All results of measurements and analyses must be recorded and copies signed by mine management within fixed time limits (determined by the DMB) and sent to the DMB.
11. Methods of air-sampling and analysis must comply with the Czechoslovak standards or must follow special regulations of CMB. Air samples must be analyzed for O_2 , CH_4 , CO_2 , CO , and any other so designated combustible or noncombustible gas.
12. In every gassy mine and in mines where damp might be expected to blow out from gobs, a barograph must be installed. Barometric pressure must be closely watched, mainly before man hoisting. An underground superintendent must be immediately notified about any sudden decrease of barometric pressure. Barograph data must be stored for a minimum period of 6 months.
13. Composition of mine airflows with regard to the methane content.

The methane content in mine airflows in all underground workings where miners are present or might be present must not exceed a value of 1.0%. In other areas located well away from the effective range of air-currents, local concentrations of methane of up to 2.0% are allowed.

When it is not technically feasible to decrease the amount of methane to the values previously stated (1.0% and 2.0%,

respectively) the manager is entitled to allow for increased methane content up to the following values for a necessary period of time:

- a. Up to 1.5% of methane content in all air currents including stopes and all working sites, excluding overall air current in upcast air shaft, adits, or boreholes.
- b. Up to 2.0% in through upcast air currents downstream from the last working sites and up to the overall upcast air current in an upcast air shaft, adit, or borehole, under precondition that within a period of 6 months, the amount of methane will be decreased by remedial action to not more than 1.5%.

With written permission, the manager must state a period of time for which the permission has been issued and lay down necessary precautions as well. The following measures are required:

- (i) All possible technical precautions must be used in order to restore the original state of air quality.
- (ii) At least once every 14 days, the air must be sampled in particular places which are presumed most favorable for methane blowers and accumulations. When gas indicators are used, the air should be sampled every day.
- (iii) If the higher methane content (1.5%) is allowed and when the geologic conditions are such that methane accumulations might occur, the firedamp content must be measured in places near electric and ventilating equip-

ment with greater frequency. The methane content is measured either by gas detectors or by properly registering automatic devices.

- (iv) A thorough daily control by superintendents and mining inspectors should be conducted with emphasis on gas control measurements and coal-dust suppression.
- (v) A maximum crew of 70 is allowed in the separate department where the higher methane content has been approved.

AIR FLOW AND DISTRIBUTION

1. When ventilation is by through air current, downcast air must be directed along the shortest route to an appropriate downcast level or to a lowermost place.
From there, it is directed either horizontally or vertically to the upcast shaft or adit.
2. The inclined conduct of return air up inclines in gassy mines of the second class of danger, and in beds where blowouts of coal and gases might occur, is allowed for a vertical height of 10 meters, and in mines of the first class of danger, for a vertical height of 15 meters, if the methane content will be 1.0% or less.

In gassy mines auxiliary fans must not be installed more than 5 meters away from a fresh air current.

Procedures when gas accumulations are quantified.

1. If the amount of underground damp exceeds the allowable values and it is not feasible to restore normal conditions by

ventilation, all personnel must leave the affected workings and the workings must be fenced off. The management of the mine must be notified immediately and measures taken to improve conditions. DMB must be notified if the conditions have not been improved during one shift.

2. If the methane content reaches the upper maximum allowable value for the use of electric equipment, it is mandatory to switch off all electric equipment. Machines essential for mine functioning such as pumps and main fans, are excepted if the danger of explosion is not imminent. Decisions are made by the head of mine safety in accordance with the established safety procedures.
3. In mines where damp might be expected to occur (when barometric pressure decreases) the management must determine necessary measures to deal with the higher possible content of explosive gases in the air. All precautionary measures must be included in the accident plan.
4. Stopes can be remanned and the electric equipment switched on only when the mine air again contains less than the prescribed maximum allowable values for combustible gases.

BLOWERS AND BLOW-OUTS OF COAL AND GASES

Blowers

1. The management must be immediately notified about any occurrences of blowers and take safety precautions. The DMB must be acquainted with all measures taken by management to deal with blowers.

2. The mine manager must immediately determine precautions necessary for the control of blowers (blowers must be intercepted and drained off in order to prevent the gas leaking into the fresh air current).
3. All blowers must be described in detail and recorded.

Blowouts of Coal and Gases

All mines where coal and gas blowouts might occur must comply also with a special regulation issued by the CMB.

Isolation of Air Current

In all gassy mines classified as second class of danger, or where it is ordered by the DMB, explosion proof bulkheads, or bulkhead doors must be erected in the following locations;

- a. Between downcast and upcast shaft
- b. Between separate ventilation departments
- c. Between separate ventilation departments and combined joint down-cast and up-cast air currents.

Ventilation of Stopes

All stopes must be ventilated by through air flow. In all gassy mines, the air current must flow close along working faces and must be conducted horizontally or vertically. The temporary inclined conduct of the air current must be approved by the mine manager. In all stopes of gassy mines, the following is mandatory:

- a. Measurement of the methane content (must not exceed 1.0%)
- b. The methane content must be measured also in the uppermost place of any inclined air current.

- c. In uptake headings from the top level of the inclined air current, an air sample must be taken and analyzed weekly.

APPENDIX V
WEST GERMANY
FIRE PROTECTION
EXPLOSION AND FIRE PROTECTION
SECTION 37

- (1) In the sense of this regulation, rooms and regions in which, by local and usual conditions, any gas, vapor, smoke or dust that forms explosive mixtures with air can accumulate in dangerous amounts, are in danger of explosions.
- (2) In the sense of this regulation, rooms and regions which contain materials or items that are easily flammable and in which a fire is difficult to extinguish, in such quantity that by their inflammation dangerous fire can break out, are in danger of fires.¹
- (3) In rooms or regions in danger of fire or explosion, any association with open fire or light as well as smoking is forbidden. Sparks may not be generated. Rooms or regions in danger of fire or explosion must be marked as such with reference to this prohibition.
- (4) If in rooms or regions in danger of explosion, explosive mixtures are demonstrably not present and not expected, then the works manager, in special substantiated individual cases, departing from paragraph (3) can give written permission to weld, cut and solder. With the granting of this permission, the requisite safety measures for each particular case are to be laid down.
- (5) Departing from paragraph (3), equipment for welding, cutting or soldering or other work equipment by which open flames

are used or sparks are generated, may be used with written permission of the works operator in rooms and regions in danger of fire. With the granting of this permission the requisite safety measures must be laid down.

- (6) For shaft structures and conveyer framework, the permission of paragraph 5 is also required, where it is not a question of rooms and regions, but rather the shaft that is in fire danger.
- (7) The mines office can also declare rooms or regions as being in danger of fire or explosions, for significant reasons other than those in paragraphs (1) and (2).

¹Rooms and regions in danger of fire include, for example, woodworking shops, wood depots, sack depots, depots for flammable liquids, explosives-depots, workshops for motors or motor vehicles. Easily flammable materials include especially the building materials that are cited in DIN 4102, sheet 4, figure 3.2.3, and sheet 10, figure 6 (compare also appendices 2 and 3 of RdErl. D. Nds. Fin.M. of June 14, 1966 - Nds.MBC. page 675 and following), as well as flammable liquids following § 3 Appendix 1 of the regulations on flammable liquids of February 18, 1960 (BGBI.I pages 83 and following) in the version of June 5, 1970 (BGBI.I page 689) with the exception of group A, danger-class III. Difficult to extinguish are, for example very hot fires.*

²This regulation is concerned with the neighborhood of the shaft, the reason being that falling weld-beads and glowing pieces of metal are empirically known to be able, even at a depth of many hundreds of meters, to start fires.

Section 37a

- (1) In as much as electrostatic charging capable of igniting explosive air/gas mixtures is to be expected during the working and use of plastics, as well as during the use of _

* *Note: Translations of the cited publications and appendices are not at present available. Despite repeated efforts, we have not been able to obtain a complete edition of the German codes.*

drive-belts and v-belts, safety measures which guarantee safe working conditions must be taken.

- (2) In rooms or regions in danger of fire or explosion, drive-belts and v-belts must be relatively non-flammable.

Section 52
Safety of Boreholes

With the exception of drainage bore-holes, all test bore holes underground in non-fissured areas must be so operated and, before being vacated, so secured, that neither liquids or gases can enter into the underground working.

SPECIAL OPERATING PLAN FOR HATTORF WERKEN, PHILIPPSTHAL/WERRA
FOR THE YEAR 1981

Reproduced, courtesy of Kali und Salz AG, Kassel, West Germany.

Concerning the danger of CO₂ entering the mine chambers. Because of the occurrence of CO₂ during the extraction as well as the exploration of the deposit the following measures are to be taken in all working areas of the mine for the protection of the work force.

A) In general:

- 1) Every member of the work force will be informed of the dangers associated with the occurrence of CO₂, and instructed as to appropriate behavior in the event of a CO₂ occurrence. The CO₂ pamphlet will be handed out to every member of the work force.

- 2) In the mining districts as well as in the ventilation return air, flame safety lamps will be installed, to indicate in the blasting room above ground the occurrence of CO₂ during blasting sequences.
- 3) In every construction area a microphone will be installed, whereby CO₂ outbursts will be heard over a loudspeaker in the surface blasting room.
- 4) Blasting in the potash district at the end of every shift will be done only when all members of the work force have left the underground. Exceptions are the remaining people in the region of the Ransbach and Hattorf shafts, according to the permit 76.d 20-310/18/6 from January 3, 1973 (Appendix 1).*
- 5) During blasting in the NaCl district at the Hattorf shaft, the work force from the potash district must stay at the Ransbach** shaft. People will not be allowed, during the regular blasting in the NaCl district, to stay in the bunker region or at the Hattorf shaft.*** All people must stay in the Hattorf blasting chamber.
- 6) Single blasts during the shift will require the approval of the managers of the operation.
- 7) All members of the work force must carry matches with them, as indicators to detect CO₂.

* This appendix was not attached to the original German and is not available.

** Ransbach is the man-hoisting shaft.

*** This is probably an allusion to blasting during road-building, which is not normally done within the seam.

- 8) Inspection of the discovery of a CO₂ occurrence will always be carried out by two people acquainted with the locality; as soon as CO₂ is noticed, the inspection will be made only on foot, to confirm the presence of CO₂ by measurement.

All members of the work force must be instructed to give the appropriate notification of the occurrence of CO₂ immediately.

- 9) All members of the work force must carry with them an oxygen-self-rescue system OXY SR 45.

B) Drilling Large Diameter Boreholes:

- 1) The large hole drilling wagon (GBW) is automated so that upon reaching the borehole length the drill rods are retracted and the drilling motor automatically shuts off.
- 2) The operators of the large boreholers must abandon the drill site when drilling begins.
- 3) The drill site will be closed off by signs with the inscription:

"The large-hole drilling wagon is running! Entrance forbidden!"

The minimum distance from the drillhole site should be 30m.

- 4) If the drill place must be entered during the operation, the GBW must be shut down before entering the area by using the FI* switch.
- 5) The large-hole-drilling wagon will not be put into operation again until the drilling rod is backed-up 20 cm, so that the operator can leave the drill site before the drilling bit can commence cutting.

C) Drilling Regular Blast Boreholes:

- 1) If blow holes are encountered while drilling a blast hole the appropriate notification must be made.
- 2) For large blow-holes the drill place must be abandoned and closed off. Any further measures necessary will be designated by authorized supervisory personnel.

D) Blasting of the loaded drill holes:

- 1) The shift boss will name a mine blast inspector for setting off blast holes from the blast-room on the surface.
- 2) The supervisor responsible for the man-hoisting cage will hand over the blast token, and therewith the permission to blast, at the end of the regular end-of-shift hoist.
- 3) Personnel who remain in Works 1 red-marked regions will be registered and will stay in telephone connection with the mine blast inspector.

* Remote switch in the control room.

- 4) The blast inspector will watch over the CO₂ control lamps in the blasting room for 45 minutes after the blast impulse.

E) Measures to be taken at the extinguishing of the CO₂ lamp(s) in the mine workings:

- 1) The foreman will inform the shift boss about the extinguishing of the CO₂ lamp(s).
- 2) Two people well acquainted with the affected mine workings will set out immediately to gather information on the extent of the CO₂ gas.
- 3) Central communications underground will be manned immediately.
- 4) The CO₂ Warning signal posts with the inscription "Stop! Carbon dioxide!" with the appropriate warning siren, on the approaches to the Ransbach shaft, will be set in operation by the blast-mine inspector.
- 5) The work force will start out of the mine, but will wait for further instruction in the shaft region.
- 6) The personnel who go out to investigate will close off the haulage way of the affected mine works with chain and a CO₂ warning sign, and set out for the working area.
- 7) If the working area is free of gas, the work force in the mine works at the Ransbach shaft will be released.

- 8) The work force of the affected mine area will wait for further instructions at the working area control point.
- 9) Mine workings in which CO₂ is present will be closed off at all entrances.
- 10) The haulage ways will remain closed off until the mine inspector announces that the area is free of CO₂.
- 11) Existing CO₂ accumulations will as soon as possible be purged into the normal ventilation system by blowers.

F) Others:

(a) Exploration Boreholes

- 1) At those horizontal and vertical boreholes necessary for exploration of the perimeter, a CO₂ lamp will be placed in a conspicuous place.
- 2) At the occurrence of a blow-out, the drill operation will cease immediately and the supervisor will be informed.

(b) Coming upon basalt veins:

- 1) If basalt veins are encountered a blast hole will be drilled through the intersection with the basalt and shot with explosives to purge the CO₂ gas from behind the basalt.

We ask permission for this special operating plan.

APPENDIX VI
INDIA

Excerpts from the Code of Mining Legislation (Sixth Edition) 1980

141. PRECAUTIONS AGAINST INFLAMMABLE AND NOXIOUS GASES

1. For the purposes of this regulation, inflammable gas shall be deemed to have been found or detected when it is indicated by the lowered flame of a flame safety lamp or, where methane indicators are used, they indicate 1.25 percent or more of inflammable gas.
2. When any person detects the presence of inflammable gas, he shall not brush or waft it out, but shall immediately withdraw from the place and shall inform his superior official about the same.
3. Where in any place in a mine, inflammable or noxious gas is detected, all persons shall be withdrawn from the place, and the place shall be immediately fenced off so as to prevent persons inadvertently entering the same. The competent person in charge shall, without delay, take steps to remove the gas by improving the ventilation.
4. During the removal of such gas all persons, except those necessary for such removal, shall be withdrawn from the return side of the ventilating district in which the gas has been detected unless the quantity of gas is, in the opinion of the competent person, so small that such withdrawal is not necessary.

Provided that where the danger arises from the presence of inflammable gas, no naked light shall be used in the ventilating district in which the gas is detected.

5. No person shall be re-admitted into the place where the gas was detected until a competent person has examined the place and has reported that the place is free from gas. Every such examination shall be made with approved flame safety lamp and, in case of noxious gas, also with a cage containing suitable birds or other means of detecting carbon monoxide gas approved by the Chief Inspector.
6. Particulars of every occurrence referred to in subregulation (2) and of every examination made under subregulation (5), together with a statement as to where and when the gas was found and when it was removed, and in case of inflammable gas, the percentage thereof, shall be recorded in a bound paged book kept for the purpose. Every such entry shall be signed and dated by the competent person making the report and countersigned and dated by the manager.
7. In any part of a mine to which regulations 123 (1) and 142 apply, or where the Regional Inspector may require by an order in writing, all unused workings which have not been sealed off, shall once at least in every seven days be inspected by a competent person for the presence of inflammable or noxious gas. A report of every such inspection shall be recorded in a bound paged book kept for the purpose, and shall be signed and dated by the person who made the inspection.

142. SAFETY LAMPS TO BE USED IN GASSY MINES

No lamp or light other than an approved safety lamp or torch or other installation permitted under the Indian Electricity Rules 1956, shall be used or permitted to be used below ground in any mine:

- (a) in any part of a mine in which an explosion or ignition of inflammable gas has occurred;
- (b) in any ventilating district in which inflammable gas has been found; and
- (c) in any place in which, in the opinion of the Regional Inspector, inflammable gas is likely to be present in such quantities as to render the use of naked lights dangerous.

Provided that if safety lamps are not immediately available in the case of any mine to which clauses (b) and (c) apply, the Chief Inspector may, by an order in writing and subject to such condition as he may specify therein, grant a temporary exemption from the operation thereof until such time as safety lamps can be obtained:

Provided, further, that the Chief Inspector may, by an order in writing and subject to such conditions as he may specify therein, exempt any mine or part thereof from the operation of this regulation on the ground that on account of the special character of the mine or part, the use of safety lamps is not necessary therein.

APPENDIX VII
ITALY

Excerpts from Norme di Polizia Delle Miniere e Delle Cave, 1959
Article 389

When the Chief Engineer of a mining operation, through inherent characteristics, stratigraphic and tectonic, of the deposit, or through analogy with other existing mines, becomes aware of the possibility of firedamp or other toxic or noxious gases, after reporting to the Superintendent of Mines, he should provide for monitoring the operation. This should continue for two years.

This provision should include the following measures:

- a) Periodical samples of the underground air under conditions of normal ventilation during the more crowded shift, and analyses of these samples;
- b) Methodical inspection of all the underground ways, worksites, and areas, carried out by inspectors with appropriate direct reading gas detectors;
- c) When necessary, precautionary safety measures, especially with regard to ventilation and lighting.

The provision above should also specify the locations and the respective methods for the taking of samples of the atmosphere and the execution of the inspection. It should specify the frequency of any operation of monitoring and also other eventual measures to be adopted for the safety of the personnel.

As established in article 263, provision should be made for the expenses of sampling and analyses and for recording the results. Furthermore in the provision the precise limits of the underground areas should be specified and also the nature and the

frequency of the communications that the mine authorities should forward to the Mining District, not only with regard to the quantity of firedamp and toxic and noxious gases detected, but also to the conduct of the various operations in question.

MINES WITH OCCASIONAL AND WEAK OCCURRENCES OF FIREDAMP,
TOXIC OR NOXIOUS GASES
Article 390

The underground mines in which even weak occurrences of firedamp have been noticed should be subjected to a regime of monitoring at the instigation of the chief engineer. This monitoring should last for two years.

Besides the measures listed as a), b), c), in preceding articles, provision should be made for periodical draft measurement of the primary and secondary ventilating air, following procedures specified in art., 263.* The results of these measurements should be recorded.

Article 391

When the measured volume of firedamp detected under conditions of normal ventilation is less than 0.3%, the Chief Engineer should provide for intermittent checking of firedamp that occurs underground during pre-arranged periods of stopped ventilation, and when normal ventilation is resumed.

After consultation with the mine authorities the chief engineer will establish regulations as follows:

- a) The choice of the time for monitoring and safety measures to be adopted;

* Note: A translation of Article 263 is not available.

- b) The duration of the periods of stopping and resumption of normal ventilation in which the checking should be done;
- c) The frequency of measurement of the concentration of firedamp to be made during such a period with the help of official accepted direct reading gas detectors, along with a collection of air samples for later analyses.

The location for the measurement of firedamp concentration should also be specified, both in the general underground circulation and in the various roadways and working sites. The said operations should be done as indicated in article 263.

The above mentioned inspection data are to be recorded together with the date and the signature of the mine authority.

Article 392

The superintendent of the mine being monitored should notify the Mining District in writing of each new occurrence of firedamp, toxic or noxious gases and of any notable variations in the amount of the existing gases occurring in this mine.

He should also signify the place, time, and circumstances as well as any other relevant data, and state the provisional measures adopted.

Article 393

The chief engineer, when he considers it necessary to follow the specified checks by safety measures will, after consulting with the mine superintendent, establish which of the security

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measures prescribed by the present Act ought to be adopted in all or parts of the mine being monitored, and will set a deadline for action.

Article 394

The mines subject to monitoring should be equipped with at least 4 firedamp detectors of which two should be spares, and at least two detectors, one being a spare, for each of the toxic or noxious gases whose presence has been ascertained or suspected.

The chief engineer may order a greater number of detectors. These direct reading instruments ought to be of the officially accepted standard. The efficiency of the detectors ought to be checked every three months or more often if necessary.

Article 395

When the data acquired in the preceding period has not served to properly classify the mine (for safety), the chief engineer can prolong for only one more year the period of time established for monitoring.

Article 396

During the period established for monitoring, when the manifestation of firedamp or toxic or noxious gases continues or increases, the chief engineer will classify the mine.

For mines not recognized as classifiable, following the period of monitoring the contractor is excused from following the safety measures provisionally set. The chief engineer can order that the methodical monitoring of the underground be started and

be entrusted to a responsible and technically prepared person to reveal the presence of suspect gas, and (can order) that data on this is to be periodically furnished to the Mining District.

The conditions that define such monitoring are specified in the appropriate order issued by the Superintendent.

The Mining District should be notified of the name of the person responsible for the above mentioned inspection.

CLASSIFICATION OF THE MINES FOR FIREDAMP, TOXIC
AND NOXIOUS GASES
Article 398

The underground mines, or parts of these, in which continuous emanations of firedamp have been found are declared [firedamp hazard] and assigned to one of the following categories:

1st category, or slight firedamp hazard, when the concentration of firedamp having been measured according to art. 389; 390; 391; has never exceeded 0.3% by volume during the period of monitoring in the general air flow, in the main and secondary circuits, immediately upstream of entrance into the principal flow, measured in the maximum flow area by direct reading detectors of the officially accepted types and by analyses.

2nd Category, or definite firedamp hazard, when the concentration of firedamp in some places is determined, by the means and method above indicated, to be greater than 0.3% by volume.

To the same category is assigned a mine, or part of it, in which although the concentration of firedamp is not greater than 0.3%, as determined during the monitoring and in the places indicated in the present article, even one of the following conditions occurs:

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1. An accumulation has been noticed under conditions of normal ventilation in worksites;
2. The release of firedamp per ton of ore produced in twenty-four hours, at normal production rate, is in excess of four cubic meters;
3. The presence in the underground of an accumulation of firedamp is measured in the first hour of deliberate stoppage of the main ventilation

DEFINITION OF ACCUMULATION OF FIREDAMP

Article 399

As defined in the present Act, an accumulation of firedamp exists when the percentage volume in the atmosphere reaches 1%. In the case of a toxic or noxious gas an accumulation exists when the volumetric percentage reaches the limit given in article 413.

The accumulation is considered hazardous when the volumetric percentage of firedamp or other toxic or noxious gases, considered singly, reaches the limits given in articles 444, 445, and, if needed, 446.

MINES SUSPECTED OR CLASSIFIED FOR OUTBURST OF FIREDAMP, TOXIC, OR NOXIOUS GASES

Article 401

When the chief engineer having consulted with the superintendent recognizes that the mine (having regard to the characteristics of the deposit, and through analogy with other mines) is subject to outburst of gas, or through other suspect manifestations occurring in this mine, may presume the presence, in the ore, in the adjacent rocks, of a gas under pressure, capable of an outburst, he should declare the mine to be liable to outburst of gas. The

same precaution should indicate those safety rules of the present Act whose adoption is made necessary in all or parts of the mine, should fix the deadline by which these rules ought to be put into action, and should establish the first safety measures for immediate adoption.

Article 402

The mines, or part of these, in which have occurred, at least once, the instantaneous eruption of firedamp or other toxic or noxious gas, either singly or mixed, will be classified as having instantaneous development of gas.

PERCENTAGE LIMITS

Article 444

When at any point of the ventilation circuit in a full air current, firedamp in a quantity greater than 2% is noticed or detected, the compartment or the sector served by such circuit ought to be evacuated immediately.

The inspector orders the evacuation of the underground, adopts precautionary measures, and informs the superintendent.

If other places of the underground that are accessible to workers may be affected, he should adopt the same precautionary measures, and also when in some part of the same underground an ignition occurs.

Article 445

If in a certain point of a ventilation circuit, in full current of air for each of the following gases considered separately, the volumetric percentage is greater than 2.5% of carbon dioxide,

20 per 100,000 of carbon monoxide*, 10 per 100,000 of sulphur dioxide, the personnel in charge should order the workers to make immediate use of the means of protection or, if deprived of them, to evacuate the underground.

Notice of the measures adopted should be given immediately to the Superintendent who, if he recognizes a need for security, will order the total or partial evacuation of the workings.

* *This is an exact translation from the original Italian.*

APPENDIX VIII
REPUBLIC OF SOUTH AFRICA

Excerpts from the Mines and Works Act and Regulations,
1st June, 1977

DEFINITIONS

Fiery Mine

Means a mine which is for the time being a fiery mine in terms of a declaration made under these regulations by the Inspector of Mines with the approval of the Government Mining Engineer;

Non-fiery Mine

Means a mine which is for the time being not a fiery mine in terms of a declaration made under these regulations by the Inspector of Mines with the approval of the Government Mining Engineer;

Exemption from regulations

3.15.1 Whenever the circumstances at any mine or works are such that any provisions of these regulations cannot be applied or are unduly onerous to such mine or works, or whenever it is necessary for the purpose of carrying out experiments or tests as to the expediency of any regulation or proposed regulation, the Inspector of Mines or Inspector of Machinery, with the approval of the Government Mining Engineer, may grant exemption from such provisions under such conditions as he may determine.

3.15.2 The Inspector of Mines or Inspector of Machinery, with the approval of the Government Mining Engineer, may withdraw such exemption if considered necessary in the interests of safety or health.

Fiery mines - declaration

3.18.1 The Inspector of Mines, with the approval of the Government Mining Engineer, may declare any mine to be a fiery mine by reason of the danger from inflammable gas in the mine. Such declaration shall be by written notice to the manager.

Application of fiery mine regulations to other mines

3.18.2 The Inspector of Mines, with the approval of the Government Mining Engineer, may direct that any regulation applicable to a fiery mine shall be applied to any other mine or part thereof by giving written notice to that effect to the manager and such regulations shall thereupon apply to such mine or part thereof. Each such regulation shall be specified in the notice to the manager who shall cause legible copies of the notice to be kept posted up in both official languages at suitable places at the mine where they can be conveniently read by the workmen.

Inflammable gas - no work

8.5.1 No person shall, except as is provided for in regulation 8.5.2, commence work or continue to work or cause or permit any other person to commence work or to continue to work in any part of the workings of any mine if, in the same ventilating district there is in or within a radius of

30 meters of such part, any place known to contain sufficient inflammable gas to show a distinct cap on the reduced flame of a safety lamp.

Exception

8.5.2 The foregoing provision shall not apply-

- (a) when the amount of inflammable gas is so small that it does not show a distinct cap on the reduced flame when the lamp is held 0,5 meter from the working face or from the point of issue of flowers or jets of inflammable gas, and
- (b) to any person employed in the actual presence and under the immediate supervision of the holder of a blasting certificate, valid for the class of mine to which the mine belongs and issued in accordance with these regulations, who is engaged in the erection of brattice or in other work necessary for the clearing away of inflammable gas.

8.9.4 At the commencement of his shift the ganger or miner-

- (a) shall examine every working place in his section for inflammable gas with an approved flame safety lamp,
- (b) shall place his initials and the date of the examination in chalk or crayon in a conspicuous place other than on the coal face itself, in every working place immediately after he has examined it,
- (c) shall immediately fence off or set up a barrier at the entrance to any place which he finds to be in an unsafe condition and which he cannot there and then make safe

and, until he shall have personally made such place safe, he shall allow no person to enter therein except such persons as may be necessary to assist him in making such place safe,

- (d) shall inform the mine overseer or shift boss by the quickest means available if noxious or inflammable gas is found during his examination, and
- (e) shall immediately after the inspection of the section record in duplicate on a form approved by the Inspector of Mines in a book provided for the purpose by the manager a full and accurate report specifying whether or not and where noxious or inflammable gas, defects in roof and sidewalls and other sources of danger were found or observed. The ganger or miner in charge shall sign the report and shall send the original thereof, immediately it has been made, to the surface for transmission to the manager's office. This report shall be countersigned by the manager on receipt and shall be retained by him for at least three months...

Tests for inflammable gas...

8.9.9 In the course of every inspection made in terms of regulation 8.9.6 the ganger or miner in charge shall test for inflammable gas with an approved flame safety lamp, and if inflammable gas is detected in quantity sufficient to show a distinct cap on the reduced flame of the safety lamp to necessitate the withdrawal of persons in terms of regulation 10.6.5 he shall immediately report its presence to the manager, mine overseer or shift boss by message sent in writing...

8.9.10 Unless exempted in writing by the Inspector of Mines with the approval of the Government Mining Engineer, where there is no shift boss a test for inflammable gas similar to the test required in terms of regulation 8.9.9 shall be made in the course of each shift by the manager or by a competent person other than the ganger or miner, appointed by the manager, who shall be the holder of a permanent blasting certificate appropriate to the class of mine to which the mine belongs, of every part of every miner's section in which workmen work or travel or may be required to work or travel during that shift. A report on each such test shall be recorded at the end of that shift, by the person making the test, on a form approved by the Inspector of Mines in a book provided for the purpose by the manager. Such report shall be signed by the person making it and it shall be examined and countersigned by the manager or mine overseer within 24 hours.

Examination before firing in fiery mine...

8.10.12..., shall not fire any charge in any mine where in terms of regulation 9.27 only "permitted explosives" may be used unless he has examined, as shortly before firing as practicable, the place where the charge is to be fired, all accessible workings into which the charge may blast, and the ventilating air current entering the place where the charge is to be fired, and has found no danger of the firing causing an explosion of inflammable gas or coal dust. In a fiery mine the said examination shall be made with a flame safety lamp...

Examination before firing if gas found in preceding 24 hours...

8.10.13..., shall not in any mine fire a charge in any place in his section in which inflammable gas has been found during the preceding 24 hours unless he has examined with a flame safety lamp, not only the place where the charge is to be fired but also all accessible workings within a radius of 30 meters from such charge and has found that inflammable gas in quantity sufficient to make it unsafe to fire the charge has neither accumulated at or near the place where the charge is to be fired nor is approaching it...

Permitted explosives

9.27 In any fiery mine, and in any coal mine where in the opinion of the Inspector of Mines there is danger of a coal dust explosion, no explosive other than "permitted explosive" as specified in the First Schedule to these regulations shall be used. Provided that the Minister may at any time prohibit the use of any explosives so specified or, if he is satisfied that they comply with safety requirements, may permit the use of any explosives not so specified.

Who may conduct blasting operations

9.28.1 Except as provided for in regulation 9.28.4 no person shall conduct, or cause or permit any other person to conduct, the operations of preparing or firing explosives charges in the workings of a mine or at a works unless he or such other person holds either a provisional or a permanent blasting certificate valid for the class of mine or works to which the mine or works belongs. The holder of a blasting certificate shall produce his blasting certificate which

shall be retained by the manager until termination of the period of his engagement.

(a) such operations shall only be carried out in the actual presence and under the immediate supervision of the said ganger or miner, and

(b) such operations shall be carried out in accordance with the procedures laid down in these regulations.

No firing where inflammable gas

9.29 No person shall fire any explosives charge, or cause or permit any other person to fire any explosives charge, in any place where there is sufficient inflammable gas present to show a distinct cap on the reduced flame of a safety lamp ordinarily in use in the mine.

Shot-firing apparatus

9.30.1 Where firing takes place by means of electricity, the shot-firing apparatus shall be maintained in efficient and safe working order. Each shot-exploder shall be provided with a removable operating handle or key or with a locking arrangement to secure it against unauthorised use and shall be marked with a serial number, and a record shall be kept of all examinations and tests carried out on it.

Testing of circuit: Approval of apparatus by G.M.E.

9.30.2 No person shall apply, or cause or permit any other person to apply, any electrical test to a circuit containing an electrical detonator, electrical initiator or similar device except by means of an efficient testing apparatus approved for the purpose by the Government Mining Engineer.

9.30.3 In any fiery mine or in any other mine where in terms of regulation 9.27 only "permitted explosives" may be used-

Shot-firing apparatus: Approval by G.M.E.

9.30.3.1 No person shall fire charges, or cause or permit any other person to fire charges, except by means of an efficient electrical shot-firing apparatus approved for the purpose by the Government Mining Engineer;

Withdrawal of workmen where danger...

10.6.5 If at any time it is found by the person for the time being in charge of the workings of a mine or any part thereof that, by reason of inflammable or noxious gases present in the workings or such part thereof, the workings or such part is dangerous, every workman shall be withdrawn by him from the workings or part so found dangerous and the matter immediately reported to the manager, mine overseer or shiftboss, who shall not allow any person to resume work in such working place until he has satisfied himself by personal inspection that the working place is safe: Provided the prohibition relating to the resumption of work shall not apply to persons employed in the presence and under the direct supervision of a competent ganger or miner for the erection of brattice or for other work with a view to the clearing away of inflammable or noxious gases.

Permissible quantities of gas and dust...

10.6.6 In the general body of the air at any place where persons are required to work or travel, under normal working

conditions-

- (a) the amount of carbon dioxide shall not exceed 5000 parts per 1,000,000 of air by volume,
- (b) the amount of carbon monoxide shall not exceed 100 parts per 1,000,000 of air by volume,
- (c) the amount of oxides of nitrogen shall not exceed five parts per 1,000,000 of air by volume,
- (d) the amount of hydrogen sulphide shall not exceed 20 parts per 1,000,000 of air by volume,
- (e) the amount of inflammable gas shall be insufficient to show a distinct cap on the reduced flame of a safety lamp, and
- (f) the concentration of dust shall not exceed such standard as may from time to time be specified by the Government Mining Engineer.

Notification of inflammable gas...

10.6.8 The manager shall immediately notify the Inspector of Mines of the presence of inflammable gas detectable by a flame safety lamp in any ventilating district of the mine if inflammable gas has not been detected therein within the previous three months. Such notification shall be confirmed in writing.

Underground fans - installation and operating instructions...

10.14 No fan shall be installed or operating in the workings of any fiery mine or any non-fiery coal mine except under the following conditions...

Auxiliary fans...

10.14.1 Where it is intended to install an auxiliary fan in a return airway from a ventilating district, the Inspector of Mines shall first be notified. The site of such fan shall be selected by the manager and the installation shall be such that the motor is situated in intake air and there shall be no possibility of return air passing over the motor and ancillary electrical gear.

Other fans...

10.14.2 In the case of any fan installed elsewhere than in the return airway from a ventilating district-

- (a) each such fan shall be installed at a site personally selected and authorized by the manager or mine overseer,
- (b) no such fan shall be operated, or caused or permitted to be operated, if any recirculation of ventilating air takes place,
- (c) no such fan shall be removed without the authority of the manager or mine overseer who shall make a suitable endorsement in the book referred to in regulation 10.14.3 and

- (d) not more than one such fan shall be installed at any one site except with the written permission of the Inspector of Mines under such conditions as he may prescribe.

Record of operating instructions...

10.14.3 Each fan shall be operated in accordance with the instructions given by the manager or mine overseer who shall record in a book provided for the purpose the particulars of the authorization and the safety instructions relative thereto. The manager or mine overseer shall ensure that the shiftboss and the miner in charge are made aware of such instructions.

Stoppage of fan - testing for gas...

10.15 In the workings of any fiery mine or any non-fiery coal mine an electrically driven fan shall not be started or restarted after it has stopped unless tests are carried out with a flame safety lamp by a competent scheduled person immediately before the fan is started or restarted and the site of its motor and ancillary electrical gear have been found to be clear of inflammable gas.

Internal combustion engines underground...

10.25.1 No internal combustion engine other than a diesel engine shall be used underground in any mine.

10.25.2 No diesel engine shall be used underground--
(a) in any mine unless there is sufficient ventilation to render harmless the exhaust gases produced; and

(b) in any fiery mine or in any other mine in the workings of which there may be a risk of such diesel engine igniting gas or coal dust unless it is of a design and construction approved in writing by the Government Mining Engineer, and then only under such conditions and subject to such restrictions as he may specify.

Only approved lamps in fiery mines and new coal mines...

15.5.1 No light or lamp other than an enclosed and locked or sealed light or lamp of a design and construction approved by the Government Mining Engineer shall be allowed or used in the workings of any fiery mine except such stationary lights or lamps at such places as may be permitted in writing by the Inspector of Mines with the approval of the Government Mining Engineer.

15.8.5..., no person shall take into the workings of the mine or have in his possession in the workings of the mine any contrivance for opening the lock of a portable lamp unless he has been appointed for examining and relighting lamps under regulation 15.8.4.

Contraband...

15.9.1 At every fiery mine except as provided by regulations 15.10.1 and 15.10.9 no person shall take into the workings of the mine, or have in his possession in the workings, any device for the intentional creation of any arc, spark or flame or any match or appliance of any kind for striking a light and no person shall smoke in the workings or take into the workings or have in his possession in the workings any pipe, cigar, cigarette, tobacco other than chewing tobacco

and snuff, or any contrivance or material for smoking: provided that this prohibition shall not apply to the re-lighting device within an approved flame safety lamp.

15.10.1...., no welding, flame-cutting, grinding, vulcanising, soldering or similar equipment shall be taken into or used in the workings except in a workshop established with the permission of the Inspector of Mines under conditions approved by the Government Mining Engineer...

15.10.6...., in such workshop an effective alarm system shall be installed and maintained in working order to give an alarm in the workshop whenever the main fan, which serves the workings in which the workshop is situated, ceases to operate. When such alarm is received the use of all equipment for the purposes contemplated in terms of regulation 15.10.1 shall cease forthwith...

Flame proofing: Approval by G.M.E.

21.16 Where there may be risk of igniting gas, coal dust or other explosive material, only flameproof, explosion proof or intrinsically safe apparatus of a design and construction approved by the Government Mining Engineer shall be used.

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CHAPTER 28

CERTIFICATES OF COMPETENCY

Procedure to obtain certificates

28.1.1 The certificates of competency mentioned in this chapter shall be granted by the Government Mining Engineer in accordance with the recommendation of the relevant Commission of Examiners, except where specifically stated to the contrary.

28.1.2 Any person wishing to obtain a certificate of competency, as provided for in this chapter, shall make application therefor to the relevant Commission of Examiners, appointed from time to time or other examining authority.

Appeal

¹28.1.3 A candidate may appeal against any decision of any examining authority to the Government Mining Engineer, who may refer the matter back to the commission for further report and the decision of the Government Mining Engineer shall be final. Each such appeal, which shall be in writing, shall be lodged within 31 days after the date of the examining authority's decision and each such appeal shall be accompanied by R5 in the case of a written examination and R3 in the case of an oral examination: Provided that in the event of the appeal being successful the fee shall be refunded.

Non-scheduled persons

28.2.1 The certificates of competency mentioned in this chapter shall not be granted to non-scheduled persons: Provided that any certificate granted to a non-scheduled person in the Cape Province or Natal before 1st January, 1960, shall be valid within such province.

Alterations on certificates

28.2.2 Any certificate in which any alteration or erasure has been made, other than by the relevant issuing authority or other legally authorised person, shall be invalid.

Appointment and discharge of commission

28.3 Each Commission of Examiners shall be selected, appointed and discharged by the Government Mining Engineer, and shall furnish regular reports of its proceedings to him: Provided that in the case of mechanical and electrical engineer's certificates of competency, such selection, appointment and discharge shall be in consultation with the Chief Inspector as defined in the Factories, Machinery and Building Work Act, 1941.

Date and time of examination

28.4 Examinations shall be held by the said Commissions at such times and places as may be determined by the Government Mining Engineer: Provided that in the case of examinations for mechanical and electrical engineers' certificates of competency the arrangement of such times and places shall be in consultation with the Chief Inspector as defined in the Factories, Machinery and Building Work Act, 1941.

Application forms

28.5 An applicant for examination may obtain gratis from the secretary to the Commissions of Examiners the appropriate application form and a copy of the relevant examination syllabus and of the rules applying to candidates.

Rules

28.6 Instructions for the guidance of examining and issuing authorities, as well as rules for the conduct of examinations by such authorities, including syllabi for such examinations, shall be framed by the Government Mining Engineer who shall have the power to amend such instructions or alter such rules as occasion may require: Provided that in the case of mechanical and electrical engineers' certificates of competency the framing of such instructions and rules, including syllabi, and the amendments thereto shall be in consultation with the Chief Inspector as defined in the Factories, Machinery and Building Work Act, 1941.

Quorum of Commission

28.7 A quorum of a Commission of Examiners shall consist of the chairman and two members or, in the case of a Commission of Examiners for blasting certificates, of the chairman and one member. Should any difference of opinion arise in any matter connected with the examination of a candidate, it shall be decided by a majority of votes of the members of the Commission. If the votes be equal the chairman shall have an additional or casting vote.

Secretary to Commission

28.8 An officer of the Mines Department shall act as secretary to every Commission of Examiners and shall keep minutes of the proceedings of such Commission.

¹S. 28.1.3 substituted by s. 11, R 513 of 1.4.77.

Limited Certificate

28.9 Any Commission of Examiners, in any special case, may recommend to the Government Mining Engineer the issue to a candidate of a certificate limited in scope in accordance with rules framed in terms of regulation 28.6, provided such candidate has the requisite experience and qualifications, and satisfies the Commission that he has sufficient knowledge of his statutory responsibilities and of the subjects appropriate to his work. The validity of a certificate issued in terms of this regulation may be further limited to a specified period of time. The Commission may require such candidate to submit himself to a written or an oral examination in any of the subjects prescribed, and shall make a recommendation regarding the limitations to which such certificate is subject.

Value of stamps to be affixed to applications

28.10 An initial application for acceptance as a candidate and each application thereafter for examination for a certificate of competency shall, when handed or sent in, bear uncanceled revenue stamps to the value shown hereunder.

	On initial application for acceptance as a candidate	On each application for examination for a certificate
(1) Mine Manager's Certificate	Part A, R2 Part B, R2 Parts A and B together, R2	Part A, R7 Part B, R7 Parts A and B together, R14
(2) Mine Overseer's Certificate	R2	R6
(3) Mine Surveyor's Certificate	R2	Part A, R6 Part B, R6 Parts A and B together, R12
(4) Mechanical Engineer's Certificate for Mines and Works	R2	Part A, R7 Part B, R7 Parts A and B together, R14
(5) Electrical Engineer's Certificate for Mines and Works	R2	Part A, R7 Part B, R7 Parts A and B together, R14
(6) Mine Assayer's Certificate	R2	Part A, R4 Part B, R8
(7) Winding-Engine Driver's Certificate	R1	R6
(8) Locomotive-Engine Driver's Certificate	R1	R6
(9) Stationary-Engine Driver's Certificate	R1	R6
(10) Boiler Attendant's Certificate	R1	R6
(11) Blasting Certificate:		
(i) Permanent Certificate	—	R2
(ii) Provisional Certificate	—	R2
(iii) Exchange of a provisional for a permanent certificate	—	10 cents
(12) Lampman's Certificate	—	50 cents
(13) Onsetter's Certificate	—	50 cents

Applications for examination

28.11 No person shall submit an application for examination unless and until he has been accepted as a candidate.

Lost certificate

28.12 ¹On proof being furnished by the holder, to the satisfaction of the Government Mining Engineer, that a certificate mentioned in regulation 28.10 has been lost, defaced, destroyed or has become dilapidated, a duplicate certificate shall be issued on payment of a fee of R2, except in the case of a blasting certificate, onsetter's certificate or lampman's certificate when the fee shall be 25c. The prescribed fee shall be paid in uncanceled revenue stamps. Such certificate shall bear the words "Duplicate—Duplikaat".

MINE MANAGER'S CERTIFICATE**Commission for mine manager's certificate**

28.13.1 The constitution of a commission of examiners for a mine manager's certificate of competency shall be as follows:—

¹ 28.12 substituted by S.23, R.2(1) of 15.11.74.

A Deputy Government Mining Engineer, who shall be chairman; an Inspector of Mines; an Inspector of Machinery; and at least three certificated mine managers, whether actually engaged in the management of a mine or not, of whom at least one shall be the holder of a certificate appropriate to the examination being conducted.

28.13.2 The examination shall consist of two parts, namely: –

Part A. – Mine surveying, geology and mechanical and electrical engineering.

Part B. – The Act and the regulations made or deemed to have been made thereunder and mining including mine ventilation.

Parts A and B may be taken at the same examination or at separate examinations, but a candidate who has passed one part only shall receive credit for such part for a limited period only, as laid down in the rules framed under regulation 28.6.

28.13.3 An applicant who can satisfy the Government Mining Engineer –

(a) that he holds a mine manager's certificate of competency not issued in terms of this chapter or a mining engineer's degree of a university or any other qualification, provided such certificate, degree or other qualification is recognised for the purpose by the Government Mining Engineer, and

(b) that he has had *such period* of mining experience, acceptable for the purpose by the Government Mining Engineer, gained in the workings of a mine, shall be exempted from such part or subjects of the examination as the Government Mining Engineer may determine, provided he submits an application bearing uncanceled revenue stamps to the value specified in regulation 28.10 for the whole of the examination.

Qualifications of candidate

28.14.1 An applicant shall not be accepted as a candidate for Part A of the examination unless he has produced evidence satisfactory to the Commission –

(a) that he has attained the age of 21 years,

(b) of his sobriety and general good conduct,

(c) that he is the holder of a permanent or provisional blasting certificate recognized by the Government Mining Engineer for the purposes of the examination, and

(d) that, except as is provided for in regulation 28.14.3, he has had at least four years' mining experience acceptable to the Commission. At least three of the said four years' mining experience shall be experience acceptable to the Commission, gained in the workings of a mine.

28.14.2 An applicant shall not be accepted as a candidate for Part B of the examination unless he has produced evidence satisfactory to the Commission –

(a) that he has attained the age of 23 years,

(b) of his sobriety and general good conduct,

(c) that he is the holder of a permanent blasting certificate recognized by the Government Mining Engineer for the purposes of the examination,

(d) that, except as is provided for in regulation 28.13.3, he has had at least five years' mining experience acceptable to the Commission. At least four of the said five years' mining experience shall be experience, acceptable to the Commission, gained in the workings of a mine and such experience shall include at least six months at the working face on rock-breaking or winning minerals or work directly connected therewith, and

(e) that he has had at least six months' mining experience acceptable to the Commission, in the workings of the class of mine appropriate to the certificate for which he wishes to qualify.

28.14.3 An applicant who can satisfy the Commission –

(a) that he holds a mining engineer's degree of a South African university, or

(b) that he holds a mechanical or electrical engineer's certificate of competency for mines and works issued in accordance with these regulations, or

(c) that he holds any other degree, certificate or diploma recognized by the Government Mining Engineer for the purposes of the examination,

may be exempted from not more than three of the number of years of mining experience required in terms of regulation 28.14.1 or 28.14.2, the period of exemption being as laid down in the rules framed under regulation 28.6. The period for which no exemption is granted shall be a period during which experience was gained in the workings of a mine.

28.14.4 *The experience gained by the applicant in the workings of a mine during the unexempted period referred to in regulation 28.14.3, shall be such as is acceptable to the Commission and as much thereof as may be required by the Commission shall be practical experience additional to the experience prescribed for the said degree, certificate or diploma.*

¹ S. 28.13.3 (b) amended by R. 303-5 G.G. 3397 dd. 1.3.72.

¹ S. 28.14.4 substituted by S.36, R 537 of 21.3.80.

Examination subjects

28.15 Except as is provided for in regulation 28.13.3, a certificate shall not be issued unless the Commission is satisfied that, within the scope indicated in the syllabus for the examination drawn up in terms of regulation 28.6, the candidate possesses a sufficient knowledge of mining, mine ventilation, mechanical and electrical engineering, mine surveying, geology, and the Act and the regulations made or deemed to have been made thereunder.

Separate certificates

28.16.1 Separate certificates shall be issued for metalliferous mines and for coal mines and the examination shall be conducted to suit each class of certificate.

Validity of certificate

28.16.2 A certificate for metalliferous mines shall be valid for all mines except coal mines. A certificate for coal mines may be limited in scope to non-fiery coal mines.

Certificate for coal mines

28.16.3 The holder of a mine manager's certificate for non-fiery coal mines shall qualify for a mine managers' certificate for coal mines if he can furnish proof that he has had six months' experience acceptable to the Commission in fiery mines and submits an application bearing uncanceled revenue stamps to the value of R 14.

MINE OVERSEER'S CERTIFICATE*Commission for mine overseer's certificate*

28.17 The constitution of a Commission of Examiners for a mine overseer's certificate of competency shall be as follows:—
An Inspector of Mines, who shall be chairman; an Inspector of Machinery; and at least two certificated mine managers whether actually engaged in the management of a mine or not. The qualifying certificates shall be appropriate to the examination being conducted.

Qualifications of candidate

28.18.1 An applicant shall not be accepted as a candidate for examination unless he has produced evidence satisfactory to the Commission —

- (a) that he has attained the age of 22 years,
- (b) of his sobriety and general good conduct,
- (c) that he is the holder of a permanent blasting certificate recognized by the Government Mining Engineer for the purposes of the examination,
- (d) that, except as is provided for in regulation 28.18.2, he has had at least four years of practical experience, acceptable to the Commission, gained in the workings of a mine and such experience shall include at least six months at the working face on rock-breaking or winning minerals or work directly connected therewith, and
- (e) that he has had at least six months' mining experience, acceptable to the Commission, in the workings of the class of mine appropriate to the certificate for which he wishes to qualify.

28.18.2 An applicant who can satisfy the Commission —

- (a) that he holds a mining engineer's degree of a South African University, or
 - (b) that he holds a mechanical or electrical engineer's certificate of competency for mines and works issued in accordance with these regulations, or
 - (c) that he holds any other degree, certificate or diploma recognized by the Government Mining Engineer for the purposes of the examination,
- may be exempted from not more than two of the said four years of practical experience in the workings of a mine, the period of exemption being as laid down in the rules framed in terms of regulation 28.6.

28.18.3 The experience gained by the applicant in the workings of a mine during the unexempted period referred to in regulation 28.18.2, shall be such as is acceptable to the Commission and as much thereof as may be required by the Commission shall be practical experience additional to the experience prescribed for the said degree, certificate or diploma.

¹ 28.18.3 Substituted by s. 37, R 537 of 21.3.80.

Examination subjects

28.19.1 A certificate shall not be issued unless the Commission is satisfied that, within the scope of the syllabus for the examination drawn up in terms of regulation 28.6, the candidate possesses a sufficient knowledge of mining practice, shaft practice, ventilation, gases, dust control, underground machinery, mine plans and the Act and the regulations made or deemed to have been made thereunder.

Separate certificates

28.19.2 Separate certificates shall be issued for metalliferous mines and for coal mines and examination shall be conducted to suit each class of certificate.

Validity of certificates

28.19.3 A certificate for metalliferous mines shall be valid for all mines except coal mines. A certificate for coal mines may be limited in scope to non-fiery coal mines.

Certificate for coal mines

28.19.4 The holder of a mine overseer's certificate for non-fiery coal mines shall qualify for a mine overseer's certificate for coal mines if he can furnish proof that he has had six months' experience acceptable to the Commission in fiery mines and submits an application bearing uncanceled revenue stamps to the value of R6.

MINE SURVEYOR'S CERTIFICATE*Commission for mine surveyor's certificate*

28.20.1 The constitution of a Commission of Examiners for a mine surveyor's certificate of competency shall be as follows:

A Deputy Government Mining Engineer, who shall be chairman; a Chief Government Mine Surveyor or a Government Mine Surveyor; and at least four certificated mine surveyors.

28.20.2 The examination shall consist of two parts, namely:—

Part A. — Mine valuation, geology and mathematics.

Part B. — Surveying, and the relevant portions of Mining laws of the Republic of South Africa.

Parts A and B may be taken at the same examination or at separate examinations, but a candidate who has passed one part only shall receive credit for such part for a limited period only, as laid down in the rules framed under regulation 28.6.

Qualifications of candidate

28.20.3 An applicant shall not be accepted as a candidate for examination unless he has produced evidence satisfactory to the Commission—

(a) of his sobriety and general conduct, and

(b) that he has had at least one year of practical surveying experience, acceptable to the Commission, gained in the workings of a mine.

Examination subjects

28.20.4 A certificate shall not be issued unless the Commission is satisfied that, within the scope indicated in the syllabus for the examination drawn up in terms of regulation 28.6 the candidate possesses a sufficient knowledge of surveying, mathematics, mine valuation, geology and the relevant portions of the mining laws of the Republic of South Africa.

Land surveyors

28.20.5 An applicant who can satisfy the Commission that he is an admitted land surveyor in any province of the Republic and that he has had experience of underground surveying for at least six months on a mine where at least 200 non-scheduled persons or 100 scheduled persons on an average were employed underground, shall be qualified to receive a certificate of competency provided that he submits an application bearing uncanceled revenue stamps to the value of R10 and satisfies the Commission that he has a sufficient knowledge of mine valuation, geology and the relevant portions of the mining laws of the Republic of South Africa.

MINE ASSAYER'S CERTIFICATE*Commission for mine assayer's certificate*

28.21.1 The constitution of a Commission of Examiners for a mine assayer's certificate of competency shall be as follows:—

¹S. 28.20.1 substituted by s. 12, R 513 of 1.4.77.

An officer of a Government Chemical or Metallurgical Laboratory, who shall be chairman; an analytical chemist and a metallurgist, of whom at least one shall be engaged in academic work; and two certificated mine assayers, of whom at least one shall be engaged in assay work at a mine.

Examination subjects

28.21.2 Except in the case of candidates accepted before 1st September, 1959, the examination shall be conducted in two parts, namely:—

Part A: Elementary, theoretical and general chemistry.

Part B: Analytical chemistry and assaying, including a practical examination.

28.21.3 An applicant who can satisfy the Commission that he has a degree, recognized for the purpose by the Government Mining Engineer, shall be deemed to have satisfied the Commission in respect of Part A of the examination, provided he submits an application in respect of such part bearing uncanceled revenue stamps to the value specified in regulation 28.10.

28.21.4 An applicant who can satisfy the Commission that he possesses a satisfactory knowledge, training and experience in theoretical and practical analytical chemistry and assaying may be deemed to have satisfied the Commission in respect of the whole or such part of the examination as the Commission may decide, provided he submits an application in respect of the whole or such part, as the case may be, bearing uncanceled revenue stamps to the value specified in regulation 28.10.

Qualifications of candidate

28.21.5 An applicant shall not be accepted as a candidate for Part A of the examination unless he has produced evidence satisfactory to the Commission—

(a) that he has attained the age of 17 years,

(b) of his sobriety and general good conduct, and

(c) that, except as is provided for in regulation 28.21.6, he has had at least two years of practical experience, acceptable to the Commission, in an assay or analytical chemical laboratory.

28.21.6 An applicant for Part A who can satisfy the Commission that he holds a degree, diploma or certificate, recognized for the purpose by the Government Mining Engineer, may be exempted from part of the said two years of practical experience, the period of exemption being as laid down in the rules framed in terms of regulation 28.6.

28.21.7 An applicant shall not be accepted as a candidate for Part B of the examination unless he has satisfied the Commission in respect of Part A and has produced evidence satisfactory to the Commission—

(a) that he has attained the age of 19 years,

(b) of his sobriety and general good conduct, and

(c) that, except as is provided for in regulation 28.21.8 he has had at least two years of practical experience, acceptable to the Commission, in an assay or analytical chemical laboratory in addition to the experience required in respect of Part A.

28.21.8 An applicant for Part B who can satisfy the Commission that he holds a degree, diploma or certificate, recognized for the purpose by the Government Mining Engineer, may be exempted from part of the said two years of practical experience, the period of exemption being as laid down in the rules framed in terms of regulation 28.6.

28.21.9 A certificate shall not be issued unless the Commission is satisfied that, within the scope indicated in the syllabus for the examination drawn up in terms of regulation 28.6, the candidate possesses a sufficient knowledge of chemistry and assaying.

MECHANICAL AND ELECTRICAL ENGINEERS' CERTIFICATES FOR MINES AND WORKS

Commission for engineers' certificates

28.22.1 The constitution of a Commission of Examiners for mechanical and electrical engineers' certificates of competency shall be as follows:—

A Deputy Government Mining Engineer or a Chief Inspector of Machinery, who shall be chairman; a Chief Inspector of Machinery, or an Inspector of Machinery; at least two certificated mechanical engineers; and at least two certificated electrical engineers: Provided that for the purpose of this regulation "certificated engineer" shall mean a person who holds a mechanical or electrical engineer's certificate of competency granted in terms

of regulations made under section 12 of the Act, or under section 51 of the Factories, Machinery and Building Work Act, 1941.

28.22.2 The examination shall consist of two parts namely:—

Part A. — Power plant, properties and strength of materials including design of structures, electrical engineering.

Part B. — Driven machinery, mining plant, the Act and the regulations made or deemed to have been made thereunder.

Parts A and B may be taken at the same examination or at separate examinations, but a candidate who has passed one part only shall receive credit for such part for a limited period only, as laid down in the rules framed under regulation 28.6.

Qualifications of candidate

28.23.1 An applicant shall not be accepted as a candidate for examination unless he has produced evidence satisfactory to the Commission—

- (a) that he has attained the age of 23 years,
- (b) of his sobriety and general good conduct, and
- (c) that, except as is provided for in regulations 28.23.2 and 28.23.3, he has had at least nine years of practical experience acceptable to the Commission and appropriate to the certificate for which he wishes to qualify.

28.23.2 An applicant who can satisfy the Commission—

- (a) that he holds a degree in either mechanical or electrical engineering of a South African University, or
- (b) that he is the holder of any other degree, certificate or diploma, recognized by the Government Mining Engineer for the purposes of the examination, or
- (c) that he has served an apprenticeship in a designated trade approved by the Government Mining Engineer for the purposes of the examination, or that he has served a pupilage equivalent thereto, may be exempted for not more than seven of the said nine years, the period of exemption being as laid down in the rules framed in terms of regulation 28.6.

28.23.3 The experiences gained during the unexempted period under regulation 28.23.2 shall be such as is acceptable to the Commission and shall be additional to any practical experience prescribed for the said degree or diploma or gained during the period of practical experience prescribed for acceptance for examination for the certificates referred to in paragraph (b) of regulation 28.23.2.

28.23.4 An applicant who can satisfy the Government Mining Engineer—

- (a) that he holds either a mechanical or electrical engineering degree of a university or any other qualification, provided such degree or other qualification is recognized for the purpose by the Government Mining Engineer, and
 - (b) that he has had at least three years of engineering experience, acceptable for the purpose by the Government Mining Engineer,
- shall be exempted from such part or subjects of the examination as the Government Mining Engineer may determine, provided he submits an application bearing uncanceled revenue stamps to the value specified in regulation 28.10 for the whole of the examination.

Examination subjects

28.24 Except as provided in regulation 28.23.4, a certificate shall not be issued unless a candidate has satisfied the Commission that, within the scope indicated in the syllabus for the examination drawn up in terms of regulation 28.6, the candidate possesses a sufficient knowledge of the design, construction, erection, operation and maintenance of machinery, apparatus and plant, and of the Act and the regulations made, or deemed to have been made thereunder.

WINDING-ENGINE DRIVER'S CERTIFICATE

Commission for winding-engine driver's certificate

28.25 The constitution of a Commission of Examiners for a winding-engine driver's certificate of competency shall be as follows:—

A Deputy Government Mining Engineer or an Inspector of Machinery, who shall be chairman; at least one certificated mechanical engineer; at least one certificated electrical engineer; and at least two certificated winding-engine drivers employed in driving engines used for the purpose described in regulation 16.83.

Qualifications of candidate

- 28.26.1** An applicant shall not be accepted as a candidate for examination unless he has produced evidence satisfactory to the Commission –
- (a) that he has attained the age of 19 years,
 - (b) of his sobriety and general good conduct,
 - (c) of having had experience, acceptable to the Commission, of shaft operations and of the work of an onsetter or a banksman for at least 12 shifts,
 - (d) of having had experience, acceptable to the Commission, on reversible winding engines fitted with clutches and depth indicators and operated at a normal winding speed of not less than 2,5 metres per second, as specified in regulations 28.26.2.1, 28.26.2.2, 28.26.2.3 and 28.26.2.4, and
 - (e) of having had experience, acceptable to the Commission of the working of steam boilers, as specified in regulations 28.26.2.1, 28.26.2.2, 28.26.2.3 and 28.26.2.4.
- 28.26.2.1** To obtain a certificate to drive an electric winding engine, the experience required in terms of paragraph (d) of regulation 28.26.1 shall be at least six months, which shall include at least 50 shifts on alternating current electric winding engines and at least 50 shifts on direct current electric winding engines. No experience shall be required under paragraph (e) of regulation 28.26.1.
- 28.26.2.2** To obtain a certificate to drive a steam winding engine, the experience required in terms of paragraph (d) of regulation 28.26.1 shall be at least five months, which shall include at least 75 shifts on steam winding engines. The experience required in terms of paragraph (e) of regulation 28.26.1 shall be at least 25 shifts.
- 28.26.2.3** To obtain a certificate to drive all types of winding engines, the experience required in terms of paragraph (d) of regulation 28.26.1 shall be at least eight months, which shall include at least 50 shifts on alternating current electric winding engines, at least 50 shifts on direct current electric winding engines and at least 50 shifts on steam winding engines. The experience required in terms of paragraph (e) of regulation 28.26.1 shall be at least 25 shifts.
- 28.26.2.4** The experience specified in regulations 28.26.2.1 and 28.26.2.2 shall be periods of full-time employment.
- 28.26.3** *An applicant who can satisfy the Commission that he has completed a course of training for winding engine drivers approved by the Government Mining Engineer, may be accepted as having had training and experience equivalent to that specified in paragraphs (c), (d) and (e) of regulation 28.26.1.*
- 28.26.4** An applicant who can satisfy the Commission that he holds any of the undermentioned certificates issued in accordance with these regulations, may be exempted from some or all of the experience specified under paragraphs (c), (d) and (e) of regulation 28.26.1 as follows:–
- (a) Stationary-engine driver's certificate or steam locomotive-engine driver's certificate:
75 shifts in charge of winding engines and 25 shifts on boilers.
 - (b) Locomotive-engine driver's certificate other than for steam or internal combustion locomotive:
75 shifts in charge of winding engines.
 - (c) Boiler attendant's certificate:
25 shifts on boilers.
 - (d) Onsetter's certificate:
12 shifts of shaft operations and the work of an onsetter or a banksman.
- 28.26.5.1** An applicant, who can satisfy the Commission that he holds a winding-engine driver's certificate for electric winding engines only, issued in accordance with these regulations, and who wishes to obtain a certificate for steam winding engines, shall not be accepted as a candidate for examination unless he has produced evidence of having had experience, acceptable to the Commission, of at least 50 shifts on reversible steam winding engines fitted with depth indicators and clutches and operating at a normal winding speed of not less than 2,5 metres per second and at least 25 shifts in the working of steam boilers.
- 28.26.5.2** An applicant who can satisfy the Commission that he holds a winding-engine driver's certificate for steam winding engines only, issued in accordance with these regulations, and who wishes to obtain a certificate for electric winding engines, shall not be accepted for examination unless he has produced evidence of having had experience, acceptable to the Commission, of at least 75 shifts on both alternating current and direct current electric winding engines, with a minimum of 25 shifts on each type of engine, such engines to be reversible, fitted with depth indicators and clutches and operating at a normal speed of not less than 2,5 metres per second.
- 28.26.6** An applicant for a certificate to drive electric winding engines only who can submit a certificate granted to him by the manager to the effect that –

¹ S. 28.16.1 amended by s. 38, R 537 of 21.3.80.² S. 28.26.3 substituted by s. 39, R 537 of 21.3.80.

- (a) he has completed a course of training of seven months of full time service as a learner driver, which period shall include at least 50 shifts on alternating current electric winding engines and at least 50 shifts on direct current electric winding engines under the supervision of a certificated winding engine driver, such winding engines to be reversible, fitted with clutches and operating at a normal speed of not less than 2,5 metres per second, and
 - (b) he has acquired competency in the handling of winding engines to the satisfaction of the person appointed in terms of regulation 2.13.1, 2.13.2 or 2.13.3 and the certificated driver under whose supervision he received his training.
- may be accepted as having had training and experience equivalent to that called for under paragraph (d) of regulation 28.26.1.

28.26.7 An applicant for a certificate to drive steam winding engines only who can submit a certificate granted to him by the manager to the effect that—

- (a) he has completed a course of training of seven months of full time service as a learner driver, which period shall include at least 75 shifts under the supervision of a certificated winding engine driver on reversible steam winding engines fitted with clutches and operating at a normal winding speed of not less than 2,5 metres per second and at least 25 shifts on the working of steam boilers, and
 - (b) he has acquired competency in the handling of steam winding engines to the satisfaction of the person appointed in terms of regulation 2.13.1, 2.13.2 or 2.13.3 and the certificated driver under whose supervision he received his training,
- may be accepted as having had training and experience equivalent to that called for under paragraphs (d) and (e) of regulation 28.26.1.

Physical fitness and subjects of examination

28.27 A certificate shall not be issued unless the Commission is satisfied that neither the sight nor hearing of the candidate is defective, that he is not subject to any other infirmity, mental or physical, likely to interfere with the efficient discharge of his duties, and that, within the scope indicated in the syllabus for the examination drawn up in terms of regulation 28.6, the candidate possesses a sufficient knowledge of the working of winding plants, of winding operations, of other machinery and ancillary equipment used in or in connection with winding, and of the Act and the regulations made or deemed to have been made thereunder.

LOCOMOTIVE-ENGINE DRIVER'S CERTIFICATE

28.28 A locomotive-engine driver's certificate may be granted for any one or for all types of locomotives used at a mine or at a works and shall especially qualify the holder to drive the type of locomotive specified on his certificate while such locomotive is in use for the conveyance of persons at a mine or at works.

Commission for locomotive engine driver's certificate

28.29 The constitution of a Commission of Examiners for locomotive-engine drivers' certificates of competency shall be as follows:—

A Deputy Government Mining Engineer or an Inspector of Machinery, who shall be chairman; at least one certificated engineer; and at least two certificated engine-drivers, of whom at least one shall be the holder of a locomotive engine-driver's certificate.

Qualifications of candidate

28.30 An applicant shall not be accepted as a candidate for examination unless he has produced evidence satisfactory to the Commission—

- (a) that he has attained the age of 19 years,
- (b) of his sobriety and general good conduct, and
- (c) of having had training and experience on locomotives. Such training and experience shall be acceptable to the Commission and shall include at least six months on the footplate of a running locomotive in the case of a steam locomotive-engine driver's certificate and three months of equivalent experience in the case of any other locomotive-engine driver's certificate.

Physical fitness and subjects of examination

28.31 A certificate shall not be issued unless the Commission is satisfied that neither the sight nor hearing of the candidate is defective, that he is not subject to any other infirmity, mental or physical, likely to interfere with the efficient discharge of his duties, and that, within the scope indicated in the syllabus for the examination drawn up in terms of regulation 28.6, the candidate possesses a sufficient knowledge of the construction and operation of locomotives, trains and ancillary equipment, and of the Act and the regulations made or deemed to have been made thereunder.

STATIONARY-ENGINE DRIVER'S CERTIFICATE

28.32 A stationary-engine driver's certificate shall qualify the holder to drive any stationary engine, other than a winding engine used for the purpose described in regulation 16.83.

Commission for stationary-engine driver's certificate

28.33 The constitution of a Commission of Examiners for a stationary-engine driver's certificate of competency shall be as follows:—

A Deputy Government Mining Engineer or an Inspector of Machinery, who shall be chairman; at least one certificated engineer; and at least two certificated engine-drivers of whom at least one shall be the holder of a stationary-engine driver's certificate.

Qualifications of candidate

28.34.1 An applicant shall not be accepted as a candidate for examination unless he has produced evidence satisfactory to the Commission—

(a) that he has attained the age of 16 years,

(b) of his sobriety and general good conduct,

(c) that he has, for not less than one year on a full-time basis, been in charge, or been employed in connection with the working, of one or more units of machinery, such as a steam engine, steam turbine, steam or electrically driven turbo- or reciprocating compressor, totalling not less than 100 kilowatt; and

(d) that he is the holder of a boiler attendant's certificate.

28.34.2 An applicant who can satisfy the Commission that he has had not less than one year of experience in charge of, or in the working of, steam boilers on a full-time basis may be exempted from the requirements of paragraph (d) of regulation 28.34.1.

Physical fitness and subjects of examination

28.35 A certificate shall not be issued unless the Commission is satisfied that neither the sight nor hearing of the candidate is defective, that he is not subject to any other infirmity, mental or physical, likely to interfere with the efficient discharge of his duties, and that, within the scope indicated in the syllabus for the examination drawn up in terms of regulation 28.6, the candidate possesses a sufficient practical knowledge of the working of compressors, steam engines, turbines, boilers, and electric motors and mechanical and electrical ancillary equipment, as well as the methods of transmitting power from the driving units to various classes of machinery, and a sufficient knowledge of the Act and the regulations made or deemed to have been made thereunder.

BOILER ATTENDANT'S CERTIFICATE

Commission for boiler attendant's certificate

28.36 The constitution of a Commission of Examiners for a boiler attendant's certificate of competency shall be as follows:—

A Deputy Government Mining Engineer or an Inspector of Machinery, who shall be chairman; at least one certificated engineer; and at least two certificated engine-drivers, of whom at least one shall be the holder of a stationary-engine driver's certificate.

Qualifications of candidate

28.37 An applicant shall not be accepted as a candidate for examination unless he has produced evidence satisfactory to the Commission—

(a) that he has attained the age of 19 years,

(b) of his sobriety and general good conduct, and

(c) of having been in charge of, or assisting to operate, a boiler plant on a full time basis for not less than one year.

Physical fitness and subjects of examination

28.38 A certificate shall not be issued unless the Commission is satisfied that neither the sight nor hearing of the candidate is defective, that he is not subject to any other infirmity, mental or physical, likely to interfere with the efficient discharge of his duties and that, within the scope indicated in the syllabus for the examination drawn up in terms of regulation 28.6, the candidate possesses a sufficient practical knowledge of boilers and ancillary equipment as well as of their operation, and a sufficient knowledge of the Act and the regulations made or deemed to have been made thereunder.

¹ 28.34.1 (c) substituted by S.26, R.2101 of 15.11.74.



BLASTING CERTIFICATES

Commission for blasting certificates

28.39 The constitution of a Commission of Examiners for blasting certificates shall be as follows:—

An Inspector of Mines, who shall be chairman; the holder of a mine manager's certificate; and the holder of a blasting certificate. The qualifying certificates shall be appropriate to the examination being conducted.

Application form

28.40.1 Every application for examination for a permanent or for a provisional blasting certificate shall be on the appropriate form and shall be addressed to the secretary of the relevant Commission of Examiners or to the Inspector of Mines for the district, as the case may be; and —

- (a) shall bear uncanceled revenue stamps to the value indicated in regulation 28.10,
- (b) shall contain a true record, certified by the manager under whom the applicant is working, of the applicant's experience and qualifications.
- (c) shall contain a statement by the manager, under whom the applicant is working at the time of making application, that he is a fit and proper person to be the holder of a blasting certificate.

¹ (d) shall contain proof that the applicant is in possession of a valid first aid certificate recognised by the Government Mining Engineer.

Endorsement

28.40.2 Notwithstanding anything stated to the contrary, the issuing authority in exceptional circumstances, may accept an application for a provisional or for a permanent blasting certificate without the application being endorsed by a manager.

Provisional blasting certificate transferable

28.40.3 A provisional blasting certificate shall be valid for an indefinite period but only for the mine or for the works in respect of which it is issued, provided that it shall be transferable by the issuing authority from mine to mine or from works to works on application of the manager of the mine or of the works to which it is to be transferred.

Exchange for permanent blasting certificate

28.40.4 A provisional blasting certificate may be exchanged for a permanent blasting certificate on application to the issuing authority, provided that the applicant has attained the age of 20 years and the application —

- (a) bears uncanceled revenue stamps to the value indicated in Regulation 28.10,
- (b) contains a record of the work which the applicant has performed prior to and while holding a provisional blasting certificate, and provided that the total period of his work is sufficient to qualify him for a permanent blasting certificate,
- (c) is endorsed by the manager under whom the applicant is working to the effect that the applicant has performed the work indicated in paragraph (b) of this regulation and is a fit and proper person to be the holder of a permanent blasting certificate, and
- (d) is accompanied by the provisional blasting certificate.

Exemption

28.40.5 The holder of a mining engineer's degree or diploma recognized by the Government Mining Engineer may be exempted from one-half of the period of experience required for a blasting certificate.

¹ **28.40.6** A student of the Government Miners' Training College or a student attending a training course in mining approved by the Government Mining Engineer, may be exempted from the age restriction of 20 years, and from such part of the qualifying period of experience for a provisional or a permanent blasting certificate, as the issuing authority may determine.

Any other applicant for a provisional blasting certificate may be exempted from the age restriction of 20 years, provided that he has undergone training acceptable to the issuing authority.

¹ **28.40.7** Except as is provided for in regulations 28.40.6, 28.40.8.1 and 28.40.8.2 —

28.40.7.1 an applicant shall not be accepted as a candidate for examination for a provisional blasting certificate for any mine or for any works unless he has produced evidence satisfactory to the issuing authority that —

- (a) he has attained the age of 20 years, and
- ¹ (b) subject to regulation 28.41.3.1, he has had at least the required number of shifts of experience, acceptable to the issuing authority, gained in the workings of a mine or in a works. Of this period at least 75 shifts shall have been spent at the working face on rock-breaking or winning minerals or work directly connected therewith, of which shifts, in the case of a mine, at least 25 shall have been in a mine of the class to which the certificate is appropriate;

28.40.7.2 an applicant shall not be accepted as a candidate for examination for a permanent blasting certificate for any mine or for any works unless he has produced evidence satisfactory to the issuing authority that —

¹ S. 28.40.6 substituted by s. 13, R 513 of 1.4.77.

¹ S. 28.40.7 substituted by s. 14, R 513 of 1.4.77.

¹ S. 28.40.7.1(b) substituted by s. 15, R 513 of 1.4.77

¹ S.28.40.1 added by s. 40(1) (b), R 537 of 21.3.80.
w.e.f, six months following promulgation.

- (a) he has attained the age of 20 years, and
¹(b) *subject to regulation 28.41.3.2, he has had at least the required number of shifts of experience acceptable to the issuing authority, gained in the workings of a mine or in a works. Of this period at least 75 shifts shall have been spent at the working face on rock-bearing or winning minerals or work directly connected therewith, of which shifts, in the case of a mine, at least 25 shall have been in a mine of the class to which the certificate is appropriate;*

28.40.7.3 an applicant for a provisional or permanent blasting certificate for fiery mines shall further satisfy the issuing authority that he has attended at least 75 per cent of the lectures and passed the prescribed examination on a course on gases and gas-testing based on a syllabus approved by the Government Mining Engineer and conducted by an institution recognized by the Government Mining Engineer.

28.40.8.1 An applicant shall not be accepted as a candidate for examination for a provisional certificate for opencast mines or for works where no subterranean tunnel operations are in progress unless he has produced evidence satisfactory to the Inspector of Mines that—

- (a) he has attained the age of 20 years, and
 (b) he has had at least 60 shifts of experience acceptable to the Inspector of Mines.

28.40.8.2 An applicant shall not be accepted as a candidate for examination for a permanent blasting certificate for open-cast mines or for works where no subterranean tunnel operations are in progress unless he has produced evidence satisfactory to the Inspector of Mines that—

- (a) he has attained the age of 20 years, and
²(b) *subject to regulation 28.41.3.2, he has had at least the required number of shifts of experience acceptable to the Inspector of Mines.*

Subjects of examination

28.41.1 A blasting certificate shall not be issued unless the issuing authority has satisfied itself that, within the scope indicated in the syllabus for the examination drawn up in terms of regulation 28.6, the applicant is competent to conduct blasting operations and to perform the duties of a ganger or miner in accordance with the Mines and Works regulations.

The issuing authority shall further satisfy itself that the applicant has good hearing and, in the case of a certificate for mines, other than opencast mines and for works where subterranean tunnel operations are in progress, the candidate is able to detect small percentages of inflammable gas by means of a flame safety lamp.

Limited certificates

28.41.2 Any issuing authority, in any special case, may issue to a candidate a certificate limited in scope in accordance with rules framed in terms of regulation 28.6, provided such candidate has the requisite experience and qualifications and satisfies the issuing authority that he has sufficient knowledge of the responsibilities appropriate to his work.

³**28.41.3** *The number of qualifying shifts for a provisional blasting certificate and a permanent blasting certificate shall be not less than indicated in regulations 28.41.3.1 and 28.41.3.2.*

28.41.3.1 Provisional blasting certificate:

(a) University students in mining	110 shifts	Blasting certificate valid for the mine.
(b) (i) Government Miners' Training College students	110 shifts	{ Blasting certificate valid in training section only
(ii) Learner officials		
(iii) Learner miners attending a training course in mining approved by the Government Mining Engineer		
(c) (i) Government Miners' Training College students	154 shifts	{ Blasting certificate valid for the mine, but holder to be under the supervision of a certificated ganger or miner.
(ii) Learner officials		
(iii) Learner miners attending a training course in mining approved by the Government Mining Engineer		
(d) Other learners	200 shifts	Blasting certificate valid for the mine, but holder to be under the supervision of a certificated ganger or miner.

28.41.3.2 Permanent blasting certificate:

(a) University students in mining	200 shifts
(b) (i) Government Miners' Training College students	312 shifts
(ii) Learner officials	
(iii) Learner miners attending a training course in mining approved by the Government Mining Engineer	
(c) Other learners	400 shifts

¹S. 28.40.7.2(b) substituted by s. 16, R 513 of 1.4.77.

²S. 28.40.8.2(b) substituted by s. 17, R 513 of 1.4.77.

³S. 28.41.3 inserted by s. 18, R 513 of 1.4.77.

BLASTING CERTIFICATE FOR SCHEDULED MINES*Issuing authority*

28.42.1 The issuing authority for blasting certificates for scheduled mines shall be a Commission of Examiners.

Validity of certificate

28.42.2 A blasting certificate for a scheduled mine shall be valid for a works where subterranean tunnel operations are in progress and for any mine other than a fiery mine and an opencast mine.

BLASTING CERTIFICATE FOR FIERY MINES*Issuing authority*

28.43.1 The issuing authority for blasting certificates for fiery mines shall be a Commission of Examiners: Provided that an Inspector of Mines authorised by the Government Mining Engineer may issue a provisional blasting certificate for a fiery mine.

Validity of certificates

28.43.2 A blasting certificate for a fiery mine shall be valid for a works where subterranean tunnel operations are in progress and for any mine other than a scheduled mine and an opencast mine.

BLASTING CERTIFICATE FOR OPENCAST MINES*Issuing authority*

28.44 The issuing authority for blasting certificates for opencast mines shall be the Inspector of Mines in whose district the applicant is, or is to be, employed. Such certificates shall be valid only for opencast mines.

BLASTING CERTIFICATES FOR OTHER MINES INCLUDING NON-FIERY COAL MINES*Issuing authority*

28.45 The issuing authority for blasting certificates for mines other than those referred to in Regulations 28.42.1 and 28.43.1 and for works, shall be the Inspector of Mines in whose district the applicant is, or is to be, employed. A certificate issued for such mines shall be valid for all mines other than scheduled mines, fiery mines and opencast mines.

A certificate issued for works shall not be valid for any mine.

A certificate issued for works shall only be valid for the class of works for which the certificate is appropriate.

LAMPMAN'S CERTIFICATE*Application for certificate*

28.46.1 Every application for examination for a lampman's certificate shall be submitted to the Inspector of Mines in whose district the applicant is, or is to be, employed. The Inspector who shall be the issuing authority shall conduct such examination as he may deem necessary.

28.46.2 Such application shall bear uncanceled revenue stamps to the value indicated in regulation 28.10.

ONSETTER'S CERTIFICATE*Application for certificate*

28.47.1 Every application for examination for an onsetter's certificate shall be submitted to the Inspector of Mines in whose district the applicant is, or is to be, employed. Such application shall bear uncanceled revenue stamps to the value indicated in regulation 28.10.

28.47.2 An applicant shall not be accepted as a candidate for examination unless—

(a) he has attained the age of 18 years, and

(b) he has at least 12 shifts of experience acceptable to the Inspector of Mines.

28.47.3 An onsetter's certificate shall be issued by the Inspector of Mines or Inspector of Machinery.

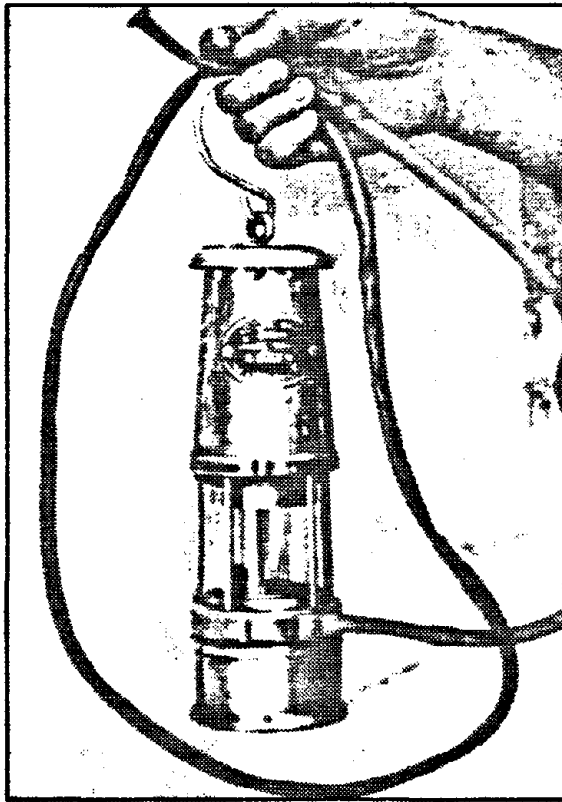
28.47.4 A certificate shall not be issued unless the applicant has been examined by an Inspector of Mines or an Inspector of Machinery assisted by two persons, one of whom shall be a person appointed in terms of either regulation 2.5.1, 2.6.1 or 2.14.1, and the other appointed in terms of regulation 2.13.1 or 2.13.3.

28.47.5 A certificate shall not be issued unless the Inspector of Mines or the Inspector of Machinery is satisfied that, within the scope indicated in the syllabus for the examination drawn up in terms of regulation 28.6, the applicant is competent to perform the duties of an onsetter, has sufficient knowledge of the shaft operations which he has to control, of the signals to be given in connection with such operations and of the regulations appertaining to the duties of banksmen and onsetters.

28.47.6 Subject to the provisions of regulation 16.90 an onsetter's certificate shall be valid for all times.

28.47.7 An onsetter's certificate issued prior to the date of promulgation of these regulations shall retain its validity for such time as the holder thereof is employed at the mine in respect of which such certificate was issued. Subject to the provisions of regulation 28.2.1 it may be exchanged without examination for a certificate issued in terms of this regulation, provided the holder submits an application bearing uncanceled revenue stamps to the value of 50 cents.

METHANE, THE FLAME SAFETY LAMP
AND METHANE CODE OF PRACTICE



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1. METHANE CH4.

1.1. PROPERTIES OF METHANE:

1.1.1. Colourless, odourless, and tasteless. Can therefore not be detected by the senses.

1.1.2. Lighter than air (plus/minus half the weight of air). Therefore tends to accumulate against the hanging in the form of a rooflayer, or in the faces of raises, boxholes and orepasses.

1.1.3. Non-poisonous but more than 15 per cent will render the atmosphere deficient in oxygen and thus cause asphyxiation.

1.1.4. Inflammable when mixed with air in certain proportions. (Most dangerous property).

If the percentage in the air is:—

- i) Below 5 per cent it will burn with a pale blue flame.
- ii) Between 5 per cent and 15 per cent it will explode when ignited. (Most violently at 9,3 per cent.

1.2. MODE OF OCCURRENCE:

1.2.1. Methane is found in all metalliferous and coal mines in this country to a lesser or larger degree.

1.2.2. The theory is that the gas originates from the coal seams overlying the gold bearing strata. From its origin, the gas penetrates the earth's crust through faults, dykes and fissures and if any of these are intersected during mining operations, the methane that may be present is liberated into the mine atmosphere.

1.2.4. If a water bearing fissure is intersected, the presence of water can be considered as a warning that methane may be present. Faults, dykes and dry fissures must however be treated with suspicion as they can emit gas without warning.

1.3. DETECTION OF METHANE:

Only competent personnel will or may be issued with a flame safety lamp fitted with a probe attachment. This lamp has proved itself over many years to be the best and most reliable means of detecting methane and oxygen deficiency. Mine Overseers, Shift Bosses and Gangers in methane areas will or may be issued with a D6 methane-ometer.

- 1.3.1. If the percentage of methane is small (less than 5 per cent) it will burn above the lamp flame, forming a so-called cap. Larger percentages (5 to 15 per cent) cause an explosion inside the lamp extinguishing the flame.
- 1.3.2. A deficiency of oxygen is indicated by the flame flickering and eventually going out.
- 1.4. **DANGERS OF METHANE ACCUMULATIONS:**
- 1.4.1. As previously explained, the danger of methane lies in its inflammability. Now, if methane is prevented from accumulating and forming an explosive mixture, then there can be no explosion.
- 1.4.2. **ACCUMULATIONS ARE CAUSED BY:**
- Large discharges of methane for which the existing ventilation is inadequate.
 - Defective ventilation appliances.
 - Absence of ventilation.
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- 1.5. **PREVENTION OF ACCUMULATIONS:**
- Test for methane regularly and report on emissions immediately so that the necessary steps can be taken as quickly as possible.
- 1.5.2. Check ventilation regularly i.e. the quantity of air available at the working place.
- 1.5.3. Check fans regularly for stoppages or blockages and keep column leakage at a minimum.
- 1.5.4. All working places should be adequately ventilated. Report all unventilated or inadequately ventilated areas to "supervisors" immediately.
- 1.6. **CAUSES OF METHANE EXPLOSIONS:**
- 1.6.1. The ignition of an explosive accumulation of methane is the one and only cause of a methane explosion.
- 1.6.2. Ignition of an explosive accumulation can be caused by the following:-
- Naked lights - matches, flint lighters, smoking of pipes and cigarettes, torches, etc.
 - Defective safety lamps.
 - Defective caplamps.
 - Electrical equipment.
 - Underground blasting operations.

- Underground fires.
2. **THE FLAME SAFETY LAMP.**
- 2.1. **NAME:** Wolf No. 7 R.M.B.S. relighter with probe attachment.
- 2.2. **PRINCIPLE OF OPERATION:**
- A flame will not pass through fine mesh wire gauze. The lamp is so designed that air to be sampled must pass through fine mesh wire gauze in order to reach the lamp flame. If there is methane in the air that is being blown into the lamp, but the methane will be ignited by the lamp flame, the burning gas cannot pass through the gauzes to ignite the methane in the surrounding atmosphere.
- 2.3. **DESCRIPTION OF THE SAFETY LAMP:**
- The tank at bottom contains the fuel supply and wick.
 - The bottom air admission ring with the relighter attached, fits into a groove at the top of the tank. There is a thin gasket between the two sections to make the joint airtight.
 - On the bottom air admission ring is the heavy glass cylinder resting on a thick gasket.
 - This is followed by a gasket and then double gauzes.
 - The whole assembly is held together by a metal frame called the bonnet which screws onto the fuel tank.
 - A magnetic locking device on the frame prevents the lamp from being opened once the bonnet is screwed onto the fuel tank. The wick and relighter are operated by means of a knob and swivel respectively at the bottom of the fuel tank.
 - Air admission ports which can be opened or closed are at the bottom and the middle of the bonnet.
 - On the bottom ring of the bonnet next to the magnetic lock, is a 6.4 mm. copper tube to which the probe is attached.

2.4. CARE OF THE SAFETY LAMP:-

- 2.4.1. The lampman must ensure that all safety lamps are in order before lamps are issued for underground use.
- 2.4.2. Before taking a safety lamp into the mine, make sure the lamp is in order by carrying out the following visual examination in the lamproom:-
- i) See that the suspension hook at the top of the lamp is in order, whether there is a G.M.E. approval stamp on the bonnet and the lamp is clearly and permanently numbered.
 - ii) The lamp and especially the glass must be scrupulously clean. If the glass is not clean, difficulty will be experienced in recognising the gas cap.
 - iii) See that both the top and bottom air admission rings can be opened and closed with ease.
 - iv) Check the glass cylinder carefully for cracks and also for chips on the ends at the gaskets. Grip the glass cylinder between thumb and fingers and rotate. If the glass is loose, the lamp is incorrectly assembled. There must however, be some movement in the glass to allow for expansion when the glass is heated by the lamp flame. Make sure there are gaskets above and below the glass.
 - v) Check the fuel tank for leakage by wiping the hand over the bottom.
 - vi) Make sure the lamp is locked by trying to unscrew the fuel tank.
 - vii) Light the lamp - turn the round knob in the lamp base clockwise until the wick protrudes (plus/minus 3 mm). Bring out the relighter swivel and rotate anti-clockwise until a spark is produced setting light to the wick. Turn the flame down until only a speck of yellow shows and check if the blue flame is spread over the entire width of the wick tube. This blue flame is the testing flame. Turn the wick down to see if it can

be turned down far enough to extinguish the flame.

- viii) Check the probe and see that the rubber is not perished. Operate the bulb and see if the air is drawn in at the long end and blown out at the shorter end, which is attached to the copper tube on the bottom air ring i.e. make sure that the probe will blow air into the lamp from outside.
- ix) Relight the lamp and take the burning lamp into the mine with a flame about 10mm. long. Protect your lamp by holding it under your coat and keep it in a clean condition while underground.
- 2.4.3. No person may unlock or break the seal of a safety lamp underground.
- 2.4.4. No person may take into the mine, or have in his possession in the mine, any contrivance for opening the lock or seal of a safety lamp.
- 2.4.5. All safety lamps must be returned to the lamp-room at the end of a shift by the person to whom they were issued.
- 2.5. **USE OF THE SAFETY LAMP:**
- 2.5.1. The person in charge must at all times have an approved safety lamp on hand.
- 2.5.2. The lamp must be left burning during the entire shift with the flame approximately 10 mm. long. If a lamp breaks or is damaged underground, extinguish the flame and remove the relighter key by turning it clock-wise. Keep the key in your possession. Lock the lamp away in your toolbox and at the end of the shift, return it together with the relighter key to the lamproom and hand over to the lampman personally. Remember, a damaged safety lamp is dangerous, so do not attempt to use it.
- 2.5.4. Safety lamps may not be lit or relit except:-
 - i) In through ventilation.
 - ii) STOPES: In through ventilation away from the face, i.e. on the intake side of the stope or at points where the immediate previous tests were negative.

- iii) DEVELOPMENT ENDS: In fresh air delivery end of the force ventilation column.

2.6. HOW TO TEST FOR METHANE:

- 2.6.1. If tests for methane are to be made, re-examine the lamp in through ventilation.
- 2.6.2. Extinguish or cover all lights in the vicinity of testing point - complete darkness is necessary to see a gas cap.
- 2.6.3. Reduce the lamp flame to a testing flame. Close the bottom air admission port. Hold the lamp steady, slightly above eye level so that the bottom air ring just conceals the blue testing flame.
- 2.6.4. Position the end of the probe at each point to be tested. Hold it in each position squeeze it gently, and release the bulb at least ten times (this ensures that air from the area being tested has filled the probe and passed into the lamp). When testing at high places the end of the probe must be attached to a charging stick.
- 2.6.5. When testing at faces the lamp must be held as far away from the face as possible while the intake end of the probe is held firstly against the hanging, and then in all sockets and fissures on the face.
- 2.6.6. i) If there is methane in the atmosphere, a pale blue triangular flame, called a cap, will form above the testing flame. The more gas emanating, the longer the cap will become.
ii) From the apparent length of the cap an estimate of the percentage of gas can be made:-
"Half Glass" - plus/minus 2 per cent.
"3/4 Glass" - plus/minus 3 per cent.
"Full Glass" - plus/minus 4 per cent.
iii) If methane is present in large quantities of plus 5 percent the lamp flame will go out with a "Flare-up" inside the lamp.
This "Flare-up" has the characteristic pale blue colour. Alternatively, the lamp flame may just suddenly go out.
- 2.6.7. If methane is detected, stop all further testing and remove the lamp to fresh air.
- 2.6.8. When testing in a pump chamber or other place

where the lights cannot be extinguished, test with a flame plus/minus 5 mm. high. If the illumination and the length of the flame increase it is a sign that methane is present. Testing in darkness with a reduced flame is however preferable.

3. THE METHANOMETER.

3.1. CARE OF THE METHANOMETER:

- 3.1.1. The lampman must ensure that all methanometers are in order.
- 3.1.2. Before taking a methanometer into the mine the following examination must be carried out in the lamproom:
- See that the methanometer is clean.
 - See that the G.M.E. approval stamp in the front of the methanometer is clearly and permanently numbered.
 - Press the switch button. The needle of the meter will move to one side or the other, then gradually return to zero. This should take less than 10 seconds.
 - Check the battery voltage. If the voltage is less than the required minimum DO NOT use the instrument.
- 3.1.2. (E) Check the probe for blockage and the aspirator bulb to see that the rubber is not perished.
- 3.2. MAINTENANCE OF THE METHANOMETER BY THE LAMPSMAN:
- The lampman will receive instructions on the maintenance of methanometers by the Ventilation Officer. Operating instructions shall be posted in the lamproom. The lampman must carry out the following maintenance on all methanometers daily.
- Check and charge batteries if required.
 - Check and adjust zero setting if required.
 - Check the accuracy against a standard mixture of methane.
 - Check the aspirator bulb.
 - Test and check the airflow system through the probe for blockage.

- (vi) Send defective methanometers away for repairs.

3.3. USE OF THE METHANOMETER:

- i) All persons to whom methanometers are issued must be instructed and found proficient in the use of the instrument by the Ventilation Officer, before being allowed to use the instrument underground.
- ii) Methanometers are to be collected at the lamproom.
- iii) Methanometers must be returned to the lamproom personally by the person to whom they were issued and not later than the end of the same shift on which they were issued.
- iv) The methanometer does, by no means, replace the flame safety lamp or the use of a safety lamp as a faulty methanometer can give a wrong reading.
- v) For remote sampling an extension probe can be fitted onto the connection on top of the instrument. Note that the aspirator bulb must be squeezed at least once for every 15 cm of the length of the probe e.g. if the is 60 cm long squeeze blub at least (4) times.
- vi) If plus 5 percent methane is detected the instrument must be switched off immediately as the combustion block can burn out.
- vii) No water must be allowed to enter the probe or the instrument as water will cause electrical short circuiting and burn out the combustion block.
- viii) A methanometer is a delicate instrument and must be handled with care.

4. WHEN TO TEST FOR METHANE:

- i) At the commencement of the shift, even if shifts are changed on the face.
- ii) After a ventilation failure lasting more than 30 minutes, or a deterioration in ventilation conditions.

- iii) After pilot holes have been drilled.
- iv) Before charging up.
- v) Immediately before blasting.
- vi) When water, a dyke, a fissure or fault is intersected.
- vii) Before lighting any cutting torch, blow lamp or using an electric welding apparatus.
- viii) Before commencing work in an established underground workshop, sub-station, battery charging station, hoist room, pump chamber and hopper repair bays.

5. EXAMINATION OF STOPES AND DEVELOPMENT ENDS FOR METHANE.

5.1. EXAMINATION OF DEVELOPMENT ENDS VENTILATED BY THE FORCING SYSTEM.

(Carried out by the responsible ganger or developer or competent responsible person.)

Check that the fan is operating and is facing in the correct direction. If the fan is operating, proceed as follows:-

- i) Test in the return air from the end after it has mixed with through ventilation i.e. plus/minus 15 m. down stream on the return side of the end.
- ii) Test in the direct return air from the face plus/minus 5 m. inside the entrance of the end.
- iii) When proceeding to the face, test all high places in the hanging, at faults, dykes and other places where methane could possibly have accumulated.
- iv) Test at the face against the hanging and in all sockets.
- v) Test at all electrical equipment before the initial starting of the motors.
(Sign "Methane Record Card").
- vi) Test at the blasting point before connecting the blasting cable to the exploder or to the

centralised blasting point.

- vii) Test in all adjacent workings that are within 30 m. of any holes to be blasted, whether directly or indirectly connected to the working place (Regulation 8-10-12).

5.2. EXAMINATION OF STOPES:

Carried out by the responsible ganger or stoper or competent responsible person).

Check all ventilation appliances i.e. exhaust fans, booster fans, ventilation doors etc., that effect the air flow through the stope, are in order. If the ventilation appliances are in order, test for methane as follows:-

- i) Test the return air from the stope.
- (ii) At the top limit of each face, west siding and back stope. Test also the airflow. (Minimum velocity 0,5 m/s.)
- iii) At the highest point of a "U Tube". Test also for airflow. (Minimum velocity 0,5 m/s.)
- iv) At various places along the stope face and at faults, dykes, fissures, sockets and high places in the hanging.
- v) In advance scraper gullies, stope raises and such places where methane can accumulate.
- vi) At all electrical switch gear and machinery before the initial starting. (Sign "Methane Record Card").
- vii) At the blasting point before connecting the blasting cable to the exploder or the centralised blasting point.
- viii) Test in all adjacent workings that are within 30 m. (100 ft.) of any holes to be blasted whether directly or indirectly connected to your working place.
- ix) Where a locomotive has to enter a tunnel which is dependent upon a fan and ventilation piping for its ventilation, a methane test must be carried out at the face of the tunnel and also in the return air immediately before it joins in the through air stream.

5.3. ROUTINE TESTING FOR METHANE BY THE SHIFTBOSS:

The shiftboss shall supervise or carry out the examination for methane in at least one working place on each shift. The results of these tests and the number of the safety lamp and or methanometer used shall be logged in his log book.

6. PROCEDURE WHEN METHANE IS DETECTED:

If at any time during a test, the presence of methane is detected, the following procedure is to be adopted.

6.1. THE GANGER IN CHARGE:

- i) Stop all work in that working place.
- ii) Withdraw all persons from that working place.
- iii) Send for the Shiftboss or next senior official.
- iv) Place guards at all entrances until the necessary barricades are erected to prevent inadvertent entry.
- v) Barricade all entrances to the working place with a methane barricade, bearing the following signs:

**NO ENTRY : METHANE END,
YELLOW TRIANGLE, METHANE FLAME
SIGN, METHANE RECORD CARD AND
FOLDER.**

- vi) Stop all locomotives from entering on the return air side of the working place.
- vii) Switch off the winch isolating switch or switches in through ventilation; Do not operate switches if they are in an atmosphere containing methane; but send for the electrician to isolate the winch from a methane free point.
- viii) Warn persons on the return side of the working place.
- ix) The Shiftboss will after completing his test instruct the ganger on allowable operations. (See 6.4. vii a,b,c).

6.2. THE COMPETENT PERSON IN CHARGE.

(See chapter 13.)

6.3. THE DIAMOND DRILLER OR COMPETENT PERSON IN CHARGE.

(See chapter 14).

6.4. THE SHIFTBOSS:

- i) Test in the return air from the working place.
- ii) If the test in the return air is **POSITIVE** warn all persons on the return side.
- iii) Ensure that all ventilation appliances are functioning properly. Do not re-start fans or operate winches in any area where there is a detectable amount of methane in the atmosphere.
- iv) Ensure that all persons have been withdrawn from the working place.
- v) Ensure that guards have been posted until such time as barricades have been completed.
- vi) Check that all entrances to the working place have been barricaded off and that the required signs have been posted thereon.
- vii) If no distinct cap can be detected on the reduced flame of the safety lamp, or less than 2 per cent on an approved methanometer, proceed to the point of origin.
- a) If a distinct cap or plus 2 per cent is found outside a radius of 50 cm. from the source, no further work, including blasting, may be done within 30 m. of the source in a stope and beyond the last point of through ventilation in a development end and in any adjacent working place within 30 m. of the point of issue of the methane.
- b) If a distinct cap or plus 2 per cent is found just outside the source, but negative within a radius of 50 cm. then normal work, but excluding blasting may continue. No blasting may be done within 30 m. of the point of issue in a stope, and anywhere beyond the last point of through ventilation in a development end and in any adjacent working place that is within 30 m. of the point of issue of the methane.

- c) Blasting may take place if NO distinct cap or less than 2 per cent can be detected just outside the source.

- viii) Report to the Mine Overseer in charge, or if he is not available, to any other Mine Overseer or official of equal or higher rank.

6.5. THE MINE OVERSEER:

- i) Ensure that the correct procedure has been adopted.
- ii) Report the matter to the Section Manager and Chief Ventilation Officer/Ventilation Superintendent as soon as possible.

6.6. SECTIONAL ENGINEERS, MECHANICAL AND ELECTRICAL PERSONNEL:

- i) Stop all work.
- ii) Withdraw all persons to through ventilation.
- iii) Notify the Shiftboss or Mine Overseer in charge of the affected area.
- iv) Trip the isolating switch to all electrical equipment except fans, not situated in through ventilation from a point where no methane is present in the surrounding atmosphere. If necessary, this must be done from the main substation.

7. PROCEDURE WHEN VENTILATION SYSTEM FAILS OR DETERIORATES:

7.1. DEVELOPMENT END VENTILATION

FAILURES:

- i) Open the compressed air in the face.
- ii) If an "Emergency compressed air blower" is installed it may be opened by the responsible ganger **IMMEDIATELY AFTER A FAN FAILURE AND NOT AT ANY OTHER TIME** except when the blower is being used during methane clearing operations under the direct supervision of a Mine Overseer, The Shaft Mine Overseer must be notified to maintain the compressed air supply on that level.
- iii) Withdraw all persons to through ventilation.
- iv) Switch off power to all electrical equipment

inside the end.

- v) Erect barricades at all entrances to the end.
7.1.2. The fan(s) ventilating the end and electrical equipment inside the end may be restarted by the responsible ganger or Shiftboss provided that:

- i) No methane is detected at the fan, fan switch and entrance to the end.
- ii) The power failure has not lasted more than 30 minutes.
- iii) That no methane has at any time been detected inside the end. NOTE that all ends are above 20 level elevation shall be considered as methane ends irrespective of whether methane was previously detected or not.

- 7.1.3. After starting the fan test continuously for methane in the return air from the end until all the air from the end has been replaced (allow one minute for every 15 metres that the end has been advanced from through ventilation). If a methane cap forms at any time during this period, stop the fan at once and do not attempt to restart it.
7.1.4. All power failures of longer than 30 minutes in methane areas must be reported to the Shiftboss, Mine Overseer, Electrical Foreman, Sect. Engineer, Sect. Manager and the Ventilation Officer.
N.B. Note that work shall not be resumed in such a working place until the ventilation current therein has been restored and the Ganger or Miner in charge has examined the working place and satisfied himself that conditions are safe (Regulation 10-11-2).

- 7.1.5. Only an Official with minimum rank of Mine Overseer may re-start fans in methane areas. Where a power failure has lasted for more than 30 minutes in a non-methane area, Shift Bosses may re-start the fans.
7.2. **STOPE VENTILATION FAILURES:**

All persons must be withdrawn from a stope if the air current in the stope:-

- i) Weakens noticeably.
- ii) Comes to a standstill.
- iii) Changes direction.

Also see 4 (ii).

CLEARING OF METHANE FILLED WORKING PLACES AND STARTING OF FANS IN METHANE AREAS:

All methane clearing operations and starting of fans in methane areas must be done under the direct supervision of an official with minimum rank of Mine Overseer. The following procedure must be followed if a working place is filled with methane.

- i) The clearing of the methane must be done by the Mine Overseer assisted by a member of the ventilation department. The clearing should be done preferably between shifts. Ensure that no person can enter the return side of the end to be cleared.
- ii) Before starting the fan of a methane filled end, test for methane at the fan and fan switch which is situated in through ventilation.
- iv) The methane filled working place should be blown out in such a manner that the return air, after mixing with through ventilation, does not contaminate through ventilation to an extent greater than 2 per cent methane. The "Blow in" volume of the fan should be regulated in such a way that this is achieved.
- v) After starting the fan, test continuously for methane in the return air from the methane filled working place until all the air has been replaced (Allow one minute for every 15 metres that an end has been advanced from through ventilation). If 2 per cent methane is detected in the through ventilation at any time during this period, stop the fan at once and reduce the "Blow in" volume of the fan.
- vi) If a stope must be cleared, install a fan in fresh air as close to the footwall as possible at such a distance from the start of the stope that the ventilation current will just blow into the stope and that the fan will not recirculate.

- vii) After clearing the first 5 metres of the stope, the ventilation column must be extended one length at a time, blowing out short sections until the whole stope has been cleared and normal ventilation flow has been restored.

9. VENTILATION STANDARDS:

Working places, that do not conform to the following standards, must be stopped immediately and rectified.

9.1 DEVELOPMENT:

9.1.1. FLAT DEVELOPMENT:

(i) Force outlet volume (min.)	2,3 m ³ /s
(ii) Exhaust inlet volume (min.)	3,3 m ³ /s
(iii) Face wet Kata reading (min.)	6
(iv) Force outlet to face (after the blast) (max)	12 m
(v) Discharge of waterblast (after the blast) (max)	12 m
(vi) Exhaust inlet to face (after the blast) (max)	20 m
(vii) Force-exhaust overlap (max)	15 m
(viii) The force fan or fans must be installed in through ventilation, 10 m on the intake side of the end, and not inside the end.	
(ix) All fan starters must be in through ventilation on the intake side of the fans they serve.	

9.1.2. FORCING ONLY SYSTEM OF VENTILATION FOR RAISES ETC. UNDER 45 DEGREES.

(i) Force outlet volume (min.)	2,3 m ³ /s
(ii) Force outlet to face (after the blast) (max)	12 m
(iii) Discharge of waterblast to face (after the blast) (max)	12 m
(iv) Face wet Kata reading (min)	6
(v) The force fan or fans must be installed in through ventilation 10m on the intake side of the end and not inside the end.	
(vi) All fan switches must be in through ventilation on the intake side of the fans they serve.	
(vii) The force fan or fans must be electrically	

interconnected with all electrical machinery inside the ends, so that when the fan becomes inoperative, the power supply to such electrical machinery will be discontinued.

9.1.3. BOXHOLES AND INCLINES OVER 45 DEGREES AND STOPE RAISES: FORCING ONLY SYSTEM OF VENTILATION:

(i) Force outlet quantity (min)	1,4 m ³ /s.
(ii) Force outlet to face (max. after the blast)	12 m
(iii) Discharge of waterblast to face (max. after the blast)	12 m
(iv) Face wet Kata reading (min)	6
(v) Fan switches, must be in through ventilation on the intake side of the fans they serve.	

9.1.4. OTHER DEVELOPMENT STANDARDS:

9.1.4.1. (a) The breakway of a development end from an existing development end.	
i) Stop all work in the existing end.	
ii) Disconnect the electrical supply to all electric appliances in the existing tunnel.	
iii) Extend the compressed air to within 3m from the face of the stopp'd end and fit a 13 mm jet.	
iv) Install a standard barricade in the stopped end just beyond the breakway of the new end.	
v) The compressed air control valve is at the barricade of the stopped end.	
9.1.4.1. (b) PROCEDURE AT THE END OF THE SHIFT i.e. BLASTING TIME.	
i) Open compressed air valve at barricade, in the stopped end.	
ii) Remove two lengths of ventilation piping, opposite the new end, of the stopped end.	
9.1.4.1. (c) PROCEDURE AT COMMENCEMENT OF SHIFT:	
i) Replace the two ventilation pipes (or tubing) opposite the new breakaway.	
ii) Carry out a complete methane survey in the stopped end.	
iii) If no methane is detected, close off compressed air.	

9.1.4.1. (d) PROCEDURE ON COMPLETION OF NEW BREAKAWAY:

When the new end has advanced for a maximum of 5m.:

- i) Restore normal ventilation in the stopped end.
- ii) Install a fan and pipes to ventilate the new end.

9.1.4.2. VENTILATION PIPES:

- i) 570mm diameter or larger pipes must be used in all flat development ends, raises and winzes.
- ii) 380mm diameter pipes may only be used in boxholes, steep inclines and stope re-development where the total length of column will not exceed 50 m.

9.1.4.3. INSPECTION PIECES:

Ventilation columns in boxholes and steep inclines must be fitted with a T-piece in the crosscut instead of a bend. The open end must face downwards, and be blanked off. Rock must be removed from this trap daily.

9.1.4.4. PROTECTION PIECES:

- i) A short piece of old ventilation pipe (1m to 2m) must be installed on the outlet ends of all forcing columns. If damaged by the blast, it must be hammered out, or replaced immediately.
- ii) All fans must have at least one length of ventilation pipe on the intake side in the case of forcing fans and on the discharge side in the case of exhaust fans.

9.1.4.5. USE OF FLEXIBLE PLASTIC VENTILATION TUBING.

When flexible plastic tubing is used, at least three lengths of galvanised ventilation piping must be installed in front of it to prevent damage from the blast. In areas where methane is known to be present, only an anti-static type of flexible tube or galvanised piping are allowed to be used. Damaged ventilation tubing must be sent to surface to the salvage section for repair.

9.1.4.6. USE OF COMPRESSED AIR FOR VENTILATION PURPOSES:

Compressed air must not be used for ventilating any working place except for:-

- i) Dissipating methane roof layers by means of a 25 mm steel pipe. Fitted with a 6mm jet. An official layout from the ventilation department is required.
- ii) Breaking new ends away from existing ends.
- (iii) Raise stopped and awaiting holing of box-hole (see mine standard No. 2.5.1.)

9.1.4.7. SCREENS:

Expanded metal screens must be installed on the intake ends and also between the permanent column and the protection piece of all ventilation columns.

9.1.4.8. VENTILATION PIPE JOINTS:

All ventilation column joints must be equipped with an approved type of sleeve and bolts.

9.2. SCREENS:

9.2.1. VENTILATION STANDARDS:

- (i) Volume available 1 sided mining (min.) 4 m³/s
- (ii) Volume available 2 sided mining 8 m³/s
- (iii) Specific Cooling Power (S.C.P.) 1.25W/m²
- (iv) Face velocity (min) 0.5 m/s
- (v) West siding, back stopes (min) 0.5 m/s
- (vi) Dust counts (max) 250 P/ml
- (vii) Strike curtains dist to face (max) 8.5 m
- (viii) Air utilization index (A.U.I.) target 100%

9.2.2. CENTRE GULLY BRATTICES:

Not less than two (2) centre gully brattices per panel must be installed, one at the top and the other at the bottom of the centre gully.

9.3. VENTILATION LAYOUTS: 9.3.1. INSTALLATION OF VENTILATION APPLIANCES:

- (i) Ventilation appliances must not be installed anywhere in the mine unless an official layout authorised by the Section Manager and Chief Ventilation Officer/Ventilation Superintendent has been obtained.
- (ii) If any installation is to be made, a request by the Mine Overseer for a layout must be submitted in writing to the Section Ventilation Officer at least three (3) days before hand. Such request must be authorised by

the Section Manager.

- (iii) A short length of 100 mm dia. pipe on the footwall for water drainage and a short length of 25 mm dia. pipe against the hanging for periodical methane testing must be built into the wall.

9.3.2. VENTILATION DOORS:

- i) All ventilation doors must be interlocked and be fitted with counterweights to make them self closing.
- ii) Doors that will cause a disruption of the general ventilation flow, if left open, must have attendants.
- iii) All main ventilation doors to be fitted with travelling way doors.

9.3.3. TAMPERING WITH VENTILATION APPLIANCES:

Ventilation appliances or arrangements must not be tampered with nor altered without the authority of the Ventilation Officer.

This includes the breaking of walls and stoppings, the removal of barricades, and interfering with the settings of the regulator.

9.3.4. BUILDING OF PERMANENT WALLS:

Walls in permanently stopped ends, connecting crosscuts in twin development ends, and walls in crosscuts, sealing abandoned stopes etc., must be constructed as follows:

- (i) Walls must be built not more than 2,5 m inside the end, i.e. from through ventilation
- (ii) Walls must be built of concrete or concrete bricks and must not be less than 230 mm thick.
- (iii) A 2000 mm length of 100 mm pipe on the footwall for water drainage and a 2000 mm length of 25,4 mm pipe against the hanging for periodical methane testing must be built into the wall.

9.4. HOLING OF DEVELOPMENT ENDS AND STOPES:

- (i) The survey department must notify the the Section Manager and the Ventilation Superintendent in writing on form No. Gen. 399 of all holings to be effected.

- (ii) The Mine Overseer must notify the Section Ventilation Officer in writing of any expected holings in his section, at least 7 days before such holing is expected.

10. POTENTIAL METHANE TRAPS:

Attention is drawn to a letter from the Chief Inspector of Mines Ref. I.M.W. 54/4/13 Vol. G.M.E. 14/3/2 Paragraph D3 (1) (2) (a) (b) (c) dated 26th March, 1973, which states the following:-

10.1. METHANE LOCKING:

Due to faulting or return airways being on a lower elevation than the working, ventilating air if often required to flow from a higher to a lower elevation resulting in a syncline or "inverted U tube" condition. Any decrease in the air quantity flowing can lead to a Methane accumulation or lock of Methane present in the vicinity of the working.

10.2. BACKSTOPES AND UP-DIP SIDINGS (WEST SIDINGS ETC.):

A backstope is any part of a stope that is not connected at its highest point to other working on a higher elevation than the said point.

Methane can easily accumulate in a poorly ventilated back-stope and up-dip siding (West siding etc.). To prevent methane accumulations, an air velocity of at least 0,5 m/s must be maintained along the entire length of the faces at a backstope and up-dip siding (West siding).

10.3. PREVENTION OF METHANE ACCUMULATIONS AT METHANE TRAPS.

To avoid any Methane locking or accumulation of methane, the following instructions must be observed by:-

i) MINE OVERSEER

Working places with "inverted U tube" West sidings or backstopes, will not be started without an authorised layout from the Ventilation Department. The Mine Overseer must apply, through his Section Manager, to the Ventilation Department for

such a layout.

ii) **THE SHIFTBOS:**

The Shiftboss shall test and inspect weekly, the following:-

- a) At the highest point of the "U tube", West siding, or back stope for methane and countersign the Methane Record Card.
- b) For airflow at the U tube or along the faces of the West siding or backstope.
- c) Inspect the Ventilation appliances, e.g. fans, doors, brattices, plastic curtains, etc., affecting this working place.

The results of these tests and inspections by the Shift Boss will be logged in his log book.

iii) **THE GANGER:**

The ganger in charge of such a working place will proceed to the highest point of the U tube, West siding or backstope, and test for methane and airflow at this point before work commences in the working place. The result of the Methane Tests to be entered on the Methane Record Card kept at this point. This procedure is additional to any test laid down in the Methane Code. On completion of the Methane Record Card, this card will be countersigned by the Mine Overseer and forwarded to the Ventilation Department for filing.

The ganger must test daily the air velocity by means of aluminium dust along the face of a West siding or backstope. Work must not be allowed unless the velocity is at least 0,5 m/s.

The aluminium puffer bottle must be kept by the ganger.

11. STOPPED END AND STOPPED BACKSTOPE STANDARD PROCEDURE.

11.1. APPOINTMENTS:

11.1.1. Section Managers and Mine Overseers:

- i) When Section Managers and Mine Overseers are appointed, a copy of the Inspector of Mines' letter I.M.W. 54/4/13 Vol. 2 G.M.E.

14/3/2, dated 26th March, 1973, will be issued to each official. A copy of the letter dated and signed by the official in acknowledgement of receipt will be kept in the appointment file. On each such occasion the official being appointed will be provided with a copy of the said letter, and he will acknowledge receipt on the copy kept in the appointments file.

- ii) Section Managers and/or Mine Overseers relinquishing or accepting responsibility for adjustments to their existing sections, must ensure that when handing over or taking over, the stopped ends/backstopes involved in the adjustment to sections in Methane Registers No's 1, 2A and 2B.

11.1.2. SHIFT BOSSES:

- i) When Shift Bosses are appointed the limits of their sections will be clearly defined and noted in their log books.
- ii) The Shift Boss will acknowledge his appointment for his stopped ends/backstopes in the following books:-
 - a) Methane Register No.1 - Permanently Stopped Ends/Backstopes.
 - b) Methane Register No. 2A - Temporarily Stopped Ends (With no Methane).
 - c) Methane Register No. 2B - Methane Stopped Ends/Backstopes.

11.2. PERMANENTLY STOPPED ENDS / BACKSTOPES:

11.2.1. Definition and Stoppage Procedure:

If it is officially known that an end will not be advanced in the foreseeable future, it may be declared permanently stopped by the Section Manager, and the following procedure must be followed:

- i) Carry out the standard holing point examination.
- ii) Whilst maintaining normal ventilation conditions, reclaim all other equipment in the end.

- iii) Erect a barricade with appropriate signs at the entrance of the end.
- iv) Stop all fans ventilating the end and carry out a through test for methane throughout the entire end after it has been unventilated, firstly for 24 hours and secondly for 7 days. These tests must be carried out by the Mine Overseer accompanied by the Ventilation Officer.
- v) If methane, however slight, is detected in this end, it must be declared a Methane Stopped End until removal of ventilation appliances is authorized by the Ventilation Superintendent in writing.
- vi) If all tests are negative, restart fans and remove ventilation pipes starting from the face.
- (vi) When reclamation is complete, erect 230mm thick concrete wall immediately inside the end, not more than 2.5m from the entrance. Install a short length of 100mm dia pipe through the wall on the footwall for water drainage and a short length of 25mm dia. pipe against the hanging for periodical methane testing. In the case of a backstope, barricade off all entrances.

11.2.2. Methane Register No. 1 – permanently Stopped Ends/Backstopes:

This book must be kept at the Shaft Offices and must contain the following information regarding the permanently stopped end/backstope.

- i) Name of end / backstope, shaft and section.
- ii) Date declared permanently stopped.
- iii) Date and result of Methane Test after being unventilated for 24 hours and for 7 days and signature of Mine Overseer and Section Ventilation Officer.
- iv) Date wall completed and signatures of Shift Boss, Mine Overseer, Section Manager and Ventilation Superintendent.
- v) Date wall opened and ventilation restored.
- vi) Reason for opening wall.
- vii) Signature of Shift Boss, Mine Overseer and

Section Manager.

- viii) Date and result of monthly inspection and signature of Shift Boss.

11.2.3. If another working approaches a permanently stopped end/backstope within 60 m. and will advance to within 30m. the wall must be removed and normal ventilation restored therein.

11.2.4. When the approaching end is within 30m. of the end. it shall be declared a temporarily stopped or Methane stopped end/backstope whichever is applicable. Tests for Methane must then be made in the stopped end/backstope at the commencement of the shift and again before blasting in the approaching end. These tests must be made throughout that portion of the stopped end/backstope that is within 30 m. of the approaching end.

11.2.5. A Methane record card must be kept in the stopped end/backstope at the holing point and the person doing the test must examine within a radius of 30 m. of the holing point daily. The Ganger or substitute appointed by the Mine Overseer of the approaching end and the Shift Boss or substitute in charge, must sign the card daily after each test.

11.2.6. SHIFT BOSSES will be appointed, in writing, by the Section Manager to inspect at least once a month the wall at the entrance of a permanently stopped end or barricade of a backstope. This wall/barricade shall be kept in good order and condition.

11.2.7. The inspection shall also include a test for methane in the 25 mm dia pipe through the wall against the hanging with an accurate instrument and/or flame safety lamp fitted with a probe. In the case of a backstope, the test is at the barricade.

11.2.8. The result of this inspection shall be entered in Methane Register No. 1 on the same day. If Methane is detected in the 25 mm dia pipe or barricade, the Mine Overseer will notify the Ventilation Superintendent immediately. The Ventilation Officer shall personally supervise the wall being broken down and the methane dispersed.

11.3. TEMPORARILY STOPPED ENDS (WITH NO METHANE):

11.3.1. Definition and Stoppage Procedure:

If it becomes necessary to suspend work in an end for more than 14 days or if an end is stopped on elevation or for another end to hole into it, the Section Manager will declare such end as temporarily stopped if no methane has been detected therein. The following procedure must must then be followed:—

- i) Make sure all ventilation appliances are in good order and condition and according to standards.
- ii) Erect a stopped end barricade with appropriate signs at the entrance to the end.

11.3.2. Methane Register No. 2A – Temporarily Stopped Ends:

This book must be kept at the Shaft Offices and the following information must be entered therein regarding the temporarily stopped end:—

- i) Name of end, shaft and section.
- ii) Method of Ventilation and quantity.
- iii) Condition of all ventilation appliances.
- iv) Date barricade was erected.
- v) Signature of Shift Boss, Mine Overseer and Section Manager.
- vi) Authority to restart - signature of Section Manager and date.
- vii) Result of test prior to restarting, date and signature of Mine Overseer.
- viii) Date restarted and signature of Shift Boss.
- ix) The name, date and distance that any approaching end is from the stopped end when such approaching end is within a radius of 30 m. of the stopped end.
- x) Results of the monthly inspection showing date, condition of ventilation equipment, methane, signature of Shift Boss, Mine Overseer and Section Manager.

11.3.3. Normal ventilation conditions must be maintained in such end at all times.

11.3.4. A temporarily stopped end will only be restarted with the prior approval of the Section Manager.

and then only after the Mine Overseer has tested for methane in the end with negative results.

11.3.5. If another end approaches the temporarily stopped end within a radius of 30 m daily methane tests must be carried out in the approaching end throughout that portion of the stopped end that is within a radius of 30 m. from the approaching end at the beginning of each shift and immediately before blasting. These daily tests and the distance between the two ends must be entered by the Shift Boss in Methane Register No. 2A on the same day.

11.3.6. A Methane record card must be kept in the stopped end at the holing point and the person doing the test must examine within a radius of 30 m. of the holing point daily. The Ganger of the approaching end and the Shift Boss in charge or the substitute appointed by the Mine overseer must sign the record card after they have tested.

11.3.7. Shift Bosses will be appointed, in writing, by the Section Manager to inspect at least once a month the ventilation equipment over the entire length of all stopped ends in their sections. These appliances shall be maintained in good order and condition.

11.3.8. The inspections shall also include a through test for methane over the entire length of the end with an accurate instrument and/or flame safety lamp fitted with a probe.

11.3.9. The result of this inspection shall be entered in Methane Register No. 2A on the same day. If Methane, however slight, is detected in the end during this inspection, the end must immediately be declared a methane stopped end, and transferred to Methane Register No. 2B. The Mine Overseer will countersign each such entry in Methane Register No. 2A, within 3 days.

11.4. METHANE STOPPED ENDS/BACKSTOPE:

11.4.1. Definition and Stoppage Procedure:

If for any reason it becomes necessary to suspend work for more than 14 days in an end/backstope where methane, however slight, has been detected

the Section Manager will declare such end a "Methane Stopped End". The following procedure must then be adopted:—

- i) Make sure all ventilation appliances are in good working order and condition and according to standards.
- ii) Erect a Methane Stopped End barricade with appropriate signs in the entrance to the end/backstope.

11.4.2. Methane Register No. 2B - Methane Stopped Ends/Backstopes:

This book must be kept at the Shaft Offices and the following information regarding the Methane Stopped End must be entered therein:—

- i) Name of End/Backstope, shaft and section
- ii) Methane at source, 15 cm. away, 50 cm. away, general air.
- iii) Method of ventilation and quantity.
- iv) Condition of ventilation appliances.
- v) Date barricade was erected.
- vi) Signature of Shift Boss, Mine Overseer and Section Manager.
- vii) Authority to re-start - date and signature of Section Manager.
- viii) Result of test prior to restarting, date and signature of Mine Overseer.
- ix) Date restarted and signature of Shift Boss.
- x) Date and result of daily inspection at barricade and signature of Shift Boss, Mine Overseer and Section Manager.
- xi) Date and result of monthly complete inspection and signature of Shift Boss and Mine Overseer.
- xii) Ends approaching within 30 m: Date, methane content, the distance apart and signature of the Shift Boss.

11.4.3. Normal ventilation condition must be maintained in such end/backstope at all times.

11.4.4. A Methane Stopped End/Backstope will only be restarted on authority from the Section Manager, and then only after the Mine Overseer accompanied by the Ventilation Officer has examined the place, and a clearance, in writing, has been

issued under the signature of the Ventilation Superintendent.

11.4.5. If another end approaches the Methane Stopped End/Backstope within a radius of 30m. daily, methane tests must be carried out at the beginning of each shift and immediately before blasting takes place, in the approaching end throughout the entire length of the Methane Stopped End/Backstope. The results of these daily tests and the distance between the two ends must be entered in Methane Register No. 2B on the same day.

11.4.6. A methane record card must be kept on the face of the Methane Stopped End/Backstope. The Canger of the approaching end and the Shift Boss in charge must write the date, the result of the test and their signatures on this record card after each test they have made.

11.4.7. The Section Manager will appoint Shift Bosses, in writing, to inspect daily all Methane Stopped Ends/Backstopes in their sections. The Shift Boss shall ensure that all fans ventilating the ends/backstopes are operative, and that the barricade at the entrance is in good order and condition. This inspection shall also include a test for Methane at the barricade with an accurate instrument and/or flame safety lamp fitted with a probe.

11.4.9. The result of this daily inspection will be entered in Methane Register No. 2B on the same day. The Mine Overseer must countersign each such entry within 3 days and the Section Manager will countersign each such entry within 14 days.

11.4.10. The Mine Overseer accompanied by the Shift Boss shall at least once in every month carry out an inspection of the barricades and ventilation appliances throughout the whole length of all Methane Stopped Ends/Backstopes, and these appliances shall be maintained in good order and condition.

11.5. BARRICADES:

11.5.1. Construction of Barricades:

A sufficient number of uprights (mining poles) must be wedged firmly between footwall and hanging and braced with timber cross pieces.

Cover the whole area of this frame work with chicken wire in such manner as to prevent any persons from having access to the barricaded area without breaking the barricade or portion thereof:-

11.5.2. Type of Barricades:

- i) Barricades in through ventilation will be called "No Entry" barricades, and will bear a "No Entry" sign.
- ii) Barricades in Temporarily Stopped Ends (with no Methane) will be called "Stopped End Barricades" and will bear the following signs:
 - a) No Entry.
 - b) Metal folder for methane record card.
 - c) Yellow Triangle.
- iii) Barricades in Methane Stopped Ends or Backstopes will be called "Methane Barricades" and will bear the following signs:-
 - a) No Entry.
 - b) Metal Folder for Methane Record Card.
 - c) Yellow Triangle.
 - d) Methane Flame Sign.
 - e) Methane End.

11.5.3. Inspection of Barricades and Reporting:

- i) The Section Manager will appoint Shift Bosses, in writing, to inspect all barricades in their sections at least once every week. and to maintain these barricades in good order and condition. Note that methane barricades must be visited daily.
- ii) The result of these inspections must be entered in the barricade inspection book on the same day.
- iii) The Mine Overseer will countersign each such entry within 3 days and the Section Manager will countersign each such report at intervals not exceeding 14 days.
- iv) The Ventilation Department will examine all barricades of stopped ends and backstopes, and also ventilation equipment of all

Methane stopped ends/backstopes once in every month and non-methane stopped ends once a quarter. Weekly reports will be submitted to Section Managers on inspections made during the preceding week. These inspections must be carried out as far as the barricade only.

11.6. STOPPED ENDS/BACKSTOPES IN AN ABANDONED AREA:

- 11.6.1. When no methane is present in the return air of an abandoned area, all stopped ends/backstopes which fall in this area shall be grouped together and be entered in the Methane Register No. 2A. When methane is present in the return air from such an abandoned area, the stopped ends/backstopes will be entered in Methane Register No. 2B.

- 11.6.2. Regarding appointments, inspections and maintenance of barricades and methane tests, the abandoned areas will be treated the same as for stopped ends.

11.7. PROCEDURE TO BE ADOPTED WHEN ENDS/BACKSTOPES ARE TO BE STOPPED:

- 11.7.1. The Mine Overseer will notify the Ventilation Superintendent, Resident Geologist and Chief Surveyor daily of any ends/backstopes stopped, permanently or temporarily, on form GEN 431. The Ventilation of the end/backstope will remain in full operation until stoppage is authorized, in writing, by the Ventilation Superintendent.
- 11.7.2. (i) The Ventilation Superintendent will notify the Section Manager on form Gen. 2595 of the procedure to be carried out before the place can be stopped permanently.
- (ii) After the methane tests have been carried out the Section Manager will be notified by the Ventilation Superintendent on form Gen. 2594 in duplicate where wall/s or barricade/s have to be built and which methane register the place must be entered in. The original duly signed must be returned to the Ventilation Department and the copy filed at the shaft by the Mine Overseer concerned.

12. REGULATIONS REGARDING METHANE:

12.1. PROFICIENCY CERTIFICATE:

Every ganger or miner, and every other person who is required to test for inflammable gas, shall attend a special course in gas testing and shall not be considered as competent until he has obtained a Certificate of Proficiency from a person appointed by the Manager.

- (i) All holders of blasting certificates.
- (ii) All members of the Ventilation and Geology departments.
- (iii) Pumpmen.
- (iv) All Diamond Drilling and Cementation Personnel.
- (v) All Underground Engineers and Foremen.
- (vi) Underground Fitters, Electricians, Boiler-makers Riggers, Handymen, Truck Repairers and Winding Engine Drivers.
- (vii) Certain Non-Scheduled persons i.e. Pump Attendants, Diamond Drill Crews, Team Leaders, Gang Supervisors and aides.

12.1.2. CLEARANCE CERTIFICATES:

- (i) Members of Survey and Sampling Department.
- (ii) Onsetters and Skipmen.
- (iii) Shaft Personnel Officer and Departmental Personnel Officer.

12.1.3. ISSUE OF PROFICIENCY CERTIFICATES:

The abovementioned personnel and certain non-scheduled persons when engaged or on transfer shall, before starting work underground, attend a course of instruction in methane detection which shall include instructions regarding methane precautionary measures and use of the flame safety lamp in detecting methane.

12.1.4. RENEWAL OF METHANE CERTIFICATES:

The following procedure will apply to all holders of Methane Proficiency and Clearance Certificates, regarding the renewal thereof.

- i) A call up system is in operation. Head of Training will inform Heads of Departments at least one month prior to employees due date of attendance.
- ii) Employees will be retained in the Training Centre until the Methane Examination has been passed to the satisfaction of the Examiner.
- iii) Blacks will be required to undergo a refresher course every twelve months upon notification by the head of training to the Section Manager concerned.
- iv) It is the responsibility of Section Managers, Section Engineers, Mine Overseers, Diamond Drill Foreman and Heads of Departments to ensure that all their employees (including competent persons) mentioned in 12.1.1. are in possession of valid proficiency certificates.

12.2. PROHIBITED ARTICLES:

12.2.1. Contraband Reg. 15-9-1.

- i) No person shall take into the Mine or have in his possession in the mine, matches, lighters, pipes, cigarettes, cigars or smoking tobacco or any contrivance for striking a light or setting light to any material, and no person shall smoke in the workings of the mine.
- ii) The above prohibition shall not apply to the re-lighter within an approved flame safety lamp.

12.2.2. Reg. 15-8-4 and 15-8-5. Locking of Lamp.

No person shall take into the working of the mine or have in his possession in the workings of the mine any contrivance for opening the lock of a portable lamp and no person shall unlock or break the seal of a portable lamp in the workings of a mine.

12.2.3. Exemptions – Use of Flint Lighters:

- i) Persons authorised by the Section Manager may take pistol and squeeze-grip lighters, into the mine for the sole purpose of

- lighting welding torches and blowlamps
- (ii) Lighters shall at all times be in the physical possession of the person to whom it has been issued until it is returned.
 - (iii) All lighters must be clearly and permanently numbered.
 - (iv) A record shall be kept of persons to whom lighters can be issued and a copy of this record shall be posted up in the banksman's cabin.
 - (v) Mine Overseers are responsible to ensure that only persons holding a valid certificate issued by the Boilermaker Foreman are allowed to use Oxy- Acetylene equipment.
 - (vi) A person appointed by the Section Manager may issue lighters and keep a daily record of officials to whom lighters have been issued.

12.2.4. Exemptions -- Use of Welding Torches and Blowlamps:

Welding and cutting torches, blowlamps, handgas lamps and electric welding apparatus may be used underground only with the Prior approval of the Section Manager and subject to the following instructions being adhered to:--

- i) In a sinking shaft provided that the shaft is ventilated by means of the forcing system with a quantity of air not less than 7 m³/sec and that the master sinker, foreman shaft sinker, foreman fitter or foreman electrician has tested for inflammable gas with a flame safety lamp immediately before the equipment is lit and found the place to be free of any detectable traces of inflammable gas provided further that no drilling shall be done in the shaft while the equipment is being used.
- ii) In places, approved by the Manager which are adequately ventilated, but excluding such places to which water is directly piped from a fissure or plug and provided that the

scheduled person using such apparatus has tested for inflammable gas with a flame safety lamp immediately before the equipment is lit and found the place to be free of any detectable traces of inflammable gas and provided that no drilling is being done in the vicinity of where the equipment is being used.

In places other than through ventilation, permission in writing must be obtained from the section manager to use such apparatus. In addition, a Shift Boss must test for inflammable gas before using the apparatus. If there is any history of methane in such an End, a Ventilation Official accompanied by the Shift Boss must test for methane before the apparatus is used.

12.2.5. Authority to search:

Regulation 15-11-1 and 15-11-2.

- i) A Mine Overseer or an official of equal or higher rank shall have the right to search any person in the mine for prohibited articles in his possession, and no person shall hinder or obstruct such Mine Overseer in his search.
- ii) Banksmen must ask every person about to enter the cage on surface whether he has any prohibited articles in his possession. He shall have the right to search any person if he suspects that such person has prohibited articles in his possession.

12.3. OCCURRENCE OF METHANE:

12.3.1. Firing of explosive charges where inflammable gas is present -- Regulation 9-29.

- i) If inflammable gas is detected outside the source, no firing of explosive charges shall take place within a radius of 30 metres of the point of issue in a stope, and inside a development end beyond the last point of

through ventilation, or in adjacent working places that are within 30 metres of the point of issue of the inflammable gas. Other work may however continue. The firing of explosive charges shall not be prohibited where inflammable gas can only be detected with the probe held in drill holes, sockets, fissures, etc.

12.3.2. Working within 30 m. of Methane:

Regulation 8-5-1 and 8-5-2 (a and b)

No person shall be allowed to work in any part of the mine within 30 metres where there is known to be Methane except:-

- i) When the amount of methane is so small that a distinct cap does not form on the reduced flame of a safety lamp when the lamp is held 50 cm away in all directions from the point of issue.
- ii) When persons are working under the direct supervision of a competent scheduled person with the purpose of restoring the ventilation and or clearing away an accumulation of methane.

12.4. USE OF ELECTRICAL APPARATUS WHERE METHANE IS FOUND:

12.4.1. Regulation 8-6.

- i) If at any time, methane has been detected in a working place, such working place shall for the purpose of this regulation remain "Methane End or Stope".
- ii) If plus 2 per cent methane is detected when the lamp is held 50 cm. from the working face or source of methane, all electrical apparatus in that working place shall be switched off from a point which is free of methane.
- iii) The electricity to such a working place shall only be switched on after on official with minimum rank of SHIFT BOSS has tested for methane and certified the working place safe and clear of methane.
- iv) Above certification shall be recorded before

the end of the shift in Methane Register No. 3.

12.4.2. METHANE REGISTER No. 3:

This book which shall be kept at the shaft offices must be kept in terms of Regulation 8-6 and must contain the following information:-

- i) Name of working place.
- ii) Type of electrical apparatus in use.
- iii) Date when methane was firstly detected.
- iv) a) Date when methane was detected 50cm away from source.
- b) Percentage methane at source, 15 cm away and 50 cm. away.
- c) Signature of Shift Boss, Mine Overseer and Sectional Manager.
- v) a) Date methane was certified clear.
- b) Percentage methane at source, 15 cm away and 50 cm away.
- c) Signature of Shift Boss, Mine Overseer and Sectional Manager.
- vi) Instructions issued regarding electrical apparatus, dispersal of methane, date and signature of Sectional Manager.

12.5. USE OF ELECTRICAL EQUIPMENT UNDERGROUND:

No electrical apparatus may be used anywhere in the mine, unless of a type authorised by the Manager.

12.5.1. ILLUMINATION:

- i) In terms of Regulation 8-6 no electrical apparatus other than approved cap lamps may be used in a working place where methane is detected on the reduced flame of the safety lamp with the intake end of the probe held 50 cm. away from the point of issue in any direction.
- ii) In terms of Regulation 15-5-1- only approved locked or sealed lights or lamps must be used underground.

12.5.2. EXEMPTIONS - USE OF INCANDESCENT AND FLOURESCENT LIGHTS:

In terms of Mines and Works Regulation 15-5-1 permission is hereby granted for the use of unapproved, stationery, incandescent and fluorescent lights in the following places, provided such lights are not installed nearer than 15 cm. to the hanging wall of such places:-

- i) In any through-airway.
 - ii) In any sump, hoist-chamber, shaft station, conveyor belt station and pump-station, provided that such place is so ventilated as to prevent any accumulation developing of inflammable gas sufficient to show a cap on the reduced flame of a safety lamp.
- No pump-station to which water under pressure from a water bearing fissure or plug is being fed shall, however, be included in this permission.

- iii) No non-flame proof lighting equipment will be allowed in development ends or other working places that are not in through ventilation or in airways where the air velocity is less than 0,25 m/s.

12.5.3. SUB STATION, RECTIFIERS AND BATTERY CHARGES:

The abovementioned types of electrical equipment must as far as possible, be installed in through ventilation with an air velocity exceeding 0,30 m/s. Where this is not possible, the station housing the equipment must be ventilated by means of a fan and in accordance with an authorised layout from the ventilation department.

12.5.4. ELECTRIC FANS:

- i) Electric fans and switches must under no circumstances be installed anywhere in the mine unless an official layout showing where these have to be installed has been obtained from the Ventilation Department.

- ii) FAN SWITCHES AND DISTRIBUTION BOXES.

Switchgear and distribution boxes from which fans are operating, must be in through ventilation on the intake side of the end or

ends they serve. Switchgear must be equipped with an effective "NO VOLT" tripping device.

- iii) INTERCONNECTIONS OF ELECTRICAL MACHINERY WITH FANS:

All electrical machinery erected inside a development end must be electrically inter-connected to the ventilating fan which must be situated in through ventilation. The interconnection between the fan and such machinery, must be so arranged that should the fan stop, all machinery within the development end will immediately become inoperative and must further be arranged so that it cannot be used again until the fan has re-started.

- iv) METHANE RECORD CARDS AT FANS:

A methane record card must be kept at each fan that is not in through ventilation.

- v) FAN FAILURES:

Should a fan in a development end become inoperative a standard barricade is to be erected at the entrance of the development end served by that fan.

In the event of an approaching end being within 30 metres of this end, the waterblast in the unventilated end is to be extended to within 3 metres from the face and installed so that it can be controlled at the barricade. The waterblast must then be opened 30 minutes prior to entering the end for the necessary methane tests. During this period tests for methane must be made at the barricade. If the holing end is within 10 metres of holing, the waterblast is to be left open throughout the shift.

12.5.5. WINCHES:

- i) Winches may not be installed in winch chambers or cubbies.

- ii) INTERCONNECTION OF WINCHES

Winches in development ends beyond through ventilation must be inter-connected

with the fan in through ventilation, ventilating the end, and in such manner that, should this fan fail, the winch power will automatically be cut off at the winch isolation switch which shall be in through ventilation.

iii) METHANE RECORD CARDS AT WINCHES:

A methane record card must be kept at every winch and must be filled in daily by the ganger after he has tested for gas. The Shift Boss must countersign the record weekly.

12.5.6. BATTERY AND OVERHEAD TROLLEY LOCOMOTIVES:

(i) Battery locomotives may only be used in methane free areas. In addition to the tests as laid down in 5.1. tests to be carried out at the following times:

After the pilot holes have been drilled.

When water or dry fissure is intersected.

Before charging up.

After charging up.

If the presence of gas is suspected for any reason whatsoever.

If there is any change in the ventilation conditions.

(ii) Should it be found that air discharging from a development end into a haulage where electric or battery locomotives are in use, contains sufficient methane to show a cap on the reduced flame of a safety lamp, the operation of all such locomotives must immediately be stopped, until such time that the air has been tested and found to be clear of methane. Such tests to be carried out by an official of at least the rank of Shift Boss or by a member of the Ventilation Dept.

12.5.7. DIESEL LOCOMOTIVES:

(i) Diesel Locomotives may not be operated in haulages and/or development ends, where the air velocity is less than 0,25 m/s or where methane is detected in the face

or elsewhere. If the air velocity falls below 0,25 m/s in a development end, the locomotive must immediately be removed from the end to through ventilation.

ii) Diesel Locomotives must under no circumstances be left idling inside the end, but must be taken to through ventilation and left there until required.

iii) Smoke boxes to be checked regularly during shift.

iv) A Diesel Locomotive must under no circumstances be started inside a development end beyond the last point of through ventilation, unless tests made show that there is no methane gas present.

12.5.8. EXEMPTION FOR DAILY METHANE TESTS AT ELECTRICAL MACHINERY:

(a) Circumstances for Exemption.

Exemption from daily routine testing for methane in pump chambers, substations, etc., may be granted by the Manager under the following conditions:-

- i) If it is considered unlikely that methane will occur in such a place.
- ii) If the machinery in question is in fresh downcast air, or in a large, volume of methane free return air.
- iii) Provided the area is tested for methane at least once every three months by the Ventilation Department.

12.6 BLASTING UNDERGROUND:

12.6.1 Check and test before blasting.

In terms of Regulation 8-10-12 and exemptions applicable to this Regulation the following must be adhered to:

- i) No blasting may take place in any stope unless the ganger has tested for gas in the return air from his stope face, in all adjacent working within 30 metres of the charge to be fired and at the blasting point, and the results of these tests are negative.

Certificate of Proficiency. This certificate is only valid for a period of 1 year.

13.3. DUTIES OF COMPETENT PERSON (MINING).

On instruction from the certified ganger or miner in charge, the competent person shall take the necessary precautions with regard to methane in any working place in which blasting has not taken place since the last examination by the certified ganger or miner in charge, and which has not remained idle for more than 48 hours.

13.3.2. Tests for inflammable gas shall be carried out by the competent person in all adjacent workings, including advance strike gullies, and other working development ends, during the initial examination of the working place at the beginning of the shift.

13.3.3. In no circumstances shall competent persons enter or be caused, permitted or required to enter any stopped, abandoned, or discontinued end or any current working place in which methane is known to be issuing.

13.4. PROCEDURE ON DETECTING METHANE AT ANY POINT IN THE WORKINGS: THE COMPETENT PERSONS IN CHARGE SHALL:-

13.4.1. Withdraw all persons from the affected workings under their control.

13.4.2. Barricade off such working place, and place a guard to prevent inadvertent entry.

13.4.3. Report immediately to the Ganger or Shift Boss in charge.

13.5. DUTIES OF COMPETENT PERSON (PUMPS).

Where a European is not readily available to test for methane, at electrical machinery, when it is necessary to do so, the competent person may carry out the test.

13.6. RE-STARTING THE FANS:

Ventilation fans shall under no circumstances be restarted by or on the instruction from competent persons.

13.7. DUTIES OF SCHEDULED PERSON WHEN THE PRESENCE OF METHANE IS REPORTED:

ii) No blasting may take place in any development end unless the ganger has tested for gas at the development face and in all adjacent workings within 30 metres of the charge to be fired, and at the blasting point, and then only if the results of these tests are negative.

iii) No blasting may take place in any working place if the ventilation conditions do not conform with the mine standards.

12.6.2. BLASTING POINT:

A blasting point of each working place must be fixed by the Section Manager or Mine Overseer. It must be in through ventilation and provided with a notice board to mark the point.

BLASTING BY MEANS OF A SHOT-FIRING APPARATUS - REGULATION 9-30-3-1.

In terms of the above Regulation no charges shall be fired except by means of an approved electrical shot-fire apparatus.

12.6.3. EXEMPTION - USE OF IGNITER-CORD, SAFE TY FUSE AND CENTRALISED BLASTING:

Blasting with fuse and igniter cord is permitted and must be ignited electrically from the centralised blasting system if it has not been ignited by means of an approved shot-firing apparatus.

13. COMPETENT PERSONS:

13.1. TESTING FOR METHANE BY 'COMPETENT PERSONS:

13.1.1. DEFINITION:

Competent and experienced persons acting under instructions from a responsible certificated ganger or miner in charge who are called upon to examine and make safe and person in charge of work such as diamond drilling, erecting or salvaging equipment and work which is not the specific responsibility of a ganger or miner, shall be termed "Competent Persons".

CERTIFICATE OF PROFICIENCY:

13.2. All competent persons shall be holders of a valid

13.7.1. Ganger or Miner in Charge:

- i) When the occurrence of inflammable gas has been reported, having been detected in the workings under the charge of a competent person or diamond driller, the ganger or miner in charge shall examine such workings without delay and thereafter take the appropriate action in regard to any such inflammable gas found to be present. (See chapter 6).
- ii) Additional methane tests should be carried out as set in (chapter 5).

13.7.2. Duties of the Shift Boss regarding competent persons:

The Shift Boss shall supervise daily the testing for methane by at least one competent person. The results of each such inspection shall be logged in his logbook.

14. DIAMOND DRILLING AND CEMENTATION:

14.1. GENERAL PROCEDURE:

- 14.1.1. The European Supervisor and the Black Crew leader must be in possession of valid Methane Proficiency Certificates.
- 14.1.2. All black assistants in diamond drill teams must attend a course of general instructions regarding Methane precautionary measures.
- 14.1.3. Diamond drilling and cementation operations are only to be carried out under the direct supervision of the European or Black crew leader.
- 14.1.4. All Blacks in diamond drill teams are to receive instructions from the diamond drill Foreman regarding water intersections.
- 14.1.5. The supervision of two diamond drill teams by one European diamond driller is only to be done where the points are situated so that the driller can visit each team within 40 minutes without undue exertion. The diamond driller Foreman is to satisfy himself that this condition can be adhered to and shall instruct the driller as to the route to be taken.
- 14.1.6. The diamond drill Foreman must ensure that the Black Crew leaders at all times are aware of the

locality of the other crews operating under the same European Supervisor in order that they may contact the Supervisor in the event of an emergency.

- 14.1.7. Where it is decided that one diamond driller is to be in charge of two drilling crews, the Geological Department must be advised of this decision
- 14.1.8. Each diamond driller or cementation team is to be issued with a safety lamp.

- 14.1.9. The diamond driller is to see that this lamp is hung in a safe place in such a way, that it can be seen at all times and that the lamp is on the return air side of the hole being drilled or cementated. The lamp must be kept alight.

- 14.1.10. The diamond driller (or Black crew leader where there are two teams under the supervision of one driller) shall carry out methane tests at or above the collar of the hole at the following times:-

- i) Before he starts work at the commencement of a shift.
- ii) At all evenly numbered hours (8 o'clock, 10 o'clock, etc.).
- iii) As soon as he has intersected water.
- iv) If the presence of gas is suspected for any reason whatsoever.

14.2. PROCEDURE WHEN METHANE IS INTERSECTED:

- 14.2.1. If any of the tests are positive, the diamond driller (or the black crew leader, in the absence of the driller) must carry out the following procedure

- a) Stop all work, close valves on the casing pipe if possible.
 - b) Withdraw all personnel from the end.
 - c) Inform the ganger in charge of the end.
- N.B. If the ganger is not available or if the ganger has no persons working in the end, the diamond driller or Black crew leader must barricade the end and place a "NO ENTRY - METHANE" notice on the barricade. (If a ready made notice is not available he must use chalk).

- d) Place a guard to prevent unauthorised entry.
 - e) Inform the Shift Boss or next senior official available.
 - f) Stop any flame-proof diesel or electric locomotive which may be exposed to a high concentration of methane on the return side of the end.
 - g) Black crew leader to notify the diamond driller who will see that the above is carried out correctly.
- 14.3. Where two drilling crews are under the supervision of one European driller, each crew shall be visited by the driller at least once during each shift.

The following sections concerning Methane Proficiency Certificates are reproduced by courtesy of the Anglo-Transvaal Consolidated Investment Company Ltd.

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METHANE PROFICIENCY CERTIFICATE.

EXAMINATION SYLLABUS.

PART 1 ALL SECTIONS.

PART 11 ALL SECTIONS.

METHANE PROFICIENCY CERTIFICATE EXAMINATION.

SUGGESTED QUESTIONS FOR THE METHANE PROFICIENCY CERTIFICATE EXAMINATION.

P A R T 1.

ALL HOLDERS OF BLASTING CERTIFICATES.

PRACTICALA. THE LAMP

A number of lamps, with one of the following defects, will be provided:

<u>ITEM</u>	<u>DEFECT</u>
Lock	Unlocked
Glass	Cracked
Gaskets	One missing
Lighter mechanism	Inoperative
Wick and adjustment	Inoperative
Ports	Jammed open
Probe	Reversed

as well as one lamp in good working order.

The candidate must select the correct lamp by examination and indicate the defects of the other lamps.

B. THE USE OF THE LAMP

The candidate must carry out a methane test in a mock-up and demonstrating:

1. Lighting of lamp.
2. Adjusting the flame.
3. Setting of ports
4. Starting testing at carrying height and testing up to the hangingwall.
5. The correct position of the lamp relative to the eye.
6. The use of the probe.

C. RECOGNITION OF THE METHANE CAP.

The candidate will first be subjected to a colour perception test and then a practical recognition test as follows:

Three methane demonstrators will be provided showing, in random order, the following conditions:

1. No cap
2. Minimal cap $\pm$ 10 mm.
3. Maximal cap $\pm$ 30 mm.

The candidate will be required to describe what he sees.

/Part 11.....

P A R T 11.

WRITTEN AND ORAL.A. PROPERTIES OF METHANE.

Question: What are the properties of methane?

Answer: It is Colourless
 Odourless
 Tasteless
 Lighter than air
 Highly explosive
 Can cause oxygen deficiency

B. OCCURRENCE OF METHANE.

Question: How does methane get into the workings?

Answer: Methane is generally associated with water and enters the workings through faults, dykes, cavities, fissures which may be opened up by a blast, or fall of hanging or intersected by drill holes.

C. PREVENTION OF ACCUMULATIONS.

Question 1: What causes methane to accumulate?

Answer: A reduction or stoppages of ventilation, or an increase in methane.

Question 2: How are accumulations of methane prevented?

Answer: By adhering to ventilation standards.

D. PREVENTION OF IGNITION.

Question 1: Apart from SMOKING, what could cause a methane explosion underground?

Answer: Matches
 Ignitercord
 Burning fuses
 Blasting
 Welding and cutting apparatus
 Diesel and electrical machinery
 Defective safety lamps

Question 2: What methane precaution, if any, must be taken before using any of the previously listed equipment?

Answer: Test for Methane.

Question 3: What do you do in the event of a ventilation failure?

Answer: (a) - MINING PERSONNEL WITH BLASTING CERTIFICATES.
 1. Stop all work.
 2. Withdraw all persons to the waiting place in through ventilation.
 3. Close the barricade and place a guard.
 4. Trip the isolation switch to all electrical equipment not in through ventilation in the affected area.
 5. Notify the Shift Boss.
 6. Remove the locomotive to through ventilation.

/(b) - DIAMOND.....

(b) - DIAMOND DRILLERS AND CEMENTATION PERSONNEL.

1. Stop all work.
2. Withdraw all persons to the waiting places in through ventilation.
3. Notify the ganger and/or Shift Boss.

Question 4: If it is possible for you to restore your ventilation, what procedure would you adopt?

Answer: Here the candidate would have to describe his procedure at the same time demonstrating on the model;

FORCING SYSTEM:

1. Check that winch isolating switch (where applicable) is off.
2. Test at the fan switch and at the fan for methane. if no gas is present start the fan.
3. Test in the return air from the end continuously until all the air in the end has been replaced. allow one minute for every 15 m. that the end has been advanced from through ventilation.
4. If a methane cap forms at any time during this period, stop the fan at once and send for the Shift Boss or next senior official.

N.B.

DO NOT enter the end. Barricade the end, place a "No Entry" Methane notice on the barricade, post a guard to prevent unauthorised entry.

5. If no cap forms repeat the initial entry test.
6. If the end is clear of methane re-close the winch isolating switch (where applicable) and restart normal work.

OVERLAP SYSTEM WITH ELECTRIC FORCE FAN.

1. Check that winch isolating switch (where applicable) and force fan switch are off.
2. Test at the fan closest to the delivery end of the exhaust column and its switch for methane. If no gas is present restart the exhaust fan.
3. Wait 15 minutes.
4. Re-enter the development end, testing continuously as you go in.
5. If any other fans in the exhaust column are passed on the way in, test at the fan and at the switch. If no gas is present restart the fan.
6. When the intake of the exhaust column is reached, test at the intake.
7. If no gas is present, return it to the force fan isolating switch in intake ventilation and close the switch.
8. Re-enter the end and test at the force fan and the force fan switch (where applicable) in the end.
9. If no gas is present restart the force fan and wait 5 minutes.
10. Re-examine the end as for first entry, from the force fan to the face.
11. If no gas is found reclose the winch isolating switch in intake ventilation (where applicable) and recommence normal work.

/12.....

12. If at any stage during the above examination a methane cap is found do NOT continue with this procedure but carry out the procedure laid down for the case where methane is found in an end.

OVERLAP SYSTEM WITH COMPRESSED AIR FAN.

If it is discovered that the exhaust system has failed the compressed air fan should be left running and all personnel withdrawn.

Procedure for restarting is the same as for the overlap system with electric force fan in respect of the exhaust fan or fans i.e.

1. Check that the winch isolating switch (where applicable) is of
2. Test at the fan closest to the delivery end of the exhaust column and its switch for methane. If no gas is present restart this exhaust fan.
3. Wait 15 minutes.
4. Re-enter the development end, testing continuously as you go in.
5. If any other fans in the exhaust column are passed on the way in, test at the fan and at the switch. If no gas is present restart the fan.
6. When the intake of the exhaust column is reached, test at the intake.
7. Re-examine the end as for first entry.
8. If no gas is found reclose the winch isolating switch in intake ventilation (where applicable) and recommence normal work.
9. If at any stage during the above examination a methane cap is found do NOT continue with this procedure but carry out the procedure laid down for the case where methane is found in an end.

E. DEVELOPMENT EXAMINATION:

Question 1: Referring to the models (i.e. of a flat and an inclined end) ventilated by the FORCING SYSTEM describe a full methane examination indicating the positions.

Answer: 1: AT THE WAITING PLACE IN THROUGH VENTILATION

1. Recheck the flame safety lamp. The lamp must be burning and must be in order.
2. Leave all boys, except those directly necessary to assist with making safe and testing, at the waiting place.
3. Check the Ventilation System. If the fan or fans is/are running and in the right direction, prepare to enter the working place.
4. Ensure that no contraband is taken beyond the waiting place.

/2. AT THE.....

(5)

2. AT THE ENTRANCE TO THE WORKING PLACE.

1. Test in the return air from the end after it has mixed with through ventilation approximately 15 metres downstream (on the return side) of the entrance to the end - if no cap is found.
2. Test in the direct return air from the end approximately 6 metre inside the entrance of the end - if no cap forms continue into the working place.

3. INSIDE THE WORKING PLACE.

1. Test high places in the hanging on the way to the face, i.e. places where methane could have accumulated - if no cap is found.
2. Check at the winch and winch switch (where applicable).
3. Test at the face at any visible sockets and against the hanging - if no cap is found -
4. Allow the remaining blacks of the gangs to enter the working places after the initial entry tests have been completed.
5. Check that ventilation column is within standard distance from the face before allowing normal work to be started.

Question 2: Referring to the models (i.e. of a flat end and an inclined end) ventilated by the OVERLAP SYSTEM describe a full methane examination indicating the positions.

Answer: 1. AT THE WAITING PLACE IN THROUGH VENTILATION.

1. Recheck the flame safety lamp. The lamp must be burning and must be in order.
2. Leave all boys, except those directly necessary to assist with making safe and testing, at the waiting place
3. Check the Ventilation System. If the exhaust fan is running correctly and if the delivery end of the exhaust column is accessible, test the air leaving the exhaust column. If no cap forms, or if the exhaust delivery is inaccessible, proceed to the force column intake.
4. Ensure that no contraband is taken beyond the waiting place.

2. INSIDE THE WORKING PLACE.

1. Test at faults, dykes and fissures on the way to the face.
2. Check at the winch and winch switch (where applicable).
3. Check that the force fan is running and in the correct direction. If the force fan is running correctly, test in the overlap section, i.e. the section where two columns are in use. Special attention must be given to high places or domes in the hanging in this section. If no cap forms -
4. Test the exhaust intake i.e. approximately 2 metre on the face side of the exhaust column.
If no cap forms -

/5.....

(6)

5. Test any high places or domes in the hanging on the way to the face i.e. any places where methane could have accumulated. If no cap is found -
6. Test at the face at any visible sockets and against the hanging. If no cap is found -
7. Allow the remaining blacks of the gangs to enter the working places after the initial entry tests have been completed.
8. Check that ventilation columns are within standard distances from the face before allowing normal work to be started.

Question 3: When do you make this full examination for methane in a Development End?

- Answer:
1. At the beginning of every shift.
 2. When the working place has stood for more than 6 hours.
 3. On re-entry after a blast.
 4. On re-entry after a ventilation failure.
 5. On taking over from another ganger.

Question 4: What additional methane tests do you make during the shift?

- Answer:
1. After the pilot holes have been drilled.
 2. After the round has been completed.
 3. Before charging-up.
 4. After charging-up.
 5. Before blasting.
 - (i) At the face.
 - (ii) At the exploder.
 - (iii) At all accessible workings within a radius of 30 metre of a point where charge is to be fixed.
 6. When water and/or gas is intersected.
 7. After a fall of hanging.
 8. If methane is suspected for any reason whatever.

Question 5: If you have two or more ends in close proximity what would you do?

- Answer:
1. Examine all the ends before the blacks are brought in.
 2. Check that ventilation columns are within standard distances from the faces.

Question 6: If you have another end +150 metre away what procedure would you adopt?

- Answer:
- Treat the ends as separate ends, examine one end and start work, then examine the second end.

Question 7: If there is any electrical equipment (i.e. winch) in the end what do you do?

- Answer:
- Test at the winch and winch starter before the motor is started.

/Question 8.....

Question 8: What would you do if the fan is running in the wrong direction?

- Answer:
1. Do not enter the end.
 2. Send for the electrician and have the fault rectified.
 3. After fault has been rectified carry out the normal full methane examination as previously described.

F. STOPE EXAMINATION

Question 1: Referring to the model describe a full methane examination indicating the positions.

Answer: Test at the following places:

1. Intake air
2. All winch positions.
3. All advanced track cuttings.
4. All fissures, Faults and Dykes.
5. In any high places or domes in the hanging.
6. Any recent falls of hanging.
7. The top limits of stope faces.
8. All development ends off the stope face as for development ends.
9. In sweeping areas.
10. Return air.

Question 2: When do you make this full examination for methane in a Stope?

- Answer:
1. At the beginning of every shift.
 2. When the working place has stood for more than 6 hours.
 3. On re-entry after a ventilation failure.
 4. When taking over from another ganger.

Question 3: What additional tests do you make during the shift?

- Answer:
1. When water and gas is intersected.
 2. In the return air from such stope face before charging-up.
 3. In the intake air to such stope face before blasting, and at the blasting point.
 4. After a fall of hanging.
 5. If methane is suspected for any reason whatever.

FOR BOTH STOPE EXAMINATION AND DEVELOPMENT.
EXAMINATION.

Question 4: What do you do if the presence of methane is detected?

- Answer:
1. Stop all work.
 2. Withdraw all personnel to a safe place in through ventilation.

/3

3. Barricade each entrance to the working place.
4. Place a warning notice on the barricade.
5. Post a guard or guards to prevent unauthorised entry.
6. Stop any non-flameproof diesel or electric locos on the return side of the working place.
7. Warn persons on the return side of the working place.
8. Send for the Shift Boss or next senior official.

G. ENGINEERING PRACTICE.

1. ELECTRICAL.

Question 1: What safety precautions apply to lights and electrical apparatus where methane sufficient to form a cap on a safety lamp is present underground?

- Answer:
1. No lights other than approved electric cap lamps may be used.
 2. No electrical machinery may be used or installed.

Question 2: Where must electrical lighting switches be situated?

Answer: In through Ventilation.

Question 3: Who may authorise the restarting or installing of electrical machinery in an area where methane had previously been detected in sufficient quantity to show a cap on the lamp?

Answer: The Mine Overseer or Underground Manager or Manager.
N.B. Answers from the Mine Overseers upwards must include "and certified as safe in a book kept on surface in the mine office."

Question 4: What does an approved light mean ?

Answer: Approved in writing by the Government Mining Engineer.

Question 5: Where and under what condition may "ordinary" lights be used?

- Answer:
1. Non-flameproof station lights or "ordinary" lights are permitted in pump chambers, sumps, hoist chambers, conveyor belt stations and shaft stations, provided that the ventilation of such places will ensure that no inflammable gas, sufficient to show a cap on the reduced flame of the safety lamp, is present at any time thereat.
 2. Any pump station to which water under pressure from a waterbearing fissure or plug is being fed; is, however not included in this permission.
 3. In any through airway provided that lights and cables are kept at least 15 cm. clear of general hangingwall level in order to prevent them from being in a possible "methane roof layer" or hanging pockets and domes.

Question 6: What safety precautions must be taken when winches are installed in developments ends ventilated by the forcing system?

Answer:

1. The winch must be fed from an isolating switch in intake ventilation. The switch must be on the intake side of the development end. The switch must be

/interlocked.....

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interlocked with the fan ventilating the end in such a way that if the fan stops, the winch is automatically isolated.

2. If methane is at any time discovered in the end the winch power supply must be switched off at the isolating switch in intake ventilation.
3. The winch isolating switch in intake ventilation must not be used for other machinery and must be clearly labelled "Winch" and with the name of the end in which the winch is situated.
4. If methane in high concentration is likely to be intersected during the development of the end, the winch and its switchgear must be flameproof.

Question 7: What safety precautions must be taken when winches are installed in development ends ventilated by the overlap system?

- Answer:
1. The winch must be installed on the fresh air side of the exhaust column intake.
 2. The exhaust columns must extend at least 6 metre past the winch.
 3. The winch should be fed from an isolating switch in intake ventilation. The switch should be on the intake or fresh air side of the end. This switch should be interlocked with the exhaust fan ventilating the end in such a way that if the fan stops the winch is automatically isolated.
 4. If methane is, at any time, discovered in the end, the winch power supply must be switched off at the isolating switch in intake ventilation.
 5. The isolating switch in intake ventilation must not be used for any other machinery and must be clearly labelled "Winch". (name of end in which winch is situated.)
 6. The intake of the force column must not extend past the winch, i.e. the winch MUST NOT be in the overlap.

Question 8: What safety precautions must be taken when sub-stations, rectifier stations and battery charging stations are installed underground.

- Answer:
1. Electric sub-stations, rectifier stations and battery charging stations should be installed in through ventilation.
 2. If the normal air velocity through any of the stations listed above is considered to be insufficient, auxiliary ventilating appliances must be installed.
 3. Unapproved, incandescent or fluorescent lights may

/bc.....

be installed in the stations listed above.

2. ELECTRICAL AND DIESEL MACHINERY INCLUDING RE-STARTING.

Question 1: What precautions are required for the operation and especially the starting of diesel machinery underground?

- Answer:
1. Diesel locos must be left in through air at the end of each shift.
 2. If a loco has to be started and is not in intake ventilation, a test for methane must be made and no drilling operations should take place in the area whilst the loco is being started.
 3. Diesel locos must be removed if methane is present.

Question 2: What precautions must be observed when operating overhead trolley locos underground.

- Answer:
1. They may only be used in through airways, unless the manager has given permission for them to be used elsewhere.
 2. Before operating any overhead trolley loco in through airway which is not an intake airway, a test for methane must be made.
 3. Should any development end, discharging into such a through airway reveal, on test, a gas cap, the trolley loco shall be stopped and will only be allowed to operate again when the point of discharge is declared free of methane after a test made by a mining official of at least the rank of Mine Overseer.

Question 3: What precautions must be observed when operating battery locos underground?

- Answer:
1. Battery locos can only be used in:
 - (i) Through airways
 - (ii) Development ends provided the end is ventilated by the exhaust or overlap system and provided that the loco does not proceed beyond the intake of the exhaust column.
 - (iii) Dead ends provided that the ends are ventilated and free from methane.
 2. Tests for methane must be carried out in through airways which are not intake airways and in development ends or dead ends before the locos operate in such airways or working places.
 3. Should any development end, discharge into such a through airway, reveal, on test, a gas cap, the battery loco shall be stopped, and will only be allowed to operate again when the point of discharge is declared free of methane after a test made by a mining official of at least the rank of Mine Overseer.

/3. PUMPS.....

(11)

3. PUMPS.

- Question 1: Describe a full methane examination in a pump chamber which is not in intake through ventilation.
- Answer: 1. Check that the ventilation system, including the auxiliary air to the pump motors is operating.
2. Test above and around each motor
3. Test at the back of the pump chamber against the hanging.
- Question 2: When is this test made?
- Answer: At the beginning of the shift and after a ventilation failure.
- Question 3: What additional methane tests must be carried out?
- Answer: 1. Above and around each motor before stopping and starting.
2. At any other specific place indicated by the Foreman or Engineer.
- Question 4: Who is responsible for ensuring that the pump boy knows the correct testing point?
- Answer: The Engineering Foreman.
- Question 5: What is the pump boy's duty on detecting methane?
- Answer: 1. Notify his direct superior - Pumpman or Shaft Foreman.
2. Do not stop or start any electrical machinery.
- Question 6: What does the pump boy do in the event of a failure of ventilation?
- Answer: 1. Withdraw to through ventilation.
2. Notify his immediate superior - Pumpman or Shaft Foreman.
- Question 7: What does the pump boy do if his lamp breaks?
- Answer: 1. He removes the igniter key.
2. Extinguishes the lamp immediately if it is burning.
3. Does not stop or start any electrical machinery.
4. Notifies his direct superior immediately.
- Question 8: What action must the Pumpman and/or Foreman take if methane is reported to him?
- Answer: 1. Report to Shift Boss, Mine Overseer or Underground Manager. He must ensure that the pumps are switched off from a methane free point.
2. Check test for methane.
- Question 9: Can a black pump attendant declare an area free of methane?
- Answer: Yes - for himself for pump operation but not for any other work.
- Question 10: What provision must be made in those portions of sumps or dams to which persons have access?

/Answer:.....

(12)

Answer: They must be ventilated.

Question 11: Can water be piped directly from a fissure or plug to a sump or any other part of the mine workings?

Answer: Yes - only with the approval of the Inspector of Mines.

4. GENERAL.

Question 1: What do you do in the event of a ventilation failure or on detecting methane?

Answer: A. ELECTRICIANS, FITTERS, BOILERMAKERS, MECHANICAL FOREMEN AND ALL PERSONNEL NOT IN POSSESSION OF A BLASTING CERTIFICATE WHO USE CUTTING OR WELDING APPARATUS.

1. Stop all work.
2. Withdraw all persons to the waiting place in through ventilation.
3. Notify the nearest official.

A. ELECTRICAL FOREMEN AND SECTIONAL ENGINEERS.

1. Stop all work.
2. Withdraw all persons to the waiting place in through ventilation.
3. Notify the nearest official.
4. Trip the isolation switch to all electrical equipment not in through ventilation in the affected area from a point where no methane is present in the surrounding atmosphere.

II. DIAMOND DRILLING AND CEMENTATION.

Question: 1. Where must the Diamond Driller have his lamp?
2. In a safe place on the return air side of the hole he is working on. He must be able to see the lamp flame at all times.

Question 2: When must methane tests be carried out?

Answer: 1. Before he starts work at the commencement of his shift.
2. At all evenly numbered hours (8 o'clock, 10 o'clock etc)
3. As soon as he has intersected water.
4. If the presence of gas is suspected for any reason whatever.

Question 3: What action is taken if methane is detected?

Answer: 1. Stop all work, close valves on the casing pipe if possible.
2. Withdraw all personnel from the end.
3. Inform the ganger in charge of the end.

N.B. If the ganger is not available or if the ganger has no persons working in the end, the Diamond Driller must:

/Barricade.....

Barricade the end and place a "No Entry" - Methane" notice on the barricade. (If a ready-made notice is not available, he must use chalk.)

4. Place a guard to prevent unauthorised entry.
5. Inform the Shiftboss or next senior official available.
6. Stop any non-flameproof diesel or electric locomotives which may be exposed to a high concentration of methane on the return side of the end.

Question 4: What ventilation conditions apply to an end in which Diamond Drilling and Cementation is taking place?

Answer: They must be well ventilated. Ventilation of other ends must not be improved at the expense of an end stopped on water or for water cover (diamond drilling).

Question 5: What ventilation conditions are required during methane testing?

Answer: "Normal" conditions must apply. Fans ventilating the end must NOT be stopped.

1. WELDING, CUTTING AND BURNING.

Question 1: Where may Welding, Cutting or Burning torches be used underground?

- Answer:
1. In sinking shafts.
 2. In temporary pump chambers.
 3. At places approved by the Manager or Underground Manager.

Question 2: Under what conditions may they be used in Sinking Shafts?

Answer: They may be used in a sinking shaft, provided that the shaft is ventilated by fresh air, forced into the shaft bottom at a rate of not less than $7 \text{ m}^3/\text{s}$ and that the master sinker, shaft foreman, foreman fitter or Foreman Electrician has tested for gas with a flame safety lamp immediately before the welding torch is lit and provided, further, that no drilling shall be done while the welding torch is alight.

Question 3: Under what conditions may they be used in temporary pump chambers?

Answer: They may be used in a temporary pump chamber in any shaft, provided that the pump chamber is adequately ventilated by fresh air at a rate of not less than $1 \text{ m}^3/\text{s}$ and that an official of rank not less than that of Shift Boss has tested for inflammable gas with a flame safety lamp immediately before the welding torch is lit and provided further that no drilling shall be done in the pump chamber while the welding torch is alight.

/Question 4.....

(14)

Question 4: Under what conditions may they be used at approved places?

Answer: They may be used at places approved by the Manager or Underground Manager in intake and through airways, provided that the person in charge of welding and cutting operations has tested for inflammable gas with a flame safety lamp immediately before the apparatus is used.

Question 5: Under what conditions may they be used beyond through ventilation?

Answer: Only with the special permission of the Inspector of Mines.

Question 6: When do you make a methane examination for welding, cutting or burning?

- Answer:
1. Before welding, cutting or burning starts.
 2. If more than 60 minutes have elapsed after the initial test.
 3. If any drilling has been done.
 4. After a change in ventilation conditions.

Question 7: Who has to make the initial test for methane before torches are lit?

- Answer:
- A. In mines where smoking is permitted - the man himself.
 - B. In mines where smoking is not permitted - an official with the minimum rank of Shift Boss.

Question 8: How would you light your torch?

- Answer:
- A. In mines where smoking is permitted - with matches.
 - B. In mines where smoking is not permitted - with a flint lighter issued by the Underground Manager.

Question 9: What precautions must be observed during welding, cutting and burning?

- Answer:
1. The lamp must hang above the point where the apparatus is being used.
 2. No drilling may take place in the area where the apparatus is being used.

Question 10: Under what conditions must you stop welding, cutting or burning?

- Answer:
1. If there is a power failure or any other occurrence which interferes with the normal ventilation at the working point.
 2. If drilling starts in the area.
 3. If the safety lamp developes a cap, flares up or goes out.

/J. MINING.....

J. MINING AND VENTILATION PRACTICE.

1. CLEARING METHANE ACCUMULATIONS.

Question: (To the Shift Boss): What would you do if a methane filled end is reported to you?

- Answer: 1. Check that the initial methane precautions have been carried out.
2. Ensure that no persons can inadvertently come within 30m of the end.
3. Report to Mine Overseer. Re-check with miner the point where the methane has been detected.

Question (To Mine Overseer): What would you do if a methane filled end is reported to you?

- Answer: 1. Ensure that the Shift Boss has carried out his duties as listed.
2. Report to the Manager.

2. STOPPED ENDS.

Question 1: What ventilation conditions apply to temporary stopped ends?

Answer: The ventilation of the end must remain in full operation.

Question 2: What ventilation conditions apply to permanently stopped or abandoned ends?

- Answer: 1. The ventilation of the end must remain in full operation until stoppage is authorised by the Ventilation Officer.
2. The end must be
- (i) continuously ventilated if this is considered necessary by the Ventilation Officer, or
 - (ii) walled off by means of a brick or concrete wall if continuous ventilation is not considered necessary by the Ventilation Officer.

Question 3: How do you prevent inadvertent entry into these ends?

Answer: By erecting an effective barricade.

Question 4: What records are required in respect of these ends?

- Answer: 1. A list of permanently stopped or abandoned ends and details as required by I.O.M.
2. A list of temporarily stopped ends and details as required by I.O.M.
3. A list of all inspections of these ends and details as required by I.O.M.

/Question 5

(16)

- Question 5: How near to a known accumulation of methane may work take place?
 Answer: Not nearer than 100'.
- Question 6: What is a dead end?
 Answer: Any excavation which has been advanced more than twice its width.
- Question 7: Who does the initial re-entry test when a temporary stopped end is re-started?
 Answer: The Shift Boss accompanied by the ganger. The results of the Shift Boss' test shall be entered in his log book.
- Question 8: Who does the initial re-entry test when an abandoned end is re-started?
 Answer: A senior member of the Ventilation Department who shall be accompanied by a Mine Overseer or Shift Boss.
- Question 9: What notices are required on a barricade?
 Answer: In all cases a "No Entry" sign must be used and ONLY if methane is present must a "Methane" notice be added.
- Question 10: What is meant by an effective barricade?
 Answer: An effective barricade is one which is physically impossible for a man to pass and which requires the use of a tool or tools to gain entry.
- Question 11: How far must be discharge of the Ventilation column be from the face or beyond the barricade?
 Answer: The column must extend either 30 m. beyond the barricade or it must end within 2 m. of the face.

3. RESTRICTED AREAS.

- Question 1: What is meant by "Restricted Area"?
 Answer: "Restricted Areas" are areas defined in the mine by the Manager, in which methane gas in large quantities is likely to be encountered. A restricted area can be considered safe to work in if not more than ONE per cent. methane is present in the general atmosphere, blasting must cease until the concentration has been reduced.
- Question 2: What special precautions are required in Restricted Areas?
 Answer: 1. Only flameproof equipment may be used.
 2. Mine Overseers should have suitable instruments available for the accurate determination of methane concentrations in the general airstream.

/3.

3. Additional methane tests must be carried out:
 - (a) IN DEVELOPMENT ENDS
 - (i) In each pilot hole; and
 - (ii) 300 mm. above each pilot hole.
 - (b) IN STOPES.
 - (i) At faults.
 - (ii) In any domes in the hanging.
 - (iii) In pilot holes in stope development; and
 - (iv) One foot above pilot holes in stope development.
4. Shiftbosses must supervise these additional gas tests at least once a week.
5. Pilot holes must be drilled in all development ends, including stope development ends, even if the area is above the water table.
6. The ganger must examine the portable lamps of all members of his gangs and assure himself as far as practicable from external observation that the lamps are in safe working condition and securely locked and sealed before allowing them into his working places. He shall not allow any lamp which is found to be unsafe or not securely locked and sealed, to be taken into his working places.
7. All compressed air driven machinery must be earthed in the same way as electrical equipment is earthed to prevent static sparking. (Winches, fans, cementation pumps, venturies etc.)

Question 3: What are the dangers of using a compressed air hose to blow out methane?

- Answer:
1. Static electricity from a metal tip could form a spark..
 2. Compressed air comes out at high velocity and quartzite sparks could result.
 3. The person using the hose is too close to the methane accumulation.

Question 4: What are the causes of a Ventilation failure?

- Answer:
1. Stoppage of main or underground fans.
 2. Removal of Brattices and Doors.
 3. Broken ventilation columns.
 4. Inadequate distances of vent columns to the working faces.

METHANE PROFICIENCY CERTIFICATE EXAMINATION FOR ELECTRICIANS

METAANBEDREWENHEIDSERTIFIKAAT EKSAMEN VIR ELEKTRISIËNS

Naam/Name _____

Datum/Date _____

Skag/Shift _____

1. Name all the points on the safety lamp to be checked before taking it underground.

Noem al die dele van die lamp wat ondersoek moet word voordat dit ondergrond geneem word.

2. What are the properties of methane?

Wat is die eienskappe van metaan?

3. How does methane get into the workings?

Hoe gebeur dit dat metaan in die werksplekke voorkom?

4. What causes methane to accumulate?

Wat is die oorsake van metaan opgarings?

5. What could cause a methane explosion underground?

Wat kan 'n metaan ontploffing ondergronds veroorsaak?

6. What do you do in the event of a ventilation failure or on detecting methane?

Wat moet gedoen word ingeval van 'n belugtingsonderbreking of wanneer metaan gevind word?

7. How are accumulations of methane prevented?

Hoe word metaan opgarings voorkom?

8. Where must electrical lighting switches be situated?

Waar moet elektriese ligskakelaars geleë wees?

9. Who may authorise the restarting or installation of electrical machinery in an area where methane had previously been detected in sufficient quantity to show a cap on the flame?

Wie mag die installering of hergebruik van elektriese masjienerie magtig in 'n gebied waar voorheen genoegsaan metaan gevind was om 'n kappie op die lampvlam te vorm?

10. Where and under what conditions may ordinary lights be used?

Waar en onder watter omstandighede mag gewone ligte gebruik word?

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11. What precautions should be adopted where battery locos are used?
Watter voorsorgmaatreëls moet getref word wanneer battery-lokomotiewe
ondergronds gebruik word?

12. Where may welding, cutting or burning torches be used underground?
Waar mag sweis-, sny- en brandlampe ondergronds gebruik word?

13. Under what conditions may welding, cutting or burning torches be used
beyond through ventilation?
Onder watter omstandighede mag sweis, sny en brandlampe gebruik word
verby die laaste punt van deurvloeilug?

14. What must be done before the following is started?
Wat moet gedoen word voordat die volgende aangeskakel word?
(i) Fan/Waaier

(ii) Winch/Windas

15. What precautions must be observed during welding, cutting or burning?
Watter voorsorgmaatreëls moet getref word gedurende sweis, sny of brandwerk?

METHANE PROFICIENCY CERTIFICATE EXAMINATION FOR SHIFTBOSES

METAANBEDREWENHEIDCERTIFIKAAT EKSAMEN VIR SKOFBASE

Naam/Name _____
Datum/Date _____
Skag/Shift _____
Section/Seksie _____

1. What are the properties of methane?
Wat is die eienskappe van metaan?

2. How does methane get into the workings?
Hoe gebeur dit dat metaan in die werksplekke voorkom?

3. How are methane accumulations prevented?
Hoe word metaanopgarings voorkom?

4. Apart from smoking, what could cause a methane explosion?
Wat, behalwe as om te rook, kan 'n metaanontploffing veroorsaak?

5. What instruments do we use for the detecting of

(a) Methane? _____

(b) Deficiency of oxygen? _____

Watter instrument word gebruik vir die toets vir :

(a) Metaan? _____

(b) Tekort aan suurstof? _____

6. What defects on a flame safety lamp could prove dangerous?
Watter defekte aan 'n veiligheidslamp kan gevaarlik wees?

7. Name in sequence all points where tests must be carried out in a development end ventilated with a forcing system.
Noem in die regte volgorde, al die plekke waar in 'n ontsluitings ent getoets moet word vir metaan as die ent met 'n inblaas sisteem geventileer word.

8. When are full methane examinations carried out in a development end?
Wanneer moet 'n volledige toets vir metaan in 'n ontsluitings ent gedoen word?

9. Where do you make methane tests in a stope at the beginning of the shift?
Waar moet getoets word vir metaan in 'n afbouplek aan die begin van die skof?

10. When are full methane examinations carried out in a stope?
Wanneer moet 'n volledige toets vir metaan in 'n afbouplek gedoen word?

11. What do you do if the presence of methane is detected by the miner?
Wat doen u as die spanbaas metaan opspoor in sy werksplekke?

12. What do you do in the event of a ventilation failure?
Wat moet gedoen word in die geval van 'n belugtingsonderbreking?

13. Describe the procedure you would adopt if it is possible to restore your ventilation after a ventilation failure.
Beskryf die prosedure wat jy sal volg as dit vir jou moontlik is om die ventilasie vloei te herstel na normaal nadat 'n onderbreking plaasgevind het?

14. What procedure is adopted when an end is temporarily stopped?
Wat is die prosedure wat gevolg moet word as 'n ontsluitings ent tydelik gestaak word?

15. Watter ventilasie toestande is van toepassing op
What ventilation conditions apply to
(a) temporary stopped end? (a) tydelik getaakte ent?

- (b) abandoned end? Permanente gestaakte of
(b) verlate ent?

16. How do you prevent inadvertent entry into an abandoned end?
Hoe sal jy voorkom dat persone gestaakte ente onverhoeds binnegaan?

17. Who does the initial re-entry test when (a) a temporary stopped end
(b) an abandoned end is re-started?
Wie moet die aanvanklike heringangs toets uitvoer wanneer
(a) tydelike gestaakte ent (b) verlate ent heropen word?

(a) _____

(b) _____

18. What notices are required on a barricade?
Watter kennisgewing word benodig aan 'n skans?

19. Define (1) Effective barricade
(2) Dead end
(3) Back stope
(4) Temporary stopped end
(5) Abandoned end

Definieer:

- (1) Doeltreffende skans
(2) Dooiepunt ent
(3) "Back stope"
(4) Tydelike gestaakte ent
(5) Permanent gestaakte of verlate ent.

20. How near to a known accumulation of methane may work take place?
Hoe ver van 'n bekende opgaring van metaan mag werk verrig word?

21. What safety precautions must be taken when
(i) A fan is started?
(ii) A winch is started?
Watter veiligheidsmaatreëls moet getref word wanneer
(i) 'n waaier aangeskakel word
(ii) 'n windas aangeskakel word

22. What safety precautions must be taken when winches are installed in a development end ventilated by the forcing system?
Watter veiligheidsmaatreëls moet getref word wanneer windasse in ontsluitings ente geïnstalleer word wat met die inblaasstelsel belug word?

23. How often is a test for methane carried out in (i) a stopped end with a known methane history and (ii) abandoned end?
Hoe gereeld moet daar getoets word vir metaan in 'n gestaakte ent met (i) 'n bekende metaan geskiedenis (ii) verlate ent?
-
24. What procedure must be followed in the event of stoppage of the ventilation system in a stopped end with a known methane history?
Watter stappe moet gevolg word wanneer daar 'n belugtings onderbreking voorkom in 'n gestaakte ent met 'n metaan geskiedenis?
-
-
-
-
-
-
25. What is the procedure when a holing is going to take place into a stopped end?
Watter veiligheidsmaatreëls moet getref word wanneer 'n ontsluitings ent in 'n gestaakte ent gaan deur skiet?
-
-
-
-
-
-
26. Where may you use a cutting torch underground?
Waar mag sweis- sny- en brandlampe ondergronds gebruik word?
-
-
-
-
27. Under what conditions may you use a cutting torch underground?
Onder watter omstandighede mag jy sweis-, sny- en brandlampe ondergronds gebruik?

28. Under what conditions may you use a cutting torch in a "restricted area - methane"?
- Onder watter omstandighede mag jy sweis-, sny- en brandlampe gebruik in 'n "beperkte gebied - metaan"?
-
-
29. How would you light your torch?
- Waarmee behoort 'n sweislamp aangesteek te word?
-
-
30. Under what conditions must you stop welding, cutting or burning?
- Onder watter omstandighede moet sweis-, sny- en brandwerk gestaak word?
-
-
-
-
31. What is meant by "restricted area - methane?"
- Wat word bedoel met "Streke met beperkings - metaan?"
-
-
32. What safety precautions apply to lights and electrical apparatus where methane, sufficient to form a cap on a safety lamp, is present underground?
- Watter veiligheidsmaatreëls is van toepassing op elektriese toerusting waar daar ondergronds genoegsaam metaan is om 'n duidelike kappie op die vlam van die lamp te wys?
-
-
-
-
-

33. Who may authorise the restarting or installing of electrical machinery in an area where methane had previously been detected in sufficient quantity to show a cap on the lamp?
Wie kan die installering of hergebruik van elektriese masjienerie magtig in 'n gebied waar voorheen genoegsaam metaan gevind was om 'n kappie op die lampvlam te vorm?
-
-

34. What does an approved light mean?
Wat beteken 'n goedgekeurde lig?
-
-

METHANE TRAPS. INVERTED "U" TUBE, BACKSTOPES, UP - DIP SIDINGS

NAME OF WORKING PLACE: _____ SHAFT: _____ SECTION: _____

A potential methane trap exists in this working place at point _____
and a dangerous accumulation of methane gas can occur when there is a decrease in the
quantity of air flowing.

THE GANGER:

- (a) The ganger in charge of this working place will proceed to the highest point of the methane trap, and test for methane and airflow at this point before work commences in this working place. The result of the methane test is to be entered on the methane card kept at this point. This procedure is additional to any tests laid down in the Methane Code.
- (b) The ganger must test daily the air velocity by means of aluminium dust along the face of a west-siding or backstope. Work must not be allowed unless the velocity is at least 0,5 m/s.
- (c) The ganger must inspect the following ventilation appliances before commencing work in this working place: _____

THE SHIFT BOSS:

The shift boss shall test and inspect weekly the following:

- (a) At highest point of the methane trap for methane and airflow, and countersign the methane record card.
- (b) For airflow at the "U" tube or along the faces of the westsiding or backstope.
- (c) Inspect the ventilation appliances, e.g. fans, doors, curtains, etc. affecting this working place.

The results of these tests and inspections by the shift boss will be logged in his log book.

SKETCH:

GANGER(D/S) _____	SECT./ENVIRN. OFFICER _____
GANGER(N/S) _____	ENVIRN. SUPERINTENDENT _____
SHIFT BOSS(D/S) _____	SECTION MANAGER _____
SHIFT BOSS(N/S) _____	MINE OVERSEER _____

GEN. NO. 850

THE SECTION MANAGER
THE MINE OVERSEER SECTION _____
NO. _____ SHAFT

ENVIRONMENTAL CONTROL DEPARTMENT

DATE: _____

TEMPORARY/PERMANENT STOPPAGE OF DEVELOPMENT AND/STOPE

Working Place: _____

Before the above working places can be stopped permanently, the following tests have to be carried out.

1. Stop fan/fans on _____ and erect barricade not more than 2,5 m from through ventilation.
2. Mine Overseer and Environmental Officer to do methane test on _____ at the barricade and the whole length of working place.
3. If methane negative, keep fan/fans switched off for a further 7 days.
4. On _____ Mine Overseer and Environmental Officer to test for methane at barricade and whole length of working place.

ENVIRONMENTAL OFFICER: _____

SECTION ENVIRONMENTAL OFFICER: _____

ENVIRONMENTAL SUPERINTENDENT: _____

MINE OVERSEER: _____

SECTION MANAGER: _____

P. & P. NO. A.50.
GEN. NO. 2595
81-03-17

THE SECTION MANAGER
THE MINE OVERSEER SECTION _____
NO. _____ SHAFT

ENVIRONMENTAL CONTROL DEPT.

DATE: _____

TEMPORARY/PERMANENT STOPPAGE OF DEVELOPMENT AND/STOPE

Working Place: _____

- a) The above development end can be stopped permanently. No detectable methane after unventilated for seven days. Entry to be made in Methane Register No. 1.
- b) The above development end has a methane history and cannot be stopped permanently. Temporary stoppage as a methane stopped end is allowable. Entry to be made in Methane Register No. 2B.
- c) The above development end has no methane history and can be stopped temporarily. Entry to be made in Methane Register No. 2A.
- d) The above development end has a methane history and can be stopped temporarily as a methane stopped end. Entry to be made in Methane Register No. 2B.
- e) The above stope can be stopped permanently.
- f) The above stope can be stopped temporary.
- g) Wall off not more than 2,3 m from through ventilation at _____.
- h) Wall completed on _____.
- i) Barricade completed on _____.
- j) _____

ENVIRONMENTAL OFFICER: _____
SECTION ENVIRONMENTAL OFFICER: _____
ENVIRONMENTAL SUPERINTENDENT: _____
SHIFT BOSS: _____
MINE OVERSEER: _____
SECTION MANAGER: _____

P. & P. NO. A.50.
GEN. NO. 2594
81-03-17

CCN. NO. 313 - 80-01-08

TO: THE SECTION MANAGER, NO. 1 SHAFT
FROM: ENVIRONMENTAL CONTROL DEPARTMENT

SECTION:

QUARTERLY ABANDONED END/METHANE TRAP REPORT FOR QUARTER ENDING:

[illegible]

ENVIRONMENTAL OFFICER:

ENVIRONMENTAL SUPERINTENDENT:

SECTION ENVIRONMENTAL OFFICER:

MINE OVERSEER:

SECTION MANAGER:

METHANE PROFICIENCY CERTIFICATE EXAMINATION FOR
DIAMOND DRILLING PERSONNEL

METAANBEDREWENHEIDSERTIFIKAAT EKSAMEN VIR DIAMANTBOORMANNE

Name/Naam : _____
Date/Datum : _____
Shift/Skag : _____

1. Wat is die eienskappe van metaan?
What are the properties of methane?

2. Hoe gebeur dit dat metaan in die werksplekke voorkom?
How does methane get into the workings?

3. Name all the points to be checked on the safety lamp before taking it underground.
Noem al die dele van die lamp wat ondersoek moet word voordat dit ondergrond geneem word

4. What causes methane to accumulate?
Wat is die oorsake van metaanopgarings?

5. How are methane accumulations prevented?
Hoe word metaanopgarings voorkom?

6. What do you do in the event of a ventilation failure?
Wat moet gedoen word ingeval van 'n belugtingsonderbreking?

7. Apart from smoking, what could cause a methane explosion?
Afgesien van om te rook wat anders kan 'n metaanontploffing veroorsaak?

8. What action is taken if methane is detected?
Watter optrede is nodig wanneer metaan gevind word?

9. Watter ventilasietoestande is van toepassing in 'n ent waarin diamantboorwerk
en sementering plaasvind?
What ventilation conditions apply to an end in which diamond drilling and
cementation is taking place?

10. Where must the diamond driller leave his lamp after completing the tests
for methane?
Waar moet die diamantboorman sy lamp laat as hy die toets vir metaan voltooi
het?

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**METHANE PROFICIENCY CERTIFICATE EXAMINATION FOR
PERSONS WHO USE WELDING, CUTTING OR BURNING TORCHES**

**METAANBEDREVENHEIDSERTIFIKAAT EKSAMEN VIR PERSONE
WAT SWEIS-, SNY- OF BRANDWERK VERRIG.**

Name/Naam _____

Date/Datum _____

Shaft/Skag _____

Occupation/Beroep _____

1. Name the items on the safety lamp to be checked before taking it underground.
Noem al die dele van die lamp wat ondersoek moet word voordat dit ondergronds geneem word.

2. What are the properties of methane?
Wat is die eienskappe van metaan?

3. How does methane get into the workings?
Hoe gebeur dit dat metaan in die werksplekke voorkom?

4. What causes methane to accumulate?
Wat is die oorsake van metaanopgarings?

5. What could cause a methane explosion underground?
Wat kan 'n metaanontploffing ondergronds veroorsaak?

6. What do you do in the event of a ventilation failure or on detecting methane?
Wat moet gedoen word ingeval van 'n belugtingsonderbreking of wanneer metaan gevind is?

7. Where may welding, cutting or burning torches be used underground?
Waar mag sweis-, sny- of brandlampe ondergronds gebruik word?

8. Under what conditions may welding, cutting or burning torches be used underground? *Sigant genoeg ventileren?*
Onder watter omstandighede mag sweis-, sny- of brandlampe gebruik word verby die laaste punt van deurvloeilug?

9. What precautions must be observed during welding, cutting or burning?
Watter voorsorgmaatreëls moet getref word gedurende sweis-, sny- of brandwerk?

10. Under what conditions must you stop welding, butting or burning?
Onder watter omstandighede moet sweis-, sny- of brandwerk gestaak word?

APPENDIX IX
ROMANIAN REGULATIONS

INSTRUCTIONS

concerning method of placement of sensor units
of monitoring installations

- Art. 1 The given instructions are to be applied to mines equipped with continuous monitoring installations.
- Art. 2 Locations for methane detection units will be reviewed monthly, and at any time that changes in the initial situation occur. These decisions are to be made by the section foreman and the head of the ventilation department jointly. Work places will be registered and marked on the mine's ventilation scheme chart, which will be posted in the monitoring control center.
- Art. 3 In choosing the work areas that require detectors, the following situations should be taken into consideration:
- (i) Mine works in a dead-end in which the concentration of methane anywhere exceeds 1%; those in which blowers have been produced; those which traverse coal strata having a known potential for the emission of gases; those in which leaks of liquid hydrocarbons have appeared; shafts in use with intense emissions of methane, etc.
- (ii) Multiple entry workings in thick coal seams.
- (iii) Fresh air currents in which there exists the possibility of the permissible level of methane being exceeded (due to emanations from the formation, polluted air forced out from works in closed headings, etc).

(iv) Main return air currents from any sector or area in which the concentration of methane exceeds 0.8%.

(v) Return air currents from any long wall face, with concentrations of methane greater than 1% taking priority.

(vi) Workings with a known high level of danger as regards methane, in which activity is carried on according to a pre-determined work program.

(vii) Workings with high methane emissions near trolley lines.

Art. 4 All areas belonging to the category covered in Art. 3 will be listed and recorded by the head of the sector together with the head of ventilation. Workings to be equipped with detectors will be included in Table 1.

Art. 5 The methane detectors will be suspended from the roof or hanging wall at the highest points possible.

Art. 6 In workings entered in Table 1, the sensors will be placed:

(a) In closed headings; in those that traverse strata with a known danger of hydrocarbon and gas emissions; and in workings in thick seams. In the case of negative-pressure ventilation, sensors will be placed at the face between the last two supporting frameworks, in the part opposite the opening of the air intake. In the case of forcing or exhausting ventilation, 5 m behind the mouth of the ventilation column; and in the case of workings

with inclines of 2-3 sections, in the zero* angle of the raise or incline.

In the case of combined ventilation, sensors will be placed at 5 m behind the mouth of the expulsion column; in the case of shafts being sunk, directly below the first platform at the working level of the blind shaft.

(b) In currents of clean air at points where the concentration of methane is 0.4% or more, and with priority given to those points near trolley lines.

(c) In currents of return air from working faces, in the top (upper) gallery at a point at least 5 m from the point of intersection with the working.

(d) In the main return at 25 m (max.) from the junction with the last evacuation circuit (secondary return?).

(e) In workings in which local degassing is applied, at 1 m from the point at which the gases are exhausting from the dilution chamber.

(f) In workings with a high degree of danger in which activity is carried on according to a work program, at the points specified in the program.

Art. 7 The methane sensor alarm thresholds will be set at the maximum concentrations permissible for the conditions and technology used at the work place.

* "zero" angle may mean a shallow roof angle wherein methane could layer.

Art. 8 Among the areas described in Table 1, the following will be equipped with sensors to automatically register levels of methane in the following order of preference:

- (a) working faces with high concentrations of methane
- (b) main ventilation return airways
- (c) roads and haulage ways
- (d) workings with local degassing equipment.
- (e) workings with a high danger level in which activity proceeds on the basis of a work program (with leaks of liquid hydrocarbons, leaks of carbons and gases, intense methane emissions, etc.)

Art. 9 In places for which manual readings have been prescribed, a competent person will check the methane level at least twice per shift, and the results will be entered in the appropriate register.

Art. 10 For blasting operations the sensors exposed to possible damage will be withdrawn and properly protected by the shot-firer. Immediately after blasting, the sensors will be returned to their previous locations.

Art. 11 To assure efficient monitoring, those persons in charge of measuring gas levels, and the mining foreman, will observe the following guidelines:

- (a) In addition to monitoring the atmosphere at the workplace, it is mandatory to measure the methane with a methanometer at the level of the sensors, noting the results in the personal notebook and in the methane register. If there is a difference of greater than 0.2% methane between the indications shown by the sensors and those shown on the methanometers, the head of ventila-

tion and degassing will take steps to verify and remedy the situation.

(b) The siting of the sensors will be verified, and any deficiencies running counter to these instructions will be remedied.

Art. 12 The verification and adjustment of the sensors will be performed by an electrician in compliance with the instructions in the technical manual.

Art. 13 The section foremen and the head of ventilation and degassing will insure that the technicians, gas measurers, and shot-firers are versed in the given instructions.

Art. 14 Protocol The head of the unit will assure the organizing of study sessions for the present instructions with all staff assigned to workings equipped with methane detectors.

Protocol The present instructions can be modified and supplemented by CCP in collaboration with CCSM, obtaining the agreement of the agency that drew up and approved them.

TABLE I: Placement of Methane Detectors*

Number of detectors and ventilation scheme	List of workings requiring detectors (type of working, strata of coal, barren rock, horizontal, sector, etc.)	Monitored methane content (% vol.)	Manual monitoring yes/no	Registration yes/no	Alarm yes/no	Disconnection of electricity yes/no	Instructions for the dispatcher in case of methane excess (telephone, disengagement, evacuation of personnel, reporting to sector head, direction [line] along which power was disconnected, etc.)
1	2	3	4	5	6	7	8

* Table 1 appears to be a required format.

INSTRUCTIONS

Concerning security measures in mine workings
executed in [sterile] in mines in the Jiu Valley and in
[sterile] rocks with manifestations of
liquid and gaseous hydrocarbons

Art. 1 The given instructions refer to mine workings carried out in sterile*, and the safety measures differ depending on the degree of danger presented by the manifestations of liquid and gaseous hydrocarbons (methane, crude oil, etc.)

Art. 2 Mine workings that are carried out in sterile rock, depending on the degree of danger from manifestations of liquid and gaseous hydrocarbons, are classified in the following categories:

1. CATEGORY A: includes workings in sterile without methane emissions, or with normal** emissions of methane in which the provisions of NDPMAN and the following instructions can be applied.

2. CATEGORY B: includes workings in sterile with dangerous manifestations of liquid and gaseous hydrocarbons, where special measures need to be taken. The following types of workings fall into this category:

- a) workings in which intense blowers of gas appear, in which the methane output is greater than $1 \text{ m}^3/\text{min}$;
- b) workings in which leaks of liquid hydrocarbons have appeared, with or without methane emissions;

* "sterile" probably means barren rock, outside the seam.

** "normal" may mean low-level, low-volume, methane emissions, free from sudden outbursts.

- c) workings near coal strata known to have a danger of violent blowouts of gas and particulate matter;
- d) workings in which an increase in methane emissions has been detected along with the characteristic warning signs (changes in the stratification and structure of the rocks, and changes which are determined by the evident increase in the speed of boring; cracks in the mass, and slides of debris from holes; larger than normal quantities of broken material after blasting; swelling of the floor).

Art. 3 For workings near coal strata with a known danger of gas emissions, the special safety measures listed herein will be taken, beginning 10 m from the coal seam(s).

CATEGORY A. MINE WORKS IN STERILE WITH
NO EMISSIONS OR WITH NORMAL METHANE EMISSIONS

Art. 4 In mining works in sterile without gas emissions, or with normal emissions of methane, in accordance with the provisions of NDPMAM* blasting operations will be executed using the following explosive materials.

a) Ordinary explosives (dynamite), and electric detonators with a long delay (0.5 seconds), with copper tubing, in situations in which:

(i) at the working face the presence of methane above the permissible limits has not been found (below 1% in the general body of air or above a probe hole; up to and including 2% in pockets, for 4 consecutive days with the ventilation off for 15 minutes at a time);

* La "Normele Departmentale de Protectie a Muncii in Activitatea Miniera".

- (ii) the working face is located at a distance greater than 10 m from a known fault or from an old working;
- (iii) probe holes in the working face have not revealed the presence of coal or coal shale.

b) Permissible explosives, using instant electric detonators sheathed in copper tubing, with a maximum delay of 75 ms between two neighboring charges capable of interacting, and a maximum 400 ms delay between the first and the last charge to be detonated, in situations in which:

- (i) methane has appeared at the face, and in activating the ventilation the concentration of the methane has been reduced below the admissible limits (below 1% in the general body of air or above a probe hole; up to and including 2% in pockets);
- (ii) the working face is located less than 10 m from a known fault or from an old working;
- (iii) probe holes in the working face have revealed the presence of coal or of coal shale.

Where millisecond detonators are applied, the following measures will be observed:

- (i) the holes shall be at a distance of at least 0.5 m from each other;
- (ii) obligatory reverse detonating (the primed end of the cartridge shall be at hole bottom, the bottom of the cap pointing out towards the mouth of the hole);
- (iii) forbidding of the use of [degree? step?] zero*.

* *This is the literal translation, and may be a reference to simultaneous detonation of a number of charges.*

c) The method of blasting under the protection of a [cloud?] of bicarbonate of soda in horizontal workings, wherein by all the usual means a reduction in the concentration of methane to below 1% has not been achieved, may be applied for concentrations of methane up to 2% (in the general body of air and in pockets) on the condition that the safety measures appropriate for this process are carefully followed.

- Art. 5 Along with the provisions of NDPMAM regarding the execution of blasting procedures, all regulations concerning safety measures that refer to work procedures in sterile will be observed.

CATEGORY B: MINE WORKINGS IN STERILE WITH INTENSE
MANIFESTATIONS OF LIQUID AND GASEOUS HYDROCARBONS REQUIRING
SPECIAL SAFETY MEASURES

- Art. 6 All mine workings in sterile in which the phenomena specific to Category B, Art. 2, are found will be declared mine workings requiring special safety measures, and will be marked with a warning sign:
"WORKING REQUIRING SPECIAL SAFETY MEASURES"!
- Art. 7 If the elements specific to Cat. B, Art. 2 are present, the head of the working party will stop the activity at the face, will evacuate the personnel, and will inform the sector foreman.

1. Exploration of the rock mass

- Art. 8 Exploration of the rock mass ahead of the working face will be carried on by maintaining 3 pilot holes, having a length of 5 m, oriented in the direction of the

gallery. One of these holes will be placed on the hanging wall (or the roof) and one other on the floor, as close as possible to the rib, but not more than 1 m from it.

If, during routine advance of a working, and during normal conditions of ventilation, accumulations of methane above the prescribed limits are produced, degassing boreholes will be drilled and maintained. Depending on the intensity of the methane emissions, these can be connected to the mine's local and central gas drainage system.

Accumulations of liquid hydrocarbons must be removed and deposited in safe areas.

2. Monitoring of gases and of ventilation of the working

Art. 9 Monitoring of the methane in workings designated as requiring special measures of safety will be performed with adequate apparatus (methane sensors with continuous read-outs and optical and acoustic alarms, local installations with automatic controls, monitoring centers, etc.).

If monitoring centers are used, the continuous registration of the results of the methane monitoring will be assured.

Art. 10 In workings with only manual methanometry, a competent person will monitor the methane every hour, entering the results into the monitoring center's register. Periodically, at predetermined intervals, gas samples will be collected for analysis.

Art. 11 Deleted

Art. 12 Partial ventilation of the working will be achieved by means of an air intake system or a combined system, with pneumatic axial ventilators, or with electropneumatic ventilators, with the assurance of commutation from the electric ventilator to the pneumatic one when the concentration of methane at the face reaches 2%. The electric ventilators can be used only if they are mounted in the current of fresh air and only if a forced-air system is being used. In this case the sensor unit of the monitoring system will be placed 10 m from the entrance of the working*.

3. Blasting procedures

Art. 13 In these workings all blasting processes are excluded which utilize ordinary explosives (dynamite) and detonators with long delays (0.5 sec).

On faces where liquid hydrocarbons have appeared in the form of leaks the following measures will be taken.

(i) Only permissible explosives will be used, with instant detonators with copper tubing, or millisecond, anti-firedamp caps, with a maximum delay of 75 milliseconds between two neighboring charges capable of interacting, and a maximum delay of 400 ms between the first and last charge being detonated at the face.

* This is the literal translation; they may be simply ducts, but "pneumatic axial ventilators" are probably axial fans driven by air motors; "commutation" probably means being part of the same air circuit; "electric ventilators" are probably auxiliary fans with electric motors.

- (ii) The holes will be drilled at least 0.5 m apart.
- (iii) Holes in which crude oil leaks have been found can be charged with explosives only if the cartridges are inserted into polyethylene tubes.
- (iv) Reverse detonating (indirect priming) mandatory.
- (v) The use of (degree? step?) zero forbidden.

4. Use of electrical equipment

Art. 14 In mine workings in sterile requiring special safety measures, the following types of protection for the electrical installations will be used.

a) Intrinsic safety for installations controlling the mine atmosphere, telecommunications, and signalling independent of the other electrical installations.

b) Anti-combustible capsuling for: automatic methane monitoring installations, with provision for the automatic disconnection of the electrical energy when the methane concentration reaches 2% by volume; the automatic controls, and for all electrical insulation on automatic circuits, which shall be designed to prevent leaks of liquid hydrocarbons into any of the apparatus.

c) Special protection for the portable electric lamps with individual energy sources; these are to be certified daily before using them underground, with special consideration given to the state of charge in the energy source, and the condition of all terminals; entry into these workings with flame (oil) lamps is forbidden.

Art. 15 The electrical network in this type of working will be provided with a device for automatic disconnection when the concentration of methane reaches 2%.

Art. 16 Diesel locomotives are permitted with [firedamp safety], with anticomcombustible capsuling, and with special protection.

Electric locomotives with accumulators are permitted with special firedamp protection for the batteries of the accumulator, and anti-combustion capsuling for the rest of the electrical equipment of the locomotive. During blasting, electric locomotives will be out of operation (de-energized and parked); diesel locomotives may remain in operation under certain conditions*. Locomotive operators will have continually functioning and signalling methane meters placed in the cabin of the locomotive.

Art. 17 In mine workings in sterile rock, cutting with a combine (shearer, mining machine) will be permitted only if there is no danger of sparking.

Art. 18 Work places will be supplied permanently with a source of water and a means of putting out fires.

5. Final provisions

Art. 19 The personnel responsible for the drilling of probe holes will be specially instructed regarding danger signs that can appear at the work face (change in quantity, or gushing of detritus from the hole, acceleration in the speed of boring, leaks of gas under

* these could not be identified for this translation

pressure and an increase in the concentration of methane above the permitted level, leaks of liquid hydrocarbons).

Art. 20 Mine workings in sterile in which special measures of safety are applied (Cat. B), will no longer be classified in this category after all manifestations of gaseous and liquid hydrocarbons have disappeared.

Art. 21 The phenomena of dangerous manifestations of gaseous and liquid hydrocarbons will be registered together with the characteristic data (location, specific effects, technology applied, intensity of the phenomenon, mode of manifestation, etc.).

ADDITIONAL REQUIREMENTS FOR GASSY MINES

A. GASSY MINES IN CATEGORIES I-IV

Table 2.

Specification	Category of Mine Depending on Type of Emission					
	0	I	II	III	IV	V
Quantity of CH ₄ produced in 24 hrs. (methane produced in cubic meters per metric ton).	Accidental emissions of methane. Only mines of solid mineral substances, other than carbon and salt (metal mines).	0-5	6-10	11-15	Over 15 in mines with blowers.	Mines with eruptions of methane and particulate matter (violent outbursts).

Art. 169 #1 Mines in which the presence of methane has been detected are classified depending on the type of emission and according to the relative output, as shown in Table 2.

In classifying new mines the conditions (ref. gases) in adjacent mines should be taken into consideration.

- #2 In mines belonging to Category "0", only work areas where methane has been found, and all work places at dead-ends of new horizontals (development levels) dug in geological formations similar to those which have had methane emissions will be considered "gassy".

In these work areas the stipulations regarding the control of methane, illumination, and partial ventilation will be the same as those observed for gassy mines in Category I.

Art. 170 #1 In gassy mines the use of open flames and of any smoking paraphenalia is forbidden. To this end there will be daily checks of all persons entering the mines.

- #2 Underground repair and construction work requiring the use of an open flame (welding, soldering, etc.) will be executed in accordance with the stipulations in Art. 150*, and the attached instructions, with the advice of the head of the ventilation department, and with the approval of the chief technician, and only if no accumulations or depos-

* Art. 150 #1. To perform autogenous welding underground, pressurized oxygen and acetylene will be used. #2. Welding, vulcanizing, soldering and moulding of insulating masses can be done only after measures have been taken to prevent fire.

its of explosive methane or coal dust above the limits set in Art. 172 are found within 50 m of the work area concerned.

In gassy mines belonging to categories III-IV, this work will be carried out in the presence of a representative from the ventilation department.

Art. 171 #1 Monitoring of methane will be done with methane detectors (methanometers) or flame safety lamps.

Every work place must have at least one methane detector or a flame safety lamp.

#2 In gassy mines the monitoring and checking of methane concentrations will be done;

(i) by the supervisor, upon entering the work area, and during the change in shifts;

(ii) by the head foreman and the technical staff [technician] whenever the work area is inspected;

(iii) by checking gas levels in Categories III-IV, at least twice per shift in each work area.

It is permissible to perform a single inspection per shift in work areas where continuously monitoring detection terminals, connected to a gas-metering station, are located. These will be metered (calibrated) at the beginning of each month, and whenever changes occur that could influence the conditions under which the methane is

escaping; by order of the section head, on the advice of the ventilation department, and with the approval of the chief engineer of the mine. Excepted from this rule are work areas in zones where thick layers of coal have been cut, works of opening and preparation (development works) which traverse coal strata in areas declared to be in danger of leaks of carbons and gases, as well as all sectors and inclined planes in coal actually in the process of being excavated (lor ascendente). In all such areas there will be two methane checks per shift, irrespective of the presence of detector terminals.

- #3 The results of the monitoring of the methane will be recorded in a table [chart] at each work place, and in a register maintained specially for the purpose.
- #4 In gassy mines, flame safety lamps can be used to monitor gases only by the technical staff, gas meter readers, shot-firers, and the supervisor of the work team.

BLASTING OPERATIONS

Art. 172 #1 In mines with firedamp and coal dust, blasting can be executed only if the concentration of methane is as follows:

- a) under 1% methane, measured with a methanometer, in the general body of air;

b) up to and including 2% methane, also measured with a methanometer, in pockets.

In the absence of a methane detector (methanometer) blasting can take place only if, upon checking with a flame safety lamp, the presence of methane is not indicated.

- #2 Methane monitoring will be done at the blasting site, and 20 m from the site.

It will be performed by the shot-firer before loading the blast holes, after loading them, and upon returning to the site after the blast. If two adjacent blasting sites have less than 10 m between them, the adjacent site must nevertheless also be checked for methane.

Art. 173 #1 In blasting in mines with firedamp and coal dust, only primers (caps) with copper tubing must be used. A Bickford wick can be used only in mines [with firedamp] belonging to Category I, and only under the conditions described in Article 175.

- #2 The maximum admissible charge of powder in blasting with safety devices for firedamp and coal dust is determined at the time of approval of the use of the explosive concerned.

- #3 The initiation of the primer will be done only with blasting devices (caps) which have an impulse duration (delay) of a maximum of 4 ms..

Art. 174 #1 At works in sterile, the following will be used:

a) ordinary explosives, and ignition with electric detonating primers (caps) with a long delay, in work areas where;

(i) test bores did not reveal the presence of coal or of coal shale;

(ii) the work face is located at a distance greater than 10 m from a known fault or from an old mine;

(iii) the presence of methane over the limits set in Article 172 was not determined at the work face for 4 consecutive days after shutting down the ventilation for 15 minutes.

b) Anti-firedamp (permissible) explosives, and ignition with millisecond delay electric detonating primers (caps) in work areas in which:

(i) the conditions listed in (a) are not present;

(ii) methane was discovered, and with the activation of the ventilation, the concentrations of methane were reduced below the limits described in Article 172.

#2 At workings in mixed (sterile and coal), only explosives with anti-firedamp safety will be used. With simultaneous blasting of the sterile and coal, and also with independent (separate) blasting of coal or sterile, electric detonating primers with a long delay can be used only when the presence of

methane above the limits outlined in Article 172 has not been discovered, for 4 consecutive days with the ventilation stopped for 15 minutes.

- #3 The following will be used at coal deposits:
- (i) explosives with anti-firedamp safety
 - (ii) instant or millisecond-delay electric detonating primers.

Electric detonating primers with a long delays may be used only when the presence of methane over the limits outlined in Article 172 has not been determined, for 4 consecutive days with the ventilation shut off for 15 minutes, and at frontal workings only if methane over the limits in Art.172 has not been found.

- #4 In all workings of opening and preparation (development works) from sterile, mixed, or coal, which are located at a distance less than 10 m from a known fault, or from an old mine which cannot be checked for methane, blasting will be done only with firedamp-safe explosives. Only instant or millisecond delay electric detonating primers will be used for ignition.

- #5 In frontal workings, if methane is detected at some point in the accessible zone near the workings in concentrations over the levels admissible in Art. 172, blasting will not be permitted less than 20 m in front of the zone concerned, in the sense of the entrance of air (on the fresh air side), up to the exhaust gallery of the return air. If the principal ventilator (main fan) accidentally stops, and

methane is discovered in the frontal workings, blasting can be resumed only after the general ventilation is restored and the methane is dispersed.

- #6 In mines belonging to Category IV, electric detonating primers with a long delay can be used only in work areas where regular explosives are allowed.

Detonating primers with millisecond delay can be used in place of instant primers as follows.

a) In workings in ventilated dead-ends (blind headings with auxiliary ventilation) with partial ventilation, in all cases where the present norms (usual conditions) preclude the use of instant explosives, with the condition that between two adjacent powder charges the maximum delay should be 75 ms; and that between the first and last charges which are being detonated in the round, the maximum delay should be 200 ms in coal, and 400 ms in sterile.

b) In ventilated workings below the general level of the mine, as well as in workings in a dead-end which fulfill the provisions in paragraphs 2 and 3 of this article, all available grades of primer [caps] may be used.

- #7 Millisecond-delay caps can be used with explosives only according to the following prescriptions:

a) blasting holes will be located at a minimum distance of 0.5 m from each other;

§

b) the primed cartridge will be placed in the hole first (detonator at the bottom of the hole).

- #8 In horizontal workings in which the concentration of methane cannot be reduced by all the usual means to below the limits set in Art. 172, blasting under the protection of an [extinguishing cloud] of bicarbonate of soda is permitted in any concentration of methane up to a maximum of 2% measured in the general body of air, or at 2 cm above the shot holes or exploratory holes, or in pockets.

The application of the method will be on the basis of a work program drawn up and approved in conformity with the annexed instructions.

- Art. 175 #1 In firedamp mines of Category I, in rooms and frontal workings in which no methane has been found, blasting with astralite, and ignition with a Bickford wick is allowed on condition that:

(i) between adjacent workings and *piliere* (sic) of coal the difference between levels [i.e. altitude] should not exceed 6 m;*

(ii) the face of the working should be at a distance greater than 5 m from the boundary (hotar), or from a known fault.

* *piliere* does not translate readily

#2 In firedamp mines of Category I in which no methane has been found in any work area for a year, and in which there are no [aquiferous sands] holding methane, the use of astralite and ignition by means of long-delay electric detonating primers is permitted. These may also be used in development headings in coal.

Art. 176 #1 If, following a blast, standing holes* are found and the presence of methane is detected, their elimination will be effected only after a reduction in the concentration of methane to below the limits provided for in Art. 172 is achieved through ventilation.

Art. 176 #2 When, after loading blastholes with regular explosives or safety explosives, to be detonated electrically by caps with delays, the presence of methane above the limits provided in Art. 172 is determined, blasting will proceed only after the reduction of the concentration of methane to below the respective limits, and only after the adoption of special safety measures approved by the technical supervisor of the workings.

Art. 177 Special procedures, for blasting in conditions other than those described, may be applied only with the approval of a higher body on the basis of

*

most likely refers to unexploded charged holes

the opinion of the Center for Research on Mine Safety in Petrosani.

VENTILATION

Art. 178 #1 General ventilation of firedamp mines will be achieved with the intake of air (negative pressure ventilation), except in mines in Categories 0 and I, in which it is permitted to ventilate by means of the expulsion of air (exhaust, or forcing system).

#2 Principal ventilator units will be equipped with 2 ventilator motor assemblies*, one functioning, the other in reserve. The exceptions to the rule are mines in Categories 0 and I, which may have a reserve motor only. In these mines, the provisions in Art. 92 #2 are valid.

#3 In mines belonging to Categories IV-V, the reserve unit must be turned on (within) 30 minutes, at the most (of the main fan going down).

Art. 179 #1 (Summary): When continuing exploration downward through adjacent transverse strata of (containing) firedamp, the quality of air must be maintained, conforming with provisions in Art. 90.

*
main fans will be equipped with reserve motors and independent power supplies

Art. 180 #3 If a series of several development headings are served by a single channel (column) of air, the proportion of methane at the exit of (return from) each working, and at the last site in the series, should not exceed 0.75%.

Art. 181 #1 In gassy mines, ventilation by diffusion is permitted only in subterranean chambers up to 10 m long, on the condition that the concentration of methane does not exceed 0.5%.

#2 Ventilators (fans) in gassy mines must always be on (operating).

#3 The maximum distance allowed from the head of the ventilation column to the work face is 2 m in coal workings, and 4 m in barren workings. If either partial combined ventilation or forced air ventilation is being used, this distance can be extended to 10 m.*

Art. 182 #1 In work areas where the proportion of methane has been determined to be from 1% to 2% (in profile or in layer), the supervisor of the work force must report these measurements to the head mining foreman.

#2 If the accumulation of CH_4 exceeds 2%, all personnel will be evacuated to fresh air, and measures will be taken to reduce the accumulation.

* "partial combined ventilation" may be a reference to the use of both forcing and exhausting auxiliary ventilation, exhaust overlap, etc..

ELECTROMECHANICAL INSTALLATIONS

Art. 184 #1 In gassy mines in Categories I-IV, electrical equipment will be used according to the conditions outlined in Table 3 and the following articles.

TABLE 3

Degree of danger in workings	Max. level of CH ₄ in the working atmosphere, in percent	Type of safety equipment required
a.	0.5 in the principal current of fresh air, without blowers of CH ₄ in the vicinity, and with no accumulation of CH ₄	Normal construction, for stationary and moving equipment
b.	1.0 in air current below the general depression of the mine, (negative-pressure air currents), with exception as noted in #3 below	Equipment for gassy mines, with the following types of protection: - protection in oil - protection with ventilation
c.	2.0	Equipment for gassy mines with the following types of protection: - protection in an anti-combustion framework - protection with sand - protection with intrinsic safety - special protection

Art. 184 #2 All types of protection, whether imported or manufactured in the country, must be certified by CCSM, Petrosani.

#3 Lamps, with enhanced protection for gassy mines, can be used in open workings and development headings in Categories O-III.

#4 Electrical equipment suitable for use in mines of danger level "c" must have terminal boxes with enhanced, gassy mine protection, and only built-in illumination.

Art. 185 #1 The chief electrician, ventilation foreman, and technical foreman will consult together when deciding what areas should be equipped with the installations described in the preceding article.

#2 In determining which areas are to be assigned danger levels "a" and "b", as in Art. 184, the following should be taken into account:

(i) the level of known emissions of methane in the area concerned;

(ii) variations in emissions due to tectonic activity, the proximity of old workings, etc;

(iii) the volume of air necessary to dilute the concentration of methane to below the limits in Art. 184 #1.

Art. 186 The concentration of methane in mine workings equipped with electrical apparatus must be monitored periodically, especially when there are changes in the ventilation system, or when an increase in the methane level is indicated.

Such monitoring will cover a distance of 50 m in galleries in which there is an electrical contact line for trains or trolleys, or along a railroad line.

In mines of Categories III and IV, the periodic monitoring will be at least once per shift; in those of Categories 0-II, the technical foreman will decide the frequency of monitoring.

Art. 187 #1 Any electrical installations or lines must be de-energized if, in that area the concentration of methane exceeds the limits in Art. 184, or if there is an imminent danger of it exceeding those limits, due to a slide (cave-in), damage to or fault in the ventilating equipment, or other accidents.

#2 The electrical equipment can be reconnected once the level of methane has been reduced below the maximum permissible levels outlined in Art. 184, or after the defect has been corrected.

Art. 188 Electrical measuring and monitoring equipment can be used in polluted air (return air) under the following conditions:*

* *This may be, among other things, a reference to EDM types of surveying equipment*

- (i) if the measuring is constantly supervised;
- (ii) if the power is off when the equipment is connected and disconnected;
- (iii) if beforehand, and also periodically during the measuring, the methane is monitored, and its level of concentration does not exceed 0.5%.

Art. 189 The following can be used in an atmosphere of above 2% methane:

- a) portable electric gassy-mine lamps and flame safety lamps, and
- b) remotely read methane monitoring sensor equipment.

Art. 190 #1 Repairs can be made in unauthorized shops or in the mine only if these repairs do not affect those parts of the equipment which provide the protection against gas concentrations.

Art. 191 No mining work is permitted in gassy mines with electrical installation, even if the installations are not energized, without a preceding measurement of the methane concentration in the whole area affected by the working.

Art. 192 No machinery or equipment that contains components that may heat to over 200°C when exposed to the mine's atmosphere is allowed in gassy mines.

Art. 193 Diesel locomotives may be used in Category I-IV mines as follows:

(i) those of normal construction can be used under the same conditions as electric trains or trolleys.

(ii) those certified as being of construction for gassy mines may be used in mines with a methane concentration not exceeding 2%.

B. REGULATIONS FOR MINES WITH ERUPTIONS OF METHANE AND
MATTER (VIOLENT OUTBURSTS)

Art. 194 In mines belonging to Cat. V, in addition to the measures prescribed for gassy mines, the measures below must be taken.

Art. 195 #1 Development headings for new panels in thick seams will be opened only in layers. Opening thin layers (seams) will be done in parallel transverse galleries, with a connection (crosscut) between them every 50 m.

#2 Workings on an incline in strata of coal with a danger of eruption will be executed preferably from the top down. In digging from the bottom up it is obligatory to make drill holes beforehand, along the entire length of the working. Use of explosives and mining hammers is forbidden.

Art. 195 #3 All development headings, beginning from 10 m from the danger zone forward, will be continued only after a minimum of 2 probe holes have been drilled

to penetrate the danger zone. In addition, 5 m pilot holes must be maintained ahead of all further development works in the danger zone.

In strata of great thickness and small incline, the length of the probe holes will be a minimum of 50 m. The heading may be advanced to within not less than 5 m from the end of the probe holes. The advance may continue only after new probe holes are drilled.

#4 Beginning 2 m in front of the danger zone and ending 2 m after traversing it, workings must be supported with wood or metal reinforcements.

#5 In development headings in dangerous strata, only rotating drills powered by compressed air are allowed.

Art. 196 #1 Ventilation of works will be done only below the general depression of the mine*

#2 Exhaust air from development headings on a new level will go directly into the flow of return air.

#3 Partial ventilation will be done only with pneumatic ventilators.**

#4 Monitoring of methane in mines of Category V will be done every 2 hours, with gas detectors (methanometers) only.

* Most probably means that only negative-pressure ventilation will be permitted

** Auxiliary fans will be powered only by air motors

- #1 The use of electric energy is allowed only in the main flow of fresh air, in barren workings.
- #2 Electrical equipment must be of suitable type for gassy mines, and must have the following types of protection:
 - protection with sand
 - protection with anti-combustion framework (housing, etc.)
 - protection with intrinsic safety (low-energy circuitry)
 - special protection.

Methane must be monitored during each shift as per Art. 186.

Art. 197 #3 Electrical equipment must be disconnected when the concentration of methane exceeds the limits shown in Art. 187 #1, or when an eruption of methane has occurred in a neighboring area and there is a danger of a methane inundation in the work area in which cables and/or electrical equipment are installed.

- #4 Permissible modes of transport in mines of Category V are:

(i) locomotives with compressed air;

(ii) electric locomotives with accumulators constructed for gassy mines and used only in the flow of fresh air.

#5 Fixed illumination will consist of electro- pneumatic (fluorescent) lamps, and portable illumination will consist of electric lamps (for gassy mines).

#6 In mines of Category V, soldering, vulcanizing, welding etc. to join cables is forbidden.

Art. 198 Any eruptions of methane or particulate matter will be reported to higher authority and entered in the special register for this purpose, and will be noted on the mine plan.

(Supplement to Art. 179 #1)

Art. 90 In all accessible underground mine workings, the air must contain at least 19% oxygen. Maximum concentrations of toxic gases in work places are shown in Table 4.

Table 4

Toxic Gas	Maximum Admissible %	Concentration mg/m ³ of air
Sulfur dioxide	0.00052	15
Hydrogen sulfide	0.00097	15
Oxides of Nitrogen	0.00048	10
Carbon monoxide	0.004	50

Fresh air is mine air that has circulated through the mine and which contains up to 0.5% CH₄ or CO₂.

In the general exhaust current (main return), the maximum percentage of CH₄ or CO₂, previously determined before entering the ventilator canal (return air duct), will be 1%. In the exit currents of the sectors (secondary returns), the respective percentages can be a maximum of 1%.

- #2 The maximum admissible temperature of the air at a given subterranean (underground) workplace will be 25°C, except chambers under compression (closed headings with forced ventilation), where the air temperature will not exceed 35°C.

In rooms with machines, transformers, etc., the temperature will not exceed the temperature of the neighboring mine working by more than 5°C.

- #3 The minimum speed of the air current in subterranean workings will be 0.2 m/s, and a maximum limit of 8 m/s in workings in which transport of personnel is carried on, and a limit of 15 m/s in workings that are used exclusively for ventilation.

Supplement to Art. 178, #2

- Art. 92 #2 Principal ventilator installations will be equipped with a reserve motor and a second energy source, separate from the one which powers the primary motor.

Mines in which the workers can be evacuated in 30 minutes or less to the outside or to a horizontal (level) with fresh air in case the principal motor stops, are not required to have a reserve motor or a second energy source.

APPENDIX X

SPAIN

Excerpts from Legislacion de Minas, 1972

CLASSIFICATION OF UNDERGROUND WORKS

Art. 50 The Provincial Delegation will classify all underground works or sections thereof by their firedamp or other combustible gases, by their degree of fire risk, and by their flammable dusts. "Firedamp" shall be understood to mean a mixture of air and methane with small amounts of other gases. When combustible gases other than firedamp are found in underground works, the General Board (Direccion General), after hearing the statements of the Firedamp and Mining Safety Commission, shall proceed to classify it in one of the categories established for that gas. If necessary, the General Board shall dictate special rules, the purpose of which shall be the attainment of degrees of safety similar to those obtaining where firedamp exists, and to that end it shall consider the explosive concentration limits and the minimum ignition temperatures of the emanating gases.

Art. 51 Mines can be divided into independent areas, and these can be classified in different categories. Two areas shall be considered to be independent from each other when they only have in common, from the standpoint of ventilation, the main galleries of air inflow and outflow.

An air return which is common to several independent areas shall be considered as part of the area with the

strictest classification. The entire personnel of the mine shall be duly informed with regard to the classification of the various areas in the mine.

Art. 52 Those mines, or areas thereof, where spontaneous combustion of the mineral or of the encasing rock occurs frequently, shall be classified as mines having a tendency towards fire (mines with a fire-hazard?).

Art. 53 Those mines, or areas thereof, which extract combustible substances, the dust of which is capable of producing or propagating an explosion, shall be classified as mines or areas with flammable dusts. This classification category shall include those mines which have:

1. A volatile matter content of more than 12%, if the mine or area is classified as having firedamp.
2. A volatile matter content of more than 15%, if the mine or area is classified as not having firedamp.

In order to determine the composition of the dust, samples will be taken at different points on the floor, roof and walls, over distances of at least 50 meters in length in the gallery, and for analysis purposes, they shall be determined to be free of humidity, carbonic anhydride and ash.

The above notwithstanding, when the deposited dust has been effectively neutralized by natural conditions in the mine, either because it is found in clay form, or

because it is found in amounts such that its dispersion in the air does not cause high enough concentrations to produce an explosion, or when, from experience or from studies performed by an officially recognized testing station, it has been demonstrated that the dust is not susceptible to the propagation of an explosion, the mining company may request that the Provincial Delegation reclassify the mine or quarters.

Art. 54 Mines, or areas thereof, and underground works in general, where the existence of firedamp or other flammable gases is possible, shall be classified in one of the following four categories:

1. Without firedamp, or first category. Where firedamp or other combustible gases have not appeared.
2. Low in firedamp, or second category. Where firedamp or other combustible gases may form in small amounts (less than 0.3% in return air).
3. High in firedamp, or third category. Where firedamp or combustible gases form in abundant amounts (more than 0.3% in return air).
4. With instantaneous outbursts of gas, or fourth category. Where firedamp and other combustible gases may form suddenly and massively, causing significant amounts of mineral or adjacent rock to be violently ejected.

In classifying a mine, area, or work as being low or high in firedamp, the volume of the combustible gases that form shall be taken into account, as well as how fast those gases would accumulate to a dangerous point if ventilation were to stop or slow down.

In any case, "high in firedamp" shall be those:

- Independent areas or mines where the firedamp content in the general air return is higher than 0.3 per 100 (0.3%).
- Independent areas or mines where firedamp forms regularly and in such abundance that explosive concentrations are reached within one hour after ventilation and activity have stopped.
- Mines, area, or works where, due to the weak mechanical consistency of the mineral, and to the effect of gravity, the mineral spalls off, thus liberating amounts of firedamp such that its accumulation reaches levels higher than 2.5 per 100 (2.5%).

In classifying suspect occurrences of instantaneous outburst, special attention shall be paid to the study of their causes in order to differentiate these occurrences, known as "roof hits" (outbursts which occur in the roof) from ordinary rockfalls caused by gravity. The composition and danger level of the fire-damp formed shall also be taken into consideration.

Art. 55 All new underground activities shall be classified by the Provincial Delegation, taking into account the nature of the mineral extracted, the geologic characteristics of the deposit, the history of other mines in the basin, and any analogies with other similar mines. This shall be considered to be a temporary classification, until work has progressed to the point where sufficient information is available to permit a definitive classification. Even though the activity is classified in the first category (no firedamp), the Provincial Delegation may still order additional measurements during the temporary period in order to permit a correct definitive classification.

In any event, a report from the Firedamp and Mining Safety Commission is mandatory whenever a mine, or area thereof, is being classified by the Provincial Delegation as being susceptible to instantaneous firedamp outbursts.

Art. 56 The Director of a mine which has been classified in one specific category is required to notify the Provincial Delegation immediately with regard to any change in the conditions which prompted that classification.

The Provincial Delegation, based on the information received from the Director of the mine, or on data obtained from periodical tests or measurements (or others it may have specifically ordered) may revise the classification of the mine or area thereof.

Similarly, the Director of a mine may request that the Provincial Delegation revise the classification of a specific mine or area thereof.

Art. 57 If the mine has been classified as having firedamp, and he wanted it classified as not having firedamp, the Director of the mine must submit his request to the Provincial Delegation, along with a list of the tests and examinations performed during a period of at least one year, and these tests shall be underwritten with his signature. The Provincial Delegate, in view of all the background information he may have gathered, and having checked (by closing the ventilation system in the mine for 24 hours) the firedamp content of various works every 2 hours (using officially approved firedamp sensors, and taking air samples which must be analyzed in an official laboratory) will give his definitive resolution, after hearing the statements of the Firedamp and Mining Safety Commission if he so wishes, although always informing the latter of the actions that have been taken.

Art. 58 As soon as a mine or area thereof classified in the first category shows any manifestation, no matter how small, that firedamp or other combustible gases may be present, the Director of the mine must communicate this information to the Provincial Delegation, and from that moment on the Delegation shall consider this mine to be suspect and shall subject it to the following:

1. Observation and tests of the gases and air in the mine or area thereof, especially where the first manifestations took place, and under the same conditions as required for mines with firedamp.

2. Special observation of the air in the exploratory and development works, especially in the proximity of faults, geologic anomalies, and old workings.
3. Application of any additional safety measures which the Provincial Delegation may deem necessary.

The test and observation period at a suspect mine or area shall last a maximum of one year, during which, if those indications persist or worsen, the Provincial Delegation shall proceed to reclassify the mine.

If, during the maximum period of one year established for testing and observation purposes, no manifestation of combustible gases occurs, the Provincial Delegation may relieve the mining company from the special safety measures it had prescribed for it.

Art. 59 The Director of the mine is required to report to the Provincial Delegation, and the Provincial Delegation to the Firedamp and Mining Safety Commission, any incident which might be considered to be an instantaneous outburst, as well as any uncommon manifestation which may presage those incidents, such as projections or displacement of one layer, or sudden and massive release of gas, whether such events did or did not cause any injuries or fatalities.

From that moment, the Provincial Delegation shall declare the mine, quarter or layer where the incident occurred, to be suspect, and a period of testing and observation shall be put into effect, lasting a maximum

of one year, during which the Provincial Delegation shall require those mining and vigilance rules it may deem appropriate, as well as technical studies conducive to a determination of the nature and causes of the events that took place.

If, during this period of observation these manifestations continue or worsen, the Provincial Delegation shall communicate this information to the Firedamp and Mining Safety Commission, who in turn shall proceed to classify the mine or quarters in the fourth category. The Commission can also eliminate the observation period whenever it is clear that it was an instance of instantaneous outburst, in which case it shall proceed immediately to this classification.

If, during that observation period no other manifestation takes place, yet the studies carried out leave some suspicion that the first manifestation may have been due to a sudden outburst of gas, the mine shall be declared suspect, and shall be subject to the mining and vigilance rules dictated by the Provincial Delegation.

Art. 60 If the owner of a mine or zone classified as being susceptible to instantaneous outbursts of gas, wants the mine to be declassified, a testing period lasting at least two years shall be instituted, at the end of which the Firedamp and Mining Safety Commission must issue a report so that the Provincial Delegation can make a final resolution.

Note: Sections 61 through 76 deal with fire control and flammable dusts.

RULES FOR MINES IN THE FOURTH CATEGORY

Art. 77 Activities in a mine, quarter, or layer, that belongs in the fourth category, shall be carried out in accordance with the complimentary safety rules issued by the Director of the Mine and approved by the Provincial Delegation, and these rules shall take into account the characteristics of the deposit, the type of gas formed, and the nature and magnitude of its formation.

Art. 78 A log (and a plan, in a scale no smaller than that of the ventilation plan) shall be kept, recording every incident that occurs whether or not it results in injuries or casualties, numbered in chronological order for each layer, and indicating the essential characteristics of each incident.

Art. 79 In mines or areas classified in the fourth category, there must be a service (responsible for the prediction and control of) instantaneous outbursts.

The performance of this service shall follow a work plan which will be approved by the Provincial Delegation. This Delegation may authorize the grouping of several mines in the organization of this service.

Art. 80 The rules and signals established to warn of and deal with possible instantaneous outbursts shall be made known to all operating personnel.

Everyone who works in the mine shall be fully instructed in methods of artificial respiration.

Art. 81 All mines classified as having instantaneous firedamp outburst shall apply, as a minimum, those rules which relate to mines high in firedamp, especially with regard to the flow of ventilation currents, firedamp control, prevention of air ignition, and the use of explosives.

Art. 82 In mines or areas classified in the fourth category, underground first aid stations shall be provided.

APPENDIX XI
UNITED KINGDOM

Note: All of the material in the following sections is reproduced with the permission of the Mining Department of the National Coal Board, from their publication Ventilation in Coal Mines, A Handbook for Colliery Ventilation Officers, and may be protected by copyright.

Firedamp

The M&Q Act always speaks of 'inflammable gas', never of 'firedamp', the usual pit name for flammable gas. But Ventilation Regulation 3 identified firedamp with flammable gas. British Standard 3618 defines firedamp as 'a flammable gas consisting mainly of methane, found naturally in mines'. In practice CH_4 , the chemical formula of methane, is often loosely used as a short way of writing firedamp.

Section 79 of the M&Q Act requires men to be withdrawn if flammable gas:

in the general body of the air exceeds 2%, or otherwise constitutes a danger.

If the concentration in the general body of the air exceeds $1\frac{1}{4}\%$ CH_4 , or gas is seen on the lowered flame of a safety lamp:

shotfiring may not proceed: (Explosives Reg. 47 (2))

electricity must be cut off; (electricity Reg. 6)

locos must stop running. (Locos Reg. 16 (1))

Intakes within 90m of a face shall 'normally be kept free from flammable gas'. That is, the average of six samples taken by an inspector at intervals of not less than 14 days is not to exceed $1\frac{1}{4}\%$ CH_4 (Ventilation Reg. 2).

**Determination
of Firedamp
Content**

In the Ventilation Regulations the percentage of flammable gas in the general body of the air is referred to as the 'firedamp content'. The regulations concerning firedamp content need to be clearly understood by colliery ventilation staff, as these cover a major part of their duties.

Determinations of firedamp content must be made:

XI-2

where electricity is used at or within 45m of a working face (Reg. 3(1));
Where shots are fired in the ordinary course of working the face (Reg. 3(2)).

Determinations of firedamp content must be made by a competent person appointed by the Manager as follows:

- (a) either by an approved type of apparatus (e.g. D6 or C4 methanometer);
- (b) by samples (preferably NCB tube) analysed within four days.

Method (a) has the advantage that the results are known at once, and so can be used immediately for making improvements. Method (b) has the advantage that the values are more accurate and precise, and that the analysis covers not only methane but also oxygen, carbon dioxide and carbon monoxide.

The position of the sampling point is to be:

for longwall faces - on each gate 10m from the nearest working place (Reg. 5);
for faces other than longwall - at points fixed by the Manager (usually 10m from the face) Reg. 6);
additionally, in each return gate serving a face using electricity 10m from each junction (Reg. 7A).

For purposes of identification, each sampling point should have its own Station Reference Number. The initial basis of sampling interval is once a week.

So long as five successive weekly determinations are all less than 0.6%, determinations may be extended to four-week intervals. (Reg. 7(1) (b)). (The 30 days of the Regulations become 28 days in practice, because statutory samples must be taken on the last cutting/filling shift of the week (Reg. 7(3)). In practice, however, it is not unusual to continue weekly sampling even when monthly sampling is statutorily permissible.

If any statutory sample exceeds 0.8%, determinations must be made daily until seven working days after it falls below 0.8% (Reg. 7(1)(a)). Should

The above rules apply to samples at 10m from the face. Additionally, for longwall faces using electricity, whenever samples are taken at 10m from the face, a determination must also be made in each return gate at 10m from the junction thereof with any other return airway (Reg. 7A).

Electricity Regulations 1956 (as amended 1967):

The electricity supply shall not be restored until the senior official on duty at the mine so directs.

Regulation 47 (1) Restriction
on firing, due
to gas

(2) If a district deputy finds a fire-damp concentration exceeding 1-1/4%,

or can see in the general body an indication of gas on the lowered flame of a safety lamp, he shall:

- (a) ensure that no shot is fired or shothole charged in his district on the return side of that place; and
- (b) inform the deputy in charge of any other district ventilated by that air.

- (3) A deputy so informed shall ensure that no shot is fired nor shothole charged in any part of his district ventilated by that air, until authorized under subsection 47(4).
- (4) The prohibition shall continue until the senior official on duty has satisfied himself that the firedamp content at the place does not exceed 1-1/4%, and has authorized the resumption of firing.
- (5) The manager shall forthwith notify the District Inspector of any such occasion, unless the excess content was caused by temporary derangement of the ventilation.

Regulation 48 Firedamp determinations in drifts containing a coalseam. Delay detonators. If delay detonators are to be fired in a drift containing, at the face, a seam of coal (or waste) more than 300 millimeters thick (or within 5 metres of any waste) firedamp determinations must be made (during operations) at intervals not exceeding 24 hours, at the face of the drift by apparatus approved for firedamp determination. The manager is to specify the face of the drift for determinations under Ventilation Reg. No. 6.

Regulation 50 Examination for gas before firing shots This section details the examination for gas before firing, using a flame safety lamp or an approved methanometer. There is to be no firing or charging of holes if flammable gas exceeds 1-1/4% or there is an indication of gas on the lowered flame.

Locomotives Regulations 1956:

Regulation 11 Firedamp	The manager to arrange for determination of the firedamp content in all loco roadways (unless an Inspector gives exemption) as follows:
Regulation 12 How made	Determinations of the firedamp content shall be made: (a) by approved type of apparatus by competent person appointed by the manager; or (b) by samples of air, taken by competent appointed person and analyzed within four days (excluding Saturday, Sunday or general holiday).
Regulation 13 (1)Where made	Determinations shall be made: (a) at each end of every length or road in which a loco runs (but in the case of an intake beginning at a shaft or outlet only within 275 meters of any working face ventilated by it); (b) any other suitable points fixed by manager.
Regulation 14 (1)When made	Determinations must be made once a week at the time when the firedamp content is likely to be greatest. But (a) if a determination exceeds 0.8%, determinations at that point to be made at intervals not exceeding 24 hours until seven working days after it falls below 0.8%; (b) if every determination made during 30 days (i.e., the last 5 weekly determinations) at a point does not exceed - in a road not ventilated by return air from a working face, 0.2%; in any other length of road, 0.6%, then determinations at that point may be at intervals not exceeding 30 days until that percentage is exceeded.
(2)After alteration in ventilation	When an alteration is made in the ventilation which may affect substantially any such road, a determination at each point in that length shall be

made as soon as a substantial effect would be apparent.

Regulation 15 Recording

Particulars of these determinations to be recorded in book (M&Q Form No. 270 [145]).

Regulation 16 (1)CH₄ Exceeding 1-1/4% (discontinue running)

If a firedamp content exceeding 1-1/4% is detected (other than by analysis) in a road, the person detecting it shall forthwith inform the official in charge of that length of road. The latter (after forthwith verifying the accuracy of the information) shall forthwith discontinue the running of any Loco in that length of road.

(2)

After such discontinuance no locomotive shall be run in that length of road until the manager, being satisfied that the firedamp content therein does not exceed 1-1/4%, so directs.

(3)

If any determination by analysis reveals a firedamp content exceeding 1-1/4%, the manager shall forthwith cause that no loco runs in that length of road until he is satisfied that the firedamp content does not exceed 1-1/4%.

(4)

The manager to notify the Inspector of running a loco.

REFERENCES IN LEGISLATION
TO CONCENTRATIONS OF GASES

(Reproduced with the Permission of the National Coal Board)

Authority	Amount of Gas Requirement	
Vent.Reg. 2	0-0.25% firedamp	Every intake airway the air of which has not ventilated another working place shall normally be kept free from flammable gas up to within 90m of the first working place.
Loco.Reg. 14(1)(b)(i)	0.2% firedamp	Locomotive roadways ventilated with fresh air and containing not more than 0.2% firedamp over a period of 30 consecutive days need only be

sampled at intervals not exceeding 30 days.

Vent.Reg. 2(2)	0.25% fire-damp	If six samples taken by an Inspector at not less than fortnightly intervals in the general body of the air in an intake airway up to 90m from the first working place average not more than 0.25% firedamp the roadway may be classified as "free from flammable gas."
Vent.Reg. 13	0.5% firedamp	If the last six statutory determinations in a return airway 10m from the face exceed this level a specified proportion of the firedamp detectors required by Ventilation Regulation 12 must be automatic detectors.
Loco.Reg. 14(1) (b)(ii) Vent.Reg. 7(1)	0.6% firedamp	Locomotive roadways (other than those ventilated with fresh air) and also places sampled because either electricity is in use or because shots are fired need be sampled only every 30 days if every result obtained in the previous 30 days is not more than 0.6%. Weekly sampling must be commenced when any figure exceeds 0.6%.
Loco.Reg. 14(1) (a) Vent. Reg. 7(1)	0.8% firedamp	If any sample taken by virtue of the Locomotive Regulations or of the Ventilation Regulations relating to (a) the use of either shot firing or electricity shows more than 0.8% samples must be taken at intervals not exceeding 24 hours for the seven following working days.
Vent.Reg. 8(2)	1.0% firedamp	The Manager must inform the Inspector of any occasion (other than determinations made at junctions in return airways in accordance with Vent.Reg. 7(a)), when this concentration of firedamp is found to be exceeded unless the Inspector has otherwise directed or the excess was due to a temporary derangement of the ventilation.
Section 68(1)	1.25% firedamp	This is the upper limit that Regulations may prescribe as the concentration above which electricity must be cut off.

Elec.Reg. 6(1) and (3) (as amended 1967)	1.25% firedamp	Above 1.25% a person must either cut off the electricity from all electrical apparatus (other than telephone or signalling or any apparatus for detecting flammable gas, including ancillary apparatus) or report to someone who is empowered to do so. Also, when the concentration falls to this level the electricity supply may be restored only on the instruction of the senior official on duty.
Explosives Reg. 47(1) to (5)	1.25% firedamp	Shot-firing is not permitted on the return side of any point showing a greater firedamp content. The Manager must inform the Inspector of any such occurrence unless it was caused by a temporary derangement of the ventilation.
Comp.Air Blasting Reg.	1.25% firedamp	Compressed air blasting shells must not be fired if more than 1.25% firedamp is found in a test for gas in relation to the shell.
Loco.Reg. 16	1.25% firedamp	Locomotive running must be discontinued if any determination of firedamp exceeds 1.25% until the Manager so directs. The Manager must give notice of any such discontinuance.
Section 79(1) and (5)(b)	1.25% firedamp	In mines other than safety lamp mines men must be withdrawn from the affected area if a concentration of more than 1.25% is found.
Section 79(5) (a)	2.0% firedamp	In a safety lamp mine 2.0% is deemed to be an "excessive concentration" and men must be withdrawn from the affected area.
Firedamp Drainage Reg. 13(e)	2.0% firedamp	A place where firedamp is vented from a drainage system into an underground roadway must be fenced so that the concentration of firedamp at the fence will not exceed 2%.
Firedamp Drainage Reg. 13(c)	40.0% firedamp	Firedamp must not be discharged to a utilization plant if it contains less than 40.0% flammable gas.

MINING PROCEDURES FOR HELIMINERS (GASSY POTASH MINE)

(Reproduced by Courtesy of Cleveland Potash Ltd., Boulby Mine,
Cleveland, England)

OBJECTIVES:

The objectives of these rules are as follows:

1. To establish the presence of shale or secondary ore and thus decide whether the roadway should be mined by full face mining or by cyclic (cut, drill and blast) methods.
2. To establish the elevation of the top of seam and hence position the roadway with sufficient competent rock to provide a strong roof and thus minimize premature collapse of roadways.
3. To ensure that stress relief techniques are carried out by following the correct mining sequence.
4. To establish the base of seam elevation.

FULL FACE MINING

Full face mining may only be carried out under the following conditions.

1. Full face of primary ore with 0.5m minimum of primary ore above the roof of the heading.
2. Full face of salt.

Note: If there are shale bands or secondary ore either present or suspected then the heading must be mined by cutting, drilling and blasting.

Method to be adopted for Full Face mining in Potash roadways.

1. Mining will be carried out in 10m increments.
2. Each increment will be mined in 5m runs.
3. Safety holes will be drilled 3m longer than the increment, i.e. 13m.
4. The spacing and inclination of safety holes is shown in Figures 1-4.
5. Sidewalls must be marked so that the operator can clearly determine that he has not exceeded the length of run.

OR CONTINUOUS MINERS (6m wide Roadway)

VERTICAL FROM HOLES TO MAX.

COVER FROM LAST AND FURTHER HOLES

ANGLES RELATE TO BANGALONG BRIDGE
LINE OF ROAD CUT

HOLES TO BE DETERMINED BY GEOLGY DEPARTMENT

10m

15m

20m MAX (BETWEEN 20m SPACING HOLES)

উত্তরঃ

WILL © TO BE REPEATED EVERY TWO

PLAN

9-17 1125

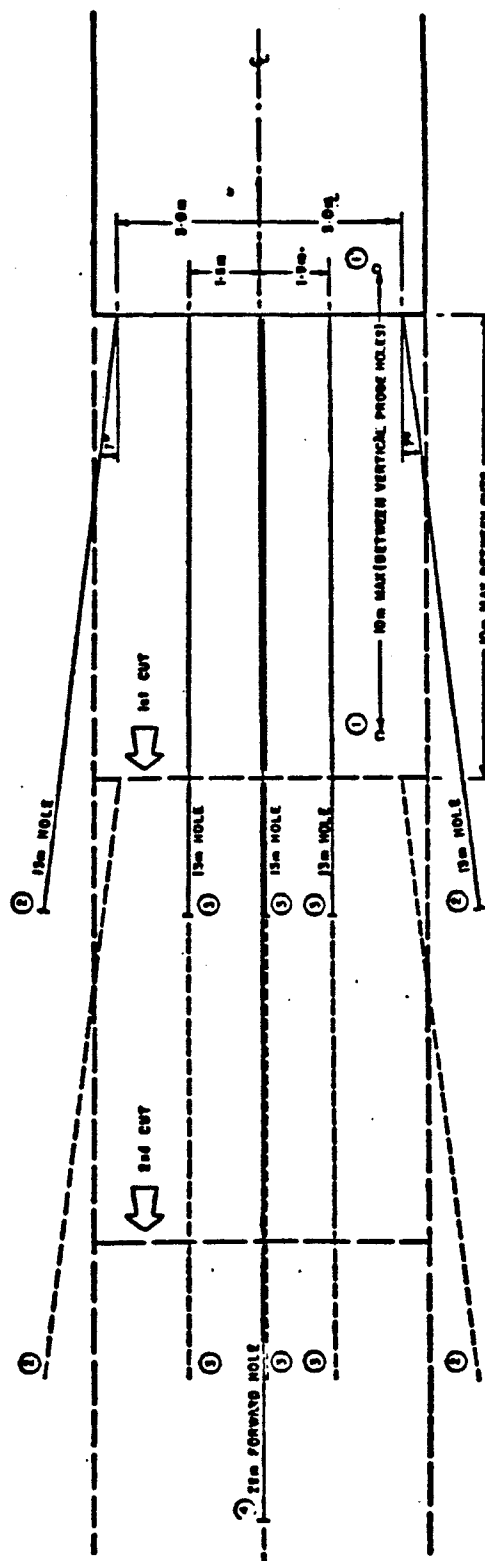
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FOR CONTINUOUS MINERS (8m. wide Roadway)



WILL BE REPEATED EVERY TWO

WALL-TO-WALL NEWS SERVICE

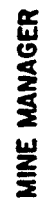
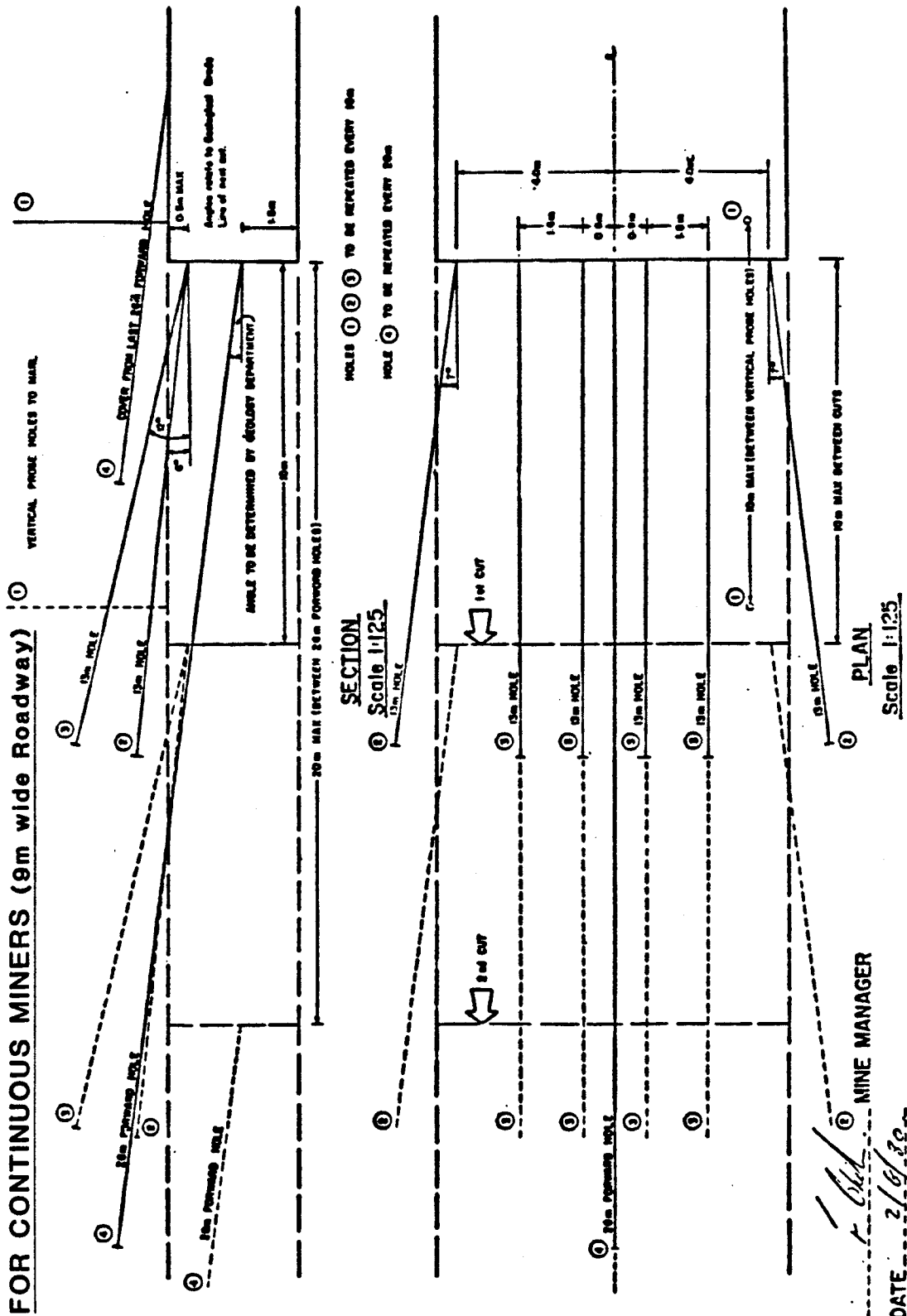


Figure 3

Figure 4

MANAGER'S FORWARD DRILLING RULES

FOR CONTINUOUS MINERS (9m wide Roadway)



Reproduced from
best available copy.

6. Safety holes are not required between roadway holings providing both roadways and relevant exploration/safety holes have been examined for presence of secondary ore or shale and that the holing distance is less than 6m.
7. Exploration holes should be drilled in all advancing roadways except with the approval of the Mining Manager.
8. If a hole is drilled less than 16m it must be re-drilled.
9. If a hole is drilled less than 26m but more than 16m a single 10m pass may be taken.
10. Additional holes may be drilled at the discretion of the Geologist.
11. Vertical up-probe holes should be drilled at 10m intervals
12. Down probe holes should be drilled where base of seam is not exposed and at 10m intervals
13. The sequence of mining in a panel will be the same as for cyclic mining

Method to be adopted in salt roadways

1. Mining will be carried out in 10m increments
2. Each 10m increment will be mined in 5m runs
3. Safety holes are not required if the base of seam is over 2m from the roof
4. Exploration holes will be drilled in the same way as for potash roadways
5. Vertical probe holes should be drilled at 20m intervals

UNDERCUTTING, DRILLING AND BLASTING

Cyclic methods, i.e., undercutting, drilling and blasting must be carried out in all roadways where shale or secondary ore exists or is suspected.

1. The cut position, drilling and charging pattern will be as specified from time to time by the Production Manager.

2. The Heliminer will load out the muck from the roof, sides, face and floor. Unless the ground is obviously fractured, the face should not be trimmed beyond the back of the cut or the sides more than 6" outside the perimeter holes. These precautions are necessary to avoid the possibility of mining into a gas blower.
3. In a 4 roadway system the two outer roadways should be maintained up to 15m in advance of the two inner roadways. The inner roadways should be advanced together i.e., as far as is possible one should not lead or lag the other.
4. Exploration holes must be drilled in the two outer flank roadways. Holes should normally be 26m in length. If a hole is less than 16m it should be re-drilled. If a hole is more than the 16m but less than 26m the heading may be advanced to a position where 6m of cover remains.
5. In the 2 inner roadways short exploration holes must be drilled each round 6 metres in length, inclined at 35 degrees, collared 3m above the floor. Geology will indicate the plan position of the hole, i.e., centre line, or near the left or right hand wall.
6. Vertical probe holes will be drilled at intervals of not more than 15 metres. Down probes will be drilled at the same position unless the base of seam is exposed in which case they are not required.

GRADIENTS

1. The maximum gradient in any roadway should not normally exceed 1:10.
2. The rate of change of gradient should be gradual, e.g. 1:10 down, 1:20 down for 5M, level for 5M, 1:20 up for 5M, 1:10 up.

If it is necessary to exceed the above gradients or changes in gradient then the matter should be brought to the attention of the Production Manager.

MINING TO BASE OF SEAM

The general policy is that advancing roadways should be mined as close to the base of seam as possible. Roadways should maintain 1.5m minimum of competent rock above the roof of the roadway. Where it is necessary to reduce this to less than 1.5m of compe-

tent material, the matter must be brought to the attention of the Production Manager

SUBJECT: USE OF CONTINUOUS READING METHANOMETERS

1. General

The use of continuous reading methanometers is necessary following experience gained of inflammable gas emissions from the strata. Mining operations specified below may not be carried out if these methanometers are not correctly sited and in working order.

2. When to be Used and Type

- (a) All full face continuous mining operations using an exhaust ventilation system - MSA unit at the face and a Sieger BM1 unit monitoring return air from the heading
- (b) Mucking out headings after blasting by either LHD or continuous miner - MSA unit at face.
- (c) Any operation specified by the Production Manager when an inflammable gas emission is probable - MSA unit at the work place.

3. Operational Checks

- (a) The MSA units must flash at the standard rate of once every fifteen seconds in the installed position before any mining equipment is started up at the workplace. If it flashes at the "alarm" rate at once per second, the presence of inflammable gas must be assumed and further checks carried out. (Set to go to "alarm" rate if CH₄ level exceeds 1.0%). The units will be changed each shift. Units which develop operational faults will be identified when returned to the Lamp Room.
- (b) The Sieger BM1 unit must be set up jointly by the Electrical Section and Ventilation Section with the detector head mounted vertically in the return air from the heading. The position of the detector head and the methane reading must be checked at least once per shift by the District Supervisor. If the mining machine trips the presence of inflammable gas must be assumed and further checks carried out. Resetting will be carried out by Electrical Section, upon the instruction of the District Supervisor (Note: "District" in this context means a district within the mine, i.e., an operating area).

4. Maintenance Checks

- (a) MSA units will be checked and calibrated after use by Ventilation Section.
- (b) Sieger BM1 Detector heads will be changed every 2 weeks by Electrical Section and re-calibrated by Ventilation Section
- (c) The electrical circuitry of the Sieger BM1 units will be checked weekly by Electrical Sections

5. Alarm on Trip Set Points

Both types of unit will be set to operate at 1 1/4% methane or such lower figure specified in writing to Ventilation Section by the Mining Manager.

APPENDIX XII

YUGOSLAVIA: EXTRACTS FROM REGULATIONS

PART I: PROTECTIVE MEASURES FOR UNDERGROUND ROCK SALT MINING

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Rudarski Institut, Belgrade)

VI. VENTILATION

Article 99

In special cases, in the exploration stage of a salt mine, underground works may be started before their independent connections to the surface (one with incoming and the other with outgoing air) are connected underground.

Underground works under Paragraph 1 of this Article may be initiated only under the following conditions:

1. The mine operations must be carried out in accordance with the mine design; these must be indispensable exploratory works for the purpose of protecting against water and gas intrushes; specific ventilation and ventilation equipment design must exist for these works to serve until the mine connections with the surface become connected underground.
2. No more than 30 men may work underground during one shift.
3. Every working must be supplied with ample ventilation of at least 6m^3 of air per minute per man.
4. Adequate spare fans must be provided, and no delay in the ventilation of individual mine workings is allowed.
5. The construction of machinery used underground must be such that it cannot cause an explosion.

6. All workings must be tested for methane during each shift, and, after an initial methane occurrence, even more often in accordance with the instructions of the mine technical manager.
7. Work must be terminated in, and the work force withdrawn from, a mine working at the first occurrence of methane there. The working must be closed with crossed bars, and work may be continued in the mine working only in accordance with the instructions of the mine technical manager.
8. The mine technical manager must issue instructions for organized urgent evacuations in cases of water or gas intrushes. The work force must be drilled in evacuation procedures, and all men must be equipped with self-rescue devices.
9. The working must be inspected by an authorized official during each shift, and the inspection must include testing for the occurrence of noxious gases.
10. At least once a day the mine working must be inspected by the mine technical manager who controls the application of provisions under Items 1 through 9 of this paragraph.

If the enterprise does not observe the provisions under Items 1 through 10 of this Article, the mine inspector is obliged to prohibit the completion of the underground works except for work associated with the interconnection of the separate mine connections with the surface if appropriate measures for this work are undertaken.

Article 100

During the opening and broader development of the pit, particular attention must be paid to the possible occurrence of inflammable and explosive gases.

Inflammable and explosive gases include methane (CH_4), ethane (C_2H_6), hydrogen (H_2), hydrogen sulfide (H_2S), and other hydrocarbons, as well as oil fumes.

Article 101

During work on the salt deposit opening, its development and trial opening, the presence of methane and other inflammable or explosive gases must be tested for in the underground mine. The results of such tests and other observations must be reported to the mine authorities so that the work hazard may be defined.

Article 102

Ventilation must be such that in rooms to depths of 400 meters every mine worker is supplied with at least $3 \text{ m}^3/\text{min}$ of air, as a rule, and at depths below 400 meters every mine worker is supplied with at least $4 \text{ m}^3/\text{min}$ of air, measured in the incoming air stream. Exceptions to this may be allowed by the authority competent for mine design approval. Because of possible occurrences of methane, carbon dioxide, or other harmful gases, the capability to increase the air supply to the mine must be available to prevent gas accumulation above allowed limits.

Article 103

(Article 103 deleted.)

Article 104

Mined-out chambers should be adequately ventilated and closed prior to re-use; i.e., abandoned so that unauthorized persons cannot enter. Such chambers must be regularly inspected by authorized supervisory officials for accumulation of explosive and harmful gases, and the findings must be entered in the mine ventilation log.

Article 105

If benzene or oil odors are smelled in a working, periodic gas analyses, particularly regarding the presence of ethane, should be carried out in addition to the normal tests.

Article 106

In cases of more severe carbon dioxide intrushes, operations required for the removal of this gas may be undertaken only in conjunction with the rescue brigade.

Article 107

The mine supervisory staff must have equipment for determining the amount of methane and other hydrocarbons, carbon dioxide, and hydrogen sulfide in the air.

Article 108

Every intrush of methane, carbon dioxide and other noxious gases into the underground rooms must be immediately reported to the mine inspection authorities.

Article 109

The incoming air stream must be as dry as possible. Dripping water in the incoming air stream shaft, i.e., the water penetrating the shaft lining, should be collected in gutters and carried by pipe to a water sump to prevent its dispersion through the shaft and the moisturizing of the inlet air.

MINE VENTILATION

Article 211

All accessible workings must be ventilated.

Workings without ventilation must be closed, and if there is danger of accumulation of poisonous gases in them they must be hermetically sealed.

1. Mine Atmosphere

Article 212

The composition of the mine atmosphere must be in accordance with the Yugoslav standard for allowed concentrations of harmful, dangerous or poisonous gases, vapors, dust, smoke, mineral dust, etc. in the air at wall faces and in workings.

In a mine at locations where workers remain or pass through, ventilation must be such that the concentration of oxygen in the atmosphere is at least 19% by volume.

The allowed maximum concentrations of dangerous gases except explosive ones in the mine atmosphere, so that work is possible and workers may pass through without the use of special protective devices, are:

- carbon monoxide	(CO)	0.05* % by volume
- sulphur dioxide	(SO ₂)	0.0004 % by volume
- hydrogen sulphide	(H ₂ S)	0.0007 % by volume
- nitric oxide	(NO ₂)	0.0005 % by volume

For carbon dioxide (CO₂) the allowed volume percentage is 0.5 and in some cases 1.

The allowed maximum concentration of mercury vapors is 0.1 mg per cubic meter of the mine atmosphere.

The allowed maximum concentration of mineral dust, i.e. the allowed number of particles in 1 cm³ of the mine atmosphere is:

- aluminum oxide	1.750
- asbestos	175
- talc	700
- mica containing less than 5% of free SiO ₂	700
- mineral dust containing less than 5% of free SiO ₂	1.750
- mineral dust containing 5% to 50% of free SiO ₂	700

* This is the figure supplied to us by the Yugoslav translators.

- mineral dust containing over 50% of
free SiO₂ 175
- free SiO₂ 175

Until Yugoslav standards define particle size limits in mineral dust (quartz, asbestos, etc), harmful particles will be considered those whose size is from 5 to 0.20*

Article 213

The allowed concentration of methane in the mine atmosphere is:

- in the inlet air stream of ventilated rooms and
wall faces 0.50%
- in the main outlet air stream of a mine 0.75%
- in the outlet air stream from wall faces and
ventilated rooms 1.00%
- at a wall face and in the outlet air stream
from that wall face 1.50%

If the concentration of methane in the air, measured in the clearance diagram ** of the working, exceeds the limit, work in the mine must be stopped.

At wall faces where methane has previously appeared and in the air stream leaving these wall faces, work is allowed in exceptional cases, even if the methane concentration is 2%, but only with the approval of the works manager. In such cases necessary protective measures specified by regulation regarding blasting, lighting, electric installations, frequent monitoring of gases, and supervision should be taken.

* Units not specified, ... presumably microns.

** Probably references a measuring point having a specified minimum clearance from the rib, face, roof, floor, etc.

If the methane concentration exceeds 2.0%, men may enter the workings only to perform rescue or repair work, and only with the permission of the works manager. They must use special precautions, be constantly supervised by a competent person, and no blasting is to be permitted.

If, in addition to methane, ethane and coal dust are noted, the limit of methane concentration will be 1.5%.

Access to the working face is forbidden if work is stopped for any of the above-mentioned reasons, and the entrance to the area will be marked with crossed laths.

Article 214

Mine ventilation must be such that in an independently ventilated room every worker has 3m^3 of air per minute at depths of 400m and at least 4m^3 per minute at greater depths, measured in the incoming air stream. Those who check the quantity of air needed in a mine should note that one horse needs as much as 4 men, and a liquid fuel locomotive needs 3m^3 of air per minute for each horsepower. When checking the quantity of mine air one must count maximum number of workers, horses and liquid fuel locomotives in one shift. The quantity of mine air calculated this way must be provided even when the shift work force is reduced.

In pits which contain dangerous gases the quantity of air must be increased to prevent the accumulation of gases above the specified limit.

Article 215

In agreement with the labor protection service, the mining company manager can decide that the air intake volume should be 1.5 m^3 per minute in some mines or certain rooms because of specific dangers, (fire, old workings, etc) with the condition that the lives and health of the workers are not imperilled.

In ferrous and non-ferrous ore mines the quantity of intake air can be reduced to 1 m^3 per minute for each worker.

Article 216

The air stream speed in the pit must not exceed:

- 4 m/sec at wall faces where opening, preparation or excavation are performed.
- 8 m/sec in other excavations used for transportation or where workers stop or just pass through.
- 10 m/sec in excavations used for ventilation and through which workers or supervisory staff periodically pass.

The air stream speed in ventilation channels, regulating holes, boreholes and vents is not limited.

Exceeding the air stream speed limit is allowed in the following cases:

- in narrowed or reduced excavation cross-sections.
- if it is the only way to reduce the gas concentration to the level allowed by Articles 212 and 213 in these Regulations, or to improve air conditions.

In excavations where the air stream speed is higher than 8 m/sec, the speed must be reduced to no more than 8 m/sec when work must be performed there.

The average air stream speed, measured in a full cross-section of the methane pit, must not be less than the following:

- in drives with electrical wire	1.0 m/sec
- lower and upper drive entry	0.5 m/sec
- in special rooms and chambers	0.1 m/sec
- in other accessible excavations	0.2 m/sec

In excavations with local methane sources, the air stream speed must be high enough to prevent the formation of methane zones, i.e. separated methane layers under the roof.

If methane layers, i.e. separated methane layers under the roof or along the side, continue to form, they must be dispersed by methods generating turbulence, including fans, compressed air injectors, boards or sheets.

Article 217

The mine ventilation should be adjusted so that the air temperature is 23°C on a dry thermometer and 28°C on a wet-bulb thermometer.

Wall faces whose temperature is higher than the normal pit temperature must be specially supervised and the temperature checked once a week.

If the dry thermometer air temperature is over 26°C the temperature must be checked every day.

The air temperature should be checked at the height of workers' heads. The results of every air temperature check must be recorded in the Mine Ventilation Book.

Article 218

Workers are allowed to work only 6 hours a day on wall faces where the temperature is 28°C on a wet thermometer or 31°C on a dry thermometer.

When the air temperature of a wall face exceeds that limit, work is allowed only if the workers are removing some danger. In such cases the number of workers must be doubled so that they can relieve each other more frequently.

In the cases from Paragraphs 1 and 2 of this Article, the air flow speed must not be under 0.5 m/sec.

Article 219

Workers who have been working in warm areas (31°C on a dry thermometer) must not work in cold areas on the same day.

Workers employed on warm wall faces must be rotated every month. After a one month period those workers may again work on warm wall faces.

2. Ventilation Plants

a) Main Ventilation

Article 220

Every pit must have one air stream inlet and one air stream outlet. The main mine ventilation is, in fact, the flow of air through excavations, from their entrances to their exits.

When the mine ventilation is interrupted, workers must be removed from imperilled excavations if the disturbance cannot be eliminated within the time limit specified by the mining company's Rule Book of Labor Protection. In such cases air composition is important (Articles 212 and 213 of these Regulations).

Article 221

Main mine ventilation may be performed by natural depression or mechanically with fans (artificial ventilation).

Coal mines and other mines in which the development of harmful dust or vapors is possible must have artificial ventilation regardless of the magnitude of the natural depressions.

The ventilation of mines with methane or dangerous pulverized coal must be permanent, artificial and by negative pressure. When calculating the negative pressure, the influence of a natural depression must be taken into account.

Mining inspectors can require a certain method of main ventilation in every mine.

Article 222

Excavations and wall faces, which cannot be ventilated by the air flow stream, must be ventilated by special ventilation devices and, in some cases, by diffusion.

Article 223

Main mine artificial ventilation is performed by main, auxiliary and additional fans.

The main fan is used for ventilation of the entire mine or just part of the mine. It must be placed on the surface.

The auxiliary fan is also placed on the surface and is used for ventilation of one part of the mine, using a small quantity of the main air stream.

An additional fan is used to improve ventilation in one room. In these cases workers must be able to pass from one end of the ventilation plant to the other.

In order to make the ventilation system as safe as possible the mine must be ventilated in such a way that each independent ventilation system with its own inflowing air stream has only one or two fans, whenever possible.

Article 224

In mines where there is methane and dangerous pulverized coal, and which are ventilated with one main fan, there must also be one reserve fan of approximately the same capacity as the main one. The fan must be equipped so that it can be operational within 10 minutes.

In mines ventilated by two or more fans placed on the surface, the reserve fan is not necessary if, when one fan stops working the other can take over its functions, as long as all workers leave the mine.

The functioning of reserve fans, from Paragraphs 1 and 2 of this Article, must be checked at least twice a year.

Every use of reserve fans must be recorded in the Mine Ventilation Book, and all changes, if any, in mine ventilation must be described.

Surface fans should be placed so that they would not be damaged by mine explosions.

Mines without methane, dangerous pulverized coal, and harmful gases need only one fan with a reserve engine.

Article 225

The engines of main, auxiliary, and reserve fans must be dimensioned for a possible long-term overload of 25% of their normal power.

Article 226

According to regulations, the transmission of energy from the engine to the fan must be direct. If the transmission is performed by belts, these must be multiple fan belts with individual safety factors for 1.5 times their maximum load. There must always be reserve fan belts near the fan.

In mines with methane, other dangerous gases, dangerous coal dust, or constant fire danger, main fans must have two independent sources of electricity, i.e, one inlet from the mine grid, and a reserve generator.

Article 227

If the capacity of the reserve fan is not enough for normal ventilation of the whole mine, then the works manager must decide which rooms (or even the whole mine) the miners must leave and stop work until the ventilation is fully restored.

If for some reason there is not a reserve fan in the mine and the working fan or engine must be mended, or if there is a power failure, the works manager must act in accordance with Paragraph 2 of Article 220 of these Regulations. Such an exceptional situation must be registered in the Mine Ventilation Book.

If for some reason it is necessary to amplify the negative air pressure it must not be done instantaneously, but gradually over a period of one hour.

Article 228

Within a radius of at least 30 m around a fan placed on the surface, there must be no inflammable material, except fuel for the reserve power source. If the fan is in a building, it must be made of non-combustible material.

The power source and its connection to the fan must be set up so that mine air is not circulated to rooms where the generator and electric plant are.

Fans on the surface must have reserve lights. A miner's safety lamp may be used as a reserve light.

If there is a switchboard in the mine, every fan on the surface, which is more than 100m from the drive control, must have a telephone line.

All active and reserve fans on the surface must have water gauges which, unless they are automatic, must be checked every two hours.

The main fan in the mines with methane, other dangerous gases, or dangerous coal dust must also have an apparatus to measure the level of negative pressure. Records must be kept for at least three months and must be checked and signed by a person responsible for mine ventilation.

Article 229

Only skilled workers are allowed to handle fans on the surface. In mines with methane, other dangerous gases, dangerous pulverized coal, or in constant fire danger, the main and auxiliary fans must be continuously monitored by a person, or have an automatic alarm system which indicates any variation of the fan performance.

Besides alarm devices, skilled workers chosen by the works manager must monitor the main mine fan every 8 hours. Any damage to the fan must be immediately reported to the works manager.

In other mines, if the fan has an automatic alarm device, the supervisor must monitor it at least once a day.

During temporary operation of the reserve fan, it must be monitored continuously, even if it has an alarm device, if the reserve fan does not match the specifications of the main fan.

Article 230

Integral parts of the main, additional, and auxiliary fans in the mine must be checked at least twice a year, and those results recorded in the Mine Ventilation Book.

In bigger mines, and in mines with methane and dangerous pulverized coal, the electrical superintendent must check all parts of the main, auxiliary, and additional fans at least twice a month and record the results in the Mine Ventilation Book.

b) Separate Ventilation

Article 231

Auxiliary ventilation can be performed by suction, blowing or a combination of these two.

Auxiliary ventilation is performed by vents, and the air stream is moved by electric fans, fans powered by compressed air, or hand fans.

In mines with methane, other dangerous gases, or dangerous pulverized coal, compressed air coming directly from a duct must not be the only method of face ventilation.

Ventilation pipes may be rigid (sheet, wood, etc) or elastic (rubber, canvas, synthetics, etc).

The ventilation method, fan locations and vent diameters are specified in the instructions of the works manager.

In mines with methane, dangerous gases, or dangerous pulverized coal, separate ventilation must be continuous even when workers are not in the mine. Short interruptions in ventilation are allowed only in exceptional and justifiable cases which must be specified in the instructions. In these instructions special

attention must be paid to reactivating the fans for separate ventilation with regard to gas concentration monitoring and the prevention of the dispersal of dangerous gas to other rooms.

Article 232

In separate ventilation by suction, return intake vents should be as close to the face as possible so that it will be well ventilated and so that the exhaust air can exit by the return air stream outlet.

In separate ventilation by blowing, vents should be at least 10 m from the face and the air may be taken from the fresh air intake stream.

Separate ventilation must be arranged so that the return air stream coming from the face does not mix with the fresh air stream.

In mines or parts of mines with methane, dangerous gases, or dangerous pulverized coal, auxiliary ventilation is allowed by regulation in drives and dip headings to a distance of 300 m. In rise headings that distance is 150 m and in blind shafts 100 m away from the fresh air stream. A drive is a room with a rise of 5%. The mining company works manager, in agreement with the labor protection service, can approve separate ventilation at even greater distances than those mentioned above, but only with corresponding protective measures.

Separate ventilation can be performed at such distances that sufficient air flow occurs at the wall face and the atmosphere is in accordance with the Articles of these Regulations referring to the pit atmosphere, which must be checked during every shift.

Axial fans must have a mesh screen on the suction side.

Article 233

Ventilation by diffusion is allowed in horizontal rooms (to 5% slope) at a distance of 50 m from the fresh air stream, in sloped rooms at a distance of 20 m, and in rooms where methane is expected at a distance of 10 m.

c) Changes in Ventilation

Article 234

Changes in the operation of the main, additional and auxiliary fans in a mine, as well as the ventilation fans, may be ordered only by the works manager or in exceptional cases by persons specified in the safety plan.

If two pit drives are connected in such a way that changes in the ventilation of one drive can influence ventilation of the other drive, the works managers of these drives must agree on the conditions of every ventilation change in those drives. Every such change in ventilation must be approved by the mine company works manager and labor protection service.

If a pit suddenly appears to be in danger of accumulating explosive or dangerous gases the supervisory staff must at once take necessary precautionary measures for better ventilation. The mine works manager must be informed and must approve those measures.

If explosive or dangerous gases have accumulated in one room more than in the others, and if these gases can be removed by intensified ventilation, but at the expense of fresh air supply to the

other rooms, such changes in ventilation may only approved by the works manager.

Workers are not allowed to make any changes in the ventilation.

Article 235

At every location in a pit where fires may occur or inflammable gases may appear in the main inlet air stream, there must be an apparatus which changes the direction of the main inlet air stream. This apparatus must be operational within no more than 10 minutes.

Changing the direction of the main inlet air stream must be done in the safest possible way, by setting a regulatory device near the main or auxiliary fan, or by placing a special suction fan in the main inlet air stream.

Stopping the fan and changing the direction of the main inlet air stream is allowed only in cases specified by, and by methods approved in the safety plan. The order to change the direction of the main inlet air stream in cases of danger can only be given by a person specified in the safety plan.

In all other circumstances not predicted by the safety plan, stopping the fan and changing the direction of the main inlet air stream can be done only if necessary to remove a danger which is imperilling miners.

The works manager and technical staff must test stopping the fan and changing the direction of the main inlet air stream in accordance with Paragraph 3 of this Article. Experience acquired

in this way should be applied to possible changes in the safety plan. During such tests in a pit with methane, electricity must be switched off in all plants.

A report must be prepared on preparations for the test, the running of the test, and acquired experience. This report must be given to a mine authority who determines the date of the next test, if he deems it necessary. There must be at least 6 months between tests.

3. Air Stream Transfer

a) Ventilation Ways

Article 236

Main mine ventilation must be such that the fresh air inlet stream goes by the shortest route to the lowest drive in a pit and from there horizontally to the pit exit. Horizontal ventilated rooms are those with up to $\pm 5^\circ$ slope.

The descending transfer of the fresh air stream is permitted for ventilation of descending works involving research, opening or preparing a deposit.

The descending transfer of the used air stream is allowed:

- 1.) during return flow of the air stream from rise headings used for research, opening or preparation of a deposit;
- 2.) during excavation of pillars above the main drive;
- 3.) if that air stream will not be used for other wall faces;
- 4.) if it helps to reduce the dustiness of the pit atmosphere and to protect against pneumoconiosis and silocosis.

The descending transfer of the used air stream, according to Paragraphs 3 and 4 of this Article, can be done in mines with methane only if the speed of the airstream flow is at least 1 m/sec in rooms with descending transfer of air. Gaps in the roof must be completely filled, or closed in such a way that it is impossible to insert a liquid fuel lamp.

The transfer of the air stream through old works and the diverting of the air stream from a wall face through old works is forbidden if the ventilation ways are not kept up properly.

Article 237

To transfer an airstream above another air stream on the same level a ventilation bridge may be used (e.g. cross-roads).

A ventilation bridge may not be used to separate the main pit inlet air stream from the outlet air stream of independently ventilated rooms in pits with methane and dangerous pulverized coal. In such pits a separate excavation, which is above or below the working level and adjoining rock, should be used as a ventilation way.

A ventilation bridge which separates the inlet from the outlet airstreams of one or two independently ventilated rooms must be made of noncombustible material. A wooden partition mortared on both sides is considered noncombustible. In exceptional cases the mine authority may permit the bridge be made of flammable material.

Ventilation bridges in ventilation rooms may be made of wood. If the air quantity is not more than 5 m^3 per second, the ventilation bridge may be made of sheet metal tubes with a cross-section

of at least 0.5 m^2 . The ends of the tubes must be built into partitions which are made in accordance with Paragraph 2 or 3 above, depending on the importance of the bridge.

In pits with methane and in pits with dangerous pulverized coal, ventilation bridges made of sheet metal tubes may only be used in independently ventilated rooms.

The cross-sections of ventilation bridges must be large enough that workers with rescue devices can pass through.

Article 238

Ventilation by use of a ventilation borehole is allowed if necessary. These boreholes must be safe from through-faulting, negative pressure must be achievable through them, and it is mandatory that the quantity of air necessary for adequate ventilation can be transmitted through them.

In ventilation boreholes through mineral ore deposits which are prone to spontaneous combustion, tubes which are grouted into the ore by cement at their ends must be used to prevent air leakage.

b) Regulation of the Air Stream

Article 239

The following air streams must be isolated from one another:

- 1) Inlets which belong to various independent ventilation systems
- 2) Outlets diverted by separate fans
- 3) The main mine inlet and the main mine outlet

- 4) Independent ventilation rooms from each other
- 5) Inlet and outlet air streams from the same ventilation room
- 6) Air branches in the same ventilation room

Article 240

Ventilation partitions must be in main rooms in which there may be mixing of air streams or loss of air.

All ventilations partitions in the cases listed in Article 239 Items 1 through 5 of these Regulations must be made of non-flammable material and must be airtight. Partitions in the same ventilation room may be made of wood.

Parallel branches which arise from a split air stream (inlet or outlet), from the reduction of the air flow resistance, are not considered separate air streams. There may not be ventilation partitions in mine rooms in between these parallel air streams.

Article 241

When choosing a location for ventilation partitions between air streams, except air streams from Article 239 Item 6 of these Regulations, it must be in hard, compact rock. The location must not be exposed to high pressure and must not be too near an intersection with another room.

In places which are dangerous because of the possibility of spontaneous combustion of ore, the ventilation partition should be placed out of the fissured area. If that is not possible, then the fissures must be filled or injected to prevent the flow of air. Instead of one, two or more ventilation partitions should be installed.

Article 242

A door must be made in the ventilation partition if:

- 1) transportation through the partition is necessary;
- 2) workers must pass through the partition;
- 3) a rescue (escape) route, laid out by the mine emergency plan passes through the partition;
- 4) that location is predicted by the mine emergency plan to be used as a short circuit to divert smoke and harmful gases in the event of a fire or explosion.

In the ventilation room, ventilation curtains may be used in places where it is impossible to have ventilation partitions with doors because of interference to plant, or because of the pressure. If necessary, several curtains may be used.

Curtains and doors may not be used in sloped rooms through which transportation by mine car or skip occurs. Every door, the use of which is not necessary at any given time, must be taken off its hinges.

Article 243

In locations where opening a door would cause a serious disturbance to the ventilation, two or more ventilation partitions with doors must be installed and measures must be taken to ensure that one door always remains closed.

If there is continuous transport through a ventilation partition, one opening can be made in the partition but it must be kept covered if possible. In the most important short circuit locations, several such partitions should be installed.

Article 244

The method of installing the door and the door's construction must comply with the following conditions:

- 1) the door must open against the air stream;
- 2) the door can be closed without obstruction;
- 3) the door dimensions are 0.70 m wide and 1.20 m high;
- 4) any worker must be able to open the door without tools from either side;
- 5) the door can not be locked;
- 6) the door is strong enough in normal mining conditions.

Doors in ventilation partitions, as specified to be used in Article 239, Items 1, 3 and 4 of these Regulations, must be iron or wooden and plated with sheet metal on both sides; partitions must be built into the drift (bulkheaded?).

Doors for Items 2 and 5 of Article 239 of these Regulations may be made of 4 cm thick boards connected by screws (bolts). Doors for Item 6 of the same Article may be of light wooden construction.

Doors and partitions must be monitored regularly and maintained correctly.

Article 245

If there is any danger that a door, mentioned in Article 239 Items 1 and 3 of these regulations, will be destroyed by explosion of methane and cause a short circuit in the air stream and serious disturbance to the pit ventilation, then in such a location a partition should be installed with a door able to withstand 10 atm of pressure.

If there is a reserve door, protected from the effect of an explosion near the place described by Paragraph 1 of this Article, which can be installed and closed immediately after an explosion, then a door able to resist 10 atm pressure does not have to be used.

Construction of the door from Paragraph 1 of this Article must comply with the conditions listed in Article 244, Items 1 through 5.

Article 246

A regulating partition with damper, which regulates the quantity of the air flow, should be placed in the inlet air stream. The damper may be adjusted only by the ventilation supervisor.

c) Air Distribution

Article 247

Air distribution in a pit should be accomplished by the division of the pit into several ventilation rooms, if necessary. An independent ventilation room is part of a pit which gets fresh air flow from the main mine inlet air stream, and used air from that room goes to the main mine outlet air stream, or through an independent ventilation exit to the surface.

In an independent ventilation room the inlet air stream should be separated into independent air branches for better ventilation of single or grouped wall faces and other rooms, and also to reduce the total air stream resistance.

Article 248

In mines with methane or dangerous pulverized coal, 130 workers may be employed at one time in independent ventilation rooms.

d) Ventilation of Wall Faces and Separate Rooms

Article 249

Wall faces should be directly ventilated, but if that is not possible there should be special ventilation, particularly if methane and other dangerous gases appear.

A fresh air stream should flow through excavations with a 5° slope, except in fault zones.

Article 250

The air stream to research workings and openings of new regions of the pit should be directed, if possible, directly from the inlet air stream.

Article 251

Special rooms in the pit which contain inflammable material, as well as liquid fuel locomotive depots, must be ventilated in such a way that used air goes to the outlet air stream. In these cases boreholes can be used, according to Article 238 of these Regulations.

If it is not possible to comply with Paragraph 1 of this Article, such rooms must have fire preventive doors and covers for ventilation openings which can be closed from the outside if fire breaks out in the rooms.

Article 252

Chambers for charging the batteries of electric locomotives must be made so that there are no corners of the roof without ventilation.

Chambers from the first Paragraph of this Article must be ventilated by air stream flow or by special fan. It is forbidden to ventilate these chambers by diffusion.

Chamber ventilation must be such that during hydrogen extraction, while charging a battery, there is only 1% hydrogen in the air.

- e) Opening of Closed Parts of a Pit.

Article 253

Reopening the closed parts of a pit can be done only as part of a project which will correspond to the overall mine plan and ventilation system.

- 4) Control of Ventilation and Air in a Pit

- a) Inspection of Ventilation Ways

Article 254

All ventilation ways must be inspected at least once a month by a person specified by the mining company Rule Book about protective measures during work.

In gassy pits and pits with dangerous coal dust, inspection of all ventilation ways is to be carried out by supervisory ventila-

tion personnel at least once a week, or more often if it is required by the mine works manager. Inspection of bricked (lined with bricks?) ventilation shafts must be carried out once every three months.

Article 255

In gassy mines, pits with dangerous coal dust, and pits in which dust, gases and steam which are health endangering gather, deputies for ventilation must be appointed. One of them is chosen to be the ventilation foreman.

In pits from Paragraph 1 of this Article, there must be as many deputies for ventilation as is necessary for correct supervision of pit ventilation.

Deputies for ventilation are forbidden to have any production duties.

If a deputy for ventilation does not come to work, he can be replaced only by a person who satisfies all regulation requirements for that job.

Deputies for ventilation must have at their disposal tools and instruments for ventilation control.

Article 256

Any person in a pit who notices any suspicious change in the air must immediately retreat to a clean air region and inform all workers and the nearest deputy about these changes. The deputy is obliged to undertake necessary protective measures whether or not there are any special deputies for ventilation.

The shift deputy or the deputy for ventilation is obligated to write down the air testing results in the shift report, to describe phenomena from Paragraph 1 of this article, and to write down what protective measures were taken. The person in charge of the following shift puts his signature on this report to confirm that he has been informed about it.

b) Inspection of Wall Faces in which Work is Stopped

Article 257

In coal mines and mines with methane and dangerous gases, supervisory personnel and persons chosen by the works manager must inspect wall faces in which no one has worked for eight hours, and rise headings and dip headings in which no one has worked for four hours, before miners start working there again. This must be done to test for the presence of methane or other dangerous gases.

If nobody has worked in a pit for eight hours, and if during that period no one went into it or monitored it, it is forbidden to allow miners to enter the pit before testing for gases in the entire pit and determining that the pit is normally ventilated and that there is no danger to workers.

The inspection of a wall face or a rise heading must be carried out just before the workers arrive there, or at most 4 hours before they arrive with escort.

The method of inspecting a wall face and the number and disposition of persons carrying out the inspection is determined by the works manager.

c) Measuring and Testing of the Mine Air

Article 258

The quantity of air which passes through an excavation, and the temperature of that air, must be measured if there is any significant change in the ventilation regime, and at least once every three months in pits without methane or any other dangerous gases. In pits with methane or other dangerous gases, it is done more often if necessary.

Monitoring of mine air is carried out at ventilation stations, located at a place determined by the works manager.

Ventilation stations must be placed in rooms with main air flow and exactly in front of and behind each branching or intersection of air flows. Ventilation stations must be at least 5 m long.

In smaller pits with a greater number of openings to the ground surface, which are endangered by methane or other dangerous gases, coal dust, etc, regulations from Paragraph 3 of this article need not be applied except if specified by mine inspection personnel.

Article 259

On the side of ventilation stations, signs must be mounted upon which the following information is recorded; area of the station cross-section, speed of the air flow, quantity of air which flows through the station per minute, air temperature, quantity of air per worker per minute, date of last monitoring, and the name of the person who carried out the monitoring and recorded the data.

Monitoring in ventilation stations is carried out by persons chosen by the works manager.

Persons from Paragraph 2 of this Article write down the monitoring results and their remarks in the Pit Ventilation Book. That book is inspected and signed by the works manager.

Article 260

Every day the barometer reading and air temperature must be checked in gassy mines and a file kept with these data.

Article 261

In pits with methane and other dangerous gases, besides regular testing for gas in the mine air, air analyses must be carried out once a month on samples from the main returns, and once every three months on air from some auxiliary fans unless mine inspection personnel specify otherwise. By air analysis is meant determining the quantities of oxygen, carbon monoxide and carbon dioxide and, if necessary, the quantity of other dangerous gases in the mine air. If there are no instruments for the analytical determination of the quantity of carbon monoxide, this can be determined using measuring devices of equivalent precision.

In addition to the points at which air analysis is carried out in accordance with Paragraph 1 of this Article, mine inspection personnel may require air analyses of the air flowing into the pit or of the air in certain sections of the ventilation.

The method of taking air samples and performing chemical analyses can be regulated by mine personnel until the Yugoslav standard is established. Results of the chemical analyses must be written in

the Pit Ventilation Book and the original recordings must be carefully preserved.

d) Pit Ventilation Book

Article 262

Each pit must have its Ventilation Book in which data on the quantity of air, results from mine air monitoring, and remarks in connection with pit ventilation are recorded.

In the Pit Ventilation Book the following data about each ventilation section are recorded: the maximum number of workers employed in one shift in the period between two monitorings, and the quantity of air per minute per worker in each section (taking into consideration horses and liquid fuel motors). Data on the temperature, barometer reading, and quantity of methane, carbon monoxide, carbon dioxide and other dangerous gases in the air must also be recorded in the Pit Ventilation Book.

Data from all ventilation stations, with their cross-sections, must be recorded in the Pit Ventilation Book.

Article 263

The pit ventilation plan, made according to Article 47 of Technical Regulations on Mine Measuring, Measuring Books and Mining Plans (Addition to "The Official Paper of FPRY", No. 45/60), is part of the Pit Ventilation Book.

VIII Explosive Gases in a Pit

Article 264

Mine inspection personnel and mine personnel must be informed immediately about the first appearance of methane in a pit and they must, at the same time, take measures to prevent the accumulation of methane and possible explosions.

Mine inspection personnel must be immediately informed about methane ignition even in cases where there is not an explosion and there are no casualties. A description of the area, and causes and possible consequences of methane ignition must be given also.

Article 265

Each pit or layer in which some work is done to exploit coal or some other raw materials, and in which methane could possibly occur, must be categorized as methane or non-methane.

In pits where two or more layers are exploited, categorization will be carried out for each layer with a separate ventilation system, so that it is impossible for the air from a methane layer to enter the air flow to a non-methane layer.

A non-methane pit is one in which, in any room ventilated by through-flow or by separate split of air there is not more than 0.1% (by volume) of naturally separated methane in the air. When the ventilation is stopped for 24 hours the concentration of methane can not be more than 1%.

Gas produced by pit fires or gas from old closed workings is not to be taken into consideration.

A methane pit is one in which it has been determined that the concentration of methane is above the limit given in Paragraph 3 of this article.

Article 266

Each excavation in a methane pit is put into one of three classifications based on the degree of methane hazard.

In classification I are excavations in which the quantity of methane in the air is no more than 0.5% by volume under normal ventilation conditions.

In classification II are excavations in which the quantity of methane in the air is no more than 1% under normal ventilation conditions.

In classification III are excavations in which the quantity of methane in the air may be more than 1%.

Classification of excavations as I or II cannot be based on ventilation using pipe ventilators.

Article 267

The categorization of pits as methane or non-methane as presented in Article 265 of these Regulations, as well as the classification of excavations according to degree of danger as presented in Article 266 of these Regulations, is carried out by mine personnel at the request of a mining organization. The categorization of existing pits and the classification of existing excavations, as given in Article 265, Paragraph 1 of these Regulations, must be carried out within one year from the date when these Regulations become valid.

The works manager must continually monitor the indicators which are used to classify certain excavations according to their degree of danger. If a phenomenon occurs which requires that the degree of danger be changed, he must undertake the necessary protective measures immediately and inform mine personnel about it in writing in order to have the category changed.

Article 268

In excavations with danger classification I, electric generators, machines and equipment without protection against explosions, and cable-driven electric locomotives may be installed and used under the following conditions:

- 1) deserted and unventilated excavations along the fresh air flow path to the area of such installations must be closed by isolation barricades (sealed off);
- 2) the flow of air through such excavations must be monitored constantly so that the methane level does not exceed the limit allowed for these excavations;
- 3) in conjunction with the work schedule and specific local conditions, measures must be undertaken to prevent the sudden appearance of methane in dangerous concentrations;
- 4) gaps and larger holes or cavities in the ceiling must be backfilled or closed so that it is impossible to insert a gas lamp into them.

Article 269

In excavations with danger classification II or III only certain electric generators, machinery, and equipment provided with protection against explosion can be installed and used.

In exceptional cases non-permissible electric generators and mobile machinery and equipment, such as cable-driven electric locomotives, and unprotected liquid fuel locomotives, may be installed and used under the conditions given in Article 268 of these Regulations, with the following additional protective measures:

- 1) a methane monitoring apparatus, which sets off an alarm at the detection of over 0.5% by volume of methane, must be placed in a suitable position to monitor the methane in these excavations;
- 2) the methane monitoring apparatus must turn off the supply of electricity to certain installations if the quantity of methane detected exceeds 1%;
- 3) an instrument for turning off the cable which supplies electricity must be placed on the fuse board or at the transformer station located in a classification I excavation.

Accumulator (battery-powered) locomotives and liquid fuel locomotives with explosion protection may be used in excavations of classification II under the conditions in Article 268, Points 1 and 3 of these Regulations.

1. Control of Methane

Article 270

Monitoring of methane (determining the quantity of methane in the mine air) is carried out using special indicators (methanometers) or mine safety lamps. Indication devices must be calibrated. The works manager must provide written instructions for handling the mine safety lamps or any of the types of indicators.

Article 271

Monitoring of methane must be carried out by the first responsible miner at the wall face at the beginning of each shift, immediately before and after blasting, after each break in work, and before abandoning the working place at the end of a shift.

The shot-firer must monitor the methane level immediately before loading, immediately before blasting, and when he returns to the site after blasting.

Methane monitoring must be carried out by both a ventilation deputy and a shaft deputy during inspection of a wall face at least once every shift.

Methane monitoring must be done at all wall faces, and at all other places where methane may appear or accumulate.

Article 272

Special methane indicators must:

- 1) reliably indicate the presence of methane in the mine air if it is over 0.2%;
- 2) be intrinsically safe from explosion in the highest air speeds;
- 3) have a power supply such that they can be used for two hours longer than the shift working time;
- 4) have a magnetic clack valve or other valve of the same safety level, if required by that type of indicator.

As far as the keeping, testing, issuing, and storing of indicators is concerned, the decrees of these Regulations about lamp-cabins apply.

Article 273

Mine safety lamps must have a glass cylinder made of thick safety glass, the ends of which are bevelled in the direction of the cylinder axis to accept gaskets.

If air is brought into the lamp from below, the air entrance must be adjusted so that the flame cannot penetrate through the opening.

Lamps must have two wire gauze screens with 144 equal holes per square centimeter. The wire thickness must not be less than 0.3 mm or greater than 0.4mm. The inner wire gauze must be made of steel. The wick and relighter must be enclosed in the inner part of the lamp. Lamps must have a magnetic lock.

All parts of the lamp must be made or arranged in such a way that the wire gauze screen and the glass cylinder cannot be damaged.

Lamps used in airflows with speeds more than 5 m/s must have a metal mantle.

Article 274

Monitoring of methane with a mine safety lamp is done first with a normal flame in the lamp in the following way: the lamp is slowly lifted from the floor to the ceiling and then it is slowly lowered to the floor. If, during testing with the normal flame, the flame does not extend, then the test is to be repeated in the same manner with a reduced flame.

Article 275

The works manager must also include in his special orders provisions for the everyday control of methane sources in excavations and the control of devices for breaking up methane layers (Article 216). He must regulate the duties of the supervisory ventilation personnel regarding the detection of new sources of methane in the pit and the appearance of methane layers.

Once a year in each pit a complete methane balance in the air flow for the whole ventilation system must be done. All known sources of methane must be marked on the ventilation plan.

2. Work in Methane Pits

Article 276

If methane is found in a pit in which it has not appeared before in an amount of 1.5% or more, the wall face must be abandoned and two crossed boards placed at the entrance to signify that entrance is forbidden. Supervisory personnel and the works manager must be immediately informed about such an appearance of methane and they must undertake the necessary measures.

Article 277

If a new unknown area is opened up, and if, according to the geological forecast, methane or water is expected to appear in the area, effective measures for flushing the gases and surmounting the water must be planned.

EXTRACTS FROM THE MINING LAW OF SERBIA

Workers with Special Tasks and Responsibilities in
Performing Technical Mining Jobs

Article 98

Certain mining jobs in the exploitation of mineral raw materials may be performed only by persons who fulfill specified conditions.

Article 99

Jobs of workers with special tasks and responsibilities, which deal with technical and supervisory matters, and the questions of mine safety, may be performed by those who fulfill specified conditions.

Article 100

The job of a mine foreman may be performed by a worker who has finished Intermediate Vocational School in an equivalent profession, who has two years of work experience, and who has passed a professional exam.

The job of a foreman in mining projects may be performed by a worker who was a supervisor (ganger?) in an equivalent project for at least two years.

Article 101

The job of technical manager in the organization may be performed by a worker who has finished Advanced, Intermediate or Higher School in an equivalent profession or field, who has at least

four or five years of work experience, and who has passed a professional exam.

Article 102

The job of main technical manager in an organization which deals with the exploitation of mineral raw materials may be performed by a worker who has finished Advanced School in a corresponding profession; who has five years of work experience; who has passed a professional exam; who has, for at least two years, performed the job of technical manager in a pit, an open cast mine or a project for the preparation of mineral raw materials (mill?); who has worked in a mine safety service; and a service for development or planning (mine engineering office?).

Article 103

The job of main technical manager in an organization which deals with the exploitation of oil and gas may be performed by a worker who fulfills the conditions from Article 102 of this law, and who has performed the job of technical manager in projects for oil or gas exploitation for at least three years.

Article 104

The job of independent pit surveying, or surveying open dumps, may be performed by a worker who has finished Intermediate mining or Geodesy School, who has had two years of work experience, and who has passed a professional exam.

Article 105

In the case of pits endangered by methane or dangerous coal dust, jobs in Articles 102 and 104 of this Law can be done only by

workers who have spent at least one year in pits endangered by methane or dangerous coal dust.

Article 106

By work experience, described in Articles 100, 101, 103, and 104 of this Law, is meant experience gained after graduating, performing jobs in an equivalent branch of mining. By work experience for technical management in electricity of mechanics, and for technical management in civil engineering-construction or other specific jobs, is meant experience gained after graduating, doing equivalent mining jobs.

Article 107

The program and passing requirements for the professional exam are determined by a Self-Management Contract, drawn up by the Council of Federation of Labor Units of the Socialist Republic of Serbia; the Economic Chamber of the Socialist Republic of Serbia; organizations of associated labor which plan and carry out the technical control of mining projects; and organizations which exploit mineral raw materials.

VII Mine Inspection

1. Organization

Article 108

Mine inspection jobs are carried out by the Republic Managing Authorities in charge of mine inspection, except for jobs which are, according to this Law, under the authority of the Municipal Managing Authorities in charge of mine inspection.

Article 109

Mine inspection jobs are carried out by mine inspectors. Inspectors perform mine inspection jobs independently and act according to their duties and rights as determined by this Law and other regulations.

Article 110

A mine inspector may be a mining engineering graduate with at least five years work experience in organizations which exploit mineral raw materials, and who has passed a professional exam.

In addition to the conditions specified in Paragraph 1 of this Article, a mine inspector who supervises mining projects endangered by methane or dangerous coal dust must have at least one year of work experience in pits with methane and dangerous coal dust, or in mine inspection.

A mine inspector in charge of supervising the application of regulations for electric and mechanical installations and devices may be a mechanical engineering graduate, or a mining engineering graduate in an equivalent field, with at least five years of work experience, who has passed a professional examination.

ROCKSALT MINE "TUSANJ" - TUZLA

The construction of Rocksalt Mine "Tusanj" was initiated in 1948 by hoist shaft sinking. The shaft was completed in 1967. Over the period 1952 to 1964 the ventilation shaft was constructed. Currently mining activities are carried out on horizon -250 m and -190 m. To date 5,500 m of drifts have been driven in inclined underground rooms, as well as 1,152 m of shafts. Mining is performed at a depth of about 500 m by the chamber-and-pillar

method. Chamber dimensions are 100x10 m. Blasted material is loaded manually or by the use of mechanical loaders.

A central ventilation system is used. The fresh air stream flows down the hoist shaft to the -250 m horizon and from there through a raise to the -190 m horizon. The air stream is discharged to the surface through the ventilation shaft. The air volume is approximately 1,200 m³/min. The principal mine fan capacity is 1,800 m³/min, while the depression is 80 mm water gauge.

Methane occurs only in laminated bituminous and anhydritic schists.

Hitherto in Mine "Tusanj" the categorization of underground rooms regarding methane hazard was carried out three times. During each categorization, only one mine working was found with methane removal above the allowed concentration specified by regulations, and hence the mine was declared a gassy one. During the last categorization carried out in February and March 1970, methane concentration measurements were completed at 10 measurement locations including all underground rooms. During categorization a methane concentration of 1.5% was determined only after 24 hours of separate fan non-operation at the development working No 251 M. On the basis of this data, drive development workings were classified into the III level, and all remaining underground rooms into the I level of methane hazard.

During normal operation of the principal mine fan no methane occurrences were found in any one of the flow ventilated underground rooms.

The complex methane balance for the mine yielded a gassiness value of "0" for all flow ventilated rooms.

PROBLEMS OF SALT MINE "TUSANJ" VENTILATION*

1. Introduction

Opening of Salt Mine "Tusanj", as well as initiation of exploitation operations, indicated a series of features compared with coal mine operations which had a specific effect on ventilation problems.

Along with the deposit exploration and development, ventilation problems were solved by using foreign experience, carrying out studies and drawing up designs, and by inviting the opinions of professionals employed in the mine and competent state authorities.

The following are emphasized as the most significant features related to ventilation problems.

- large volume mining chambers required significant amounts of air in order to achieve appropriate air flow velocities;
- the criteria provided by existing regulations for gassy mines ventilation control, methane concentration control, blasting in gassy mines, etc. were not fully applicable to the Mine "Tusanj";
- climatic conditions specified for coal mines regarding underground mine air temperature also were not fully

* 1st Yugoslav Symposium on Ventilation in Mining and Industry - 1973
(Authors: Ivan Jakovec, min. eng., Abdulah Basic, min. eng., and
Seid Saracevic, min. eng.).

achievable in Mine "Tusanj" (frequently the dry thermometer temperature exceeded 28°C, while the wet thermometer indicated values far below 23°C);

- valuable mined material is very hygroscopic. This property and the variable pit air moisture content caused by seasonal temperature variations and external air humidity have a pronounced effect on the pit microclimatic conditions and the state of ventilation;
- the existence of blind headings and large volume haulage drifts and chambers required the use of a significant number of separate fans;
- the method of occurrence and the amount of gases, and other influential factors on sudden gas intrushes, were unknown.

To facilitate the pointing out of numerous problems related to ventilation, we limit ourselves to their outline and a review of common solutions.

2. General information on the deposit

The Tuzla rocksalt deposit is located northeast of the town Tuzla, and has a Dinaric * strike direction and a surface area of approximately 1.5 km². Along the strike it ranges over about 2.5 km with a width of up to 0.6 km. From the east to the west it is divided into three mining districts: Trnovac, Hukalo and Tusanj. In the first two, mining is carried out by deep boreholes and saline wells, and in Tusanj by underground mining.

* possibly a reference to the mountains to the south-west.

Exploitation of saline water in Tuzla dates back to the oldest history of this region. Initial serious explorations in the Tuzla surroundings, as well as saline water exploitation by saline wells, date back to the end of the last century. They were intensified in 1885, especially in the mining districts Hukalo and Trnovac. The initial attempt to open a salt deposit in the mining district Trnovac by a shaft failed in 1895 when it was flooded at a depth of 166 m due to a sudden water inflow.

Exploration of the deposit's western portion (mining district "Tusanj") was initiated in 1935 by exploratory boreholes, and by 1938 ten boreholes were drilled. On the basis of data obtained, the Commission of the Federal Ministry of Mining proposed the change over to underground mining in mining district Tusanj.

The construction of underground mine "Tusanj" was started in 1948 by hoist shaft sinking and in 1951 by ventilation shaft sinking.

The hoist shaft was flooded twice, in 1952 at a depth of 257 m, and in 1964 at a depth of 281 m.

The ventilation shaft was flooded in 1956 at a depth of 290.63 m. Up to the first flooding both shafts were constructed by a classical method. After unsuccessful attempts at reclamation and continuation of sinking operations by the classical method, the ground-freezing method was introduced with the aid of Polish experts and equipment.

The ventilation shaft was completed in 1964 and the hoist shaft in 1967, and for all practical purposes, the exploratory-development and exploitation operations began then.

Mine "Tusanj" was opened by two shafts each 542 m deep, and developed by a principal horizon at 520 m (H-250 m) and a sub-horizon at 460 m (H-290 m).

The deposit geological structure includes lower, middle and upper Miocene sediments, as well as Quaternary river detritus of Rivers Jala and Solina and their tributaries.

The salt formation was precipitated in a lagoon type basin and is represented by the so-called "striplike" series, composed of striplike marls and marly slates, and less frequently of pelitic sandstone partings. Rocksalt, Glauber's salts, anhydrite and gypsum strata are associated with the striplike series, and due to this it was declared a salt formation.

The salt deposit was classified into five salt series of variable thickness and grade, both along strike and dip, and due to this it was categorized as a bedded-lenticular type of deposit.

First salt series has a thickness of 15-17 m. It is checkered by marl partings in upper and lower sections. It spreads over the entire deposit and it is being leached by saline wells. The footwall consists of water-bearing quartz-clayey-halitic pelite with a uniform thickness of about 14 m. Exploitation of this series is not proposed in mining district Tusanj.

Second salt series is separated by a series of marls 8 m thick into an upper and a lower one. Its total thickness is 70 m and it is checkered by marly partings and inclusions, but is still the purest salt series of the deposit.

Third salt "B" series has a thickness of about 30 m. It represents an alternating sequence of anhydritic marl and salt partings with an approximate 50:50 ratio. Glauber salt is present in the series' lower section.

Third salt "A" series has a thickness of approximately 100 m. It is similar to the third "B" series, but with less frequent Glauber salt partings.

Fourth salt series is checkered with marl partings. It is characterized by a high presence of Glauber salt, particularly in the lower section. Its overall thickness is about 70 m. It is not proposed for underground mining.

The described salt series are separated by series of striplike and laminar bituminous, anhydritic and clayey marls, so that the overall thickness of all series, including the marly sub-series, in Tusanj is approximately 450 m.

Five water-bearing horizons are distinguishable in the deposit, the first three being above the salt, with a thickness of about 30 m, a water pressure of 25 atm, and an influx of 295 to 420 litres/min.

The fourth water-bearing horizon is in pelite, i.e. in the footwall of the first salt series, with a water pressure of 3 atm and an influx of 0.5 litres/min. The fifth water-bearing horizon is in the footwall, located in the salt formation floor, with a thickness of 30 m, a water pressure of 60 atm, and an influx of 4 litres/min.

From the foregoing it is evident that the Tuzla salt deposit is a special one, both in its geological and tectonic structure and

its hydrogeological characteristics. It imposes entirely new important questions and problems regarding mine design and exploitation.

3. Mine "Tusanj" Ventilation*

Mine "Tusanj" is ventilated mechanically by a negative-pressure system with an axial fan mounted in the ventilation shaft. In regard to the positions of the hoist and ventilation shafts, the mine has a central ventilation system.

The system of air stream distribution falls into a complex diagonal system. The method of air stream handling is ingoing-descending.

Fresh air is introduced into the mine through adits and the shaft, and finally through the hoist shaft to the subhorizon -190 (level MH-190), where the air stream splits into two parts.

A smaller portion of the air stream ($80 \text{ m}^3/\text{min}$) flows into MH-190 for ventilating the auxiliary underground rooms (locomotive depot and electrical chamber), and when spent goes into the ventilation shaft. The larger portion of the air stream ($1120 \text{ m}^3/\text{min}$) flows through the shaft to the level of horizon -250 (H-250) where it is split into two branches. One part of the air stream, amounting to $120 \text{ m}^3/\text{min}$, ventilates the depot and electrical chamber, and the larger part ($1000 \text{ m}^3/\text{min}$) serves to ventilate horizon -250. The air stream branch serving H-250 ventilation splits into two branches.

* The diagram accompanying this section is captioned in Serbo-Croat, and is not of reproducible quality.

One branch, amounting to $25 \text{ m}^3/\text{min}$, flows through drift 256 and ventilates chambers No 255/3, 255/2 and 255/1, and then flows through raise No. 6 to subhorizon MH-190. The other, larger air stream branch (973 m^3 per min), flows through drift 254 and ventilates mining chambers 254/g, 5, 3 and then flows through raise No. 2 to subhorizon MH-190.

IN MH-190 the air stream from raise 2 flows through drift TPZ-1 towards raise U-8, and at the raise splits into two branches. One part of the air stream ($625 \text{ m}^3/\text{min}$) flows through drift 194 and chambers 192/5, and 192/1 and 192/4, through the ventilation and stowing roadway of level -180 and raise U-7, descends into haulage roadway 194, ventilates chambers 191/4 and 191/5, flows into the main haulage roadway 191 where it joins the air stream from raise U-6, and as spent flows towards the ventilation shaft.

The second air stream portion ($350 \text{ m}^3/\text{min}$) flows through raise U-8 to level -170, and then flows through the haulage roadway and chamber drifts 170/2 and chamber 170/3 into the blind shaft SC-2 and through it into MH-190.

The spent air stream flowing through shaft 20-2 and roadway 192 towards the ventilation shaft pit-bottom joins the air stream flowing from the main haulage roadway, and then goes into the ventilation shaft where it combines with the air stream coming from H-250 and, as spent, is discharged through the ventilation shaft.

3.1 Development roadheads ventilation

Ventilation of development roadheads is carried out by axial fans with an output of $145 \text{ m}^3/\text{min}$ and plastic ventilation ducts, $\varnothing 300$ mm.

3.2 Mining stopes ventilation

Depending upon the mining chamber locations and their dimensions, chamber ventilation may be:

1. Flowing, due to the general mine depression;
2. By separate fans, and
3. Combined.

4. Ventilation Problems

4.1 Occurrence of Gases

4.1.1 General generic properties of gases in the deposit.

In the rocksalt deposit "Tusanj" the occurrence of the following gases was confirmed during exploratory and exploratory-development operations:

methane, hydrogen sulphide, carbon dioxide, carbon monoxide, and ammonia.

Without going into details of the determination of the genesis of the above gases, the lithologic members of the salt series with which they are associated are outlined.

- Methane occurs in laminar bituminous and anhydritic clayey marls in the footwall of the II, IIB and IIIA series. Methane also occurs in smaller amounts in bituminous rocksalt partings.

- Hydrogen sulphide is associated with granular, medium and coarse crystalline white salt.
- Carbon dioxide, carbon monoxide, and ammonia were found, but it was not determined with which lithologic members of the salt series they are associated.

4.1.2 Gas occurrences

The first gas occurrence was recorded during drilling Exploratory Borehole I at a depth of 492.30 m where a gas inrush took place. During the first day of the occurrence about 1.78 m³/min of gas was separated and after five days the intensity of gas separation fell to 0.02 m³/min.

By chemical analysis the following gas composition was determined:

methane	86.66%
nitrogen	7.7%
oxygen	2.0%
carbon dioxide	0.5%
carbon monoxide	0.2%

The strata through which the borehole passed were composed of striplike salt with marl partings.

Methane occurrences were noted during hoist shaft sinking between HM-190 and H-250. In development faces with normal ventilation the methane concentrations ranged from 0.1% to 1.0%. Results of methane separation measurements upon blasting, compared to concentrations prior to blasting indicate that methane concentra-

tions upon blasting ranged from 0.05% to 1.2%. Specific methane separation ($\text{m}^3 \text{CH}_4/\text{t}$) amounted to between 0.04 $\text{m}^3 \text{CH}_4/\text{t}$ and 1.74 $\text{m}^3 \text{CH}_4/\text{t}$.

The results obtained lead to the conclusion that salt carries small amounts of methane poorly bound (sorbed)*, filling up pores and voids. During mining operations it rapidly separates into the mine atmosphere, so that its concentration upon blasting quite rapidly falls to a negligible level.

To date in mine "Tusanj" no occurrences of primary and secondary gas leaks from fissures, and no occurrences classifiable as so-called gas intrushes have been noted.

* *This is an exact reproduction of the original translation.*

APPENDIX XIII

SUDDEN OUTBURSTS OF SALT AND GAS

Note: This material has been translated and condensed from the writings of a number of East German researchers (13). The original material may be protected by copyright law. This section is included for those readers who may be interested in the phenomena of violent outbursts of gas and particulate matter.

1.0 HISTORICAL OVERVIEW

In mines in the Kali-Werra, Hannover, and Kali-Sudharz regions of Germany, outbursts of salt and gas have been recorded for many years. These events in the Kali-Werra district have occurred since 1895. There has been a constant increase in occurrences since then as mine workings have been extended south towards the Rhone Mountains, whose tertiary magmatism is closely associated with the presence of outburst gases. Approximately 30,000 outbursts have occurred there since 1962. The Desdemona mine in the Hannover region has been closed for many years; however, there were a few sudden outbursts there before 1907. The outburst cavities measured between one and five meters in length. There are no other known incidents in this region. The first sudden outbursts in the Kali-Sudharz region occurred in 1913 in Wilhelms-hall in Dinglestadt, which is no longer in operation. Although the outbursts became more significant after 1950 the number and intensity never approached that of the Kali-Werra district outbursts.

Outbursts in other countries have only occurred relatively recently. Outbursts began in the Kujawy salt mines in Poland in 1954, and even later in the Koma potash mines in the Soviet Union.

With the founding of the research group "Mineral-Bound Gases" in the DDR* in 1958, scientific research into the mechanism of, prediction of, and fight against outbursts began on a large scale. Earlier work in this field did not effectively explain the outburst mechanism or provide methods of control. It was generally believed that shock impulses caused outbursts; in particular, that blasting was necessary to release outbursts. The outburst mechanisms and how they interacted were poorly understood. Both seismic and electrical methods of outburst prediction were tried, but without success. The systematic control of outbursts began only after the tragedy in Kaiserode II/III in 1938. The mines began evacuating the work forces during blasting, and safety measures were later incorporated into the work procedures. Research by the "Mineral-Bound Gases" group has led to significant advances in the explanation, prediction, and control of sudden outbursts.

The reader is referred to Eckhart, Gimm and Thoma (1966) for a complete description of the theory, aero-dynamics, prediction and control of outbursts in all branches of mining (13).

2.0 DESCRIPTION OF THE SUDDEN OUTBURST OF SALT AND GAS

2.1 Werra Potash Mine

A statistical summary of sudden outbursts, with over 100 t. of salt refuse, in the DDR part of the Werra district is shown in Table 1. As outbursts have only been systematically recorded since 1960, and only incomplete data is available from earlier years, the actual number of outbursts is probably larger than is indicated by this table.

* *Deutsche Demokratische Republik (East Germany).*

The stratigraphic horizons of the Werra salt deposit, with special regard to the Marx-Engels mine workings, are shown schematically in Figure 1. The horizons shown are:

1. Upper Werra rock salt
2. Upper accompanying seam to the Hessen seam
3. Upper potash stratus (Hessen seam)
4. Middle Werra rock salt
5. Lower potash seam (Thuringen seam)
6. Lower Werra rock salt.

The horizons are not equally prone to outbursts. Outburst occurrences are limited for the most part to metamorphosed zones in which alteration has been caused by ascending water transporting gas. The disturbed zones associated with outburst-active regions strike mainly between NNW and NNE. The gas-transporting water infiltrates the horizons in a horizontal direction from these disturbed zones. The alteration is of significantly greater extent in the potash seams (10 to 100m) than in the rock salt seams (10m maximum) because of the different solubilities of rock salt and potash salt (originally probably mainly carnallite). In Table 2 the outburst tendency in the different seams in 1963 and 1964 is shown. Horizons No. 2 and No. 5, the Hessen accompanying seam and the Thuringen seam, show the highest outburst tendency, and the most severe outbursts occur in the Thuringen seam. In the potash seams the outbursts are in sylvite, which is always secondary, and in secondary carnallite. In the rock salt horizons (Nos. 1, 4, and 6) outbursts occur only in metamorphosed coarse-crystal zones and in zones in which thin, potash bearing horizons are primarily imbedded, or those in which secondary impressions of potash strata are present.

As mentioned previously, the formation of outburst-active zones is closely associated with the Oligocene basaltic magmatism of the Rhone. The gases, which well up in association with steam

TABLE 1: Statistics of sudden outbursts of salt and gas with over 100t of salt refuse in the Werra District to 1965

Mine	Number of Outbursts 100-1000t	Number of Outbursts 1000-10000t	Number of Outburst over 10000t	Number of Outbursts Total	Average Outburst Intensity in t/outburst	Largest Outburst In t.
Marx-Engels	141	100	3	244	1700	20000
Menzengraben	107	34	6	147	2470	100000
Thalmann II/III	35	7	1	43	1000	15000
Dietlas ¹⁾	28	5	-	33	550	3000
Springen	16	4	-	20	510	1800
Salzungen ¹⁾	3	-	-	3	440	720
Alexandershall	1	-	-	1	250	250
	331	150	10	491	-	-

¹⁾ Currently shut-down

TABLE 2: Dependence of the outburst frequency and intensity on the geologic position in the Werra District (Eckart, Gimm, Thoma, 1966)

Geologic Position		Outbursts ¹⁾		
No.	Stratigraphic Horizon	Facies	Number	Average Intensity in t/outburst
				Largest Outburst in t
1,2	Upper Werra rock salt and accompanying Hessen seam	sylvite	16	990
		secondary carnallite	6	550
		salt compounds	11	1160
		Recrystallized or secondary rock salt	4	1330
				3000
3	Hessen seam	kieserite	9	1700
				7500
4	Middle Werra rock salt	secondary rock salt	2	410
				600
5	Thuringen seam	sylvite	24	2750
		secondary carnallite	9	660
				18000
				2000
6	Lower Werra rock salt	secondary rock salt	1	450
				450
TOTAL			82	

¹⁾ Only outbursts with over 100t of salt refuse in 1963 and 1964

Fig. 1: Geologic position of sudden outbursts in different horizons of the Werra series (after Gimm, 1964).

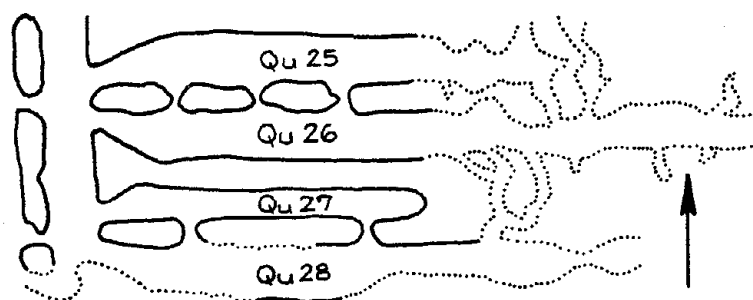
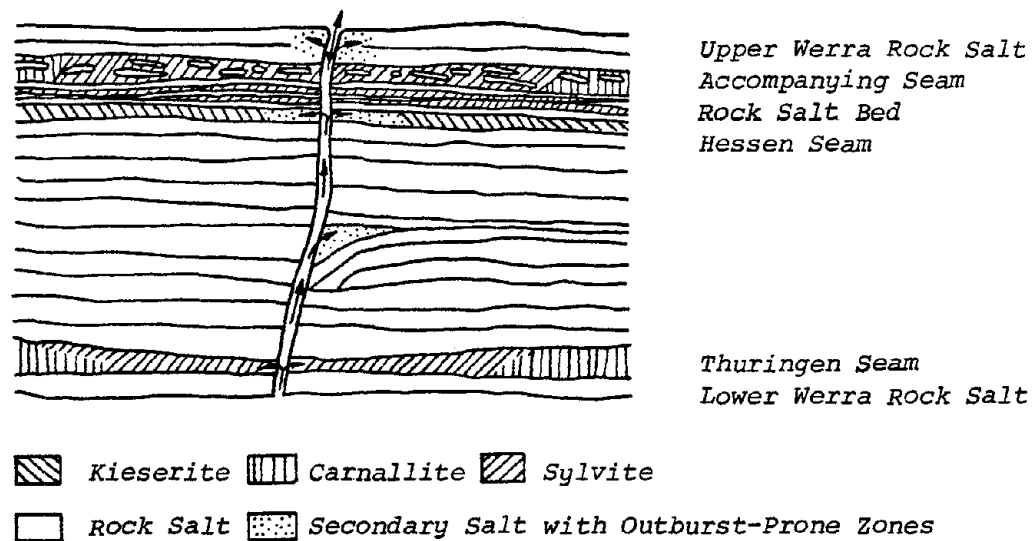


Fig. 2: Tube-shaped Outburst Cavity in the Menzengraben Mine (Thoma, 1963).

Rock Salt
0.2m Carnallite
2.5m Rock Salt

2.6m Carnallite
0.2m Rock Salt

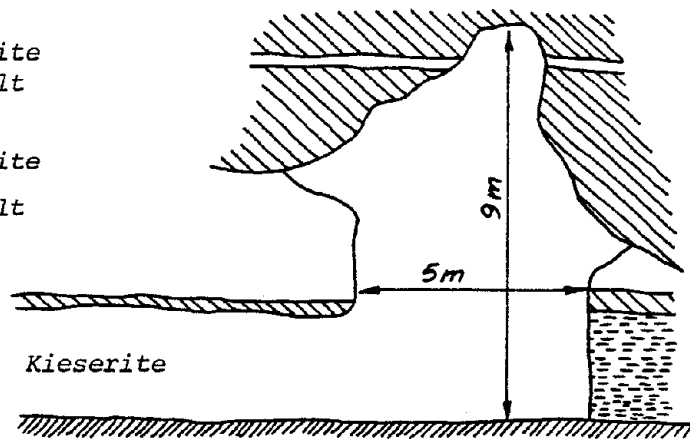


Fig. 3: Block-shaped Outburst in the Marx-Engels Mine
(Thoma, 1963)

and hot springs, are locked into the mineral structure during the metamorphosis of primary rock salt. Although part of the gas is accumulated interstitially, the majority is found intergranularly, in pore spaces between the individual mineral crystals. Larger amounts of gas are thought to be attributable to the solidification of large, concealed sub-volcanoes, and subsequent release of large quantities of residual solution and gas, rather than to the relatively small quantity of known effusive basalts. There is usually no immediate connection between outburst zones and basalt flows, because not enough gas-bearing water rises in all basalt flows, and because many disturbed zones above sub-volcanoes remain free of basalt under certain conditions.

Earlier, it was generally assumed that outburst gases were almost exclusively carbon dioxide with only minor impurities of aromatic hydrocarbons. Newer analytic research has indicated the presence of significant amounts of nitrogen and other gases as well as carbon dioxide (Table 3). The gas content varies between 3 and 20 m³ per tonne of salt refuse.*

There are essentially two types of outburst cavities; tube-shaped and block-shaped. Most are tube-shaped; that is, the length of the cavity is many times its width (Figure 2). Block-shaped outburst cavities result from mining the roof (hangingwall) of the associated seam of the upper potash stratum (Figure 3). This type of outburst can occur in regions of relatively low outburst activity because of the additional contributing force of gravity. Larger outbursts of both types are often associated with violent roof falls in which immense, partly rubble-filled cavities are formed. An interesting phenomenon, the splintering of the wall face and, to some extent, of the hangingwall and pavement also, can be seen in outburst cavities. The splintering is associated

* Method by which these figures were arrived at is not known to the translators.

TABLE 3: Composition of the mineral bound gases in the Werra District, resulting from gas analytical tests on samples from the Marx-Engels Mine (Hoffman, 1963)

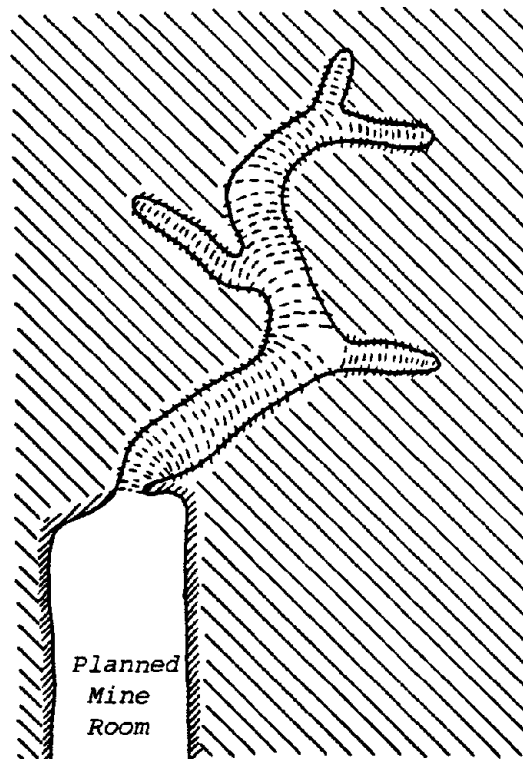
Kind of Gas	Number of tested samples	Average	Maximum	Minimum
CO ₂	48	84,0	95,0	45,0
N ₂	47	14,0	50,0	4,0
CH ₄	47	1,0	9,5	0,1
O ₂	2	0,5	0,7	0,2
Ar	2	0,2	0,3	0,1
H ₂	1		0,4	
He	1		0,5	
CH ₄	2		0,01 ¹⁾	
CO	47	0,05 ¹⁾		
H ₂ S	3		0,1	

¹⁾ Lower limit of evidence

with the tube-shaped crack system that forms during an outburst and precedes the outburst front. The laminae are symmetric to the long axis of the cavity and run convex to the outburst direction (Figure 4).

Almost all outbursts in the Werra district have been released by blasting. The domination of blasting work as the cause of release can be attributed to the almost exclusive use of drilling and blasting as the mining method. There have been no confirmed cases of delayed outbursts associated with this mining method. Sudden outbursts in this district have also been released by mechanical mining methods. An outburst of 50 t. occurred during the sinking of the Marx-Engels shaft No. 2 on November 25, 1961 while a cutter was being operated. Two small outbursts (under 1 t.) occurred in the Marx-Engels mine on April 24, 1959 during cutting by a gallery-driving-machine. Outbursts of up to 6 t. occurred between 1928 and 1954 in the Menzengraben mine during the mining of carnallite, using mining hammers. It is also conceivable that outbursts could be released during extreme rock mechanical incidents such as rockbursts.

One of the worst outbursts of salt and gas occurred in the Kaiseroda II/III (since renamed Ernst Thalmann II/III) mine on July 30, 1938, in which 3700 t. of salt were ejected and approximately 50,000 m³ of gas were released. The outburst occurred during blasting in an exploration gallery on the second footwall in the immediate vicinity of a raise leading to the upper footwall. The shots were set off by remote control from the first footwall, to where the 11-man mine work force had been pulled back. The outburst-released gas quickly reached the upper footwall and spread out over 1.4 km towards the fresh air stream. The miners were overcome by gas and died while trying to flee. Extensive material damage occurred in the second footwall and development work there was delayed for half a year.



Outburst cavity with
lamination of the
walls.

Fig. 4: Schematic reconstruction of the crack system that is
formed by an outburst (Thoma, 1963).

The largest sudden outburst to date in the entire mine occurred on July 7, 1953 in the Menzengraben. The outburst occurred during blasting in the sylvite facies of the Thuringen seam after the work force had ascended to the surface. One hundred thousand tonnes of rock salt were ejected and about 100,000 m³ of gas were released in the outburst.* The mine could not contain such a large volume of gas, and it streamed out of the two existing 520 m deep shafts to the surface (for 25 minutes from the hoisting shaft). Three fatalities by asphyxiation due to gas-contamination were recorded, and the destruction of mining equipment was on a scale hitherto unknown.

Fatal accidents and catastrophic material damage caused by sudden outbursts have not happened for over ten years in the Werra district because of the continually improving outburst control methods.

2.2 Sudharz Potash Mine

Statistics on sudden outbursts of salt and gas (with over 100t. of salt refuse) in the Sudharz district through 1965 are given in Table 4. The systematic documentation of outbursts began only in 1961; information on earlier outbursts is somewhat fragmentary. The outburst frequency is similar to that in the Werra district, however the total output is significantly less and the size of the outbursts significantly smaller. In the biggest outburst to date 4000 t. of salt were ejected; outbursts resulting in over 1000 t. of salt refuse are extremely rare. Particularly favorable geologic conditions for the infiltration of mineral-bound gases exist in the western part of the Sudharz district (Thomas Muntzer mine).

* *These are the figures supplied by the original German source.*

TABLE 4: Statistics of sudden outbursts of salt and gas with over 100t of
of salt refuse in the Sudharz District up to 1965

Mine	Number of Outbursts 100-1000t	Number of Outbursts over 10000t	Number of Outbursts Total	Average Outbursts Intensity in t/outburst	Largest Outbursts in t.
Thomas Muntzer	116	9	125	410	4000
Karl Liebknecht	6	-	6	240	500
Gluckauf	1	-	1	100	100
Wilhelmshall ¹⁾	1	-	1	100	100
	124	9	133	-	-

¹⁾ Currently shut down

Large-scale tectonically disturbed zones from the Saxon age resulted in favorable conditions for the welling-up of gas-bearing water in the Sudharz district, analagous to the situation in the Werra district. A factor that further favors the welling-up of gas-bearing water is the relatively limited extent of older rock salt. The mechanism of gas infiltration is the same as in the Werra district, but the stratigraphic position of outbursts is different. In the Sudharz, the Stabfurt series, which contains the Stabfurt potash seam, is prone to outbursts. There, just as in the Werra series, favorable physical conditions for gas infiltration exist in zones of extensive recrystallization, in the region of facies boundaries. Local tectonic factors have also played an important role. An overview of the dependence of outbursts on geologic position is given in Table 5 for the Thomas Muntzen mine. The largest outbursts occurred in sylvinitic kieserite as a result of strong tectonic stressing of the seam.

The source of the outburst gas in the Sudharz region is organic. The gas content in outbursts is about 3 to 5 m³ of gas per tonne of salt refuse.

The outburst type in the Sudharz district is mainly tube-shaped. The splintering of the outburst face occurs in the same way as it does in the Werra district.

The main cause of outburst release in the Sudharz is blasting. Delayed outbursts have not been recorded. Some small outbursts (up to 6t. of ejected salt) have been released by gallery-driving machines. There have been only minor effects on operating practice. Only in extremely large outbursts, for example, the 4000 t. outburst that occurred March 26, 1954 in the Thomas Muntzer mine, has there been damage to equipment. To date there have been no casualties due to sudden outbursts in the entire district. This can be attributed to the withdrawal of the mine work force during blasting, based on previous experience in the Werra district.

TABLE 5: Dependence of the outburst frequency and intensity on the geologic position in the Sudharz District (Eckart, Gimm, Thoma, 1966)

GEOLOGIC POSITION		OUTBURSTS 1)				
Facies Boundary	Facies	Distance from Facies Boundary	Tectonic Conditions	Number	Average Intensity in t/outburst	Largest Outburst
sylvinitic	sylvinitic	0.....100	normal stratification	49	147	1500
kieserite/impo- ishment	kieserite	0.....200	+ strongly stressed	17	450	1600
	impo- ishment	0.....75	(ditto)	8	137	440
sylvinitic kieserite/salt compounds(?) salt hybrid salts)compounds(?)	sylvinitic kieserite	0.....100	normal stratification	32	124	640
	locally disturbed	0.....50		35	144	660
TOTAL				141		

1) Only outbursts with over 5t. of salt refuse in the years 1960-1962

2.3 FURTHER OCCURRENCES

There have been outbursts in Polish and Soviet mines. They are, however, of significantly less importance than those already described.

2.3.1 Polish Rock Salt Mines

In the Kujawy region of Poland there have been sudden outbursts of salt and gas since 1954. So far about 40 outbursts have been registered, most under 100 t. In the largest so far 800 t. of salt refuse were ejected. The outburst occurrence, and also the source and composition of the outburst gas, are very similar to those in the Sudharz. Especially noteworthy are two outbursts, one with over 100 t. of salt refuse, that occurred in Inowroclaw during debrining.

In the Bochnia mine (Carpathian formation) a sudden outburst of 200 t. of sandstone and methane occurred, with an associated firedamp explosion, causing four deaths.

2.3.2 Soviet Potash Mines

In the Solikamsk and Berczniki mines in the upper Koma there are sudden outbursts of salt and gas, as well as occurrences of free gas. The main components of the mineral-bound gases are nitrogen and oxygen, followed by methane and carbon dioxide. The outburst potential of the gas-enriched salt (mostly carnallite) is small, so that outbursts occur primarily from the hanging wall with the assistance of gravity. Up to 1000 t. of rock salt can be released in this way. There are also small outbursts at the working faces. These are usually released by blasting; however, in earlier years smaller outbursts were caused by mining hammers, which now may no longer be used.

2.4 OUTBURST MECHANISM

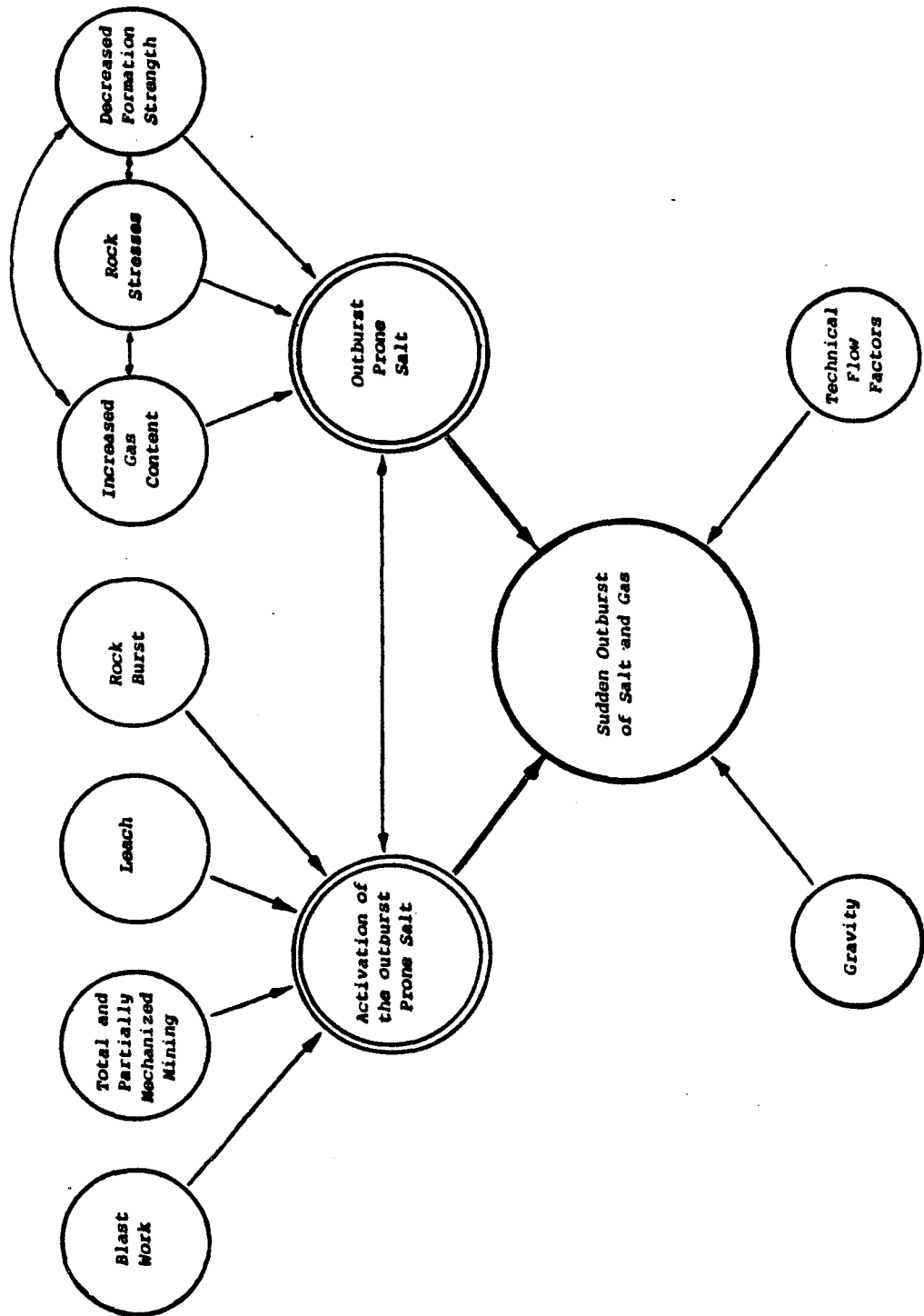
The previously accepted explanation for salt and gas outbursts, impulse theory, can be considered invalid because salt mine outbursts have been triggered by almost every mining method used. Blast impulses are not necessary for the release of outbursts. In the modern view of the outburst mechanism the complex character of the phenomenon and the interaction of separate factors are taken into account.

Modern theory is based on a careful evaluation of observations and experience in mines, and on many experiments both in situ and in the laboratory. Figure 5 presents a schematic summary of modern outburst theory. Outburst-prone salt differs from "normal" rock salt by its unique state of stress that arises through the interaction of a number of factors. When a zone which is outburst-prone is exposed by mining or by an extreme rock mechanical event, the change in the stress field releases the outburst.

2.4.1 Contributing Factors

As a result of the metamorphosis by gassy solutions, gas infiltration can occur in secondary rock salt. The gas may have either a juvenile (that is, derived from sources within the earth and coming to the surface for the first time) or an organic origin. Most of the gas (over 90%) is confined in microscopic cavities between the crystals (intergranular union) and the rest is within the crystals themselves (intragranular union). Confined carbon dioxide generally remains fluid. Research into the structure has shown that the gas inclusions are not random, but are oriented in certain directions. The results of these measurements, however, gave no criterion for the inclusion of the carbon dioxide molecules in the crystal lattice. The concentration of mineral-bound gases in outburst-prone zones is approximately between 3 and 20 m³ of gas per tonne of salt.

FIG 5: Schematic representation of the outburst mechanism (after Eckart, 1965)



These outburst-prone zones, with significantly higher gas content than surrounding "normal" rock salt, are distributed more or less randomly. Rock-mechanically the outburst-prone zones are different from normal rock-salt in the following ways:

- lower tensile strength
- greater tendency toward brittle fracture by splintering
- the release of noticeable amounts of energy in brittle fracture.

In the undisturbed rock mass, that is, far enough from the mine, there is a three-dimensional state of stress. Rock mechanical stresses and internal gas stresses are in equilibrium. The confined gas can be freed only by the direct exposure of the outburst-prone zone or by a very close mine structure causing a transition from the three-dimensional to a two-dimensional state of stress, with the associated unloading allowing a shear strain to develop.

The aerodynamic factors that determine the flow of the salt-gas stream during an outburst are, among others, the amount and intensity of the streaming out of the salt and gas mass, and the speed of the flow developed by the static and dynamic forces combined with the forces of resistance.

Under certain conditions gravity may also play a role. Where the seam thickness is large, with the outburst-prone zone in the hanging wall, the available energy is higher because of gravitational forces. Further, especially if the mine has large dimensions, tensile forces can play a contributing role. Because the tensile strength of rock salt is only a fraction of the compressive strength, even a few gas inclusions can greatly decrease the strength. A higher danger of roof falls exists when initiated roof falls can intensify the potential for outbursts, so that even weakly outburst-prone rock can be violently released. If the

amount of gas-infiltration is too small, then aerodynamic transport does not occur. At the onset of a true outburst gravity operates as an additional accelerating force, causing the saltgas mixture to flow down, thus exploiting the force of gravity.

2.4.2 Initiation, Progression, and Conclusion of Outbursts

The rock mechanical initiation phase of a sudden outburst of salt and gas begins when the stress front, which moves ahead of the working face, enters an outburst-prone part of the rock mass. It is completely immaterial which mining method is employed. The state of stress associated with the mining (which is exactly the same as that caused by boring blast holes, but which in that case causes no outbursts) leads to outburst activity only when the exposure of the outburst-prone zone exceeds a certain critical minimum dimension. This could also occur during extreme rock mechanical incidents, such as rockbursts. In such cases there is no direct association with the mining process.

In the exposure region the primarily three-dimensional state of stress is transformed into an unstable two-dimensional state. The induced shear stresses in the direction of the free surface cause cracking and the release of gas, whereby the internal energy of the gas is mobilized. The splintering that is observed on the outburst faces (see Figure 4) represents the remnants of the rock mechanical initiation phase. The splintering extends to 1 m into the rock mass on the average, but can reach as far as 10 m. This indicates that the cracking precedes the outburst front and that the gas energy alone cannot release an outburst without this rock mechanical activation.

That the splintering that develops convex to the outburst front is truly a rock mechanical phenomenon can be proven by comparing observations and laboratory tests. The same exfoliation occurs, even without gas infiltration, if the rock mass in the vicinity

of the mine is so stressed that it can no longer support fracture-free deformation. Thus, practically the same exfoliation can be observed, for example, in especially intensely stressed pillars in salt mines. Similar experiences have been noted in deep mines also. Research in gas-free rock in the laboratory confirms that the relationship between load state and strength is crucial to the generation of the described exfoliation. This exfoliation also occurs if one drives a pilot hole in an area prone to outbursts.

During the rock mechanical preparation phase before outburst activation, the splintering penetrates the potential outburst zone with certain geometric and temporal parameters. If the speed and intensity of the splintering reach certain minimum values, that is, if enough gas is freed per unit time, and if the necessary streaming-out relationships occur, then the prerequisites for the splintering and disintegration of the rock salt, as well as for its being carried away, are present. The gas freed during the initial splintering contributes to the secondary rock disintegration, which in turn activates more gas. A salt-gas stream forms and the activated gas acts as a pneumatic transport system for carrying away the continually accumulating disintegrated rock salt. Thus new surfaces are continuously exposed, bringing about the necessary critical changes to the stress field. This event continues in the manner of a chain reaction.

The results of numerous seismo-acoustic measurements made in situ indicate that outbursts begin during blasting or at least immediately afterwards. The occurrence of delayed outbursts could not be confirmed. Over the duration of the outburst its strength is subject to oscillations. Figure 6 shows an example of an outburst in which there are three outburst phases, separated from each other by intermediate phases in which the typical outburst signal is missing. During the intermediate phases the exposure

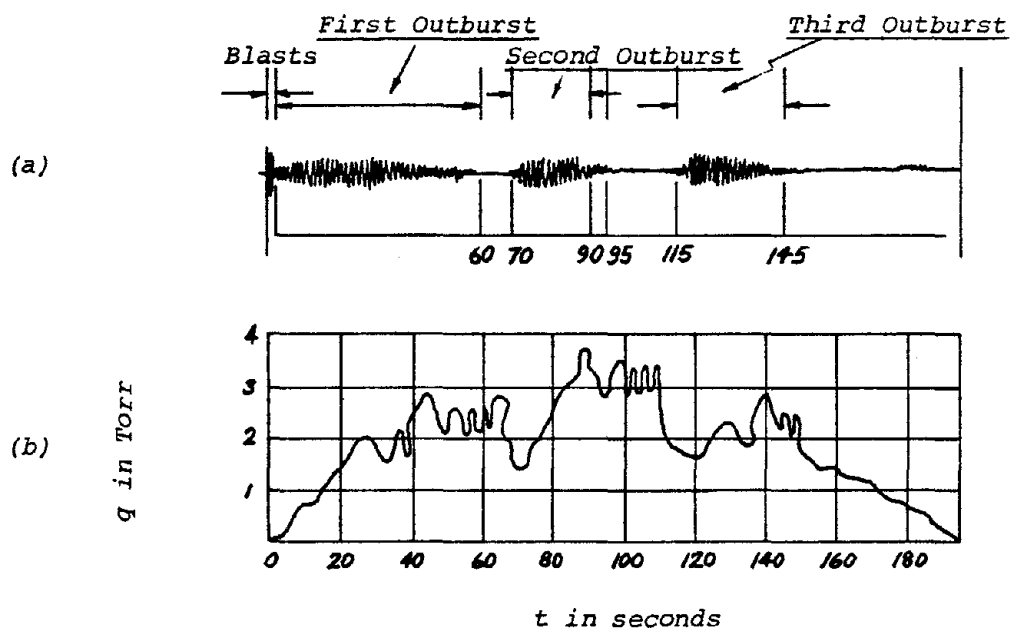


Fig. 6: Seismoacoustic (a) and aerodynamic (b) measurements of outbursts from January 14, 1962 in Menzengraben (salt refuse: 8000t) (after Gimm et al, 1963)

of sidewall and hangingwall surfaces causes an apparently far-reaching pre-fissuring that leads to the continuation of the outburst if the fissuring reaches other outburst-prone regions.

The penetration speed of the outburst front in the rock mass is about 0.7 to 2.4 m/sec. There is no relationship between the duration of the outburst and the amount of ejected salt refuse. Outbursts proceed with an intensity that changes with time, and it can be confirmed that this intensity, that is, the average salt mass ejected per unit time, varies with the mean diameter of the outburst opening in a systematic way that can be roughly described by a quadratic parabola (Figure 7).

The conclusion of the outburst event can have one of two causes. The outburst may reach an area in which the outburst factors are insufficient to sustain an active outburst condition, usually because of too small a gas content. The outburst can, however, halt before reaching an inactive zone if the outburst mechanism is disturbed.

This could occur, for example, if the aerodynamic transport of the ejected refuse does not ensue freely. The collected outburst salt, possibly augmented by roof fall refuse, may narrow the outburst opening, thus making the streaming-out relationship less favorable. A complete plugging up is not necessary, and has not been observed, but even a retardation of the aerodynamic process obstructs the progress of the outburst front. If the retardation is such that the outburst intensity, or the speed of the outburst front, becomes less than the minimum required to maintain the outburst, it can prematurely come to a halt. Outbursts that halt prematurely form a secondary unloaded and de-gassed protective layer about 0.5 m thick, with a higher strength than outburst-prone rock, that keeps the still outburst-prone rock mass stable. For the most part this layer is formed by the unloading of the inactivated outburst rock. A zone of already-fissured materials is created at the working face.

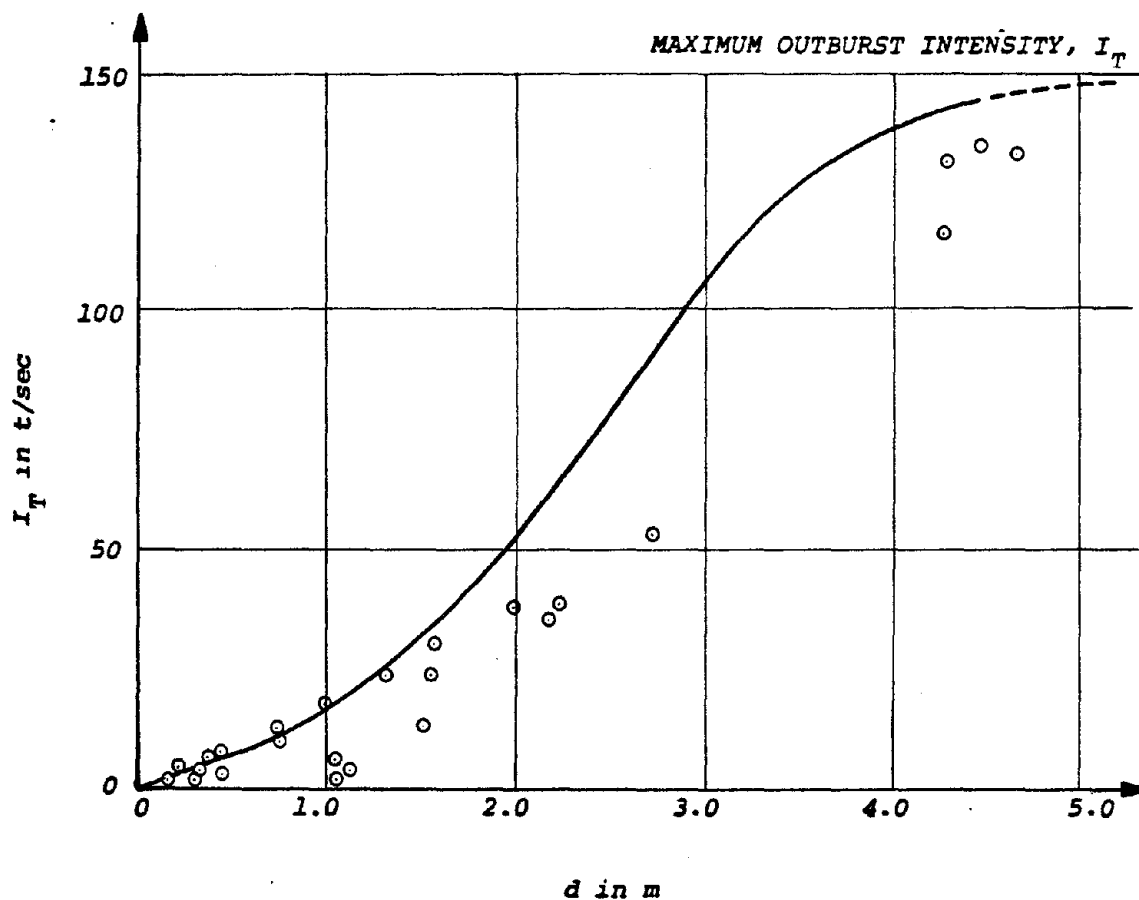


Fig.7: Time-varying outburst intensity, I_T , in tonnes/sec as a function of the diameter, d , in meters, of a circle having the same area as that of the outburst cavity (after Marggraf).

Finally, a short comparison with rock bursts is presented. Gas outbursts and rockbursts are both extreme rock mechanical events that are distinguished from normal rock mass disturbances by their dynamic character, and by the freeing of noticeable amounts of energy. Even though in exceptional cases a rockburst can release a sudden outburst, the source of energy in the two cases is different. The energy released by a rockburst comes from gas-free rock, but while a sudden outburst may be initiated by rock mechanical events, the energy comes for the most part from the gas.

