Safety In Mines Research Advisory Committee

SIMRAC

DRAFT

Final Project Report

Title: DEVELOP INFORMATION AND TRAINING AIDS TO ASSIST ALL EMPLOYEES TO RECOGNIZE FRICTIONAL IGNITION HAZARDS

Author/s: J-W OBERHOLZER

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Executive Summary

This report describes the process followed in establishing training aids to make employees aware of the dangers of frictional hazards.

The actual outputs of the project are the training aids that will be used by trainers to transfer the knowledge. These are mainly presented in the trainer's manual attached to this report.

During the project's progress, many aspects of value with regard to the establishment of such material were experienced and these are also presented in this report.

Conclusions and recommendations are given that could be used to make future work of a similar nature more effective.

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Mr M. Du Plessis	Member of working group
Mr T. Barnard	Member of working group
Mr D. Nkosi	Member of working group
Mr Rorich	Member of working group
Mr M. Campbell	Member of working group
Mr P. Viljoen	Member of working group
Mr H. Moorcroft	Representing COLEEAG

The managers of Koornfontein and Douglas Collieries, who allowed the required footage to be shot underground.

The management of Miningtek and the staff of Kloppersbos who assisted and allowed night shots of the explosions to be taken.

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1 Introduction

Previous work done with the sponsorship of SIMRAC highlighted the need to address the frictional ignitions problem as it was deemed to be the most probable cause of serious explosions in underground collieries. Based on recommendations made by Phillips (Phillips, 1995) which emphasized the need for training, SIMRAC awarded a project to Miningtek to establish training aids that could be used to train employees at all levels on a mine to become aware of the hazard and about methods that can be employed to reduce the risk of frictional ignitions occurring.

This report, which is directed mainly at the members of the SIMCOL committee system, presents the process followed, the rationale behind the decisions that were taken and the final output of the project. It also gives reasons for recommended changes in the scope of the project.

2 Methodology

One of the most significant lessons that Miningtek (or COMRO) learned from previous work on establishing training or awareness packages is that the diversity of opinions of the sponsors can have a profound effect at the end of the project.

This is especially true in the case of visual material and material that has to be translated. Once a video has been compiled, and voice-overs and sound tracks have been added, even a small change can have serious implications. When the video has been translated into several languages and the soundtrack of each translated video has been linked with the visuals, then changes to the original script could easily necessitate the whole process having to be repeated. As most of the costs involved in producing a video are usually incurred in the final stages, the financial implications of late changes may be very severe.

To minimize the occurrence of late changes, a process of continual consultation was followed in the drawing up of the training aids. In this way the required changes became smaller as the work progressed.

To ensure compliance with the technical criteria, as well as acceptance and the quality of the product, work groups and consultants were used to evaluate the outputs from the project.

Each different training aid was developed in a slightly different way, as described below.

2.1 Choice of the training aids methodology

Although the original request for a project proposal specified the training aid methodology the project nevertheless included a re-examination of the most suitable methods for presenting such training.

Various alternatives for presenting the training material were investigated. These included industrial theatre, pure video productions and detailed manuals that would be suitable for self-study.

In determining the most suitable method, the following factors were considered to be of great importance:

- The training course had to utilize known technology.
- It was not necessary for the training aids to incorporate, or strive to devise, new technology.
- The literature base used in the report on frictional ignitions (Phillips, 1995) was deemed to be more than sufficient.
- The level of education of the target audience may vary from illiterates to post-graduates. (Although the original requirements for course attendance specified literacy, this was later changed to allow illiterates.)
- The course had to be able to be presented in four languages.
- The course had to be presented on a recurring basis so as to cater for staff turnover.

- The inability or reluctance of the mines to withdraw large numbers of staff at any one time to attend such a course had to be considered.

- The course had to be of a sufficient standard to meet the requirements of the MQA.

- The course had to be suitable for presentation by several parties, e.g. by mine staff or by a contractor on behalf of the mine.

2.2 The need to cater for modern day technology

Taking all these factors into consideration the course was designed to be presented by trainers in a similar way to that originally specified in the project proposal. (The way the training aids are presented is detailed in section 3.)

It should be noted that during the last meeting of the work group it was decided that there is a need to train the trainers so that they can tailor the subject matter to the level of the participants at a particular course.

2.3 Inclusion in the MQA

In the original project proposal it was specified that the course should be able to be included in the MQA. After the first workshop on the training aids, this specification was changed.

In the context of training to obtain a qualification, a pre-requirement for the participants has to be set. This is necessary to enable the trainers to achieve the required outcomes. However, it was decided that the course had to cater for illiterates, pre-requirements could not be accepted. The initial objectives of the course were therefore changed so that it would fit in with industry training. It is foreseen that once the subcommittees of the MQA have been established and are fully working, the training aids could be used to lead to a recognized qualification.

2.4 Written material

The written material was drawn up using the original specification and then later was changed to cater for the altered requirements of the working group. The following considerations were used in drawing up the material:

- The written material is mainly directed at the trainer who will use it to transfer the knowledge. Although material is supplied, the role of the trainer is pivotal in the process and will ultimately decide what material is used in the training situation.

- The training aids have to cater for two levels of audience: a senior level and a lower level, which could include illiterates.

- The audience can be considered to be reluctant readers so the material has to include as much visual matter as possible.

- The material has to be interactive so as to allow the trainer to tailor it to the audience or circumstances.

In the approval process that was followed, the curriculum was firstly approved in principle by COLEEAG representatives and by academics from the University of the Witwatersrand. Based on this draft material, visuals were drawn up and presented to a large industry workshop on frictional ignition training aids. At this workshop five representatives were nominated to evaluate the final draft of the material.

Also at the workshop, the main rationale of the course message was presented and accepted. (It was at this workshop that the scope of the training aids was changed to cope with lower-level participants. It was also decided that the senior-level material would be reduced to that supplied to the trainer.)

The final draft was presented to the working group at a workshop. Minimal changes were required. Prof. Phillips did the final review before it was presented to COLEEAG for consideration.

Translation of the workbook was done after this final review by Prof. Phillips.

2.5 Visual material

The visual material included in this course was deemed to be very important to the success that could be achieved with the course. Attention was given to the technical integrity of the drawings used. Before the drawings/slides were drawn up a study was made of suitable techniques for visualizing technical subjects as well as how to cater for the ethnic diversity of the audience. It was, however, accepted that lower-level participants, especially illiterates, would have difficulty in grasping some of the concepts from their visualization. The only way that this could be catered for was for the trainer to spend time on explaining the actual visual presentation.

To further ensure that the material was suitable, the majority of the drafts were presented to Prof. B Sauer of Carnegie Mellon to assess visual suitability. Based on the feedback received from her, as well as from the workshop, changes were required to the visualization of the main theme. These were implemented and presented to the working group who approved them.

To ensure that no confusion was created, the main visual concepts used in the slides and in the video were kept similar.

2.6 Video

A draft script was included in the proposal submitted to and accepted by SIMRAC. This draft was given to various people for comment. The altered script was then submitted to Prof. Sauer for her comments. Use of the video as a post-graduate project provided some sound recommendations. These were presented to the working group and the script and proposed visuals were then accepted with only minor changes. A draft video, using animation and footage of underground shots was made to which only slight changes were required. The group, however, recommended that aspects of dust reduction be incorporated into the video, and this was easily done. A final English draft was then sent to the members of the working group for evaluation. This video will also be presented to SIMCOL for consideration before the expense of translating the soundtrack into other languages is incurred.

3 Output

The output of this project is a set of training aids which can be used by a trainer on a mine. The following factors determined the way the output was devised.

- The reproduction of the training aids should not encumber SIMRAC or the project funds.
- The reproduction should be based on actual demand rather than on anticipated usage.
- Use should be made of modern-day electronic technology for storage. (This is also in keeping with the present SIMRAC strategy of distributing research reports.)
- The material should be interactive so that the trainer can alter, add to or delete any of the material as he wishes.

It was decided that all the training aids, except the video, would be presented on CD-ROM, using the latest version of the Microsoft Office suite of programs. The CD-ROM would contain the following material:

- Curriculum according to which the course is structured.
- Information required for the course. (This information can also be presented to more senior staff for reading.)
- Visual material. This material is in the form of a slide presentation in PowerPoint. All the slides have been left in presentation format, thereby allowing the trainer to adapt and change them.
- Trainer's recommendations. These are recommendations which can act as guidelines to the trainers when they prepare for the course.
- A workbook (in four languages) to be used by the participants when they attend the course.

- Reference material. This is a selection of the primary relevant literature on the subject of frictional ignitions. The material is presented in two ways: the first in the original scanned format and the second in compiled Word documents so that the trainer need only print them.

- A README document in Word format which explains the usage of the CD-ROM and the file names used on the CD-ROM.

- A master trainer's manual containing all the material in the curriculum, information, trainer's recommendations, English slides and English workbook arranged according to sessions. (This material is presented as an Appendix to this report for SIMRAC's approval.)

It is foreseen that any person with basic computer skills, a computer capable of running Microsoft Office 97 and a colourink jet printer would be able to reproduce the course.

The video will be presented in four languages, namely English, Afrikaans, Northern Sotho and Zulu. In addition, a short video showing the use of some of the demonstrations and experiments has been included. This video does not form part of the original project but has been made so that the trainer can visualize how some of the experiments are done. In the light of the need for training the trainer, the aspect of experiments will receive significant attention during the trainer's course.

Training of the trainer was never included in the project definition. Miningtek could provide this training on a commercial basis as and when the need arises.

4 Conclusions

It should be noted that there are no conclusions forthcoming from the frictional ignitions aspect. There are, however, some conclusions that can be drawn from the work done to establish the training aids.

It has become evident that courses where the technical content is specialized, but where the knowledge has to be transferred to workers with a lower level of technical competence, have to be drawn-up using a multi-disciplinary process. It has become very evident throughout the progress of this project that, on the whole, technologists are inadequately prepared for transferring the technological knowledge they possess to a mine audience. The level of transfer has to be reduced to the point where the technologist is no longer concerned with the details of his scientific field but with the fundamentals that the science is based on.

The characteristics of the audience cause the technologist difficulty in that the means he usually uses to transfer technology are not the most suitable for a mining audience. On the other hand, the normal and accepted training mechanisms cannot handle the necessary technical details.

The best way to handle the transfer and training process is to involve as many experts as the project can afford so that as wide a base as possible is used.

The process of making the contents acceptable to all is seriously constraining with regard to meeting deadlines. Based on previous experience and as confirmed in this project, the need to cater for a wide diversity of participants leads to a wide diversity of opinions and conflicting requirements. Because of the varied experience and objectives of members of such groups, the identification of pertinent points, aspects to be included and the way that these aspects should be presented always gives rise to a wide variety of requirements. In trying to satisfy all these requirements, the project is expanded and altered. This leads to work having to be redone and the milestone dates having to be extended.

The Outcomes Based Education methods have great potential for application in the transfer of information. Although it is imperative for the people involved to be fully aware of what is required, at present there is unfortunately very little assistance in this regard, in terms of both the outcomes and the methods used to assess them. Providers of both teaching and assessment at present have to rely on their own ingenuity to determine what would be the right process to follow.

With this lack of readily available information, the users of training should be cautioned against quick-fix providers who use old methods in a glossy format.

In designing training processes, methods that not only transfer the required information but also enhance the learner's understanding of the underlying science should be employed. In this way the training course will not only satisfy the requirements of the mining industry but at the same time enhance the abilities of the workers, as well as satisfying their need for knowledge.

It is evident that to enable training courses to be drawn up to satisfy the needs of the industry, new processes will have to be developed and more efficient methods devised. It is foreseen that greater use will have to be made of visual means to present the technological concepts. This is a field in which local expertise is not readily available and could very well be a subject for investigation through the SIMRAC process.

5 Recommendations

If further projects like this one are to be done in future, a method whereby the course requirements are specified well ahead of the project proposal should be devised so that changes in the specifications do not occur once the project is under way.

It should also be clearly spelled out how interaction with the MQA should occur and precisely what criteria should be adhered to.

Reference

Phillips, H.R. 1996 Identify methods to reduce the risk of explosions and fires caused by frictional ignition hazards. Final Project Report. SIMRAC.

APPENDIX 1

CURRICULUM FOR FRICTIONAL IGNITIONS COURSE

CURRICULUM FOR FRICTIONAL IGNITIONS COURSE

COURSE DESCRIPTION

This course will focus mainly on the two lower levels of the cognitive domain, knowledge and comprehension, with some aspects going into the third domain, application. The higher levels can be addressed by using this course coupled with the higher level reference guide and additional reading.

PREREQUISITES (If used for mine qualifications training)

Basic literacy and writing skills in one of the four languages utilized.

The ability to understand three dimensional figures drawn in two dimensions.

Basic understanding of arithmetic in terms of percentages, larger than, smaller than.

Basic knowledge of mining situation and environment, mining machines, ventilation occurrence and mining terms.

Gas testing certificate an added benefit.

No previous skills required if the training aids are used purely for Industry training except that of knowledge of the mining environment.

TEXTBOOK AND TRAINING AIDS

Course workbook for frictional ignitions.

Trainers manual for frictional ignitions.

Training aids as proposed for each period

Video materials as supplied for this course.

EXIT COMPETENCIES

This course will enable the student who is or will be working in the underground coal mining environment to execute his work so that it contributes to the maintenance of safety of the mine by reducing the potential for frictional ignitions.

The student should be able to:

Describe the factors that could lead to a frictional ignition.

Predict the outcome of an uncontained or unsuppressed ignition in the underground environment.

Recognize the role of the factors increasing the hazard of frictional ignitions.

Describe the methods used to reduce the risk of frictional ignitions occurring.

Recognize the role he has to play to reduce the risk of the frictional ignition occurring.

Apply the principles he has learned in the underground environment.

Distinguish between practices conducive to reducing the potential for frictional ignitions and those that increase the risk.

CURRICULUM

PERIOD ONE : IMPORTANCE OF FRICTIONAL IGNITIONS

Objective

To give an overview of the course and to show that underground explosions are the major source of catastrophic accidents in coal mines. The majority of coal mine explosions are caused by frictional ignitions and the course's objective is to enable the student to make a greater contribution to his and other workers safety.

Learning activity

To create an awareness of the importance of frictional ignitions as a source of the greatest taker of human lives if the explosion is allowed to occur and to propagate out of control.

Practical activity

Discussion on what this course could mean to the participants and why they should be involved with their own and other's safety.

Exit outcome

Recognize the importance of frictional ignitions.

Recall the content that is covered by the course.

CURRICULUM

PERIOD TWO : FIRE AND EXPLOSION COMPONENTS

Objective

To show the components that are required to create a fire and explosion

Learning activity

For the coach to lead the participants to understand that there are three components required to make a fire or have an explosion. This is the main theme around which this whole course revolves and should be well understood by all the participants.

By linking the concept to practical examples the participants will also understand how they create and prevent fire in the everyday life.

Another concept that will have to be understood is the difference between a fire and an explosion as well as the principle of the progression of a fire or explosion. This will bring home to the participants that a small, almost insignificant occurrence could have disastrous consequences.

Practical activity

Giving demonstrations that illustrate the principles. The participants will be required to make comments and derive principles from what they have seen and experienced.

Exit outcome

Name the three components that are required for a fire or explosion to occur.

Describe the difference between a fire and explosion.

Identify the components of fires and explosions from everyday life experience.

Recognize that unless the three components are present there can be no fire or explosion.

Recognize that it is the source of heat that is the initiator.

CURRICULUM

PERIOD THREE : FRICTIONAL HEAT

Objective

To show what the role of the friction is in starting a frictional ignition. (General)

Learning activity

By means of lectures and discussions, to gain an understanding of the concept of friction. He will be led to understand that there are factors that influence the friction and this friction can lead to heat.

To enable the participant to understand this concept use will be made of everyday examples of friction. The participant will also be made aware of the fact that not all such physical occurrences are bad and they are used in our everyday life.

Practical activity

Simple exercises and group discussions where the participants can relate their experience with regard to this concept.

Exit outcome

Describe what friction is and how it is manifested.

List everyday examples of friction

Recognize the role of material characteristics in the heat generated by friction.

Explain the effects of lubrication on friction

Predict the relative amount of heat generated between materials in frictional contact.

Recognize the role that the applied forces have in generating heat.

Recognize that sparking is a form of frictional heat.

Explain why friction can be the source of initiation without causing a spark.

Recognize the influence that forces and speed have on the generation of frictional heating.

CURRICULUM

PERIOD FOUR : FRICTION DURING COAL CUTTING

Objective

To apply the principles of friction to the cutting situation;

Learning activity

To impart the basics of coal cutting through lectures. The relationship between the practical aspects of coal cutting, horizon control and the occurrence of intrusions in the seam as well as roof materials will be covered.

The lecture will be linked to the practical activities.

Practical activity

Doing exercises to create an understanding of the cutting principle. This will be expanded by illustrating to the participant the type of material that the pick could encounter whilst cutting.

The effect of such materials on the generation of sparks and hotspots will also be shown through exercises.

Exit outcome

Describe the role of the pick in extracting coal.

Distinguish between materials a pick can come into contact with.

Describe the path of a pick through the coal.

List the types of rock that could generate frictional ignitions or sparks.

Describe the influence of speed on frictional heating.

Describe the effect that blunting of the picks has on frictional heating.

CURRICULUM
PERIOD FIVE : OTHER FORMS OF FRICTIONAL HEAT

Objective

To indicate other sources of frictional ignitions. These other sources of ignitions can be caused by rock on rock and by metal on metal.

Learning activity

To make the participant aware of other factors that could cause fires or explosions in a mine due to *other* types of frictional heating.

Practical activity

As this is an information-only session there is no practical work scheduled, except a group discussion wherein the participants can relate and expand their field of experience.

Exit outcome

Describe other aspects in the mine where frictional heating can lead to an ignition.
Recognize which of these are controlled by law and/or Codes of Practice.
Distinguish which of these are preventable and which are not or with great difficulty.

CURRICULUM

PERIOD SIX : METHANE

Objective

To show the role of methane as the fuel

Learning activity

To create an understanding, mainly through lectures and discussions, of the origins of methane and how it occurs in the workplace.

It is important for the participants to understand the danger of methane and how this is exacerbated by the fact that it can be neither smelt nor seen. The participants should further be made aware of the role of methane in the ignition as well as the contribution such an ignition could make with regard to a coal dust explosion.

Practical activity

A few demonstrations to illustrate the characteristics of methane, but mainly group discussions.

Exit outcome

Describe the source of methane in the underground environment.

List the characteristics of methane

Explain the role of methane in a fiery ignition.

Describe the interrelationship of methane in a coal dust explosion.

Predict the results of a methane explosion in the underground environment

Recognise the areas where methane occurs in the working environment.

Describe the methods used to determine the presence of methane

Select the most appropriate places to sample for methane.

CURRICULUM

PERIOD SEVEN : PRINCIPLE OF REMOVING A COMPONENT

Objective

To show that to stop ignitions from occurring one of the components of the fiery reaction must be removed

Learning activity

To demonstrate, by means of a lecture, how the action of removing a component from the triangle prevents an explosion occurring. The participant should be made aware of the mechanisms of how components are removed in his everyday life and then use the principle to apply it to the underground situation.

How these principles are applied to stop explosions from spreading should be covered. The main focus in this period will be to create the understanding of how removal or shielding of components can prevent or stop explosions.

Practical activity

Group discussions where the process of removing components is applied to prevent fires and explosions from occurring as well as stopping fires once they have occurred. Participants will have to link their practical experience to the presented information and then extrapolate that to the underground situation.

Exit outcome

Recognize that removing one of the components stops a fiery ignition from occurring.

List methods to remove one of the components of fiery ignitions in day to day examples.

Apply the principle to reduce the potential for frictional ignitions.

CURRICULUM

PERIOD EIGHT : RESPONSIBILITY OF PREVENTING AN IGNITION

Objective

To make the various participants aware of which of the components they have an influence over.

Learning activity

To learn about the general laws that pertain to the mining situation and environment.

Familiarization of the codes of practice that are directly of relevance to ventilation, measuring of methane and maintenance of machines and systems on the mine.

To learn about the greater role and responsibility of each and every worker not only to keep himself but also his fellow workers safe.

Practical activity

Group discussion where the personal responsibility and social responsibility in terms of keeping themselves and fellow workers safe are discussed.

Led and closely supported group workshop where the participants become aware of what they could do to conform to the overall objective of safety with regard to frictional ignitions. To identify where they can act to further the goal of preventing frictional ignitions and where they have identified problems in their personal sphere with regard to achieving this goal.

Exit outcome

Identify the occurrence of the three components in the area of the mine they work in.

Recognize which of the components they have an influence over

Distinguish those that they do not have any control over.

Explain what must be done when issues out of our control occur that could increase the potential for frictional ignitions.

Understand and accept their own and others' role and responsibility in preventing frictional ignitions.

CURRICULUM
PERIOD NINE : REMOVING METHANE

Objective

To show what actions can be taken to remove the methane as fuel.

Learning activity

To create an understanding of the mechanisms employed to remove or dilute the methane.

The importance of maintaining these systems in good working order should also be stressed.

Practical activity

Group discussions with regard to problems that could occur with the ventilation.

Familiarization with the instruments with all participants.

Exit outcome

Explain the use of ventilation to dilute the make of methane.

Recognize the importance of keeping the ventilation up to date and according to the accepted practice.

Describe the use of methane measuring equipment on the mine.

Recognize the need for regular measurement of methane levels.

Recognize the need for airflow at the working face and other places where methane can occur.

CURRICULUM

PERIOD TEN : PICKS AND GOOD CUTTING PRACTICE

Objective

To show what actions can be taken to reduce the picks as a source of initiation.

Learning activity

To create an awareness of the importance of changing the picks regularly to ensure that there are always picks in a good condition on the cutting drum. The other learning activity is for the participants to become aware of the fact that a blunt pick could still be perceived as being usable.

Practical activity

To give the participant a feeling for when picks are sharp and when they are blunt. Practical exercises and group discussions.

Exit outcome

Distinguish between sharp and blunt picks.

Recognize the increase in hazard due to not cutting within the horizon.

Recognize the increase in hazard due to cutting with unevenly worn picks.

Explain why it is necessary to regularly check the picks and to change them if necessary.

CURRICULUM

PERIOD ELEVEN: OTHER METHODS EMPLOYED

Objective

To show what other actions are being taken, out of the direct control of staff at the face, to reduce the frictional ignition hazard.

Learning activity

Trainer to communicate and illustrate the various methods employed to reduce the possibility of frictional ignitions.

Trainer to reinforce the principles involved with each of the methods.

Practical activity

Group activity to discuss the values of implementing methods as related in course.

Exit outcome

Describe possible other methods that could be and/or are being taken to reduce the frictional ignition hazard.

Recognize the value of implementing such measures.

APPENDIX 2

INFORMATION

INFORMATION

PERIOD ONE : IMPORTANCE OF FRICTIONAL

Introduction

This course is designed to make the workforce of South African coal mines aware of the problem of frictional ignitions of methane / air mixtures and to understand how that risk can be substantially reduced. Any ignition of gas in the underground environment, however small the quantity, is a dangerous event and the number of fires and explosions experienced in South African coal mines over recent years gives no cause for complacency. Indeed, since the recording of mine events began, explosions have been a feature of coal mining worldwide.

South African coal mining operations commenced in 1874, when a mine was established at Molteno in the Eastern Cape. The first recorded explosion occurred in 1891 at Elandslaagte Colliery in Natal, and between then and the end of 1997 more than 350 explosions have caused the death of some 1100 coal miners while a further 560 have been injured. While these facts are of a mainly historical nature, the ratio of killed to injured, at about 2:1, already indicates to us why explosions are regarded as such serious, disastrous events. While many of the 350 explosions have been minor events not involving fatalities, injuries or even minimal damage, it is the few major explosions which have generated a great deal of public interest and criticism of the mining industry. The 10 most significant coal mine explosions in South African history, which between them account for 615 fatalities, are listed below in Table 1.

Table 1 The Ten Worst Explosions In South African History

COLLIERY	DATE	KILLED	INJURED
Durban Navigation Collieries	08/10/1926	125	0
Natal Navigation Collieries	16/05/1923	78	4
New Marsfield Collieries	31/07/1935	78	0
Hlobane Colliery	12/09/1983	68	8
Hlobane Colliery	12/09/1944	56	13
Middelbult Colliery	13/05/1993	53	0
Glencoe Colliery	13/02/1908	50	5
Burnside Colliery	20/05/1930	38	0
Ermelo Mine Services	09/04/1987	35	11
Middelbult Colliery	12/08/1985	34	7

Are Explosions The Most Serious Accidents In Coal Mining?

Before analysing the causes of coal mine explosions in South Africa, it is important to place this type of incident in perspective when compared with other coal mining accident statistics. All reportable mining accidents in South Africa are recorded in the Department of Minerals and Energy's SAMRASS system, which started recording data in 1988.

The accident statistics for underground coal mines can be analysed according to three very broad areas, i.e. rock engineering, mining and engineering, and fires and explosions. Since major incidents (particularly explosions) cause a distortion in individual years, accident statistics should be studied over a reasonable period. Too short a time will lead to distortion while too long a period will not reflect improvements (or otherwise) in accident rates or capture the effects of changing technology. For the following analysis the period 1988 (when SAMRASS began) to the last full year of available data (1996) has been chosen. The total figures for this nine year period are given below in Table 2.

Table 2 Total Underground Coal Mining Accidents 1988-1996

	FATALITIES		INJURIES		INCIDENTS	
ROCK ENGINEERING	177	43.50 %	647	25.70 %	739	27.40 %
MINING & ENGINEERING	146	35.90 %	1808	71.80 %	1922	71.30 %
FIRES & EXPLOSIONS	84	20.60 %	63	2.50 %	35	1.30 %
TOTAL	**407**	**100 %**	**2518**	**100 %**	**2696**	**100 %**

It can be seen that in this nine year period, 407 coal miners died in underground accidents and that both rock engineering and mining and engineering (haulage/transport/machinery, etc.) accidents caused more fatalities than explosions. Despite this evidence, it is fires, and more especially explosions, which are generally regarded as the most sinister type of coal mining accidents. This can best be illustrated by using the data in Table 2 to calculate the number of fatalities per incident for each category or accident. Over the past nine years (1988 - 1996) each rock engineering incident led to 0.24 fatalities, each mining engineering incident led to 0.08 fatalities, while the equivalent figure for explosions and fires was 2.40 fatalities/incident. This means that the risk of being killed if involved in a coal mine fire or explosion is 30 times that of being killed if involved in an engineering accident. This obviously contributes greatly to the average mineworker's fear of explosions.

Causes of Coal Mine Explosions

For any fire or explosion to take place three factors must be present:- fuel (e.g. methane and coal dust), oxygen and a source of ignition. Since oxygen will always be present in the air circulating through the mine, explosion prevention techniques involve eliminating or controlling the source of fuel and ignitions. The fuel can generally be managed by diluting the methane with sufficient air to make it harmless, while coal dust can be made inert by adding stone dust. There are, however, a number of ignition sources that need to be controlled and it is important to understand the changing pattern of ignition sources with time in order to see where improvements in safety measures have reduced the risk and where new problems have arisen as a result of deployment of new technology or changes in mining methods. Data for the past three decades has been analysed (Phillips and Brandt, 1995) and, in Table 3, is compared with that for the first three years of the 1990s.

Two very obvious changes are the steady increase in frictional ignitions following the introduction of continuous miners (CMs) in the early 1970s and an equally noticeable decrease in the percentage of incidents caused by blasting. A more difficult phenomenon to explain is the increase in ignitions caused by coal cutter (CC) picks. While the number of coal cutters in use and the tonnage mined by conventional mechanised mining increased during this period, the quite remarkable increase in ignitions from this source may well have arisen from a perception that coal cutters only excavate kerf and so are inherently less dangerous than continuous miners.

A more realistic view of the current situation can be obtained by analysing the source of ignition and the incident epicentre for occurrences in recent years (Phillips and Brandt, 1995). For the period 1984 to 1993, 51 incidents were reported, providing an average of four ignitions and 1.1 explosions per year. Of these, 24 ignitions and two explosions were either too insignificant to be investigated or were so complex that the enquiry failed to determine the actual source of ignition. The cause of the remaining 25 incidents is analysed in Table 4.

Table 3 The Changing Pattern of Ignition Sources

IGNITION SOURCES	PERIOD							
	1960's		1970's		1980's		1990 to 1992	
	I	%	I	%	I	%	I	%
CM Picks	0	0	1	5.5	14	29.5	6	25.5
CC Picks	1	4.5	3	17	11	22.5	0	0
Shearer Picks	0	0	0	0	1	2	0	0
Stone on Stone	0	0	0	0	4	8	1	4
Blasting	14	64	6	33.5	5	10	1	4
Spontaneous Combustion	0	0	0	5.5	0	0	2	8
Heated Surface	1	4.5	1	5.5	1	2	0	0
Naked Flame	2	9	1		0	0	0	0
Electricity	2	9	2	11	5	10	0	0
Lighting	2	9	4	22	3	6	0	0
UNKNOWN	0	0	0	0	5	10	14	58.5
TOTAL	22	100	18	100	49	100	24	100

I = number of incidents of ignitions/explosions

Table 4 Sources of Ignition In South African Collieries For The Period 1984-1993

SOURCE OF IGNITION	IGNITIONS	EXPLOSIONS	TOTAL	% TOTAL
FRICTIONAL:				
CM Picks	8	3	11	44
CC Picks	2	0	2	8
Shearer Picks	1	0	1	4
Stone on Stone	3	0	3	12
TOTAL	14	3	17	68
FLAME/HEATED SURFACE				
Blasting	0	2	2	8
Spontaneous Combustion	0	1	1	4
Heated Surfaces	1	0	1	4
TOTAL	1	3	4	16
ELECTRIC				
Electric Sparks	1	2	3	12
Lightning Stray Currents	0	1	1	4
TOTAL	1	3	4	16
OVERALL TOTAL	16	9	25	100

Frictional ignitions obviously play a dominant role as an ignition source, being the cause of 68 % of incidents for which the cause was determined. On the other hand blasting and electric sparks form only 8 % and 12 % respectively of the known sources of ignition.

The location within the mine where the incident occurred also tells us a great deal about where additional safety precautions are required. In order to assess the influence of mining methods on the occurrence of explosions and ignitions, the data for the period 1982 to 1993 (two years longer than that in Table 4) has been analysed. In all 64 incidents were reported but the epicentre in 11 cases was not identified. The remaining 53 incidents are included in Table 5 below.

Table 5 Location of Incident Epicentres in South African Underground Collieries For The Period 1982 to 1993

LOCATION	IGNITIONS	EXPLOSIONS	TOTAL	% TOTAL
FACE AREA:				
Bord and Pillar	25	10	35	66
Longwall Development	4	0	4	8
Longwall (Face)	3	0	3	6
TOTAL	32	10	42	80
ABANDONED AREAS:				
Bord and Pillar	2	3	5	9
Longwall	1	0	1	2
TOTAL	3	3	6	11
NON-FACE AREAS:				
Intake Airways	0	2	2	4
Return Airways	0	2	2	4
Shaft Areas	0	1	1	1
TOTAL	0	5	5	9
OVERALL TOTAL	35	18	53	100

This analysis which shows that 80 % of all incidents occur in the face area is in close agreement with the finding in Table 4 that cutting and blasting activities account for 76 % of all incidents. In fact it can be concluded that the overwhelming majority of ignitions and explosions in South African coal mines are the result of frictional ignitions caused by the picks of mining machines. This is similar to the trend found worldwide (Phillips, 1996) that mechanised methods of underground coal mining carry an inherent risk that machine picks will generate incendive sparking. In South Africa, where coal seams are significantly harder than average, cutting machines need to be powerful and relatively high drum rotation speeds are required in order to achieve acceptable production levels. Under these circumstances and in the presence of sandstone roof, floor or inclusions in the seam, the likelihood of frictional ignitions must be high. However, the situation is not as bad as it might appear, since this problem has been researched for most of this century and not only are the mechanisms involved understood but the principles on which to base preventative measures have been clearly spelled out.

Conclusions

The introductory period has shown that explosions in coal mines are catastrophic accidents and that they have occurred regularly in South Africa mines. At present the major cause is the ignition of methane caused by friction of the cutter picks on mining machines, particularly continuous miners. There is a great deal of literature available in which the results of extensive research into this phenomenon are discussed and the methods of preventing frictional ignitions are well known. Some of these methods can be incorporated into the design of mining machines, while others must be practiced on the mines. These training aids for the prevention of frictional ignitions are designed to give the student an understanding of how frictional ignitions occur and how elementary precautions in the workplace can significantly reduce the risk of a frictional ignition of methane.

INFORMATION

PERIOD TWO : FIRE AND EXPLOSION COMPONENTS

The explosive reaction

A fire and an explosion is an exothermic reaction.
This means that the chemical reaction that occurs when something burns gives off more heat than what is required to start or maintain the reaction.

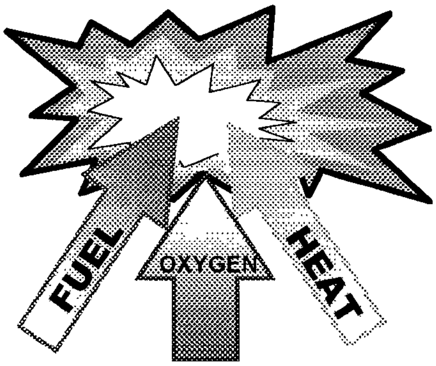
A fire is a relatively slow reaction because it takes minutes or hours for the reaction to end.
During the fire the fuel is consumed at a relatively slow rate. This is due either to the way that the fuel is mixed with the air or to the way that the fuel can be reached by the reaction.

An explosion is a fast reaction because the reaction takes seconds or small fractions of a second from start to finish.
During the explosion the fuel is consumed very rapidly by the reaction. This is usually due to the fact that the fuel and the oxygen are mixed very well and in the correct proportion for the reaction to occur very quickly.

Explosions give off the energy or heat at a much faster rate than fires. A fire usually occurs over a period of many minutes whereas an explosion happens in a fraction of a second.

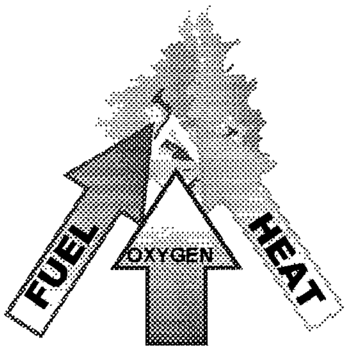
Components required for a fire or an explosion

For both fires and explosions there are three components required.
A fuel that forms the basis of the reaction.
Oxygen, to oxidize the fuel.
Energy or heat to start the reaction.
Once the reaction has started it gives off enough heat to keep the reaction going until all the fuel or oxygen is consumed.
All three components must be present otherwise the reaction cannot occur.

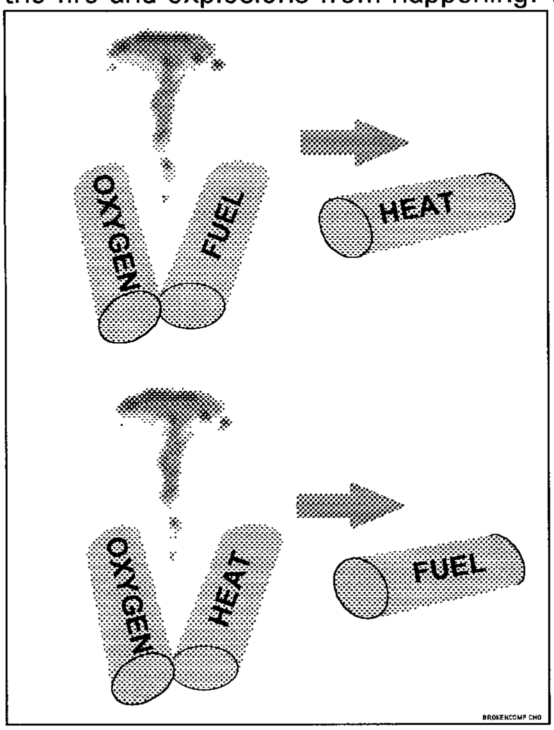


EXPLOSION
QUICK REACTION
FAST CONSUMPTION OF FUEL

FIRE
SLOW REACTION
SLOW CONSUMPTION OF FUEL



By removing one of the components, the fire cannot occur.
If we remove the initiating heat the fire cannot start or keep going or if we remove the fuel the fire will stop.
This is a very important principle to remember as this is the basis of how we prevent the fire and explosions from happening. **We remove a component.**



And no fire or explosion can exist.

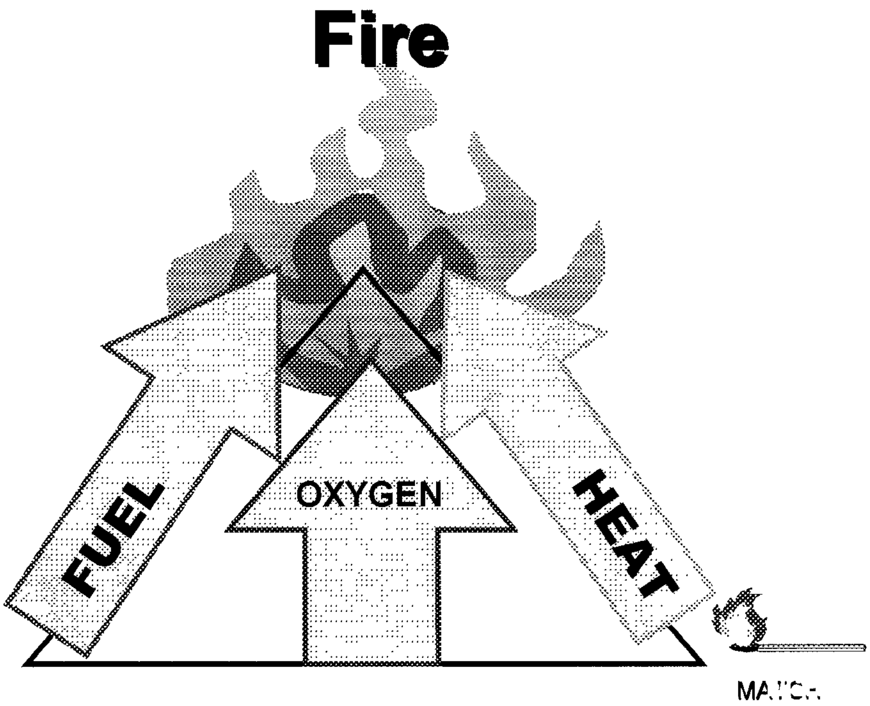
Examples of the components of everyday occurrences of fires and explosions

In a common fire that we make to cook food:
The wood is the fuel.
The air supplies the oxygen.
The heat required to start the fire is supplied by a match.

The match is also a fire.
The fuel is the chemical on the head of the match.
The oxygen is the air.
The heat required or energy required to start the match burning is from rubbing the match against the side of the matchbox.

The amount of heat needed to start a fire or explosion

Certain materials that act as fuels need very little heat to start the fire while other materials need a lot of heat to get the fire going. This heat to start a fire or explosion is called the **initiating energy**. The amount of energy needed is determined by both the physical and chemical characteristics of the material. Fine particles of a material can ignite much more easily than large particles of the same material. Small pieces of wood or coal can be lit much more easily than large pieces. Unless gases are mixed in the right proportion with the oxygen they cannot be ignited without difficulty or with a significant increase in the amount if energy.



The progression of a fire

Small fires can turn into very big fires.

The reason for this is that the small fire supplies the energy for a larger amount of fuel to start reacting.

An example of this is the wood fire.

A small fire like a match starts the fire; usually one cannot get the wood to burn and use is made of paper or kindling which burns easier.

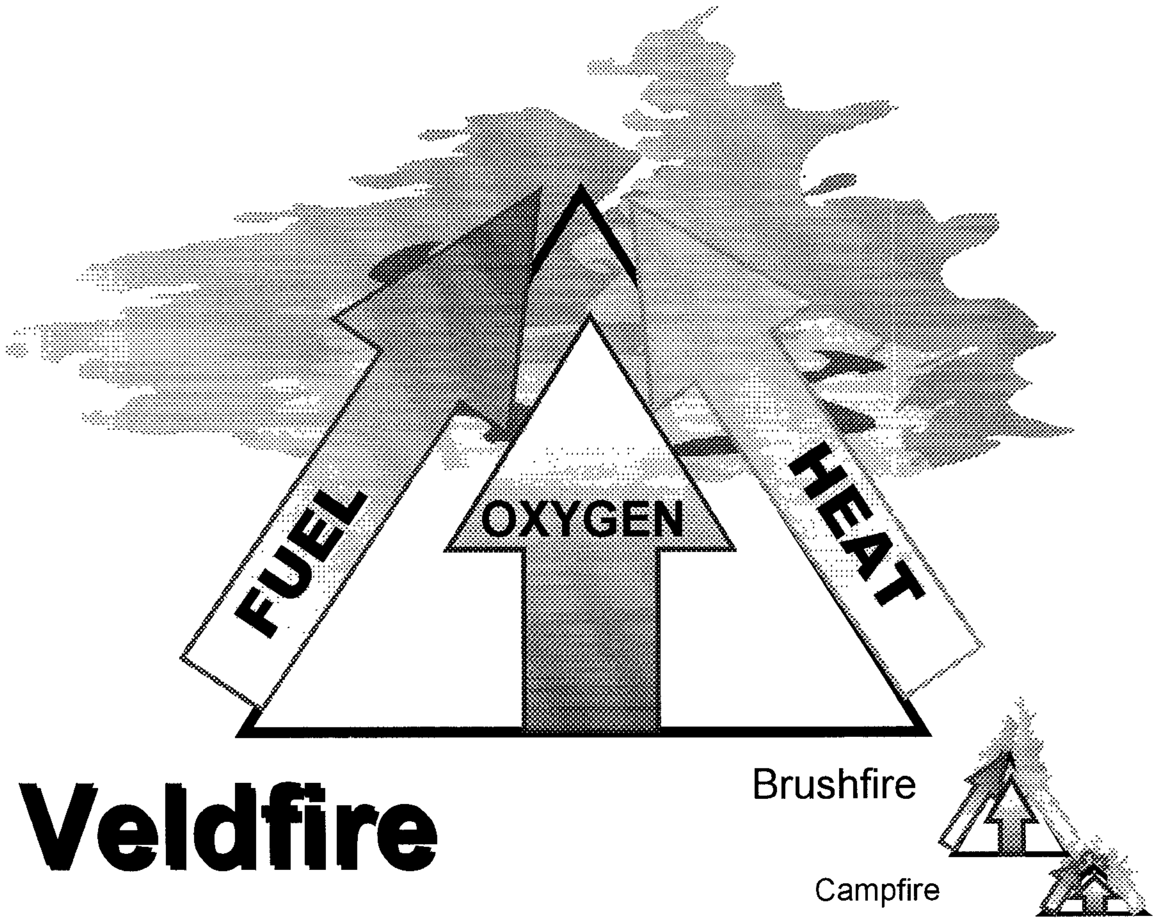
The woods starts burning.

If we make a fire like this out in the veld, this fire can cause the grass and brush in the close vicinity to burn. The small fire has supplied the energy to start this much larger fire.

This fire can now increase to become a major veld fire that destroys an entire area.

A small match started the large fire.

This principle of the progression of fires is very important in the mine.



In the above picture it can be seen how a very large fire is started by a sequence of smaller fire. A whole district can be burnt down just by the use of one match.

Fires and explosions in mines

In a mine there are many sources of fuels. On the whole the law prevents materials that burn easily to be used in a mine.

The most common fuel for a fire or explosion is the coal itself.
In the coal and in the strata surrounding the coal there is methane.
Methane is not only a fuel but requires very little energy to start a fire or an explosion.
One of the characteristics of methane is that it gives off energy at a very fast rate.

When a methane ignition occurs, the flame spreads very rapidly throughout the whole mixture of methane and air. The temperature of the reaction rises very quickly.

If there is enough methane burning, enough energy can be generated to ignite the coal dust in the mine.
Because the coal dust consists of small particles, it burns easily and at the same time gives off energy at a very fast rate.
This is the reason why coal dust explosions are very dangerous and can be so big that they can kill all the people in a mine.
The progression of a methane ignition is a big danger in a mine and every effort should be made to prevent this from happening.

Coal in big particles or pieces cannot be ignited that easily by a methane explosion.

Characteristics of the methane

For methane to obtain sufficient oxygen to burn there must be between 5 -15 % of methane mixed in the air.
To ignite methane very little energy is required.

ENERGY REQUIREMENTS TO IGNITE METHANE

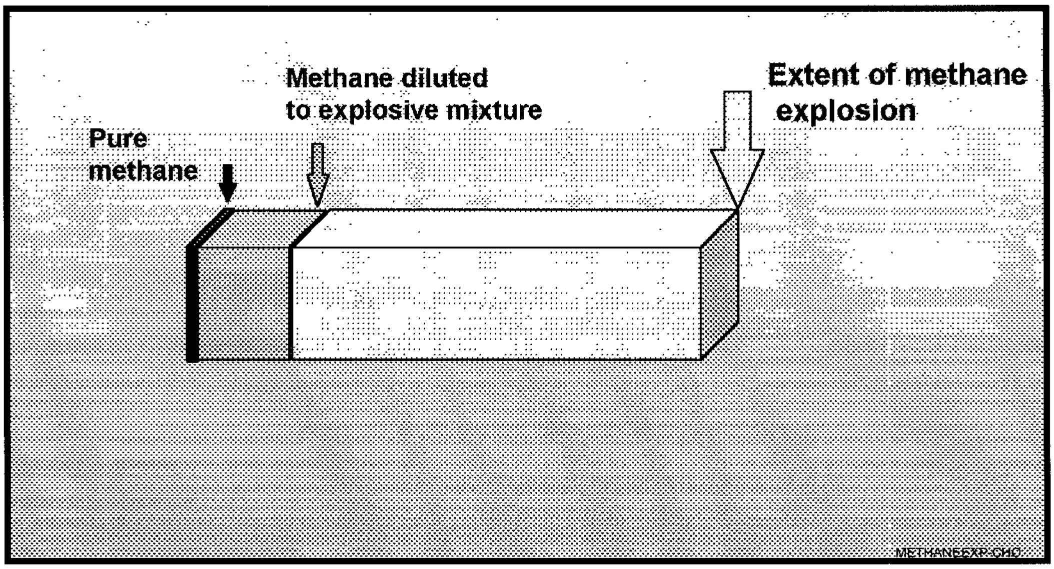
0.3 millijoule of energy is required to ignite a methane/air mixture.
This is equivalent to 1/120 000 000 of the energy used by a 50 horsepower motor or about 1/50 of the static electricity accumulated by a man walking on a carpet on a dry day.
The minimum ignition temperature of methane under very favourable conditions is about 540° C.

This temperature is similar to the temperature of an object that is heated to a dull red color in a darkened room.

When the methane burns it burns at a temperature of 1950°C.
When methane burns the whole mixture of air and gas is heated to this temperature and the hot gases expand due to the heat.

The flame or burning methane expands to about five times the original quantity of the mixture.

A methane layer where mixing the gases has not occurred will burn at a speed of about 0.5 m/s. When the conditions are right and the gases well mixed in the right proportions the mixture could detonate. This means that the flame would almost instantaneously move throughout the whole volume of gas.



EXPANSION OF METHANE WHEN EXPLODING

In the preceding illustration it is shown how much pure methane is required to be diluted to an explosive mixture. If this mixture is then ignited it will then expand to the size as shown. It is thus evident how far the effect of a small amount of methane will be felt in a section in the event that it ignites.

Mixtures of above 15 % of methane in air are difficult to ignite because there is not enough oxygen present.

Initiating a coal dust explosion

The minimum quantity of pure methane to start a coal dust explosion is only 0.4 cubic metres of pure methane. If this is diluted to the right concentration to explode it would form a volume of about 4 cubic metres (at 10 % concentration).

At a concentration of 30 gm/cubic metre, the coal dust can explode and generate enough energy to propagate.

This will mean that in a roadway of 6 metres wide and 3 metres high, 540 gm of coal dust per metre of roadway will be required in the air for a coal dust explosion to start.
This concentration can be obtained with a 0.05 mm layer of dust on the floor.
It can also be obtained with a deposit of only 0.0125 mm on the floor, pillar sides and roof.
This thickness can almost not be seen in the underground environment.

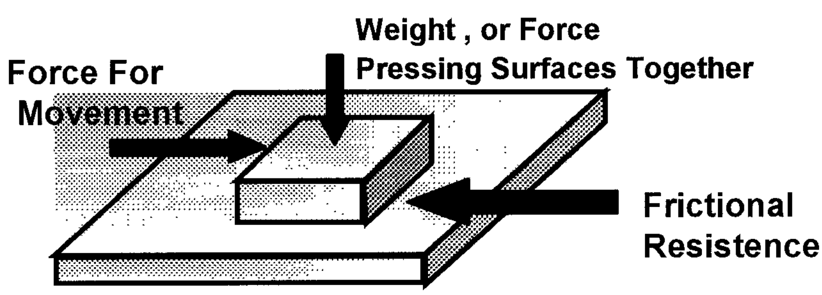
INFORMATION

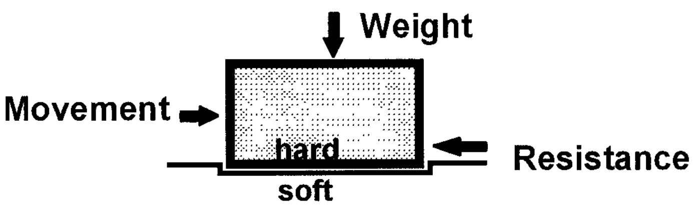
PERIOD THREE : FRICTIONAL HEAT

Friction is the resistance offered to the motion of one body upon or through another.

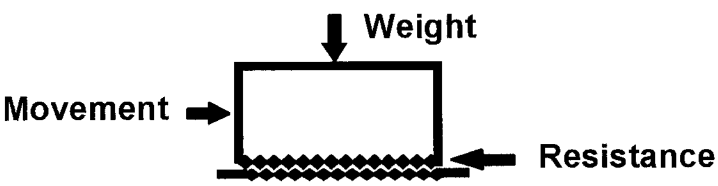
The chief causes of friction are the interlocking of minute irregularities on the rubbing surfaces, or the adhesion between the surfaces and the indentation of the softer body by the harder body.

The following illustration depicts the principles graphically





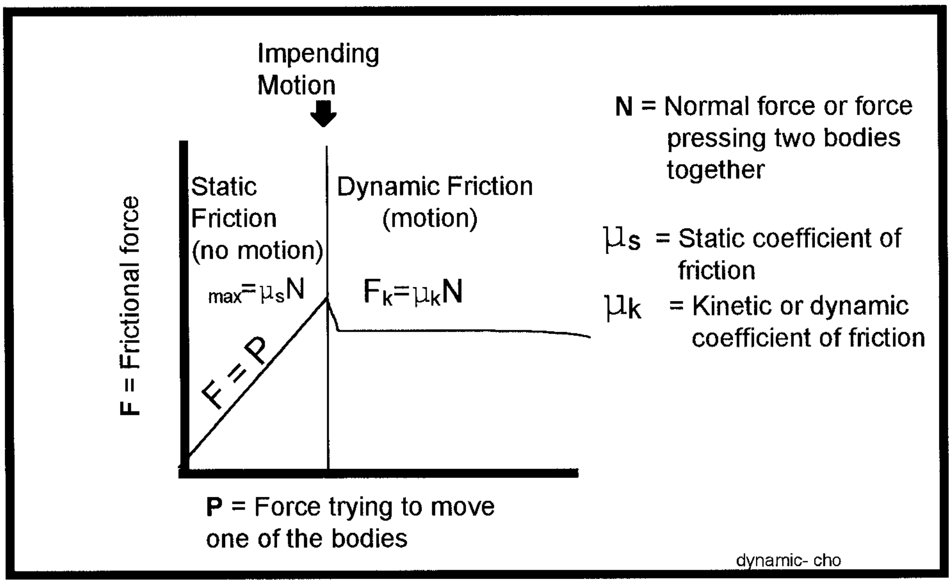
Frictional resistance caused by indentation



Frictional resistance caused by irregular surfaces

The friction that exists between two bodies when they do not move relative to one another is called **static friction** and the friction that exists between two bodies when they move relative to one another is called **dynamic friction**.

The static coefficient of friction is always larger than the dynamic coefficient of friction
The friction between two surfaces is slightly higher just before motion begins than when the surface is in steady relative motion.
This is shown in the following graph



The friction force is proportional to the force (F) pressing the surfaces together.

It is independent of the area of contact and of the speed of the relative motion.

The constant ratio of the friction force (F) to the force pressing the surface together (N) is called the coefficient of friction.

Typical values.

Leather on metal	0.55
Iron on stone	0.50
Wood on stone	0.40
Stone on stone	0.65
Well oiled metals	0.05

Examples of friction

Foot walking.
Holding of an object
Grinding of an object on an emery wheel.

Lubrication is used to reduce the friction between two surfaces. By introducing another material like oil between the two surfaces they are removed a distance from each other and are not in direct contact. The resisting force or friction is now determined by the characteristics of the lubricating material and not by the characteristics of the two surfaces.

When two surfaces move across each other, energy is required. Part of this *mechanical* energy is used to move the one body and another part is used to overcome the friction. The energy used to overcome the friction is converted to heat. This heat causes the temperature of the two bodies in contact to increase.
If the materials have a high conductivity, the ability to transfer the heat away from the point where it is applied, then the heat caused by the friction is taken away from the

two surfaces in contact. There will be a steady increase in the temperature of the bodies in contact.

If the materials have a low conductivity, meaning that they do not transfer the heat away then the surfaces in contact become very hot.

In some cases when the friction is high enough, the material of the surfaces in contact can actually melt.

It has been determined that the temperature reached by the two surfaces will not be higher than the melting point of the material with the lowest melting point.

At this temperature the lower melting point material becomes molten, the coefficient of friction drops to a very low value and the ability to generate further frictional heat by rubbing is lost.

When the force applied is so great that the particles from the one surface break off particles of the other surface, abrasion occurs.

Abrasion is the action whereby materials from the one or both of the surfaces are removed by the action between the two surfaces.

When the abrasion is of a very high intensity, the heat generated by the particles being broken off or torn off the one material can be so great that the particles burn in the air.

An example of this are the sparks caused by metal when impacted by stone or a grinding wheel.

Uses of friction

Friction has many useful applications in everyday life.

Friction allows you to hold something in your hand.

Friction allows a car or a bicycle to be propelled forward on a road.

Friction allows the bicycle or car to come to a stop when the brakes are applied.

The role of friction

Three main types of friction that could generate sufficient heat to initiate a frictional ignition in the underground environment have been identified.

Pick on rock or metal on stone: This is when the cutting tool encounters stone. The entire next period will be devoted to investigate this further.

Rock on rock: This usually occurs when a piece of sandstone falls from the roof and hits another piece of sandstone.

Metal on metal: This is when metal rubs against another piece of metal with sufficient force and duration to generate heat of sufficient size to ignite either coal or another flammable material in close contact with the metal pieces.

Frictional ignition of cutter picks is of the greatest concern: 70 % of all ignitions are likely to be caused by this means.

INFORMATION

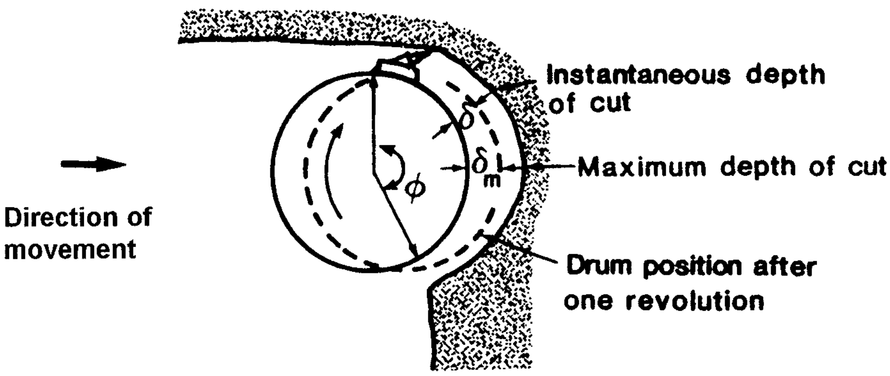
PERIOD FOUR : FRICTION DURING COALCUTTING

Before one can consider the way that friction is generated in the cutting process, it is advisable that a basic understanding of the cutting process is obtained.

Cutting of the coal

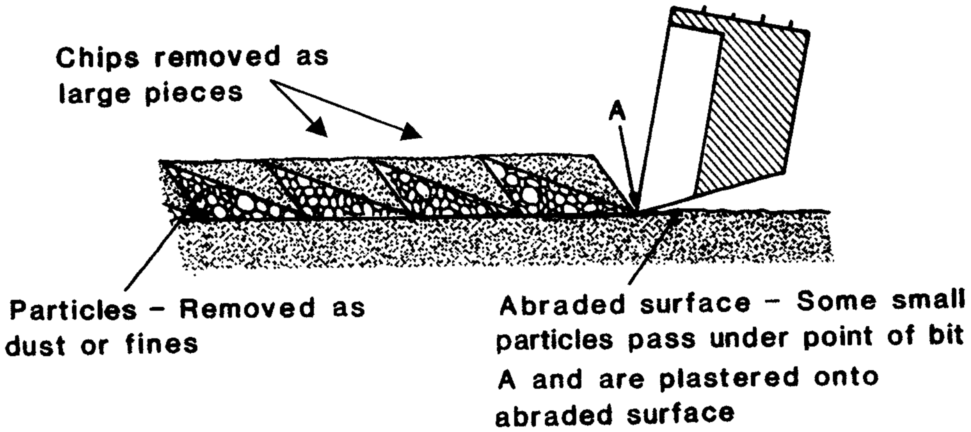
When using any form of mechanical miner, the coal is broken from the solid through the action of the cutting picks on the cutting drum. These cutting drums rotate and are forced into the coal through the action of the machine.
The picks on the drums do the actual breaking out of the coal from the solid.
These picks are tipped with an abrasive resistant material. In the majority of cases this material consists of a Tungsten Carbide insert into the body of the pick.

In the following illustration the path of the pick through the coal is shown

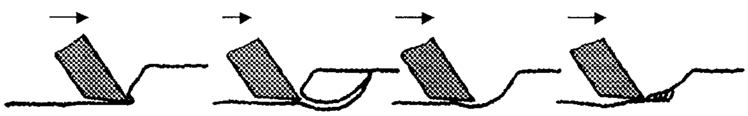


Where ϕ is the included angle over which the drum is cutting, or where the picks are in contact with the coal, δ is the instantaneous depth of cut, and δ_m is the maximum depth of cut, which is also the same as the distance that the drum has moved forward in a horizontal direction per revolution.

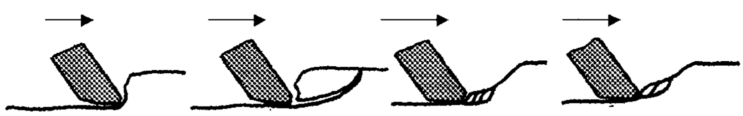
The cutting action of the pick in removing coal from the solid is presented in the illustration. In the majority of minerals, breakage is achieved by means of a brittle failure mechanism. This breaking of the mineral makes use of the fact that for most rocks the tensile strength is about Eq 1 $\frac{1}{10}$ to Eq 2 $\frac{1}{20}$ of the compressive strength. A certain amount of crushing is however required allowing the pick to enter the coal, thereby allowing the tool to obtain sufficient hold on the material to break it out using the tensile mode.



It can be seen from the illustration that there is a relationship between the number of fine particles generated by the cutting action and the number of larger particles. When the pick becomes worn, and the tip is blunt, then the number of finer particles will increase. A greater amount of effort in cutting the coal is now spent on crushing the coal to allow the pick to get the required grip on the coal so that it can break it in the tensile mode. This can be illustrated as follows.



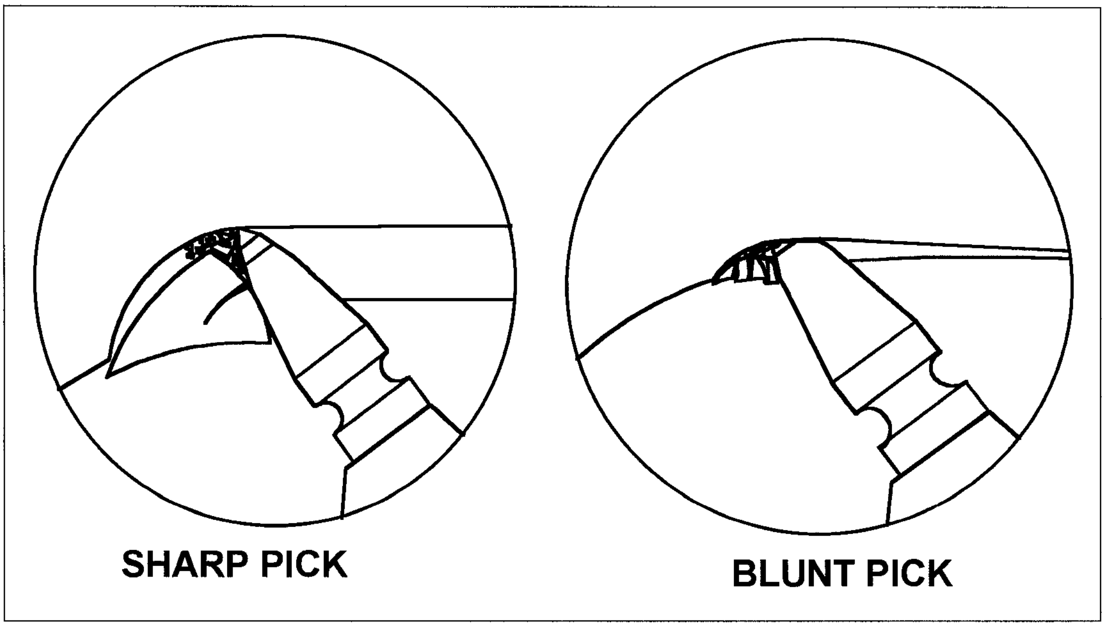
Sharp pick cutting coal



Blunt pick cutting coal
Note increased amount of fine generated.

It should be further borne in mind that there is only a limited amount of force available to push the picks into the coal. If a pick is sharp then the depth that the pick is pushed into the coal will be deeper than for a blunt pick. When blunt picks are used for cutting they do not penetrate the coal very deeply and produce a lot of fines. In the event of a blunt pick cutting into stone, which is significantly harder than coal, very little material is removed, and all of it will be fine particles.

This comparison can be seen in the following two illustrations.

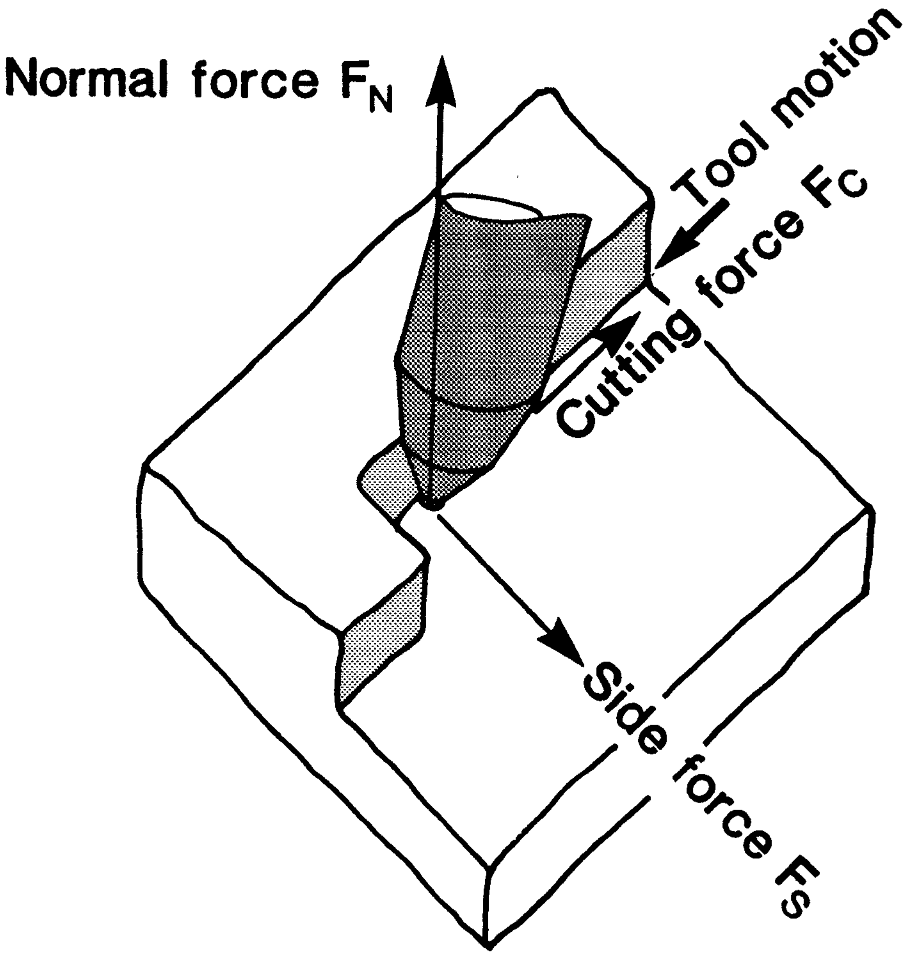


Where sharp picks cut through the coal, the depth of cut is large and the bulk of the coal that is removed is in the form of large particles. When the pick is blunt, the pick cannot enter the coal deep enough to get a good depth of cut and the resultant particles are fine. In both case fine particles are produced, but in the case of the blunt pick it is the majority of the material that is produced. In the case of the sharp pick only a small fraction of the material produced consists of small particles.
In the case of the sharp pick, the majority of the coal being broken is done by the tensile mode, whereas in the case of a blunt pick a significantly larger amount of

the material is produced using a crushing or compressive mode of breaking. As the compressive mode requires more energy to break the coal, the use of blunt picks leads to a higher use of energy per amount of coal produced. This means that the specific energy of the cutting process has increased, or alternatively the process has become less efficient.

When the pick travels through the coal it is subjected to certain forces. These forces can be seen as the forces trying to push the pick out of the coal or the forces that are required to keep the pick in the coal so that it can cut.

The following illustration shows how these forces act on a pick.



In the illustration three forces are indicated. These are:

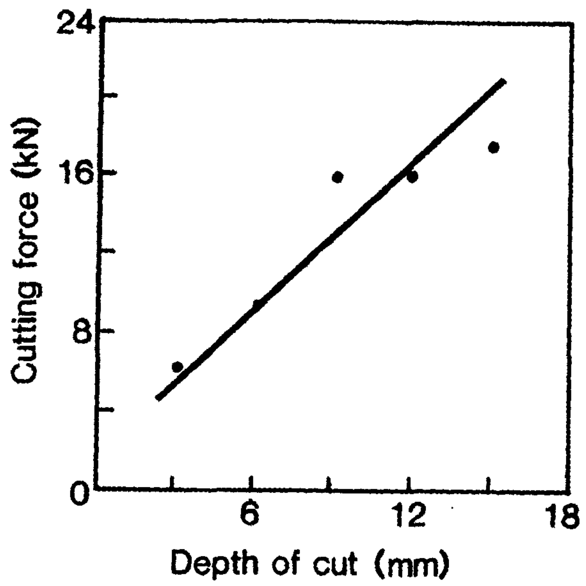
F_c The Cutting Force. This is the force that resists the turning motion of the drum in the coal

F_n **The Normal Force** This force resists the penetration of the pick into the coal. This is also the force that will cause the friction between a pick and the material it is cutting in. (It is sometimes also called the penetrating force.)

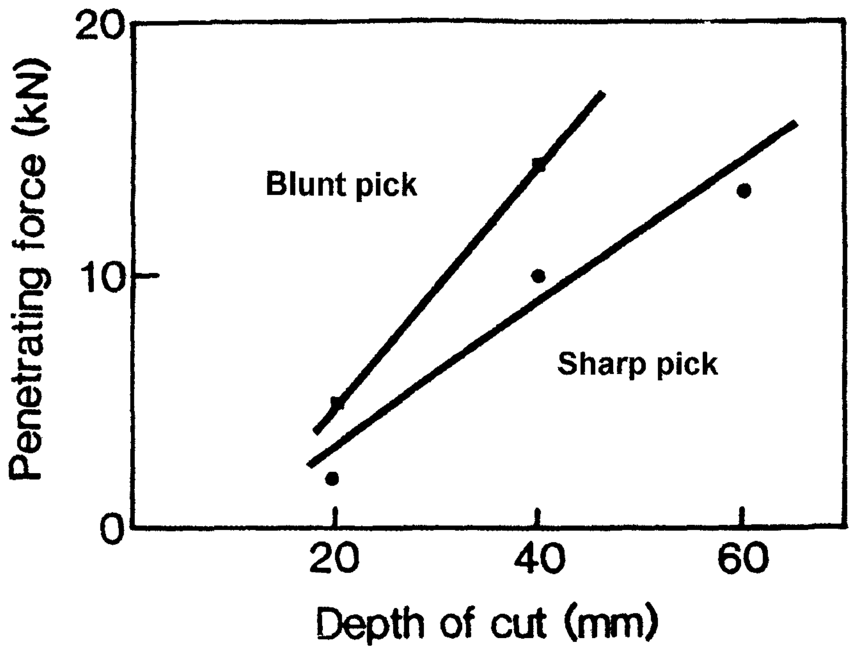
F_s The Sideways Force is the force acting on the side of the pick and is at right angles to the direction the pick is moving. Usually these forces are not very large except in the case of picks on the side of the drum where they are installed at an angle. The side forces in this case are significantly larger than for picks in the centr eof the drum.

The sum of all the normal forces of the picks on a drum is the force that is required to push the drum into the coal. The rotational force, or the torque that is required to turn the drum, is given by the sum of the cutting forces of the drum. This is true for the average situation as well as for a point in time.

The deeper a pick penetrates into the coal, the larger the forces that are required to keep the pick moving through the coal.
In the following two illustrations the relationship of the force with an increase in cutting depth is presented for the cutting force and the normal force. In the graph of the penetrating or normal force the effect of a blunt pick is also shown. The forces increase much faster with increasing depth for a blunt pick than for a sharp pick.



Graph showing force increase with depth of cut

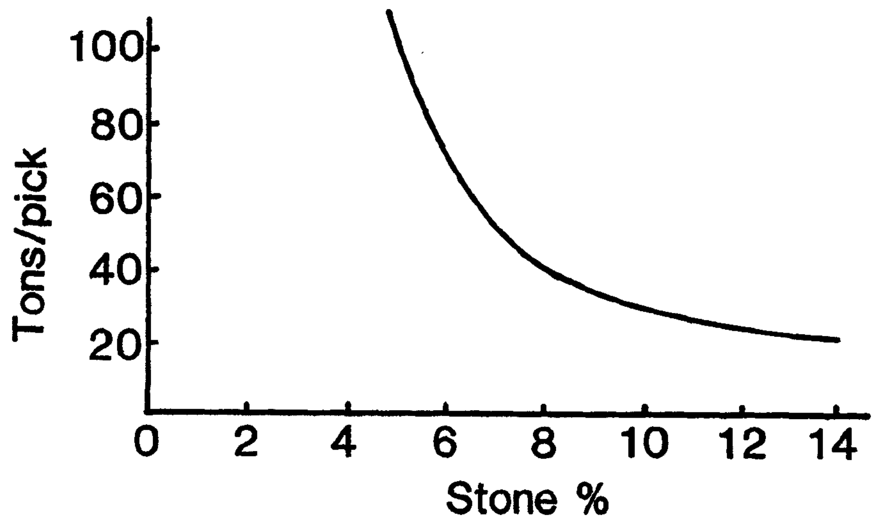


Graph showing force increase with depth of cut for both a sharp and blunt pick

Pick wear

It has been established, through work done by the Chamber of Mines research establishment as well as work overseas, that the main cause of pick wear is cutting into stone minerals. The greater the amount of stone that has to be cut in the horizon, the higher the wear on the pick and thus the shorter its useable life. In the following figure the relationship between the life of the pick given in ***tons per pick*** is compared to the amount of stone (given as a percentage of the whole cutting horizon) in the horizon.

RELATIONSHIP BETWEEN PERCENTAGE OF STONE AND PICK CONSUMPTION



Frictional ignitions caused by the cutting process

In a coal mine a frictional ignition occurs when an amount of methane is set alight by a source of heat created by two materials rubbing against each other.

To enable the methane to ignite, the source of heat has to be of sufficient size and duration to transfer enough energy into the methane -air mixture so that an exothermic reaction can occur.

Usually the initial amount of methane that is ignited is small in quantity, but if there is sufficient methane in the vicinity, caused by a build up of the gas, the ignition develops into a methane explosion.

Forming of a spot hot enough to ignite methane (hotspot)

When the picks encounter a material like sandstone, which is significantly harder than coal, two things happen. The forces acting on the picks increase dramatically and the surface of the pick in contact with the sandstone is abraded, or worn away, very rapidly.

This action of when a pick cuts into a material such as sandstone and the metal of the pick is very rapidly worn away is called **frictional abrasion** and leads to the formation of a wear flat on the tip of the pick point. Due to the increase in the area in contact with the material and the increase of forces acting between the pick and the sandstone, the friction also increases dramatically. This increase in friction causes severe frictional heat to be generated.

The conductivity of the metal allows an amount of the heat generated to be led away from the pick itself, but as the sandstone has a very low conductivity the heat is not led away from the contact surface. This causes the sandstone to reach a very high temperature very rapidly. The temperature can be so high that the sandstone particles actually melt. The moment melting occurs the sandstone loses its strength and becomes like a lubricant reducing the friction. Only when the pick has moved away from the molten area can sufficient friction be generated and heating can occur again.

This process has also been described by other researchers to be the following:

The cutting process involves a sequence of chipping, crushing and abrading processes such as shown in previous figures. The tip of the pick or that of the wear flat that has formed on the pick cuts off a chip of the sandstone. The wear flat, which also has a small wear angle to the front, crushes a layer of the remaining sandstone. During this process abrasion occurs between the newly formed layer of sandstone and the crushed particles of sandstone. In effect the sandstone substrate is thus abraded by a layer of crushed particles, and not metal. As both of these surfaces consist of sandstone material the heat generated will be higher than when steel is abraded by the sandstone, and the temperature reached will also be significantly higher.

With a steel tip the smear is considered to consist of molten steel at 1450° C. This is due to the steel melting while the sandstone is still solid.
With a high melting-point tip material, such as tungsten carbide whose melting point is above that of silica the silica, particles will melt before the tip material and therefore the smear would involve molten silica at 1710° C.
It should, however, be noted that when the steel melts the sandstone will also have the same temperature. Although the temperature of the steel smear or pick tip could drop fairly quickly due to the conductivity, the temperature on the sandstone would be more than sufficient to ignite methane. When the steel comes into contact with the sandstone it is usually when the pick is worn. This results in a significantly larger area over which friction occurs and therefore a significantly larger area for a smear to form. The larger the area of the smear the easier it is to ignite the methane.
When a sharp pick encounters sandstone there could be a higher temperature smear but, because of the relatively smaller area of the hot spot, the potential for igniting the methane is lower. If the tungsten tip is badly worn so that a larger area of friction is formed, then the potential for igniting methane is very high because of both an increase temperature and an increased area.

Characteristics required of sandstone to give a high potential for a frictional ignition

Sandstone is a poly-mineral material made up of grains of quartz cemented together into a solid mass by a matrix of another mineral which can be feldspar, a carbonate, or some or more of several other minerals.
The grain size distribution of the quartz is variable as is the ratio of the quartz grain to binder material.

The porosity of the material is also variable.
The strength of the sandstone varies as the three aforementioned characteristics change.

The incendivity of sandstone also varies with differences in composition.

The melting point of the matrix determines the melting point of the sandstone.
In coarse grained sandstone this is about 1250 °C.
Due to the conductivity of the sandstone, the time that a streak of molten material will stay hot enough is in the order of 15 - 30 millisecond.
This is long enough for an ignition to occur.

The only material that is associated with coal that has the required characteristics of high strength, high melting point and low thermal conductivity is sandstone.

The incendivity of sandstone increases with increasing quartz grain size.
The incendivity of sandstone increases with increasing quartz content.

Sandstone with a dominant particle size of greater than 100 microns and a quartz content of more than 50 % is incendive.

Siltsone (a very fine grained form of sandstone) with particle sizes of between 10 and 100 microns and with a quartz content of more than 50 % is incendive but less so.

Examples of two typical sandstones overlying the South African coal seams.

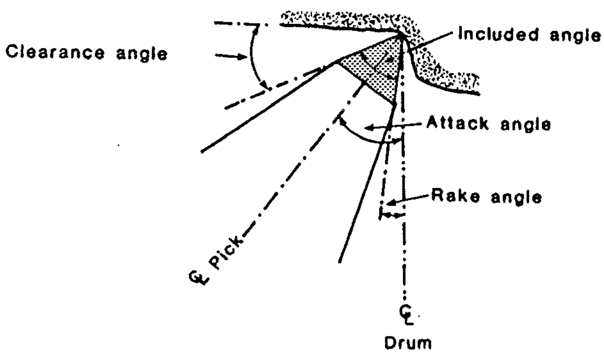
Characteristic	Sandstone a	Sandstone b
Strength	70 Mpa	50 MPa
Quartz Content	80 %	73 %
DOMINANT GRAIN SIZE	4 mm	0.53 mm

From this it is evident that typical sandstones in South African collieries are highly incendive.

Factors conducive to the formation of hotspots or smears.

Pick design

The type of picks as well as their shape and the angle at which they are attached to the drum describe the characteristics of picks. These angles, which include the angle of rake, the angle of clearance as well as the angle of attack are illustrated in the following drawing.

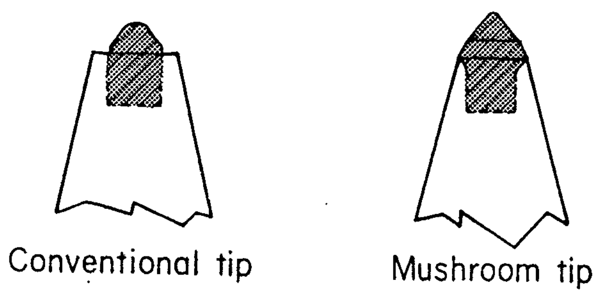


The known frictional ignition effects caused by pick characteristics are the following

- Ignitions occur when a pick wears and then rubs on quartzite rock, of which course grained sandstone is a good example, producing heating. Although ignitions can and do occur from rubbing of the tungsten carbide tip on the rock, the body or steel shank of the pick rubbing against the rock causes most ignitions.
- Larger mushroom tips, where there is more tungsten carbide presented to the stone in the path of the pick through the stone, decrease the chances of frictional ignitions occurring but does not prevent them from occurring.

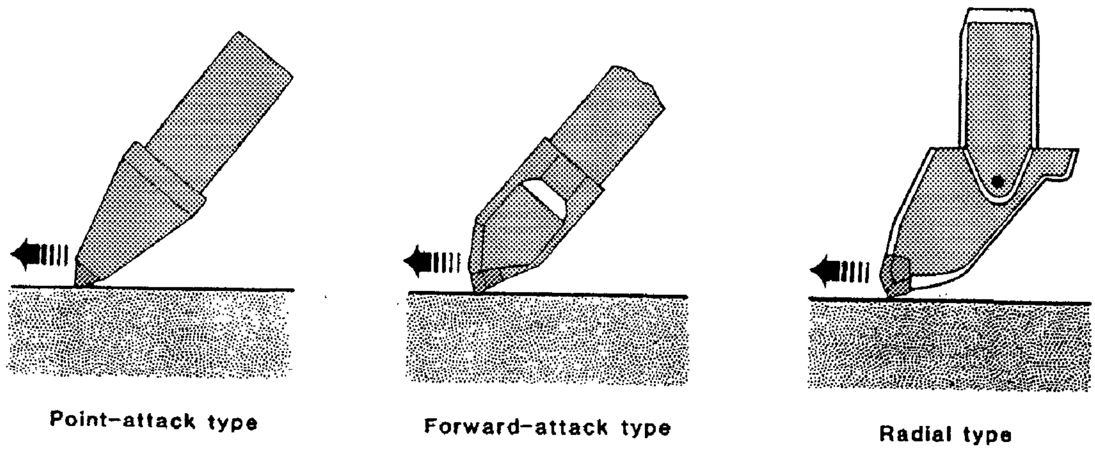
- The pick shape is important because the sharper the cutting edges the lower the chance of an ignition occurring. The point attack or conical pick is an inherently blunt shape and could cause ignitions much more easily than the radial or forward attack picks that have defined cutting edges.
- Larger radial or forward attack picks appear to be safer than smaller picks.
- Rounded clearance faces on tips appear to be safer than those having angular surfaces.
- To be able to cut rocks safely the picks would have to be able to stand up to the cutting of rock much better that they do presently with existing tungsten carbide tips.
- Polycrystalline layers on the pick, both on the rake and the clearance side of the tip, not only make the pick last much longer but can also prevent ignitions occurring even without the use of water.

The following figure illustrates the difference between a normal and a mushroom tipped pick.
The figure also indicates the other types of picks as described by Powell.



The mushroom tipped pick will allow less contact of steel with the sandstone due to the larger tungsten carbide insert preventing rapid wear on the side of the pick tip. At the same time the tip, although larger, will cause a smaller area to form a hotspot than a seriously worn tungsten carbide pick.
There is no doubt that a worn pick increases the potential for a dangerously big hotspot forming at a temperature that can easily ignite methane.

This is one of the reasons why the different types of picks, as presented in the illustration, have been proposed as they will cause a smaller area of the hotspot to be formed even if the pick has become slightly blunt.



Other aspects conducive to the forming of hotspots during the cutting process

The heat generation process taking place when a pick cuts into sandstone will be intermittent and be sensitive to small changes in the pick shape.
The material being cut must have characteristics that make the force between the materials intermittent or spotty. In this way higher forces are generated when the pick material encounters the harder part of the material

The intermittent heat generation process results from intermittent pressures between the pick and the material being cut which is mainly due to the way that the chips are formed but also due to the entrapment of smaller particles beneath the pick and material being cut.
The heat generated during the cutting of sandstone with a pick involves mechanical friction or frictional abrasion and will be dependent on the normal force experienced by the wear flat of the pick at a particular point in time.

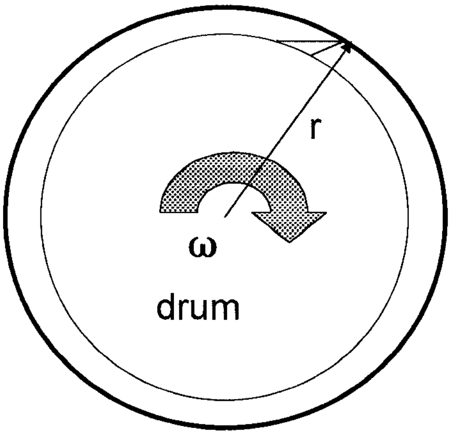
The time period to form a hot spot is very small. This is mainly due to the low conductivity of the sandstone or the quartz particles in the sandstone.
Although the friction and heating occur very rapidly, the temperature reached becomes so high that many incidences of melting of the tip when cutting sandstone have been reported.
Smears of melted metal have been found on the sandstone in the path the pick followed.
The melting of the tip implies that the temperature of the wear flat of the tip during cutting is about 1450 °C.
In experimental work into the mechanism of frictional ignitions, temperatures of 400 °C were measured 0.5 mm below the surface of the wear flat of the pick and a temperature of 300 °C was measured at 1.2 mm. Although the temperatures are not high, it does indicate the rate at which the heat is conducted away from the surface.

Stone on stone action in the cutting process.

An intermittent heat generation process might also be due to the formation of chips or small particles, where the partly formed chip presses between the wear flat and the sandstone substrate and thereby momentarily generates an excessively high local normal force on the bit. This sandstone particle can also be part of the wearing mechanism where two pieces of sandstone now rub against each other.
It should also be noted that the period that this increase in normal force lasts will be so short that it will be easily overcome by the momentum of the turning drum and can be likened to an impulse loading of very short duration
Another mechanism that can cause stone on stone friction is when an entrapped particle is pushed into a softer part of the pick, such as the steel body. This quartz particle would then be the material that could form the friction and higher temperatures would be reached. Entrapped particles themselves would however only cause a small area to be heated.

Speed of bit

It has been found that when the speed of the pick traveling through the material being cut exceeds 1.5 metres per second, the potential for a frictional ignition increases significantly. This speed is determined by the product of the rotational speed of the drum and the radius of the pick path through the material being cut.



The Speed, **S** in meters per second, of a pick is given by **2π rw** where

ω = The rotational speed of the drum in revolutions per second.

r = The radius from the centre of the drum to the pick point in metres.

Latter-day studies have shown that the likelihood of an ignition with a worn pick is not reduced significantly with a reduced speed until a very low velocity is reached.
From a coal cutting point of view the results have indicated that a lower pick velocity is not a reasonable alternative to avoiding frictional ignitions with worn picks in a practical mining operation.
As South Africa has hard and abrasive coal, a higher drum speed is required to maintain the cutting rates that are necessary to obtain the required outputs. In some cases it has been found that, with slower drum speeds, it is possible to still maintain the output from the section even when the cutting rates are marginally affected.

How the frictional ignition process works when the pick does not rotate.

When the pick does not turn in the pick box then it can be said to be frozen. This causes uneven wear on the pick causing the side in contact with the material being cut to wear down to the angle that the pick is rubbing against the material.
All radial picks can be seen to be of the non-rotational type as they fit into a pick box that holds them rigid and stops them from turning in the box.

A working hypothesis for the mechanism of frictional ignitions with a frozen conical bit cutting sandstone might be as follows.

1. The pick point or tungsten carbide insert point initially abrades very rapidly to form a wear flat. The initial linear wear rate of the tip is slower with a harder or more durable tip material.
2. The tip of the wear flat forms chips of sandstone and the wear-flat abrades the remaining layer of the sandstone and the resulting sandstone particles. During chip formation the normal force exerted by the pick on the sandstone is momentarily very high, leading to the intermittent formation of a small hot spot on the surface of the sandstone.
3. The small hot spot on the sandstone is about 1450 °C and ignites a small flame kernel. The small flame heats the wear flat and increases its wear rate, but is subdued by the coverage that the body of the pick and the sandstone gives and does not propagate into and ignite the bulk of the combustible environment.
4. The area of the wear flat on the tip increases because of frictional abrasion. The rate of increase of the wear flat depends upon the linear wear rate of the pick tip and the tip geometry. The linear wear rate is increased in a combustible environment because of heating of the tip by the flame kernel. Eventually a large flame kernel ignited by a large hot spot formed by a larger wear flat, propagates into and ignites the bulk combustible environment.

FACTORS DETERMINING THE POTENTIAL FOR A FRICTIONAL IGNITION

Mine management will have to determine the risk of a frictional ignition occurring in their particular mine.
As there is no coal mine that is not fiery it has to be accepted that there is always the chance of methane that could accumulate to form the fuel for a methane ignition.

The other aspect to consider is the chance of a hotspot forming that could be the initiating source of heat.
The chance of cutting into the roof is always present as it is determined by the operator's skill in controlling his machine. Further, most continuous miner drums in South Africa rotate at a speed that would generate a hotspot behind the pick.
The best means for determining the potential for a frictional ignition occurring is to measure the characteristics of the material that the cutting process will encounter.
If there are sandstone lenses in the coal seam or the immediate roof consists of sandstone of an incendiary type, then there is a significant risk of a frictional ignition occurring.
If this is accompanied by a high methane emission on the mine, the risk is increased.
It can then be expected that mine management would have to take not only preventative actions but also actions that would stop any ignitions from spreading further than the immediate vicinity of the continuous miner drum.

INFORMATION
PERIOD FIVE : OTHER FORMS OF FRICTIONAL HEAT

In this section we will be considering other types of friction in the mining situation. Up to now we have mainly been considering the metal on stone friction. This is where metal is moved against stone. This is be similar to stone on metal where the stone now moves against a stationary piece of metal. Although the mechanism is very similar to metal on stone, the circumstances that could lead to it vary significantly.

The other areas that will be considered are metal on metal and stone on stone. In these cases, metal moves against other metal or stone moves against other stone.

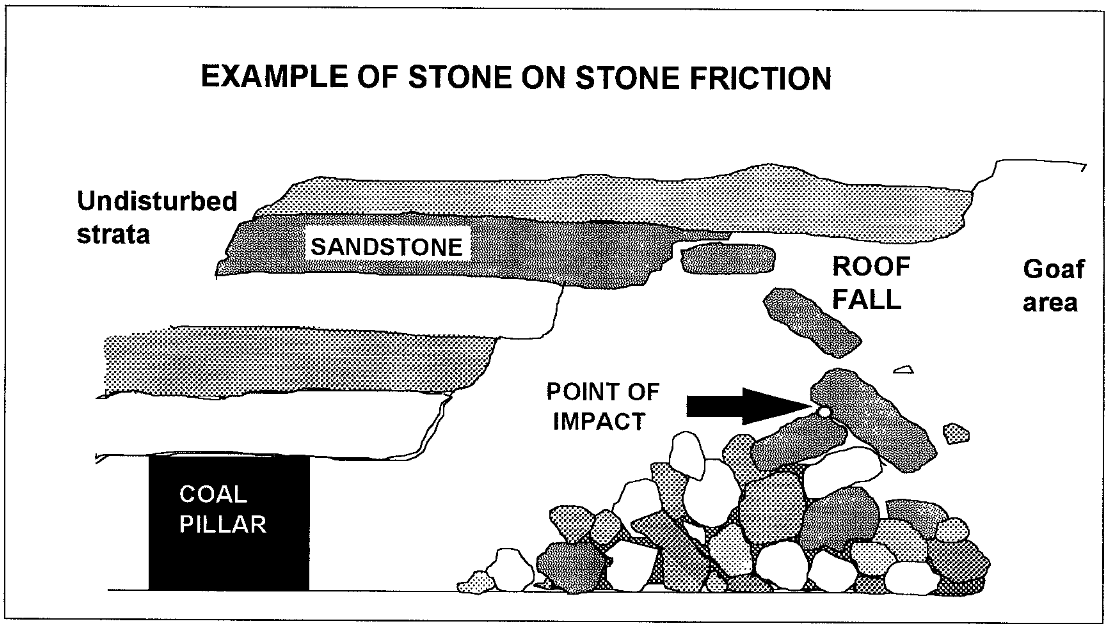
STONE ON STONE

Frictional ignitions of methane / air mixtures can occur when rock slides on rock or rock strikes rock due to falls of ground when certain conditions are fulfilled.

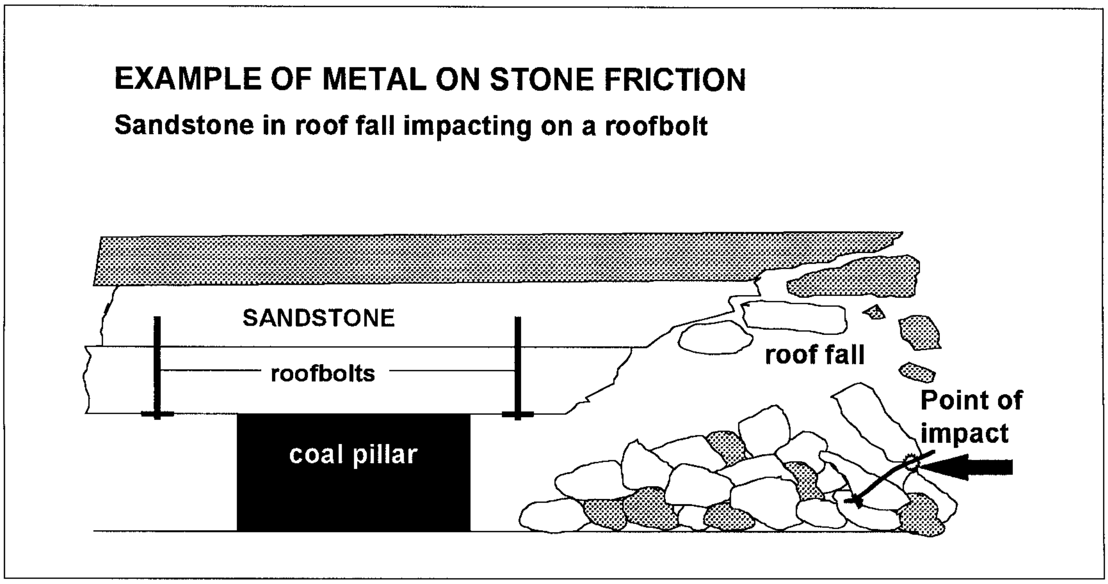
1. The rock types have to contain a minimum quartz grain size and quartz content. The pieces of broken rock must slide over each other at a particular speed and contact pressure.
2. A minimum speed of sliding contact, for a given rock type and contact pressure, is exceeded.
3. A minimum contact pressure, for a given rock type and speed of sliding contact, is exceeded. In practice this contact pressure will be dependent on the mass and configuration of the sliding rock as well as the distance it could have fallen before making contact.

In the majority of cases in South Africa where goafing occurs after mining under sandstone roofs these conditions could be met.

In the following illustration an example of stone on stone friction is shown. From this illustration it can be seen that the rocks involved must be of the incendiary type. (sandstone). The falling sandstone piece must be of big enough and fall through a distance of sufficient length so that enough kinetic energy is released to obtain an impact of sufficient size that will generate the heat for an ignition.



STONE ON METAL



In the following illustration a possible metal on stone frictional ignition in a goaf is shown.

[1]If a piece of sandstone of sufficient size should fall through a sufficient distance and impact on a roofbolt, than enough heat can be generated to ignite methane that is present in the goaf.

As in the case of stone on stone friction in a goaf, the methane is drawn down by the falling rock and could mix to an explosive mixture due to the mixing action caused by the falling sandstone piece.

METAL ON METAL

Metal on metal friction occurs when two metals move in relation to one another. Frictional heat is generated to the point where fires can be ignited mainly due to the duration of the friction rather than the severity of the impact between the metals. Usually metal on metal friction is of significantly longer duration than that occurring between metal and stone or stone and stone.

It has been found that the pure metal on metal friction will seldom, or never, be able to ignite methane . This is because the heat generated takes a long duration to reach the ignition temperature. Usually this type of occurrence happens when, say a conveyor belt roller seizes, i.e. at lower levels in the belt road where the chances of methane occurring are very slim. This type of frictional heating can however be

[1] An experiment showing the principle of thermite reaction can be conducted if so required. By reading up in chemistry books to obtain the right volumetric relationship, a mixture of aluminum dust mixed with iron oxide is prepared. When this mixture is set alight a violent heated reaction occurs. The aluminum will draw the oxygen from the oxide and, after the reaction has died down, particles of pure iron will be found in the residue. It should be pointed out that this is a dangerous experiment and should not be attempted unless a competent person carries it out.

sufficient to start a coal fire using the dust and coal particles along the belt-road as fuel.

There is however one situation where metal on metal friction can initiate a frictional ignition. This is in when aluminum with a high magnesium content is involved in the friction. When a piece of aluminum is struck on a bed of metal rust then the possibility of a thermite reaction is strong.

A thermite reaction is one where an exothermic reaction is initiated between aluminum and an oxide. The aluminum is such a strong reducing agent that it actually draws the oxygen away from the oxide. This leads to a significant release of heat. The amount of energy released by such a reaction is of such intensity that it could easily ignite methane. It also occurs over a very short time period.

It is for this reason that aluminum wrappers for candy and other forms of aluminum are prohibited in coal mines.

INFORMATION

PERIOD SIX : METHANE

Methane - the fuel for frictional ignitions.

The role of methane in the explosive triangle has already been pointed out.
Methane is a fuel for an explosion.

Methane has caused more lives to be lost in collieries than any other gas. This is because it burns or explodes violently when ignited in the underground environment. When it explodes, not only are the workers in the vicinity hurt or killed but also the gases released during the explosion could affect workers quite a distance away from the explosion. The hot gases formed by the explosion are detrimental to human beings and the remaining gases can kill people that survive the initial explosion.

What is methane?

Methane is the most common strata gas.
Although methane is odourless, colourless and tasteless, it is often accompanied by traces of heavier hydrocarbon gasses in the paraffin family that do have characteristic oily smells.
Unless it is present in such quantities that it can suffocate a person due to lack of oxygen it does not affect breathing in any way.
It is not poisonous.

Methane can only be detected by means of measuring instruments.

A methane air mixture is also called **Firedamp** and methane sometimes Marsh gas

Firedamp is the traditional name given to the gas that burns in collieries prior to it being identified as methane. In marshes the rotting plant material emits methane hence the word marsh gas. (It is called Firedamp in collieries because of its inflammable nature.) A large amount of effort and money has been spent worldwide on researching this gas because it occurs naturally in collieries and poses a very real danger.

Methane is the simplest form of a **hydrocarbon.** Hydrocarbons are, as the name suggests, chemical compounds that contain only hydrogen and carbon atoms.
Methane (CH_4) is the first member of the **paraffin family** of compounds that have the general formula C_nH_{2n+2}, where n can be 1, 2 etc.

The formation of methane

Methane is the gaseous by-product of bacterial and chemical decomposition of wet plant matter in the absence of oxygen. (This is called an anaerobic process.) It would seem that the production of methane starts from the moment life ceases in a plant and continues until all moisture is completely used up. The decaying process is speeded up by heat and in general the greater the amount of hydrogen and oxygen (in the form of moisture that is present), the greater the amount of methane that is produced.
This process is used today by farmers to use farm refuse (decaying plant matter and manure) to generate gas to run electricity generators and water heaters.
Coal is compressed decayed plant matter that has been covered by mud and stone (sediments) and compressed (over hundreds of thousands of years) to undergo a complete alteration over time - from decaying plant matter, first to peat, and then to coal.
The generally accepted theory is that the various types of coal have been formed by material that has undergone different stages of decomposition depending on the heat and pressures it has been subjected to. The more decomposition of the original material that has occurred, the higher the rank of the coal that has been formed. Anthracite has the highest rank of all coal and is generally relatively free of methane.

Methane emissions

The usual source of methane in mine workings is from an exposed coal surface where it is released either from the pores of the coal or from the cracks in the coal bed, due to the gas pressure difference between the seam and workings.

In newly exposed coal faces there is a greater release of methane as the pressure difference between the in-seam gas and working area is at a maximum. Also, when the coal is broken into smaller pieces by the continuous miner more surface and cracks are exposed so methane leaves the chunks at a fast rate. This is why the greatest amount of methane is usually found in the working face.

Sometimes methane can be heard issuing from a fissure in the coal - it is then called a blower. Methane can sometimes be seen bubbling through the water in a drill hole or on the floor. In such cases adequate precautions must immediately be taken to monitor the area and dilute it to a safe concentration. The most dangerous conditions often arise, however, when a very small flow of methane escapes unseen and unheard from a fissure in the coal in an area where there is not adequate ventilation. The methane may then accumulate at the roof where an explosion may occur if an ignition source is present, i.e. pick hotspot, electrical short, falling rock, etc.

The physical characteristics of methane

Pure methane is a gas with a ***specific gravity*** of 0.553. This means that methane is just under 50 % lighter than air at the same conditions. This has the effect that methane will tend to rise above the air and settle at the top.

Although methane has a tendency to rise to the top of an enclosure, it has also been found that once it has been mixed with air it will only separate out (in exceedingly still conditions) over a very long period.

Layering of methane in mine workings is thus more easily formed under conditions where the ventilation is inadequate or not present at all.

Methane gas burns but does not support combustion. When a jar full of methane is inverted and a burning taper is inserted into it, the methane will immediately start burning at the bottom of the bottle where it is in contact with air, but the taper which is immersed in the gas will be extinguished.

When the methane burns or explodes with sufficient or an excess of air, then it does so with a clear blue flame. When there is an excess of methane or insufficient air to supply the oxygen, then the flame will be tipped with yellow. As the amount of air is reduced, the flame increases the yellow colour. This yellow colour is caused by carbon particles formed by the incomplete combustion of the mixture.

The chemical reaction which takes place when methane burns or explodes is:-

(methane + 2 oxygen = carbon dioxide + 2 water)

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$

Two molecules of oxygen are thus required to combine with each molecule of methane. Air normally contains about 21 % oxygen and 79 % nitrogen by volume. When 9 % methane is added to the air, the oxygen percentage is automatically reduced to 19 % and the mixture thus contains exactly twice as much oxygen as methane. This is the reason why the most violent explosion occurs at this concentration.

When methane burns in the presence of a lack of oxygen, as can easily occur in the confines of underground workings, only partial combustion occurs leading to the formation of highly poisonous carbon monoxide.

$$2CH_4 + 3O_2 = 4H_2O + 2CO$$

The ignition temperature of methane is normally about 650 °C which means that only sources like a flame or a hot spark are hot enough to ignite it. When methane, however dilute, is brought into contact with a flame, it will burn. However, when the concentration is low, the molecules are so far apart that one molecule which is burning does not create a sufficiently high temperature to ignite the molecule nearest to it. When the concentration is high enough, however, each molecule ignites the one nearest to it and the flame rapidly spreads throughout the mixture. This causes an explosion and such a mixture of methane and air is said to be an inflammable mixture. If the mixture contains too much methane, the percentage of oxygen is reduced and the rate of combustion is reduced to such a degree that insufficient heat is developed to propagate a flame and consequently there is no explosion.

The Inflammability of methane.

The most important property of methane from a mining and frictional ignition standpoint is its ability to ignite /explode under certain conditions.

As pointed out before there are limits to when a methane and oxygen mixture will sustain burning. The lower limit has been defined as the smallest percentage of gas that will allow self propagation of the flame through the mixture and the upper limit is the highest percentage of methane that will act the same. The lower limit is due to the amount of methane present that will enable a flame to propagate and the upper limit is determined by the amount of methane that replaces so much of the oxygen that an explosion cannot occur.

The lower limit (LEL) for methane is 5 % and the upper limit (or Higher Explosive Limit (HEL)) is 15 %.

During experimental tests to determine the lower explosive limit (LEL) for methane, values ranging from 5 to 6.7 % were determined. This variance in lower limit values was understood at a later stage when the influence of the initiating energy was more closely investigated.

The ability of methane to be ignited by a source is determined not only by the temperature but also by the time the methane is subjected to this source. A heated wire and electric sparks would result in a lower limit at a lower methane percentage than would flames from some explosives and a gas flame of short duration.

Another aspect, called the lag in ignition, is caused by the time required to transfer the energy to the methane. This lag is also dependent on the size of the ignition source that transmits the energy.

The larger the size of the heating element the shorter the time lag.

The higher the initiating temperature the shorter the time lag.

The air pressure has however no effect on either the time lag nor the ignition temperature.

It was also found that the better the flame or initial flame is aerated, the better the propagation.

All of this has a profound meaning in terms of supplying fuel for a frictional ignition.

1. The methane in and around a pick will be well aerated, due to the movement of air caused by the movement of the drum.

2. There will be turbulence that will mean that a relatively wide range of methane concentrations could be presented to a hotspot.

3. The temperature of the hotspot is usually above that which is required to ignite the methane in a very short period.

Where is methane found in a mine?

The most likely source of CH_4 is the actual seam being mined. The CH_4 source could also be an adjacent seam from where it flows to the 'working' seam. Also, goafs can release plenty of CH_4.

Because methane is much lighter than air, it is more likely to accumulate in high places such as raises and roof cavities. It is therefore sometimes necessary to direct an air stream directly onto the roof in order to break up layers of methane.

To identify the areas where dangerous amounts of methane can be found in a mine three determining factors should be looked at:

1. The source of the methane
2. How methane reacts
3. Areas where there is no or insufficient ventilation.

Although methane is liberated throughout the mine, in areas where mining is being carried out there is usually more methane liberated than in older workings.

Abnormal high amounts of methane will be detected where blowers are encountered, close to dykes and horizontal in-seam exploration boreholes.

In poorly ventilated headings significant methane build-up could be found.

Where there are cavities in the roof due to roof falls or due to an incline or rolls in the roadway, methane could accumulate in the higher lying roof areas.

In sealed off areas where there is no ventilation, methane can be found in significant quantities.

In a similar way methane accumulations can form in goafed out areas of a high extraction mining method.

Measuring for methane

There are various techniques that are currently available to determine the percentage of methane in the mine atmosphere. Among these are pellistor detectors, flame safety lamps, thermal and acoustic methods, optical (infrared) methods, mass spectrometers, and gas chromatographs. Although all of these methods can measure methane concentrations, only a few are suitable for practical underground use.

Traditionally the Davy type of safety lamp was used to determine the presence of methane. This lamp has an adjustable flame which can be observed through a strong glass. Air enters and leaves the lamp through a double layer of fine gauze. When this lamp is carried into an atmosphere containing 2-5 % methane, a cap, caused by the methane in the atmosphere, can be seen on a reduced flame. The height of this cap gives an indication of the percentage of methane present. When the methane concentration exceeds 5 %, the gas will explode inside the gauzes without igniting the outside atmosphere.

The safety lamp is no longer used in South African collieries. This is mainly due to the inability of the lamp to measure the levels required by the law. Whereas previously the lower reportable limit of methane was 2 % it is now only
1.4 %. This gives a bigger margin of safety in the mines but requires a more sensitive instrument than the safety lamp.

In the place of the safety lamp, there are two other common types of hand held instruments that are often used for detecting methane and other flammable gases.

Both use electricity that is supplied by batteries. The **resistance type of methanometer** consists of a balanced electrical whearstone bridge containing two catalytic oxidation (pellistors) detectors that are heated. The one is coated with a catalyst that causes any inflammable gas passing over it to become oxidized. This causes it to heat up even more and the electrical resistance is altered. The resultant imbalance of the bridge is indicated on a galvanometer that gives a measure of the percentage of inflammable gas present in the air.

The majority of hand held instruments that are used in the sections today are of this type. As this type of sensor relies on oxidation it requires oxygen to operate. In air containing 10 % or more methane the oxygen deficiency becomes great enough to affect the accuracy of the sensor. Hence these types of sensors are generally used to measure methane in the range of 0 % to 5 % in air.

To overcome this problem, these sensors are combined with thermal conductivity type sensors which give accurate readings from 5 % to 100 % methane in air. With this type of sensor the difference in thermal conductivity between pure air and methane is used to replace the pellistors in the electrical bridge set-up. These sensors are not very accurate for methane concentrations below 5 %.

The infrared, acoustic **interference type of methanometer** or interferometer works on the principle that the passage of light through a gas is affected by the refractive index of the gas. A light beam passing through a gas like methane is thrown out of phase with another beam passing through pure air, giving rise to black interference lines which provide a measure of the percentage of methane in the air.
These types of instruments can detect methane in the range from 0 % to 100 %.

A drawback of the instrument is that the presence of other hydrocarbons, high humidity, dust, etc., can influence the reading. Hence care has to be taken when such instruments are being used.

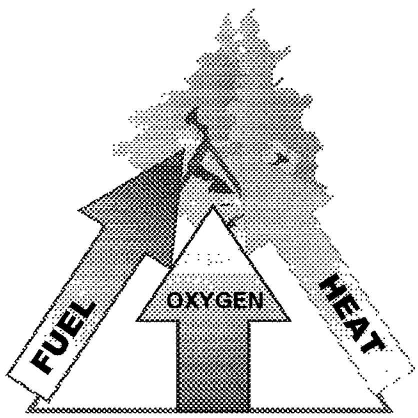
INFORMATION
PERIOD SEVEN : PRINCIPLE OF REMOVING A COMPONENT

The purpose of this period is to show and let the participants understand that explosions cannot occur unless all three of the components are present. If one of the components is removed then there is no chance of an explosion or a frictional ignition occurring.

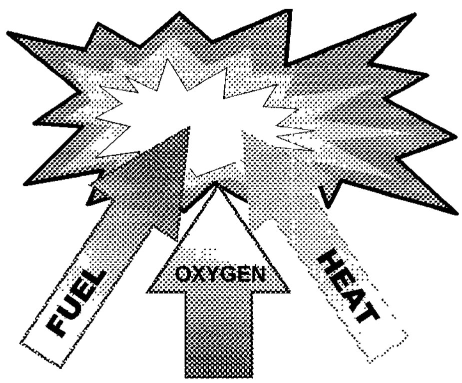
It is important that the participants understand this principle, as this is the basis of the prevention of frictional ignitions. It is not always possible in the mining environment to prevent either the presence of methane or the chance of a frictional heating. If attention is given to removing both the methane and the heating, the chances of the two occurring at the same time to cause a frictional ignition would be so small as to be non-existent.

It has been shown that for a fire or explosion to occur, three components have to be present.

These components are:
Oxygen
Fuel
Heat to initiate the reaction.



FIRE



EXPLOSION

To stop a fire or explosion or prevent it from occurring one of the components of the fire must be removed or prevented from participating in the explosion.

It should be pointed out that an explosion usually happens so fast that once the conditions exist to form an explosion, and it has started, the only action that can be taken is to stop it from growing larger or to stop it from spreading further.

Each of the components will be considered on its own.

Oxygen

Oxygen has to be removed or kept away from the fuel so that they cannot together participate in a reaction.

In the mining environment it is difficult to remove oxygen from the working area, as workers need it to breathe.

The removal of oxygen is however not an impossible way of preventing fires and explosions and is often used to extinguish fires that are already burning.

In the case of highwall mining where there is nobody close to the machine extracting the coal, use is made of inert gases to dilute the oxygen to the point where neither a fire nor an explosion can occur.

The majority of modern fire extinguishers use the principle of keeping oxygen away from the fire. This is done either by spreading an inert gas in the area of the flame or by covering the fuel with an incombustible powder that keeps oxygen from reaching the fuel.

The successful use of water to douse a fire is partly due to water forming a barrier between the fuel and the air and partially by cooling the reaction.

Another way that the oxygen factor, or the lack of it, can be used to stop a fire in a mine is to seal the area off so that the fire will use up all the oxygen in a contained area. Once this oxygen has been used the fire will die out.

Fuel

The fuel has to be removed or separated from the oxygen so that it cannot react. The simplest way of stopping a fire from burning it to take the fuel away. By taking the wood away from a wood fire the fire will die out.

In a similar way when the gas is turned off, a gas fire will die and when the little valve on a lighter is released the flame dies out.

By preventing fuel from being present, no explosion or fire can occur.
If methane is removed it cannot ignite, just as without wood you cannot make a wood fire.

In the case of an explosion, the reaction uses up the fuel so quickly (milliseconds) that there is nothing that can be done to remove or reduce the amount of fuel. The only way to stop explosions is not by trying to remove the fuel but by preventing the fuel from being present in sufficient quantities so that a dangerous explosion could occur.

In a coal mine there is always methane present so the actions directed at eliminating the fuel are not to stop it from being there but rather to ensure that no dangerous concentrations of the gas are allowed to collect anywhere in the working area.
Similarly the very material being mined in a coal mine is fuel. The coal itself is a very powerful fuel for a fire or an explosion. To remove the coal as a fuel is thus very difficult or almost impossible. To stop the coal from becoming a fuel in an explosion is thus not by reducing its presence, but by keeping it in a form that is not conducive for it to take part in a reaction. If coal is in large particles then it will not take part in a coal dust explosion. If sufficient heat is present then the larger particles can however ignite to form a slow fire.
The most dangerous form of coal is dust. When particles are small they can ignite easily and take part in a explosion. The only way to reduce the danger of coal dust as a fuel is to add so much inert material to it that it cannot take part in an explosion.
The most common material used for this purpose is stone dust.

The Initiating Heat

For a fire or an explosion to occur there must be sufficient heat to start the exothermic reaction. The heat given off by the reaction is enough to keep the reaction going until either the fuel or the oxygen is depleted.

To stop a fire or explosion from occurring, the amount of heat must not be allowed to increase to the point where a reaction can be started. To stop a fire or explosion from continuing the amount of heat that is generated by the fire must be removed to the point where the reaction cannot continue.

Preventing the heat

The best way of using the heat parameter to stop the occurrence of fire or explosions is to stop the heat from occurring.

To stop a lighter from being lit, the wheel giving off the spark should not be used, or to stop a wood fire from being lit, the match should not be struck.

To stop metal on metal frictional heat from occurring the most commonly used method is to lubricate the surfaces in contact. By lubrication of the surface the friction is reduced significantly and there is a significantly lower build-up of heat.

In a mine the heat leading to a frictional ignition should be stopped from occurring, and to prevent a coal dust explosion from happening the methane explosion that provides the initiating heat should be stopped from occurring.

How this is achieved forms the topic of the following chapters.

It has however been proven that the best way of stopping the heating from occurring is to firstly prevent the conditions that lead to frictional heat from being there and, as a second line of defense, removing the heat that might have occurred.

Removing the heat

To extinguish a fire, water is usually thrown on it. The water partly stops the oxygen from reaching the fuel but mainly cools down the reaction to the point where insufficient heat is released to maintain the reaction.

When water is thrown on a hot object it withdraws energy or heat from the object because it is at a lower temperature than the object. Heat flows from a hot object to a cold object. Further heat is also withdrawn when the water is turned into steam by the hot object. Water is used because it is cheap, readily available and can get into close contact with the object to allow a transfer of energy.

This principle of cooling is used in the flame proof enclosure of the mine where the thickness of the metal and size of the gap in the enclosure is such, that, when an explosion occurs in the box, the flame is cooled to an acceptable temperature before it reaches the outside. It is also one of the characteristics used by stone dust to stop a coal dust explosion. When the stone dust is dispersed into the air by the force of the explosion, the stone dust particles have a cooling effect or extract the heat energy from the explosive flame.

One of the best ways of removing the heat from the hotspot that has been caused by friction is to cool it down with water just as you would use water to cool down a hot piece of steel.

Description of mechanisms used.

MECHANISM	DESCRIPTION
Prevention	Stop it from happening
Barrier or sealing	Putting something between
Removal	Taking it away
Dilution	Reducing the concentration
Cooling	Reducing the temperature or energy release

INFORMATION

PERIOD EIGHT : RESPONSIBILITY OF PREVENTING AN IGNITION

In determining the issues that will influence what actions a person will do to keep himself and others safe, we will consider the following aspects that motivate this person's actions.

These aspects fall both within the organization and outside of the organization.

They can also be mainly split into two categories, i.e. those where a legal or organizational obligation is placed on him and secondly an obligation that he places on himself and which is derived from his personal experience and environment.

Key influences on a person to keep himself and others safe

Himself

His family

His colleagues and friends

His organization

Mine rules and codes of practice

Mining law of South Africa

The general law and statutes of South Africa.

The social system within which the person lives and operates (this is based on the morality, values and mores, and other social values of this system.)

Every person working on a mine is subject to all the above. Depending on the person's position in the organization, the weight of the influences on a person's actions will however change.

The owner of a mine is responsible through the law to keep the workers safe on the mine. His efforts in keeping workers safe, therefore, although not exclusively, is mainly determined by the law.

The manager also has an obligation in terms of the other influences to do his duty to keep workers safe and healthy.

The operator of a machine has a responsibility in terms of the mine codes of practice and the other rules of the mine to keep himself and other workers safe.

Although the labourer has no direct responsibility for the safety of others, he has a responsibility to himself and to his colleagues based on the other influences identified.

Keeping workers safe is thus not only a matter of conforming to the law or codes of practice, but also to the other obligations that determine your actions in daily life.

In this course only those aspects that have a direct connection with the mine will be presented. The other aspects will be dealt with through group discussions amongst the participants.

The law

The trainers should present the aspects of the Law relevant to the audience.

Codes of practice

The trainers should present the Codes of Practice relevant to the audience.

Mine rules and procedures

The trainers should present Mine Rules and Procedures relevant to the audience.

General discussion of the period

As this period could be deemed controversial in nature, a general discussion is presented to highlight the paradigm shift that is required as well as the anticipated problems that might arise.
Part of this discussion is also repeated in the Trainers Recommendations.

This period should be spread over two sections. The first one is done after period eight at which stage the participants should be sensitized to the fact that the greatest contribution to their safety rests in their own hands.
At this point they will not yet be fully aware of all the activities that could be taken to prevent frictional ignitions from occurring. This will prevent them from fully understanding and accepting their responsibilities and roles.

At the end of the course this period will have to be revisited so that the participants can clarify any doubts in their minds as to what is expected from them.
They should also be clear how the whole issue is motivated, not only from the point of view of a responsibility towards the mine and the installed rules and regulations, but also based on their responsibility towards themselves and society in general.

As it is anticipated that the workshops could generate controversy and possible conflict between lower management levels and the workforce, it is proposed that this period is done under the guidance of a more senior and experienced manager. It is also foreseen that expectations could be generated amongst both management and workers. This will have to be closely monitored by management so that the process reinforces no unrealistic expectations on the part of either party.
It is however imperative that the workers become aware of their rights as well as their responsibilities.

Following the lecture in which the framework of the responsibilities as determined by the Law as well as the mines procedures are spelt out, the rest of the period will be spent on group discussions.

Group discussion one

The task to the group is to identify the reasons why it is important for each of the participants to ensure that frictional ignitions do not occur. They should then further determine whom they believe should keep themselves safe in the following situations.

When crossing a street.
When walking alone at night in a less safe environment.
When walking in a busy section with shuttlecars all around.
When walking in an old area with an unsafe roof.

An important question that should be put to the group that they should consider and give an answer to is: why is the person, whom they identified, responsible?

The group should determine whose responsibility it is to help the following over a busy street:

A blind person.
A young child.
A drunk person.

They again should determine the reason for their answer.

Finally the group should formulate a reason why and under which circumstances the responsibility for an act that improves safety is the individuals and when it is one of the bystander or fellow workers.

Aspects such as - Responsibility for oneself when one is capable; Assistance when one cannot see or be aware of - should be one of the answers forthcoming from this discussion.

The trainer in summing up the outcomes of the exercise should reinforce the fact that every person has a responsibility to himself as well as to members of society. Other members of society cannot always be aware of a danger and it is the responsibility of people to make others aware of dangers if a person becomes aware of it.

Group Discussion two

In this exercise each of the participants should identify and formulate where they have seen dangers in the underground environment that could have led to a frictional ignition.

(This is also a good control point for the trainer, as during this discussion the knowledge of the factors that could lead to a frictional ignition would or should be used by the participants.)

Once these dangers have been identified they should be ranked in order of importance with regard to their relative danger. Which of these factors could have easily led to a frictional ignition and which would have not.

Once these factors have been identified and ranked, the second exercise concerns what the participants believe are other factors that could lead to a frictional ignition, and how they would determine if these factors were present in the mine or section they were working in.

By combining the various factors as identified by the groups and leading the groups to a certain degree, the trainer should be able to come up with a fairly comprehensive list. In the following exercises the group will not only use those factors that they have identified but the complete list as determined by the group.

After determination of these factors, the participants must propose in each of the identified cases whose responsibility it is to address the dangerous situation.

Further to this they should also determine what each of them should do when the responsible person is not there, and what they should do if the dangerous situation persists.

Group exercise three

In this exercise the groups must take these factors and the responsibilities that they have given themselves and identify why they think they will be able to execute these actions. (In other words they must formulate a motivation why they believe they can contribute.)

The groups should then identify issues that they believe stand in their way of "them" doing what they believe each one of them should do or should be done by the fellow workers to reduce the dangers of frictional ignitions.

The results of this exercise should be presented to mine management so that it can be seen that mine management takes the issue very seriously and are concerned about the issues that could stand in the way of the measures being implemented. At the same time one of the participants will have to present to mine management what they believe the various participants feel they can do and contribute to reduce the dangers of frictional ignitions.

At the end of this discussion the attending manager should take note of the issues so that feedback in terms of them can be given at a later stage. It is also important that the manager gives recognition to the fact that the workers have identified possible reasons for the danger and that they have proposed actions on their part.

This exercise is very critical as it is used to create a paradigm shift in the workers thinking. The workers are ultimately responsible for their own, and other workers safety. At the same time the workers will require that certain actions on the part of management be taken to enable them to take responsibility and act when they, the workers, become aware of dangerous situations.

INFORMATION

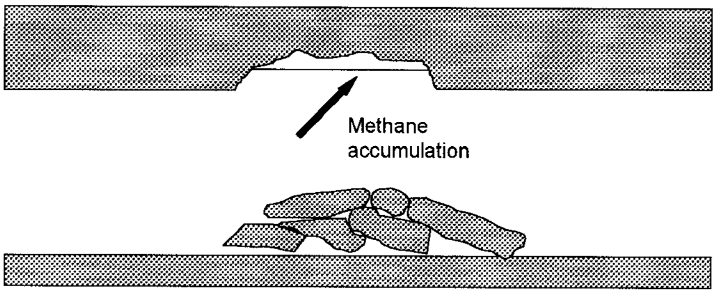
PERIOD NINE : REMOVING METHANE

Background

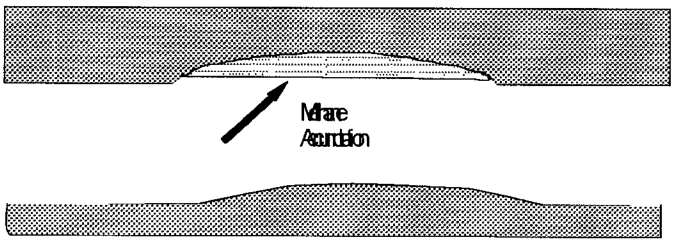
Before methane can be removed from underground working areas, particularly those areas where it can be most dangerous, such as the working faces, we must first find out where it is.

From previous lecture periods you are now aware that for an ignition of methane to occur there must be an igniting source and the methane must be mixed with the ventilating air so that the percentage of methane is within the explosive range of 5 % to 15 %. You have also learnt that methane gas is lighter than air and will mainly be found near the roof of the mine workings. If there is a cavity in the roof, such as when there has been a fall of roof, this is also a place where methane might be found. Also, when underground roadways are not horizontal but are inclined, methane will tend to accumulate in the higher parts of the roadways.

Diagrams of where methane might be located.



Roof fall



The source of ignition caused by cutting picks on either a continuous miner or a longwall shearer drum is most likely to occur when the cutting drum is at roof level and the picks cut into a sandstone roof. Thus, when cutting drums are at roof level this is when we are most likely to have the fuel and the source of ignition that may lead to an explosion. For this reason, machine operators should try and not cut into the roof, or should keep to a minimum the amount of roof cutting done.

An ignition can occur at other positions other than when the cutting drum is at roof level. For example, the coal seam may contain a sandstone parting or intrusion which could be in the middle of the seam and this could be the cause of the frictional heat source. Although the methane is generally found at roof level, the disturbance of the air in the heading caused by the rotating cutting drum mixes the methane and the air and can cause the methane/air mixture to move away from the roof. Provided the pick generates the required 'hot spot' and the methane percentage is within the explosive range (5 % to 15 % methane), an ignition can be caused at any position between roof and floor during the cutting operation.

To prevent the ignition occurring, we must prevent the methane from falling within the explosive range. You have already learnt that when the percentage of methane is greater than 15 % there is not enough oxygen present in the air to cause an explosion, and below 5 % there is not enough methane to cause an explosion. If we allow the methane to be higher than 15 %, we create an additional problem of there being too little oxygen in the mine atmosphere and underground workers in that atmosphere could be asphyxiated. In addition, a percentage of methane greater than 15 % must be reduced in percentage before it goes out of the working area and it will have to pass through the explosive range before it can be reduced to an acceptable level. While the methane passes through the explosive methane reaching the lower explosive limit of 5 %.

To assist in keeping methane levels less than the lower explosive limit, the Mine Health and Safety Act and the associated Regulations stipulate a legal limit of 1,4 % at which mine employees and supervisors must take certain precautions.

The only way we can ensure that methane is not allowed to accumulate and levels increase in percentage is to ensure that the mine ventilation system and other devices to assist air movement are maintained in working order according to the mine's Ventilation Code of Practice.

Mine Ventilating Air

There are four main reasons why air is circulated through mine roadways and working places:

- to provide the oxygen necessary for workers to breathe
- to dilute and remove all noxious and inflammable gases
- to cool the mine workings, and
- to dilute and remove dust.

Because we cannot see or smell methane, the only way we know if it is present in the working areas is to test for its presence using a methanometer. If we find dangerous levels of methane then we can dilute and remove it by making use of the mine ventilating air.

Detection of Methane

The underground personnel who should have gas testing certificates and who should use methanometers during their working shift are designated in the Mine Health and Safety Act and Regulations. When and where to use the methanometers are also stipulated by law.

A number of different kinds of methanometers are available but generally fall into one of three categories: hand held, fixed position and machine mounted. The hand held methanometers are carried around by the relevant underground employees and are available for use when required. Fixed position methanometers are usually suspended at roof level in the working area and will give a flashing light or sound an alarm when a pre-set level of methane has been detected. Machine mounted methanometers are usually part of the cutting machine, continuous miner or longwall shearer, and are electrically linked to the cutter motors so that, if a pre-set level of methane is detected, the cutter motors are automatically switched off as a precautionary measure. If a certain level of methane (the fuel) is detected by the machine mounted methanometer, then to continue cutting could create the source of ignition (friction from the cutting picks) which could create an explosion. By stopping cutting, the source of ignition (friction) is removed and the explosion cannot take place.

Whichever types of methanometer are in use at a mine, they must be regularly checked to ensure they are working correctly and they must be properly used in the workplace. If this is not done, methane that is present may not be detected and if it is detected and the methanometer is incorrectly calibrated, the wrong reading may be obtained. Your Code of Practice on your mine should explain your mine's requirements.

Use of the Ventilating Air

Correct use of the mine ventilation is the only way that you as an underground worker can ensure that methane does not reach the level where it can become explosive in your working area.

The amount of air that should be circulated to your underground section, continuous miner or longwall section, should be stipulated in the Code of Practice. The Code of Practice should also indicate how each of the headings in a continuous miner section should be ventilated and how fans or brattice cloth should be used to direct the air to where it is required. It is much easier to ventilate the area in which a longwall shearer works compared to the working situation of a continuous miner. This is because air flows straight past and over the shearer on its way between the intake airway and the return airway, whereas, with a continuous miner in a 'blind' heading, the air has to be blown in and/or sucked out. The distance that the continuous miner is from the point of 'blowing' or 'sucking' is of great importance to the safety of the operation.

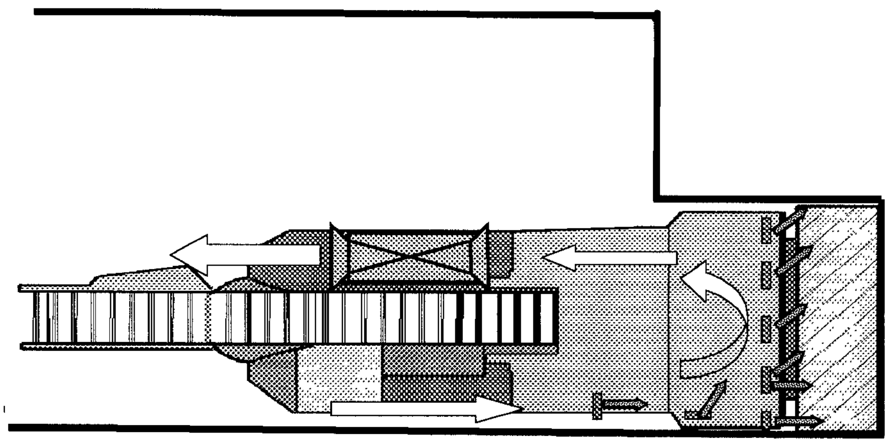
Show ventilation of a shearer on a longwall face in comparison to the ventilation of a CM in a heading.

Although the amount of air going into a continuous miner section should be sufficient to dilute and remove methane from the working areas, sometimes methane levels may be higher than normal. This may be because the issue of methane from the seam has increased, as often happens close to a dyke or fault, or because the flow of ventilating air has been disrupted or has not been directed to the right place, i.e. the face of the continuous miner heading.

Show methane flowing into workings from vicinity of a fault or dyke.

When cutting in a heading with a continuous miner, it is important to advance no further than the stipulated distance given in the Code of Practice. This is because the cutting drum is now too far away from ventilation and any methane that may be at the face will not be diluted or removed easily.

To assist the air movement at the cutting drum of a continuous miner, water spray systems are available which are positioned on the cutter boom so that the flow of water from the sprays helps to move air in the direction that the sprays are pointed.

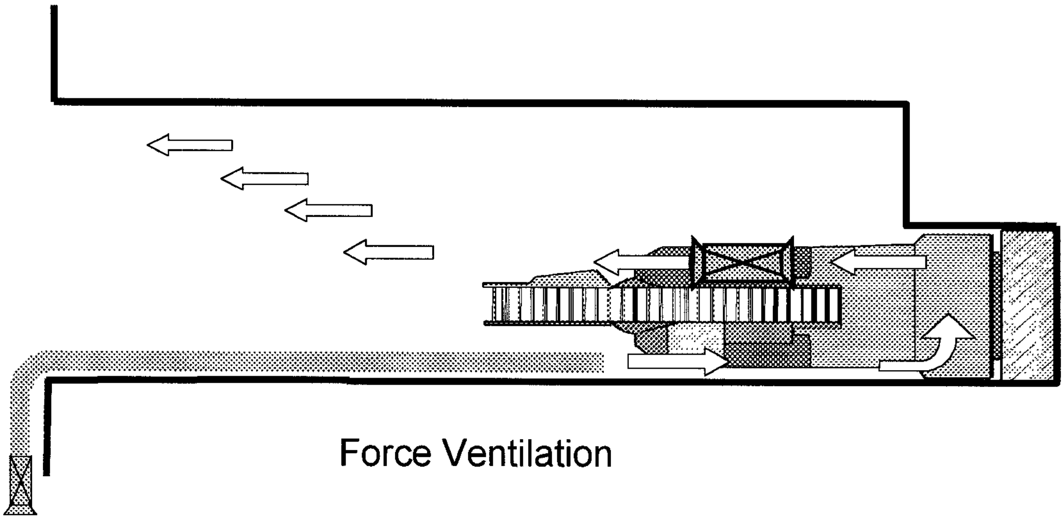


Plan of CM cutter boom showing influence of directional water sprays moving air in heading.

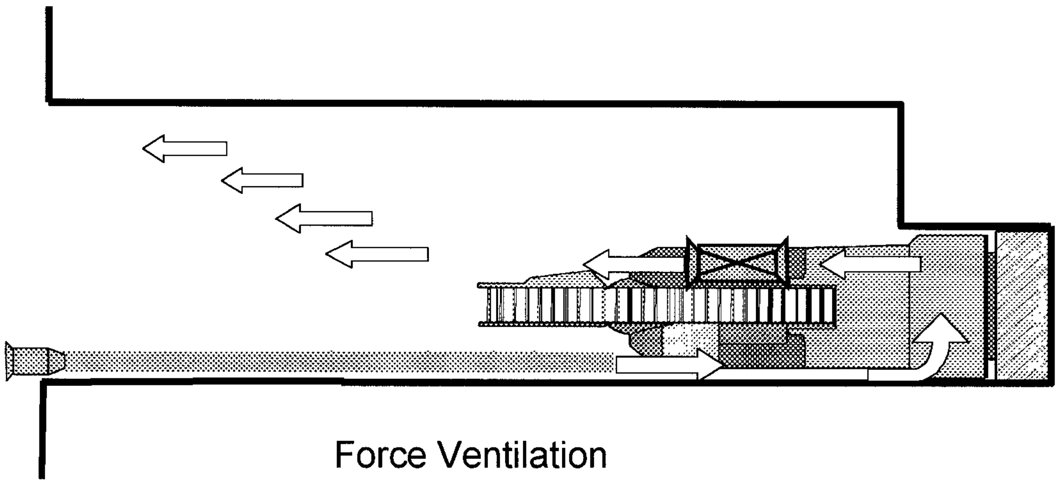
These directional water sprays must be positioned so that they assist the normal heading ventilation system and not oppose it.

Can above statement be demonstrated by a couple of pictures?

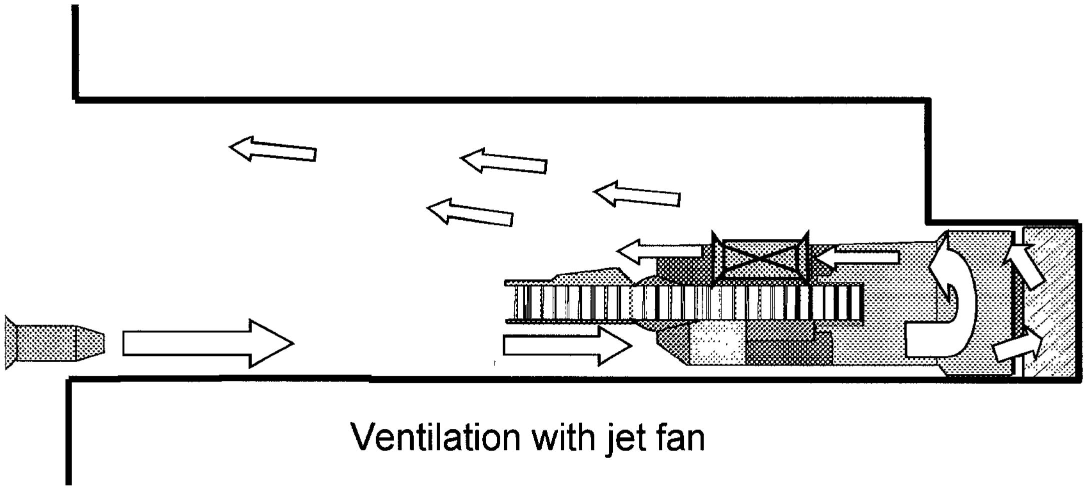
The normal heading ventilation must be specified in your Code of Practice but will consist of some means of blowing air into the heading sucking the air into the heading, or even a combination of the two methods.



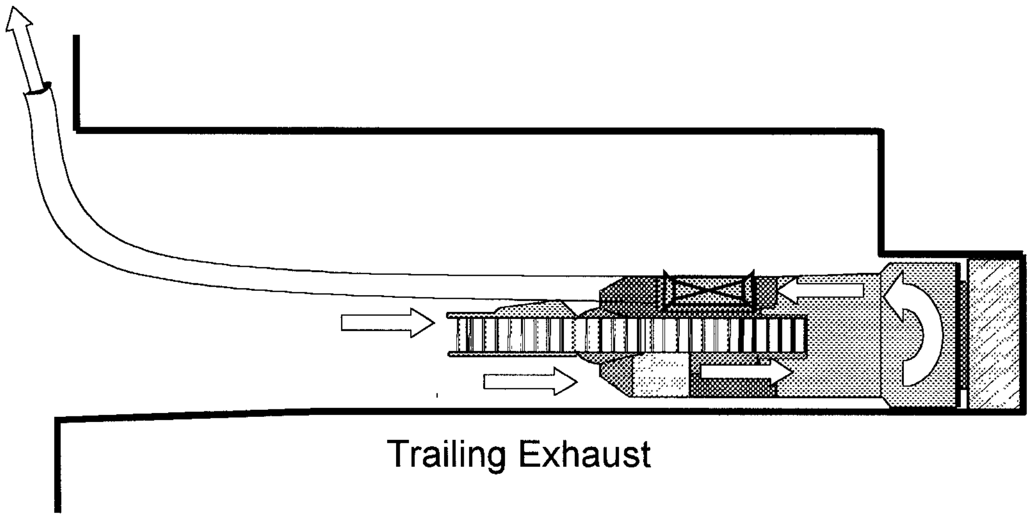
Force Ventilation



Force Ventilation
with a Jetfan



Ventilation with jet fan



Trailing Exhaust

Diagrams showing means of ventilating a CM heading - forcing with ducting, forcing with a jet fan, exhaust through ducting, overlap system force-exhaust.

Blowing air into the heading requires forcing fans which may be of the type that require ventilation ducting or be of the jet type fan which does not need ducting. Brattice cloth, however, can be used in conjunction with a jet fan. An exhaust fan is used with reinforced ducting and sucks air into the heading by having the inlet end of the duct positioned close behind the continuous miner on the side opposite to where the operator usually sits. When forcing fans are used, the end of the duct should be on the same side of the heading as the continuous miner operator and just behind him so that he receives fresh air. Your Code of Practice for your mine will specify positions of fans and positions of ducting in relation to the continuous miner and in relation to the face being cut.

Because it is the constant supply of ventilation air that maintains methane levels below the level required by the mine standard, the position of fans and the location of the ducting required by the mine standard must be adhered to at all times.

Two situations can arise that result in the continuous miner being too far in front of the supply of ventilation air:

> the continuous miner has cut further than it should have done, according to mine standards, and

> the ventilation ducting, where used, has not been advanced forward to keep within the required distance of the continuous miner. This can happen even though the continuous miner is still cutting within the required distance from the start of the heading to the working face, for example the ducting might have been damaged by a shuttle car and no more ducting is available in the section.

In either of the two situations above, the result will be a shortage of air at the working face and an increase in the percentage of methane in the heading. Although the use of directional water sprays are of benefit in the above situations, they do not supply air and only move the air that is present in the heading.

<u>Maintaining Systems and Equipment in Good Working Order and Using Equipment Correctly</u>

A Code of Practice stipulates the ventilation requirements that are needed for safe operation of cutting machines in headings or on longwall faces. If the ventilation devices, such as fans, ducting and spray fan systems, are not maintained in good working order they will not operate as efficiently or as effectively as they are intended and the supply of air will be less than it should be. This can cause an increase in the level of methane. If the increase in the level of methane is not detected because of incorrectly adjusted methanometers, or methane detection is not done correctly, continued cutting with a continuous miner, for example, could lead to a methane ignition.

It is of utmost importance, therefore, that operating procedures do not deviate from those laid down in the Codes of Practice and that equipment is maintained in good working order at all times.

<u>Summary</u>

One reason for the supply of ventilating air to underground workings is to dilute and remove explosive and poisonous gasses. Normal airflow through the mine workings will remove most of the methane (an explosive gas) that comes out of the coal seam and the surrounding strata. However, some situations may cause an increase in the supply of methane, such as working close to a dyke or fault, and other situations, such as an interruption to the ventilation system, may lead to a reduction in the air supply. Both situations can lead to an increase in the level of methane in the underground workings and underground employees must be aware of these situations. If the levels of methane are not detected soon enough, methane can build up to a level within the explosive range and an explosion can occur if an igniting source is also present.

To prevent the occurrence of methane ignitions, monitoring devices must be in correct working order, methane detectors must be used correctly and the use of mine ventilation devices, including water spray fan systems, must follow procedures laid down in the mine Code of Practice.

INFORMATION

PERIOD TEN : PICKS AND GOOD CUTTING PRACTICE

When a pick cuts through coal there is a constant abrasion of the pick material in contact with the coal. To reduce the rate at which the pick body is worn away, use is made of a hard insert in the pick. This material is called Tungsten Carbide and is significantly harder than the steel that the body of the pick is made of. When the pick cuts only in coal the steel is usually worn away leaving the tungsten carbide insert.

If on the other hand the pick cuts into a harder material like shale or roof and floor stone, the abrasion the pick is subjected to increases significantly. In such a case the tungsten carbide insert is also worn away.

The more the pick cuts into sandstone the higher the rate at which it wears away.

When the pick can rotate freely in its pick box then the abrasion is even around the pick. This type of wear is called even wear and the pick takes on a profile dependant on the angle it is in contact with the sandstone.
When the pick cannot rotate the wear is uneven. At first only a small wear flat is created on the pick during its non-rotational stage. Once a wear flat has developed and the pick becomes loose in the box, it tends to favour the orientation of the wear flat and the wear flat keeps on increasing.

This uneven wear creates friction problems as the area in contact with the sandstone is increased. Thus an unevenly worn work pick is a greater frictional ignition hazard.
A pick that is unevenly worn also causes an increase in the forces required to push it into the coal and causes an inefficient cutting condition.

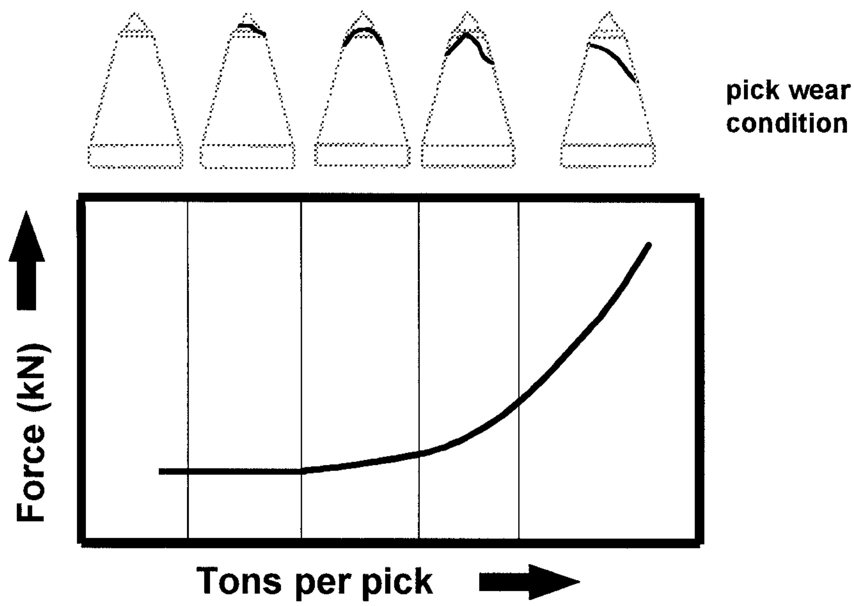
What is a significantly blunt pick?

One of the most important questions to be answered is:

What is a blunt pick?

As a pick becomes blunter the forces required to push it through the coal increase. This increase is steady until a point is reached when the force requirement increases dramatically.

In the following graph the increase in force is depicted. It is evident that as the pick is used the force required increases. Pictures of the pick also show the physical condition of the pick as wear increases. At some point, just after the fourth pick condition, the line indicating the forces starts rising sharply. It is at this point that the pick can be considered to be blunt.
This is not an easy condition for the operator to consider because the pick that he is inspecting could be very close to the blunt condition but for the present could be sharp enough. It is therefore good to change the pick before it gets into the condition when one is sure that the pick is blunt.



It is at this point, just before the force requirement of the pick increases with further blunting, that a pick can now be considered to be blunt.
It is important for operators, or those staff dealing with the changing of picks, to be able to recognize a blunt pick by its appearance.

As this was considered to be a very important issue, work was carried out into investigating how pick wear developed from the new condition.

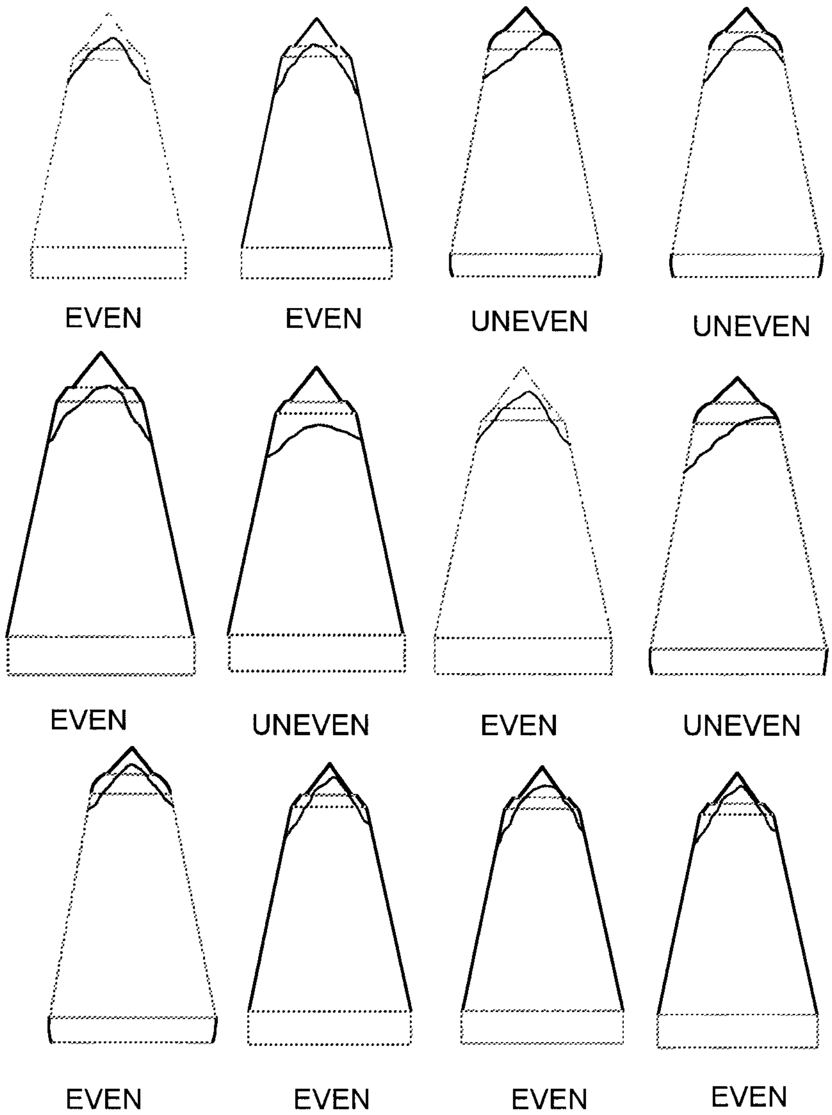
It was firstly found that, for both even and uneven wear on the normal type of pick used on continuous miners, that after about 15 g loss of metal the pick could be considered to be blunt.
After investigating the wear profiles of many picks, typical contours of the picks at the point of bluntness were drawn up.
These contours are graphically illustrated on the next page.
In this illustration the outline of a new pick is given and the wear that the pick was subjected to is given as a line across the point of the pick. Examples of both even and uneven wear are presented.
By using this illustration, a good indication of worn picks can be obtained.

It should be noted that in the majority of cases there is still quite a bit of the carbide insert left in the pick. The fact that there is carbide in the pick does not mean that the pick can still be used.

A good general rule is that only in the case where only coal is being cut, that is where the roof and the floor consists of coal, can the pick be used until the carbide is lost. Usually in this case the wear pattern will not be similar to those illustrated. It has been found that in this case the wear will tend to wash away the steel leaving the insert open.

An example of such wear is given at the end of this period where the various types of pick wear and proposed solutions are presented.

Examples of picks worn down to the point where the cutting forces start increasing rapidly



Methods to prevent the wear and blunting of the picks

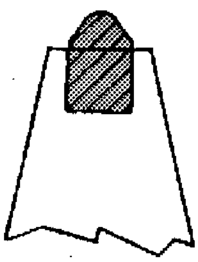
There is very little that can be done to prevent the actual blunting of the picks. What can be done, however , is to reduce the rate at which the picks wear away to an acceptable rate.

The first action that can be taken to ensure maximum life is obtained from the pick is to **choose the right pick for the cutting conditions.** The grade of tungsten carbide being used, the size and shape of the insert as well as the size of the actual pick all have an influence on the amount of cutting that can be done before the pick is blunt.

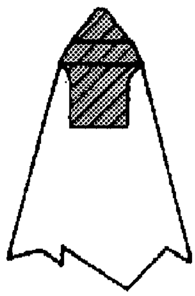
Examples of types of wear and the action that can be taken is given at the end of this period.

By using more innovative shapes of insert like the mushroom insert, more tungsten carbide is presented and this prevents the steel around the insert from being worn away.

This type of pick is presented in the following illustration.



NORMAL INSERT



MUSHROOM INSERT

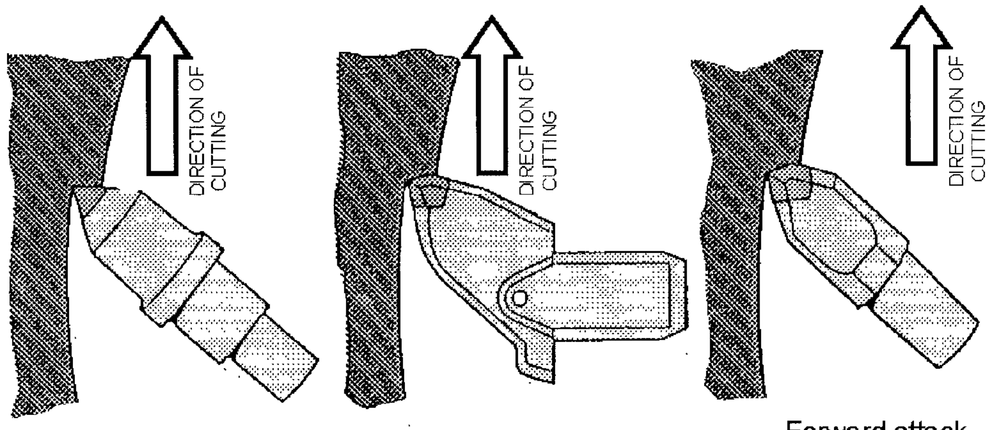
Normal insert allows metal to touch sandstone
Mushroom insert protects metal

In a similar way, picks for use with shearers have been designed to give the best life while at the same time reducing the potential for friction ignitions.

These picks also have a deeper depth of cut and thus must be significantly longer and stronger.

Examples of such picks are presented as follows.

DIFFERENT TYPES OF SHEARER PICKS



It should be noted that all of these picks have strong and large carbide inserts. As only the point attack pick can rotate in its box, the other picks are so designed that the carbide pick will be subject to a significant amount of wear before its effectiveness diminishes.

The next action that can be taken to reduce the wear on a pick is to **reduce the amount of stone** it comes in contact with. In many cases this is very difficult for the operator to achieve as the stone is in the middle of the seam. It has been found however that the most wear actually occurs when the roof and floor stone is being cut.

Previous research into reducing the amount of wear to which picks are subjected found that the pick usage increases dramatically once a limit of 5 % of stone (in the cutting horizon) is exceeded. At the same time it was found that in the mines that were investigated very few stone or other inclusions in the seam exceeded the 5 % limit. This led to the conclusion that a lot of stone is being inadvertently or deliberately cut.

Much can be done to reduce the amount of floor and roof stone that is cut.
The first action is that the cutting process should be well disciplined. In many mines the practice of roof and floor trimming is being practiced. Although it can, in some cases, lead to a safer or more even roof, it should be realized that such practices destroy picks very quickly. If such practices have out of necessity to be followed, they should be coupled with a strict pick replacement policy.

Another practice that indirectly leads to pick wear is the practice of cutting in both an upwards and downwards motion. When such practices are followed, the amount of blind cutting to a horizon is doubled and it has also been found that the fault level with regard to stopping at the right horizon when shearing upwards is significantly greater then when shearing downwards.

Although the method of cutting up and down has found favour on some mines, it should be pointed out that it has been proven over and over again that this method is less productive and also tends to produce more dust than the more normal process of cutting.

Another method that alleviates the problem of finding the right horizon is the use of horizon control equipment. Equipment is presently available for use on both roadheaders and drum miners whereby the horizon to be cut can be pre-set and the drum can be kept out of the roof and floor stone. The use of such a method not only decreases the chance of cutting the stone, but it was found that the need for roof trimming is eliminated and the rate at which the boom can be lifted can be increased significantly. Studies done into the use of such equipment showed a reduction in pick consumption and an overall increase in output of over 17 %.

Changing of picks

The effects of blunt picks can only be combated in one way. The picks have to be changed regularly.
It is imperative that it is understood that sharp picks lead to a lower frictional ignition hazard potential, better cutting rates and less dust.
Pick replacement should be done in a conscientious way, regularly and based on the operator's knowledge of when the picks could be blunt. It should not be done when the operator feels like it or when there is a break in production. The changing of picks is an integral part of production and should not be seen as an impediment to production. It is an enhancement of the production process.

INFORMATION

PERIOD ELEVEN : OTHER METHODS EMPLOYED

Introduction

These training aids have dealt with measures that can be taken on a mine to reduce the risk of a frictional ignition of methane. There are, however, other measures that can be applied during machine design or when designing and choosing the picks that will be purchased or by specifying retrofit safety devices such as wet cutting heads or onboard active suppression systems. This period will deal with those measures that are largely outside the control of mine employees. For this purpose, it is considered that employees have control over monitoring and diluting methane and in deciding when to change cutter picks.

Methods of reducing the frictional ignition risk by changing the design of continuous miners.

The results of an extensive international research effort have shown that machine design can be modified in two ways to substantially reduce the risk of frictional ignitions - by reducing drum rotational speed and by applying water accurately behind each pick.
Both principles were adopted by longwall shearer manufacturers in the 1960s and 1970s and have resulted in much safer machines. However, the complexities of continuous miner design have resulted in the application of these principles being deferred and only recently has serious consideration been given to incorporating them in the next generation of machine designs. The two aspects that could make a major impact are discussed separately

Research has shown conclusively that reducing pick speed reduces the risk of frictional ignitions because the length of hot spot also decreases. However, the risk does not start to diminish noticeably until the linear cutting speed of the picks falls below 1,5 m/s or even 1 m/s. For a continuous miner with a drum diameter of 1 m, this would imply limiting the rotational speed to 28 or even 19 rpm. Experience with modern, heavy-duty continuous miners has shown that the rotational speed can be reduced, certainly to 37 rpm, with no adverse effect on production.

However, at the present time, there appears to be no prospect of continuous miners being manufactured with rotational speeds of below 20 rpm. Nevertheless, the advantages of slower speed cutting are so overwhelming that the mining industry should take every opportunity to encourage machine manufacturers to move in this direction.

The most effective means of preventing frictional ignitions during cutting is to spray water directly behind the pick, parallel to its direction of travel. This quenches the hot spot within the lag time for methane ignition, provided such important criteria as quantity, droplet size and to a much lesser extent minimum water velocity are met. Research has produced proven designs of suppression systems to be used in conjunction with all common types of pick. For many years cutting drums on longwall shearers and some roadheaders have been equipped with phased water supplies to nozzles in front of and behind individual picks. However, wetheads for continuous miners have proved problematic because of technical problems associated with large-diameter rotary water seals. The progress of three recent developments is, however, being monitored.

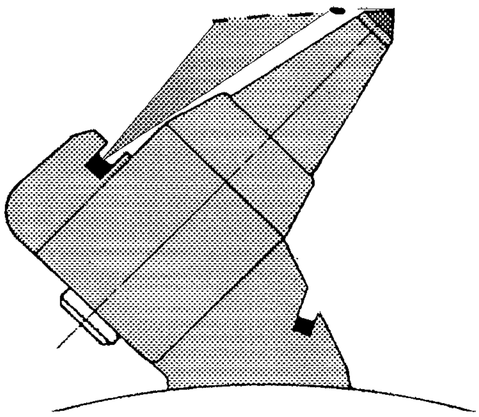
1) The Consol Coal Company in the United States has used two Eimco continuous miners equipped with wet-heads for three to four years without experiencing undue difficulties. During this time the number of frictional ignitions experienced at that mine has dropped from about six each year to virtually zero.

2) Joy Mining Machinery in the United States have developed a wet-head cuttercase for their machines. While wet-heads for continuous miners were considered in the late 1970s and experimental heads manufactured in the 1980s, potential customers were unwilling to pay the additional cost necessary to provide a wethead option on a machine. However, in 1995 Joy manufactured a prototype wethead, which experienced teething problems due to the porosity of the castings involved and also with the seals. Since then a new housing and seals have been obtained and this machine entered service in the United States early in 1996. It completed about nine months of production work before requiring a major overhaul.

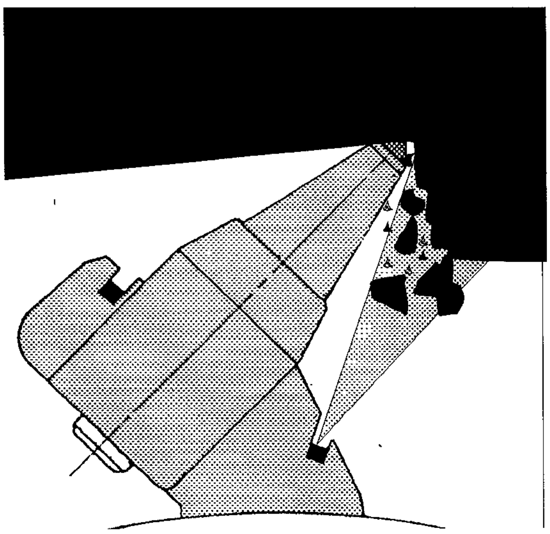
3) The other development, by the United Kingdom company, Hydra Tools International PLC, involves the design of a wet-head capable of being retrofitted to continuous miners. After extensive testing of the system in a potash mine, one of these heads was

installed on a machine at Matla Colliery in South Africa during November 1996 and this head has subsequently been modified in various ways and applied in several trials at Matla. Progress with this project is currently being watched with interest.
The following illustrations show firstly a pick with the water spray at the back of the pick and next with the water spray at the front of the pick.

SANDSTONE



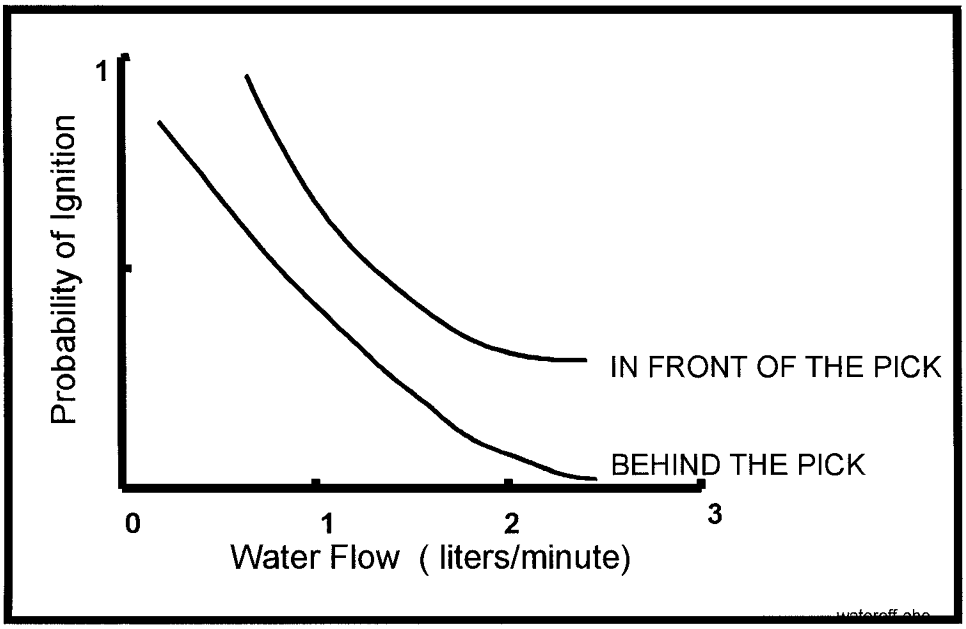
PICK WITH SPRAY BEHIND COOLING THE HOTSPOT.



PICK WITH SPRAY IN THE FRONT.

When comparing the two illustrations it can be seen that, in the case of the pick with the spray at the back, the water spray is directed at the hotspot that forms behind the pick. When the water spray is in the front then the water is not directed at the hotspot but at the material being broken. When the sprays are in front there is a significant reduction in dust but less of an influence on the reduction of the ignition potential.

The reduction in the probability of a frictional ignition occurring when using sprays at the front and the back of the pick is given in the following graph.



It has however been found in work done lately that this difference is becoming less and less and that, especially in the area of dust the use of sprays at the back of the pick can be made almost as efficient as the use of those in front of the pick.

A method of limiting the impact of a frictional ignition

Since there will always be some risk of frictional ignitions, irrespective of whether cutter speeds are reduced to their practical limits and water is supplied to the cutter head (mainly because of the practical difficulty of keeping every device functioning at all times), it is important that high risk situations are identified and means of preventing the spread of ignitions used as a second line of defence. In this way even if a gas ignition occurs, it remains a localised event at the face with no fatalities and very little chance of injuries.
It is known that the risk of a frictional ignition at any particular site is a function of a large number of factors including:- likelihood of the presence of flammable gas, type and condition of mining machine and presence of quartz and pyrite in the material being cut. Since risk assessment has been introduced as a safety management tool for the South African mining industry, it would seem appropriate that a risk assessment should be made for every site at which a cutting machine is to be employed, including classification of any strata to be encountered by the picks.

For a frictional ignition to occur cutter picks must come into contact with strata containing either quartz or iron pyrites. Quartzitic rock must contain at least 30 per cent of fairly coarse quartz grains before the risk of ignition becomes significant. It is, therefore, possible to use petrographic and other analytical techniques to undertake a risk assessment of any site where a machine is to be deployed.

Since the application of precautions against non-existent risk undermine their credibility, risk assessment would allow appropriate levels of precautions at different sites, e.g. where the strata indicates a high risk site in a known gassy seam, it may be appropriate to specify that machines be equipped with a machine mounted active suppression system. To specify similar equipment at a low risk site in a seam generally free of methane would not only be inappropriate but would devalue the whole concept of risk assessment.

Although considerable work has been undertaken in Europe and the United States in the development of active or triggered barriers, either as fixed devices in roadways or mounted on road heading machines, the size of headings in South Africa (up to 6 m high and 7 m wide) and the fact that the majority of machines are continuous miners, dictated that further development work is necessary before these devices could be deployed. This has been undertaken at the Kloppersbos research facility of the CSIR -Miningtek and one system has been shown to be effective. The use of such a system, i.e. Explostop, as a second line of defence can give a mining crew a "second chance" should a frictional ignition occur.

Conclusions

While an adequately trained and alert workforce can do a great deal to prevent frictional ignitions by ensuring blunt picks are changed at the appropriate stage of wear, it is also the duty of management and machine suppliers to ensure that the mining machine used has appropriate safeguards built in at the design stage.

Two important machine modifications, both of which are only now emerging from their prototype stages, are wet-heads in which water can be applied directly behind each cutter and the addition of on-board active suppression systems. It is to be hoped that risk assessments are carried out for each machine application and that, where necessary, wet-heads and active suppression systems are applied.

APPENDIX 3

TRAINING RECOMMENDATIONS

TRAINING RECOMMENDATIONS

PREAMBLE

In the drawing up of the training aids and these recommendations, note of the important role of the trainer in transferring the information has been taken. If the wide diversity of persons that could attend a course on frictional ignitions is considered, it is evident that no training aid can ever fully encompass all the conditions and situations that could arise. No training aid can ever replace the trainer and the role he plays in the transfer of knowledge. At best, a training aid can only assist the trainer in carrying out his tasks.

These training aids and recommendations are therefore only an aid to the trainer who should feel free to change the way the course is presented as the situation dictates.

In a similar way, the workbook is a recommendation which can be used as is, or changed according to the trainer's preference.

GENERAL

It is very important for all instruction to be as visual as possible. Ensure that salient features are understood by every delegate through reinforcement of concepts, linking with overall objectives and repeated use of visual aids.

The trainer is to lead and coach the group rather than use traditional teaching methods.

Use of group activities and group discussions should be given preference at all times unless the subject or situation makes it impractical.

It is important that throughout the course the work that is being covered is linked to its importance in preventing frictional ignitions which in turn has to be linked to the importance of such prevention to the individual participant. If the importance of preventing ignitions in a mine is stressed and reinforced to the individual, it should motivate him not only to try and understand what is being taught to him in the class but also motivate him to implement the knowledge he gains in the underground environment.

A very important aspect of this course that should be reinforced throughout is the issue of responsibility. The safety of persons is not only the responsibility of management and their supervisors. Each person must take responsibility for his own safety and that of his fellow workers. In period eight this issue is addressed in depth. Aspects which participants feel could constrain their own actions should also be identified. As these could present situations where contentious non-related issues are raised, or where mine policy and procedure are involved, it is proposed that during this period management is represented in some or other form at the course. During the final session when the course is closed and aspect of learning is controlled, management presence is also recommended.

<u>NOMINAL GROUP/TEAM BUILDING TECHNIQUE</u>:

1. Divide class into groups of 3 to 4 people.
2. For each exercise/set of exercises allocate a specific role to each group member, e.g. observer secretary, participants.
3. Nominate and rotate person responsible for the report-back (other members may illustrate issues).
4. Decide on daily prize or incentive. (Coca-cola/beer etc.).
5. Set rules on flip chart and keep rules up on wall for the entire duration of the programme. Rules to include a) Honesty, b) Constructive criticism, c) Everybody to participate, d) Hard work - prompt group for more.
6. Reinforce the role of the trainer not as teacher but as facilitator and coach. Reinforce the role of the learner.
7. Comment on the role of the trainer - facilitator.

Overhead projector slides are very important to reinforce the information that has been transmitted. When using overheads be sure to link the contents with that of the overall course and its objectives.

OVERHEAD PROJECTION SLIDES

1. Introduce slide briefly.
2. Switch overhead projector (O.H.P.) on and discuss information.
3. Answer any questions and summarize before switching off the O.H.P.

During small group discussions the trainer should move between groups, keeping a careful watch for individuals who are not - involved/attempting to side-track a group, etc.

TRAINING RECOMMENDATIONS

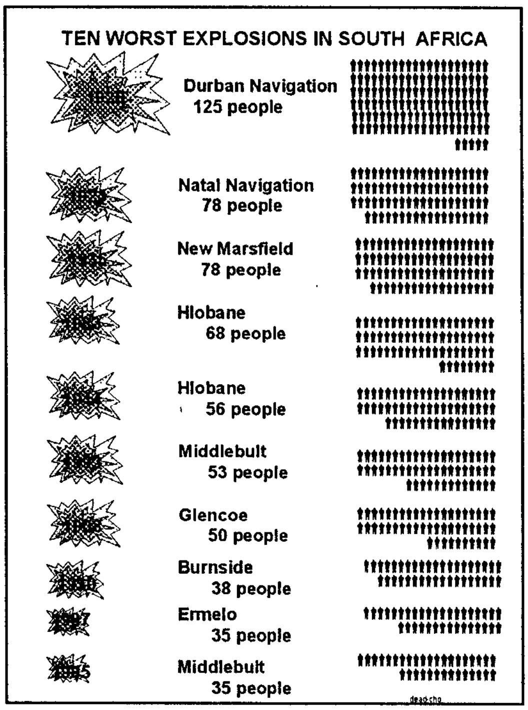
PERIOD ONE : IMPORTANCE OF FRICTIONAL IGNITIONS

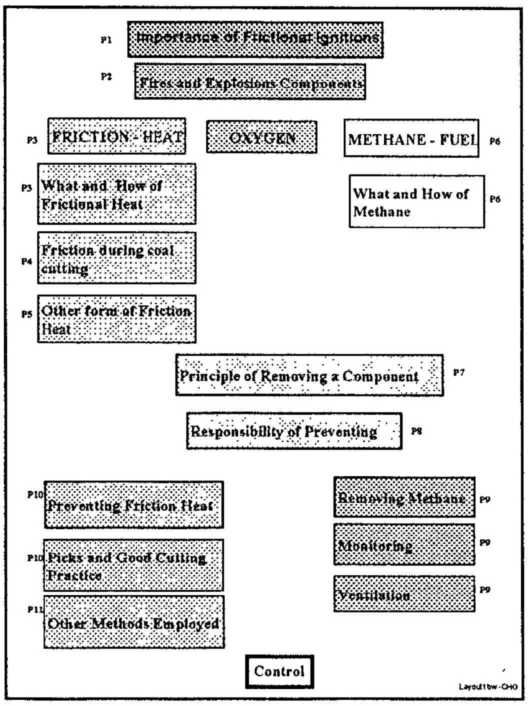
The main purpose of this lesson is for the participants (learners) and the trainer to get to know each other, and to communicate to the learners the importance of the course and the way it will be presented.

It is proposed that the lesson follow in general the following proposed format.

It should be remembered throughout the course that more is expected from the participant and less from the trainer in the way of transferring the information. The participants should draw on their own experience and a high level of cross-pollination of ideas should occur. Only when the trainer sees that the group needs input of information should he present it. The course should ideally be driven by the information requirements of the group rather than be pushed by the trainer.

1. Welcome delegates.
2. Trainer to introduce himself and allow each delegate to do so, e.g. Name, Origin, Family, and Responsibility on the mine, Aspirations/Ambition.
3. Ask groups to list dangers/problems underground and to rank in order of importance.
4. Use action three and then give short overview of the course and course objectives.
5. Learners to state what they would like out of the course they are about to do.
6. Ask groups to define how frictional ignition, fires and explosions could affect:
   - i) themselves
   - ii) their subordinates/ colleagues
   - iii) the mine
7. Report back and summarize.
8.


TEN WORST EXPLOSIONS IN SOUTH AFRICA
Durban Navigation
125 people
Natal Navigation
78 people
New Marsfield
78 people
Hlobane
68 people
Hlobane
56 people
Middlebult
53 people
Glencoe
50 people
Burnside
38 people
Ermelo
35 people
Middlebult
35 people


P1 Importance of Frictional Ignitions
P2 Fires and Explosions Components
P3 FRICTION - HEAT
OXYGEN
METHANE - FUEL P6
P3 What and How of Frictional Heat
What and How of Methane P6
P4 Friction during coal cutting
P5 Other form of Friction Heat
Principle of Removing a Component P7
Responsibility of Preventing P8
P10 Preventing Friction Heat
P10 Picks and Good Cutting Practice
P11 Other Methods Employed
Removing Methane P9
Monitoring P9
Ventilation P9
Control

TRAINING RECOMMENDATIONS

PERIOD TWO : FIRE AND EXPLOSION COMPONENTS

The objective of this lesson is creating an understanding of the explosive or fiery triangle amongst the participants. The importance of having all three components together before an explosion can occur needs to be fully understood.

The lesson should take the format of a lecture followed by demonstrations and then group exercises

The following general format is proposed.

1. State objective of the period
2. Show slides with fire/explosion and its components - indicate components singly. Use the progression of components for both a fire and an explosion.
3. Demonstrate the requirements for initiating heat and the fuel

Ask delegates who smokes - delegates to place smoking utensils on table.

Ask delegates to smoke without

- a cigarette
- a match/lighter

Show delegates how

- the spark of the lighter ignites the gas
- the friction of "sulfur" ignites the wood

4. Demonstrate the importance of oxygen

Light a candle and place it in a measuring jug. Smear Vaseline on the edge of a round glass disc and close the top of the jug. Outcome - candle dies.

5. Demonstrate the difference between a fire and an explosion.

This is done using either petrol or gas burners and showing the importance of mixing fuel and oxygen.

6. Group exercises:

a) Groups to name the vital components of a fire/explosion.

b) What is the difference between a fire and an explosion?

c) Identify some everyday examples of fires and explosions.

d) Which of the examples are beneficial and which are detrimental?

7. Show the progression of fire slide and discuss - indicate the value of the initiating energy.

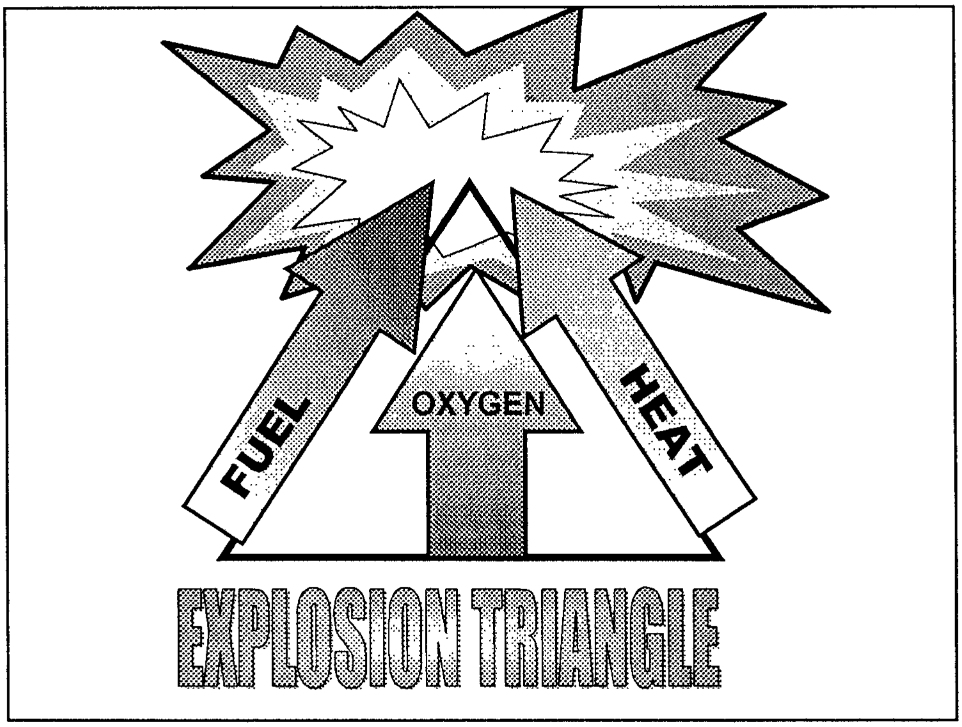
These examples/exercises may be substituted with others, e.g. gas bottle, stove, fire, etc.

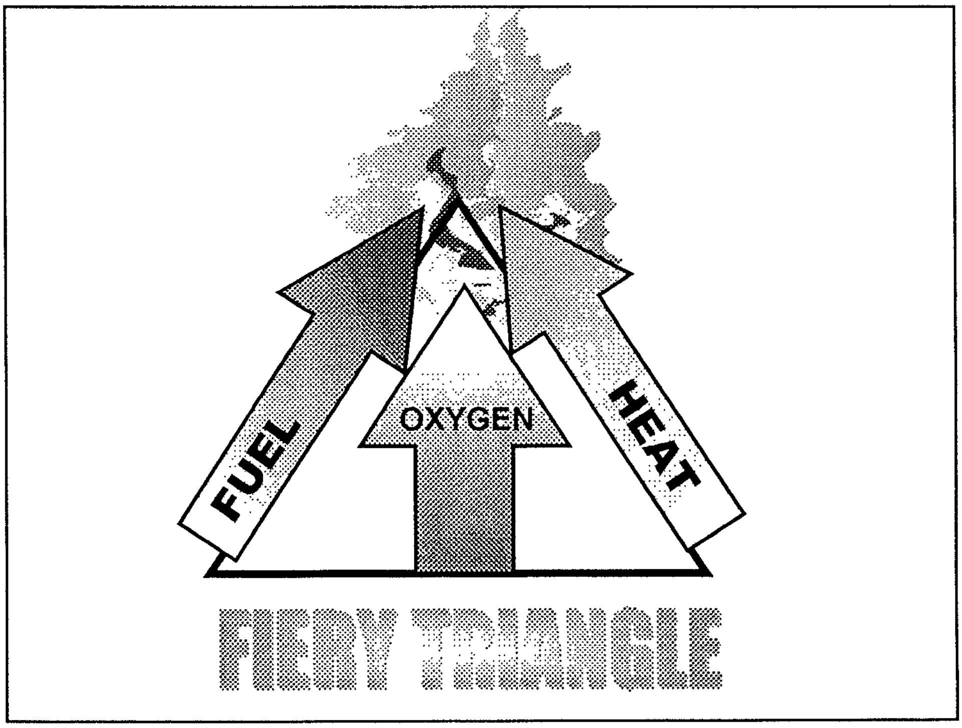
List of experiments and the apparatus required.

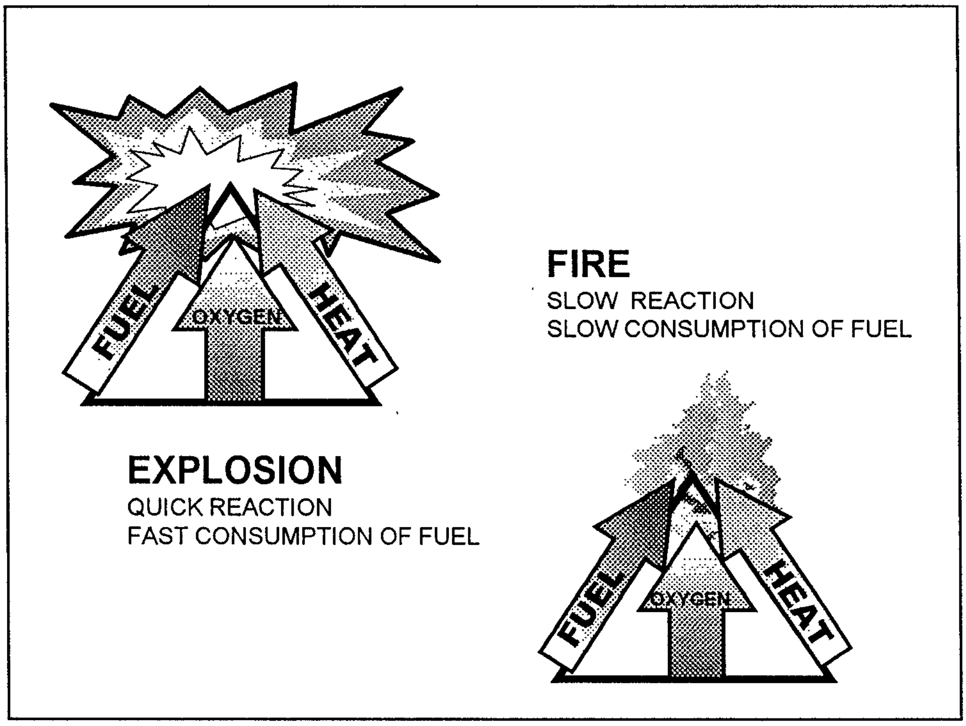
EXPERIMENT	EQUIPMENT
Methane/gas ignition	Gas torch (butane) Lighter Grindstone
Candle experiment	Candle Glass jug or container Bowl Water
Difference between fire and explosion	Petrol or benzene or methylated spirits Little lamp made out of bottle and wick Source of butane gas – gas torch Matches Cardboard box with small hole made at the bottom

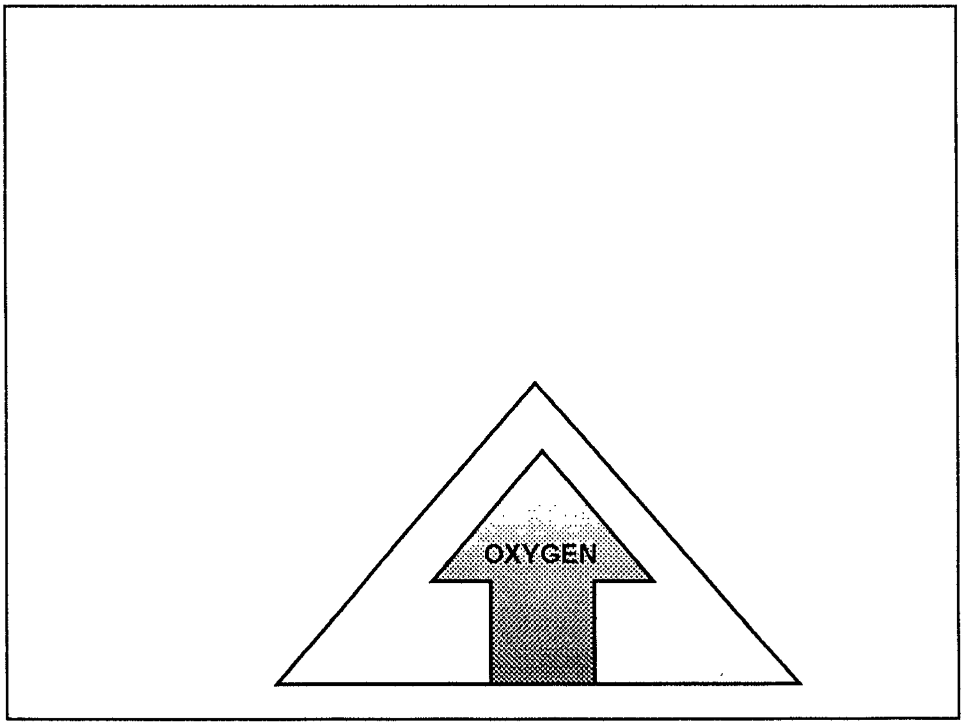
List of slides to be used

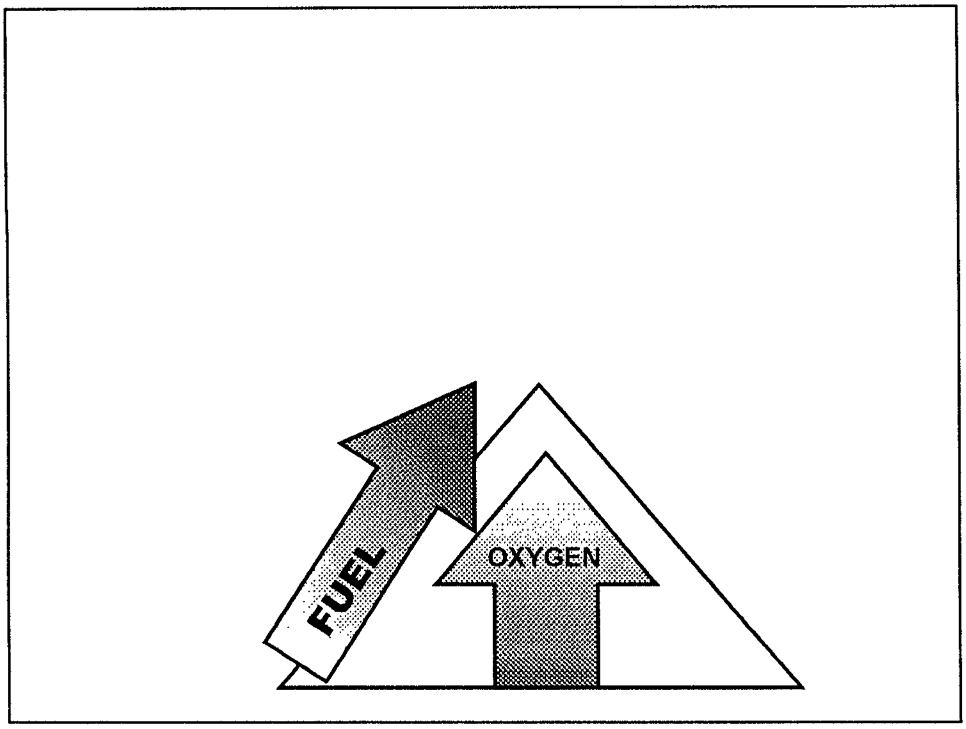
Description	File name
English slides	Per2eng
Afrikaans slides	Per2afr
Sotho slides	Per2sotho
Zulu slides	Per2zulu

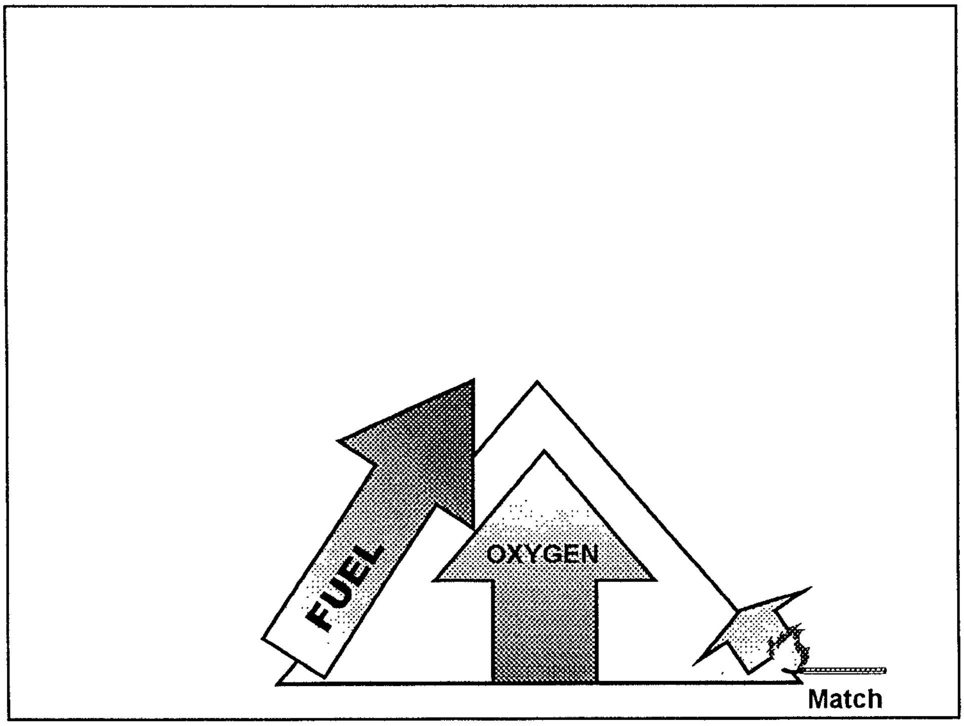

FUEL
OXYGEN
HEAT
EXPLOSION TRIANGLE

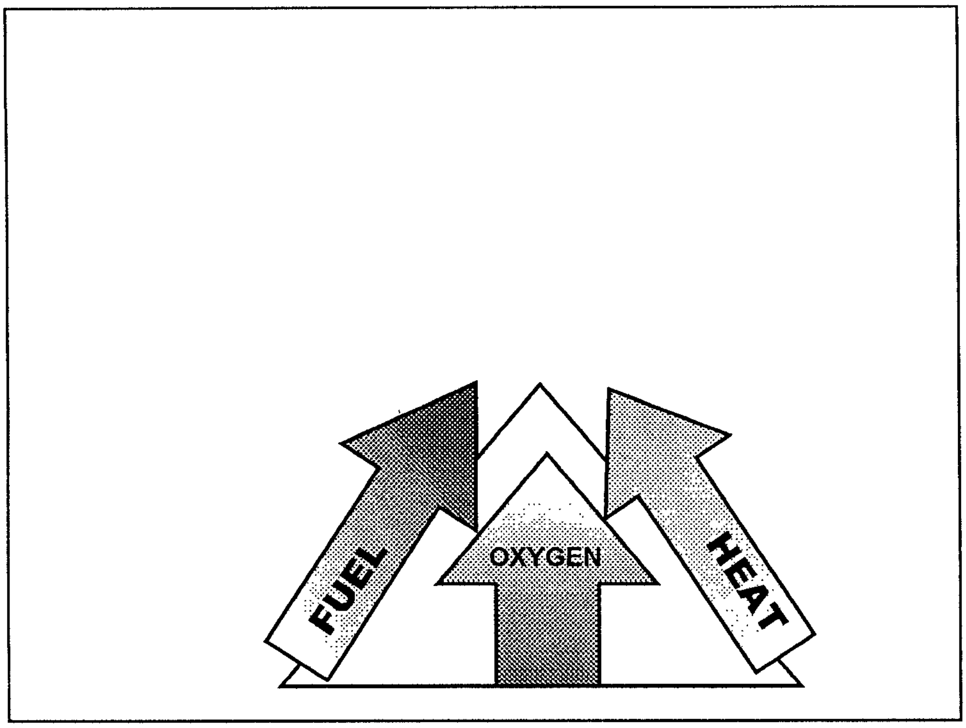

FUEL
OXYGEN
HEAT
FIERY TRIANGLE

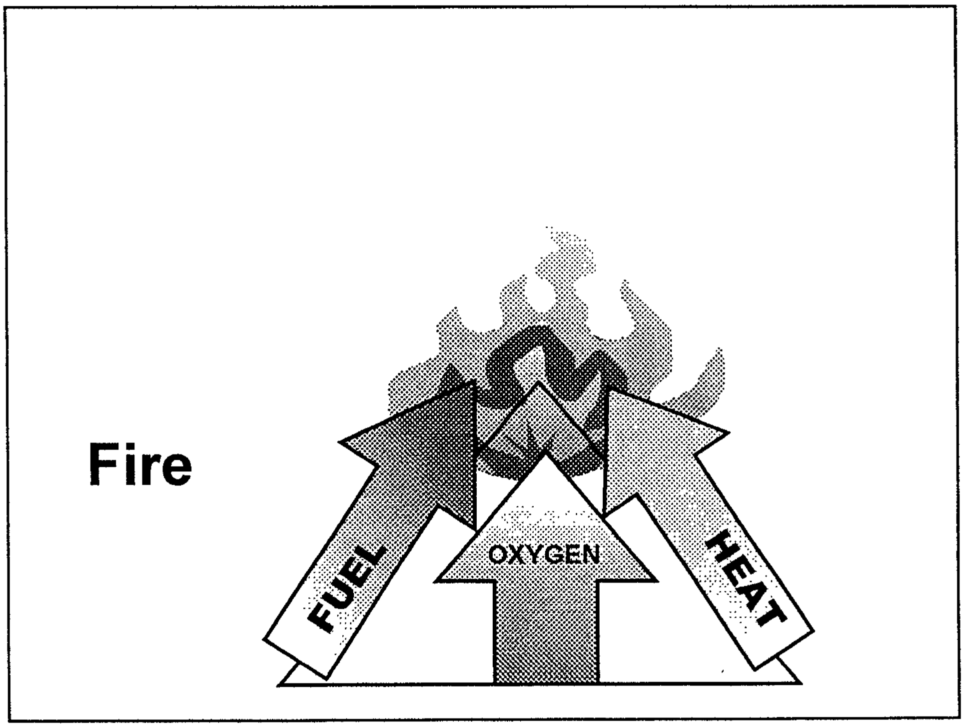

FIRE
SLOW REACTION
SLOW CONSUMPTION OF FUEL
EXPLOSION
QUICK REACTION
FAST CONSUMPTION OF FUEL
FUEL
OXYGEN
HEAT
FUEL
OXYGEN
HEAT

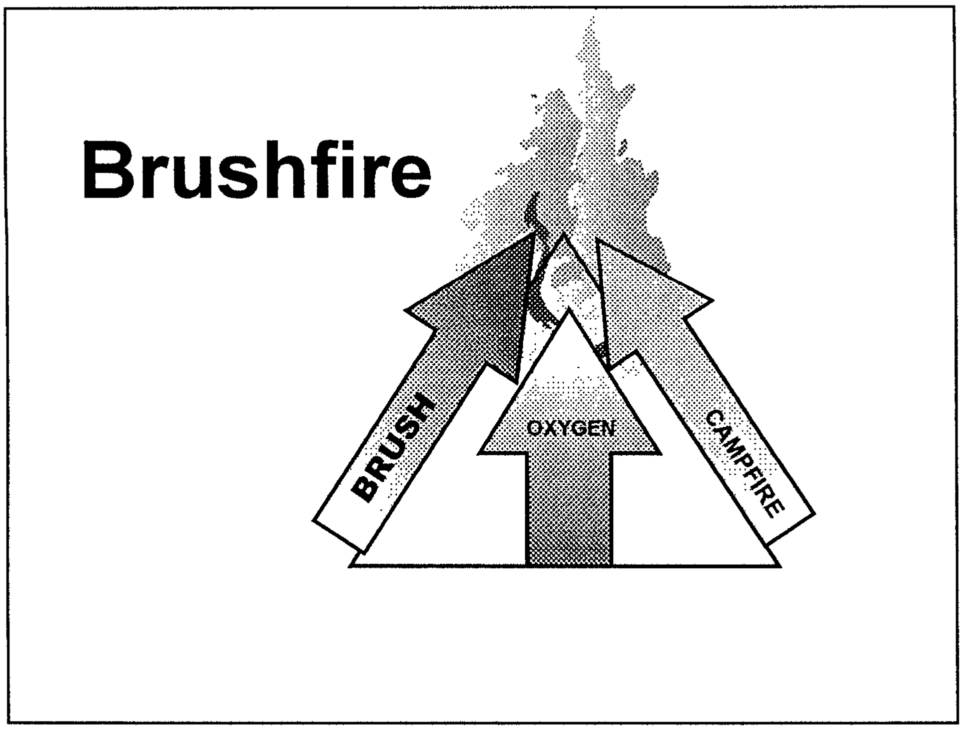

OXYGEN

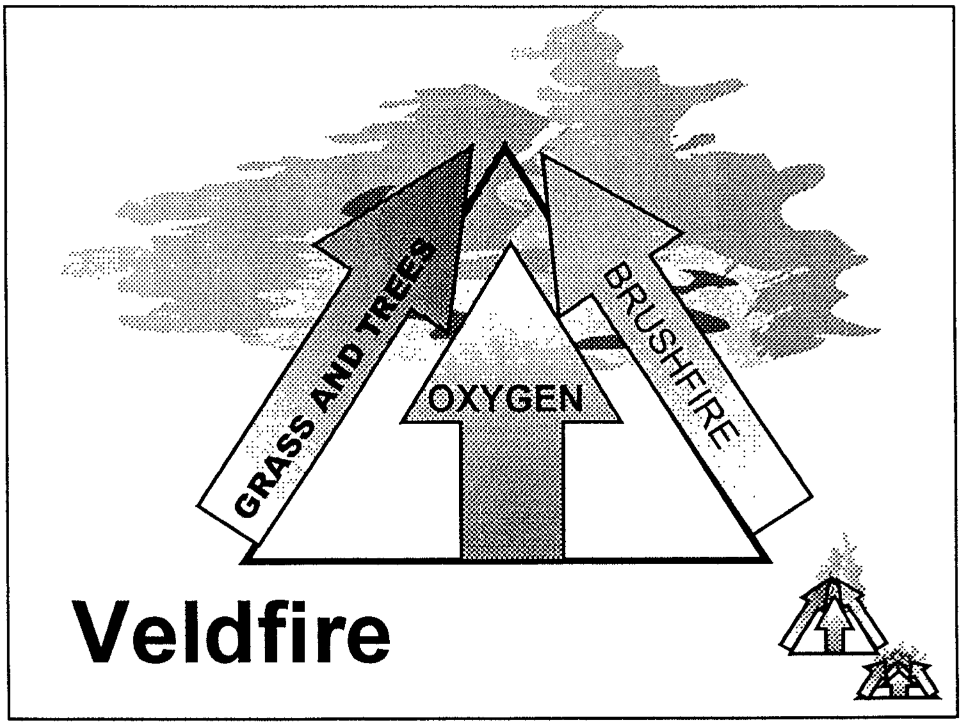

FUEL
OXYGEN

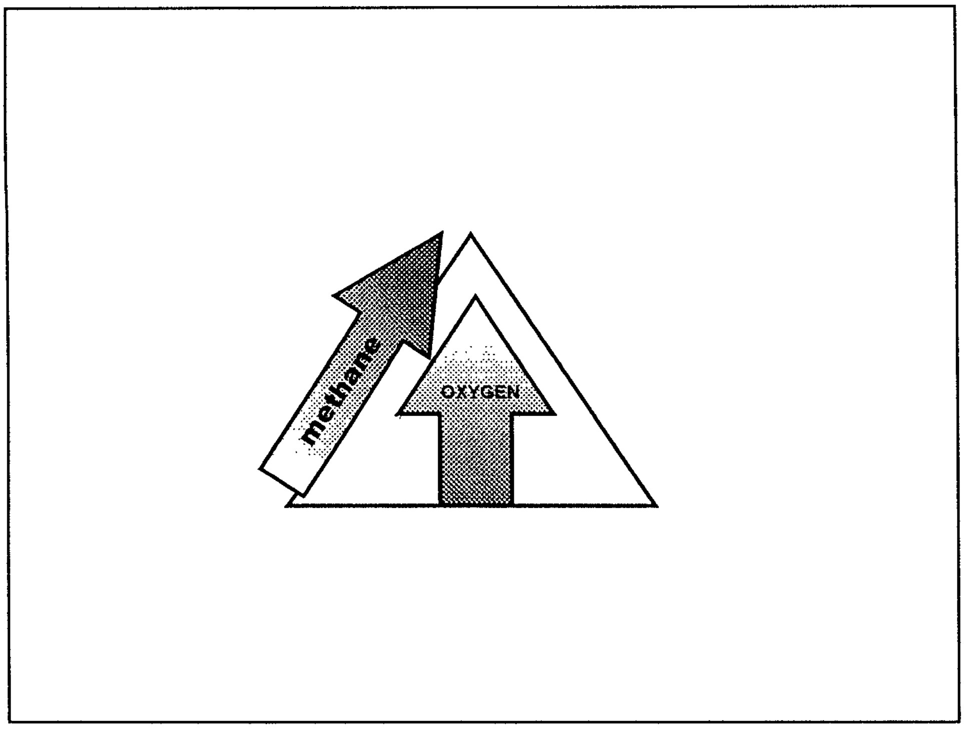

FUEL
OXYGEN
Match

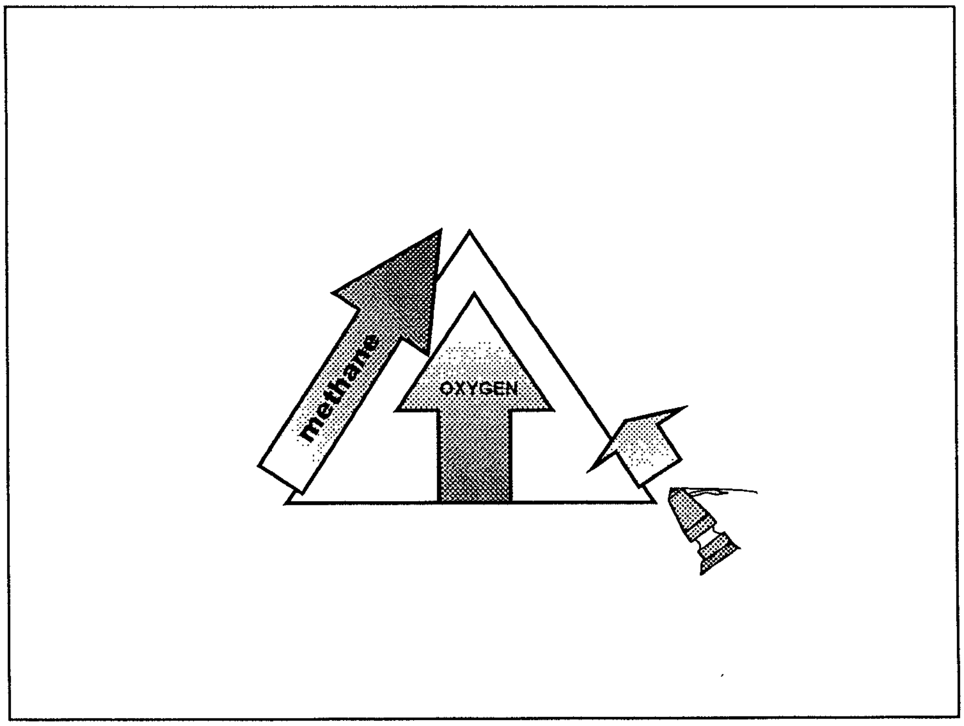

FUEL
OXYGEN
HEAT

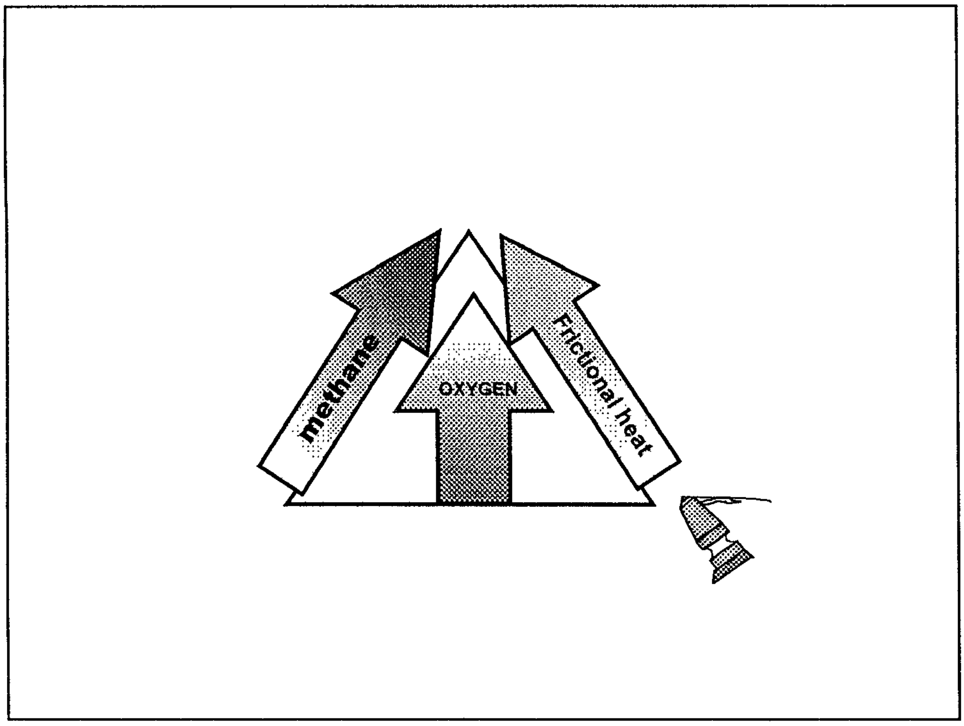

Fire
FUEL
OXYGEN
HEAT

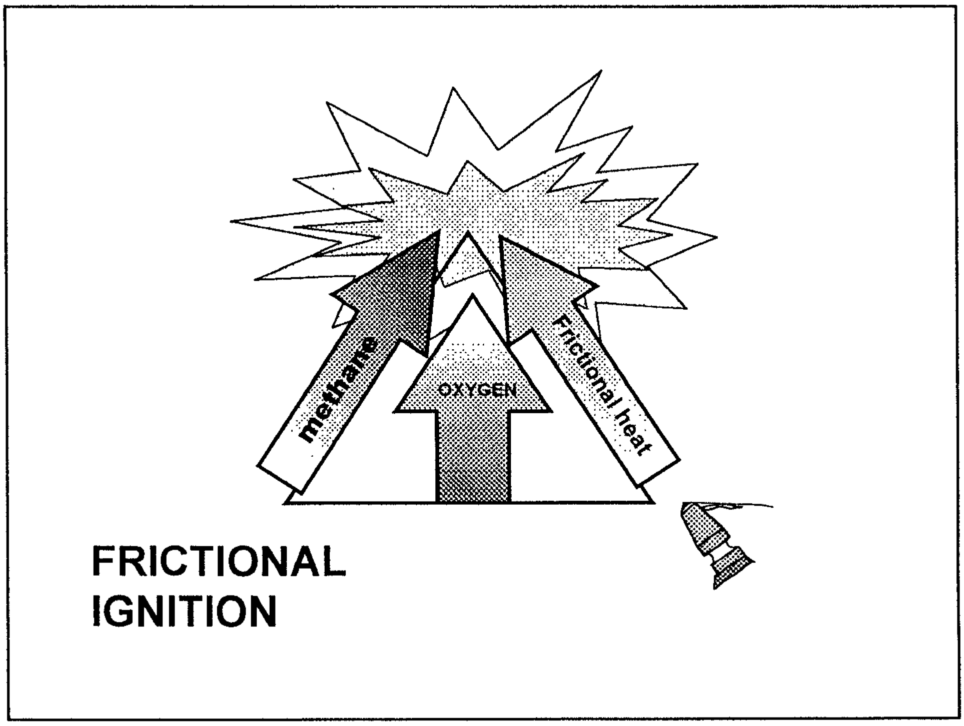

Brushfire
BRUSH
OXYGEN
CAMPFIRE

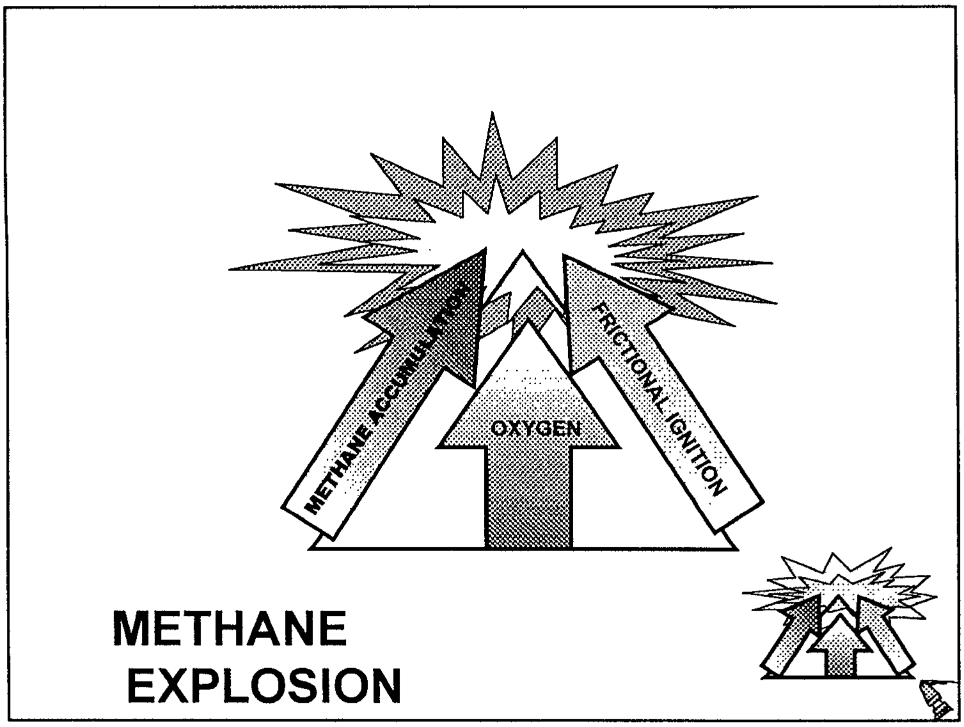

GRASS AND TREES
OXYGEN
BRUSHFIRE
Veldfire

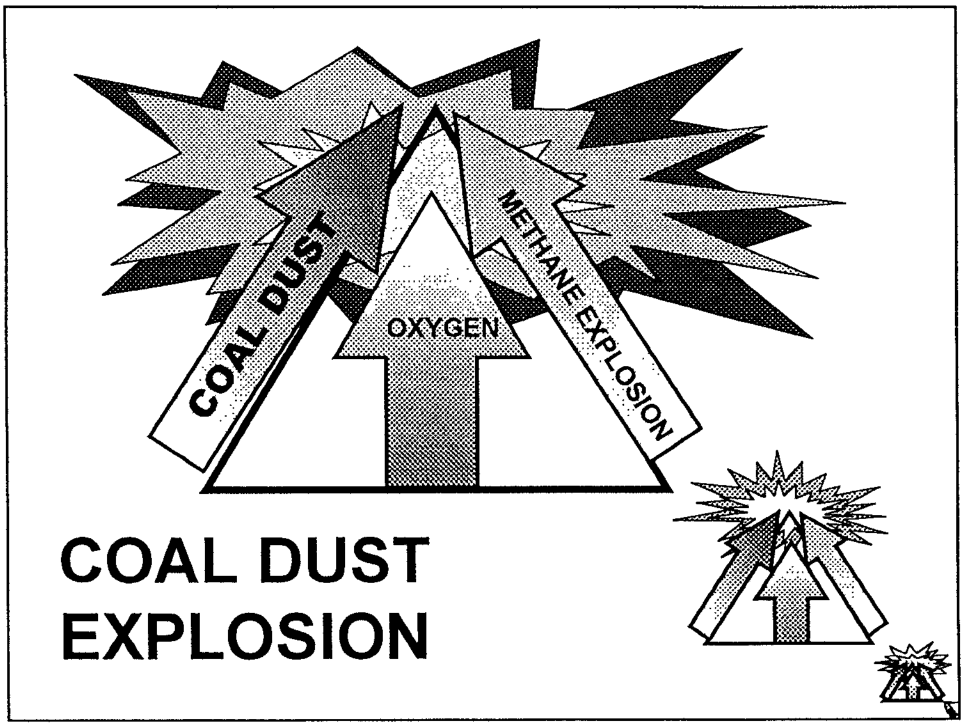

methane
OXYGEN

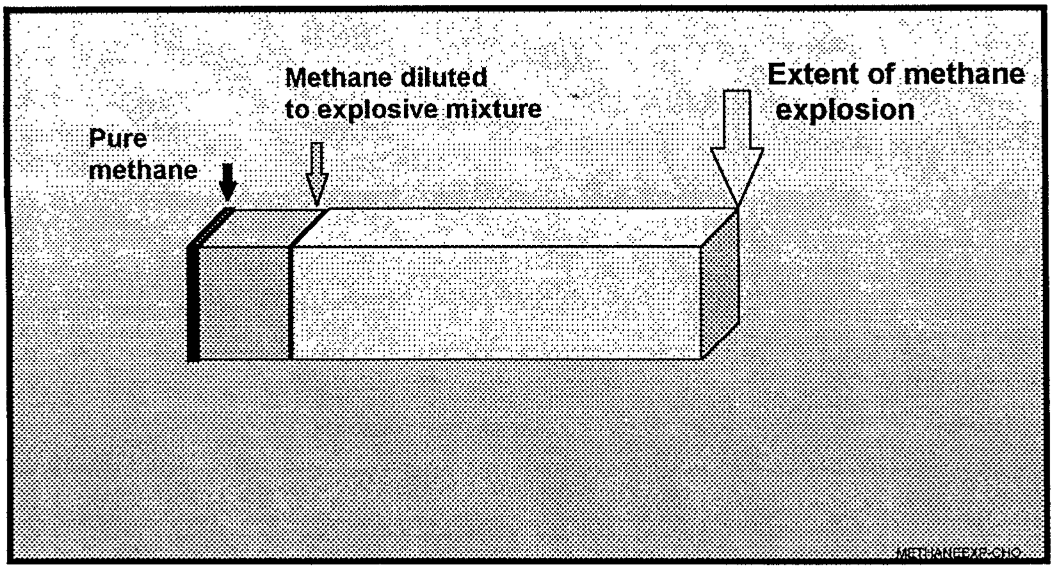

methane
OXYGEN


methane
OXYGEN
Frictional heat


methane
OXYGEN
Frictional heat
FRICTIONAL
IGNITION


METHANE ACCUMULATION
OXYGEN
FRICTIONAL IGNITION
METHANE
EXPLOSION


COAL DUST
OXYGEN
METHANE EXPLOSION
COAL DUST
EXPLOSION



EXPANSION OF METHANE WHEN EXPLODING

TRAINING RECOMMENDATIONS

PERIOD THREE : FRICTION HEAT

The objective of this lesson is to make the participants aware of friction and the factors that govern it. Of greater importance is for them to understand how friction can generate heat, sufficient to start a fire.

An awareness of the factors that influence friction and the capacity to generate heat would be advantageous to understand how easily such a mechanism can cause an ignition

This lesson will take the format of a presentation to the entire group, followed by a set of demonstrations; afterwards the group will be divided into small working groups to complete the series of exercises.

One of the important aspects of this period is to show the participant how friction is also used in our everyday life. That it is not a detrimental physical occurrence but in certain cases it can provide the basis for a hazard.

The report-back presentation from the group should serve to confirm the findings or where there are shortcoming in understanding. The principle of using feedback as part of the control mechanism to determine if the participants understand what they have learnt should be used throughout the course. In this way peer adjudication can be used indirectly to evaluate an individual's increase in knowledge.

It should be remembered that learning should take place through the experience, which is linked to the subject and the overall topic. It will be necessary for the trainer to continually reinforce this with the participants in the course.

DEMONSTRATIONS.

Using a drill press with the following materials in the chuck:

wooden dowel, high carbon steel rod, brass rod.

And pressing down, while the drill is on at different speeds, on the following materials

Wooden block.

Piece of rock (not sandstone)

Piece of steel

Piece of sandstone

Show how heat/friction can start a fire without flames - hot steel on paper.

It should also be noted that by using a Butane torch, which is set at a low flow rate, it is possible to show that gas can be ignited purely by friction when using the steel rod and sandstone. This is however difficult to achieve and should not be attempted in front of a class unless it has been well practiced beforehand.

Each group to take note of the demonstrations so that they can apply the concepts to the exercises they have to do.

Ask groups to state what they think of forces and speeds regarding friction. (Prompting may be needed)

EXERCISES

In these exercises an understanding of the effect of force between materials, speed, material characteristics and other aspects to do with friction has to be transferred to the participant. The trainer should lead when he sees that participants are not understanding or carrying out the necessary alternatives. (Safety rules should be enforced when using equipment)

Exercise 1: Delegates to rub their hands together slowly and then fast, and record the results.

Exercise 2: Each group receives six materials - coal, rock, wood, lead, steel, rubber. Delegates are required to use a hacksaw to saw these materials and to record the results.

Exercise 3: Delegates are required to use a bench grinder on the above-mentioned materials and to record the results.

Exercise 4: Repeat Exercise 2 using first water and then oil. Record the results.

Exercise 5: Repeat Exercise 3 using first water and then oil. Record the results.

Exercise 6: Delegates to record examples of friction in everyday life, and to indicate if this friction is beneficial or detrimental to man.

In doing the exercises emphasis should be placed on discussion of the results in collaboration with the team members. The discussion is of greater importance than the conclusions that the participants draw from the results achieved.

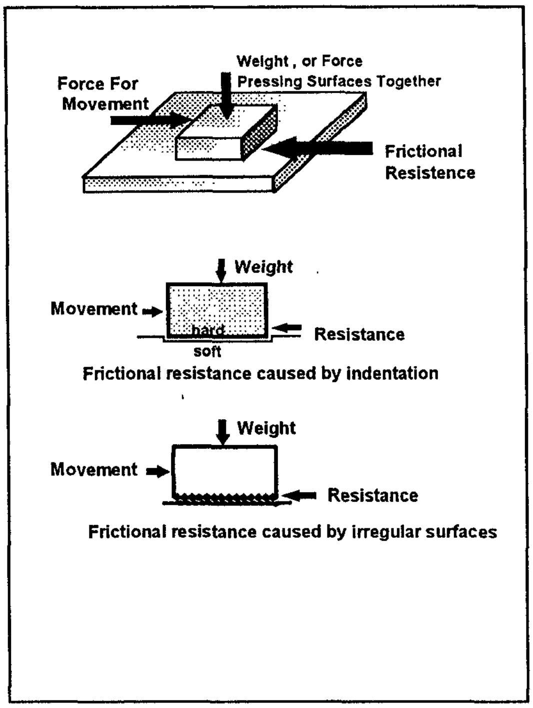
List of experiments or demonstrations and apparatus

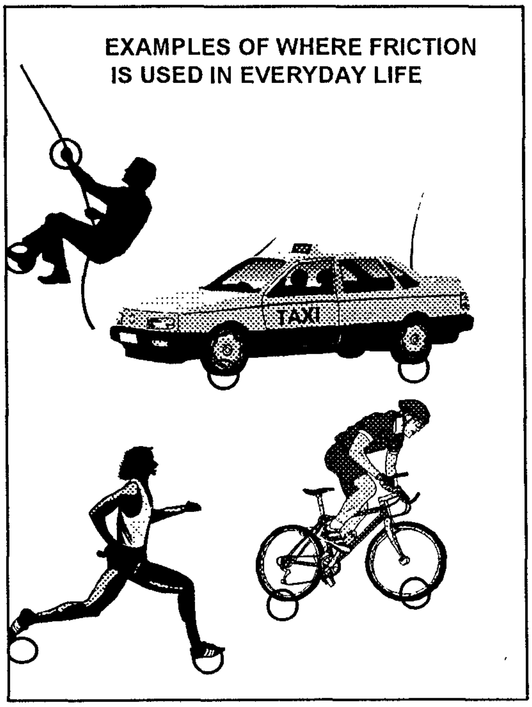
EXPERIMENT	EQUIPMENT
Frictional ignition principles (Using drill press)	Drill press Carbon steel rod ± 6-8 mm Sandstone coarse grained flattened on one side Gas torch Canopy Wooden dowel pieces of harder wood e.g. Eucalyptus Brass rod Container water
Frictional ignition principles (Use of bench grinder)	Hacksaw Bench grinder with medium coarse stone Pieces of low and high carbon steel, brass and wood Bench vise Container water

List of slides to be used

Description	File name
English slides	Per3eng
Afrikaans slides	Per3afr
Sotho slides	Per3sotho
Zulu slides	Per3zulu

See slide show examples on following pages.


Weight, or Force
Pressing Surfaces Together
Force For
Movement
Frictional
Resistence
Weight
Movement
hard
soft
Resistance
Frictional resistance caused by indentation
Weight
Movement
Resistance
Frictional resistance caused by irregular surfaces


EXAMPLES OF WHERE FRICTION
IS USED IN EVERYDAY LIFE
TAXI

TRAINING RECOMMENDATIONS

PERIOD FOUR: FRICTION DURING COAL CUTTING

The purpose of this period is to create awareness amongst the participants of the mechanism of cutting coal. An understanding of how friction can be generated in the cutting situation is to be obtained as well as factors that contribute to friction. As the participant by now should understand how friction, with significantly lower forces, can generate heat, he should now use this information to understand how, with the greater forces present in the coal cutting situation, frictional ignitions can be started,

In this period he will also gain an understanding of the materials involved in the cutting process as well as how the cutting process reacts when it encounters any of them.

Although not directly of relevance to the frictional ignition problem, an understanding of the effects of blunt picks is also advisable as this gives a greater motivation for the picks to be kept in good order.

This period will be structured more around doing exercises than participating in lectures. Apart from giving the participants a break in the information flow, this period strives more at allowing the participant to arrive at some discoveries himself.

The coach will nevertheless link the first set of principles with regard to the cutting situation with the cutting situation underground.

The class will then consider the occurrence of stone in the cutting horizon. This will have to be controlled by showing the participant the provided slides.

Exercise 1: Group lecture using writing bord:

a) Cut an apple with a knife (this can be done by all delegates).
b) Explain the principle that the knife succeeds because it wedges one part of the apple away from the rest.
c) Illustrate this principle further by explaining how Iron Age man could cut huge slabs of rock from mountains to build monuments like Great Zimbabwe (i.e. wooden wedges and water to crack granite slabs).

Exercise 2: Each group receives a piece of rock, and also coal. The objective is to dislodge a small piece without exerting undue force. When this proves somewhat difficult, hand each group a chisel. Ask them to record the outcome and groups then report back.

Exercise 3: Each group required to place drawings of the picks in position on the continuous miner:

a) Small groups are required to explain how these picks exert force on the coal-face like chisels.

b) Groups are required to describe the actual path of these picks through the coal in detail. (Reinforce and correct using the provided slides). Report back.

Exercise 4: Illustrate the principle of friction and how it relates to bluntness by drawing on the writing board using the round edge and the flat edge of a piece of chalk.

Exercise 5: Illustrate the cutting action of the picks on the continuous miner using the illustration provided in the workbook.

Exercise 6: Using the workbook illustrations, the participants place the materials that occur in and around the cutting horizon.

Exercise 7: Using the workbook illustrations, the participants to identify the type and location of materials that can cause frictional heat in and around the cutting horizon.

Using the OHP slides the lecturer can control the work in the previous two exercises.

Exercise 8: The participants have to look at the slides and predict what will happen when various types of picks encounter the materials as shown in the slide.

Experiment list

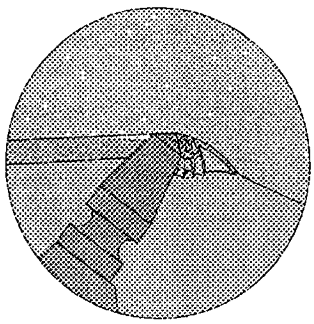
EXPERIMENT	EQUIPMENT
Principles of cutting	Fruit, wood, paper and a knife
Principle of breaking, using tension or wedging	Pieces of coal, rock, shale and a chisel hammer
Friction and creation of bluntness	Blackboard chalk

List of slides to be used

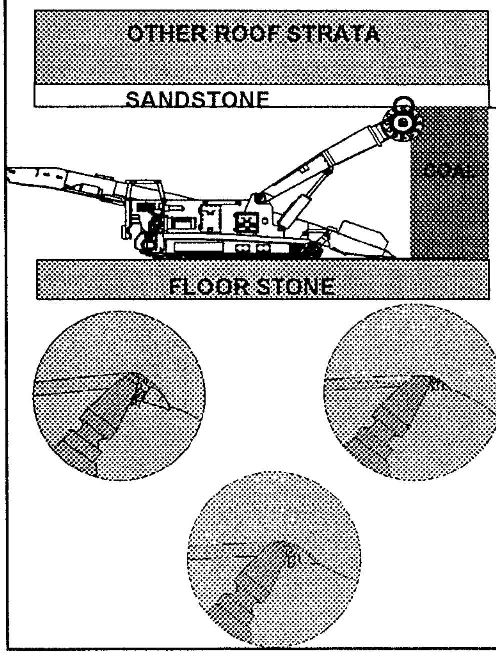
Description	File name
English slides	Per4eng Per4aeng
Afrikaans slides	Per4afr Per4aafr
Sotho slides	Per4sotho Per4asotho
Zulu slides	Per4zulu Per4azulu

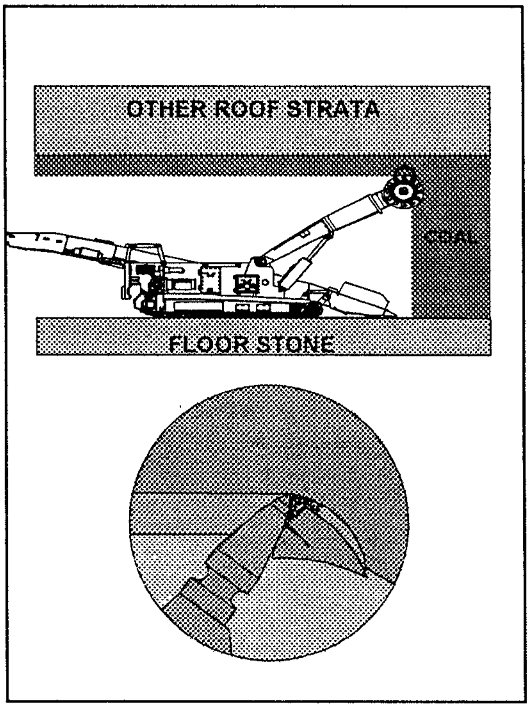
EVENLY WORN PICK CUTTING INTO INCENDIVE SANDSTONE

Hotspot formed by friction.
Area of hotspot is significant
Chance of ignition significant



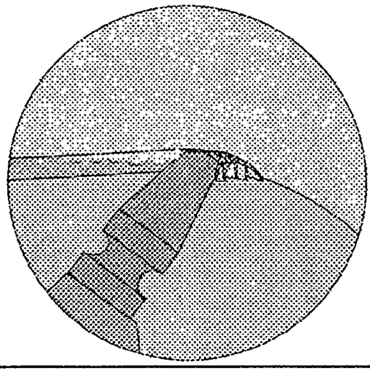
PICKS CUTTING IN ROOF SANDSTONE



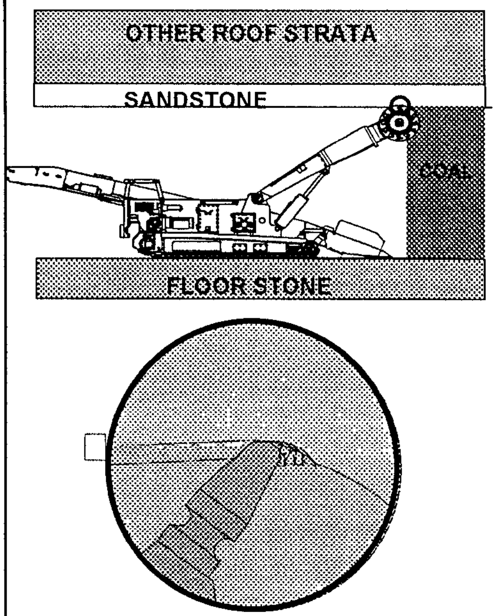


UNEVENLY WORN PICK CUTTING INTO INCENDIVE SANDSTONE

Large hotspot formed by friction.
Area of hotspot is long and wide
Chance of ignition very high

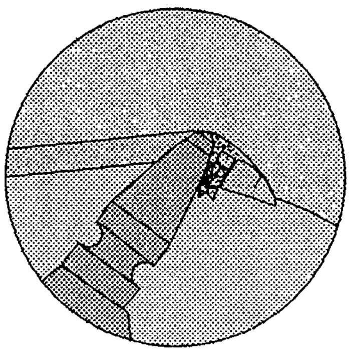


UNEVENLY WORN PICK CUTTING IN STONE



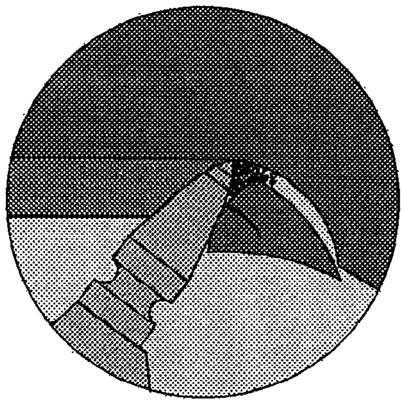
SHARP PICK CUTTING INTO INCENDIVE SANDSTONE

Deeper cut. Large pieces.
Very small hotspot.

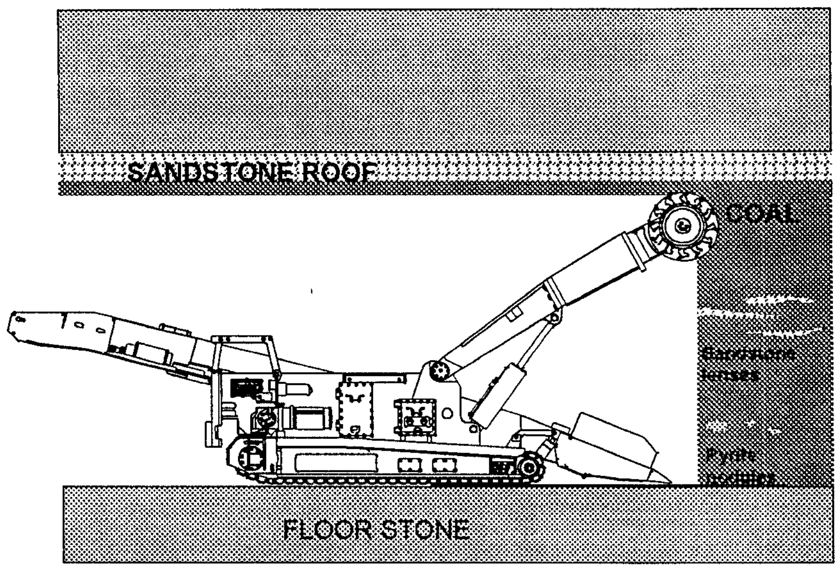


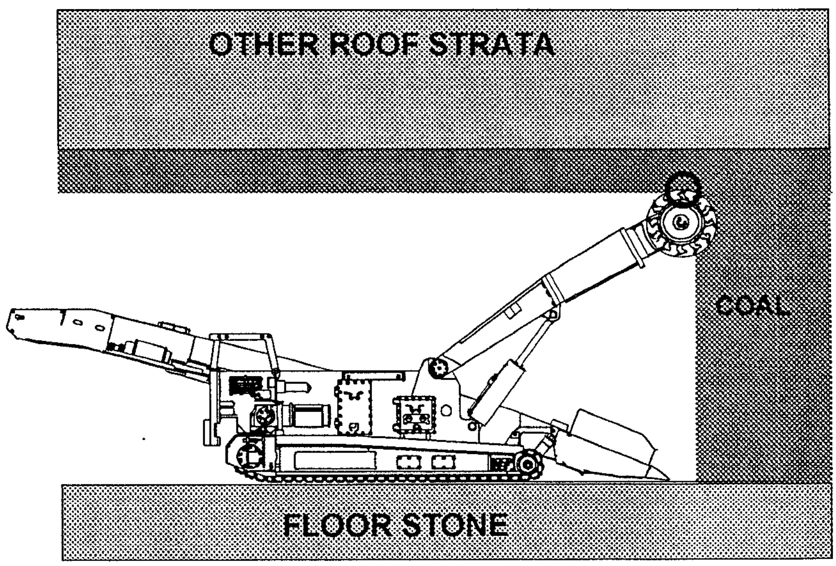
Sharp Pick Cutting Coal

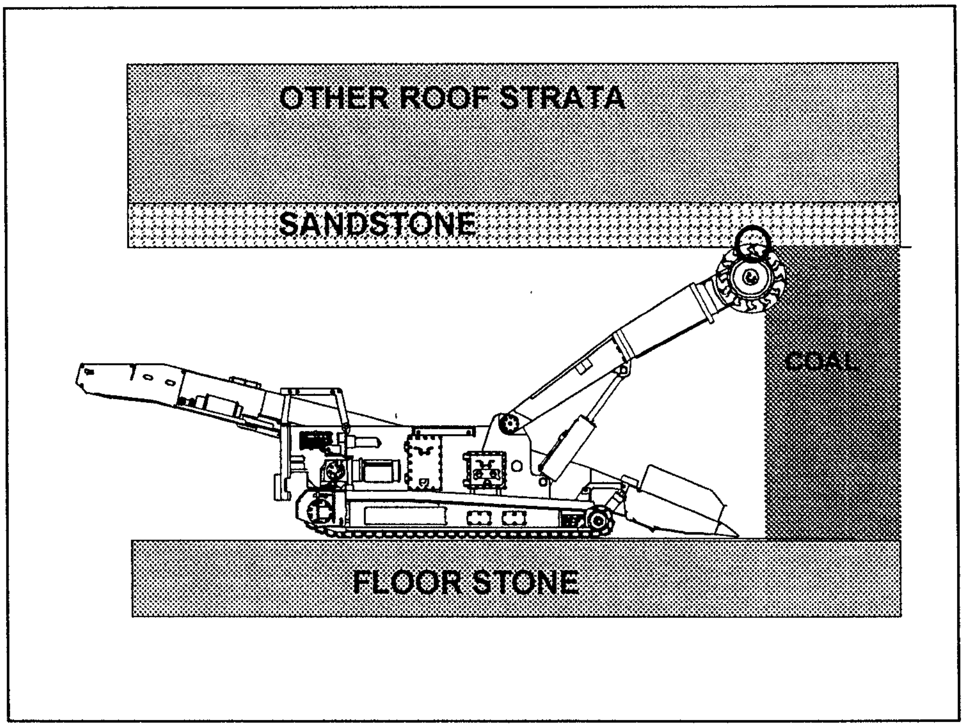
Deep cuts and large coal pieces

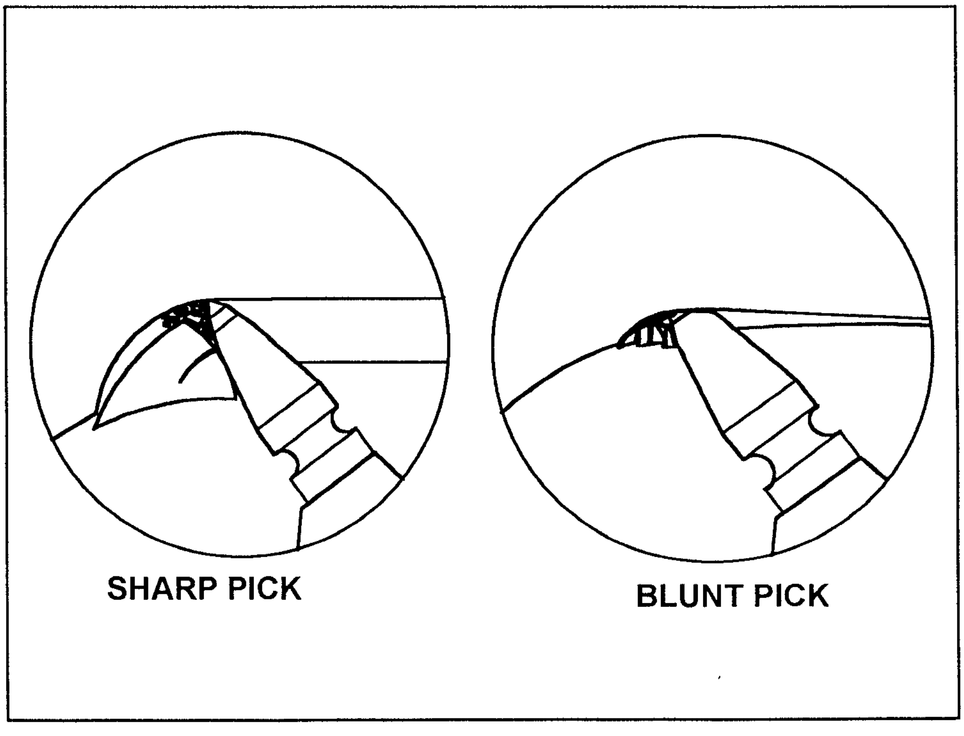


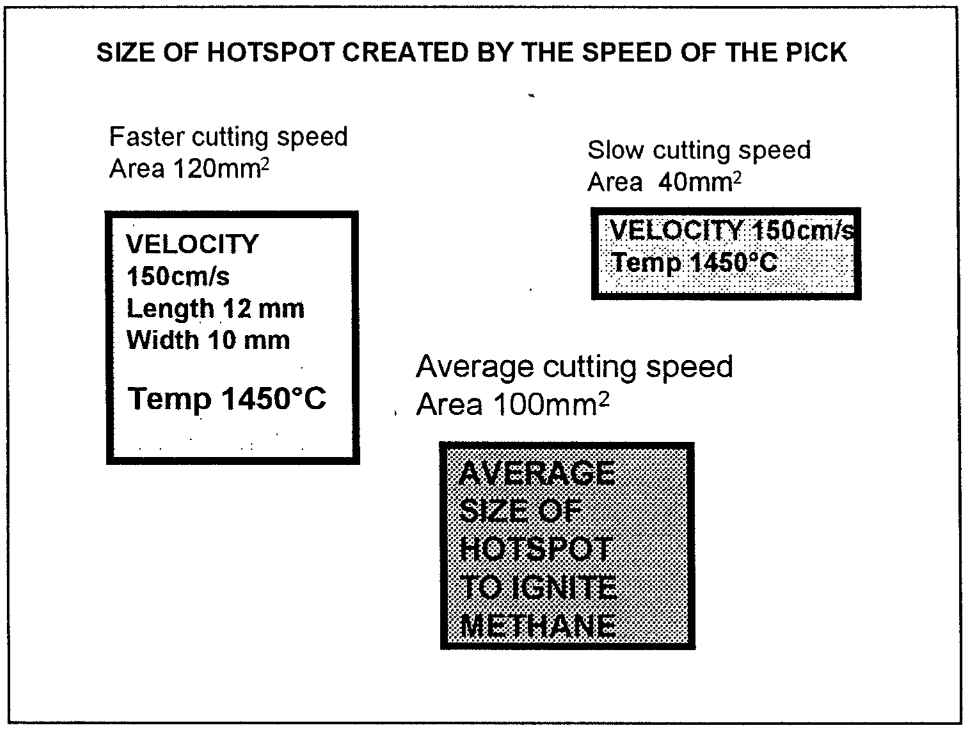
LOCATION OF MATERIALS THAT CAUSE FRICTIONAL IGNITIONS






OTHER ROOF STRATA
SANDSTONE
COAL
FLOOR STONE


SHARP PICK
BLUNT PICK


SIZE OF HOTSPOT CREATED BY THE SPEED OF THE PICK
Faster cutting speed
Area 120mm²
VELOCITY
150cm/s
Length 12 mm
Width 10 mm
Temp 1450°C
Slow cutting speed
Area 40mm²
VELOCITY 150cm/s
Temp 1450°C
Average cutting speed
Area 100mm²
AVERAGE SIZE OF HOTSPOT TO IGNITE METHANE

TRAINING RECOMMENDATIONS

PERIOD FIVE : OTHER FORMS OF FRICTION HEAT

The objective of this period is to make the participants aware of other sources of friction heat in a coal mine.

The main part of this period will consist of a guided discussion on where such friction can occur.

1. Reiterate the role of the heat generated by friction.

2. Lead the participant to think of occurrences in the mine where forces between two objects can occur:

   - two vehicles colliding
   - vehicle colliding with a pillar
   - friction between metal, like in conveyor roller
   - roof falls

   Look at the identified circumstances and discuss the heat that can be generated when considering:

   - the size of impact
   - the time of friction
   - the materials under consideration

3. Expand on goaf and roof falls and how this can lead to an ignition.
4. Expand on other aspects like metal on metal friction. Reinforce the time factor.
5. Indicate to participants that the one situation where sufficient heat is generated between two metals is in the case of aluminum and iron rust.

Bring in the effects of aluminum and light alloys and that the heat is not caused by the actual friction but by the thermite reaction caused by the frictional heat.

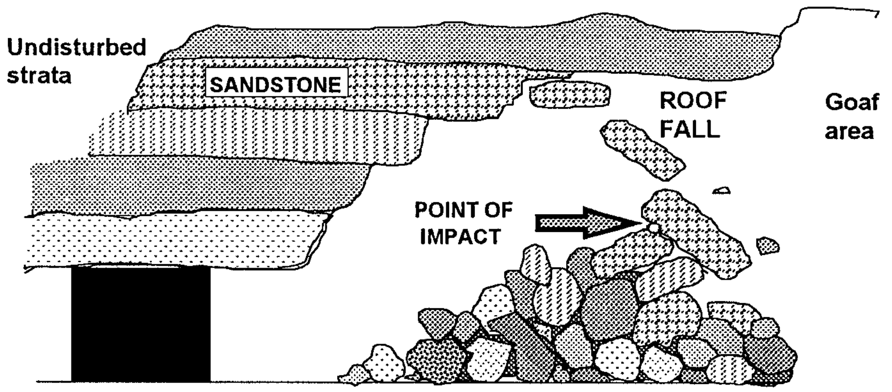
(This could be illustrated with an experiment but it is difficult to obtain materials and conduct the experiment.)

Final aspect: Participants to further propose areas where in their field of expertise they can think of such occurrences.

List of slides to be used

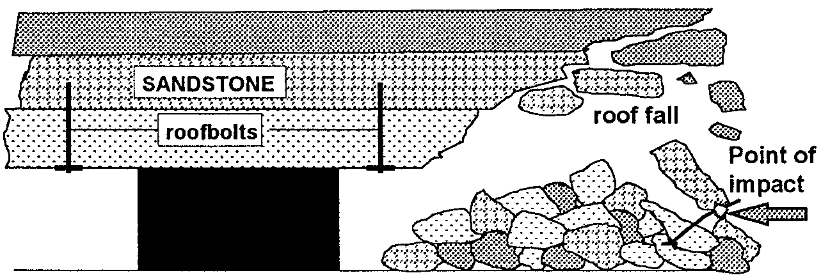
Description	File name
English slides	Per5eng
Afrikaans slides	Per5afr
Sotho slides	Per5sotho
Zulu slides	Per5zulu

EXAMPLE OF STONE ON STONE FRICTION



EXAMPLE OF METAL ON STONE FRICTION

Sandstone in roof fall impacting on a roofbolt



TRAINING RECOMMEDATIONS

PERIOD SIX : METHANE

The objective of this period is to create an understanding of methane as a gas in the underground environment. The participants should understand not only the way that the gas occurs but also its characteristics. Finally the participants should become aware of the particular hazard that methane poses because of the fact that it cannot be seen, is tasteless and odourless and can therefore only be detected by a methanometer.

This period will consist mainly of interactive discussions of the trainer with the participants, demonstration exercises and group discussions.

The first concept that the participant will need to understand is what a gas is and what the characteristics are of a gas. Aspects like: a gas occupies space and thus has volume and weight.

- This can easily be illustrated by blowing up a balloon/condom or through the displacement of water in a container.

The next concept that needs to be understood is that different gases have different weights.

This can be illustrated through the use of a balloon condom filled with exhaled breath and by filling a balloon/condom with pure methane.

The way these containers react after having been released will clearly indicate that methane is lighter than air.

The following concept to be illustrated is that methane is without smell.

This can easily be illustrated by letting participants smell the difference between an amount of methane that has been released in a container and other gases and vapours like Butane (which has an odour added) and petrol, and or benzene. A good example is for the participants to try and determine the difference between air and methane.

The following concept to illustrate to the participant is the absorption of the gas.

This is done showing how carbon dioxide is released by a soft drink like Cocoa Cola.

Using the prescribed apparatus the gas from the soft drink displaces a greater volume of air than was available.

The participants will be required to note their experiences down in the work book.

Trainer will at this stage have to recount the characteristics of the methane.

A group exercise will be held where the sources of methane are identified. At first the participants will have to relate where they have experienced the occurrence of methane.

The trainer will then list and show where methane occurs.

Other characteristics of methane will be listed and explained to the participants. What is of importance is for the participants to understand the flammability limits of methane and how this can manifest itself in the underground environment.

To allow for understanding of the percentages used it would be advantageous to use relationships like one in a hundred or one in ten as well.

The role of methane as the fuel, and how the energy of the methane leads to longer explosions has to be reinforced.

Aspects to be covered include:

Where ignitions can occur
The explosion of the methane
The large amount of heat released

A group exercise, wherein the results of a methane explosion are predicted, is to be held. This will reinforce the danger of such explosions.

The trainer should conduct a short talk and demonstrate the use of methanometers.

From the characteristics of methane, as well as the way methane occurs in the working areas, a group exercise, to determine the best place to sample for methane, is conducted.

The trainer confirms the testing of methane in terms of the mine procedures. It is important that the accepted process of the mine to test for methane is reinforced and explained. This will allow the participant to understand that the rules are in existence to keep the workers safe.

LIST OF EXPERIMENTS TO BE CONDUCTED AND THE REQUIRED APPARATUS.

EXPERIMENT	EQUIPMENT
Balloon experiment (methane lighter than air)	Balloon or preferably condoms Source of methane under pressure (cylinder)
The desorption of a gas (also to illustrate the fact that gas takes up volume and that one gas show the presence of gas by the replacement of water in a bottle)	Bottle of mineral water preferably Coke Specially prepared stopping Plastic tube Container of water Empty bottle can be used to collect gas.

List of slides to be used

Description	File name
English slides	Per6eng
Afrikaans slides	Per6afr
Sotho slides	Per6sotho
Zulu slides	Per6zulu

TRAINING RECOMMENDATIONS

PERIOD SEVEN : PRINCIPLE OF REMOVING A COMPONENT

The objective of this period is to make the participants aware of the fact that when one of the components of a fiery triangle is removed then there cannot be an explosion or a fire. (It may seem that too much attention is given to this concept. As this is the underlying rationale of the course it cannot be reinforced enough.)

The participants are also to be made aware of the processes that are used to remove a component from the triangle.

1. The trainer should, when revising the components of a fire, point out the necessity of having all three components present to have a fire or explosion.

2. The trainer should then lead the participants through the mechanisms employed on how components are removed.

Finally the concepts are reinforced by letting the participants apply the mechanisms to examples of everyday life of fires and explosions.

At this point the participants must not progress to applying the mechanisms to the underground environment. These mechanisms will be expanded on in further periods.

It is important that participants understand the concepts embodied in this period very well before going on to other aspects.

List of slides to be used

Description	File name
English slides	
Afrikaans slides	
Sotho slides	
Zulu slides	

TRAINING RECOMMENDATIONS

PERIOD EIGHT : RESPONSIBILITY OF PREVENTION

The purpose of this period is to make the participants aware of their responsibility with regard to the prevention of frictional ignitions on the mine.

This is not as generic as the other periods as each of the individual participants, based on his work category, his particular field and organizational responsibility will have a different responsibility and method of taking action. It can also be expected that some of the higher level participants will have responsibilities in terms of the law.

In contrast to this there are also constraints as to which actions can be taken by the various participants when functioning in the work situation. A shiftboss can for example not tell a mine manager to acquire certain pieces of equipment purely on his perception of a problem.

It will thus require great tact and control from the trainer to control the groups so that the problem is addressed and the issues raised during discussion are not hijacked for other purposes.

As this period could become difficult it is suggested that preparation for this period is done in conjunction with a senior manager and, even better, that during the first few times of this period, a senior manager is present for the entire time. It would soon become evident to the trainers which subjects should be avoided and how to tackle the other more sensitive issues.

The first part of this period should be spent on making the participants aware of why they, as a group as well as individuals, should be aware of the hazards of frictional ignitions as well as why they have to take action to prevent them from happening.

Their responsibility ranges from a legal one through organizational to the social and moral motivations.

This should be done, firstly by the individual listing what he believes he should do, which is then followed by a group discussion wherein these responsibilities are confirmed.

In the case of illiterates, the trainer will have to keep these lists but in the case of those that can read and write these responsibilities will be listed in the workbook.

It is further proposed that no value judgment is given on the results as the results will be used for comparison during the last period.

The first exercise will thus be a listing of the reasons why the participants feel they should act to prevent frictional ignitions.

The second exercise will be directed at making the participant aware of his own and the other participant's responsibilities in preventing frictional ignitions. In this exercise it is not required for the participant to be action directed but rather responsibility directed. In other words a participant might point out that he is responsible for ensuring that the water in the section is kept up to date rather that the water is used on the machine for sprays. A ventilation person would indicate that he is responsible for the ventilation rather than the dilution of methane. This linkage should not be brought up this early but will be required later on in the course.

The second part of the second exercise is to determine why each of the participants has this responsibility. Is this due to the law, an organizational job description or a social or moral reason?

During this part of the course it is therefore imperative for the trainer to be aware of the organizational responsibilities that are allocated to the various participants.

The exercise will be done by individual contribution followed by a group evaluation that is then evaluated in terms of the allocated mine responsibilities.

It will not be necessary to list all the responsibilities of a task but only those that have particular relevance to the prevention of frictional ignitions.

The final part of this exercise is to enable feedback to management on what the participants believe are constraints in the working of the section which could prohibit or detract from them spending the required attention on measures to combat frictional ignitions.

Under no circumstance should the trainer allow soft issues to be raised during this part of the period. It is not the purpose of this course to sort out employer dissatisfaction but rather to identify processes that could constrain the worker in doing the maximum to prevent frictional ignitions.

TRAINING RECOMMENDATIONS

PERIOD NINE : REMOVING METHANE

The purpose of this period is to create an understanding of the importance of controlling methane in the workplace so that no dangerous levels or accumulations occur. As the main method of combating methane is the ventilation systems, the importance of the installed systems on the mine and keeping them functioning well cannot be over-emphasized enough.

The methods of measuring for methane and the importance of the readings are also of great importance.

There is however a problem in devising any firm training aids for this period as not all the mines have similar or standardized ventilation systems. It will thus be necessary for the training person to establish visual aids to enable him to transfer the methods to all the participants. Where slides and visuals are given in this period they can be used as guides.

The whole aspect of ventilation is sometimes a difficult concept to understand and to visualize and it is thus important that the participants gain some or other form of understanding of the whole process. It is necessary that they understand the principles of dilution, gathering and removing and how the ventilation breaks up concentrations of methane. It is not necessary that the same type of model that is presented in this course is used but any similar device can only be an asset.

Use of the ventilation model will illustrate the following aspects to the participants.

The flow of a fluid can seldom be seen, except by the use of an indicator like dye.

The way that the flow of a fluid or gas dilutes and moves a pollutant.

The way that methane at first stays together and then with time disperses in the general environment.

It would be advantageous if the trainers on the mine can establish some or other form of training aid that could illustrate these principles.

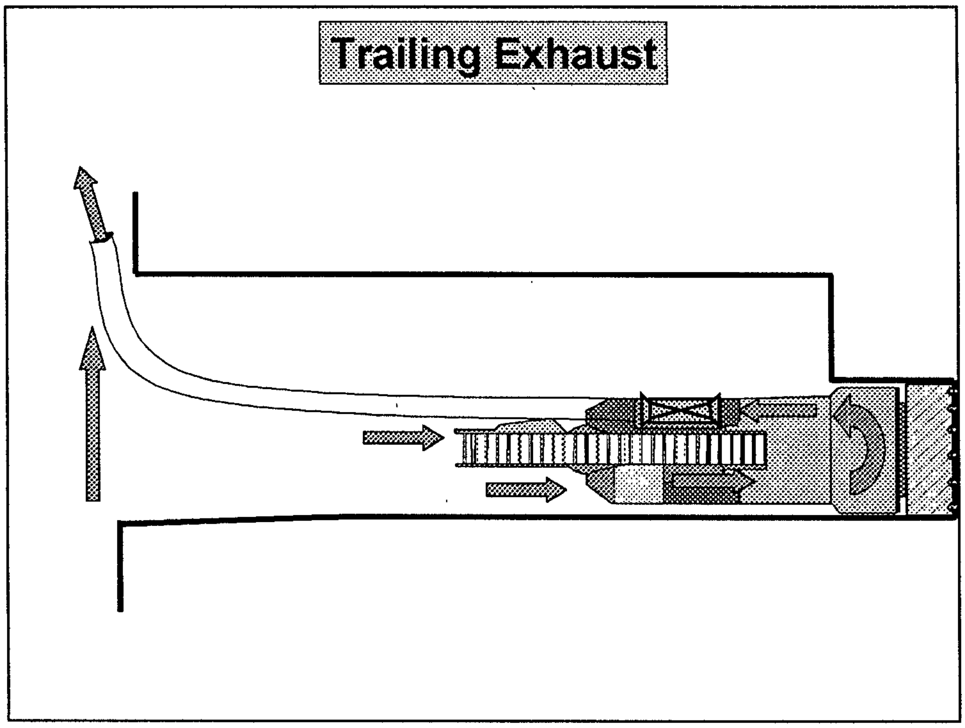
It would also be necessary for the trainer to show to the participants how methane is detected in the section. It is important that all workers and participants know why and how testing for methane has to be done. It can be anticipated that this forms the basis of other courses like the gas testing certificate, however reinforcement of the concepts and principle as used on the mine will also be important.

It is also important for the participants to become aware of their own role in maintaining good testing practices in a section even if they are not directly involved with the testing. Attention to the use of the on-board methane monitors should be included in the detection of methane.

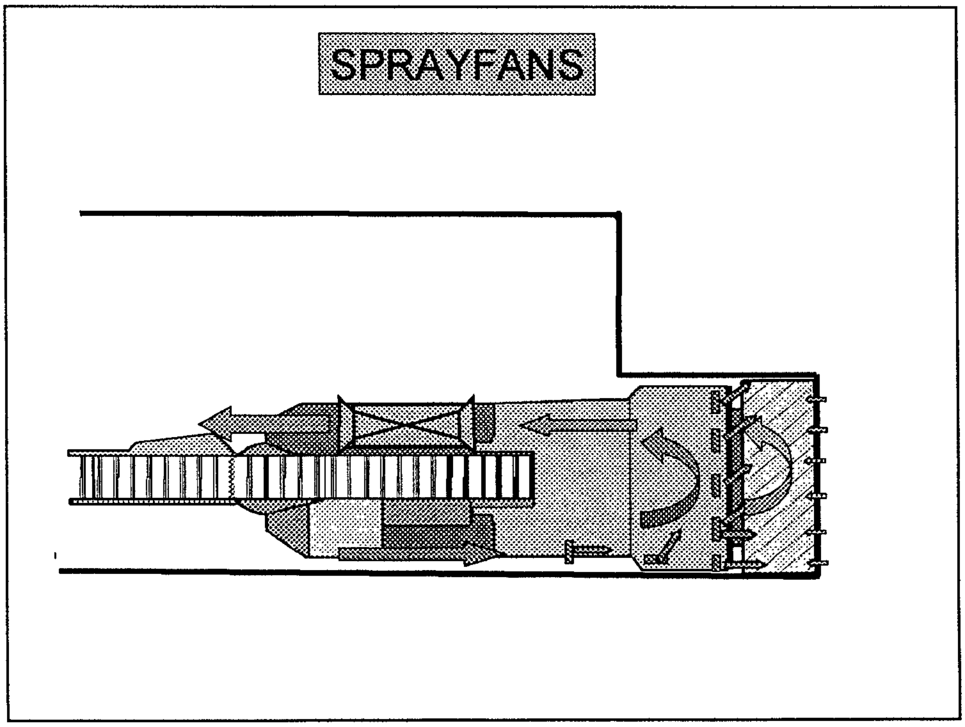
The maintenance of these instruments and ensuring that they work at all times should also be brought home to the participants. How this system safeguards them should be emphasized to all participants.

List of slides to be used

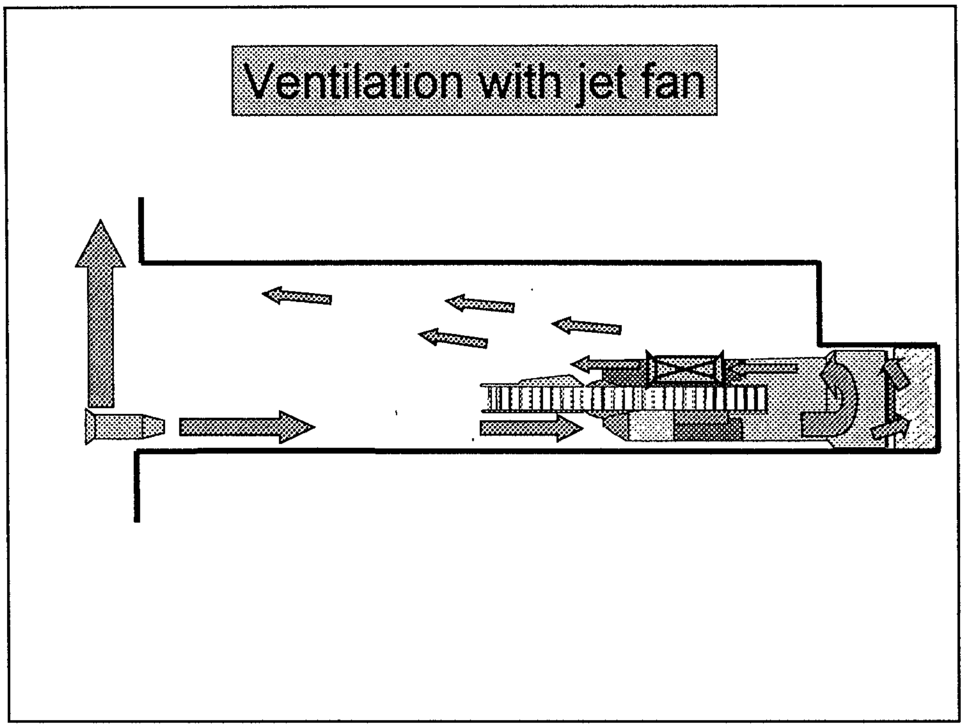
Description	File name
English slides	Per9eng
Afrikaans slides	Per9afr
Sotho slides	Per9sotho
Zulu slides	Per9zulu

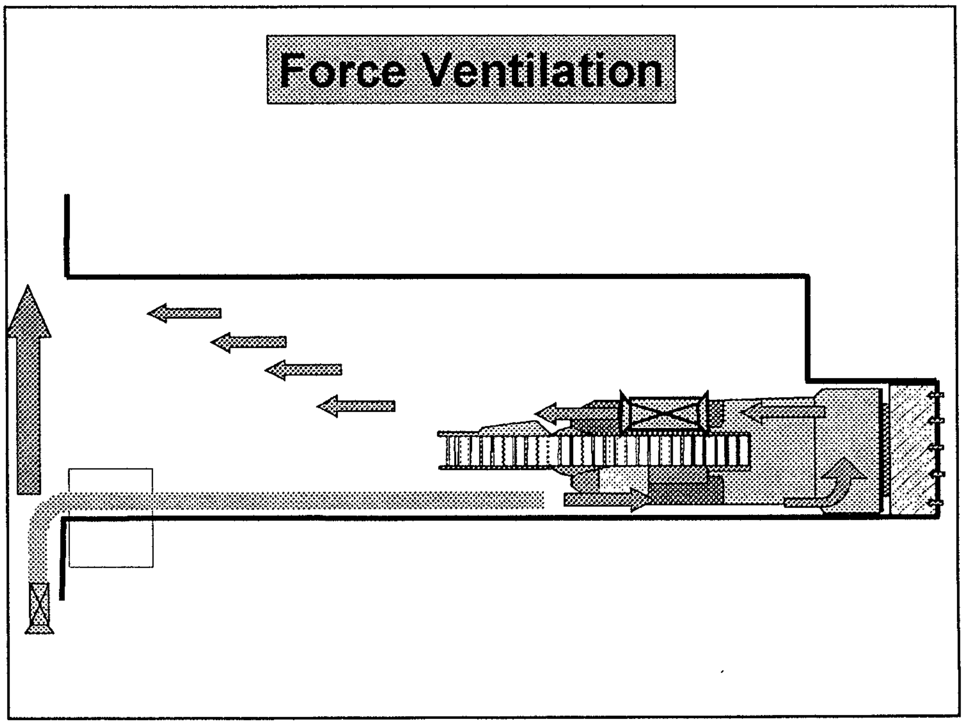


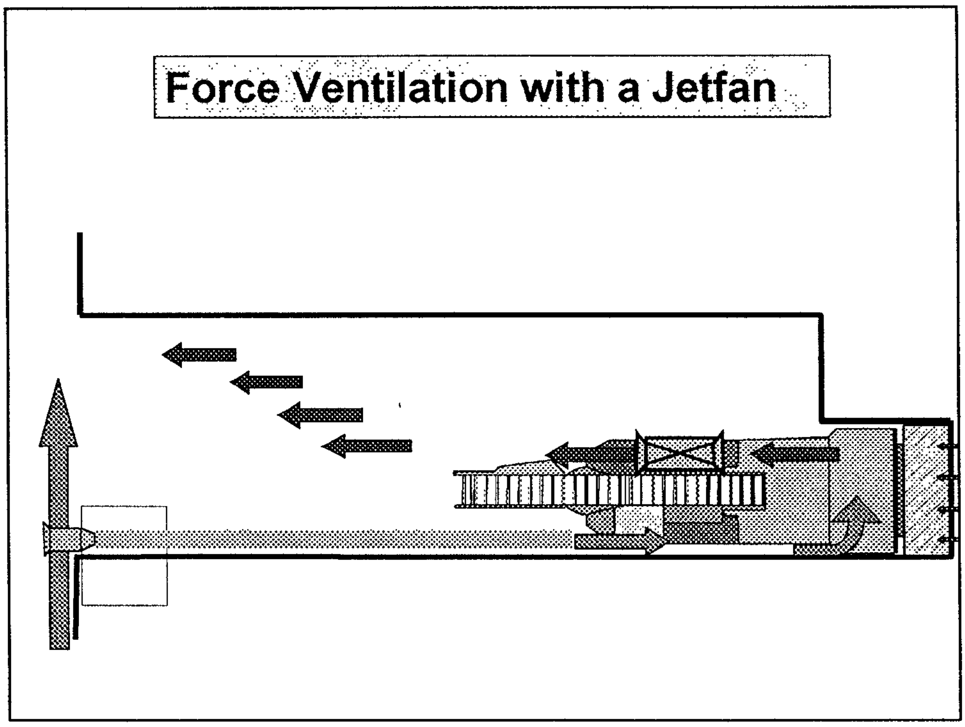
Trailing Exhaust

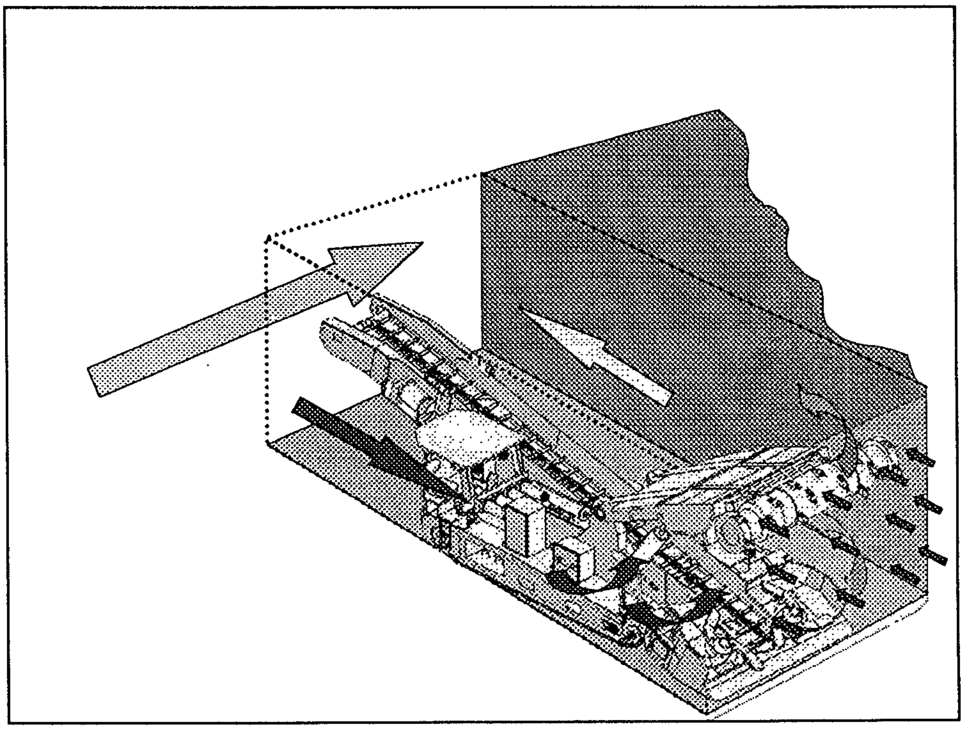


SPRAYFANS


Ventilation with jet fan


Force Ventilation


Force Ventilation with a Jetfan



TRAINING RECOMMENDATIONS

PERIOD TEN : PICKS AND GOOD CUTTING PRACTISES

The purpose of this period is create an understanding of the effect of blunt picks in the potential for frictional ignitions as well as the methods used to identify when a pick is blunt.

The blunting of picks is a difficult issue and has been the subject of considerable research work. The first aspect requiring an understanding to be created is that, when a pick is blunt, it is detrimental to the cutting process, produces more dust and poses a frictional ignition hazard. The second aspect that has to be brought home is that no production gains are made when keeping a pick in the box when it is blunt, but that there is a production loss.

A further aspect which could be difficult to create an understanding of is that even though the pick still might have tungsten carbide in it, it could be unacceptably blunt. The fact that a pick has something of a sharp point also does not mean that it is sharp if it is unevenly worn.

It is proposed that this entire issue is not only discussed by the whole class but is also the subject of a group discussion.

Examples from everyday life where things that still look useful but are actually useless should be found.

Examples like razor blades, car tyres, brake shoes, pens etc. can all be used to convey the concept of objects that have been used up but that the majority of the original object is still there.

The final concept that has to be understood by the participants is that of replacing the pick just before it becomes blunt. In this way the machine always cuts with sharp picks. This decision will be left up to the operator who will have to make the decision when to replace the picks. He should be aware of the fact that prevention is better than cure and that it is actually an error if a pick is allowed to become very worn on the drum.

This period will be spent mainly on group discussions that are guided by the trainer. The trainer will, however, have to show the participants how picks that are blunted, or just on the point of becoming blunt, look.

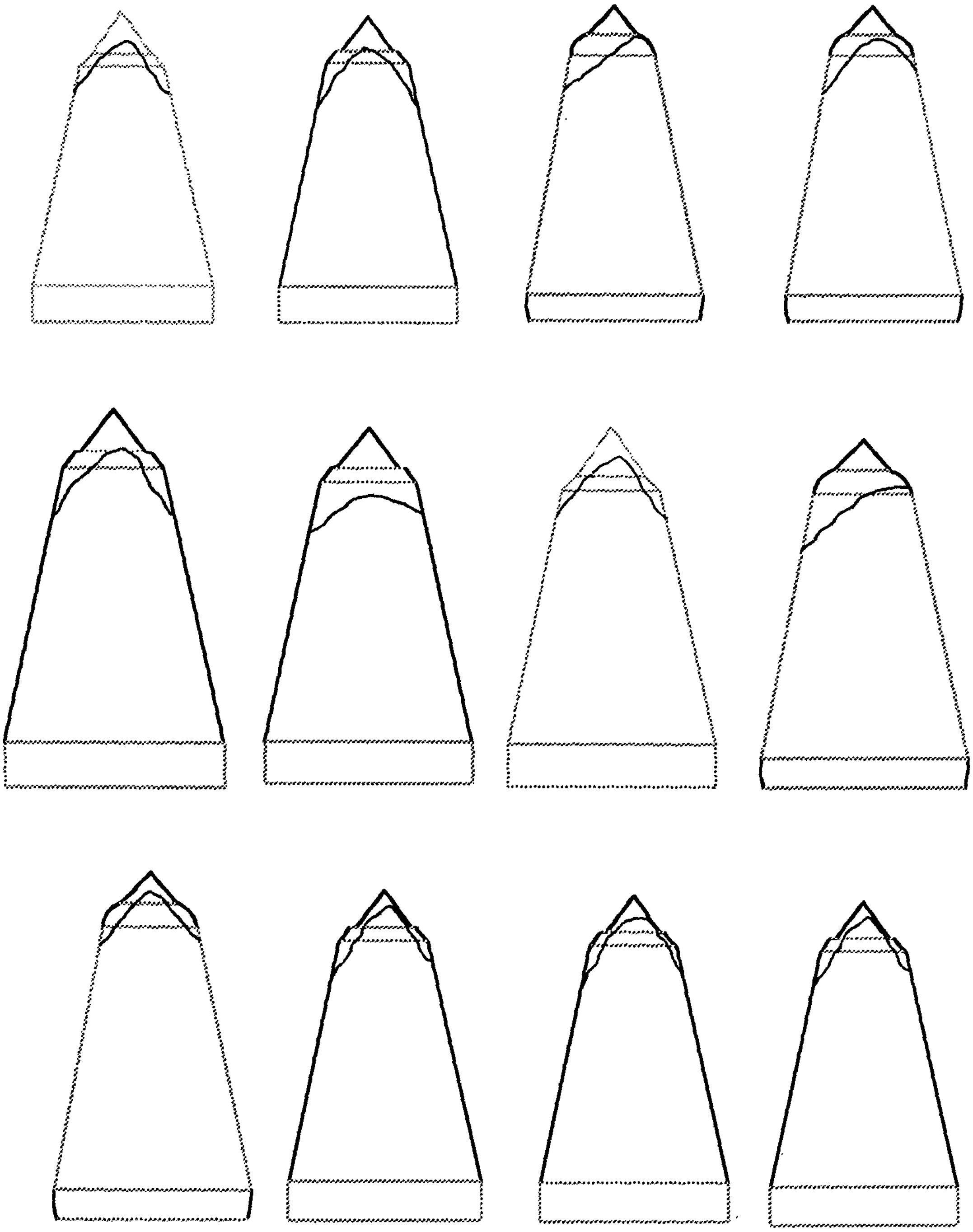
There is an exercise in the workbook where photographs of picks are used but it is recommended that during this period the participants also handle an array of picks in various conditions from the mine. This forms the basis of a group exercise to choose which picks are acceptable or not.

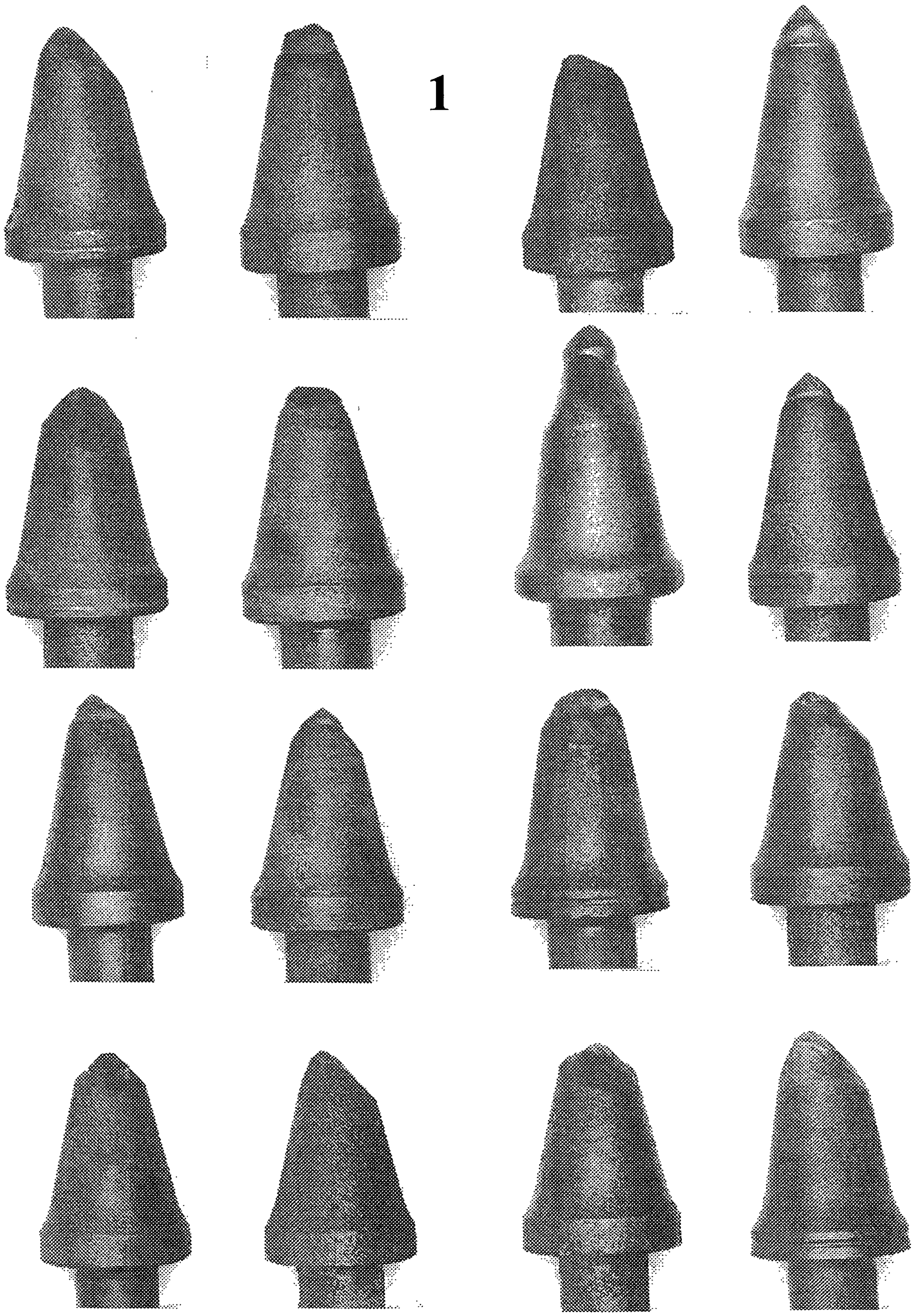
One of the greatest benefits of this period would be to sensitize the participant to the fact of blunt picks so the actual definition of where the point of acceptability lies is actually of lesser importance than the fact that the participants now have become aware of the issue.

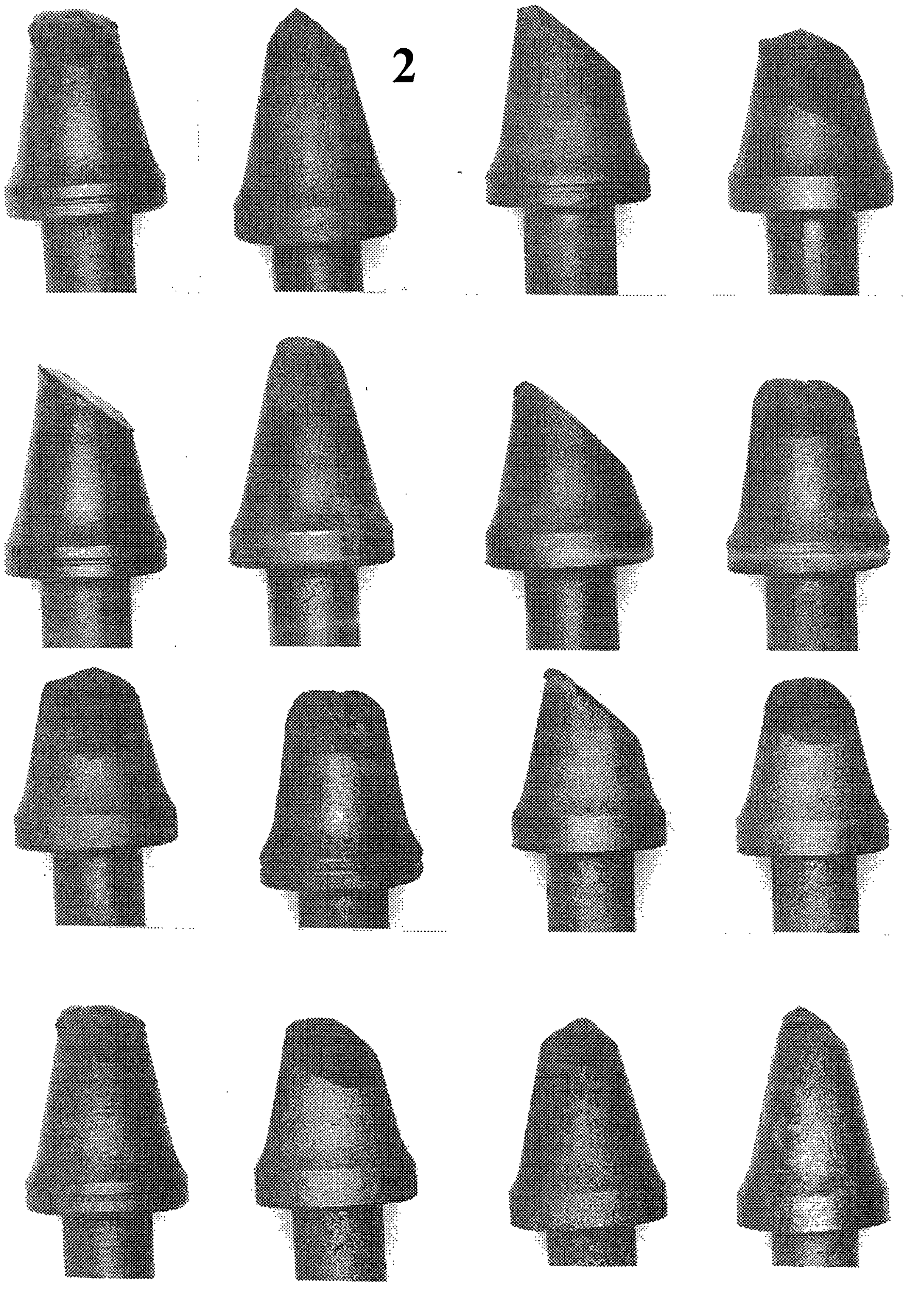
List of slides to be used

Description	File name
English slides	Perteneng
Afrikaans slides	Pertenafr
Sotho slides	Pertensotho
Zulu slides	Pertenzulu

Examples of picks worn down to the point where the cutting forces start increasing rapidly




1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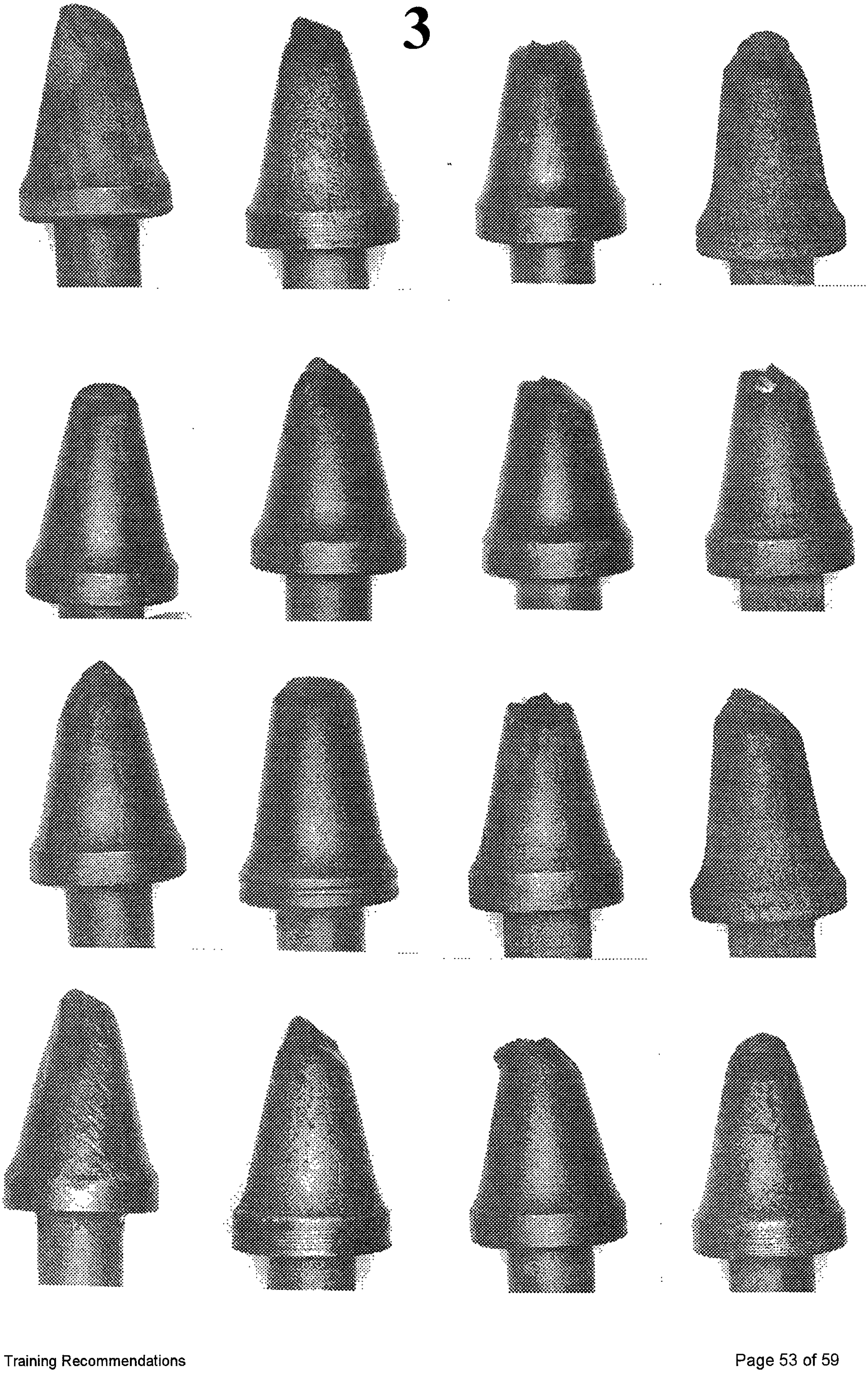

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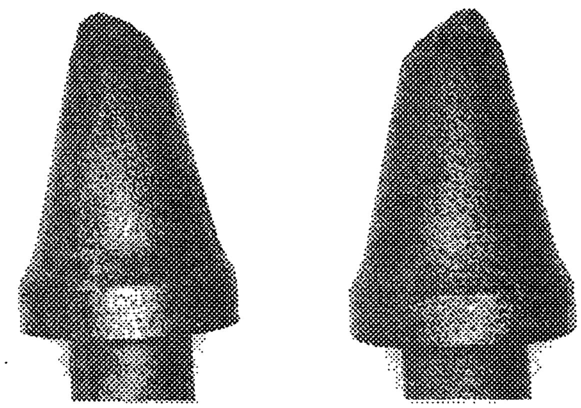
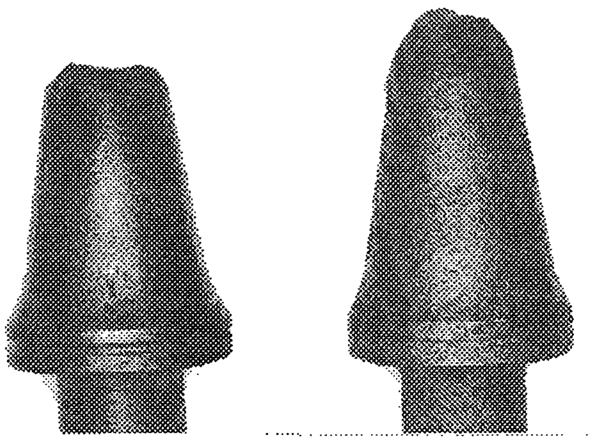
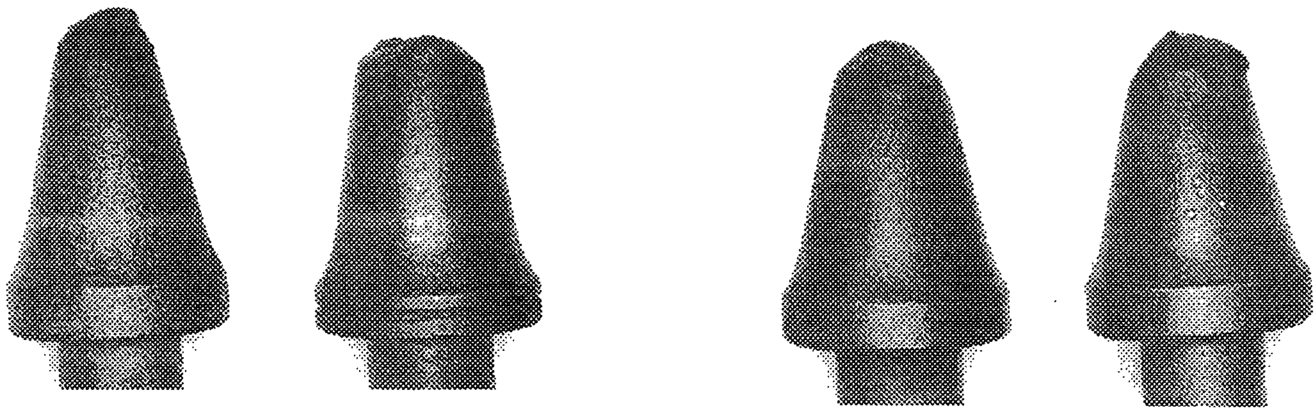






MARK THE PICKS YOU WOULD KEEP WITH AN **X**

TRAINING RECOMMENDATIONS
PERIOD ELEVEN: OTHER METHODS EMPLOYED

The objective of the final period is to inform the participants of the other methods that are available, or in the process of being developed, to reduce the occurrence of frictional ignitions.

It should be clearly pointed out to the participants that the coal mining industry has spent considerable effort on developing systems to prevent frictional ignitions from occurring.

An aspect that should also be brought home to the participants is that, when systems like those under discussion are introduced on the mine, they should be aware of the purpose of such systems. This will allow the participants to support and assist as much as they can in the successful application of these new systems.

This period will basically consist of a lecture, which will then be followed by a discussion so that the participants can express their opinions and ask questions.

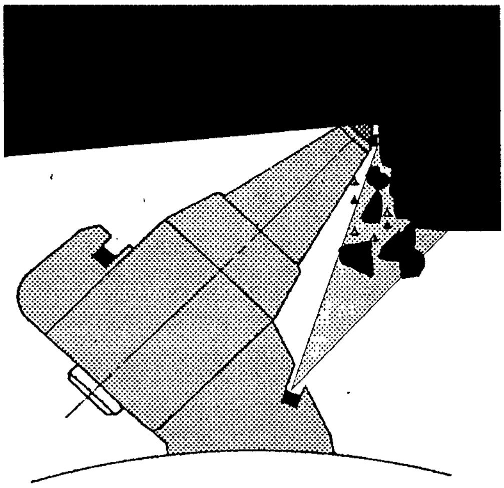
It would be advantageous for the trainer to be aware of the products on the market. Information with regard to this is available in the reference section under the submissions made by the manufacturers.

List of slides to be used

Description	File name
English slides	Per11eng
Afrikaans slides	Per11afr
Sotho slides	Per11sotho
Zulu slides	Per11zulu

SPRAY PLACED IN FRONT OF PICK

Cannot cool frictional heating
Good for the control of dust



SPRAY BEHIND PICK

Stops frictional ignitions. Less efficient for dust

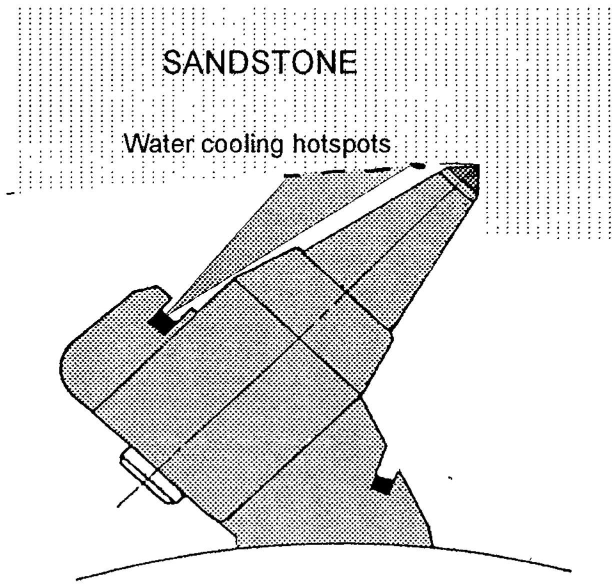
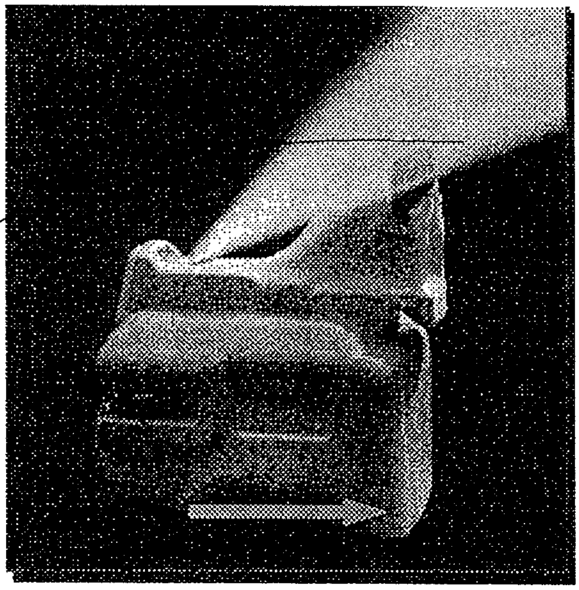


ILLUSTRATION OF SPRAY BEHIND PICK



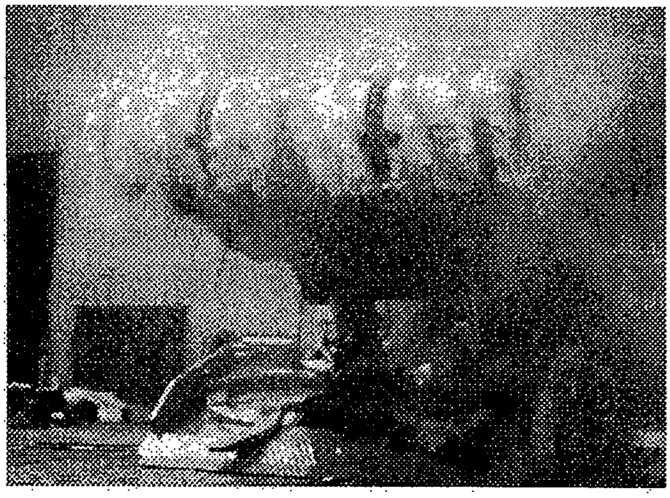
Profile of area being cut

Visuals courtesy of HYDRA TOOLS

SPRAY AROUND CONTINUOUS MINER DRUM CAUSED BY THE WATER FROM PICK SPRAYS

Visuals courtesy of HYDRA TOOLS

CONTINUOUS MINER FITTED WITH WATER SPRAYS



Visuals Courtesy of HYDRA TOOLS

TRAINING RECOMMENDATIONS

PERIOD TWELVE – CONTROL

The objective of this period is to wrap up the course and to reinforce the concepts and principles that were transferred to the participants during the preceding periods.
At this point in time the video can be shown the rest of this period should take place in two phases. The first is a revisiting of the allocation of responsibilities as done during period eight.
The second part of the exercises as set in period eight should now be concluded.
These exercises will reaffirm the responsibility and roles that the various participants have to play.
When the previous exercise was done the participants were not fully aware of what actions should be taken to prevent frictional ignitions from occurring.
After completing the previous periods the participants should by now be aware of the action that can be taken as well as how they could fit in with the tasks he has to perform in the underground situation.

By doing the exercise where the participants look at their own responsibilities and what they can do to stop frictional ignitions from occurring, the whole issue is reinforced.
This entire aspect of placing the responsibility of keeping persons safe from the results of a frictional ignition, not only on mine management, but also on the individuals in the work situation, is a very important aspect of this course and should be reinforced throughout.

The second part of this period should be spent on obtaining feedback from the participants on how they experienced the course.
What is also of importance is to determine what aspects they still have uncertainties about and what aspects they would like to have expanded. This will allow the trainer to restructure his training course so as to address these problems in future courses.

At this point the course is not intended to form part of any standards, therefore the actual outcomes are not assessed.
It will however be beneficial if the trainer, in an informal way, tests the increase in knowledge amongst the participants even if it is as an indication for himself with regard to the success of the course.

APPENDIX 4

ENGLISH WORKBOOK

Course on frictional ignition hazard in collieries

English Language Workbook

Date course attended...............

Name of participant.........................

COURSE LAYOUT

P1 Importance of Frictional Ignitions

P2 Fires and Explosions Components

P3 FRICTION - HEAT

OXYGEN

METHANE - FUEL P6

P3 What and How of Frictional Heat

What and How of Methane P6

P4 Friction during coal cutting

P5 Other form of Friction Heat

Principle of Removing a Component P7

Responsibility of Preventing P8

P10 Preventing Friction Heat

P10 Picks and Good Cutting Practice

P11 Other Methods Employed

Removing Methane P9

Monitoring P9

Ventilation P9

Control

WORKBOOK

PERIOD ONE PARTICIPATION

A. SECTIONS TO BE COVERED IN THIS COURSE

1. Introduction
2. Components of fires and explosions
3.
4. Principles of friction in the cutting situation
5.
6.
7.
8.
9.
10.
11.

B: Dangers/problems encountered underground:

Danger/Problem	Why?	Rank
____________	_________________________________	_____
____________	_________________________________	_____
____________	_________________________________	_____
____________	_________________________________	_____
____________	_________________________________	_____

C: We are attending this programme to understand how we can influence the occurrence of fires and explosions caused by Frictional Ignition.

D. How could fires and explosions caused by Frictional Ignition affect:

i) ourselves? ______________________________

____
____
____
____

ii) our subordinates/colleagues?______________________________

____
____
____
____

iii) the mine? ______________________________

____
____
____
____

E. What I expect to benefit from this programme ______________

____
____
____
____
____

WORKBOOK

PERIOD TWO : FIRE AND EXPLOSION COMPONENTS

THE OBJECTIVE OF THIS LESSON IS:

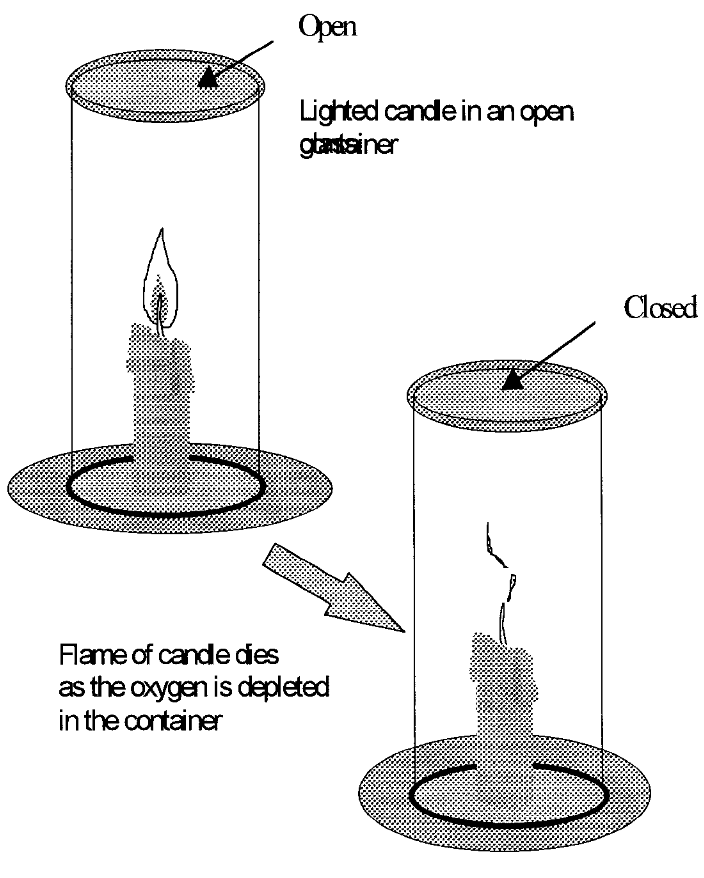
____

____

____

COMPONENTS OF A FIRE/EXPLOSION ???

DEMONSTRATION WITH CANDLE



What happens to the candle when the glass disc is placed on the measuring jug? Why?

………

………

………

………

………

GROUP ASSIGNMENT EXERCISES

The main difference between a fire and an explosion is:

a) the heat of the reaction
b) the speed of the reaction
c) the fuel of the reaction ______________

Some everyday examples of fire or explosions are:

	Good or Bad
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________

Show the progression of a fire/explosion using your own examples:

1. ______________
2. ______________
3. ______________

Examples of initiating heat.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

WORKBOOK

PERIOD THREE

Exercise 1: Result of rubbing hands together

slowly ______________________________

fast ______________________________

Exercise 2: Using a hacksaw

Material	Time	Blade heat
Wood	________	________
Coal	________	________
Lead	________	________
Brass	________	________
Rock	________	________
Steel	________	________

Exercise 3: Using a grinder

Material	Time	Heat	Sparks
Wood	________	________	________
Coal	________	________	________
Lead	________	________	________
Brass	________	________	________
Rock	________	________	________
Steel	________	________	________

Exercise 4a: Using a hacksaw and water

Material	Heat	Time
Wood	________	________
Coal	________	________
Lead	________	________
Brass	________	________
Rock	________	________
Steel	________	________

Exercise 4b: Using a hacksaw with oil

Material	Heat	Time
Wood	________	________
Coal	________	________
Lead	________	________
Brass	________	________
Rock	________	________
Steel	________	________

Exercise 5a: Using a bench grinder with water

Material	Heat	Sparks
Wood	________	________
Coal	________	________
Lead	________	________
Brass	________	________
Rock	________	________
Steel	________	________

Exercise 5b: Using a bench grinder with oil

Material	Heat	Sparks
Wood	________	________
Coal	________	________
Lead	________	________
Brass	________	________
Rock	________	________
Steel	________	________

Exercise 6: Give examples of friction in everyday life.

Examples of everyday friction	Good/Bad
________________________________	__________
________________________________	__________
________________________________	__________
________________________________	__________
________________________________	__________
________________________________	__________

Exercise 7: Friction can generate sufficient

____________________ to ignite a fire without (Heat, steam, sparks, smoke)

____________________ being present (Oxygen, fuel, other forms of initiation, smoke, sparks)

How do you think force and speed influence friction?

____

____

____

____

____

____

WORKBOOK

PERIOD FOUR : FRICTION DURING COAL CUTTING

Exercise 1:

A pick cuts, like a knife, using the

____

principle.

Exercise 2: What happens when one tries to break rock with

a) a hammer ____

____ (FORCE)

____

____ (PREDICTABLE OUTCOME)

b) a hammer and a chisel ____

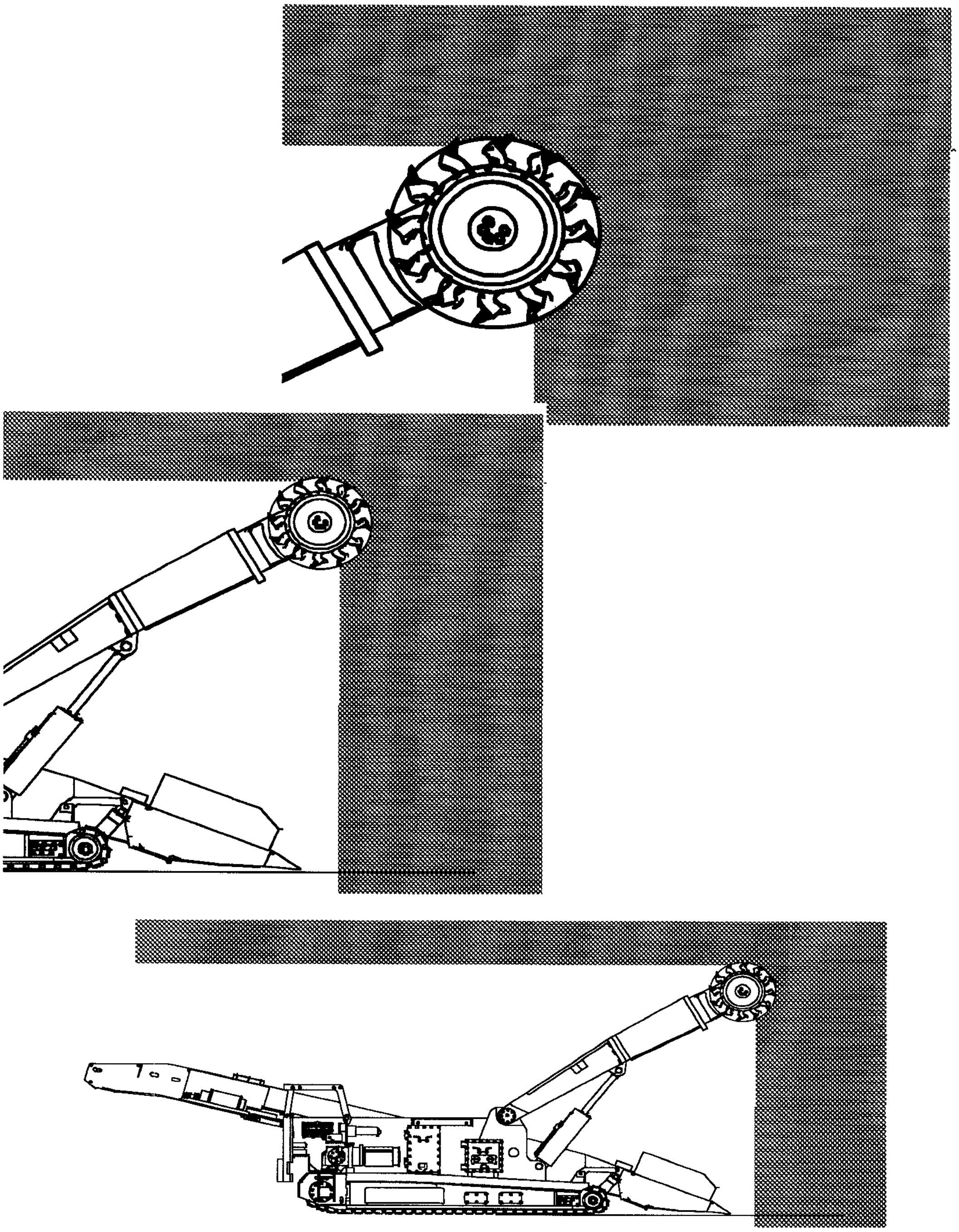
____ (FORCE)

____

____ (PREDICTABLE OUTCOME)

* PICKS

Exercise 3: place the picks on the continuous miner drum



Exercise 4:

By using a piece of blackboard chalk compare the resistance of when it is used with a sharp point and when it is used with a blunt point.

Resistance with sharp point: ____

____

____

Resistance with blunt point: ____

____

____

Exercise 5:

Make a rough drawing of a pick. Show how this pick goes through the coal.

Exercise 6:

List the materials that you have seen in the section that could cause frictional heat.

Exercise 7:

Identify the materials that can cause frictional heat. (Make a schematic drawing of the face and show where these materials could occur).

Exercise 8:

What will happen to a pick if:

a) It cuts only coal

b) It cuts into floor stone

c) It cuts into a Sandstone roof

____

d) It cuts into a Sandstone lens in the face ______________________________

____

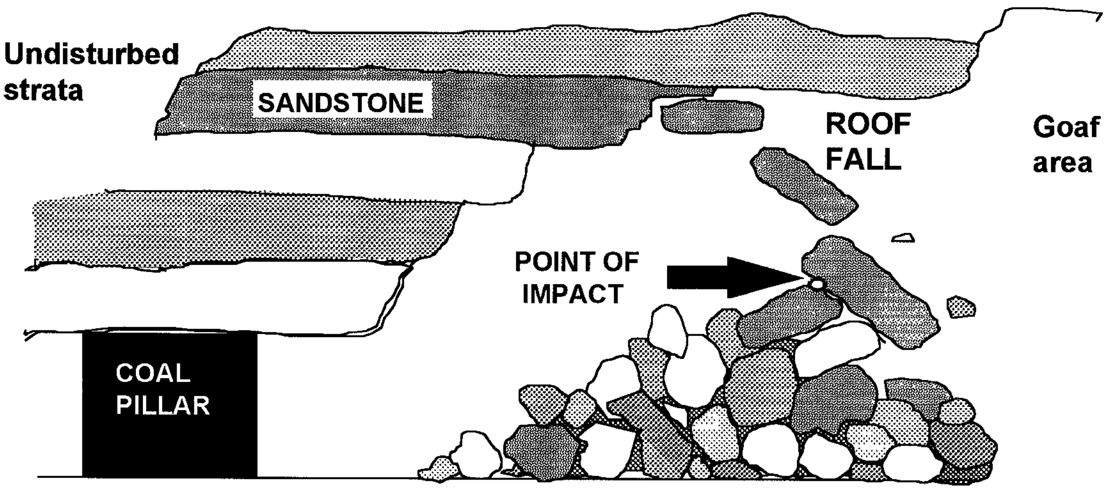
____

WORKBOOK

PERIOD FIVE : FRICTION HEAT

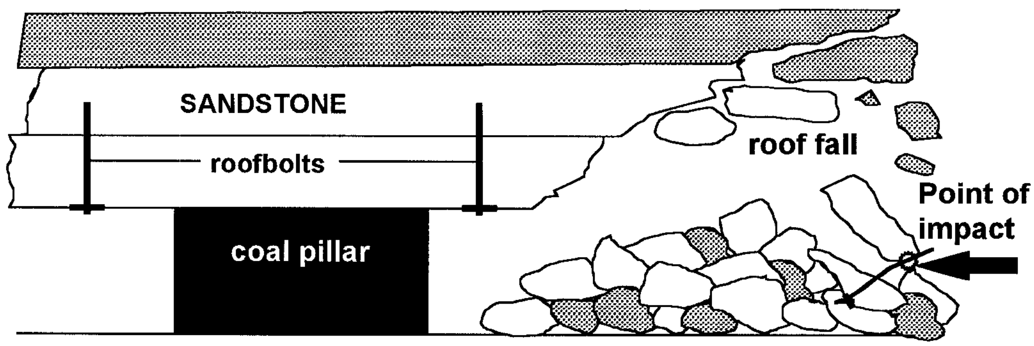
Exercise 1:

EXAMPLE OF STONE ON STONE FRICTION



EXAMPLE OF METAL ON STONE FRICTION

Sandstone in roof fall impacting on a roofbolt



Look at the above pictures and think where this could occur in the mine that you work in.

Exercise 2: List where you believe other forms of friction can occur that could cause enough heat for a frictional ignition. Also explain what type of friction it is. Stone on stone, metal on metal, or stone on metal.

Friction	What type

Exercise 3: Which of these could happen in the mine that you work in?

Exercise 4: Which of the following is/are not allowed to be taken underground?

a) Cold drinks in bottles

b) Cold drinks in cans

c) Sweets in silver paper

d) Chocolates in fancy silver paper

e) Aluminium ladders

f) Metal lunch boxes

Why do you think these items are not allowed underground?

WORKBOOK

PERIOD SIX : METHANE

1. Where does the methane in a mine come from?

____

____

____

2. How does Methane look?

____

____

3. There are two balloons. How do they react?

   a) Filled with air or exhaled breath

   ____

   ____

   b) Filled with methane

   ____

   ____

   c) What can you say about the gas in the balloon filled with methane

   ____ than air?

   d) Can you see the difference between the gases in the balloon?

   ____

   ____

   e) How do you think you will determine if there is methane present in a mine?

   ____

   ____

4. There are two containers, the one filled with a gas and the other with methane. Which gas is in which container?

   Container A ______________________

   Container B ______________________

5. There are two containers, one filled with methane and the other with air. Which gas is in which container?

   Container C ______________________

   Container D ______________________

6. How easy is it to detect methane with human senses?

   ____

   ____

   Which senses will you use?

   ____

   ____

7. Where, from the characteristics of methane, would you think you would find methane in a mine?

   ____

   ____

   ____

   ____

   ____

8. What would you use to test for methane?

   ____

   ____

9. What instruments do you have on your mine to test for methane?

   ____

   ____

   ____

10. Where are these instruments situated?

____

____

____

11. When will methane be dangerous to you and other workers?

____

____

____

12. What do you think can ignite methane in your mine?

____

____

____

13. What do you think is going to happen when methane ignites underground?

____

____

____

WORKBOOK

PERIOD SEVEN : PRINCIPLE OF REMOVING A COMPONENT

1. What are the methods you would use to stop a fire from burning?
   a) Gas stove

   ____

   b) Candle

   ____

   c) Wood fire

   ____

   d) Lighter

   ____

2. What did you actually do when you extinguished the fire?
   a) Gas stove

   ____

   b) Candle

   ____

   c) Wood fire

   ____

   d) Lighter

   ____

3. How do you stop your house from burning?

   ____

   ____

   What are you actually doing?

   ____

   ____

   Why does one do these types of actions in a house?

   ____

   ____

4. How would you go about stopping an explosion underground?

Methane: Remove it

Prevent it

Place a barrier around

Cool it

Friction Heating: Prevent it

Cool it

Remove it

Place a barrier around it

WORKBOOK

PERIOD EIGHT : RESPONSIBILITY OF PREVENTING

Exercise one

List the reasons why you believe you should take actions to stop frictional ignitions.

1. ____________________
2. ____________________
3. ____________________
4. ____________________

The following are the main reasons why the group believes we should take actions to prevent frictional ignitions.

1. ____________________
2. ____________________
3. ____________________
4. ____________________

Exercise two

Your post or job title ____________________

The main activities in your daily activities that you believe could have an influence on the prevention of frictional ignitions;

____

____

____

____

What other activities do you believe you could do to prevent the occurrence of frictional ignitions?

____

____

____

____

What type of efforts do your normal activities include? Classify them below.

Activity	Removing the fuel	Preventing heat

What type of efforts do the other activities include? Classify them below.

Activity	Removing the fuel	Preventing heat

What things in the way that the section is normally operated do you see as a barrier or a constraint that could prevent you from doing the maximum to prevent frictional ignitions?

____

____

____

____

Group discussion

What are the main improvements that can be done to allow you to improve your contribution to preventing frictional ignitions?

____

____

____

WORKBOOK

PERIOD NINE : REMOVING METHANE

Name places where you think methane can be found on the mine that you work in.

What mechanisms do you believe should be used to remove such methane?

After looking at the model that simulates methane and how it is diluted, what are your observations with regard to:

What happens to methane when there is no ventilation in the heading?

What happens to the methane when there is a flow of air?

Where does the methane go?

What happens to the methane in the air?

What is the most important way of ensuring that there is no methane build-up in the working place?

____

____

____

What can prevent ventilation from reaching the places where methane can accumulate? (Recall your own experiences of where it could have happened.)

____

____

____

____

____

____

What types of equipment do you have on the mine to test for methane?

____

____

____

Who does the testing for methane in your section?

____

____

____

What type of ventilation system do you have in the section you work in?

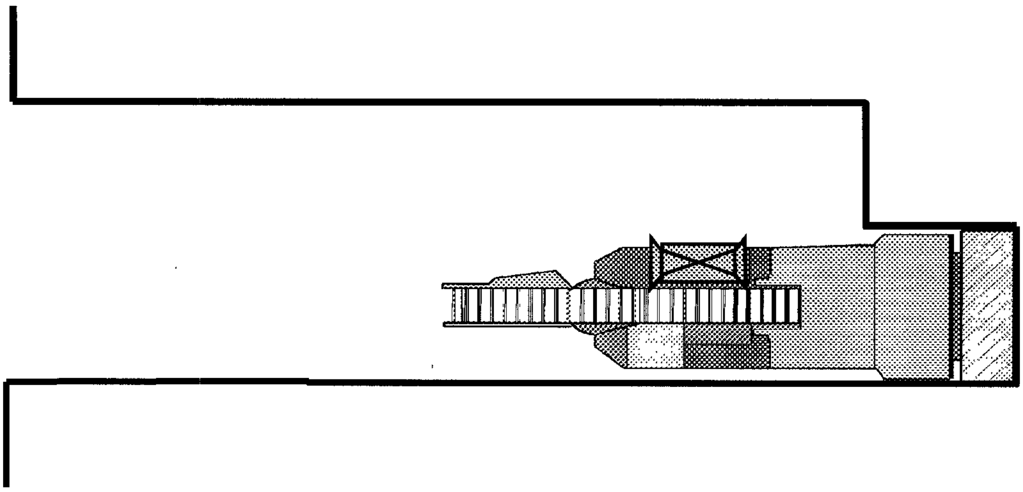
____

____

____

____

In the following picture of a continuous miner seen from above, please show how the air moves in the heading. Show the movement of air using arrows for the direction of the air. Place crosses in the places that you think that methane can be found.



What does the mine rules say about keeping this ventilation up to date?

What have you seen that can go wrong with the ventilation?

How do you know if the ventilation is not right?

Who is responsible for seeing that the ventilation is right?

Who must let this person know if they see that something is not right?

WORKBOOK

PERIOD TEN : PICKS AND GOOD CUTTING PRACTICE

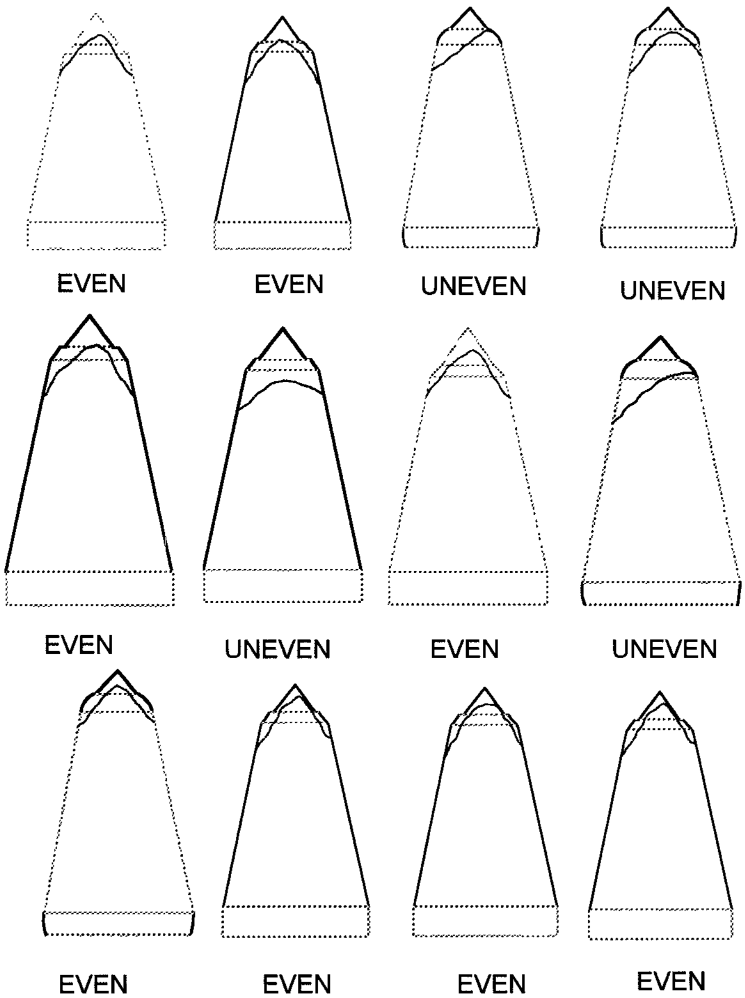
1. A pick is blunt when ____

____

____

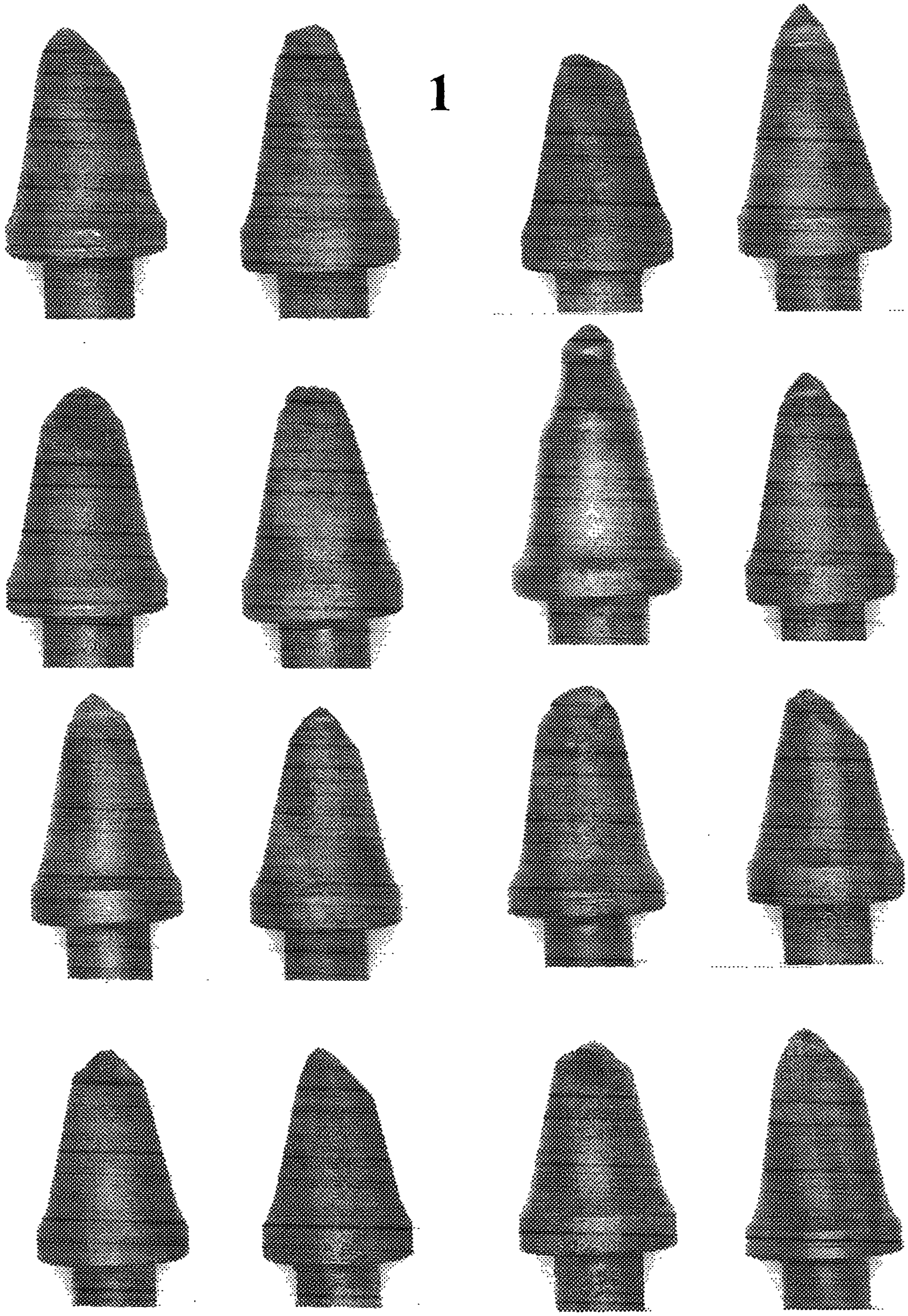
This gives an indication of blunt picks. What to you think is the effect on (a) the cutting forces and (b) the chances of frictional ignition occurring if they are used.

Examples of picks worn down to the point where the cutting forces start increasing rapidly

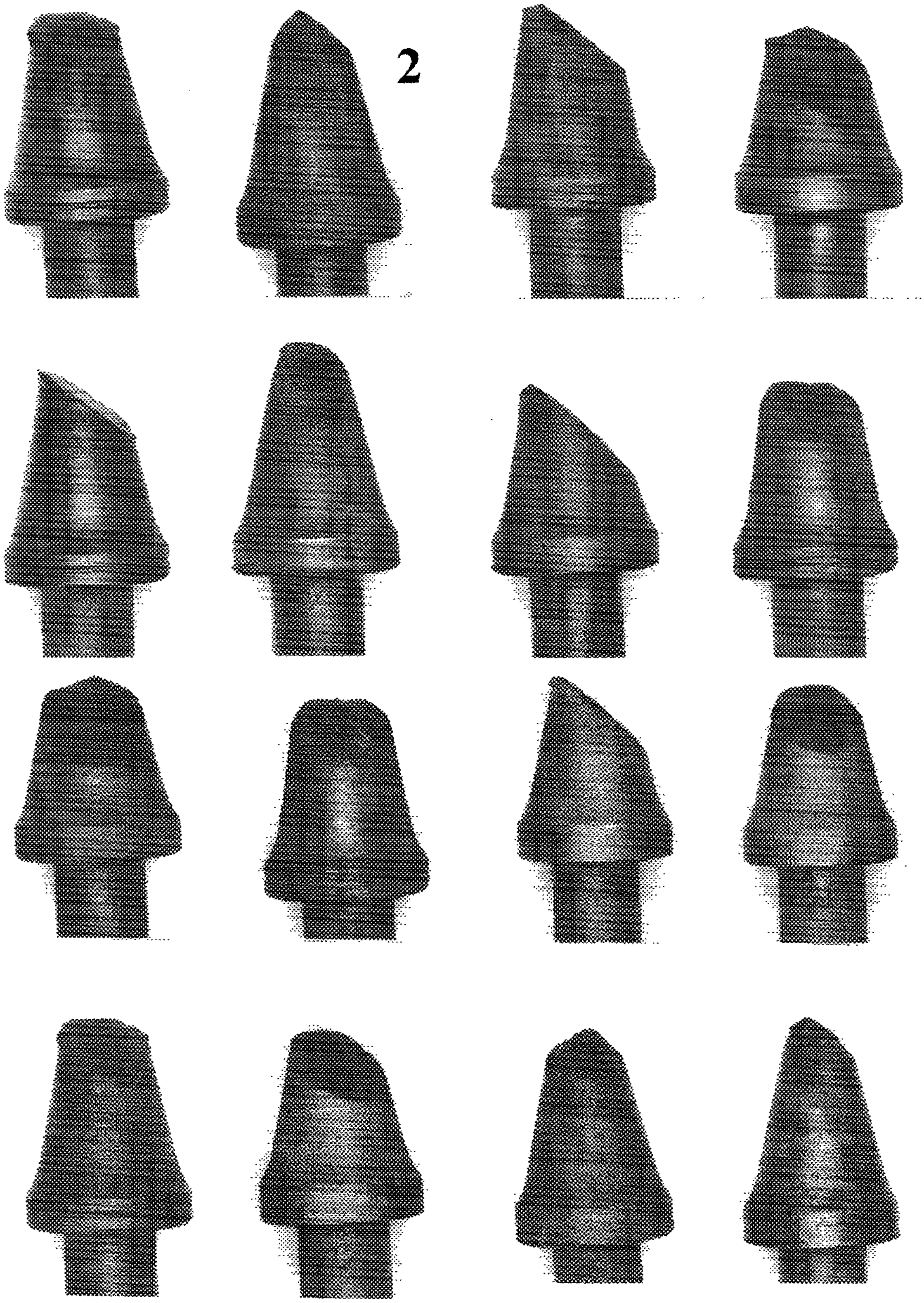


On the following pages you will find pictures of picks that come from the mine. Look at these pictures and decide if you would keep them on the drum or remove them. Look at them and say how long you think it will take for the ones you keep to become blunt.

1



2



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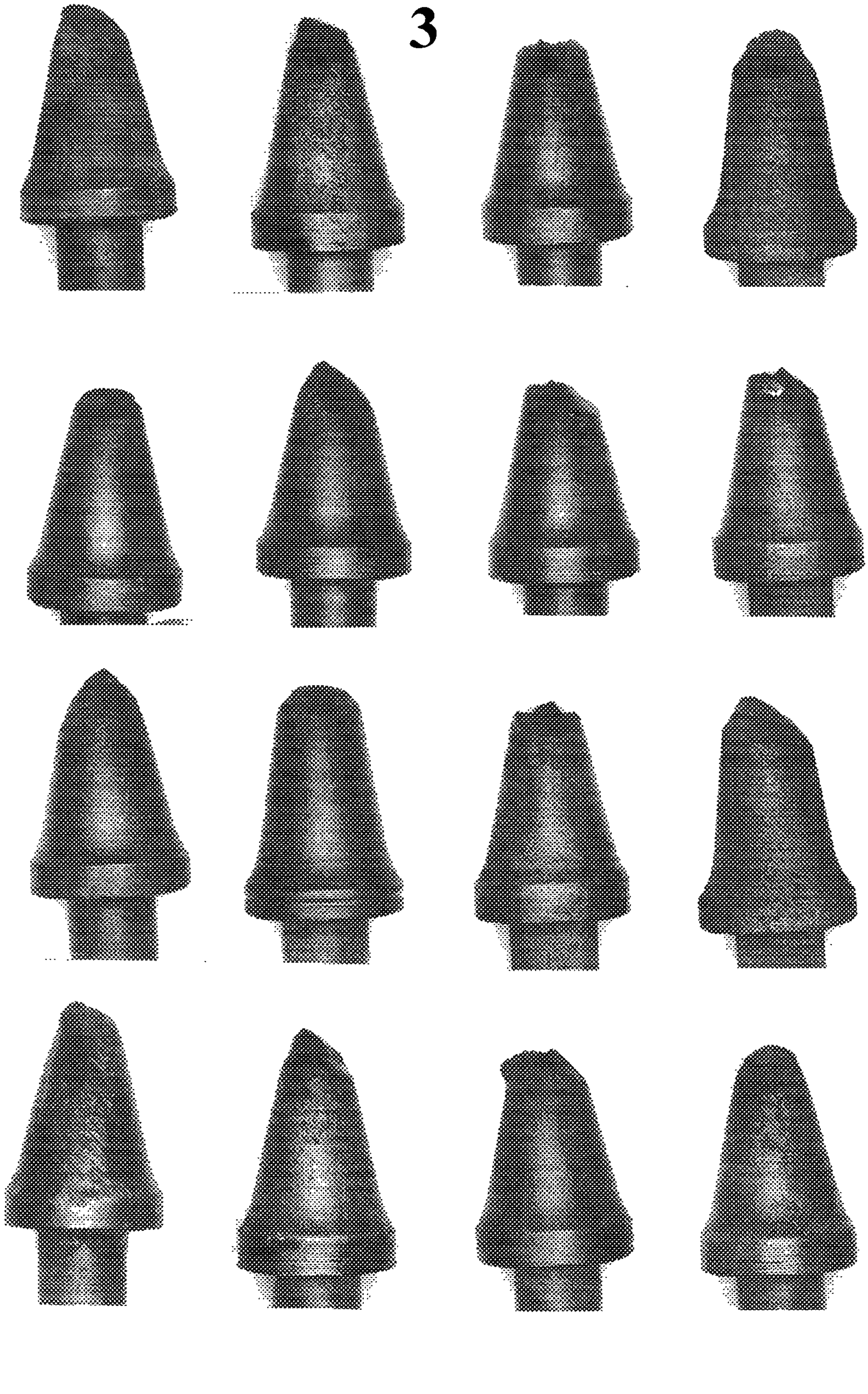

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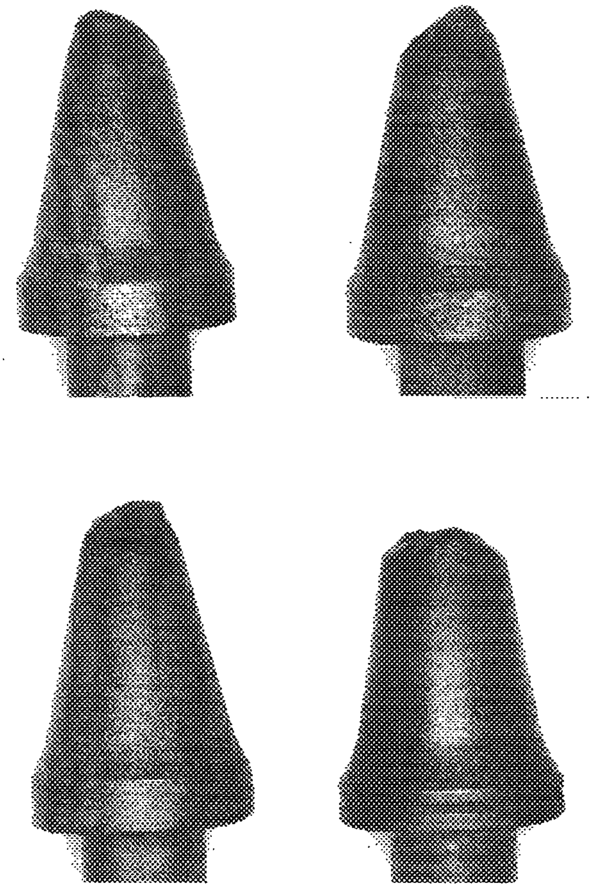
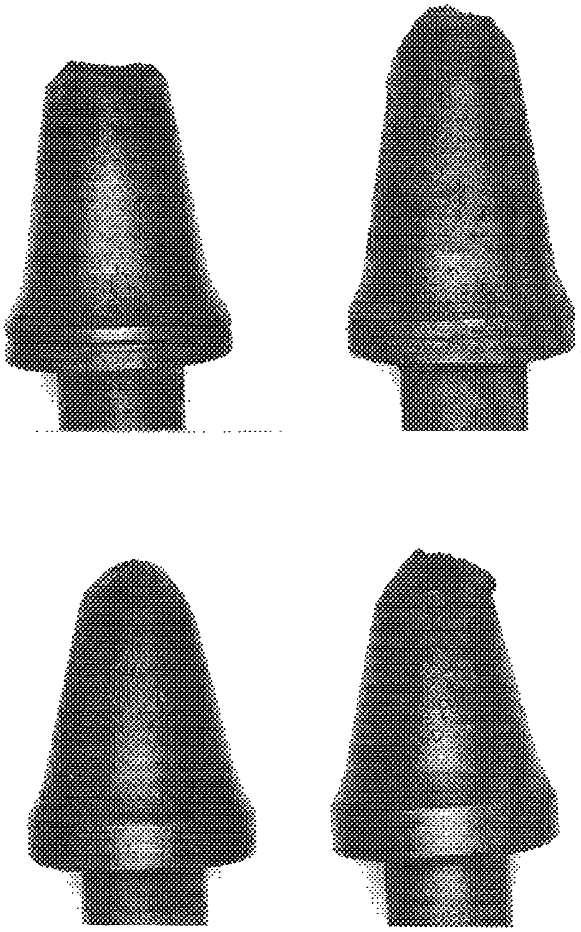




You will have been supplied with a number of picks that come from your mine.

Each of these picks has a number painted on them.

Please put the number in the following table and give your opinion if your would use them again or if they are too blunt. Also give an opinion on how long it would take for these picks to become so blunt that they could become a hazard.

Do not go into an explanation, only use 'keep' or 'blunt' and 'short' or 'long'.

Pick no	Will you keep or remove this pick	How long will it last

WORKBOOK

PERIOD ELEVEN : OTHER METHODS EMPLOYED

In the lecture the following methods of preventing frictional ignition have been presented.

Water sprays

Slower drums

Explosive suppression systems.

How do you think these systems work to stop a frictional ignition?

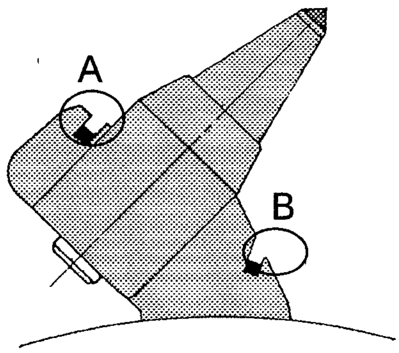
____

____

____

Water sprays on the pick

1. Show how the water sprays in front of the pick would look.
2. Mark where the hot spot will be in relation to the pick point.
3. Draw the spray at the front of the pick at point **B**.
4. Put in what you think is going to be there.



What do you think the water will do to the hotspot?

____

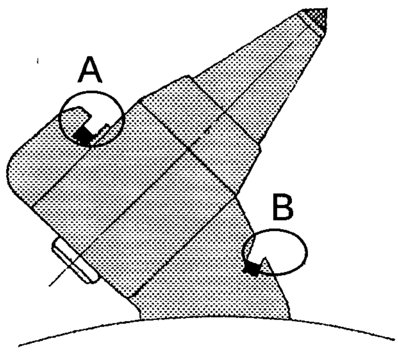
____

What effect will the water have?

____

____

1. Show how the water sprays in front of the pick would look.
2. Mark where the hot spot will be in relation to the pick point.
3. Draw the spray at the front of the pick at point **A**.
4. Put in what you think is going to be there.



What do you think the water will do to the hotspot?

____

____

What effect will the water have?

____

____

Which of the two systems is better for reducing the risk of ignitions?

____

Which of the two systems is better for reducing dust?

____

Explosion suppression systems.

An explosion suppression system is a system that stops an explosion from spreading out from where it has occurred.

Do you know if your mine has systems that suppress explosions if they should occur?

____

____

Where are explosion suppression systems usually found?

____

____

____

What is the role of the stone dust that is spread in the mine?

____

____

____

CONTROL

After you have heard about the action that can be taken to reduce the hazard of frictional ignitions it would be useful if the exercise that you did in period eight is repeated.

List the main activities in your daily activities that you believe could have an influence on the prevention of frictional ignitions?

____

____

____

____

What other action do you believe you could take to prevent the occurrence of frictional ignitions in the section or where you work?

____

____

____

____

What type of efforts do your normal activities include, classify them below

Activity	Removing the fuel	Preventing heat

What type of efforts do the other activities include, classify them below

Activity	Removing the fuel	Preventing heat

What things or conditions, in the way that the section is normally operated, do you see as a barrier or a constraint that could prevent you from doing the maximum to prevent frictional ignitions?

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Group discussion

What are the main improvements that can be done to allow you to improve your contribution to preventing frictional ignitions.

Feedback information

What was your purpose in attending this course?

Did you achieve what you wanted to?

What was the most important thing you learnt in this course?

Why is it important to you?

What do you believe you must do to prevent frictional ignitions from happening?

What are the things you must give attention to, to ensure that frictional ignitions do not happen?

What things would you have liked to know more about?

What aspects are you still unclear about and would like to know more about?

APPENDIX 5

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REFERENCES

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