SPONTANEOUS COMBUSTION IN UNDERGROUND COAL MINES

Compiled by:

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Consulting Mining Engineer

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For Coal Mine Employees

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(General notes for employees)

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FOREWORD

The phenomenon of spontaneous combustion in underground coal mines is not a new one. Its associated problems have been of great concern wherever and whenever coal mining has been practised.

Two unfortunate accidents, at Box Flat in 1972 and at Kianga in 1975, which together claimed thirty-one lives, have focused attention on the need for all associated with the industry in Queensland to gain a full appreciation of the nature of the problems and how they can best be handled.

Among the recommendations made by the Board of Inquiry into the Kianga Disaster were—

(a) There is a basic need for all members of the coal mining industry in Queensland to improve their knowledge with regard to the fundamentals of spontaneous combustion and the underground mining problems associated therewith. A lack of appreciation of these fundamentals obviously contributed to the disaster at Kianga.

(b) A publication be assembled urgently and distributed to all members of the industry by the Mines Department explaining the hazards and giving guide-lines for handling of underground fires and heatings. The Queensland Coal Owners' Association and the Queensland Combined Mining Unions should assist in this task.

This publication, under the authorship of Mr. Howard Jones, who as a coal mining engineer has had experience in the problems of spontaneous combustion in Great Britain and Australia, has been produced in a co-operative venture by the three organisations concerned, as a step in the implementation of these recommendations.

It is aimed at producing an understanding of the processes of spontaneous combustion, the mine gases associated with a heating, the methods of detection that are employed, and the role of colliery employees in contributing to their own safety and that of their fellow workers.

The distribution of this publication is to be followed up by a series of discussions in coal mining centres throughout Queensland, again on the same co-operative basis, as a further step in the education of all associated with the industry in this most important field.

J. T. WOODS,
Under Secretary,
Department of Mines.

SPONTANEOUS COMBUSTION IN COAL MINES

INTRODUCTION

Spontaneous combustion in coal mines has occupied the attention of Mining Engineers, Ship-owners, Chemists and Physicists for centuries, and without doubt it has been a prime contributing cause of many underground coal mining disasters.

Most early investigators were concerned with establishing the main reasons for its occurrence but following a disaster at Cadeby Main Colliery in Yorkshire in 1912, in which 88 men were killed, the Doncaster Coal Owners developed a Research Laboratory under the direction of an eminent Scientist, Dr. J. S. Haldane.

Since that time a constant investigation has been made of the problem and the way a spontaneous heating is developed is now well understood as are the associated dangers and methods of treatment.

Continual research is being undertaken in an attempt to develop more sophisticated methods of detection and better methods of treatment and under normal circumstances, heatings can be dealt with safely in underground coal mines, providing all persons involved are familiar with the basic problems and associated dangers.

This booklet has been prepared for use by underground mine workers who may be called upon to assist in the treatment of an underground heating. It is not intended to be a comprehensive text book on the subject. It is prepared in the hope that a better understanding can be developed relative to this underground hazard.

THE DEVELOPMENT OF A HEATING

Any coal surfaces which are in contact with air will absorb oxygen and that chemical reaction will generate heat. Experiments show that the rate of heat generation will depend on the type of coal, the size of coal, the temperature of the surrounding area etc., but unless the generated heat is removed, the temperature of the coal will rise on a continual basis until open fire conditions occur.

Unfortunately, fine coal exists under major falls, at the edges of pillars in old roadways and always in wastes associated with pillar extraction.

In some cases the ventilation is incapable of removing the heat generated when such coal reacts with the oxygen in the air. When this condition exists in an underground mine the process of combustion begins and if remedial measures are not taken a serious fire can be developed.

Many years ago, research workers established the changes which occur when such a heating takes place and work undertaken by the Wigan Coal Company in England, showed that the changes tend to occur in a fixed sequence.

Normally, if temperatures can be maintained below about 25°C., oxygen is absorbed with no serious consequences, but if the temperature is allowed to increase, changes take place in a certain pattern.

Initially there is a rapid increase in the formation of carbon monoxide and carbon dioxide until the temperature reaches about 100°C. at the heating site when signs of "sweating" occur near the area affected.

Almost immediately the coal starts to break up to give tarry substances and gases, and a faint smell of "Gob stink" is generally evident. The heating

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will progress very rapidly if not treated at this stage to give a very distinct "Gob stink", and haze conditions developing to smoke will become obvious before the next stage which is open fire.

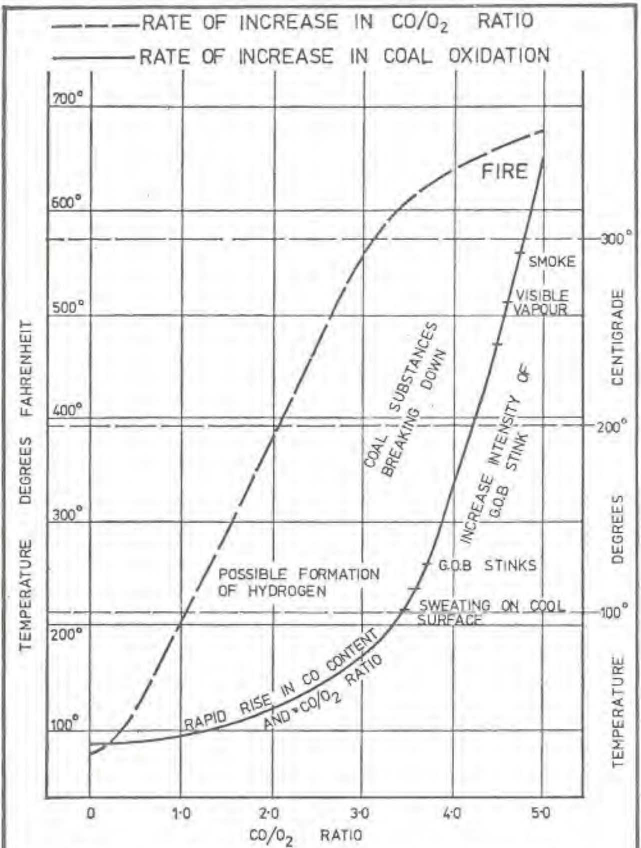
The time taken for these changes to occur is sometimes known as the "incubation period", and this varies with the type of coal and the individual mine circumstances. In some cases the period has been as short as a week, in others it has been more than a year, but generally when abnormal oxidation occurs the pattern is similar irrespective of the total time involved.

Figure 1 shows the general pattern of events which can be expected. The type of coal it refers to is similar in many respects to that found in Eastern Australian coalfields, but the precise timing and temperature of the various stages is not necessarily the same for all coal seams.

This useful diagram should be studied because it tends to illustrate the dangerous circumstances which are associated with a spontaneous heating below ground.

The graph demonstrates how the rate of oxidation speeds up as the temperature increases and serves to show the importance of early detection. All oxidation, i.e. the absorption of oxygen by coal, is accompanied by the formation of gases and the most important of these, in the initial stages, are carbon monoxide, carbon dioxide and water vapour.

The basic facts concerning such gases are given below but without doubt the most dangerous is carbon monoxide. It is, however, one of the gases which helps Mining Engineers organise an early detection system and this is outlined later.



TIME . DEPENDS ON RATES OF OXIDATION AND HEAT DISPERSION.

FIGURE 1

MINE GASES ASSOCIATED WITH HEATINGS

Carbon Dioxide

This is a colourless, odourless gas having a slight acid taste. Generally, it is not present in mine air in sufficient quantities to be dangerous. Indeed the Queensland Coal Mining Act states "that a place shall not be deemed to be in a fit state for working or passing therein if the air contains less than nineteen per centum of oxygen or more than one and a quarter percentum of carbon dioxide".

Its presence can cause death because of a lack of oxygen in the atmosphere and the symptoms associated with oxygen deficiency.

Carbon dioxide is nearly 1.5 times as heavy as air and consequently is found near the floor and in dip workings.

It is sometimes called "Blackdamp" and is produced in mines by explosions where it appears in "after damp". It is associated with underground fires, the normal oxidation of coal and sometimes is part of the gas mixture which outbursts from coal seams in underground workings. It is also produced by the firing of some explosives, the breathing of men and in the exhaust gases of underground diesel engines.

This gas can be detected on the normal flame safety lamp by its action in the flame which burns feebly or is extinguished depending on the concentration.

It is a gas very commonly found in old sealed-off districts where the oxygen has been absorbed by coal, timber, fungus etc. This type of atmosphere contains large percentages of carbon dioxide and nitrogen with very little oxygen and is commonly known as "black damp".

Its presence generally leads to a lowered vitality and heavy breathing but its effects can be quickly eliminated if the affected person rests at a fresh air base.

Generally, men dealing with a spontaneous heating problem will be working in areas which are adequately ventilated but oxygen resuscitators should be readily available under such circumstances and their normal use will soon revive an affected workman.

Carbon Monoxide

Sometimes called "white damp" by underground miners. It is colourless and tasteless. It does not support combustion but it will burn if present in sufficient concentration and it will form an explosive mixture with air.

In itself, however, a minimum of 12.5 percent is necessary for it to become explosive and such a concentration is unlikely to be found in or near areas where men are working. It has the same approximate density as air so it is unlikely that it could be detected as distinct layers at roof or floor levels. It is an extremely poisonous gas and very small quantities in an underground working place can be very dangerous.

Dr. John Scott Haldane did considerable investigation into its occurrence in underground coal mines, and he, with other researchers, found that the gas was capable of being absorbed by the blood haemoglobin 250 times as fast as oxygen. If it is present in mine atmospheres in concentrations as small as 0.1 percent, a workman will quickly develop symptoms of sickness, headaches, and a loss of muscular power.

As the concentration increases the effect becomes more marked until with about 0.3 percent in the air, a person breathing is overcome in periods which vary from 5 to 30 minutes. Such a person requires immediate first aid treatment. He should be removed to a fresh air base, and all forms of muscular exertion should be avoided.

Carbon monoxide in the blood is gradually eliminated when air free from the gas is breathed, and it is eliminated at a much greater rate when pure oxygen is inhaled.

Often in an emergency, affected men will feel better after an oxygen resuscitator is used and will offer to return to work. This should not be permitted and the man should be taken to a Doctor without delay to ensure that permanent damage is not sustained.

The presence of carbon monoxide can only be detected practically by chemical apparatus or by observing its effects on small warm blooded animals and most persons are aware of the use of canaries in this respect. Such a warm blooded animal is affected at a much quicker rate than a human being and they quickly exhibit the symptoms of poisoning. The successive symptoms in such animals are a decrease of vitality, loss of control of the legs and collapse. The use of such animals in a properly constructed cage with a built-in oxygen supply provides the best indication of safe carbon monoxide conditions to men working at stoppings etc.

Laboratory apparatus can be employed to detect very low concentrations of carbon monoxide and portable apparatus has been developed for use by trained men below ground which gives an immediate indication of concentration as small as 0.001 percent. This apparatus is normally used by Deputies, Rescue Brigade Members and Senior Mine Officials and its use in conjunction with small warm blooded animals should be sufficient to guarantee the safety of mine workers in circumstances which could lead to the development of carbon monoxide in unusual concentrations.

Water Vapour

When coal surfaces physically absorb oxygen, water vapour is one of the products of the chemical combination and this was demonstrated some 30 years ago by chemical investigation.

The water vapour formed is in relatively small quantities. It has no harmful effects on workmen but if air containing the water vapour moves away in the ventilation stream, it will eventually come into contact with cooler surfaces and water droplets will be formed. This is known in underground mines as "sweating" and if it is detected in association with a noticeable build-up of carbon monoxide, it can be considered to be a standard indication that a heating is developing. Normally this occurs when the oxidation process has built up the temperature to about 100°C at the source of the heating.

Any signs of "sweating" should be reported to a Mine Deputy or a Senior Official so that a thorough investigation can take place.

Other Gases

When coal is being subject to spontaneous combustion and a continual build-up of temperature occurs the coal (at temperatures generally in excess of 120°C) will begin to release some of the "tarry" materials which form part of the coal itself. This process can be observed on open fire, and sometimes the coal appears to form a "bubbly" surface.

When this condition exists—and it follows on quickly after "sweating" symptoms are exhibited—a distinct petrolly-tarry-benzine type of odour is detected on the return side of the heating. Generally the temperature of the heated source has reached about 140°C and the development to open fire conditions can be very rapid unless the heating is treated effectively, particularly if subsequent investigation shows that the heating is taking place in an inaccessible place such as a waste area.

The presence of such an odour should be reported immediately to a Deputy or a Senior Mine Official because its presence requires an urgent investigation by qualified personnel.

DETECTION OF HEATINGS

As described above, the way in which a heating develops, and the gases so formed are well known in the mining industry and normally such heatings are quickly detected and effectively treated without injury or loss of life.

Work undertaken by Scientists 40 years ago indicated that carbon monoxide is always present in coal mines, even when no incipient heatings are taking place.

Under such circumstances, it is normal for the return air from working districts in a coal mine to contain very low, harmless concentrations of about 0.001 percent or even less of carbon monoxide. It is, however, always the case that whatever the normal carbon monoxide level is at a mine, the presence of any abnormal oxygen absorption will increase that percentage.

Dr. Haldane invented a gas analysis apparatus shortly after he commenced his work on spontaneous combustion in coal mines and from that time it has been possible to measure the concentration of methane, carbon dioxide, carbon monoxide, oxygen and nitrogen in any sample of mine air. Since that time tremendous advances have occurred in gas analysis techniques and it is now possible to undertake a complete analysis of a mine air sample five times quicker and to a degree of accuracy which permits complete confidence in the interpretation of results.

The importance of carbon monoxide has been stressed and modern apparatus can provide an accuracy of determination of the order of one part per million. This being the case, great importance is attached to the carbon monoxide content and systematic analysis can indicate the presence of a possible incipient heating long before any of the normal signals such as gob stink, sweating and smoke become obvious.

Such systematic sampling gives the Mining Engineer an advance warning that something is wrong and he will be able to organise a detailed investigation to determine the approximate location and condition of the heating.

The presence and development of carbon monoxide can now be observed continuously with modern instruments and several of these are being purchased for installation in Queensland Mines. The value of such determination can, however, be adversely affected if unplanned ventilation changes occur because of falls etc. Because of this, a method of assessing the development of a spontaneous heating was developed by relating the percentage of carbon monoxide formed to the amount of oxygen which is being absorbed by the coal or carbonaceous material at the heating site. This ratio can be scientifically determined quickly by Chemists and Mining Engineers and is known as the CO/O_2 ratio.

This ratio is accepted generally as one of the best guides to the development of a spontaneous heating and providing mine air samples are analysed at regular intervals from properly selected points, it is possible to pin point danger areas long before dangerous circumstances can develop.

Each district in every mine will have its own individual "normal" CO/O_2 ratio. Any persistent increase is indicative of trouble and such observation will normally give sufficient warning for a safe method of treatment to be developed.

DANGERS ASSOCIATED WITH THE DEVELOPMENT OF A SPONTANEOUS HEATING

In spite of modern techniques it is still possible for a spontaneous heating to develop to open fire conditions and this is often the case when such heatings develop in inaccessible places such as a waste area where pillars have been extracted or in an old district where large falls have occurred. In these cases the only method available to the Mining Engineer is to seal off the area to ensure that the oxygen supply will be cut off and if this can be done the heating will cease because of the lack of oxygen.

In non-gassy mines the only dangers that usually occur are associated with the formation of abnormal carbon monoxide contents near the stopping sites where men are working or from smoke etc. developed from open fire conditions.

Non-Gassy Mines

Any spontaneous heating in a non-gassy mine can develop dangerous concentrations of gases such as carbon dioxide, carbon monoxide and in extreme cases hydrogen and other explosive gases which can be generated at the site of the fire.

The formation of on-site explosive gases can be detected by modern mine air analysis apparatus but its effects are generally localised at the source unless a minor explosion is capable of igniting coal dust. This risk can, however, be almost eliminated by the liberal application of stone dust well inbye of the position of seals or stoppings.

Such circumstances can be considered abnormal. They should, however, be guarded against and under normal controlled circumstances they should not cause anxiety amongst workmen building stoppings.

Figure I showed the normal progress of a spontaneous heating; smoke appears before the development of open fires and normally the presence of smoke will require the removal of workmen from the stopping sites.

Their place should only be taken by trained rescue men but under normal circumstances, all work involved on stopping erections will be moved outbye to a safe place away from the dangers and inconvenience associated with a smoke filled atmosphere.

That being the case, the main danger is associated with the inhalation of carbon monoxide and/or carbon dioxide and in general terms the method of detection and treatment has been described previously.

Gassy Mines

Without doubt the greatest risks associated with spontaneous combustion occur where a dangerous accumulation of "firedamp" exists below ground.

Firedamp is the name given to a gas found in coal mines and it consists mainly of methane together with some impurities of a minor nature which tend to give it some smell, although under most circumstances, it is odourless.

Firedamp and Methane

Firedamp is almost pure methane which is a colourless gas having no taste or smell. It is very light being little more than half as heavy as air and is normally found near the roof of workings, in breaks and where falls have occurred. Because of its natural buoyancy, it is capable of forming layers of explosive mixtures, particularly if the ventilation velocity is low and a reservoir of gas is available from which it can "bleed".

It is not poisonous in itself but if it is present in sufficient concentration to reduce the oxygen content of the air, it could lead to conditions of suffocation.

Such circumstances are unlikely to occur at sites where men are working on remedial tasks associated with the development of a spontaneous heating. Indeed the Queensland Coal Mining law in common with all coal mining countries, requires the withdrawal of all workmen if the general body concentration exceeds two and one-half percent or thereabout.

The possibilities of suffocation are therefore very remote unless a workman moves to an unauthorised-unventilated place and again such action is unlawful in coal mines throughout the world.

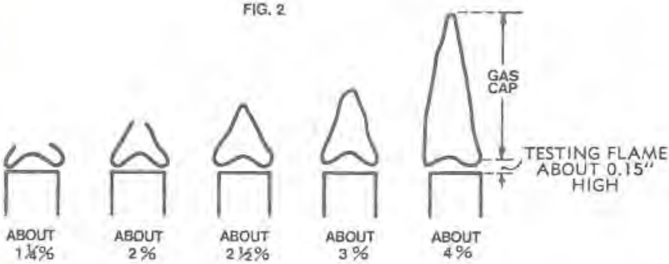
Methane can, however, accumulate in concentrations which are explosive, particularly in inaccessible places and many experiments have shown that any mixture containing between approximately 5 percent and 15 percent are capable of explosion with the maximum violence occurring at about 9 percent.

The ultimate danger, therefore, occurs when a mine spontaneous combustion develops to open fire proportions and firedamp is available at the source of the heating in explosive concentrations.

Fortunately, the detection of firedamp is a relatively simple process. It can be easily detected on the lowered flame of a safety lamp where it burns with a luminous blue flame.

Figure 2 shows the approximate dimension of the "caps" formed by the presence of firedamp, and it can be easily detected in the general body or in layers by trained workmen or a qualified Deputy.

FIG. 2



In addition mines commonly use methanometers which are portable instruments capable of indicating the precise percentage of firedamp present, and these instruments are now well known to underground coal miners.

As previously explained, it is now possible to systematically analyse the gases found in air samples taken at regular intervals from strategic points in an underground coal mine. The information obtained from such analyses and the additional data obtained from a district where a spontaneous heating is developing, should provide qualified Mining Engineers with all the necessary information required to make safe judgements on the probable development of a heating and to make assessment of the potentially dangerous circumstance which can occur.

This will lead to the correct location of stoppings if a district is being sealed off, or the correct method of treatment if a local accessible pillar heating is being treated. In either case, it is possible to develop methods of treatment which include all the safety precautions necessary to ensure a safe environment for the men involved in the remedial work.

It is obviously necessary for workmen to be kept fully informed but they in turn should proceed with the remedial work at maximum speed so that the period of risk, however small, is kept to a minimum.

GENERAL

Spontaneous combustion of coal can only occur if sufficient coal is present, particularly in a crushed state, if the ventilation circumstances are such that it cannot take away the heat generated, and if sufficient time is available for the oxygen absorption process to develop to the dangerous state of open fire.

This booklet attempts to explain the basic facts but it becomes clear that the complete co-operation of underground workmen is essential if the risks are to be minimised. Underground fires can in some cases be prevented and this section describes some of the factors which workmen can help control.

Roof Support

During the development of pillars associated with permanent airways and future extraction panels, it is of vital importance that roof supports are set quickly and efficiently. This is to ensure that unnecessary weight is not thrown on the main supporting pillar sides; and under no circumstance should a roadway be driven wider than laid down by the Mine Manager.

It should always be remembered that standard supports are not designed for the span in wide roadways.

Roof alongside pillar edges is left unsupported and this increases the risk of a roof failure which could be the direct cause of a spontaneous heating, particularly if inferior roof coal lies under a heap of stone away from the effect of the main ventilation stream.

Poorly set supports and roadways driven too wide put excessive loads on pillars which are made smaller than planned. The sides spall over to form heaps of small coal alongside pillars and visible cracks appear. These cracks have surfaces which can absorb oxygen but they are remote from the main airstream and ideal for the development of a spontaneous heating.

Ventilation

Ventilation is deliberately coursed through a mine to ensure that all travelling roadways and working places are adequately ventilated. To do this, it is necessary to construct stoppings, seals between intakes and returns, aircrossings, regulators and access doors.

A large number of minor heatings occur in coal mines at these points, mainly because they have not been erected with due care and attention. If stoppings, seals and door frames are not set well into the roof side and floor—and that means cutting into solid stable ground—air will slowly leak around the sides into coal cracks and again serious heatings can develop.

It may seem the easy way at the time, but workmen have a responsibility to undertake their tasks properly, and in the case of most ventilation aids set in roadways formed in coal, any shoddy work could cause serious future problems.

The same logic applies to aircrossings where coal has often been left in between the intake and return levels. All such coal must be removed and the structure must be constructed well back into the roof and sides to ensure that leakage cannot occur, particularly where coal is present. One heating in an aircrossing stopped work in a large section of a mine and made remedial work very difficult because eventually smoke went inbye and outbye simultaneously from the site.

It is an offence to interfere with the mine ventilation arrangements. One serious heating developed because doors were left open and short circuited air from an old return section of roadway. If obvious defects are observed in the ventilation, open doors, broken seals or increased leakage, make sure it is reported to the Deputy. The report could well prevent an incident developing.

Most mines which are prone to spontaneous combustion tend to develop panels with barriers around them. These are designed to make it easy to isolate sections. Do not hole through such barriers when you should draw back and set out another working place. If such a holing occurs, air containing oxygen can leak into a section which has been sealed off because of a minor heating. That heating could easily be rekindled by such thoughtless action.

Such action could well lead to rapid emission of firedamp and/or blackdamp. Air could be recirculated and such circumstances could easily contribute to a disaster. Indeed holes put into overcasts short circuited air from a working face in the United Kingdom in 1965, and some 31 men were killed following an explosion of firedamp which was ignited by electricians working on an electric panel with the power still on.

Chasing the dollar in such a way is illogical and if a machine holes through accidentally, make sure a Senior Official is informed so that the necessary remedial action can be taken.

If an unusual persistent odour is noticed, do not try to establish its precise location. Remember it could contain poisonous gases. Inform the Deputy without delay. The same applies if you see any signs of smoke or a faint blue haze which often occurs with a heating.

Pillar Extraction

Spontaneous heatings do not normally occur when pillars are being formed but minor heatings have occurred when very fine coal which was deposited under conveyors was left unattended for lengthy periods. The need for conveyor attendants to clean up conscientiously cannot be over-stressed.

Without doubt, however, the greatest risk occurs during pillar extraction. Normally the size of extraction districts is decided by the Mine Manager in the light of general knowledge and local experience, and he will be able to anticipate a certain minimum safe rate of retreat back to the initial entries which can then be stopped off.

It is impossible to determine any period of time precisely, and inevitably, roof coal, timber, coal fenders and spalled rib coal are bound to exist in the goaf area. This goaf retreat line should be kept as straight as possible and provided extraction occurs systematically and with speed, the coal is quickly left behind in a reasonably consolidated goaf away from the ventilation which passes along the moving goaf front. Under such circumstances, the development of a heating is most unlikely but if extraction stops or slows down below acceptable levels the coal deposited under the stone alongside the ventilated goaf edge can continuously absorb oxygen, the heat so formed will not be taken away and a dangerous heating can be formed which will slowly work its way back into the waste where more and more coal is waiting to be oxidised.

This clearly is a dangerous circumstance, particularly if the extraction panel is proceeding on a gradient because the goaf areas can slowly become reservoirs for the more buoyant explosive gases such as firedamp.

Slow rates of extraction have caused many spontaneous heatings and in one coal mine in South Yorkshire, heatings developed on one working face every annual summer and Christmas shutdown. The problem became so serious that the entire waste area had to be sealed during the two weeks before every shutdown in order to create safe working conditions.

Indeed similar circumstances developed recently in Australia and it prompted the members of an official enquiry to recommend that "all parties, i.e. Inspectors, Managers and Workmen be made aware of the dangers of interrupting pillar extraction once started particularly when spontaneous combustion is likely underground".

This recommendation is good advice because pillar extraction must be continuous and systematic if the risk is to be minimised. Indeed in areas prone to spontaneous combustion the work should be uninterrupted until extraction is complete and the main entries sealed off. If this does not occur dangerous conditions can develop.

Protection Arrangements

In most mines where a spontaneous hazard exists, arrangements are made for special precaution. Old Seals can have sample pipes which permit the withdrawal of air samples from within the sealed areas.

Special phosphor bronze tool stores are set up which can be used as protection against accidental sparking.

Apparatus for artificial resuscitation, oxygen resuscitators and special fire fighting equipment are stored in special sections.

Stores of sand, stonedust, concrete blocks etc. are set up to ensure rapid sealing in emergency.

It is important that such special arrangements should be intact in case of emergency. Too often these stores suffer from incredible acts of vandalism and this can lead to considerable problems when emergency occurs. Workmen should report any deficiencies in these safety areas without delay to Senior Officials so that the deficiencies can be rectified.

Explosion Risks

Workmen should ensure that all possible action be taken to minimise explosion risks, and the risk of injury can be reduced if airborne dust is minimised and if stonedust is applied in all areas in accordance with the requirements of the law.

A combination of open fire and firedamp can cause an explosion and the application of stonedust in working places and in association with the construction of stoppings, cannot be overestimated. Stonedust must be dispersed properly if it is to be effective, and it certainly is ineffective if the bag containing it is thrown to the side of a roadway unopened.

Generally some stonedusting can only be done by hand. Make sure it is done properly.

CONCLUSION

This booklet has attempted to provide an understanding of the development of spontaneous heatings, an understanding of dangerous gases associated with heatings, an appreciation of methods of detection, and to highlight some of the things employees can do to minimise the risks in an underground mine.

It is not complete, but it is hoped it will lead to discussion, because that will help the general understanding of the problem and will inevitably reduce the risks of disasters in the coal mining industry.

H.J. March 1976.

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