THE DANGERS ASSOCIATED WITH UNCONTROLLED COMBUSTION IN COAL MINES

By

C.H. MARTIN[1]

ABSTRACT

The diverse nature of inadvertent mine fires does not lend them to general treatment. But evolving from the unfortunate fires over past years is a simple principle in dealing with all fires to bring combustion under control. Control, in brief, means that the products of combustion, themselves possibly still with fuel values, are not revitalised by addition of fresh air. There are problems with fire-fighting, especially with water, as this may lead to production of CO and H_2.

Panel ventilation upstream of the fire must be controlled to direct all air over the fire. Some advantages in fire fighting are found by the use of "sails". Early diagnosis of fires and early treatment are essential for safety of personnel and safeguarding and recovery of property.

Preparedness extends to up to date documentation, but first hand knowledge also is invaluable to the diverse personnel gathered to fight a fire, and in the decision making involved.

DEDICATION

To Mr. Heywood Wilkinson, who discussed these matters formally and informally very many times, and with whom there were opportunities to put the theories into practice on a number of occasions.

INTRODUCTION

The late Mr. Heywood Wilkinson had intended to undertake the task of compiling such a paper as this, but was unable to do so before his untimely demise in a boating accident at Taree in 1977. It is unfortunate, therefore, that this paper is without all of the background and expertise which he would have been able to contribute.

This is not intended to be a treatise on all aspects of mine fires, on which there have been volumes written. Rather, it deals specifically with one aspect: what to do when confronted with uncontrolled combustion. Even from this topic other matters arise, such as the question of what can be built into coal mines to reduce the loss of life and property in any emergency; discussion of such things should be promoted by the material now presented.

The title stems from a suggestion made by Mr. S.B. McKensey at the N.S.W. Colliery Managers' Association Symposium on mine fires held at Terrigal N.S.W. in August, 1976. It has been adopted for the reason that whether a mine fire is controlled or uncontrolled is the factor of paramount importance in determining the actions of the management and rescue teams.

HISTORICAL BACKGROUND

There can be no gainsaying that coal mines are becoming safer as the years go by. Records of today's operations, compared to those of 50 or 100 years ago, strongly confirm this.

Nevertheless, in the last decade in

---

[1] Consultant, C.H. Martin and Associates, Wollongong, New South Wales.

Australia, some 40 mineworkers have lost their lives in situations engendered by uncontrolled combustion and explosions, and it might be argued that a contributing factor could have been a lack of proper analysis of the situation.

This has happened despite the fact that the technology of gas detection, combustion monitoring etc., has been upgraded, and also (as was evident from the N.S.W. Colliery Managers' 1976 Symposium) that there is a greater awareness of the basic problems today than there was, say, some 20 years ago.

Technology and understanding will continue to expand in line with the trends in this scientific, computerised age. But, this is not to say that mine fires and explosions will be eliminated, any more than it can be made certain that there will be no aviation disasters, marine losses or other cases of human misfortune.

All the technology mentioned can change conditions for the better. No doubt new criteria will be developed to determine more precisely projected ignition points. But, with so many unknown factors operating in a major mine fire, it will probably always be difficult to be much more accurate than it is today to define the real degree of danger in which the rescuers or recovery people are working.

Fortunately, there is one yardstick which does not alter, and can almost certainly be assessed at any point in the recovery operation, and this is: "Is the fire controlled or uncontrolled?"

IS THE FIRE UNDER CONTROL?

Much has been made of the term "is the fire under control?" As far as mine fires are concerned it would perhaps be fair to admit that not until they are completely extinguished could it be truthfully said that the situation is really under control.

However where human life is involved, whether the lives of any entrapped men or the lives of the rescue teams, there should be some yardstick for those people in authority at that particular time to rest their decision on and that specific yardstick abides in the above phrase.

The ingredients of disaster in the explosive sense are:

1. inflammable and/or explosive gas
2. oxygen
3. a source of ignition

Dealing briefly with those in turn, inflammable gases capable of forming explosive atmospheres are inherent in most coal mining operations in the form of methane, usually kept below the explosive range. In the wake of an explosion or fire with possible derangement of the ventilation system there is no guarantee as to what the true position of ventilation or of mine atmosphere may be.

In addition as mentioned earlier, fire fighting operations could produce additional incendiary gases. It is apparent therefore that one condition for an explosion is present and that there can be no positive regulation of this hazard until the fire is extinguished.

The second prerequisite is oxygen and at this stage it is the only one that can possibly be controlled. If the air current of the ventilation system can be all directed over the fire then its oxygen content will be substantially reduced and as is well-known the explosive range shrinks rapidly with decreasing oxygen content. It follows from this that when all fresh air is directed over the fire then the ventilation situation is simplified and the best possible situation exists for the Rescue Teams.

On the other hand it is obvious that if this cannot be done and if air of normal oxygen content has access to the products from the fire area, then the degree of risk of explosion is enhanced.

The third prerequisite - a source of ignition - will be almost certainly the fire itself. Provided that a continuous stream of air is directed over the fire and that the stream is maintained, then this is the basis of the control. With such a situation it is reasonably certain that the gases, explosive or otherwise, will not roll back to the fire. A major problem which could occur here of course is a sudden fall in-bye which would close off the return and produce the very condition which every effort must be made to avoid.

To sum up, the situation can be viewed with some degree of equanimity if and when, and only if and when, the people who are in the risk situation are quite satisfied that no air of normal oxygen content has access to the air behind or in-bye of the point of conflagration. Thus control is obtained over all of the air reaching the fire and over all of the atmosphere moving away from it as well.

THE SIMPLE EXAMPLE

To develop the fundamental approach in the important step of determining the state of a fire it is proposed to illustrate the situation which develops at a main road intersection fire in a simple four-heading panel with two central intakes and two outside returns as shown in Fig. 1.

As will be appreciated this is a basic situation and the position can be complicated progressively by more working places, irregularly spaced entries, falls, goaf areas and other factors but in essence the principle of the problem remains the same as in the simple four-heading example.

In this example, a fire has its origin and develops at the junction of No.2 cut-through and No.3 heading and it rapidly takes hold in that area. In this particular layout, Nos. 2 and 3 headings are intakes which are separated by conventional stoppings from the returns, headings Nos. 1 and 4.

Disregarding all other problems such as smoke (probably the major one), availability of water, stonedust etc., the fire at this

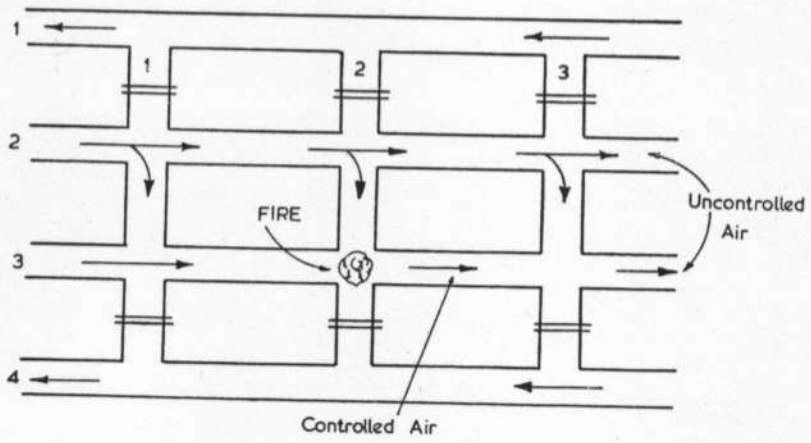


Fig. 1. The Simple Example

stage is out of control by virtue of the fact that there is an uncontrolled supply of fresh air which can mix with the products of combustion from the active fire area.

To be more specific, uncontrolled air can be defined as air which has not been reduced in its oxygen content (whether partly or completely) by contact with the fire, or air which can introduce oxygen into the zone containing the products of combustion on the inbye side of the fire.

Returning to the uncontrolled combustion stage, there is an active fire which can be generating a number of harmless (so far as explosion risk is concerned) by-products, but also possibly producing some highly inflammable gases in addition to any unburnt methane which may be present.

If water is being used to quell the flame, water-gas ($CO + H_2$) could be generated and pass into the area beyond the fire. It can be fairly safely assumed that there will be no one in this position (except those unfortunate enough to have become casualties in such a zone), so that in any case reliable information will not be available on the composition of the atmosphere adjacent to the fire and in the general area inbye of that point. However, it should be assumed that a build-up of an explosive mixture is developing.

It is not difficult to appreciate that as long as the fire remains active and No. 2 heading is open, then the potential for an explosion exists. The longer this situation continues, the more certain it is that a gas explosion will result. Thus, the first thing that must be done is to bring the fire under control from the explosion point of view, so that the extinguishing operation can be carried out in comparative safety.

To achieve this objective in the example quoted is a relatively simple matter. It requires only the erection of a brattice screen at a convenient point in No. 2 heading on the outbye side of No. 2 cut-through where the fire is (Fig. 2).

This diverts all intake air into No. 3 heading and over the fire where its oxygen content will be reduced. The resultant product inbye of No. 2 cut-through should then be in a relatively inert condition. On the face of it, this procedure would appear to assist the

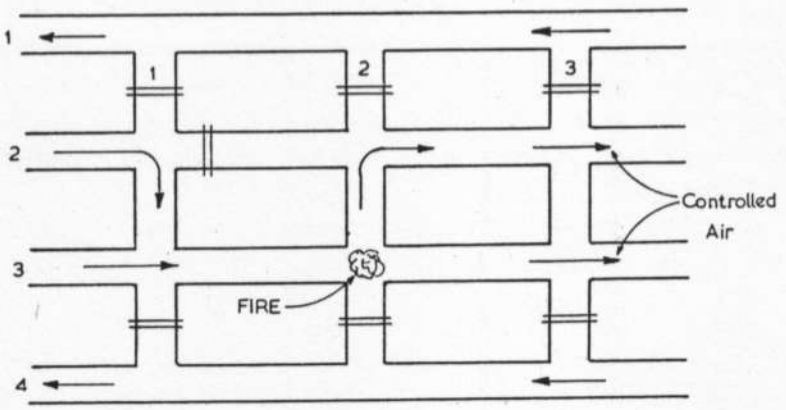


Fig. 2. Controlling the air

conflagration, and probably does. But a moment's reflection will convince an operator of the wisdom of the strategy. There are other consequences of the move, which will be discussed later.

The rule is: "put all the air over the fire", an approach which is best described as "the furnace effect" (J.G. Bailey, 1976).

Once this situation has been reached, recovery teams can operate in the knowledge that at least for the time, they are not exposed to an unreasonable degree of risk. What now remains is to ensure that the established situation continues.

Patrols must now be instituted to see, among their general observations, that the screen in No. 2 heading remains effective as an air seal. Also, every possible precaution must be taken to see that the fire does not work its way across the No. 2 cut-through to the return headings (Nos. 1 or 4). Consideration can also be given to cutting off one of these returns, as well as reducing the total air flow in the intakes. Besides these measures, monitoring for carbon monoxide is important. (The use of foam plugs can produce CO in significant proportions). As stated above, it is not intended to deal with these operations, but only with the most important matter, that of fire control.

The hazard of smoke can be a major obstacle in effective fire fighting. In some situations, possibly arising from the presence of such inflammable materials as rubber tyres and cables, smoke can "layer" back along the roof against a light airflow. When this happens, two complications arise: reconnaissance is denied to the recovery team, and it may not be possible to gain access to a point close enough to bring water to bear on the seat of the fire.

The channelling of all the air into one intake can assist in combatting smoke, by forcing it to clear along the proposed route of the recovery teams. As already mentioned, the temporary "feeding" of the blaze is of secondary importance, compared with the need to gain access to the flames.

Mention should be made here of the use of "sails" by recovery teams in such a situation. These are simple brattice rolls on sticks which come up to about the waist-line height of the team. Spread out across the width of the access way, they do two things:

- increase the velocity of the air over the sail, and so disperse smoke more quickly, and
- take some of the direct heat off the team members when they are close to the fire.

On two occasions on which the author was present, valuable minutes were lost in putting together sails in the workshop before going underground.

They are simple and elementary pieces of equipment in their use, but are almost essential at some stages of dealing with mine fires. Rescue stations should have them on hand and do teach their use as a standard drill. They should even be listed as standard equipment in an amended Mines Rescue Act.

THE MORE DIFFICULT CASES

At the other end of the scale from the simple example are other situations in which the colliery may have to be abandoned to ensure no loss of life. Three cases to illustrate the factors involved have been chosen from recent incidents in New South Wales.

The first was at Aberdare North Colliery, involving goaf heating in an inaccessible section well inbye in the mine; the second was at Liddell State Mine, where heating occurred at the pit bottom, virtually at the mine entrance; and the third was at Burwood Colliery, where heating in a sealed area became active.

Again, it is not proposed to discuss full

details, as these have been well documented and presented by those directly concerned. Suffice to say that in all cases the heating rapidly developed into active fire.

In the case of Aberdare North the heating in the goaf area (Fig. 3) could not be reached, and became active before the necessary number of seals could be erected to isolate that section. The whole mine was therefore sealed. (Aberdare North Colliery, 1976). At Liddell, (Fig. 4) the development of the fire was so rapid that the pit bottom area became untenable, and from that point the whole situation was out of hand. Once again the mine was sealed (Liddell State Mine, 1976).

Heating behind a seal in the Victoria Tunnel Seam at Burwood Colliery (Fig. 5) became active and broke out onto the main road near a bin and a manway connected to a lower seam.

Because of the danger and difficulty that would have been involved in sealing these openings and other interseam connections, the mine was sealed off at the suface until such time as its oxygen content was reduced, so bringing the fire under control. This operation involved the sealing of Nos. 3, 4 & 6 shafts and a cross measure drift (N.R. Monger, 1980 , personal communication).

One major point emerges from all this: in each case, the mine was sealed until heatings were reduced to the point at which recovery was possible. The important factor was that the situation was diagnosed early enough to enable all personnel to leave the mine in reasonable safety.

INTERMEDIATE CASE

Between the examples quoted there lie an infinite gradation of fire situations and heatings which are potentially dangerous, and which call for a variety of approaches.

It can only be repeated that the question remains the same: "is the fire under control or not?" Fortunately, it would seem that in most cases with knowledge and experience this question can be answered with reasonable accuracy, and the proper and necessary conclusions drawn.

However, there is a particular situation that poses a problem as to the factor of safety to be applied: this is the pillaring of gassy mines which are subject to spontaneous combustion.

It can be said that most coal mines are gassy, but it is only in recent years that the problem of spontaneous combustion has really been with us in Australia. Earlier, for instance, the so-called "fire belt" of the South Maitland field appeared to generate enough carbon dioxide (CO_2) in goaf areas to render them safe from explosions, although the mines concerned were mildly gassy. (A notable exception was the disastrous Bellbird explosion of 1923, in which 21 miners and would-be rescuers lost their lives).

More recently, some underground mines are developing goaves which become charged with methane (CH_4) and in which the coal has a tendency to spontaneous combustion. Whereas very high concentrations of CH_4 may be beyond the explosive range, the presence of even relatively low percentages of oxygen (O_2) in the goaf may still provide conditions under which spontaneous combustion can develop. Perhaps the problem is one to be posed to mine planners: at which point should consideration be given to abandoning bleeder headings in pillaring areas?

Whatever answer is made to that question, it does not alter the fundamental approach as already set out. It merely heightens the degree of caution which must be applied.

To summarise it can be said that control as far as possible of an active fire at any given time has been achieved when:-

(a) all the air of normal oxygen content in

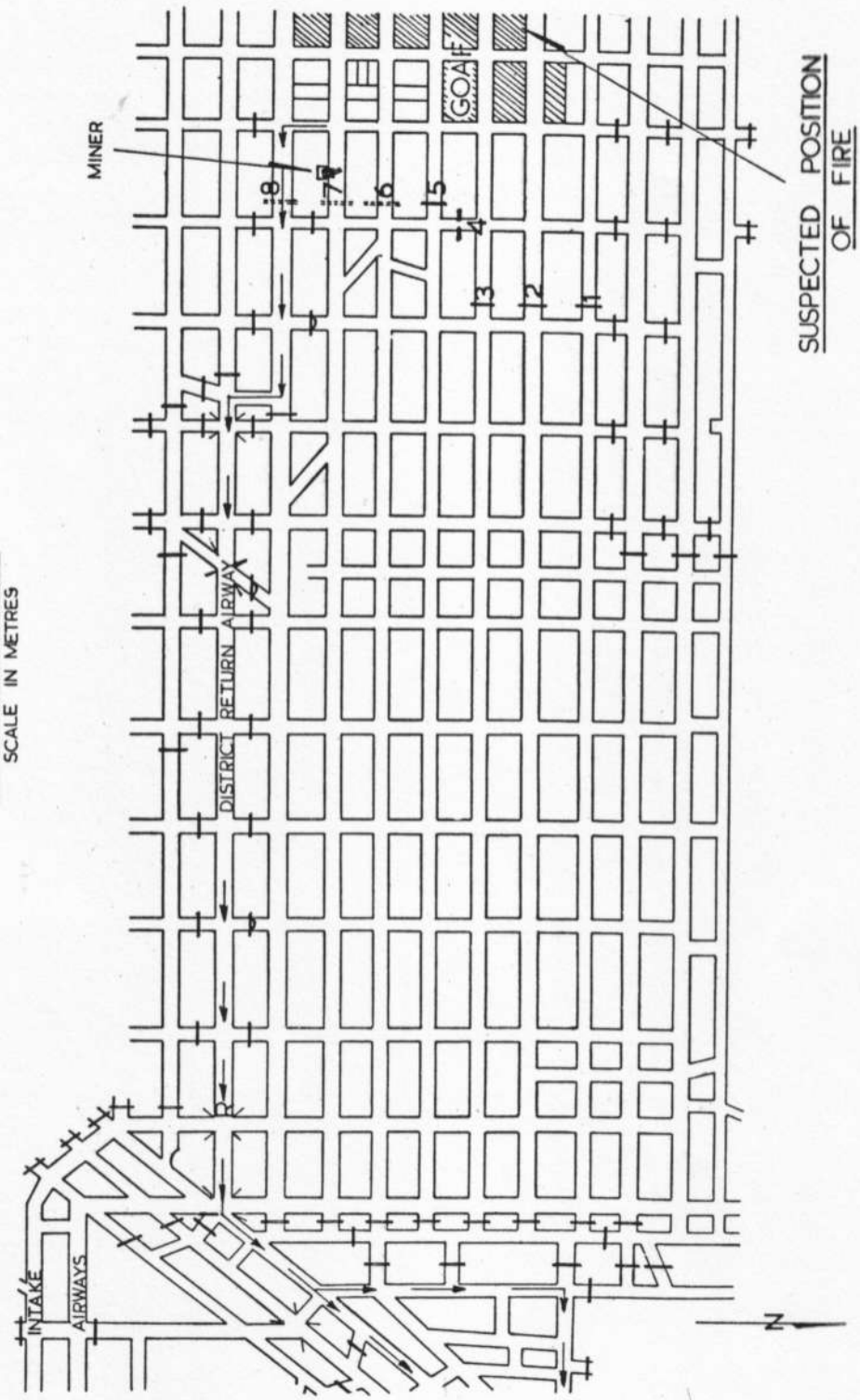
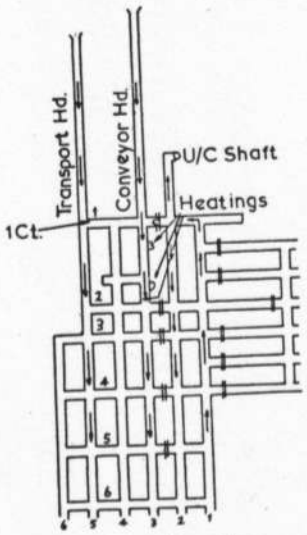


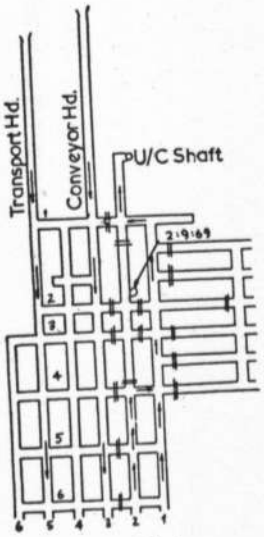
Fig. 3 - ABERDARE NORTH COLLIERY
WEST DISTRICT
SHOWING GOAF, FIRE & SEAL SITES.

Fig.4 LIDDELL STATE COAL MINE



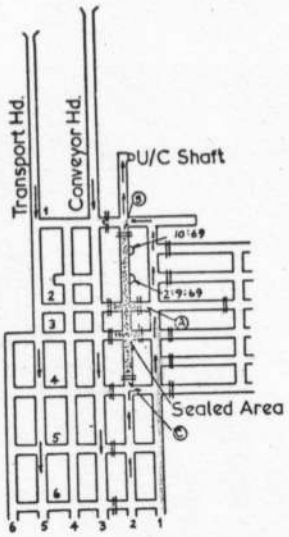
Ventilation & Location of Heatings Main Headings Prior to 1969

(A)



Ventilation of Main Headings 1969

(B)



Location of Sealed Area & Heatings Sep.-Dec. 1969

(C)

Ventilation Prior to Fire on 25:10:71 & Location of Fire

(D)

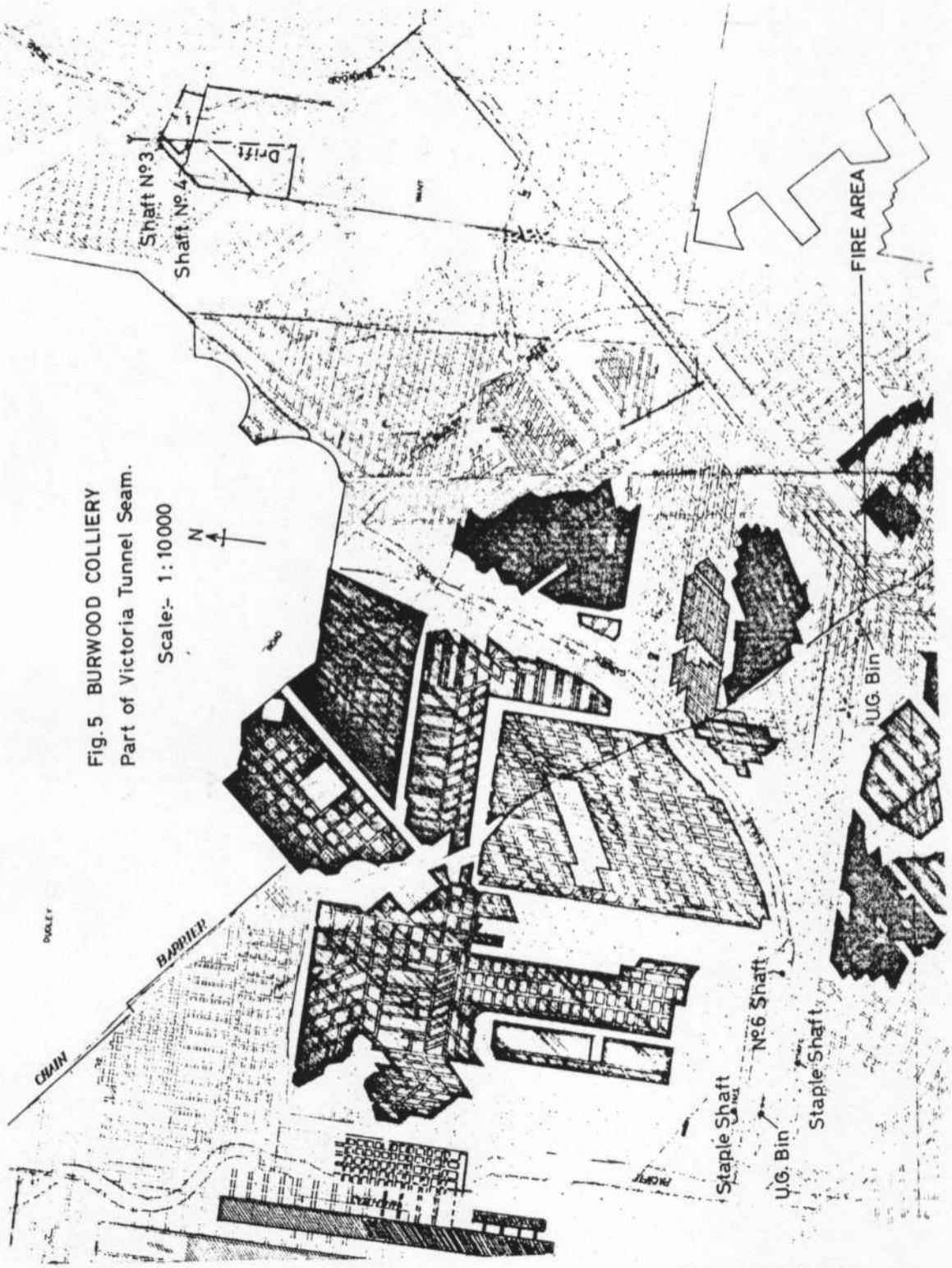


Fig.5 BURWOOD COLLIERY
Part of Victoria Tunnel Seam.
Scale:- 1:10000
N
Shaft Nº3
Shaft Nº4
Drift
FIRE AREA
U.G. Bin
BARRIER
CHAIN
Staple Shaft
Nº6 Shaft
U.G. Bin
Staple Shaft

the ventilation district concerned is being passed oved the fire so that its oxygen content will be significantly reduced, thereby minimising the risk of an explosion.

(b) the products of combustion themselves possibly with some fuel value, together with the oxygen-free or greatly reduced air cannot be revitalized by the addition of fresh air.

COMPLICATING FACTORS

It could be argued that a mine fire in which there are entrapped workmen with a possible chance of survival presents a different problem from the straightforward one, in which mine damage or loss is the only consideration.

In such a case, the decision makers usually face a situation understandably charged with emotional overtones. This may easily lead to imprudence - however heroic - and possibly additional loss of life, as has happened on previous occasions. The state of mind of responsible people under this form of stress can well be imagined; any person would have to be conscious that if a wrong move were made, he would have the consequence with him for the rest of his life.

It is suggested (in all good faith) that if the concept, "is the fire under control or not?" is clearly understood, and if it can be demonstrated that all actions taken were based on conclusions drawn from that concept, then there should be no misgivings - and no recriminations.

DECISION MAKING

Generally it can be assumed that, in an actual event, by the time a decision has to be made there will be a number of very experienced people on the scene who are capable of making sound assessments. These would include colliery managers, mine inspectors, rescue station personnel, etc. However, to avoid any possible conflict of opinion, (and to place responsibility where it should properly be) a suggested procedure is outlined:

The senior operations officer of the mine or group of mines and the manager concerned should be in a position to go underground and inspect the situation at first hand.

The rationale behind this is:

1. The senior operations men will eventually be burdened with a decision, onerous or otherwise.
2. The manager should be one of those with intimate knowledge of the actual configuration of the underground workings, and of the direction and strength of the various air currents. (Mining people will know of cases where the fire plan was not up-to-date in all aspects; such a defect led to a serious situation in one mine with spontaneous combustion problem).
3. Both men referred to should have sufficient practical experience and knowledge accurately to assess the true state of affairs.

It should be clear to everyone that, in the mining context, one good look at the problem area is worth hours of telephone or radio contact with various other officials. Where there is any degree of risk involved, there may not be time for such communication anyway.

As the Mines Rescue Act (N.S.W. Government 1978) now stands, the suggested procedure may not be possible. But all senior officials who are physically fit should be trained members of a rescue station, and those who are not should be given interim permits to make short inspections flanked by a team of regular rescue men. It is important to stress that the mission of such a team should be for reconnaisance purposes only.

To argue that the senior operations men should remain at the control centre at all times for overall direction is not always valid. Mines rescue organisations are now highly developed, and all appropriate back-up teams will be called out as a matter of routine. Consequent logistics, control of news reporters and spectators, co-operation with police and ambulance services, etc., can well be left to other competent senior officials.

At the risk of being presumptuous - or repetitious - it is once again stressed that, where men's lives are at risk, there is no room for any decision except a correct one.

CONCLUSION

Those in the coal mining industry may well question the worth of this brief paper on uncontrolled combustion. An objection could be that the grounds it covers should be well known to all engaged in mining.

In the first place, this paper was intended for young mining engineers and students. But enquiries and discussions during its preparation, made it evident that there is a significant number of people actually engaged in mining who are vague about the real factors of control as discussed.

A colliery manager today sits at the top of a highly complex organisation, embracing many facets of technology; he cannot be expected to have detailed knowledge of all of them.

But in the situations that have been discussed, the man who has the overall responsibility must be very clear about all of the factors that go into his ultimate decision:

- to withdraw all personnel from the mine when there is a measure of doubt existing; or to remain and carry out rescue or recovery operations secure in the knowledge that no undue degree of danger exists.

REFERENCES

Aberdare North Colliery, 1976. N.S.W. Colliery Manager' Association - Symposium on Mine Fires.

Bailey, J.G., 1976. N.S.W. Colliery Managers' Association - Symposium on Mine Fires.

Liddell State Mine, 1976. N.S.W. Colliery Managers' Association - Symposium on Mine Fires.

N.S.W. Government, 1978. N.S.W. Mines Rescue Act, 1925 as amended. Government Printer, Sydney.

DISCUSSIONS

R.J. KININMONTH (New South Wales, Department of Mineral Resources): Mr. Martin is provoking an argument. A situation has been set on a contentious principle. To the contrary and for a start the control should be on the surface. He has answered the argument put against that attitude by saying and accepting that some of the people who it is suggested need to go underground just don't have the knowledge or the expertise. It has also been suggested by inference that there are occasions when the senior mining men should be on the surface. Those occasions should be all the time. But questioning that, perhaps by another question, what are the occasions seen that the senior mining man should be on the surface? Perhaps a second question should be put - what would the senior mining man see underground that couldn't be seen equally by a trained rescue team?

C.H. MARTIN (C.H. Martin & Associates): The senior man will ultimately have most of the say in any decisions made so the argument in point two is that he is the man who eventually is charged with making the decision. He should, if he is the senior man and has the expertise and knowledge, gain from that by going underground and assessing the situation if it is a critical situation. It was only inferred as a possibility, not that it is necessary for him to stay on the surface. The circumstances will dictate these things, what is being said in effect is that if there is anywhere he should be it should be at the seat of operations. There are many mines today organising instruction. There are plenty of officials available to do the routine chores associated with rescue work. The important thing is to see that no further people are killed. The important thing is to also make a judgement on what the situation is - whether to stay or go, it is as simple as that.

N. SNEDDON (Coal & Allied Operations Pty. Ltd.): One of the things involved in these fires that seemed at one stage to occur regularly at Aberdare North was that they always occurred over a holiday period or on a Sunday night or a Saturday night when everyone was at the pub. Now under those circumstances the critical factors appear to be to make sure there is someone in charge at the surface not necessarily the senior bloke. There have certainly been the circumstances where the only people in a rescue situation that could be taken underground were total strangers to the mine and hence at best, under pressure. With a bit of smoke about strangers to any mine get lost following a plan. It is vital, if possible,to have someone with local knowledge, particularly an official with local knowledge on the job. So to start from scratch someone in charge is needed on the surface. Someone with local knowledge and preferably an official on the site underground and if the senior bloke happens to be the only fellow with local knowledge that can go underground with the rescue team, then, he should be the one.

C.H. MARTIN: There is some misunderstanding existing, a general principle was stated, not specific cases. Obviously there can be specific cases where someone has just got to stay there. After a thing has been going for a few hours, a good number of competent people are there; they come from all parts of the industry and it is amazing that people do come and offer assistance.

N. SNEDDON: There are sometimes too many - that is the other extreme.

C.H. MARTIN: Only general principles can be stated but the fact that should be brought out here is, "is the fire controlled or not". If it is considered to be an uncontrolled situation,

and some of the incidents of recent years could be so defined, then there is no reason to be there and it is no good sending good lives after bad. This is the situation that exists when people are trapped and are known to be trapped and does not alter the fundamental approach and this is the point that should emerge. Is it reasonably safe to stay there? During the course of this paper a number of questions were asked of various mining people and one was in trying to get to some of these people, if someone rings up in the middle of the night with news of a disaster, what is the first question to ask, and the obvious one is are there any men involved and where are they. Some of the answers would be surprising because people are going to ring the rescue station and the fire brigade etc. and no one ever thought of the poor blokes in there and if at that time a cross section had been made of the people there is no doubt that the answers would be that 30% were wrong. It is humbly suggested that if an undermanager says there was no one hurt and everybody is on the surface, the manager can let it burn or blow up and go back to bed or back to his mistress as someone suggested at the Symposium at the Hilton Hotel if you recall.

J. CARVER (Retired H.M. Chief Inspector of Mines and Quarries): On reading this paper concern was felt that two of these fires which had to be sealed on the surface occurred behind sealed areas. Now this is going to be a bold statement, but it is prompted by practical and personal experience. Once an area has been sealed no spontaneous combustion ought to occur inside it. If the possibility of spontaneous combustion exists then pressure chambers should be erected and these can be automatically controlled. This is based on U.K. experience, it would be presumptuous to say that it is possible to put it in to Australian practice in view of the multitude of entries which one sees on the plans, but please, thought should be given in Australia to the application of pressure chambers in difficult spontaneous combustion areas. They will work and they are not difficult to operate. Perhaps this plea might evoke a comment.

C.H. MARTIN: When the event is underway it does not affect this approach. But to decide whether it is good management or bad management? It could be said that the management is bad for such a position to be able to arise, to put it crudely and that may be so. Surely the fundamental question is still the same, isn't it - is the fire under control or not?