SUMMARY OF INVESTIGATIONS INTO APPIN COLLIERY EXPLOSION

by

R.J. KININMONTH[1]

ABSTRACT

At 11 p.m. on Tuesday, 24th July 1979, an explosion of methane gas in a three heading development panel at Appin Colliery resulted in the deaths of fourteen men.

The explosion followed after or was associated with a changeover of the ventilation to achieve a central intake between two returns.

Investigation by Inspectors was followed by separate Judicial and Coronial Inquiries.

Investigational information aimed at understanding the circumstances of the explosion was prepared for the Inquiries.

Recommendations following the Judicial Inquiry have been adopted by the Department of Mineral Resources.

INTRODUCTION

Appin Colliery is situated behind the Illawarra escarpment approximately 36 km from Wollongong and works the Bulli seam, approximately 3 metres in thickness at a depth of 510 to 570 m. The layout of the colliery is shown in Fig. 1.

Colliery development by continuous miners began in 1962 and high methane emission from solid coal was a feature of that development. Pillar extraction and longwall goaves also produce large quantities of methane and the return shaft now carries approximately 225.0 c.m.s. of air at 1.0% methane.

[1]Senior Inspector of Collieries, Department of Mineral Resources, Wollongong.

Ryan and Beath (1970) described the problem of gas emission during development and the use of return roadways on each side to protect the track and conveyor roads from gas emission from the virgin coal. Fisher (1976) also discussed the ventilation constraints on development and inter alia stated "Development panels needed their intake airways to be shielded by peripheral return airways to pick up methane given off from solid coal."

The layout of development panels, for both longwall retreating and pillar extraction, by the Wongawilli system have been described by Fisher (1976). The early longwalls were not high producing units and it was found that the development headings could be driven at relatively slow rates of advance. This slow advance and an emphasis on high quantities of ventilation allowed the use of two heading panels for longwall development provided the heading on the virgin side was used as the return.

As one block was mined another was formed by the next two heading development. It was then necessary only to drive a single heading on the maingate side. That heading could be driven largely in destressed conditions with a minimum number of cut through connections. The roadway was thus newly formed and supported when put into use as the next longwall maingate.

By mid 1979 five longwall blocks had been extracted and a sixth was partly finished. Blocking out for longwall seven was in progress in 'K' Panel by mining to the North East from the main White Panel development headings.

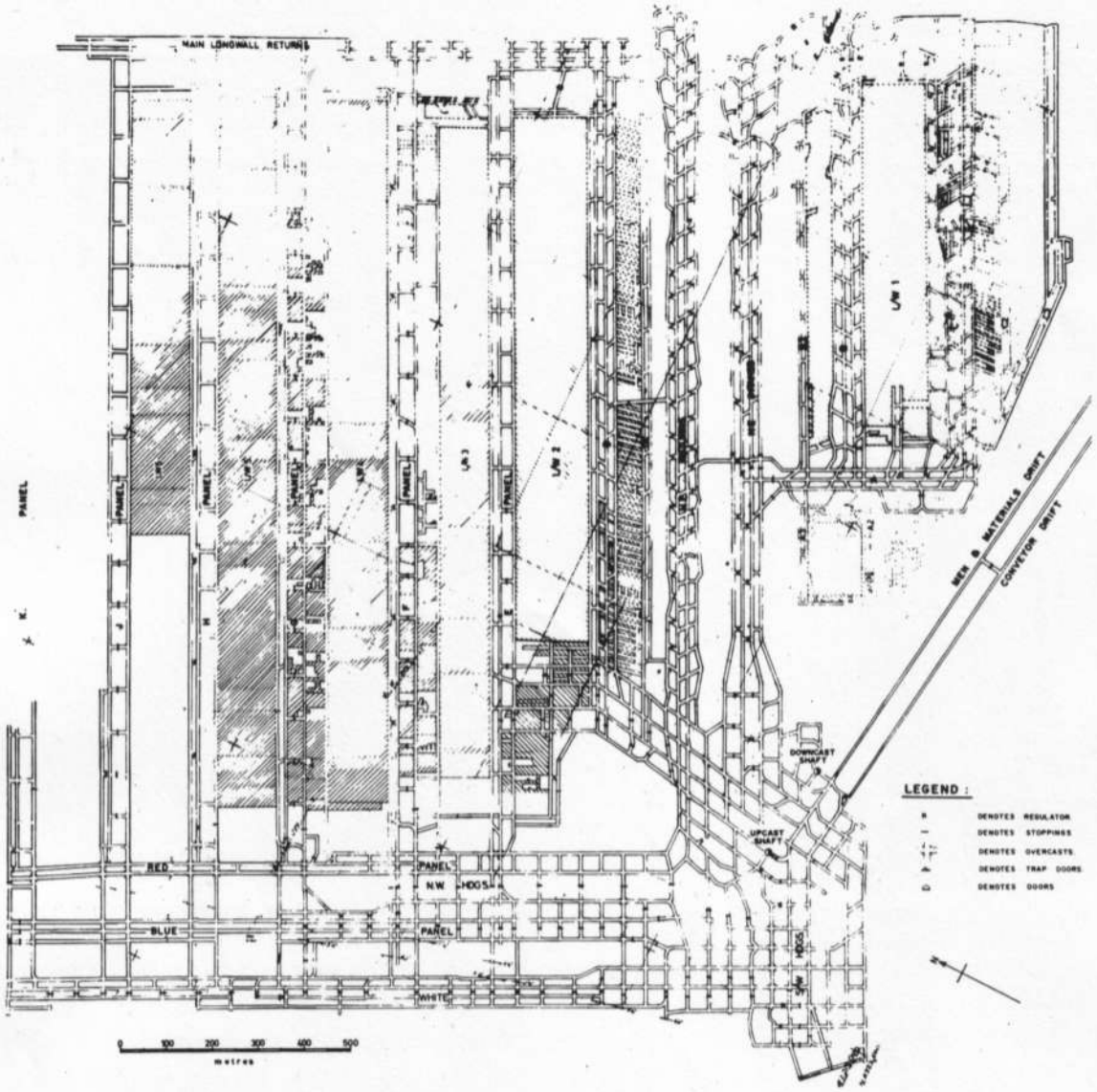

Fig. 1. General Layout, Appin Colliery

VENTILATION

As the longwalls became more successful speed of development became more important and despite continuing improvements in ventilation control it became increasingly difficult to meet the standards for methane control without periodically stopping production.

Distribution of air to the faces in development panels is normally by auxiliary exhaust ventilation. Despite the supply of up to 28 c.m.s. of air at the last cut through it was not always possible, particularly in H and J panels, to maintain intake gas levels below one quarter of one per cent at a distance of 100 m from the first working face.

Dilution of gas in development panels is largely dependent on providing large quantities of air to the face areas and in attempting to

improve face conditions the method of auxiliary fan ventilation was progressively altered. Early development panels used axial flow fans with an open circuit capacity of 8.5 c.m.s. attached to 600 mm ducting but these were changed for centrifugal fans which had an open circuit capacity claimed to be 9.4 c.m.s. The better characteristic curve of the centrifugal fans ensured larger air quantities in long lengths of ducting. At a later stage the vent ducting was increased to 760 mm diameter and eventually approval was given for two fans to be used in parallel through the single ducting.

Despite these improvements it became obvious that the gas percentage, which reached up to 0.6% at the last cut through, prevented adequate control at the face and resulted in production being stopped on numerous occasions.

DEVELOPMENT IN 'K' PANEL

The use of returns on both sides of a panel during early development at the colliery has already been mentioned. It was found, for later development, that some reduction in intake gas emission occurred if the panel was adjacent to an already driven panel. Development of two heading panels with headings at 40 m centres and cut throughs at 90 m centres was therefore possible provided, the rate of advance was slow, there was an adjacent earlier development, and the return heading was situated on the virgin side so that the bulk of the panel gas was released into the air stream after it had left the face area.

As the longwall operations at the colliery became more successful, faster rates of development drivage were required. Experience in H and J panels indicated that such faster development in two heading panels resulted in high intake gas readings and in difficulties in gas control at the face. Early experience with methane drainage had not been successful (McCoy, 1976). Some preliminary attempts at drainage off the solid in H and J panel had been tried but the technique had not been developed to the extent where it could be seen as a production tool.

The speedy development of 'K' panel became essential as a means of blocking out a new face to replace longwall six which was rapidly retreating. In the initial development two headings approximately 2.4 m high and 5 m wide were driven. Despite the need for rapid advance rates it was decided to alter the system of work and to change to a three heading development with returns on each side of a single intake. The disadvantages of this scheme were the relatively slower rate of development and the fact that the second return, which would eventually become the next maingate heading, would be formed earlier than usual and be more liable to stress deterioration. The two heading development was stopped in mid June when the panel had advanced to No. 4 cut through and the third heading was driven to catch up. It was immediately used as the single return and the other two were intakes.

It had been decided that some lost time could be made up if, after the changeover, two continuous miners were worked on production at the same time. A second miner had been sent into the panel for this purpose. Discussions were held with the District Inspector regarding use of a fan in each return and additional air was provided to ensure an adequate quantity for the two fans.

The changeover could not be made until an overcast was completed at No. 3 cut through to connect B heading and L. 8 maingate. From that point outbye to Red panel L. 8 maingate was to be a single return. Initially A heading of Red panel was to be the single continuation of that return but plans were in hand to build another overcast

to allow use of B heading of Red panel as a duplicate return.

PLANNED VENTILATION CHANGEOVER

On the day and afternoon shifts on 24th July, 1979 final preparations were being made and instructions were given to an afternoon shift deputy to make the ventilation changeover if and when the work was completed.

The conditions in the panel prior to the changeover and the intended effect of the changeover are shown in Fig. 2. Stage 1 shows the panel layout on the morning of Tuesday 24th July with A and B headings as intakes and L.8 maingate as the return. The overcast at the intersection of No. 3 cut through and A heading was being built. L.8 maingate stub inbye of No. 4 cut through was brattice ventilated,

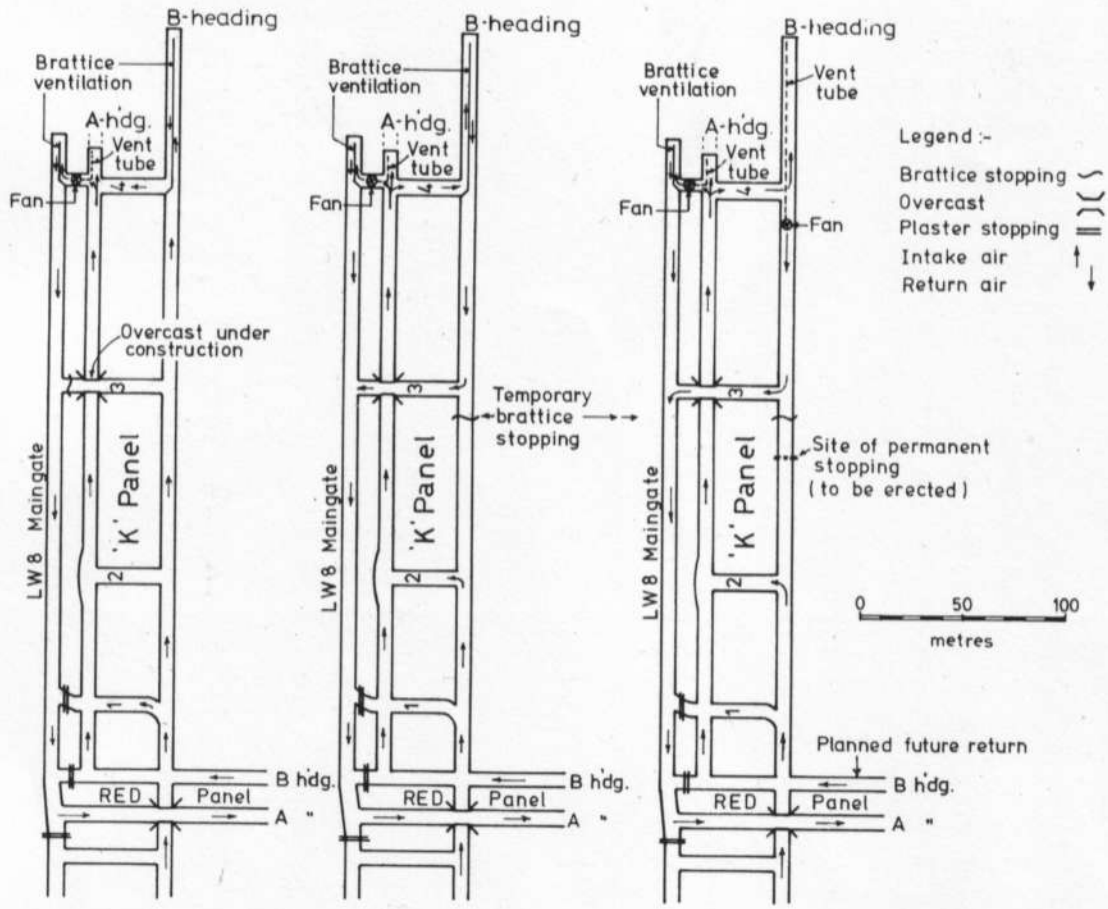

Fig. 2. Changeover Plan

A heading stub was ventilated by an exhaust fan situated in the cut through and B heading which had been driven forward 70 m as an intake stub was ventilated by brattice. Stage 2 shows the intended post changeover ventilation. This was to be achieved by erection of a temporary brattice stopping in B heading outbye No. 3 cut through and removal of the brattice in No. 3 cut through. A fan with associated vent tubes had been placed in B heading and Stage 3 shows the effect of replacing the B stub brattice by that fan, a step which was necessary before both miners could be operated.

When the overcast was completed near the end of the afternoon shift the deputy arranged for the brattice stopping to be erected in B heading. The changeover should then have been completed by the removal of the brattice in No. 3 cut through but the deputy became aware of a drift of air from the overcast across No. 3 cut through and inbye along B heading and he did not proceed. Instead as it was approximately 7-30 p.m., and the end of his shift, he left and reported to the incoming deputy who had arrived in the panel with his evening shift crew.

The extent of work carried out by the evening shift and its effect on ventilation could not be established because an explosion at 11-00 p.m., killed all 14 men in the panel.

RESCUE OPERATIONS

At the time of the explosion there were 56 men underground in the colliery. The 14 men in K panel represented a normal development crew of six men and a deputy plus an additional crew whose job it was to complete the work necessary for operation of the second continuous miner and at some stage in the shift to commence mining. There was also present an assistant undermanager who entered the panel shortly before the explosion, having spent most of the earlier part of the shift in the control cabin near the bottom of the men and material drift. A shift electrical engineer who had travelled in by diesel man car and was fitting a junction box in D heading of White panel approximately 26 m outbye of its intersection with B heading of K panel, suffered second degree burns to the fingers of both hands and first degree burns to his head and face.

The deputy in charge of a crew of men in White panel was sitting in the White panel crib room which is situated in the next cut through about 90 m outbye of the intersection of B heading of K panel and D heading of White panel. He was knocked to the floor and received minor singeing of the hair and eyebrows. The White panel crew were undoubtedly protected from the direct effects of the explosion by a substantial fall which blocked L.8 maingate 80 m from D heading of White Panel. The six men in the White panel crew made their way to the crib room.

A crew of ten men including a deputy were working on Longwall 6, some 950 m from White panel. They reached safety, under the guidance and control of the deputy, wearing self rescuers despite having to travel by feel for much of the way because of the dust laden air.

At 11-45 p.m., the Southern Mines Rescue Station was informed of the event. The Mutual Assistance Scheme was put into operation and the Superintendent and Assistant Superintendent left for Appin at 11-55 p.m., followed by three emergency vehicles which had all arrived at Appin Colliery by 12-29 a.m.

The Superintendent, Assistant Superintendent, four permanent corpsmen, the Colliery Undermanager, an Assistant Undermanager and three Colliery Rescue Men (2 Rescue teams) left to go underground at 12-35 a.m. They proceeded by drift transport, then diesel man car, to White panel crib room which was just outbye the entrance to 'K' Panel. This was established as the Fresh Air Base (F.A.B.) for the

following reasons:

(a) Rail transport was available to the pit bottom

(b) There was a telephone to the surface.

(c) Intake ventilation, though sluggish, was moving and there was no CO or CH_4 in the air when tested.

(d) It was out of the direct line of 'K' panel headings should any further ignition occur.

The F.A.B. is shown on the Rescue Operations Plan (Fig. 3), adapted from Strang (1979), which shows the features mentioned in the following text which summarises a report by Strang (1979).

A team under the captaincy of the Colliery Undermanager left the F.A.B. at 1-00 a.m., and returned at 1-50 a.m. They had discovered the

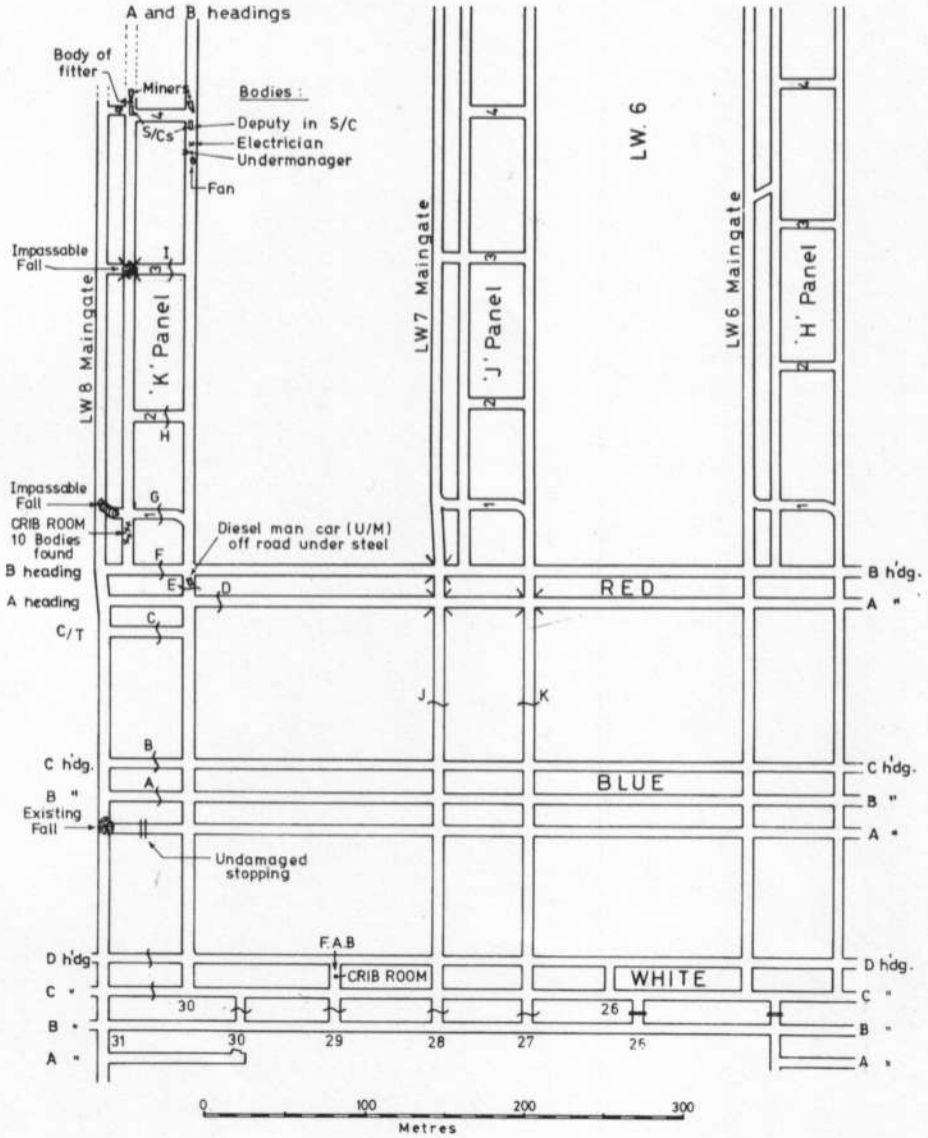

Fig. 3. Rescue Operations Plan

bodies of ten men in the 'K' panel crib room, some 290 m from the face of A heading, and found progress further inbye impossible because of poor visibility.

Brattice stoppings were erected to replace the brick stoppings which had been blown out in 27, 28, 29 and 30 cut throughs of White panel and additional stoppings 30c, 30d, A, B and C in K panel erected to force air into K panel. Arrangements were made to erect stoppings D, E, F and G to provide a return along B heading of Red panel.

The disruption to outbye stoppings had reduced the quantity of air available and the large number of brattice stoppings resulted in leakage so that progress into the panel was slow. By 10-15 a.m., a team was able to travel into the face area and discovered two bodies in B heading and one in A heading.

Stopping H was built in No. 2 cut through of K panel but it was then found necessary to erect stoppings J and K in J panel to force more air into K panel before stopping I could be built. A bag sample taken inbye of No. 3 cut through at 5-45 p.m., showed 0.6% CO, 12.2% O_2, 1.08% CO_2 and over 20% CH_4.

When stopping I had been completed and some time allowed for removal of gas a team proceeded inbye in relatively clear visibility and at 8-30 p.m., discovered the body of the last missing man behind the prop line in B heading.

The rescue operation involved 170 volunteers and lasted 41 hours from 11-45 p.m., Tuesday to 5-00 p.m., Thursday although the last 12 hours were mainly occupied in routine repair work.

DAMAGE ASSESSMENT

The major structural damage both outbye and in 'K' panel is shown in Fig. 4.

The items of special interest were:

(a) The water barrier in Longwall 7 maingate of J panel was damaged. Neither the barrier in the White panel conveyor road nor the barrier in Longwall 6 maingate in H panel were damaged.

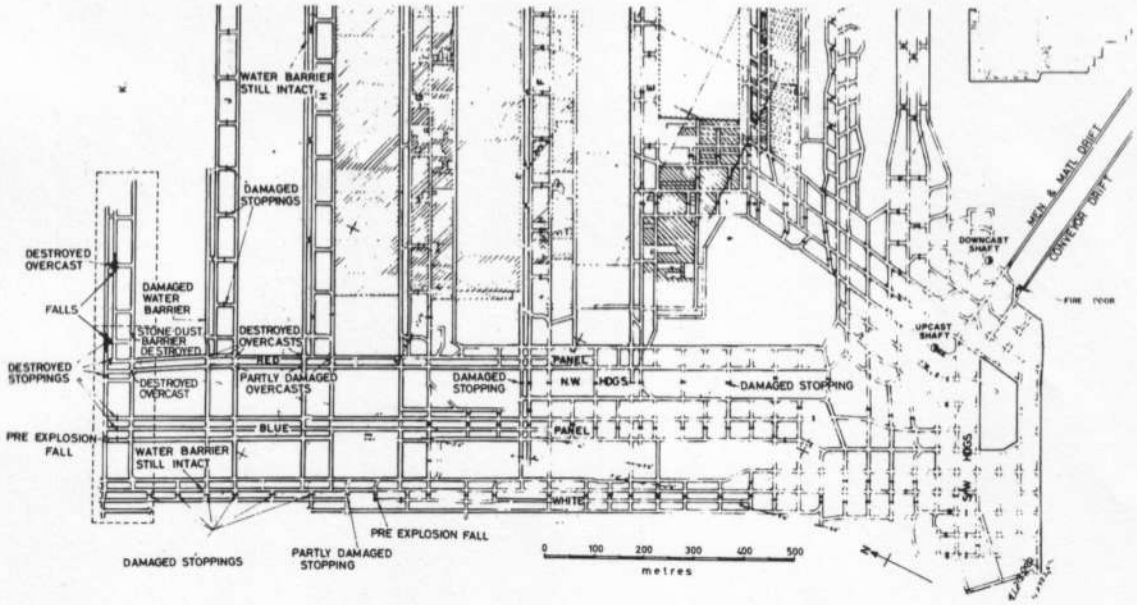

Fig. 4. Extent of Structural Damage

(b) The overcast at the intersection of B heading of K panel and B heading of Red panel was completely destroyed as was the one at the intersection of No. 3 cut through and A heading where a major fall had occurred.

(c) The stone dust barrier between No. 1 and No. 2 cut throughs in B heading was destroyed.

(d) The fan ducting in B stub was shredded and the fan blown down B heading a distance of approximately 30 m.

(e) Steel Purlins bolted to the roof in B stub were distorted.

(f) Considerable damage had been done in L.8 maingate where the wooden props had been blown out from under the steel rail supports.

The damaged equipment inside K panel which was considered relevant to assessing the cause of the explosion consisted of:

(a) The B heading fan starter which was found in a non flameproof condition.

(b) A damaged cable off the shuttle car in B heading.

(c) A damaged cable off the B heading fan.

(d) A damaged cable laid out into B heading stub and attached to the continuous miner at the intersection of No. 4 cut through and B heading.

(e) A damaged methane monitor which had been broken off the B heading continuous miner.

(f) A damaged methanometer which had been in the possession of the Assistant Undermanager.

(g) Damaged flame safety lamps.

(h) A damaged multimeter found in B heading.

FORMAL INVESTIGATIONS

On 25th July, 1979 the Minister for Mineral Resources and Development in pursuance of the powers conferred by Section 31 of the Coal Mines Regulation Act, 1912, directed that an investigation be held by the Court of Coal Mines Regulation established under the Act. The resulting Inquiry was held by His Honour Judge A.J. Goran and a report delivered on 9th May, 1980.

Subsequently a Coronial Inquiry under the Coroners Act, 1980 was held before Stipendiary Magistrate J. Hiatt and a report delivered on 19th December, 1980.

During the days after the explosion Inspectors from the Wollongong Office carried out an assessment of the situation and following an underground inspection by Judge Goran and other interested parties, arrangements were made for recovery and testing of items relevant to the Inquiry. Inspectors, along with technical staff from the Department's Chemical Laboratory at Lidcombe and the Londonderry Test Centre, made an on the spot evaluation of the equipment of special interest to the investigation. The Chemical Laboratory personnel collected samples for testing. Other items were taken to the surface for distribution to Londonderry and Lidcombe.

Colliery, staff under the guidance of an Inspector, spent many days of careful sifting and note taking which became the basis for compilation of a comprehensive set of plans which were subsequently used at the Inquiries.

Apart from a number of interim reports which were provided at the start of the Judicial Inquiry on 24th September, 1979 a total of 24 detailed reports were prepared for presentation at that Inquiry.

SUMMARY OF RELEVANT REPORTS

SITE OF IGNITION

Scientific evaluation of the post explosion evidence was carried out and Ellis (1979) stated: "It is significant that the flame was of low velocity except at its point of origin (B heading

inbye No. 4 cut through) and in Longwall 8 maingate outbye No. 3 cut through. This fact points to the presence of significant amounts of inert material, which could only be stone-dust.

I am therefore of the opinion that stone-dust played a major role in limiting the flame speed, and in eventually arresting the flame."

FLAME TRAVEL

Fig. 5 adapted from Ellis (1979) shows the extent of probable flame travel determined after examination of heat damage to marlin and after calculating the volatile content of coal matter in roadways. In discussing the flame travel Ellis (1979) commented "The extent of flame suggests the involvement of coal dust." and he

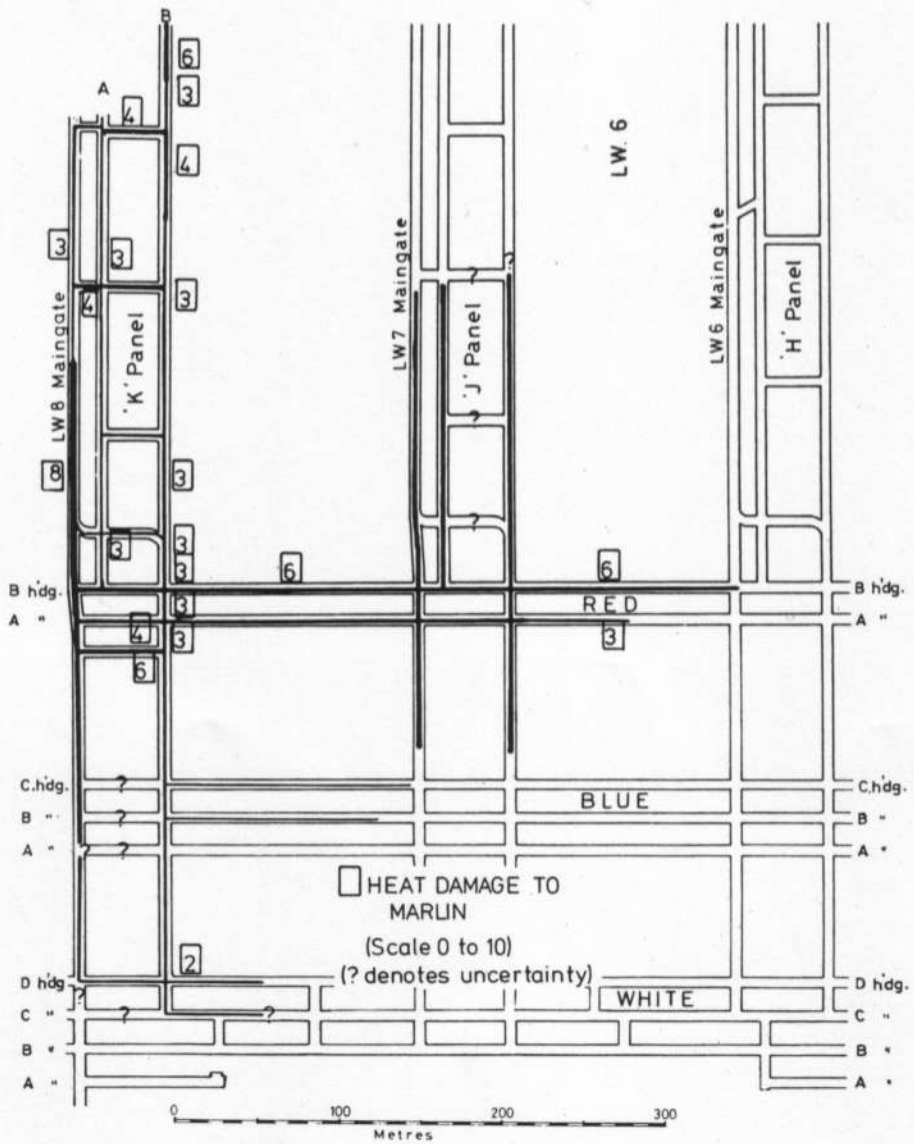

Fig. 5. Extent of Flame Travel

went on to say:

"The degree of damage produced in B heading near the face and back past No. 4 cut through suggests a violent explosion resulting from ignition of a body of gas near its inbye end.

If this conclusion is correct, it limits the possible locations of ignition of the methane to either the face, or a point from which flame could travel to the face. The vent tubes provided one path by which flame could travel to the face and there ignite a body of gas at its inbye end. I am uncertain that a roof layer of methane could behave in this way. It would seem that flame travelling via a roof layer of methane must ignite a body of gas at its outbye end. It would then produce an explosion which was incapable of initiating a coal dust explosion."

FAN STARTER

The auxiliary fan in B heading has been described as a 445CP/490CY centrifugal with an open circuit capacity of approximately 9.4 c.m.s. manufactured by D. Richardson & Son and driven by a 50 H.P., 415 volt, 3 phase squirrel cage induction motor. The associated starter was attached to the fan as a unit and consisted of a flameproof control box containing a 190 amp. three phase contactor with associated control and protection circuits. The fan assembly was found in B heading thrown some 30 m outbye from where it had been placed. Examination showed that the door was fastened by only one stud which was entered only to a depth of two threads. The remaining 23 studs were not immediately recovered but most were found during subsequent searches.

Fisher (1979) has described the condition of the interior of the fan starter, including the presence of burning on rope samples, and a dust pattern showing signs of gas flow on a receptacle end blanking plate. Attempts at Londonderry to reproduce these effects resulted in one success when a flammable mix was present in the starter but the result could not be reproduced again. It was not possible to produce the same effects when gas was ignited outside the box. Lloyd (1979) in discussing the investigations carried out at Londonderry concluded:

"The fan switch was by far the most probable source of ignition that initiated the explosion of gas at Appin Colliery for the following reasons:

(1) The switch in its condition at the time of the explosion was not flameproof due to the excessively large gap between the flanges of the cover and main enclosure and the absence of all but one of the fixing studs. Operation of the contactor with the enclosure in this condition caused an external mixture to be ignited on each occasion that a flameproof test was performed at Londonderry.

(2) Charring of flammable material inside the enclosure indicated that an internal explosion had occurred. Additionally the fineness of the dust found inside led to the same conclusion.

(3) The dust pattern in the blanking plate indicated that this explosion had been ignited from inside the starter.

(4) The electrical supply was on to the fan as indicated by arcing on the fan cable where it was damaged as a result of post explosion disturbance.

The two factors in No. (2) indicate that an explosion inside the enclosure occurred i.e., there had been an explosive mixture inside the starter. Factor No. (3) is evidence that the explosion was initiated from inside the box."

METHANOMETER

An Auer methanometer Model M402 normally carried by the assistant undermanager was found in a damaged condition approximately 5 m

inbye of the final position of the fan. Initial inspection indicated the possibility of it being the cause of the explosion but extensive testing in flammable gas mixtures showed that it was not capable of initiating an explosion.

FLAME SAFETY LAMPS

Following the explosion two relighter type Protector Safety Lamps model GR 6S(A) were found in B heading. Lamp G55 was found alongside the body of the deputy inside a shuttle car at No. 4 cut through. The other similar lamp was found still attached to the body of the undermanager. A preliminary examination of these two lamps and two non-relighter lamps found elsewhere was made and this confirmed that lamp G55 was damaged and incomplete because the glass and a washer were missing.

A comprehensive investigation was initiated and was extended to include the general standard of maintenance and the control of spares for safety lamps. In a report detailing the investigations McKenzie-Wood (1980) stated:

"Glasses with 'non-parallel' ends, found in colliery stock, fitted to a safety lamp in otherwise good condition, were found to ignite an external flammable atmosphere with internal ignition."

He went on to conclude:

"There is no evidence to suggest that Lamp G55 ignited an external flammable methane atmosphere, however this lamp contained defects that would have decreased its overall safety and, under certain circumstances, could have ignited an external flammable methane atmosphere.

These defects included:

(a) Two pyrophor flints in the relighter mechanism, increasing the amount of pyrophor particles inside the lamp and causing a spark on key withdrawal.

(b) A severely corroded inner gauze, decreasing the ability of the gauzes to prevent the passage of flame.

(c) A worn glass plate, increasing the chances of lamp failure if assembled with a defective glass."

GAS MAKE

A gas survey was made two weeks after the explosion and Ellis (1979) records that methane was issuing in the 70 m long B stub at the rate of 1.5 m^3/min.

VENTILATION

A ventilation reading taken in K panel on 23rd July indicated a total quantity of 26 c.m.s. It was expected that a slightly higher quantity would have been available on 24th July, but no information was available to indicate the likely distribution of that air after the changeover which was in progress on 24th July. Following reclamation of the panel an attempt was made to assess the effect of the proposed changeover on the split of air in the panel. Mould (1980) recorded the results of tests carried out in January/February, 1980.

The tests showed that with both auxiliary fans running the split of air was 45% along B heading and 55% along Longwall 8 maingate and indicated that sufficient air was travelling in each direction to allow use of two fans.

One of the tests confirmed that minor leakage at the overcast could cause the reverse drift of airflow noticed by the deputy at the end of afternoon shift on 24th July, 1979.

MODEL TESTS

A series of model tests carried out in co-operation with the staff of the Southern Mines Rescue Station have been reported by Ellis (1980). The model consisted of a shortened 1/12 representation of B stub and illustrated the transfer of flame to the face via vent tubes and the higher strength of explosion when initiation occurs at the inbye end. It was possible to dislodge the model fan only when the gas was initiated inside the vent tubes.

Following the Appin Explosion, the Department of Mineral Resources built a 50 m

long 2.7 m diameter circular testing gallery at the Londonderry Centre. Tests were carried out and Fisher (1980) has recorded the results. In one of the experiments the fan was moved 45 m by the violence of a 30 m length of 7.5% natural gas/air mixture which was connected to and fired from inside the starter box.

Both the above testing procedures used a uniformly mixed gas which does not simulate what would probably have been a layered condition in B stub.

INQUIRY FINDINGS

Judge Goran (1980) stated:

"It is now obvious that I cannot accept as any form of probability the proposition that the deputy's safety lamp caused the first ignition. Nevertheless, a number of Counsel, representing varied interests, urged upon me that I should return what is often called in Coroners' Courts 'an open verdict'. They acknowledged the speculative nature of any finding 'in favour of the lamp'. At the same time they adopted the argument put forward in the report on the January mine experiment that the fan switch chamber was an 'obvious source of ignition combined with an unlikely explsoive mixture'. In other words, they said that it was possible to say that the fan was the source of the ignition but it was impossible to say how the gas entered the starter-box or stayed around the back of the fan, and so the fan as the culprit was also only speculative. This, of course, was an invitation to say that I had failed to find, after a long and exhaustive Inquiry, what triggered the explosion that took 14 lives.

The argument put forward is a fallacy and a piece of sophistry which I reject. Having removed the lamp from suspicion, largely by the very failure of numerous tests to propagate an ignition through known defective lamps combined with a completely unconvincing set of circumstances as a hypothetical setting for the lamp to ignite the gas, there remains only one possible culprit - the fan starter-box."

Later in his report he said:

"I am therefore left, as a resultof the whole of the evidence, with the conviction that the explosion began by an ignition in the fan starter-box. I do not suspect that the deputy's lamp contributed in any way to the explosion. Indeed, having studied in detail the investigation of safety lamps, their defects and their inability, despite those defects, in most cases to propagate flame externally, I believe that reports of overseas explosion in mines where safety lamps have been indicated as the cause, should be treated with great reservation now: they would need careful re-examination to determine what was really amiss with the suspect lamp and how it was known that it propagated externally."

In summing up he further stated:

"My finding necessitates a finding of gas in the starter-box and around the back of the fan. I am unable on the evidence to say in any precise manner how this collected, there being no eye witnesses and the evidence itself having been largely destroyed by the explosion. The following means are, however open on the evidence:

(1) The failure of adequate ventilation of 'B' stub, because of the non-removal of the No. 3 cut through brattices.

(2) A possible failure of ventilation due to an occurrence such as a fall in a stopping outbye.

(3) The substantial leakage in the overcast and through 'B' heading stopping creating a serious deficiency of air available to the 'B' heading fan.

(4) The failure, deliberate or accidental, of the 'B' heading stopping."

Coroner Hiatt (1980) apart from his findings as to cause of death stated:

"I have spent considerable time on my deliberations concerning the question of the source of ignition and referred to many aspects both in support and against each of the alternatives advanced. Other alternatives were excluded on consideration of the evidence and another raised by Mr. Lloyd as to a spark caused by friction on the use of the steel wedge has been left up in the air, however I have determined that such a proposition is less likely as a probability than the fan starter switch in B heading or the Oil Flame Safety Lamp in the possession of Mr. Rawcliffe.

If it was the former then it is probable that some person now deceased was at fault. If it was the latter, such act or omission not being deliberate or without exercise of reasonable care, the cause of the ignition could have been without fault or accidental.

An examination of the evidence in respect of those two alternatives discloses:

In one, the fan starter switch chamber, there was a higher probability of an ignition source and less probability of gas being present in explosive proportions with a readily ascertainable flame path to the face of the headings and in the other, the Deputy's defective Oil Flame Safety Lamp, there is a higher probability of gas in explosive proportion being present with a readily exposed flame path (the vent tube or layering) with a less probable source of ignition than that available in the case of an alive electrical source.

In my view neither can be responsibly excluded on the evidence before this Court.

The evidence adduced does not enable me to say what was the source of the ignition which caused the explosion of methane gas at the face of B heading. Therefore I am not able to determine what was the proximate or direct cause of the explosion but I have concluded that there was a condition existing for a period of time whereby the B heading stub was not properly ventilated. The precise reason for that has not been disclosed on the evidence but on the balance of probability there is evidence that the acts and omissions of persons on the previous shift contributed to inadequate ventilation."

RELEVANT PRACTICAL ASPECTS

CHANGEOVER

The changeover to two sided returns was to be accomplished after completion of the overcast by the simple expedient of putting up a brattice stopping in B heading and taking one down in No. 3 cut through. The subsequent use of fan ventilation in B stub was not part of the changeover but was a necessary step before operating a continuous miner at the face. It could not be established if or when the changeover was completed.

At the time of the explosion the fan starter was in a non flameproof condition with the power on to its cable. While this situation is in breach of the law it indicates that the fan had been prepared for starting and perhaps that it had been started and found to run in reverse.

In either case the deputy would have been required to carry out an inspection. If the changeover had not been completed it is unlikely that the deputy could have gone into B heading without being aware of the lack of ventilation and the presence of layered methane.

It is suggested that the explosion was not due to lack of control during the changeover but was related to improper practice while using the fan after the changeover had been completed.

VENTILATION AFTER CHANGEOVER

At the end of the afternoon shift on 24th July, 1979 B heading was left unventilated because the changeover had been started but not completed. If the panel had been left in the

condition described there is no doubt that a massive quantity of layered methane would have been present in B stub and would have extended out into B heading and into No. 4 cut through. The reverse flow of air said to be present would have done little to prevent a major accumulation.

It was clear from investigations that the oncoming deputy had chalked his initials in both the other headings. Although no confirmatory initials could be found in B heading it is reasonable to assume that he would have gone to supervise the work being done there. He was required to be present and to test for gas before the fan could be started. Mould (1980) has demonstrated that completion of the changeover resulted in sufficient air being supplied to allow operation of the B heading fan.

After the explosion a roll of brattice was found at the intersection of B heading and No. 4 cut through. Its presence indicates that some of the brattice in B stub had been taken down and rolled up. Such action would normally only be taken after the fan had been started.

FAN STARTING

The conditions which applied to auxiliary fans at the time of the explosion required the fan to be started by a deputy or superior official and required him to test for gas. It had not been deemed necessary to make a written condition to the effect that the deputy should check the adequacy and direction of air flow because these are taken to be fundamental duties.

During the starting procedure, it is necessary, unless this has been previously determined, to check the direction of rotation of the fan. A fan running in reverse has been shown to deliver only 38% of its rated capacity and to cut out on overload in approximately eight minutes.

Reversal of rotation is normally achieved from inside the flameproof starter and it is possible that at the time of the explosion the starter was open to allow reversal to be made. The work involved could take from ten minutes upwards depending on the availability of an electrician with tools and on his ability.

A flammable mixture inside a fan starter box may be ignited at either make or break of the starting circuit. The B heading fan starter in its non flameproof condition was certainly capable of initiating an explosion and would probably have had a flammable mixture inside it at some time during the changeover.

After the changeover any gas inside the box would have tended to diffuse out and any external accumulation would have cleared away. It is difficult to establish the conditions which would allow a later accumulation to occur outside and inside the starter box which stands just over a metre above the floor in the 2.4 m roadway. One suggested cause was recirculation of the fan due to collapse of the temporary brattice in B heading. That brattice was shown to have been erected incorrectly because it had been placed on the wrong side of the props and therefore was supported only by staples. Mould (1980) recorded that recirculation did not occur until 30% of the brattice had collapsed. It should be noted that partial collapse results in leakage and reduction in pressure on the brattice and therefore reduces the risk of further collapse.

Recirculation is not a dangerous problem unless an explosive mixture is passing through the fan. A deputy present at the time of start up would be expected to ensure there was sufficient air, to test for gas, to break the tubes and lastly to test for recirculation.

If the place ventilated by the fan is left unbratticed during any fan shutdown a substantial quantity of methane can accumulate. The flow of air past the fan usually prevents

such gas layering around and inside the enclosures.

REMOVAL OF GAS

The method set down by the Department of Mineral Resources in the fan conditions for removal of an accumulation of gas was as follows:

"In the event of the fan having to be used to remove an accumulation of gas, the tubing in that place shall be disconnected back at a point where flammable gas cannot be detected at 1½% or greater, using a locked oil flame safety lamp and other device of a type approved by the Chief Inspector. Provided this point is not closer to the fan than 20 m, the fan may be started, and the tubing extended to dilute the flammable gas and render it harmless."

The method is adapted in practice by the operators so that the vent tubes are broken in one place. The fan is then started so that all the air enters the tube at the point of break. The tube which has been removed is then gradually slipped back into place and an increasing quantity of air and associated gas pulled from the inbye end of the vent tubes. Deputies not issued with a methanometer would normally assess the gas condition in the vent line by taking a Garforth bulb sample in the discharge of the fan.

Since the vent tubes in B stub were hung from the roof the most convenient place to break them would have been from the top of the miner. It is possible to visualise the circumstance where a safety lamp could have accidentally or deliberately come in contact with gas already in the tubes as the tubes were being separated or rejoined.

The provision of a regulated T piece close to the fan to allow controlled short circuiting during start up would seem to be a simpler and therefore better system for removal of gas.

RECOMMENDATIONS

The Minister for Mineral Resources (1980) announced plans for implementing the 27 recommendations or comments in the report or the Judicial Inquiry, Goran (1980).

Those ones which may have an immediate or major effect are set out below in summary form.

(1) Deputies report forms should be revised to require information about gas readings and locations.

(2) Deputies must be issued with methanometers as well as lamps.

(3) Ventilation officers should be appointed.

(4) There is a shortage of Inspectors of Collieries.

(5) No record of the result of an inspection by an Inspector is left at the mine

(6) The strictest control of gas percentages in intake roadways should be maintained.

(7) Every lampman should be supplied with an illuminated magnifying glass for the inspection of faults in gauzes.

(8) An automatic monitoring device should be installed at strategic points in headings to give a continuous reading of CH_4, CO and O_2.

(9) There is a grave danger in driving a lengthy stub in a gassy panel and leaving it stand on brattice particularly on the intake side.

(10) Stonedust and water barriers should not be removed once installed.

(11) There is a need to police the opening of flameproof enclosures.

(12) Legislation is required to prevent any flameproof enclosure being opened without the automatic disconnection of power. There is also a necessity for an interlocking circuit to cut power to the miner if the auxiliary fan stops.

(13) There is a necessity to show local competency before endorsement of technical certificates.

(14) There is the need to review recruitment and induction training.

CONCLUSIONS

The explosion at Appin Colliery which killed 14 men was initiated in a position from where it connected to a body of gas which had accumulated in B stub of K panel. The extent of the flame travel and the violence of the ensuing explosion indicated some involvement of coal dust which was eventually extinguished by the presence of stone dust.

The findings of the Judicial and Coronial Inquiries indicate some differences as to cource of ignition. These are perhaps accounted for by the lack of precise information on the distribution of ventilation and the accumulation of gas.

It is clear that the explosion was associated with the introduction of fan ventilation to a bratticed return heading and followed a ventilation changeover from two intakes and one return to one intake and two returns.

The Department of Mineral Resources plans to implement all 27 of the recommendations or comments with the force of recommendations, which were made by Judge Goran at the Judicial Inquiry.

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DISCUSSION

L. GRIFFITHS (Griffiths Consulting Services Pty. Ltd.): Apparently the Judicial Inquiry was limited in that the effects on the bodies could not be examined because the Judge is not a Coroner. Mr. Carver said before it can be tied up with too many legal people to get down to the truth. Looking at it sincerely to get the total evidence, the dynamic pressures are available on the evidence of the bodies. These have been done by the Ministry of Defence and it is understood that during the recent Vietnam war there were a lot of bodies flown back to see the effects of blast and what new weaponary could be used. Similarly in an investigation of an explosion the dynamic pressures are not available and there is a lot of evidence which could have been admitted and shown to see the pressures or the velocity facts which would have been available from decent defence forensic pathology.

R.J. KININMONTH (Department of Mineral Resources): It has been suggested elsewhere that some evidence was not introduced into the Judicial Inquiry. It is not possible to say how significant such unpresented evidence may have been.

R.J. PARKIN (Western Collieries, Collie, W.A.): Reference was made to the Deputy in the neighbouring district, reference to the fact that because of his behaviour and because of the fact that he got his men to wear self-rescuers that a great deal of life was saved. Would you comment further on the role that the self-rescuers played?

R.J. KININMONTH: It is not possible to assess how effective the self-rescuers were because there was no evidence to indicate the percentage of carbon monoxide in the airway. It is clear from sampling in K Panel that there was a large volume of carbon monoxide produced. Flame travelled into the roadways leading to longwall where the men were working and it is almost certain that without self-rescuers those men would not have got out of the district. Even with self rescuers they probably needed the control of the deputy whose leadership deserved the highest commendation. After an explosion smoke and haze remain in the air until ventilation can be restored. Rescue teams are also impeded by debris scattered in the roadways which accentuate the difficulties of lack of vision.

H.L. PEARCE (H.L. Pearce & Associates): The very last paragraph of the paper advises that the Department of Mineral Resources plans to implement all 27 recommendations that were made by the Judge and some of those are mentioned in the paper and particularly No. 9 calls for comment. What is the grave danger in driving a lengthy stub on brattice and letting it lie or stand on brattice as a ventilation medium? Also No. 13 says that there is a necessity to show local competency before endorsement of technical certificates. What thought has been given as to how that endorsement would be made and who indeed would make it?

R.J. KININMONTH: The short answer is that the findings of the Judge were adopted by the Minister and will be implemented under direction from the Chief Inspector. Evidence given at the Inquiry made it quite clear that it had not been possible under all conditions to ensure that the stub on the intake side was clear of gas. Recommendation No. 9 was probably made in recognition of the fact. The endorsement of overseas qualifications was a matter which was put to the Judge by Counsel representing interests at the Inquiry.

W. ALLISON (Queensland Colliery Employees' Union): Personal involvement in a mine rescue operation at Sirius Creek, Clutha mine in South

Blackwater leads to this question. After an explosion under similar circumstances where they had been using an auxiliary fan and the electrician at the time was involved in some electrical work on the auxiliary fan and was working alone, the fan was never ever recovered because after the person's body was brought out the mine was flooded and they were never ever able to get back there. But the person was picked up. It appeared that the explosion had also taken place inside of his lungs because of the damage that was done to his internal organs; it appeared that the lungs had exploded because his chest was sort of blown out and he would have been actually at the very source of the ignition. Please comment if similar injuries had occurred to any of these people, who may have been actually at the source of ignition. Judge Goran suggested the starter motor of the fan.

R.J. KINONMONTH: Major blast damage to a person at the actual source of the ignition is not likely. Such damage may occur some distance away where the explosion has become more violent.

T. CALLCOTT (B.H.P. Central Research Laboratories): Is there any knowledge of the relative events between the fall at the maingate and the events at B Heading and the fall at the cutthrough. Could the fall at the maingate in fact be independent of them and have preceded the B Heading events?

R.J. KINONMONTH: This matter was considered both at the time of the preliminary underground inspection and during the clean-up of the fall. There was no evidence that the fall had occurred prior to the explosion. Consideration was given to the possibility that a fall existing before the explosion could have been accentuated or lengthened as the result of the explosion. There was no indication of an intermediate ply of dust part way up the fall which may have been present if the fall occurred in stages.

A.J. HARGRAVES (B.H.P. Steel Division Collieries): Is it positive that the fall occurred after the explosion?

R.J. KININMONTH: The time of the fall could be positively determined but there is no evidence that it occurred prior to the explosion. The workmen who were killed in the crib room were in a position where they would have noticed the fall if it had occurred before the explosion because it actually broke through into the cutthrough alongside the crib room.

M. LLOYD (Department of Mineral Resources): On page 9-11 there is a section dealing with model tests, presumably scale models. The use of scale models to provide any significant sort of data is fraught with difficulty. It is necessary for the model to be scaled on a mathematical basis in accordance with the formula governing the event that it is necessary to reproduce. As far as is known there hasn't been any scaling possible with explosion phenomena and the first model that Mr. Kinonmonth refers to, the model that was shortened by a twelth and model toys used for investigating the effect of the explosion, would not fall into that category by any means and the results from such testing could not be regarded as significant and indeed should not be included in a technical paper.

Also under the heading of 'model tests' is the testing carried out at the Explosion Gallery at Londonderry and this is wrongly included as a model test. The test was carried out on full scale equipment and the Gallery was used to produce the blast effects. This is a legitimate use of Gallery and in fact is the practice overseas. Galleries do not reproduce all roadway sections. There are a number of different gallery cross-sections in use over-

seas but they cannot hope to reproduce the many roadway sections that are also used but the results from tests produced in such galleries are applied in all mines because they are tests carried out in full-scale apparatus.

In his paper Mr. Kininmonth refers to the fact that he believes there was layering in the heading. Now in the tests that were carried out at Londonderry it was seen that the dynamic pressure necessary to produce the sort of fan movement or the movement of apparatus that was evident following the explosion at Appin is extremely high, probably higher than would be produced by an ignition of methane layers. There are people here with more experience in explosion phenomena who might like to comment on this.

A personal investigation of an explosion at Sadler's Bray Colliery in Scotland is recalled. Mr. Carver might remember this one. It was a similar sort of situation to the Appin disaster and the igniting source was about knee high which could not have been classed as an ignition of methane layering, yet the damage and the disturbance that was evident following that explosion was not nearly as severe as was the case at Appin. Mr. Kininmonth in his paper points out that it was difficult to account for the presence of a methane mixture at the fan. It is often difficult to account for a methane accumulation away from a face ignition and this probably is one of the big faults of the investigation. Mr. Kininmonth is not held responsible for this - it was probably a deficiency on the part of the Department, that there was not sufficient investigation of the possibility of an accumulation of gas at the height and location of the fan starter. As far as pin pointing or putting forward the fan starter as the source of ignition was concerned it was not merely done because the starter was found in a non-flameproof condition. It was considered that there were certain positive indications that it had been in fact the source of ignition. Mr. Kininmonth quoted the two reports that were brought out as the result of the unfortunate disaster at Appin, these are Judge Goran's Report and the Coronial Report and apparently equal status is given to them in the paper. Firstly, do, in fact the two reports have equal weight? Secondly, please comment on the statement, the surprising statement, made in the Coroner's Report that it would be difficult for someone to work in an explosive atmosphere because of the oxygen deficiency.

R.J. KININMONTH: Are the Reports of equal weight? Judge Goran's was 200 pages thick, the Coroner's was about 30 pages thick and the thicker must be the weightier.

It was the function of the Judge and the Coroner to assess the methods, results and reports presented to the Inquiries. It is therefore surprising to hear Mr. Lloyd, alone, criticize the investigation of gas accumulations, especially as the Judge himself made it clear that "insufficient" tests should not be done.

The purpose of the paper was simply to present the practical circumstances so that the industry may use the information to reduce the risk of a recurrence. Neither of the model tests, as they have been called, represented the actual circumstances at the time of the explosion. The indicators which came from both sets of information were interesting but no attempt was made to simulate the natural tendency of methane to layer and the gallery shape was not typical of New South Wales coal mine roadways.

If there is insufficient oxygen then work is impossible but such a condition is not likely if layering of methane occurs in headings such as those in K Panel. Uniform mixing of a major layered accumulation could under some circumstances result in oxygen deficiency.

R. MARSHALL (Clutha Development Pty. Ltd.): This has been a healthy discussion and will promote further discussion. It is important to learn what exactly are the things to be done to prevent a recurrence of that particular incident. Those things must be learnt and learnt properly.