DAWO

# An Investigation into

PART TWO (1)
MOURA MINE INQUIRY
09.02.87

# The Moura Mine Disaster 16th July 1986

Prepared by
J P Brady
Inspector of Coal Mines

# TABLE OF CONTENTS

## ABSTRACT

At about 11.05 a.m. on Wednesday 16th July, 1986, an explosion occurred in the Dip Section of the Moura No. 4 Underground Mine.

As a result of this explosion, twelve (12) persons were fatally injured. However, another eight (8) persons working elsewhere below ground managed to reach the surface safely. The names, ages and occupations of the 12 persons who were killed are given in Appendix 1.

Rescue attempts began almost immediately. These were hampered by poor visibility, blast debris and high concentrations of noxious and flammable gases. In the following days further attempts were made to reach the Dip Section and, after the injection of nitrogen vapour, the bodies were recovered on Wednesday 23rd July, 1986. After dealing with a subsequent fire, the ventilation was restored on Monday 28th July, 1986. Detailed investigation of the face area to ascertain the nature and cause of the incident commenced on Tuesday 29th July, 1986.

## INTRODUCTION

### THE COLLIERY

Moura No. 4 Underground Mine is situated about 200 km South West of Rockhampton and about (7) kilometres east of the township of Moura.

The mine recovers a medium to high volatile, low ash, bituminous coking coal from the Baralaba coal measures. Only one coal seam, known as "C" seam is worked from the mine and is about seven (7) metres thick. The immediate roof consists of a relatively strong bed of mudstone overlain by a massive sandstone.

Development commenced in February, 1978 from the toe of an abandoned highwall. There are three portals, one for men and materials, one conveyor belt roadway with the remaining portal serving as the main return airway. Mining continued towards the dip of the seam which is about eight (8) degrees to the West, for fifty metres. At this point an additional return roadway was added.

Mining has always been carried out using units which comprised a Continuous Miner (normally Joy 12CM's) and two electric shuttle cars (usually type, Joy 15SC). These shuttle cars load their coal in the section onto 42" conveyor belts through a "grizzly" at the boot end. Materials are taken into the mine by means of Noyes Brothers, Multi-Purpose Vehicles (MPV's) and men are transported in diesel powered Mine Rovers and Domino Myne Buses.

Power is supplied to the mine's surface substation at 66kV and thence into the mine at 6600 volts. At the panel substation this voltage is further reduced to the operating voltages of the machinery ranging from 240 volts for lighting, 415 and 1000 volts for coal cutting machinery, conveyor and shuttle cars etc.

The workings have been confined to the upper 2.8 metres of the seam although some bottom coal has been mined from various partial pillar extraction sections. The layout of the Colliery is shown in Appendix 2.

In March, 1982, an outburst occurred during the development of the 3 South Section. This occurrence was relatively small, displacing about 500 kg of coal from near the roof. Subsequent investigations revealed that the outburst was associated with a mylonite zone and strike slip faulting. Since that time, there have been many encounters with strike slip faults and mylonite zones, but only a few small outbursts, or gas blowers have been encountered.

Investigations by the Australian Coal Industry Research Laboratory (ACIRL), found the "C" seam coal was generally heterogeneous with a low permeability and gas content.

Mining continued down the dip until about mid 1981 when stricter quality control requirements forced a change in direction towards the West South West. These workings were interrupted by a major thrust fault, known geologically as the P2½ fault, during the latter half of 1982.

## MANAGEMENT

The principal officials were:-

Area Operations Manager ............... G. Smith
Deputy Operations Manager ............. L. Cumner
Mine Manager .......................... D. Fowler
Undermanager .......................... G. Mason
Mine Electrician ...................... W. Greaves
Mine Mechanical Engineer .............. T. Faber

At the time of this incident, Mr. D. Fowler was on annual leave and Mr. L. Cumner was Acting Manager.

## VENTILATION

A Fox centrifugal fan is located at the portal of the return roadway and was set to produce a total quantity of 118.41 cubic metres per second at a ventilating pressure of 1.9 inches of water. Of this total, 62.12 $m^3$/sec. ventilated the Dip Section with the remainder circulating in the 3 South Section.

The last ventilation survey was carried out on 24th June, 1986, a copy of the results of which is shown in Appendix 3. At the time of this survey, 28 $m^3$/sec. was passing through the Dip North return (No. 5 heading) with 34.12 $m^3$/sec. in the Dip South return (No. 1 heading). Methane concentrations were 0.2% and 0.3% respectively from which a desorption rate of 0.16 $m^3$/sec. has been deduced. These spot tests compare favourably with the highest mine monitor reading observed during the day of 0.24% $CH_4$ and 0.3% $CH_4$ respectively and the ACIRL analysis of tube samples No. 60 and 100 which recorded 0.185% methane in the North return and 0.346% methane in the South return. A copy of the ACIRL analysis sheets is shown in Appendix 4.

On the morning of the disaster, the face ventilation was reported to be good with the majority of the air current passing directly over the Continuous Miner and thence into the South return. There was no evidence to suggest that the goaf contained appreciable quantities of methane, however, it is conceivable that the cavity above the inbye fall may have contained a body of gas. It has been estimated that such a body would approximate to 1200 $m^3$.

MINE MONITORING SYSTEM

The mine is equipped with a MAIHAK Type 4N.1 Carbon Monoxide (CO) and Methane ($CH_4$) infra red analyser which monitors the mine atmosphere drawn from six points throughout the mine.

Although there have been no recent checks on the tube bundle system to detect leaks, it would appear that the system has performed satisfactorily in the past.

The Mine Electrician, Mr. W. Greaves, maintains the system and he has kept a very good record of sample results and maintenance carried out. Sample results are plotted directly onto a continuous chart recorder, two (1 CO and 1 $CH_4$) for each station.

Mr. Greaves examined the charts every day and recorded the daily peak values of CO and $CH_4$ in a book. I have examined these records and compared the record book entry with the analyses of G.F.G. tube samples taken on the same day and I am of the opinion that the analyser at the mine was performing satisfactorily at the time of the incident.

Listed below is an extract from the monitor record book which details the maximum CO and $CH_4$ determinations for the Dip Section return airways for the month of July with the last reading taken at 10:30 a.m. on 16th July, 1986, about 35 minutes prior to the explosion.

During the first week of July, mining was confined to the brushing of floor coal and punching of the Southern rib in No. 1A heading from 27 c/t, outbye to 25 c/t. This may explain the lower $CH_4$ readings for this period. The small pillar inbye of 27 c/t No. 1 to No. 1A headings was extracted on 7th July and extraction of the pillar outbye of 27 c/t No. 1 to No. 1A headings was commenced on 8th July. This is consistent with the methane concentrations recorded.

| Date | Time | Velocity | Dip South | | Dip North | |
|---|---|---|---|---|---|---|
| | | Main Return | CO ppm | $CH_4$% | CO ppm | $CH_4$% |
| 02.07.86 | 08:25 | 6.2 m/s | 1 | 0.06 | 2 | 0.24 |
| 04.07.86 | 12:45 | 5.9 | 1 | 0.06 | 3 | 0.27 |
| 06.07.86 | 07:40 | 6 | 1 | 0.09 | 3 | 0.27 |
| 07.07.86 | 11:40 | 6 | 1 | 0.06 | 2 | 0.24 |
| 08.07.86 | 14:20 | 5.9 | 2 | 0.33 | 2 | 0.24 |
| 09.07.86 | 13:05 | 6.1 | 2 | 0.27 | 2 | 0.24 |
| 11.07.86 | 08:20 | 6.4 | 2 | 0.36 | 2 | 0.24 |
| 12.07.86 | 08:30 | 6.2 | 2 | 0.24 | 2 | 0.18 |
| 13.07.86 | 08:00 | 6.4 | 2 | 0.21 | 2 | 0.12 |
| 14.07.86 | 07:30 | 6.2 | 2 | 0.15 | 2 | 0.12 |
| 15.07.86 | 07:25 | 6.1 | 2 | 0.24 | 2 | 0.12 |
| 16.07.86 | 10:30 | 6.1 | 2 | 0.30 | 2 | 0.15 |

N.B. ppm = parts per million

eg 2 ppm = 0.0002%

5000 ppm = 0.5%

STONEDUSTING

The Dry Ash Free Volatile (D.A.F.V.) content of the "C" seam at Moura No. 4 was determined to be 32.2% on 16th December, 1985. This would require any incombustible matter content of the underground roadway dust of 72% to satisfy the requirements of the Queensland Coal Mining Act. For the major part, and for keeping the incombustible content of this limit, stonedust was distributed by compressed air operated "kettle" type stonedusting machines made out of 44 gallon drums, set up at strategic points of the mine. Smaller dusters were used on the return side of the coal cutting machines. Bulk stonedusters of 3 tonnes capacity have been used in some instances, particularly for the outbye roadways.

DIP SECTION DEVELOPMENT

Development through P2¼ fault proved difficult due to steep grades, friable roof and ribs, and higher than normal gas emissions. The roof in No. 4 roadway which was the supply heading, fell to a height of about eight (8) metres. This caused the erection of a substantial steel structure which was designed to protect persons travelling beneath the cavity, from falling rock. Hereafter this faulted zone, which is between 22 and 23 c/t's, has been referred to as the "Taj Mahal".

On the Western side of the fault, a marked increase in the virgin seam gas content was noted with values in excess of seven (7) cubic metres of methane per tonne of coal being recorded.

At the same time that these heavier than usual gas recordings were observed, mine engineers were carrying out investigations into various technical aspects of the Moura underground mines from which a report, entitled "Gas, Coal, Stress and Stability of the Moura underground mines" was produced. (See NERDDC PROJECT No. 81/1547). The area inbye of the P2¼ fault zone became a significant part of these investigations and a methane drainage programme started in December, 1983. This programme continued until production recommenced in January, 1986.

The first workings continued until the beginning of April, 1986, and upon reaching 30 c/t, it was then decided to partially extract the formed pillars and about four (4) metres of bottom coal in retreat. Due to market constraints and quality parameters, the pillars were split twice to a cutting height of 2.3 metres and 1.4 metres of coal was brushed from the floor before partially extracting the fenders.

Notice of intention to partially extract this coal was forwarded to the District Inspector of Coal Mines Office on 29th May, 1986. (Appendix 5).

Pillar extraction as specified by the manager proved to be unsuccessful. Although production rates were acceptable, the quantity of coal extracted was either too great in some areas or too little in others. Pillar remnants were yielding and there were many examples of these remnants being too large to permit large scale caving of the roof. This resulted in excessive abutment pressure loads on the pillars outbye of the face.

The panel was inspected by Mr. W. Allison, District Union Inspector on Thursday 5th June, 1986. Mr. Allison was dissatisfied with the method of extraction and his observations were recorded in the Mine Record Book. (Appendix 6).

Although partial extraction continued, difficulty still persisted with roof control and abutment pressures outbye of the face. To counter these difficulties, a proposal to totally extract the formed pillars was suggested and discussed with Union Inspectors and myself. Notification of the proposed changes was forwarded to the Inspector's Office at Rockhampton on 24th June, 1986. (Appendix 7).

On Friday 27th June, 1986, the face area was inspected by Mr. M. Best, District Union Inspector, other union officials, Mr. L. Cumner, Acting Manager and Mr. R. Sudall, Undermanager. Reports of this inspection are given in Appendix 8.

As a result of this inspection and a meeting which followed, it was agreed that: -

(a) Extraction would be carried out on a two shift basis only.
(b) Pillars would be totally extracted by splitting the pillar three times and lifting the fenders as they were formed.
(c) Progress would be closely monitored during a trial period of two weeks.

Mr. M. Caffery, Mine Planning Engineer, was given the task of monitoring the extraction rate and the immediate strata. He examined the Dip Section on Monday 30th June, 1986, and recorded the following observations:-

(a) A fall of about 600 mm of flaky roof in 28 c/t No. 1 to No. 2 headings.
(b) Extensive crushing of the outbye rib line of 27 c/t from No. 1 to No. 3 headings.
(c) Tension cracks in 27 c/t No. 1 to No. 3 headings. Floor heave had also occurred in this area.
(d) Bed slips in 26 and 27 c/t's had taken weight and opened up.
(e) The maximum span of unsupported roof was about 45 metres in the centre of the goaf area.
(f) The line of small pillars inbye of 27 c/t appeared within the abutment zone and would therefore be under less stress than the pillars outbye of 27 c/t.
(g) Generally the extracted area was quiet with very little nipping of timber, although the roof and floor movement had broken a number of props.

Another inspection was carried out on Wednesday 2nd July, 1986. Mr. Caffery was accompanied on this inspection by Mr. I. Poppit, Underground Geologist, Mr. L. Cumner, Acting Manager and Mr. G. Mason, Undermanager. The following observations were made:-

(a) The tension cracks in 27 c/t from No. 2 to No. 4 headings had extended and there had been a marked increase in the amount of floor heave in this area. Floor to roof clearances were down to two metres in places.
(b) A tension crack had opened in the roof of No. 2 heading running outbye from 27 c/t.
(c) There had been no change in the goaf area.

A further inspection on Friday 4th July, 1986, revealed no noticeable change.

On Monday 7th July, 1986, the area was inspected by Mr. Caffery, Mr. Poppit, Mr. R. Sudall, Undermanager and myself. During this inspection a small pillar inbye of 27 c/t and between No. 1 and No. 1A headings was extracted.

Mr. Caffery recorded that there had been no noticeable change in the goaf area, however, there were indications that props were taking weight soon after being set and the crush zone in the rib line outbye of 27 c/t had been extended three to four metres into the pillar, with about one to one-and-a-half metres of rib spall.

I was not satisfied with the method of extraction under the circumstances, my concerns being that:-

(i) the fender or small pillar was too wide,
(ii) the area was showing signs of excessive weight and bed separation,
(iii) insufficient floor and roof supports had been set adjacent to the Continuous Miner,
(iv) most of the breaker props which had been set, were broken,
(v) the cabin of the Continuous Miner had advanced past the last line of supports, and
(vi) there was no effective line of retreat for men or machinery.

The place was stopped and the above points were discussed with the Undermanager, Section Deputy and the production crew. It was agreed that additional supports would be erected before mining recommenced. A record of this inspection is shown in Appendix 9.

Mr. Caffery examined the workings on Wednesday 9th July, 1986, and reported that no noticeable change had occurred, however, on Thursday, 10th July, he noted tension cracks in No. 3 heading 27 c/t and rib spall along the outbye rib of 27 c/t. At about 9:00 a.m. on this day a fall occurred in the goaf outbye of 28 c/t and between Nos. 1 and 3 headings. This fall reached a height of three to four metres. Fall material consisted of 0.5 metre thick plates with some coarser grained massive sandstones from the higher strata. Considerable floor heave was noted in 27 c/t between Nos. 1 and 2 headings.

A further fall from No. 3 heading to No. 4 heading had occurred prior to Mr. Caffery's inspection of 11th July, 1986. It appeared that the roof had broken off along a joint line for a distance of twenty to thirty metres. The roof had caved to a height of four to five metres.

On Tuesday 15th July, Mr. Caffery examined the workings and noted that no further falls had occurred. There was, however, noticeable weight along the goaf edge inbye of No. 3 heading. Tension cracks were located in No. 4 heading running outbye to 26 c/t and the roof was heavy above the extracted area between roadways 1A and 2. A drawing detailing the above information is shown in Appendix 10.

Mr. L. Cumner, Acting Manager, inspected the Dip Section on Friday 11th July, 1986, with Mr. D. Atto, an experienced miner. Both men were satisfied with the progress being made. A record of this inspection is shown in Appendix 11.

Mr. A. McMaster, Electrical Inspector of Coal Mines, inspected the mine including the Dip Section on Tuesday 15th July, 1986. With the exception of hydraulic oil spillage present in the pump compartment of a shuttle car, he was satisfied with the condition of the electrical equipment, although he did comment to the section electrician about an excess of cable on the shuttle cars. A copy of Mr. McMaster's report is shown in Appendix 12

The afternoon shift production crew on Tuesday 15th July, 1986, under the control of Deputy E.C. Strong, completed the final fender inbye of 26 c/t No. 2 heading and flitted the Continuous Miner to 27 c/t No. 3 heading. Mr. Strong was completely satisfied with the state of the section, however, he has since commented that weight and bed separation were evident in the roof inbye of 26 c/t and between headings No. 2 and No. 1A. A copy of Mr. Strong's Statement and Statutory Report is included in Appendix 13.

## EVENTS OF WEDNESDAY 16TH JULY, 1986, LEADING UP TO THE INCIDENT.

The night shift of Wednesday 16th July, 1986, was a non-production shift manned by one Deputy, Mr. J.W. Blyton, and one other man, Mr. G. Bennedick who remained on the surface. Mr. Blyton inspected the Dip Workings twice during the night and he was completely satisfied with the state of them. Thorough tests were made for the presence of flammable gas along the goaf edge, but none was detected. He states that the goaf was very quiet and gave no indication of movement.

The section conveyor belt was left running during the night and it would appear that only the boot end area was examined. I believe that this practice had continued for some time. A copy of Mr. Blyton's Statement and Statutory Report is included in Appendix 14.

Prior to the commencement of the day shift on Wednesday 16th July, 1986, the Acting Manager, Mr. L. Cumner met with Undermanager, Mr. G. Mason and the Dip Section Deputy, Mr. K. Keyworth to discuss the day's work. As a result of their discussions, it was decided to take a strip of coal along the outbye side of a small pillar they were planning to extract which was on the inbye side of 27 c/t and between No. 2 and No. 3 headings. The reason for doing this was to reduce the width of the pillar to a manageable sized fender which they were to totally extract on retreat after setting additional supports along 27 c/t and fully supporting the newly exposed roof.

Following their meeting, Mr. G. Mason deployed the following persons to their respective work places:-

| NAME | JOB | PLACE |
| --- | --- | --- |
| R.K. Keyworth | Deputy | Dip Section |
| R.C. Holton | Continuous Miner | Dip Section |
| P.V. Waning | Shuttle Car No. 31 | Dip Section |
| B.A. Fechner | Shuttle Car No. 30 | Dip Section |
| R. Turner | Timberman | Dip Section |
| S.K. McPherson | Timberman | Dip Section |
| P.A. Sainsbury | Cable Hand | Dip Section |
| L.A. McCulloch | Boot End | Dip Section |
| E.K. Sleep | Greaser | Dip Section |
| P.D. Laing | Electrician | Dip Section |
| C.S. Friske | Fitter | Dip Section |
| S.C. Hull | Cadet Manager | Dip Section |
| | | |
| M. Caddell | Deputy | 3 South |
| S. Gamble | Tradesman's Assistant | 3 South |
| J. Price | Fitter | 3 South |
| J. Anderson | Electrician | 3 South |
| T. Vivian | Tradesman's Assistant | 3 South |
| C. Hughes | Greaser | 3 South |
| | | |
| P. Rose | Deputy | Outbye Roadways |
| M. Holton | Pumper | Outbye Roadways |
| | | |
| J. Dullahide | Supply Man | All Sections |
| G. Ziebell | Transport | All Sections |
| J. Alletag | Stonedusting | All Sections |
| R. Edelman | Stonedusting | All Sections |
| C. Bayles | Belt Patrol | All Sections |
| W. Foden | Belt Patrol | All Sections |
| | | |
| A. Henderson | Fire Officer | All Sections |

Mr. Mason travelled underground to the Dip Section at about 8:15 a.m. and remained there until he returned to the surface at about 10:15 a.m. During this period mining continued without incident. The Undermanager has subsequently stated that the crew were in high spirits and that he neither heard nor saw anything which caused undue concern. He did remark, however, that he thought that there would be a fall in the section sometime during the shift. A copy of Mr. Mason's Statement is shown in Appendix 15.

The conveyor belt patrolmen, C. Bayles and junior miner, W. Foden travelled the entire belt system from the surface inbye to the Dip Section. These men were employed to inspect, maintain and clean all conveyor belts throughout the mine and, in my general opinion, the conveyor systems had been maintained to a high standard. Both men stated that the Dip 3 belt was in very good condition at the time of their inspection which was completed by about 8:30 a.m. Copies of Statements by Mr. C. Bayles and Mr. W. Foden are shown in Appendix 16.

The Mine Surveyor, Mr. G. Pickering arrived in the Dip Section at about 8:15 a.m. His duties were to record on a plan, the location of the face and the area extracted during the period since his last visit. Mr. Pickering states that the goaf area was very quiet, the crew were in high spirits and everything appeared to be normal. A copy of Mr. Pickering's Statement is shown in Appendix 17.

Mr. G. Ziebell, Transport Driver, visited the Dip Section on at least three occasions during the morning. He stated that the face area was normal and that no-one had made any adverse comments. A copy of Mr. Ziebell's Statement is shown in Appendix 18.

Mr. J. Dullahide, Supplyman, also made three trips to the Dip Section during the morning. Full supply trays were taken into the section and empty trays were brought out whilst other supply trays were relocated about the face area. Mr. Dullahide is an experienced miner who had driven Continuous Miners in pillar extraction. He was of the opinion that the face area was good and he neither heard nor saw anything which caused concern. It has been estimated that Mr. Dullahide left the section about thirteen minutes prior to the explosion. A copy of Mr. Dullahide's Statement is shown in Appendix 19.

EVENTS IMMEDIATELY AFTER THE INCIDENT

At about 11:05 a.m. a number of men on the surface of the mine saw what most believed to be a thick cloud of dark grey dust rising above the spoil piles. Within seconds, a telephone call, advising that the main ventilation fan had stopped was received from the control office which is located in the open cut mine complex.

An immediate investigation revealed that:-

(i) the explosion doors on the main fan had been blown off and the internal turn baffles had been blown about 25 metres clear of the fan housing,

(ii) the thick dust had cleared quickly,

(iii) electrical power supply to the workings and the auxiliary equipment located near the portals had been interrupted, and

(iv) nineteen men were underground.

Mr. P. Reed, Manager of Moura No. 2 Underground Mine assumed control of the situation due to the Acting Manager, Mr. L. Cumner, being temporarily off site. He directed the early rescue attempts and activated the mine's emergency procedure. Telephone calls for assistance were made to the Moura Rescue Brigade, Moura No. 2 Mine and the Moura Ambulance Brigade.

Telephone contact was made with five (5) men in the 3 South Section. They were advised to make their way to the surface via "Acky's" portals where they would be met by a deputy and an experienced miner. No contact could be made with Dip Section.

Two men, Mr. J. Duncan, Undermanager, Moura No. 2 and Mr. G. Ziebell, Moura No. 4 Transport Driver, drove down to the main portals where they met Mr. C. Bayles and a junior miner, Mr. W. Foden. Both men, who were shaken, reported a very strong blast accompanied by thick dust and a strange smell.

After advising the control room that these men had been located, Duncan and Ziebell drove into the mine. They had travelled about 100 metres when poor visibility forced them to return to the surface. Here they witnessed another junior miner, Mr. R. Edelman emerge from the conveyor belt portal. This lad had travelled from about 23 c/t 3 South, outbye along the conveyor belt until he reached safety. He was badly shaken and covered in thick dust, but otherwise uninjured. The control room was advised and arrangements were made to transport Edelman to the lamp room before Duncan and Ziebell entered the mine via the conveyor belt roadway.

On reaching the Dip 1 boot end, Duncan telephoned the surface and advised Reed that visibility was very poor and that there was a strange smell in the atmosphere. He requested that a flame safety lamp be brought in to them before they advanced any further. This was arranged and Mr. P. Rose, a Deputy, was dispatched with the lamp. The time was now 11:35 a.m.

Five men, T. Vivian, J. Anderson, J. Price, C. Hughes and S. Gamble had been located in "Acky's" panel. All were reported to be well and they were making their way to the surface. Eight men had now reached the surface and it was determined that twelve men were still in the Dip Section. I spoke to the lamproom attendant, Mr. D. Atto and he gave me the twelve names and their cap lamp/self rescuer numbers.

It had now been established that:-

(a) a massive airblast accompanied by thick dark grey dust had occurred. (Only one witness thought that it may have been smoke and dust),
(b) the main fan would take some time to repair,
(c) the survivors reported no noise, just a pressure wave which caused their ears to pop, wind and dust,
(d) underground power, including that to the monitoring system had been interrupted,
(e) dust had cleared from the portals,
(f) the continuous monitor recorders indicated that all sections were normal at the time of the blast, and
(g) twelve men were unaccounted for.

From this information, it was assessed that a major fall had occurred in the goaf of the Dip Section, which was considered to be long overdue.

The following priorities were set:-

(i) to get air to the trapped men, by
  (a) a rescue team with breathing apparatus, and
  (b) repairing the fan housing with props, battens and brattice and running the fan at a low speed on the auxiliary diesel engine.
(ii) restore the power to the cut and the Maihak analyser so that the mine atmosphere could be monitored.

At about 11:51 a.m. a telephone call was received from Duncan and Ziebell. They had reached the old 4 South to Dip 2 transfer point but could not proceed any further due to very poor visibility and blast debris scattered around the walk-way. They also reported a very strange smell, but only low concentrations of methane. A rescue team was almost ready for departure, therefore, Duncan and Ziebell were instructed to return to the surface.

Men were dispatched to the face area of 3 South via "Acky's" portals to recover ten, SSR 16B breathing apparatus and to check the main water tank. It had been reported that water could be heard rushing through the underground water main. It was assumed that this was broken inbye.

By about 12 noon, sufficient mines rescue personnel had arrived on-site to make up a first team. This team (Team No. 1) comprised the following members:-

N. Pickering (Captain)
S. Bryon
A. Morieson
P. Ein
J. Parsons

The Captain was instructed to travel inbye towards the Dip Section as far as possible and search for survivors. They duly entered the mine at about 12:05 p.m. travelling in a Mine Rover to 8 c/t.

A short while later, a second team was available and they were instructed to check all ventilation appliances and the quality of the atmosphere. This team which comprised:-

L. Graham (Captain)
D. Airton
K. King
M. Squires
K. Guest

were ready to, and entered the mine at 12:15 p.m.

Prior to the second team's descent and at about 12:10 p.m., Duncan and Ziebell arrived on the surface and were debriefed by Mr. L. Cumner, who had by this time arrived on-site, Mr. P. Reed and myself. I was of the opinion that both men were showing signs and symptoms of carbon monoxide poisoning and requested ambulance officers to administer oxygen to both men. Mr. Cumner and myself then went down into the cut to inspect the main fan and the immediate return airway.

On arrival at the fan portal we were advised by a number of men that the smell was getting stronger. I had with me a Drager 21/31 multi-tube detector and a 0 to 700 ppm Carbon Monoxide tube. Cumner and I entered the fan housing to test the atmosphere. On release of the hand pump, the entire length of the tube discoloured almost immediately. All men were withdrawn from the cut and I requested a higher range CO tube. The time was now 12:25 p.m.

A short time later a telephone call was received from Graham. He advised that the atmosphere just inbye of 8 c/t contained plus 700 ppm CO, nil $CH_4$ and 21.6% $CO_2$. Visibility was restricted by thick dust to about twenty metres. This team was instructed to continue the exploration further inbye.

At about 1:00 p.m., Pickering telephoned from the Dip 2 boot end. He reported that the team had advanced inbye as far as the "Taj Mahal" which they found to be completely destroyed. Visibility was nil and blast debris prevented further progress along number four (4) heading. At No. 3 heading 22 c/t, conveyor belt structure was scattered everywhere.

Here again visibility was nil. During his report to the controller, the second team arrived at the Dip 2 boot end. Atmospheric tests at this point revealed +700 ppm CO, 2.2% $CH_4$ and 16.5% $O_2$. This information was relayed to the surface and both teams were instructed to withdraw from the mine at 1:07 p.m.

High range 0 to 3000 ppm CO detector tubes had been located and Mr. G. Ziebell and myself entered the fan portal and noted that the Carbon Monoxide concentration was well in excess of 3000 ppm. Ziebell reported that the strange smell was much stronger.

Both rescue teams arrived on the surface at about 1:30 p.m. and were debriefed in the first instance by Mr. D. Kerr, the Moura Rescue Superintendent. A short while later the team Captains attended a meeting with Mr. L. Cumner, Mr. P. Reed, Mr. D. Kerr, Sergeant First Class, D. Black of Moura Police and myself. They had nothing to add to their telephoned reports, however, they were able to give a graphic description of the conditions encountered inbye of 18 c/t.

From an assessment of all the information available it was apparent that an ignition of gas and/or coal dust had occurred and there were grave doubts about the safety of the twelve men. Fearing a second explosion, it was decided that further attempts to rescue these men would be suspended until an accurate assessment of the mine atmosphere had been completed.

Arrangements had been made at 12:30 p.m. to bring gas chromatograph and trained chemists from the Mines Department's Redbank Laboratory. In the meantime, instructions were given to monitor the atmosphere with the instruments available on-site. Three G.F.G. tube samples (Nos. 5, 60 and 104) were taken from the main return airway inbye of the fan portal and dispatched to the ACIRL Laboratory in Rockhampton. The mine's gas monitor was recording CO and $CH_4$ values in excess of the instrument's capacity, so it was decided to install the Rescue Brigade's Maihak Sifor II infra-red analysers and a Drager E12 Oxygen meter in the main fan drift. These were established and they initially recorded:-

(a) plus 5000 ppm carbon monoxide (N.B. 5000 ppm is the upper limit of this instrument),

(b) 1.7% $CH_4$ and,

(c) 18.0% $O_2$

The mine monitoring system's vacuum pump and tube bundle arrangement was used to draw mine air from the underground workings for analysis by the Sifor II instruments. There was some doubt about the integrity of the tube bundle system after the blast, however, samples were taken from lines which were located in the North and South returns of the Dip Section. At 2:47 p.m. the Sifor analysers recorded:-

| | Dip South Return | Dip North Return |
|---|---|---|
| $CH_4$ | 4% | 0.8% |
| CO | +5000 ppm | +5000 ppm |
| $O_2$ | 15% | 18% |

A borehole from the surface had been planned to intersect the Dip Workings at 26 c/t No. 4 heading and near the crib room. This site was, however, relocated to 27 c/t No. 4 heading when it was discovered that the former lay beneath the wall of a large dam. A Mayhew 1000 drill rig equipped with a 108 mm tri-cone bit commenced drilling at about 3:00 p.m. It was estimated that the target depth of 166 metres would be reached in about twelve hours.

At about 5:00 p.m. the results of the first three G.F.G sample tubes which had been taken at 2:15 p.m., were received from ACIRL. These results were as follows:-

| Gas (Vol.%) | Tube 5 | Tube 60 | Tube 104 |
|---|---|---|---|
| Hydrogen | 0.567 | 0.52 | 0.673 |
| Carbon Dioxide | 2.74 | 2.74 | 2.98 |
| Ethylene | 0.0410 | 0.0408 | 0.0462 |
| Ethane | 0.0097 | 0.0096 | 0.0111 |
| Acetylene | 0.0122 | 0.0115 | 0.138 |
| Oxygen | 17.3 | 17.2 | 16.7 |
| Nitrogen | 75.8 | 75.8 | 75.8 |
| Methane | 2.63 | 2.78 | 2.73 |
| Carbon Monoxide | 0.907 | 0.901 | 0.988 |
| $CO/O_2$ Ratio | 32.7 | 31.6 | 29.3 |
| $O_2$ Deficiency | 2.77 | 2.85 | 3.36 |

These results were assessed and plotted on the Ellicott Right Angle Co-ordinate Diagram which indicated that these mixtures were outside the explosives range. (I have since calculated a Tricketts ratio for these samples of 1.176, 1.138 and 1.049 respectively. This would suggest that an explosion, followed by a fire, had consumed gas, coal dust and possibly coal, oil, conveyor belting, insulation, polyurethane foam and wood).

Monitoring of the mine atmosphere continued with the Sifor analysers and G.F.G. tube samples were taken from the main return at two-hourly intervals. Detailed analyses of these samples were to be done by the Mines Department's chemist when they arrived.

A helicopter landing site was prepared on the main haul road adjacent to the underground mines and an RAAF Chinook helicopter transporting a chromatograph, auxiliary equipment and four chemists landed at 7:30 p.m. This equipment was transported to the Moura No. 2 Mine office and prepared for use.

Gas monitoring continued, but it was not possible to accurately detect any appreciable change with the equipment available. It had been established that a natural ventilation circuit existed with the "Acky" portals intaking air at a rate of about eight cubic metres per second. Only a very slight intake of air movement was detected in the main intakes.

Due to a possibility that the mine may have to be sealed at the portals, it was decided to construct two steel air-locks which could be pushed into two of the portals immediately prior to backfilling with soil. This action would allow access to the mine at a later date. Construction of these air-locks commenced about 8:00 p.m.

Shortly after 10:00 p.m. the initial chromatograph results were received at the control centre. These results indicated the CO concentration had shown a marked reduction, but the methane content was increasing. The priorities now were to establish a reliable trend by determining the status of the mine air at one-hour intervals and plotting the results on the Ellicott Diagram. This work continued throughout the night. (See Ellicott Trend Diagram, Appendix 20).

RECOVERY OPERATIONS - THURSDAY 17TH JULY.

Borehole 1 was completed at about 4:00 a.m. and it was noted that the hole was exhausting high concentrations of gas. However, this was not remarkable as it was known that the upper coal seams in their virgin state contained relatively high methane concentrations.

To enable the drawing of accurate samples from the "C" seam workings an attempt was made to lower a sample tube, with a weight attached down the inside of the drill stem. This was unsuccessful and the drill rods were withdrawn prior to the line being lowered down the open hole. The surface end was attached to a vacuum pump which was powered by a portable generator and the first sample was taken at 6:30 a.m. The results of this sample were as follows:-

| $CH_4$% | $H_2$ | CO ppm | $O_2$% | $N_2$% |
|---|---|---|---|---|
| 0.3 | Nil | 450 | 20.2 | 77.7 |

Further samples were taken about one hour later, the results of which confirmed that the mine air at 27 c/t No. 4 heading was relatively good, although samples taken from the tube bundle system indicated much higher concentrations of methane e.g.

| | $CH_4$% | $H_2$ | CO ppm | $O_2$% | $N_2$% |
|---|---|---|---|---|---|
| South Return | 4.4 | Nil | 600 | 19.4 | 76.5 |
| Fan Portal | 2.8 | Nil | 400 | 19.7 | 77.1 |

Ventilation readings had been taken at regular intervals throughout the night and these indicated the natural ventilation circuit had increased in quantity to about $14m^3$/sec., most of this air was intaking into the mine through the "Acky" portals. Indications were that this air was maintaining a relatively stable atmosphere in the 3 South Section. The methane concentrations as measured by the mine monitoring system from both the 3 South returns were 2% and 2.8% and stable.

As there was no evidence of an explosive atmosphere, it was decided to send a rescue team into the mine to examine the area from the surface and inbye to the 4 South seals. The team (team 3) Captained by J. Blyton, entered the mine at 9:33 a.m.

On its return to the surface at 11:10 a.m., the Captain reported that:-

(a) the main travelling road to 7 c/t was relatively free of flammable and noxious gas,
(b) the 4 South overcasts were damaged and there was a very blue haze in the air which contained 1.8% $CH_4$ and 500 ppm CO,
(c) the 4 South seals were intact, but there was a bad leak in the belt conveyor roadway seal,
(d) air movement was outbye along the 3 South intake roadway and this atmosphere was relatively free of flammable and noxious gas,
(e) with the exception of the damaged overcasts, all other stoppings between intake and return roadways were intact outbye of 12 c/t,
(f) GFG sample tubes for detail analysis had been taken at :-
  (i) 7 c/t No. 4 heading (Tube No.'s. 1 and 106)
  (ii) 12 c/t overcasts (Tube Nos. 57 and 100)
  (iii) 2 c/t 3 South (Tube Nos. 8 and 56).

Analyses of these samples confirmed the team's findings and it was therefore decided to:-

(a) effect temporary repairs to the main fan which would enable it to operate at a reduced speed,
(b) send another rescue team into the mine with instructions to explore the workings between 12 c/t and 21 c/t.

Work started on the fan and team No. 4, Captained by N. Pickering, entered the mine at 12:55 p.m.

On returning to the surface at 1:55 p.m. the Captain reported that :-

(a) the intake airways to 17 c/t were relatively free of flammable and noxious gases,

(b) the double doors at 17 c/t between No. 4 and No. 5 headings were found open and that the team had shut and secured them,

(c) the main door in 18 c/t between No. 4 and No. 5 headings had been blown out of the brickwork.

(d) the gunite stoppings at 18 and 19 c/t's between No. 4 and No. 5 headings had been destroyed,

(e) the brick stoppings at 20 and 21 c/t's between No. 4 and No. 5 headings had been breached,

(f) the stoppings between No. 1 and No. 2 headings at 20, 19½ and 19 c/t's had been levelled,

(g) the results of tests of the atmosphere taken at the following locations were:-

| | $CH_4$% | CO ppm | $CO_2$ ppm | WET°C | DRY°C |
|---|---|---|---|---|---|
| No.4 hdg 21 c/t | 1.0 | 200 | 800 | 20 | 23 |
| No.5 hdg 21 c/t | 1.0 | 200 | 1000 | | |
| No.1 hdg 20 c/t | 1.8 | 300 | 1500 | 23 | 23 |

Visibility at this point was about 20 metres with a strong airflow moving outbye.

Having considered the foregoing information, it was decided to extend exploration beyond 21 c/t and team No. 5, Captained by R. Sudall, was detailed to carry out this task and report back.

The team had just entered the mine at about 2:55 p.m. when the first of many setbacks occurred. Samples taken from the 4 South tube bundle line indicated that the atmosphere was explosive and the team was immediately recalled to the surface.

The barometric pressure at this time was 1025 millibars with the mine's barograph recording a steady fall of 8 mb since the previous high of 1033 mb. Some hours earlier, the effects of such variations were discussed by telephone with Mr. C. Ellicott from the Department of Mineral Resources, Lidcombe, N.S.W. He affirmed that variations such as this would have an adverse effect on the gas contained in the 4 South sealed area. A decision was made to continue monitoring the Dip returns and the barometric pressure which was expected to rise and in the meantime arrangements were made to bring Mr. Ellicott to the mine.

By about 9:00 p.m., it had been definitely established that the amount of gas leaking from the 4 South Panel and the resultant explosive atmosphere in the Dip South return was being controlled by variations in atmospheric pressure, i.e. when the atmospheric pressure was low, more gas leaked and inversely the opposite happened when the barometric pressure was high. At this time the pressure was at a high point of its cycle and advice from the Department of Aviation indicated that the next low would be at about 4:00 a.m. the next morning - some seven (7) hours later. Consequently, it was decided to take advantage of this barometric "window" and send another team inbye of 21 c/t. This team, No. 6, led by C. Glazbrook was given the same instructions which had been given to the previous team. The team entered the mine at 10:25 p.m. and travelled to 8 c/t on a vehicle and then proceeded on foot beyond that point.

Although unfavourable conditions were encountered, the team managed to reach 27 c/t and on returning to the surface at midnight, the Captain reported that : -

(a) ten bodies had been located in the vicinity of 26 c/t. The approximate positions had been marked on a plan,

(b) visibility inbye of 23 c/t was extremely poor, two to three metres maximum,

(c) all ventilation stoppings between intake and return roadways had been obliterated,

(d) the Continuous Miner and shuttle cars had been withdrawn from the face,

(e) blast debris and a thick dust haze had made walking conditions very difficult,

(f) samples and tests of the mine air had been taken at the following locations:-

   (i) 23 c/t No. 5 heading
   2.8% $CH_4$, 100 ppm CO, 0.5% $CO_2$
   (Sample tube No. 209)

   (ii) 26 c/t No. 4 heading
   3.2% $CH_4$, 400 ppm CO, 0.5% $CO_2$
   (Sample tube No. 103)

   (iii) 25 c/t No. 1 heading
   3.2% $CH_4$, 100 ppm CO, 0.5% $CO_2$
   (Sample tube No. 90)

   (iv) 22 c/t No. 1 heading
   3% $CH_4$, 500 ppm CO, 0.5% $CO_2$
   (No tube taken)

(g) they did not find any evidence of fire nor the source of the reported smoke and all believed that the smoke was in fact dust.

It had now been confirmed that an explosion had taken place and that all lives were lost. There was no evidence to suggest that the men had any warning of impending danger nor had any attempted to use their self rescuers.

## RECOVERY OPERATIONS - FRIDAY 18TH JULY.

As expected a steady fall in barometric pressure had caused the methane content of the mine outbye of the 4 South seals to rise to a point which was now explosive. Having completed temporary repairs to the main fan it was decided to withdraw all men from the cut and attempt to start the fan's diesel motor by remote control. After a number of electrical problems, this was achieved at 5:00 a.m. and the fan speed increased until 0.3 inches of water was measured.

Shortly thereafter a reduction in the methane content of the mine air was noted. This continued to improve with maximum methane concentration of 1.2% being recorded outbye of the 4 South seals. It was therefore, decided to send a rescue team inbye to confirm the tube bundle results and to extend the sample line down the south return.

Team No. 7, led by R. Sudall, entered the mine at 9:05 a.m. They established that the ventilation quantity and quality of the 3 South split and the Dip workings to 15 c/t was satisfactory. In the Dip South return, smoke was restricting visibility to about 40 metres. Spot tests at this point indicated that the air contained 1.4% $CH_4$ 100 ppm CO and 0.15% $CO_2$. After extending the tube bundle line from 13 c/t to 19 c/t, No. 1 heading, the team returned to the surface at 11:00 a.m.

Two mine Deputies inspected the 3 South workings and reported that they were relatively free of flammable and noxious gases. They also reported that all stoppings were intact. However, a number of doors had been blown open.

A decision was made to continue the extension of the sample line down No. 1 heading to about 25 c/t and at the same time restore the damaged overcasts and progressively the stoppings between intake and return roadways.

Rescue team No. 8, led by J. Blyton, entered the mine at 12:05 p.m. and extended the sample line along No. 1 heading from 19 c/t to just outbye of 25 c/t. At this point the air quantity was measured at 5.4 $m^3$ per second and tests indicated, 1.7% $CH_4$, 100 ppm CO, 0.15% $CO_2$. On returning to 19 c/t the team noted a vast improvement in the air flow outbye of 22 c/t No. 1 heading.

Twelve men under the control of Mr. D. Kerr had commenced temporary repairs to the overcasts and the damaged stoppings outbye of 19 c/t when a report was received from the surface control centre that there was a problem with the sample line. It appeared that this line was leaking.

Mr. W. Allison, Mr. D. Kerr and myself inspected the South return inbye of 19 c/t. The ventilation was good, although visibility was restricted to about 25 metres by blue smoke. There was a very strong fire stink and 90 ppm CO was measured. It was evident that an active fire of unknown location was present in the inbye workings. This had not been detected by exploration teams or the monitoring system. All men were withdrawn from the mine and the situation re-assessed.

It was decided that due to the unreliability of the sample line and the limited information available, no further recovery attempts would be made until a reliable sample point had been established at 25 c/t No. 1 heading. This would be provided by a borehole from the surface.

It was further decided that the possibility of introducing an inert gas or flooding the Dip Section would be investigated by a sub-committee. Various options were to be prepared for discussions, scheduled for Saturday morning.

It was agreed that:-

(a) the safety of rescue teams was paramount,

(b) the recovery of the mine and in particular the Dip Section was essential for any investigations into the nature and cause of the incident to be successful, and

(c) the recovery of the twelve bodies was very important, however, further lives would not be jeopardized in achieving this goal.

With this in mind, a sub-committee was formed to prepare various options for consideration. These options were to include:-

(a) the introduction of nitrogen or carbon dioxide gas, and

(b) flooding the Dip with water.

As a result of these discussions the mine surveyor was instructed to prepare a drill site for borehole 2. This was located immediately above the intersection of 25 c/t No. 1 heading. Drilling of this 108 mm hole, with a target depth of 152 metres, commenced at about 9:00 p.m. and it was scheduled for completion in about 12 hours.

## RECOVERY OPERATIONS - SATURDAY 19TH JULY.

In total, four options were considered, these were:-

Option 1 - Inertise the entire Dip Section inbye of 18 c/t with nitrogen vapour. It was estimated that this would require about 100,000 cubic metres.

Option 2 - Inertise the goaf and the immediate face area with nitrogen vapour.

Option 3 - Flood the goaf to about 27 c/t level with water and inertise the area outbye with nitrogen vapour.

Option 4 - Flood the entire Dip Section with water.

Another option, i.e. using carbon dioxide instead of nitrogen, was negated due to the unavailability of sufficient quantities of this gas.

After considerable discussion it was decided to adopt Option 3. The reasons for this were:-

(i) it would take some time to assemble the equipment and the expertise necessary for inertisation with nitrogen vapour,

(ii) whilst awaiting the arrival of the above, water injection could commence,

(iii) the availability of liquid nitrogen was limited, and

(iv) flooding of the section would destroy possible evidence.

Immediate action was taken to expedite the arrival of the New South Wales Mines Rescue Service "Mineshield" equipment and the trained persons required to operate same.

The "Mineshield" equipment consists of a 40 tonne liquid nitrogen "mother tanker" and a vaporising unit which converts the liquid nitrogen into gas. The nitrogen vapour is then pumped to the affected area via, in this case, boreholes. This equipment, purchased by the N.S.W. Mines Rescue Service is operated and maintained by C.I.G. at Newcastle, N.S.W.

Additional boreholes, 3, 4, 5, 6, and 7, were planned and drill rigs were assigned to holes as they became available. Details of these holes are as follows:-

| No. | Diameter | Target Depth M | Location | & | Purpose |
|---|---|---|---|---|---|
| 3 | 229 | 178 | Most Inbye | | Water injection |
| 4 | 120 | 166 | Most likely fall area | | Sampling |
| 5 | 108 | 169 | Inbye, Rise side | | $N_2$ injection |
| 6 | 187 | 173 | Inbye, Dip side | | $N_2$ injection |
| 7 | 187 | 161 | Most likely fall area | | Sampling |

Borehole 2 which commenced at 9:00 p.m. on 18th July was completed at 3:15 p.m. on 19th July. The hole was cased with 125 mm PVC casing and a sampling tube was installed. Initial sample results indicated plus 5% $CH_4$ and 100 ppm CO.

Borehole 3 commenced at 3:00 a.m., however, unstable ground conditions had caused a loss of air and water circulation and the hole collapsed on many occasions. This hole eventually reached target depth at 9:30 a.m. on Sunday, 20th July, however, it deviated to such an extent that it missed the target in the underground roadway and finished up in a coal pillar. It was thus useless and therefore abandoned.

Borehole 4 commenced at 9:00 a.m. and reached a void above the roof of the seam 6.75 hours later at 3:45 p.m. Its depth indicated a roof fall of about 7 metres high at this point, this was far less than anticipated. After inserting a 125 mm, PVC casing, a sample tube was installed and monitoring commenced. Initial results indicated plus 5% $CH_4$ and 40 ppm CO.

The drilling of borehole 5, which was scheduled for completion at about midnight, started at 4:30 p.m. As more drill rigs became available, starts were made on boreholes 6 and 7 at 6:00 p.m. and 9:00 p.m. respectively.

By about 10:00 p.m. arrangements had been made to commence water injection. High capacity water pumps and associated delivery hoses had been set up to draw water from a large dam which was located about one kilometre to the West.

At about 10:30 p.m. it was suggested that the introduction of water at this stage may cause explosive mixtures of methane to be pushed over a possible heat source. The chemists had advised that such mixtures were present and that carbon monoxide was being produced by an unknown heating or fire. Due to the fact that the "Mineshield" equipment and sufficient liquid nitrogen was not yet on-site, it was decided to delay the introduction of water until the above requirements had been satisfied. Drilling and monitoring was to continue throughout the night.

The first of four (4) liquid nitrogen tankers had arrived on-site and it was anticipated that the remaining tankers and the "Mineshield" equipment would arrive early on Sunday morning.

RECOVERY OPERATIONS, SUNDAY 20TH JULY.

As at 1:00 a.m. on 20th July, the status of the drilling programme was as follows:-

| Borehole | Depth M | Casing | Purpose |
|---|---|---|---|
| 1 Completed | 165 | Nil | Sampling |
| 2 Completed | 151.7 | 125 mm PVC | Sampling/Water Injection |
| 3 Drilling | Continuing - | Difficult ground conditions | |
| 4 Completed | 159 | 125 mm PVC | Sampling |
| 5 Completed | 169.3 | | Nitrogen Injection |
| 6 Drilling | Continuing | | Nitrogen Injection |
| 7 Completed | 152 | 150 mm PVC | Sampling/Water Injection |

An additional two holes were planned, one to penetrate the goaf area on the dip side of the workings, with the remaining hole (No. 9) located in No. 1 heading between 21 and 22 c/t's. This hole would be used to monitor the fire or heating and the nitrogen loss on the return side of the panel. The drilling of hole 9, with a target depth of 139.5 metres, commenced at 1:30 a.m. It was scheduled for completion some twelve hours later.

The mine atmosphere was monitored throughout the night with determinations being made from both the boreholes and the tube bundle system at one-hourly intervals. The sample results indicated little change in the underground conditions.

Prior to the 8:00 a.m. control meeting, the "Mineshield" equipment, technical personnel and four tankers containing a total of 64 tonnes of liquid nitrogen arrived on-site. This equipment was being readied for use, but there was some delay in the arrival of a propane gas tanker which contained the fuel for the nitrogen vaporiser.

Due to this delay a decision was made to inject liquid nitrogen, at a rate of between 7 to 10 tonnes per hour, down boreholes 1 and 5. At the same time, water would be pumped down boreholes 3 and 6 at a rate of 130,000 ltrs/hr It was later established that borehole 3 was blocked and was thus abandoned. Monitoring would continue at boreholes 2 and 4.

The experiment with liquid nitrogen injection proved to be less than successful. Back pressure in the boreholes caused the liquid nitrogen to force its way back to the surface via cracks in the subsoil. This eventually froze the ground near the surface and for up to three metres around the hole. Finally the boreholes became completely blocked. By about 6:00 p.m. a total of 60 tonnes of liquid nitrogen had been consumed and the operation was abandoned.

Problems were also experienced with water injection and it was obvious that the holes must be cased for this to be successful.

Sample results indicated that there was only a slight reduction in the oxygen content in the Dip Section and advice from Dr. Rowlands of Queensland University suggested that the liquid nitrogen may not vaporise for up to three days.

Whilst the experiment with liquid nitrogen was unsuccessful, some degree of inertisation had been achieved and valuable experience had been gained. The priorities were now to recover the blocked holes by reaming and casing and continuing monitoring until the nitrogen vaporising unit was operational and sufficient quantities of liquid nitrogen were on-site.

## RECOVERY OPERATIONS, MONDAY 21ST JULY.

The boreholes' status at 9:00 a.m. was as follows:-

| Borehole Number | | |
|---|---|---|
| 1 | - | Standpiped - but still blocked. |
| 2 | - | Sampling OK. |
| 3 | - | Abandoned. |
| 4 | - | Sampling. |
| 5 | - | Sampling. |
| 6 | - | Completed, cased and standpiped. |
| 7 | - | Completed. |
| 8 | - | Drilling continuing. |
| 9 | - | Completed and sampling. |

Sample results determined at 10:00 a.m. from the boreholes indicated that the mine atmosphere about the Dip Section, was relatively good. The results were as follows:-

| Hole | $CH_4$ | CO | $O_2$ |
|---|---|---|---|
| 2 | 1.0% | 120 ppm | 20.4% |
| 4 | 0.5% | 95 ppm | 20.5% |
| 5 | 0.6% | 80 ppm | 20.6% |
| 9 | 0.5% | <10 ppm | 20.5% |

Whilst awaiting the arrival of additional supplies of liquid nitrogen and after due consideration of the above results, it was decided to prepare a rescue team for an exploration of the Dip Section face area, provided that the 11:00 a.m. sample results were satisfactory. The 11:15 a.m. results were:

| Hole | $CH_4$ | CO | $O_2$ |
|---|---|---|---|
| 2 | 1.0% | 130 ppm | 20.4% |
| 4 | 0.5% | 90 ppm | 20.7% |
| 5 | 0.5% | 80 ppm | 20.7% |
| 9 | 0.4% | 35 ppm | 20.7% |

Rescue team number 9 Captained by R. Sudall was instructed to examine the Dip Workings inbye of 23 c/t. Should time permit, G.F.G. tube samples and ventilation quantity and quality readings in the South return inbye of 20 c/t were to be taken. The team was accompanied by Mr. M. Best, Mr. D. Kerr and myself.

Whilst telephone communications were being established at the 18 c/t Fresh Air Base (F.A.B.), Best and myself inspected the South return from 19 c/t inbye to the No. 9 borehole which was located about 20 metres inbye of 20 c/t. The bottom of the hole was located about 100 mm from the South rib and a considerable quantity of water was flowing out of the hole. The end of the sample tube from the surface had caught on the edge of a butterfly (roof bolt) plate and was still up inside the hole. There was no doubt that the results being obtained from this sample point were not showing a true indication of the composition of the general body of the atmosphere. Visibility was about 20 metres and a thick bluish smoke and a "fire stink" were present.

On-the-spot tests of the atmosphere revealed that there was 0.9% $CH_4$ and 190 ppm CO in a volume of $14m^3$ per second of air flow.

Before returning to the F.A.B., Best and I travelled across 21 c/t to No. 4 heading. It was noted that the air in this cut-through was very cold and it appeared that the liquid nitrogen had had some effect in cooling the workings. The results of our inspection were reported to the rescue team and by telephone to the control centre. Confidence in the sample results received up to this point had been destroyed because there was no doubt that an active fire existed inbye of 22 c/t.

Prior to the team's return to the surface, the sample tube was lowered down the hole about five metres and the end of the tube was repositioned in the centre of the roadway. Three G.F.G. samples, Nos. 57, 76 and 209 were taken for analysis. The team arrived back on the surface at about 1:50 p.m.

Further exploration attempts were suspended and, as all was now ready, at about 4:15 p.m. the first attempts were made to inertise the underground atmosphere by injecting nitrogen gas.

In the initial stages, this operation was plagued with problems. Borehole back pressures of up to 40 kpa damaged the cement blocks securing the standpipes and it was not until about 6:00 p.m. that the first significant injection rate of 5 tonnes per hour was achieved. This rate was increased gradually to 14 tonnes per hour at 8:00 p.m. when it was apparent that the oxygen levels were being reduced slightly. By about 11:00 p.m., it was obvious that this injection rate could not be maintained. This was because liquid nitrogen was being consumed at a rate far greater than that which could be delivered to site. The injection rate was, therefore, reduced to 5 tonnes per hour.

By 11:00 p.m., the oxygen content of the Dip Workings had been reduced to: -

| Hole | $O_2$ |
|---|---|
| 2 | 16.2% |
| 4 | 15.0% |
| 5 | 15.9% |
| 9 | 17.5% |

however, by midnight these levels had increased to:-

| Hole | $O_2$ |
|---|---|
| 2 | 17.4% |
| 4 | 18.0% |
| 5 | 18.8% |
| 9 | 17.8% |

It was obvious that such an injection rate could not hold the reduced oxygen levels and by about 2:00 a.m., the air in the panel had returned to its former atmospheric conditions.

It was quite evident that the strong ventilation flow in the panel was diluting the nitrogen vapour and it was also established that nitrogen losses increased proportionally to the injection rate. Further, it was calculated that, to maintain a level of about 12% oxygen in the workings, an injection rate of about 18 tonnes per hour would be necessary to cover losses. Such a supply could not be guaranteed and due to the fact that about 50 tonnes of liquid nitrogen had been consumed in this exercise, it was decided to suspend injection and consider other alternatives.

RECOVERY OPERATIONS - TUESDAY 22ND JULY.

One alternative was to try to reduce the quantity of the air flowing around the panel and to this end the main fan speed had been reduced and short circuits created at the fan drift and 1 c/t. It was also considered that any reduction in the size of the goaf would be beneficial in conserving the nitrogen supplies and such a reduction could be achieved by flooding the lower part of the workings. Thus, water injection recommenced, the rate being 3,600 litres per minute.

Other options were then considered, these being:-

(1) To postpone any further attempts of inertising the panel until sufficient quantities of liquid nitrogen were available.

(2) Abandon the inertisation programme and totally flood the section of the mine with water.

(3) Send rescue teams into the mine to erect brattice seals across the five roadways between 21 and 22 c/t's which would retain the nitrogen inbye.

Option (3) was selected and two (2) rescue teams were instructed to enter the mine and complete the following tasks:-

(1) Explore the roadways inbye of 22 c/t and locate the source of the smoke. Every effort was to be made to travel those roadways not covered by previous teams.

(2) Erect brattice seals across the five roadways between 21 and 22 c/t and extend a new sample tube from No. 9 borehole to a point inbye of the seals. This would be called sample point 9A.

Both teams led by J. Blyton and I. Kraemer, went underground at about 10:00 a.m. and travelled to 18 c/t before commencing their respective duties. Team 10 entered a smoke-filled atmosphere at 23 c/t No. 4 heading where visibility was reduced to about six (6) metres. An examination of 23 c/t to No. 1 heading and roadways 2 and 3 was completed before the team advanced inbye along No. 2 heading. In 24 c/t between No. 2 and No. 3 headings, they discovered a large area of smouldering floor coal and evidence of burnt out props. It was established that this area covered about 60 $m^2$. No open flame was visible.

Team 11 which comprised eight persons was divided into four-man crews and work commenced on the erection of the five brattice seals.

A new sample tube, which had been lowered down No. 9 borehole, was extended inbye along No. 1 heading to a point just inbye of 23 c/t. The Brigade Area Superintendent, Mr. R. McKenna, assisted by Mr. D. Kerr, Moura Superintendent, co-ordinated the final sealing which included the installation of the brattice doors in seals No. 1 and No. 4. All roads were effectively sealed at 12:05 p.m.

Whilst these teams were underground the nitrogen rate was stepped up to 10 tonnes per hour. On returning to the surface, and due to the low nitrogen stocks at this time, the rate was brought back again to about 4 tonnes per hour. Supplies of liquid nitrogen were eventually exhausted and additional supplies were not expected before 6:00 p.m.

Although the effect of sealing and nitrogen injection brought the oxygen content in the Dip Workings down to about 16.5%, methane was being desorbed from the seam and carbon monoxide was being produced. Hence, an increase in the volume of these two flammable gases was noted. It was apparent that sufficient liquid nitrogen would not be available in time to reduce the oxygen level to below the "nose point" before the methane content in the vicinity of 24 c/t reached the explosive range. It was therefore decided to drill an additional borehole directly over the fire and inject nitrogen vapour onto it.

Borehole 10, with a target depth of 151 metres was commenced at 5:00 p.m. Following reports that holes 1 and 9 had deviated about three and one half metres to the South West over their length, the collar of this hole was off-set three metres from the centre line of 24 c/t. The importance of a straight hole was stressed to the drillers and it was specified that a 120 mm tri-cone bit be used.

Every effort was made to expedite the transport of liquid nitrogen from both Townsville and Brisbane. All road tankers would be under police escort and it was estimated that by 3:00 p.m. on Wednesday, 107 tonnes of liquid nitrogen would be on-site.

By about 9:00 p.m. sufficient liquid nitrogen was on-site to allow a continuous injection rate of 2 to 3 tonnes per hour. This rate was maintained and the vapour temperature was increased as high as possible with a view to attaining the maximum volume.

RECOVERY OPERATIONS - WEDNESDAY 23RD JULY.

An injection rate of 2 to 4 tonnes per hour, with a few minor exceptions, was maintained throughout the night. At 5:30 a.m. borehole sample results were as follows:-

| Hole | $O_2$ | $CH_4$ | CO |
|---|---|---|---|
| 2 | 14.5% | 4.6% | 270 ppm |
| 4 | 14.7% | 3.7% | 270 ppm |
| 5 | 14.1% | 5.9% | 250 ppm |
| 9A | 14.5% | 4.2% | 320 ppm |
| 9 | 18.2% | 1.7% | 130 ppm |

The completion of borehole 10 was now critical, for it was estimated that an explosive mixture of gases would be present in 24 c/t by 9:00 a.m. At 6:00 a.m. the hole was still 11 metres short of target. The hole cuttings were being flushed out with compressed air and water and it was recognised that this additional air may cause the fire to flare up on breakthrough.

To overcome this problem, a poly-pipe was run out from the vaporising unit to the delivery side of the drill's compressor. With four metres to drill, the compressed air supply was replaced by nitrogen at a pressure of about 500 kpa. The penetration rate was reduced slightly because of the lower pressure and drilling continued with extreme caution. At 8:20 a.m. the hole broke through, much to the relief of all persons present. There being insufficient time left to retract the drill rods and install a standpipe in the hole, nitrogen vapour at a rate estimated to be about 3 tonnes per hour was pumped through the drill stem.

There was now sufficient quantities of liquid nitrogen on-site with additional supplies in transit. It was therefore decided that every effort would be made to recover the twelve bodies today. The nitrogen injection rate was increased and five rescue teams were prepared and briefed for the recovery operation.

The basic plan was as follows:-

(a) Team 12 consisting of eight men and led by C. Glazbrook would prepare the bodies for transport by placing them in suitable body bags. Each bag would be carried outbye to 25 c/t No. 4 heading. There were two (2) men still to be located.

(b) Team 13, Captained by D. Gordon, would carry the body bags outbye from 25 c/t to the door in the brattice seal - a distance of about 200 metres.

(c) Team 14, led by R. Sudall, would monitor the atmosphere outbye of the sealed area and assist as required. The bodies, at this point would be loaded onto specially constructed Multi-Purpose Vehicle transport modules.

(d) Team 15, led by J. Blyton would remain at the F.A.B. and relieve team 13 when required.

(e) Team 16, Captained by I. Kraemer would remain at the F.A.B. and act as the stand-by team.

Mr. A. Pocock, Superintendent, was in charge of the F.A.B. and Mr. C. Russell and Mr. K. Guest were responsible for the transport of the bodies to the surface. There was a total of thirty-five men involved in the recovery operation.

At 11:00 a.m. the nitrogen injection rate was increased to 12 tonnes per hour and with the exception of minor problems with the cryogenic pump, this rate was maintained until 1:00 p.m. when it was reduced to between 4 and 5 tonnes per hour for the remainder of the exercise.

The oxygen levels in the panel at noon were as follows:-

| Hole | $O_2$ |
|---|---|
| 2 | 12.3% |
| 4 | 13.7% |
| 5 | 8.1% |
| 9A | 11.7% |
| 9 | 16.9% |

These results were acceptable and the teams were transported underground to the F.A.B. at 12:45 p.m. Here they were to await the 1:00 p.m. results which were as follows:-

| Hole | $O_2$ |
|---|---|
| 2 | 10.6% |
| 4 | 11.8% |
| 5 | 9.2% |
| 9A | 12.1% |
| 9 | 16.7% |

and the operation commenced shortly after.

Physical conditions inbye of 23 c/t were extremely arduous with high temperatures and humidity, very poor visibility and blast debris, which were all causing considerable discomfort. The first four bodies were bagged and carried outbye to 25 c/t No. 4 heading, but it was evident that the extreme conditions were having a detrimental effect on the team. The duties of the advance team were thus confined to locating and bagging the bodies and leaving them for pick-up by the carrying teams.

The final two bodies were located, one of which was jammed under the front of a shuttle car which had to be jacked up 50 mm before the body could be extricated. After having located and prepared all the deceased for transport, this team returned to the Fresh Air Base at 3:15 p.m.

Eventually all the remaining teams including the stand-by team were used to carry the bodies out to the transport module. During this stage of the operation, a serious malfunction occurred in the breathing apparatus worn by Mr. I. Kraemer. This suit was replaced by a Robert Shaw Therapy Unit and the team retreated outbye. About 70 metres inbye of the brattice seal and whilst negotiating a water filled swilly, the head of the therapy unit blew off and landed in the water. Mr. Kraemer could see the seal, so he held his breath and ran outbye to fresh air.

The last of the bodies were transported to the surface at 5:15 p.m. and delivered to the Qld. Police Disaster Victim Identification Unit which photographed the bodies, removed cap lamps, self-rescuers and other personal effects. The bodies were officially identified by the Undermanager, Mr. G. Mason and Sergeant First Class, D. Black, Moura Police and then transported to the Rockhampton Base Hospital by RAAF helicopter.

Rescue teams were debriefed and a detailed plan showing body positions and other relevant information was prepared before the men left the site. This entire operation proved to be extremely arduous and emotionally disturbing, however, all Brigade personnel performed their duties in a most commendable manner.

The "Mineshield" equipment was shut down at about 5:30 p.m. with about 15 tonnes of liquid nitrogen remaining in the the "mother tanker". Inertisation of the sealed area had been very successful and at no stage did the oxygen level exceed the "nose-point" during the entire recovery operation. Due to the forecast of heavy rain this equipment was relocated from the wheat paddock in which it had been parked to an adjacent hard stand area. It was prepared for use by about 2:30 a.m., Thursday. An injection rate of 2 tonnes per hour was maintained throughout the night.

The priority now, was to re-establish the Dip Section by:-

(a) extinguishing the fire at 24 c/t,
(b) rebuilding stoppings between intake and return roadways, and
(c) re-ventilating the workings.

Various alternatives were considered before it was decided to use fly ash to cover the heating. It was estimated that about 200 tonnes would be required to totally cover the known area. Arrangements were made to transport this product from the Gladstone Power Station to the mine. In the meantime, the injection of nitrogen vapour and water would be maintained. Hole 10 would be cased with 100 mm PVC prior to the injection of fly ash.

RECOVERY OPERATIONS - THURSDAY 24TH JULY.

The atmosphere in the sealed area was maintained at a stable level by the injection of nitrogen vapour and water. It appeared that this was sufficient to replace nitrogen loss through the brattice seals.

Hole 10 was cased and standpiped by about 7:00 a.m. and an attempt was made to pump fly ash into the hole. It was estimated that about 1 tonne was injected before the hole blocked completely. It was suggested that the heat immediately below the borehole may have melted the end of the PVC casing thereby blocking the hole.

A second drill rig was deployed to drill hole 11 adjacent to the blocked hole whilst the first rig attempted to ream out the casing and fly ash from hole 10. This work continued until hole 10 was cleared at about 9:00 p.m. Unfortunately, hole 11 missed the target and bottomed in coal. This occurred at about 11:00 p.m. and it had to be abandoned.

It was decided that an attempt would be made to pump fly ash down the inside of 50 mm drill rods as a substitute for the 100 mm steel casing which had failed to arrive. During the installation of these rods, hole 12 commenced adjacent to hole 11. Nitrogen injection continued at a rate of about 5 tonnes per hour.

RECOVERY OPERATIONS - FRIDAY 25TH JULY.

Nitrogen vapour was used to clear hole 10 and to drill the final four metres of hole 11. It was also used to pump the fly ash down the 50 mm rods, however, the first attempt failed and the rods became blocked. A 25 mm spear attached to a compressed air line was used to clear the rods and it was confirmed that condensation inside the drill stem had caused this blockage. High pressure/high temperature nitrogen vapour was used successfully to completely dry out the drill rods. The pressure was reduced and fly ash, at a controlled rate was injected into pipe range. This, although slow, was successful and the first truck load of fly ash was injected by about 6:00 p.m.

The injection of fly ash and nitrogen vapour continued throughout the night.

RECOVERY OPERATIONS - SATURDAY 26TH JULY.

Borehole 12 was completed about 2:00 a.m., however, it was still to be lined with 100 mm screwed, steel casing. Fly ash/nitrogen injection continued down borehole 10 and by early morning it was decided to send rescue teams into the mine with the following objectives:-

(a) To inspect the workings outbye of the seals.
(b) To set up a fresh air base at 21 c/t No. 4 heading.
(c) To double bag all seals and erect a suitable air lock in the seal in No. 4 heading.
(d) To install a compressed air de-watering pump in the swilly in No. 4 heading, between 22 and 23 c/t's.

Three teams, 17, 18 and 19, Captained by R. Sudall, J. Blyton and I. Kraemer, entered the mine about 9:00 a.m. and completed the above tasks by 10:45 a.m.

RECOVERY OPERATIONS - SUNDAY 27TH JULY.

By about 10:00 a.m. a total of 200 tonnes of fly ash had been injected down hole 10. Hole 12 was prepared for injection but not used. Nitrogen vapour continued to be injected down hole 6 at a rate of about 2 tonnes per hour.

Rescue team No. 20 led by I. Kraemer entered the sealed area and established that fly ash had completely covered the heated zone. There was no evidence of residual "hot spots". This team also inspected the stopping site between intake and return roadways.

Rescue team No. 21 Captained by L. Graham entered the sealed area at 12:30 p.m. and erected five brattice stoppings in the cut-through's between No. 4 and No. 5 headings before returning to the surface at 2:10 p.m.

## RECOVERY OPERATIONS - MONDAY 28TH JULY.

Rescue team No. 22 Captained by J. Blyton entered the sealed area at about 8:45 a.m. and completed the erection of the five remaining stoppings between intake and return roadways before returning to the surface at 10:45 a.m.

Having completed the repair of all stoppings necessary to provide a ventilation circuit, it was decided to send a team on a thorough inspection of all roadways inbye of the seals. The objectives being to ensure that no previously undetected "hot spots" remained and that it was safe to re-ventilate the area. L. Graham leading Team No. 23 completed this inspection and reported that the area was safe to ventilate.

Shortly after midday, men were stationed at the five seals and the short circuited stoppings outbye. This operation was co-ordinated by Mr. D. Kerr, Superintendent, and on his instruction, the outbye stoppings were closed and the five seals opened. All men were withdrawn to the surface immediately.

The injection of nitrogen vapour continued at a rate of 4 tonnes per hour until about 4:00 p.m., when sample results indicated that the atmosphere had returned to normal.

This completed the recovery operation.

A precis of rescue team Captains' Reports, One to Twenty-three, is shown in Appendix 21.

Sample results for the entire operation are shown in Appendix 22.

## THE INVESTIGATION

### GENERAL

With the completion of the recovery operation, the priority now was to determine the nature and cause of this explosion.

A preliminary examination of the workings indicated that an explosion of moderate force, had affected the face area and the roadways outbye, culminating in the destruction of the main fan casing.

A detailed investigation would be conducted by Officers of the Department of Mines' Inspectorate, with valuable assistance from:-

(a) Mine Management, Staff and Employees
(b) Workers' representatives
(c) Staff of the Safety in Mines Testing and Research Station
(d) Mr. C. Ellis, Senior Scientific Officer, Safety in Mines Section, Dept. of Mineral Resources, N.S.W.
(e) Dr. A.R. Green, Senior Projects Engineer (Combustion). Londonderry Occupational Safety Centre, N.S.W.
(f) Dr. A.J. Hargraves, Consultant Mining Engineer, Woolongong, N.S.W.
(g) Dr. A.F. Roberts, Director, Explosions and Flame Laboratories, Health and Safety Executive, Buxton, United Kingdom.

The primary objectives were to establish:-

(a) The extent of the flame and blast waves,
(b) the type and source of the fuel, and
(c) the source of ignition.

The extent of the flame and the force and direction of the blast waves would be determined by:-

(a) general observation,
(b) the examination of dust and heat damaged materials, and
(c) carefully recording the physical conditions in the section including the location of all major items of equipment and other materials.

Analysis of dust samples which would be collected systematically throughout the panel would provide valuable information on the type and source of fuel.

There are a number of possible ignition sources, these being:-

(a) fire or spontaneous heating,
(b) electrical apparatus,
(c) electrical cables,
(d) mechanical equipment,
(e) conveyor belt system,
(f) frictional sparking,
(g) electrostatic sparking,
(h) aluminium alloys,
(i) contraband,
(j) flame safety lamp,
(k) explosives,

each would receive due consideration by the investigation team.

## SALIENT FEATURES OF THE INVESTIGATION

### STATEMENTS AND RECORD OF INTERVIEW

In the days following this explosion, a total of 20 persons were interviewed by myself and Sergeant First Class, D. Black of the Moura Police. As a result of these interviews, statements were taken from the following persons:-

| | | |
|---|---|---|
| Mr. L.F. Cumner | - | Deputy Operations Manager and Acting Mine Manager at the time. |
| Mr. D. Fowler | - | Mine Manager |
| Mr. G.A. Mason | - | Shift Undermanager |
| Mr. A.J. Henderson | - | Fire Officer/Spare Deputy |
| Mr. E.C. Strong | - | Dip Section Deputy Afternoon Shift of 15th July, 1986 |
| Mr. J.W. Blyton | - | Mine Deputy, Night Shift of 16th July, 1986 |
| Mr. M.R. Caddell | - | 3 South Section Deputy Day Shift of 16th July, 1986 |
| Mr. W.O.B. Greaves | - | Mine Electrician |
| Mr. T.R. Faber | - | Mine Mechanical Engineer |
| Mr. G.J. Pickering | - | Mine Surveyor |
| Mr. G.R. Ziebell | - | Transport Driver |
| Mr. W.M. Foden | - | Junior Miner |
| Mr. R.A. Edelman | - | Junior Miner |
| Mr. S.J. Gamble | - | Machineman, Miner |
| Mr. J.R. Dullahide | - | Machineman, Supplies |
| Mr. C. Hughes | - | Machineman, Greaser |
| Mr. D. Atto | - | Lamproom Attendant |
| Mr. T.G. Vivian | - | Tradesman's Assistant |
| Mr. K.N. Guest | - | Deputy Moura No. 2. |
| Mr. C. Bayles | - | Conveyor Belt Patrolman |

The statements from the persons listed above, cover the events prior to and immediately after the explosion. They are at times repetitious, however, it would appear that they are consistent with observations made during the course of this investigation.

A precis of the statements, which are shown in Appendix 23, is as follows:-

Development of the mine which is owned and operated by Thiess Dampier and Mitsui Coal Pty. Ltd., commenced in the upper portion of the "C" seam in February 1978. Access to the mine is provided by three drives, two intakes and one return, which were driven down dip from the base of an abandoned open cut mine.

The "C" seam, West of a major fault zone contained high concentrations of methane gas, however, a methane drainage programme was carried out successfully.

Main roadway development ceased in April 1986, and partial extraction of the formed pillars commenced. This extraction was less than successful with the result that excessive abutment pressure loading was evident on the pillars outbye of the face. This forced a change in the extraction method.

Total extraction of the formed pillars commenced on 7th July, 1986. This continued without incident until the day shift of 16th July, 1986.

Prior to 16th July, regular inspections of the Dip Section were carried out by the Manager, Undermanagers, Mine Planning Engineer, Geologist, Surveyor, Inspectors of Coal Mines, District and Local Check Inspectors, Mine Deputies and experienced miners. No person detected the presence of flammable gas, however, some expressed concern about the abutment loading and the large area of goaf which was still standing.

A Deputy inspected the workings on two occasions during the night shift of 16th July, 1986. He reports that the goaf was very quiet, the area was well stonedusted and no flammable gas was detected. He advised the oncoming day shift that the conditions in the Dip Section were good.

Prior to the start of the day shift, a meeting between the Manager, Undermanager and the Section Deputy, Mr. K. Keyworth, was held to discuss the extraction of the wide fender inbye of 27 c/t, No. 2 to No. 3 headings. It was decided to reduce the width of the fender by mining a strip of coal about three metres wide and supporting the exposed roof with roof bolts, prior to the total extraction of the remainder of the fender.

In the hours which followed the Workings were visited by the Undermanager, from about 8:15 a.m. to about 10:15 a.m., the Mine Surveyor, the Transport Driver - three times, two Belt Patrolmen and on three occasions, by the Supply Vehicle Operator. The latter being the last person to leave the section approximately 13 minutes before the explosion.

All of the above report that the crew were in high spirits, mining conditions were good and all normal precautions were being taken. The Undermanager was of the opinion that the goaf would fall sometime during the day.

The mine monitoring system was checked at 10:30 a.m. This was in order and no abnormal $CH_4$ or CO values were noted.

Eight men were present elsewhere in the mine at the time of the blast. Most felt a strong pressure wave which caused their ears to pop. Only one man reported a very loud bang, others described the noise as a low rumble. Two men were caught in a severe wind blast and all reported thick grey dust.

Most of the men on the surface of the mine reported thick clouds of dark grey to black dust, however one man reported smoke and dust. No-one reported any noise.

A Section Deputy in the adjacent Moura No. 2 mine reported ground vibration at about 11:00 a.m. He was located about 1,350 metres away and about 55 metres below the Dip Section.

The main ventilation fan was damaged when the explosion doors and the internal turn baffles were blown out.

Two men attempted to explore the underground workings but they were forced to return to the surface by poor visibility and a strange smell.

During work designed to repair the damage to the main fan, high concentrations of carbon monoxide were detected in the return airway. This forced the suspension of repair work.

Two rescue teams entered the mine with one team penetrating the workings to 22 c/t. After reporting high concentrations of carbon monoxide, very poor visibility and severe blast debris they were withdrawn to the surface.

## IMPOUNDING OF DOCUMENTS

Following the explosion, mine documents including all Statutory Reports, Record Books, Shift Reports and Mine Plans were impounded for scrutiny. Listed in the table below is a description of the documents seized. Relevant extracts may be found in Appendix 24.

| DOCUMENTS EXAMINED | | EXTRACTS TAKEN |
|---|---|---|
| List of Officials, Moura No. 4 | - | Yes |
| Mine Manager: | | |
| Weekly Examination Reports | - | Yes |
| Mine Deputies: | | |
| Shift Reports | - | Yes |
| Pre-shift Reports | - | No |
| Return Airway Inspections | - | No |
| Inspectors of Coal Mines: | | |
| Mines Inspector | - | Yes |
| Electrical Inspector | - | Yes |
| Testing Officer | - | Yes |
| Union Inspectors | - | Yes |
| Ventilation Surveys: | | |
| May Survey | - | Yes |
| June Survey | - | Yes |
| Mine Monitor: | | |
| Daily Record | - | Yes |
| Methanometers: | | |
| Test Certificates | - | No |
| Electrical: | | |
| Shift Reports | - | Yes |
| Daily Test Reports | - | Yes |
| Engineers Weekly Reports | - | Yes |
| Rule 23 Routine Tests | - | No |
| Mechanical: | | |
| Engineers Reports | - | Yes |
| Shift Reports | - | No |
| Water Barriers: | | |
| Weekly Examination Reports | - | Yes |
| Firefighting: | | |
| Monthly Examination Reports | - | Yes |

IMPOUNDING OF DOCUMENTS (Continued)

| DOCUMENTS EXAMINED | | EXTRACTS TAKEN |
|---|---|---|
| Stonedusting: | | |
| Zone Plan | - | No |
| Dust Samples | - | No |
| Gas Samples: | | |
| Results of Monthly Analysis | - | No |
| Conveyor Systems: | | |
| Inspection Reports | - | Yes |
| Diesel Vehicles: | | |
| Daily Gas Tests | - | Yes |
| Monthly Tests | - | Yes |
| Mine Plans: | | |
| Ventilation | - | No |
| Sequence Plans | - | No |

## PHOTOGRAPHIC RECORD

A Queensland Government photographer, Mr. Robert Curran was employed to compile a comprehensive photographic record of the conditions in the mine.

The initial observations were that the damage throughout the Dip Section was widespread, however not all areas had been equally affected. It was therefore decided that a better understanding of the forces involved would be gained by photographing all relevant details prior to the commencement of the detailed examination.

A total of 227 photographs were taken. Of these 92 have been selected and are shown in Appendix 25.

INITIAL EXAMINATION OF WORKINGS.

Blast damage was evident throughout the main airways of the mine culminating in the destruction of the casing of the main ventilation fan. Three explosion doors were blown off and the internal turn baffles were blown about 25 metres. Refer Plates 1 and 2.

Close examination of the roadways inbye of the portals revealed heavy deposits of dark grey dust, rubbish, dislodged timber and steel objects scattered about. This debris increased markedly inbye of the Dip 3 conveyor drive head. The conveyor belt system was severely damaged and where belt rollers remained in place, these were covered with thick fine dust. Refer Plates 3 and 4.

The man and supply road, i.e. No. 4 heading, was littered with twisted steel supports, timber and other materials which were used to build the structures under the "Taj Mahal" between 22 and 23 c/t's. Electrical cables from the section transformer, which was located in 22 c/t No. 4 heading, had been flung outbye with considerable force. Refer Plates 5, 6, 7, 8, 9, 10, 11 and 12.

In the conveyor belt roadway, No. 3 heading, the damage to the belt structure was most severe. The force of the blast waves had broken the belt and structure inbye of 23 c/t, pushing most of it outbye to 21 c/t. This debris made access and examination very difficult and time consuming. Refer Plates 13, 14, 15, 16, 17, 18, 19 and 20.

By careful examination of the dust patterns on roof bolts and props it was possible to ascertain the direction of the strongest blast wave. These deposits were in many instances, on both sides of the prop or roof bolt and this could cause confusion and uncertainty. However, I am satisfied that blast wave direction as shown in this report, is accurate. Refer Plates 21, 22, 23 and 24.

Inbye of 23 c/t, visibility was improved greatly by a thin coating of fly ash which had drifted throughout the workings. This fly ash had been pumped down a borehole to cover a residual fire which was located in 24 c/t. It was recognized that the fly ash would have an adverse effect on the incombustible content of the dust in the workings. However, the improved visibility far outweighed this disadvantage.

Large items of equipment were found in No. 4 heading and the adjacent cut-throughs inbye of the "Taj Mahal". Some of these had been shifted a considerable distance and most had been subjected to considerable heat and physical damage. Refer Plates 25, 26, 27, 28, 29 and 30.

A Mine Rover, No. 9, was found inbye of 26 c/t No. 4 heading. This too, had been damaged by heat and the force of the explosion. A light-gauge, steel plate, later identified as a lid from the fitter's bench was found in the back of the Rover.

A similar steel plate was found in No. 4 heading about 300 metres outbye. This and many other smaller items found during this preliminary examination indicated a complex blast wave pattern. Refer Plates 31, 32, 33 and 34.

In 26 c/t from No. 4 to No. 3 headings, the vast majority of the blast debris was located adjacent to the lower or inbye rib, with most items displaying varying degrees of physical and heat damage. The shuttle cars, units 30 and 31, were located on the intersection of 26 c/t and No. 3 heading with S/C No. 30 shunted in 26 c/t No. 3 to No. 2 heading and S/C No. 31 close to the corner of No. 3 heading. The distance between the two cars was about 30 mm. An inspection of the operators' cabins revealed:-

| | S/C No. 30 | S/C No. 31 |
|---|---|---|
| Park Brake | on | on |
| Conveyor | off | off |
| Lights | on (rear bright) | Off |
| Traction | Fast | Off |
| Main Switch | Tripped | On |

There was no evidence to suggest that either shuttle car had been moved by the force of the explosion and I cannot explain the unusual parking position for S/C No. 31.

Following advice from rescue team No. 12, regarding the position of Mr. Steven Hull's body, the front of S/C No. 31 was closely examined by the investigating officers. There was no visible evidence which would suggest that Hull was struck by the car prior to the explosion, however, dust deposits in the immediate vicinity were consistent with a body being trapped in this position immediately prior to or during a severe wind blast.

A further eight bodies had been recovered from this area. Each location had been marked with reflective arrows, with the point of the arrow signifying the victim's head. Refer Plates 35 to 50.

A damaged 1000 volt cable was observed in 26 c/t between No. 3 and No. 4 heading. Refer Plates 51 and 52.

The Joy 12CM Continuous Miner was in No. 3 heading between 26 and 27 c/t's. It appeared that the machine had been withdrawn from the face in an orderly fashion. The slack miner cable and compressed-air hose had been positioned over the front and cutter heads of the machine. This is normal operating procedure when withdrawing machines from the face.

The operator's control switches were all in the reset position, however, this was normal practice when the power supply to the machine and its cable had been isolated or tripped back to the transformer. Before the power supply can be restored to the machine all the control switches must be in the reset position.

The machine is fitted with a mini methane monitor which interrupts the power supply to the machine automatically, should the methane concentration in the air around the machine exceed 2.0% by volume. When this occurs a "flag" will be displayed in a cubicle on the off driver's side of the machine. Before the power can be restored the deputy must unlock the control switch and reset the "flag". The control switches in the operator's cabin must also be set to the reset position before the power from the section transformer can be restored.

The monitor "flag" was not showing and the reset switch was locked. This would suggest that had the power to the machine been interrupted by the monitor, the "flag" had been unlocked and reset or, after withdrawing the machine from the face area, the operator had pushed the earth leakage or continuity button, thereby tripping the power from the machine and the cable. He then set all the control switches to the reset position. Refer Plates 53, 54, 55, 56 and 57.

Plates 58, 59 and 60 show the conditions in the face area. The M.P.V. supply module had been pushed inbye towards the rib and its load of props were scattered about. An inspection of the fender which was being extracted immediately prior to the explosion revealed that a lift, possibly the third, had been started. It is estimated that about one shuttle car load of coal had been removed from the lift prior to the Continuous Miner being withdrawn.

The roof of the cut-through, including the strip exposed when the width of the fender was reduced, had been well supported with roof bolts and butterfly plates, however, only two props remained in the immediate face area.

It was evident that the roof in this area had fallen sometime after the explosion. Fresh, clean sandstone was noted for a considerable distance inbye of the lip of the fall, whilst the underside of the fallen roof rock was burnt and sooty.

Inbye of 27 c/t the roof is intersected by a number of near vertical, well-defined strike slip faults. Refer Plates 61 and 62. The fresh, clean breaks in the sandstone would indicate that this area fell sometime after the explosion.

Further inbye of 28 c/t and beyond, evidence of fresh roof falls was observed, with the underside of fallen material burnt and sooty. Refer Plates 63, 64, 65 and 66.

The joint planes in the fallen roof material are very well defined, however, it was noted that the joint faces were not slicken-sided or greasy. Scratch marks were observed on the joint planes and in some instances these had been caused by roof bolts and butterfly plates. Refer Plates 67 and 68.

The conveyor belt was situated in No. 3 heading, ending about 15 metres outbye of 26 c/t. Damage to the system was extensive and there was considerable evidence which indicated blast wave movement in both directions. A heavy, well-constructed "grizzly" which had been positioned on top of the boot end structure had been thrown about 10 metres inbye, whilst the end plate of the boot end and the tail roller had been pushed outbye with considerable force. Refer Plates 69 and 70.

Outbye of the boot end, it was apparent that the top belt had been dislodged towards the South rib and the damage to the system increased markedly outbye of 25 c/t. Refer Plates 71, 72 and 73.

The remains of three miners' helmets which had been severely deformed by heat were found on the belt structure. One of these helmets had been wrapped around the troughing idler support whilst the remaining two were resting on the idler support brackets. Refer Plates 74, 75 and 76.

The fly ash which had been pumped down the boreholes to cover the fire area had assumed an angle of repose of about eight degrees. This had completely covered the belt structure at 24 c/t before tapering off about 20 metres inbye along No. 3 heading. Refer Plates 77, 78 and 79.

Outbye of 24 c/t, the damage to the conveyor system was most severe. Both the top and bottom belts had broken and these and most of the structure and rollers were missing. Refer Plate 80.

Evidence of high velocities present in this roadway was noted on the roof bolts, butterfly plates and the water barrier support brackets, had been bent outbye to an angle of about 45 degrees. Refer Plates 81 and 82.

Many examples of heat damage were observed and in the days which followed these would be closely examined, mapped and sampled. Four examples are shown in Plates 83, 84, 85 and 86.

In the stub end of No. 1A heading 25 c/t the remnants of a small fire was observed in the floor coal. This covered an area of about two square metres, however, there was no evidence which would indicate a deep-seated heating. Refer Plates 87 and 88.

Considerable floor heave had occurred in No. 1A heading between 25 and 26 c/t's. Refer Plate 89.

In 26 c/t No. 1 to No. 1A Headings, the goaf fall had broken off adjacent to the supported roof of the cut-through. The fallen material was burnt and sooty indicating that this fall had occurred immediately before or during the explosion. The flame had swirled about in the cavity and blast debris had been deposited against the goaf edge and on top of the fall. Refer Plates 90, 91 and 92.

STONEDUSTING REQUIREMENTS

Part eleven (11) of the General Rules for Underground Coal Mines, sets out the requirements regarding combustible dust and from the Table in Rule 11.4 (1), the Moura No. 4 mine must maintain an incombustible content of 72% in all ventilated roadways.

Part twelve (12) of these Rules deal with the sampling and analysis of combustible dust and it is a requirement of Rule 12.1 that the Manager ensure that a sufficient number of samples of the dust on every length of road are systematically collected and analysed at intervals not exceeding 30 days.

A search of our records has failed to produce evidence which would satisfy the above requirements. From these records a Stonedust Zone Plan has been prepared which details the date of the last sample and the incombustible content of each zone. See Appendix 26.

On 7th July, 1986, I inspected the mine including the conveyor belt roadways from the surface to the Dip Section. Although I made no mention of stonedusting in my report, I am satisfied that the standard of stonedusting throughout the mine was of a high standard.

## DUST SAMPLES

It was recognized that the introduction of flyash into the Dip Workings would increase the incombustible content of the coal dust to an artificially high level, therefore this indicator could not be used to determine the extent of the flame. Coal dust does however, contain volatile matter and when this dust is exposed to heat or flame it loses some of that volatile matter. Therefore if the loss of volatile matter in the coal dust remaining after an explosion is determined, an approximation of the extent of the heat and flame may be made.

Due to high blast velocities and turbulence the behaviour of coal dust in this explosion is not known and it would be fair to assume that the dust may have been carried for great distances. It is also possible that turbulence or swirling may cause completely erroneous results, however this indicator has been successfully used by Ellis in his investigation of the Appin and West Wallsend explosions in New South Wales.

Initially, a total of 105 dust samples were collected from the mine and the percentage of dry ash free volatile matter (% DAFV) remaining in the minus 250 micrometre portion was determined. Spot samples of about 500 grams were collected from the ribs with a similar quantity collected from the floor to a depth of about 30 mm.

The volatile matter content of run of mine coal from Moura No. 4 had been established as 32.2% in December, 1985, whilst the volatile content of post explosion coal dust ranged from 18.5% to 34.6%.

The results of the initial sampling programme indicated a lower post explosion volatile content in the dusts inbye of 26 c/t, however, it was apparent that there was insufficient data available for the roadways immediately outbye of 27 c/t. It was therefore decided to resample this area to rectify this problem. A total of 55 additional samples were collected from the floor and ribs of the roadways immediately outbye of 27 c/t. Floor samples in this sampling programme were taken to a depth of about 6 mm.

The volatile content of the minus 250 micrometer portion of these samples ranged from 20.2% to 35.5%.

A graphic presentation of Dry Ash Free Volatile Content of the post explosion coal dust is shown in Appendix 27.

This interpretation may not be entirely valid, however, it is felt that this method provides a better understanding of a complex problem.

## EXTENT OF THE FLAME

There were many examples of heat and flame damaged materials throughout the Dip Workings, however, it would appear that the temperature, duration and path of the flame was extremely variable.

The best indicators were plastics, insulation, rubber hoses, brattice, synthetic rope, coked coal dust and teflon friction washers which are used between the nut and the steel washers of roof bolts.

Miners' helmets had been completely deformed and plastic items such as lunch bags and sandwich boxes had melted, however newspaper found in the immediate vicinity was undamaged or only slightly charred at the edges.

There was no evidence of flame damage to the insulation surrounding electrical cables in the immediate face area, however, blistering of insulation surrounding small electric light cables and telephone wires was noted about 15 metres outbye of 23 c/t.

Teflon friction washers were severely damaged in some areas, see Plate 83, whilst other washers in the immediate vicinity appeared unaffected. This and many other examples of varying degrees of heat damage depict a very complex and sometime confusing flame path.

From the evidence collected and the observations made, during the many days of this investigation, a plan showing the extent of the flame is included in Appendix 28.

ARREST OF THE EXPLOSION

There was no evidence of flame nor in-situ heat damaged materials, outbye of 22 c/t however, there was evidence of weak flame at points about 20 metres outbye of 23 c/t.

It is therefore concluded that the explosion was arrested in the vicinity of 23 c/t. There are a number of possible reasons for this, e.g.

1. A water barrier was located in No. 3 heading, just inbye of 23 c/t.
2. The cross sectional area of the roadways between 22 and 23 c/t's was less than that inbye of 23 c/t.
3. Roadways 1, 2, 3 and to a lesser extent 4, had appreciable quantities of water trapped in depressions.
4. The standard of stonedusting in the panel was normally high.

The water barrier in No. 3 heading was a G.K.N. Engineering type, which is constructed of 200 mm wide, Z-shaped galvanized steel, tub support stringers which are suspended from the roof by chemically anchored roof bolts. The tubs were a clear plastic type with a volumetric capacity of 80 litres each.

There were eight (8) equally spaced rows and a total of 47 tubs. Assuming a fill factor of 90%, this barrier would contain about 3,380 litres of water.

This installation was inspected by myself on 7th July, 1986, and I was completely satisfied that the barrier had been maintained to an acceptable standard.

Mining conditions through the P2¼ fault, which intersects the seam between 22 and 23 c/t's, were difficult, with friable roof, ribs and soft floor all being experienced. These adverse conditions forced operators to reduce the width of the roadways considerably and the soft floor and vertical displacement of the seam produced an undulating roadway profile in the five headings.

The reduced cross-sectional areas and undulating profiles, may have contributed to the arrest of the explosion by causing the static pressure inbye of 23 c/t to rise, thereby retarding blast waves and making them less effective in the raising of coal dust. This would tend to reduce the amount of fuel available for the following flame front.

It would appear that the water barrier, the reduced cross-sectional area and the high standard of stonedusting has prevented this explosion from propagating throughout the mine.

BLAST WAVES

The extent of the blast damage is graphically depicted by the photographs contained in Appendix 25, however, these photographs fail to show the very complex nature of the blast waves.

There is considerable evidence which would suggest that blast waves have been multi-directional inbye of 24 c/t and in particular roadways 1, 2, 3, 4 and to a lesser extent 5. Blast waves in the cut-throughs displayed distinct swirling patterns whilst those in the headings were more streamlined.

Blast patterns in the roadways adjacent to the crib room, i.e. 26 c/t No. 4 to No. 5 headings, were very complex and sometimes confusing. It would appear that severe turbulence had displaced both small and large items in all directions, e.g.:-

1. Steel tool box lids, from the fitters bench, were located in No. 4 heading between 20 and 21 c/t and in the back of the Mine Rover.
2. Glass from the crib room table lights was found in the north rib of No. 3 heading between 26 and 27 c/t, whilst the flameproof ends of the light were located adjacent to the inbye rib of 26 c/t No. 3 to No. 4 headings.
3. Other flameproof lights from the crib room area were located between 24 and 25 c/t's No. 4 heading.
4. An M.P.V. supply module loaded with timber props had been parked in 25 c/t adjacent to the brick stopping between No. 4 and No. 5 headings. This had been moved from one side of the roadway and deposited upside down adjacent to the inbye rib of 25 c/t, No. 3 to No. 4 headings. On closer examination it was revealed that this module had also been turned end for end.

Similar observations were made in roadways 1, 2 and 3. Blast debris had been impacted against the goaf edge in 26 c/t from No. 1A to No. 2 headings and an examination of the top of the goaf fall revealed broken props, wedges and an empty stone dust bag.

In No. 3 heading the "grizzly" from the top of the boot end was located upside down and about ten metres inbye of the boot, whilst the small angle iron stand which had been located immediately adjacent to the boot was found outbye of the boot end and on top of the bottom conveyor belt.

The Deputy's Flame Safety Lamp was located under the body, and behind the off driver's side front wheel of S/C No. 31, and his Automatic Firedamp Detector (A.F.D.) was located about ten metres inbye of the rear of S/C No. 31. Other personal effects, e.g. glasses and a ball point pen were found inbye of S/C No. 31.

A plan showing the known location of various items immediately prior to the explosion has been prepared and is shown in Appendix 29.

The Mine Surveyor, Mr. G. Edwards and his team conducted a detailed survey of No. 3 and No. 4 roadways and plotted the post explosion location of all major items of equipment. This plan, described as the Moura No. 4 Disaster Plan is shown in Appendix 30.

Mr. Edwards was also responsible for a plan which details the surveyed location of damaged stoppings. Two types of stoppings were erected in the cut-throughs between intake and return roadways. Four stoppings were constructed of mesh and a plaster product "Rockhard". These were located in the cut-throughs outbye of 20 c/t. The remainder of the stoppings were constructed of "rock blocks" and mortar. Individual blocks measured 400 x 200 x 100 mm and weighed about 22 kg. A copy of this plan is shown in Appendix 31.

As a result of observations made during the course of this investigation, a plan detailing the direction of the major blast waves has been prepared and is shown in Appendix 32.

## TYPE AND SOURCE OF FUEL

There is no doubt that all the roadways, including the goaf area, inbye of 23 c/t were affected, to varying degrees, by flame. The total volume of flame has been assumed to be about 100,000 cubic metres, which may have resulted by the ignition of about 20,000 cubic metres of a seven (7) percent mixture of methane and air. This would represent a pure methane volume of about 1,400 cubic metres.

It is unlikely however that the fuel in this explosion was methane only. The floor of the roadways in the Dip workings was predominantly coal and although it would appear that every effort was made to treat the floor dust with incombustible matter and water, it is most likely that both gas and coal dust were involved. The quantity of methane in this case would be much less.

Trickett's ratio calculations of post explosion gases may be used to estimate the type of fuel involved in an explosion. The theory is widely accepted, however a limiting factor is that the samples used for such calculations must be taken shortly after the explosion. Samples were collected from the main return portal at 2:15 p.m., some three hours after the explosion and I have been advised that Trickett's ratio calculations for these samples would be valid. Reference, Strang and MacKenzie-Wood: A Manual on Mines Rescue, Safety and Gas Detection.

$$\text{Trickett's Ratio (T.R.)} = \frac{CO_2 + .75\ CO - .25\ H_2}{.265\ N_2 - O_2}$$

(i) Explosions

| | |
|---|---|
| TR = 0.5 | If methane was the only fuel |
| = 0.87 | If coal dust was the only fuel |
| = 0.5 - 0.87 | If both methane and coal dust were involved. |

(ii) Fire

| | |
|---|---|
| TR = 0.4 - 0.5 | If the fuel was methane only |
| = 0.5 - 1.0 | If the fuel was coal, oil, conveyor belting, insulation or polyurethane foam. |
| = 0.9 - 1.6 | If the fuel was timber. |

Trickett's ratio calculations for the three samples mentioned above were 1.176, 1.138, and 1.049, respectively. This would suggest that an explosion, followed by a fire, had consumed methane, coal dust, and possible coal, oil, conveyor belting, insulation, polyurethane foam and wood.

Considerable evidence was found which indicated that coal dust, coal, oil, insulation, polyurethane foam and wood had been consumed by the explosion and the fire which followed.

The only other alternative is the ignition of a dense coal dust cloud which may have been raised from the floor by a fall of the goaf or some other violent event. Although such events are extremely rare, it has been shown experimentally that it is possible to ignite a pre-formed coal dust cloud of suitable composition.

There are therefore, two possible fuel types, viz:-

(a) a mixture of methane, air and coal dust, and

(b) a dense cloud of coal dust with no or minimal methane present.

A major problem with hypothesis (a) is; Where did the flammable gas come from?

The Dip Workings had been statutorily inspected by Mine Deputies and others on very many occasions prior to the explosion. There was however, no record of any methane being found in excess of 1.0% since 29th March, 1986.

With the exception of a relatively small fall, the goaf area was still standing immediately prior to the explosion. Therefore the only cavity which may have contained appreciable quantities of flammable gas was located about 40 metres inbye of the face. It has been estimated that the volume of this cavity would be approximately 1,200 cubic metres.

A methane drainage programme had been undertaken and this, coupled with the fact that partial extraction of the formed pillars had been in progress for about three months, would support the belief that the pillars were winded of flammable gas.

The Dip Section, as the name implies, had been worked to the dip of the seam which was, for the area inbye of 26 c/t, about 5.7 degrees. Methane gas, being much lighter than air, would therefore migrate up dip and be diluted by the ventilation current.

Ventilation in the Dip workings was very good with a total volume of 62 $m^3$/sec. available. This quantity was measured during the last ventilation survey which was carried out on 24th June, 1986. There was no evidence which would indicate that a similar volume was not available on the morning of the disaster.

Assuming that the ventilation flowing in the North and South returns remained fairly constant, at 28 and 34 cubic metres/sec. respectively, then a methane desorption rate for days prior to the explosion would be as follows:-

1. Monday 14th July, 1986 = 0.085 $m^3$/sec.
2. Tuesday 15th July, 1986 = 0.116 $m^3$/sec.
3. Wednesday 16th July, 1986 = 0.153 $m^3$/sec.

The above values are fairly low, therefore it is concluded that a major failure of the ventilation system would have had to occur, before appreciable accumulations of flammable gas were present in the Workings. There is no evidence which would indicate that such a failure occurred prior to the explosion.

In an attempt to solve the problem, "Where did the flammable gas come from?" Dr. A.I. Hargraves was commissioned to conduct an investigation into the source of the gas. A copy of his report is shown in Appendix 33.

Dr. A.R. Green, a Combustion Engineer attached to the Londonderry Occupational Safety Centre in New South Wales, was also commissioned to assist in this investigation. Dr. Green's report is shown in Appendix 34.

## SOURCE OF IGNITION

There are a number of possible ignition sources, these being:-

(a) fire or spontaneous combustion,
(b) electrical apparatus and cables,
(c) mechanical equipment including the conveyor belt system and aluminium alloys,
(d) frictional sparking,
(e) electrostatic sparking,
(f) contraband,
(g) the flame safety lamp, and
(h) explosives.

FIRE OR SPONTANEOUS COMBUSTION

Evidence of fire, was found in 24 c/t, No. 2 to No. 3 headings and at the stub end of No. 1A heading, 25 c/t, after the explosion. There is, however no evidence to suggest that these fires, or a heating was present prior to the explosion.

The mine monitoring system was functioning normally and the highest reading of Carbon Monoxide (CO), recorded prior to the explosion was 2 ppm. This is not consistent with the quantities of CO which would be produced by a fire or heating.

The "C" seam coal at Moura No. 4 has a low to moderate propensity to spontaneous combustion. This was confirmed by Humphreys, D., in a 1983 A.C.I.R.L. Report on the spontaneous combustion characteristics of the "C" and "D" seams. Dr. Humphreys concluded that the "C" upper seam had a low propensity, "C" middle a low to moderate propensity and the "C" lower had a moderate propensity to spontaneous combustion.

Finally an inspection of the conveyor belt system had been completed about two hours prior to the explosion. This did not produce any evidence of fire or heating nor was any defect likely to cause a fire or heating found.

It is therefore concluded that the fires, located in 24 c/t and in the stub end of No. 1A heading, were a result of this explosion.

ELECTRICAL APPARATUS AND CABLES

An initial examination of all electrical apparatus and cables located in the Dip Section failed to detect obvious defects which may have produced an electrical arc or spark capable of igniting an explosive mixture of gas and/or coal dust.

Mr. A. McMaster, Electrical Inspector of Coal Mines, was responsible for this phase of the investigation and his detailed report is contained in Appendix 35.

MECHANICAL EQUIPMENT, CONVEYOR SYSTEM AND ALUMINIUM ALLOYS

Mr. A.M. Hepburn, Principal Mechanical Inspector of Coal Mines, was responsible for this phase of the investigation and his interim findings are contained in Appendix 36.

## FRICTIONAL SPARKING

There have been a number of explosions and ignitions of methane/air mixture caused by what is loosely termed "frictional sparking".

The vast majority of these events have occurred as a result of the picks of coal cutting machines striking quartzitic type rocks or ironstone inclusions. It is believed that other explosions have been caused by objects with a high aluminium and/or magnesium content striking rusty steel. It is also believed that other explosions have resulted when sandstones with a relatively high quartz content have been rubbed together, or struck violently by steel objects or other like rocks.

There are therefore, two basic types of frictional ignition, viz:-

(a) pure frictional sparking, and
(b) incendive sparking.

When machine picks or like objects strike rocks of suitable composition, or when such rocks are rubbed together violently, the heat produced by either sparks or very hot surfaces may be sufficient to ignite flammable mixtures of methane and air.

This reaction is termed "pure frictional sparking" and it differs from incendive sparking in that the spark or hot surface produced, would normally cool very rapidly. Another factor which must be considered is the surface area of the spark or hot surface. Numerous experiments have been conducted which strongly suggest that the larger the surface area, the lower the temperature required to ignite flammable mixtures of methane.

Incendive sparking is a chemical reaction which occurs when aluminium or its alloys are struck by rusty steel or vice versa. The heat produced develops rapidly until the particle is totally consumed. It is therefore possible for very high temperatures to be produced whilst the surface area may remain very small. It is for this reason that aluminium and magnesium alloys are prohibited in Queensland's underground coal mines.

Aluminium objects were located in the Dip Section after the explosion and one of these, an Entonox (analgesic gas) bottle, will be discussed in detail in Mr. Hepburn's report. Other objects were found on the Mine Rover and locked in the fitters bench. A detailed search of all other roadways failed to detect any other aluminium objects.

The Continuous Miner was not operating at the time of the explosion, therefore, frictional sparks produced by this machine have not been considered.

There are at least two other possible sources of frictional ignition, e.g.:-

(a) hot surfaces resulting from large blocks of sandstone rubbing together, and
(b) incandescent sparks resulting from stone striking stone, or steel objects such as roof bolts or butterfly plates.

As early as 1928, Burgess and Wheeler concluded that ignitions of methane were possible when various types of sandstone were rubbed together. They also concluded that highly quartzitic sandstones produced ignitions more readily than sandstones with a low quartz content.

Experiments by a number of researchers since this date have concluded that quartz content, particle size and the strength of the sandstone are extremely important. The incendive temperature potential is high for rocks with a quartz content of 50% or more, intermediate for quartz content of 30% to 50% and negligible for rocks with a quartz content below 30%. The risk of high temperature sparks is much greater if the grain size is greater than 5 microns.

The roof of the "C" seam consists of massive and cross-bedded sandstones, light grey siltstones, grey shales and minor conglomerates. Petrological examination of a number of samples taken from the roof of the "C" seam would suggest that the rock is predominantly, richly feldspathic sandstones with sericite and carbonate as alteration minerals and cement. The maximum quartz content, as determined by the Petrological examination of seven samples is five percent. Petrological reports for the seven samples are shown in Appendix 37.

Whilst inspecting the Dip Section with Dr. A.F. Roberts Mr. G. Hardie, Chief Inspector of Coal Mines, Mr D. Fowler, Mine Manager and others on 23rd September, 1986, a sample of rock was selected at random from the edge of the goaf in 27 c/t, No. 3 to No. 2 headings. This sample was broken to a reasonable size and given to Dr. Roberts for detailed examination and testing, at the Buxton U.K. Explosions and Flame Laboratories of the Health and Safety Executive.

Dr. Roberts has since advised that this sample contained a quartz content of about 69%. This rock was tested by Mr. F. Powell an assistant to Dr. Roberts and his report stated:-

"The rock sample received was light in colour and did not crumble in the hands. It was, thus, a fairly strong rock and it proved fairly difficult to cut with a hack-saw. When pressed against a workshop grindstone wheel, the sample produced bright yellow heating and the surface of the rock was glazed where the rubbing had taken place.

These simple tests indicated a rock of the type likely to be involved in frictional ignitions i.e. a fairly strong with a fairly high quartz content.

This was confirmed by carrying out the grindstone test once more when it proved possible to ignite a bunsen burner (fed with methane) by the hot surface produced on the rock sample. (This is something not easily done, even with Darby Dale sandstone)."

It would therefore appear, that lenses of previously undetected quartzitic sandstones are present in the strata above the Dip Workings.

The roof is intersected by a number of strike slip faults which strike almost North, South and dip almost vertically with very little if any vertical displacement. Associated with these strike slip faults are vertically dipping slips which also display no vertical or lateral displacement. Examples of these unique structures are shown in Plates 61 and 62.

The behaviour of strata intersected by such structures during a major roof fall, is unknown, but it would be fair to assume that very large vertical faces to a height of at least eleven metres were exposed to the atmosphere during or immediately after the goaf fall. It would also appear that there was very little if any lateral movement of the strata during the fall. The rubbing friction, would therefore produce high temperatures over a large surface area. It is also important to note that the area intersected by these slips and strike slip faults was above or immediately adjacent to a cavity. This cavity being the only possible place where methane may have accumulated in the goaf.

There are also examples of vertical sandstone faces coming into contact with roof bolts and butterfly plates. Refer Plate 67. There is no doubt that this incident occurred after the explosion, but it does demonstrate that this roof may fall adjacent to a roof bolt. The heat produced by a butterfly plate, in contact with a sliding vertical face over a much greater distance, would depend on the quartz content and the grain size of the sandstone. This unfortunately is unknown.

A plan detailing the known geological features of the Dip Workings is shown in Appendix 38.

There is no doubt that a goaf fall occurred immediately prior to or during the explosion. This initial fall was followed, some days later, by subsequent falls of ground adjacent to and inbye of 27 c/t No. 3 to No. 2 headings.

A plan detailing the approximate caving sequence is shown in Appendix 39.

## ELECTROSTATIC SPARKING

There have been several accidents in coal mines caused by the discharge of electrostatic sparks.

The vast majority of these incidents have been caused by static electricity developed by dust-laden, compressed air lines, conveyor belts and compressed air venturi blowers.

An examination of the conveyor belting and compressed air hoses revealed that they were F.R.A.S. i.e Flame Resistant, Antistatic. The Mechanical Engineer advised that only F.R.A.S. belting and hoses are purchased.

It would appear that the only compressed air being used at the time of the explosion was that used to operate the face trickle duster.

It is therefore concluded that electrostatic sparking was not involved in this disaster.

CONTRABAND

Contraband is normally defined as any article which is prohibited in underground coal mines, e.g. matches, cigarette lighters, naked lights, aluminium alloys and electronic watches.

A search of the bodies failed to locate any item which contributed or was likely to contribute to this explosion. There were however three electronic watches located after the explosion. Two of these were examined and tested at the S.I.M.T.A.R. laboratory and certified safe. The remaining watch, a Citizen Digital, was removed from a body by the Pathologist during post-mortem examination. Sergeant First Class D. Black of the Moura Police has advised that this watch was still operating prior to the removal of the body from the mine site. He has also advised that this watch was buried with the body.

Aluminium alloys are discussed elsewhere in this report.

FLAME SAFETY LAMP

The Deputy's flame safety lamp was recovered from beneath S/C No. 31. Although it was intact, it was apparent that the lamp had been damaged by the force of the explosion. The base of the lamp and the carrying hook had been deformed and it is concluded that the damage was consistent with the lamp being torn from the Deputy's belt and striking the shuttle car.

The inside of the lamp was completely filled with very fine coal dust, however, much of this was lost when the lamp was picked up. The fact that the lamp was full of dust is not remarkable, for it was obvious that it had been exposed to high blast velocities.

After a preliminary examination this lamp was forwarded to the S.I.M.T.A.R. laboratory for detailed scientific evaluation and testing. The results of which are contained in the S.I.M.T.A.R. Report.

All other flame safety lamps in use at the mine were inspected by myself and Mr. R. McKenna, Area Superintendent of the Central Queensland Mines Rescue Brigade. This inspection confirmed that, although a number of lamps were dirty from normal use, all were considered safe.

It is important to note, that about two years ago a routine inspection of flame safety lamps at the Moura underground mines revealed a number of lamps which had been poorly maintained. Regular inspections since that time would indicate that the standard of maintenance has been maintained at a satisfactory level.

EXPLOSIVES

Explosive devices had not been used in the mine and in particular, the Dip Section for a period of about two years. It is therefore concluded that explosives did not contribute to this explosion.

## CONSULTANTS REPORT

Dr. A.F. Roberts, Director of the Explosions and Flame Laboratories, Health and Safety Executive, Buxton, United Kingdom, was commissioned by the Department of Mines to make an assessment of the investigation and advise on what additional works, if any, should be undertaken. He was also requested to forward any views which he may have on the nature and cause of the explosion.

Dr. Roberts' four part, Consultant's Report is enclosed in Appendix 40.

## GENERAL OBSERVATIONS

This explosion, which caused the loss of twelve lives, was totally unexpected and it occurred without warning.

Having failed to isolate and identify an obvious ignition source in the workings outbye of the goaf edge, I am of the opinion that an initial ignition of methane occurred during a goaf fall in the area between No. 1A and No. 3 headings and 27 to 28 c/t's. The most likely ignition source being the hot surfaces of the vertical slip planes which resulted from rubbing friction generated during the fall.

This weak ignition, propagated outbye along the intake roadways and the South return, before developing into a coal dust explosion, which peaked in violence on the conveyor belt roadway at about 24 c/t. The sudden increase in static and dynamic pressure at this point would cause blast and flame waves to travel violently in all directions.

There would appear to be no doubt that the water barriers and the standard of stonedusting throughout the Dip Section contained this explosion and prevented it from propagating throughout the mine.

I am also of the opinion that a tragic accident may have occurred immediately prior to the explosion. It is conceivable that during the withdrawal of the machines from the face due to an impending goaf fall, Mr. Steven Hull, the least experienced man, was struck by S/C No. 31 and pinned beneath it. I do not, however, believe that this event, if in fact it did occur, contributed in any way to the death of the men in the section.

SIGNED:

J.P. Brady

J.P. BRADY
INSPECTOR OF COAL MINES