CHAPTER 5

THE INVESTIGATION OF A COAL MINE EXPLOSION

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FORENSIC SCIENCE EXAMINATION OF RECORDS AT MOURA NO.4 MINE EXPLOSION, 1986

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5.1 Investigation of a Coal Mine Explosion

An investigation of a coal mine explosion involves an objective analysis of all the relevant factors. The prime responsibility for making the necessary investigation lies with the Inspectorate of Coal Mines. Many branches of science, engineering and medicine including forensic science and forensic pathology assist in the investigation process.

This chapter discusses the scientific methods used over many years to establish the course, nature and immediate cause of a coal mine explosion. The contribution of forensic pathology is discussed and the application of forensic science.

5.2 Methods of Examination at the Mine

According to Tideswell [19] *"The tracing of the course of a mine explosion to its source and the determination of its nature are often surprisingly difficult. There are two complementary methods of approaches. One, the intuitive approach, is based on experience and knowledge of the pit and of the mining operations in progress; the other, the analytical approach, which is the peculiar task of the scientist to follow, is based on a dispassionate survey of all the evidence recoverable. Both approaches are needed and must be related. The intuitive approach suggests the most likely answer, but taken alone may lead to conflicting views. Moreover, experience teaches that the apparent explanation is not always the true one and that the most unlikely events may have contributed. Meticulous documented evidence is needed to establish the course of events and it is important that the immediate observations, on which the conclusions are based, should be as comprehensive and as accurate as possible."*

Observations are made concerning:

- Violence.
- Burning.
- Fires.
- Coked dust.

- Explosion Dust.

- Composition of Roadway Dust.

- Collection of Specimens and Samples.

5.3 Use of Forensic Pathology in Coal Mine Explosion Investigation

Identification of the body has important psychological significance to the next of kin and is also important for legal implications. Visual identification is normally used but this may not be possible when bodies have not been recovered for some months. In such cases the forensic pathologist relies on dental records and X-ray data to establish the identity of the deceased.

Establishing the time of death is usually reasonably accurate in the case of an explosion when the consequences of the explosion cause damage to the main fan, disrupt the power supply, telephone system all of which are usually indicated at the surface of the mine.

The manner of death, or the way in which a person met his death can be classified into natural, accidental, suicide, homicide or undetermined. In the case of a coal mine explosion the deaths are classified as accidental.

The cause of death is the most significant underlying pathological entity which led directly to death. Other conditions which did not cause death directly are considered to be contributing factors. Experience in many countries that have experienced coal mine explosions record the cause of death as injuries, burns, or asphyxia or in some cases a combination of all three.

The cause of the accident can only be determined after all factors have been considered and also the results of an internal and external examination of the body, clothing and other personal effects. It would normally be necessary to send the clothing to another laboratory so that fibres in the cloth can be examined for evidence of exposure to flame or heat, or both.

If at all possible the forensic pathologist should visit the scene of the accident.

Forensic examination may provide information on the magnitude, direction and duration of the force from the explosion pressure wave as well as some idea of the temperature to which the body was exposed.

Toxicology can assist in identifying the presence of any drugs, including abused substances, alcohol and those prescribed medically.

The forensic examination can also give information on whether the victim survived the initial explosion, and if so the time of survival, whether the injuries were survivable and also whether the victim was conscious or unconscious after the event. Whether or not the victim had used the self-rescuer and its effectiveness may also be determined.

Dust and soot in the respiratory tract and also carbon monoxide in the blood indicate the victim was breathing after the explosion.

Carbon monoxide levels may reach as high as 10% after a methane or coal dust explosion and at this concentration blood saturation of carboxyhaemoglobin in excess of 50% would occur in 50 seconds or less. Carbon dioxide levels may also reach a level at which hyperventilation occurs. Oxygen may be as high as 5% after an explosion but may be as low as 1% depending on the strength of the explosion and other factors.

In one other way an examination of lung tissue from the victim will give a measure of the presence of pneumoconiosis. This information when related to dust exposure measurement can determine the effectiveness of dust control technologies and provide data on particle size distribution.

5.4 Forensic Science Examination of Records at Moura No.4 Mine Explosion 1986

Introduction

The remainder of this chapter places the work of the forensic scientists into perspective and describes the background of the information used from the Moura No.4 explosion. The second part of the chapter focuses on the work of the Forensic Science Laboratory, Victoria and gives details of the effects of the explosion on the mine, equipment and the forensic pathology of the victims.

The discussion covers analysis of the effects of blast and heat on equipment, including the flame safety lamp and the forensic pathology of the victims. The aim of the work is to relate patterns of inquiry to the course of the explosion using details from the post-mortems, photographic evidence and expert evidence. In describing injuries to the victims of this disaster there is a full understanding of the sadness of the relatives, miners and mines rescue teams.

The full examination of each victim of this disaster is rigorous in its detail. This is done not only to describe what has happened to one group of victims but to try to ensure that other miners do not become victims in the say way.

The mining industry is one of the most safety conscious industries in the world and no-one works underground without concern for the safety of everyone else. There is in the industry a real commitment to ensuring that everything possible is done to protect life.

It is the purpose of this chapter to open the field of forensic science for the mining industry and to describe the contribution of the specific pathological findings towards understanding the direction and source of an underground explosion. It is only with this information that work can start to be done to protect other miners from a similar incident.

5.4.1 Forensic Science

Forensic science provides an objective analysis of an incident using relevant scientific procedures which are co-ordinated and generally following an established procedure.

A description of the main assumptions used in scientific investigations of explosion has been provided by Yallop [20] who was head of the Explosives Forensic Science Laboratory at Woolwich Arsenal.

In explosions, examination of the damage is the usual starting point of an investigation into the cause of the explosion. Observable damage may be divided into permanent distortion of objects, displacement of objects and flame and heat effects.

With a dispersed explosion the region of maximum damage may be remote from the explosion centre. As the explosion progresses it encounters objects with resistance and this increases the turbulence and the speed of propagation and hence the pressure. The region of maximum damage is likely to be remote from the explosion centre.

Investigators can make estimates of pressure from purely theoretical calculations using values for the gas concentrations.

However the more reliable method according to Yallop is to use observations from the scene to estimate pressures actually generated. Information is also available from fragments at the scene. Yallop [20] states:

"It is a cardinal principle of explosion investigation that as many primary fragments as possible should be recovered for examination."

The damage caused by primary fragments can sometimes be used to determine the direction in which the fragment was travelling. The fragment can be examined for penetration, gougemarks and pitting.

Yallop further describes the approach to the scene of an explosion. He says:

"Fire fighters and rescue workers must, in the course of duty, take calculated risks. While the first explosives expert on the scene must not attempt to tell such people how to do their job we would be failing in his responsibilities if he did not place at their disposal his specialist knowledge of the dangers involved. ... It is vital that at the earliest possible moment the scene should be 'frozen'; that is preserved in the immediate post explosion state."

Yallop's advice is that the more spectacular the explosion the more likely it is to attract high ranking police or military officers or politicians. Such visits serve no useful purpose and are liable inadvertently to destroy evidence and should be resisted tactfully with a brief explanation of the need for the apparent discourtesy.

5.4.2 Forensic Pathology

Forensic pathology describes the injuries on the victims from the explosion and provides an understanding of the circumstances in which victims have died.

Marshall [21] provides a comprehensive description of the analysis of explosion injuries. It involves the recovery of the parts of the body that remain after an explosion, the identification and an investigation of the cause of death.

In explosions there can be very high temperatures from the explosive gases and contact with the momentary flame causes burns. People outside this range can be burned by the radiated heat. Heat radiation of high intensity can be stopped by solid objects and clothing. Persons tend to get these burns on the unclothed parts of the body, usually the head and hands.

Flash burns usually affect an area, perhaps on the face or one side of a limb more or less uniformly.

Flame burns from burning clothing and objects tend to be less uniform. Clothing is set alight by fire in the vicinity or by radiated heat - this is more likely in dark coloured clothing. Burns from clothing occur on both clothed and unclothed areas.

When the environment is set on fire the whole of the body may be burned.

The biophysics of air blast injury involve the striking of the body surface by the shock wave, part of which is deflected and part absorbed. The shock wave passes through relatively homogeneous tissues such as the heart, thigh and solid organs but air-containing organs are very vulnerable - ears, lungs and segments of the large bowel. Lung lesions take the form of alveolar haemorrhage which when severe has the respiratory passages filled with blood and froth causing suffocation.

Desaga [22] describes the action of dust in an explosion. He states that dust particles, even if very minute have quite a considerable velocity and particles of a fraction of a millimetre may penetrate deeply into the skin and cause "dust tattoos".

It has been generally known that in mine explosions Marshall [21]:

"Some miners die at once from the blast without any external signs. Some die from injuries sustained when they are hurled by the blast or buried under roof falls. Some die from the effects of the momentary fire, having sustained burns; since the flame travels nearer the roof than the floor, the upper half of the bodies is burned more than the lower half. Most, however die from the inhalation of the postexplosion fumes called afterdamp, the principal poisonous constituent being carbon monoxide. Many victims have first been immobilised by blast, injuries, or burns."

5.4.3 Recovery of the Victims at Moura

The report of the Queensland Mines Rescue teams which undertook the rescue Brady [23] describe the actions of each team that went underground and their expert observations.

The first contact with the victims of Moura occurred after Team No.6 led by Chris Glazbrook entered the mine at 10.25pm of the evening and returned to the surface by midnight reporting contact had been made with 10 bodies. Visibility was extremely poor and blast debris and a thick dust haze had made walking conditions very difficult.

Samples at 26 c/t No.4 Supply Road were 3.2% methane, 400 ppm CO, 0.5% CO_2. Ventilation movement was not detected. The team found the first body tangled in machine cables just outbye of 26 c/t in No.4 Supply Road.

In 26 c/t just south of No.4 Supply Road and near the inbye rib was a body and inbye of 26 c/t in No.4 Supply Road a body was found jammed between a vehicle (Mine Rover) and the Southern rib. The body was half under the vehicle and could not be identified. Six bodies were found at the intersection in 26 c/t No.3 Belt Road to No.2 Transformer Road. Another body was located in 26 c/t No.3 Belt Road to No.4 Supply Road.

The body recovery was carried out by five teams commencing at 12.45pm on Wednesday 23 July (seven days after the incident). One body was found on the right hand side of the roadway just outbye of 26 c/t. The body was on its left hand side, face down and entangled in "bull hose". Another was on the junction of 26 c/t No.4 Supply Road and on the inbye side of the c/t lying on his back. A third was jammed between the rib and the mine rover. This body was on its back and partially under the vehicle while another was in 26 c/t between No.4 Supply Road and No.3 Belt Road on his back.

One victim was found under the front of the cable reel compartment of s/c No.31. Only the lower portion of the legs was visible. A jack was used to lift up the shuttle car and coupled with hand removal of coal permitted the body to be pulled free.

The body was supine and appeared to be in good condition with all clothing still intact. The shirt was still tucked into the trousers. The cap lamp was on the body but the cord had been pulled apart.

Four bodies were grouped together across the c/t and at an angle to the shuttle car; one on back, two on face, and another on its back and on top of the other bodies.

The bodies were then photographed when brought out of the mine, placed in a helicopter and flown to Rockhampton for post mortem examinations.

5.4.4 Post Mortem Reports

The post mortems were carried out on the 24 July, eight days after the incident. The pathologist's tasks were to determine the injuries sustained to the bodies and to ascertain the cause of death. The bodies were photographed prior to the commencement of the post mortem examination by a police photographer. Because decomposition of the bodies was considerably advanced after eight days, no detailed sampling of the tissues could be undertaken. Observations of the external injuries, as far as could be ascertained, were recorded, and a record was kept of the clothing of each victim and the extent of their damage.

In the Inquiry the pathologist reported on cause of death and was cross-examined on the injuries to the body found beneath the shuttle car. It was announced in the Inquiry that the pathologist, Dr Ansford, would not be questioned in detail to avoid further pain and suffering to relatives in the Court.

5.5 Examination of Records

It has been well documented that the timely application of established forensic procedures to the investigation of an explosion is the only means of reliably establishing the circumstances surrounding the explosion.

The actions taken at the explosion scene will be significantly influenced by the nature of the incident. In particular, the environment in which the explosion occurred; the amount of damage and dispersal of debris; the number of casualties and their distribution within the scene; the location of the incident; the weather conditions prevailing and the likelihood of further (related) incidents. However, the essential consideration from the incident investigators viewpoint is preservation of the scene in its totality. Clearly and rightly, this consideration cannot be met without significant compromise in relation to preservation of life and property.

5.5.1 Classification of the Incident

The type of incident largely dictates the manner in which the explosion is to be investigation. For this purpose, explosions can be conveniently divided into two broad categories:

- Explosions Where the Essential Nature is Obvious -

  In these cases the investigation will be a limited one designed to determine some specific point only. Consequently, the plan of action can be likewise limited. Thus, in an incident of a legitimate nature, say the ignition of bulk fireworks during manufacture, the cause of ignition becomes the primary object of the investigation.

- Explosions Where the Essential Nature is Not Obvious -

  In these cases, the investigation may well be very comprehensive. Explosions of this type include large disasters leading to substantial demolition of building, the reduction of a room by an explosion in which no explosive is to be expected, the destruction of an aircraft in flight such as occurred in PANAM Flight 103 over Lockerbie on 21 December 1988, or the explosion which occurred within Moura No.4 Mine.

The plan of action arising from these deliberations will be unique to the particular incident and largely dependent upon the experience of the investigator and the support he has available. However, the nature of mine explosions is such that an immediate response plan may be generated which will provide a reliable framework which will ensure as far as is possible, firstly, that all necessary and appropriate emergency services are committed in a timely manner and secondly, that the scene is properly processed.

5.5.2 Approach to the Scene: Immediate Actions

Following a mine explosion, a number of actions are of immediate priority. Clearly, any necessary fire fighting and medical treatment and evacuation of injured must be undertaken but there are certain actions which should only be undertaken by specialist personnel. Most important is the "rendering safe" of the scene.

Regardless of whether or not the explosion was the cause by a solid, liquid or dispersed explosive, there is always the possibility that further unexploded material may be within the mine and can be in such a sensitive or hazardous condition that it may be initiated by those moving about the scene.

Any explosion which has caused structural damage may generate new hazards by the release of gas or vapours. Similarly, such damage may provide sources for ignition, for example electrical wiring may produce sparks. Where the explosion has given rise to a fire, the potential for further explosions almost always exists. Clearly, the advice of an experience explosion scene investigator is crucial in the early stages of the post-explosion management plan.

The scene of a mine explosion is one of considerable confusion, moreover, many aspects are transient in nature and can easily be lost if the investigation is not adequately managed. Therefore, it is essential that once the scene has been secured, all possible witnesses are identified and interviewed - once they have left the scene, the information they possess may be lost forever. Similarly, allowing the scene to become a "Tourist Attraction" for any person not directly involved in the investigation, may well enhance the difficulties faced by the post-blast analysis team, and significantly detract from the final investigative outcome.

The identification of the seat of the explosion and the source of ignition is a matter of vital importance and the primary object of the post explosion investigation. In the case of dispersed gas explosions, the region of the seat of the explosion will not contain the most severe blast damage. From this point the progress of the blast and fire front can be determined providing all "indicators" are preserved. These "indicators" include all material and deceased personnel within the mine disaster scene.

It should be noted that personnel who have been subjected to an explosion will display complex injuries. The examination of the deceased must be undertaken in two phases. Firstly, in situ by the explosion scene examiner and subsequently at autopsy by the pathologist in concert with the explosion scene examiner who will recover all objects which have penetrated the bodies and assess the extent of blast and other explosion indicators. In the case of injured personnel, every effort must be made to ensure recovery and retention of fragments from wounds and record the nature and extent of injuries.

5.5.3 General Characteristics of the Explosion

The characteristics of a dispersed gas explosion of the types which occurred within the Moura No.4 mine may be summarised as follows:

- The point of initiation may be remote from the bulk gas explosive source.
- The flame front will engulf objects and personnel close to the point of initiation (causing all round burning).
- With confinement such as that available with the Main Dips Section, a rolling flame front will develop.
- Where multiple tunnels are available for flame front progression, complex flame front interactions may develop. Modelling will assist interpretation of interactions.
- Flame front velocity is relatively low; however flame duration is short (compared to condensed explosives). Therefore burning of objects and personnel arising from the explosion will be relatively short-lived.
- Without detailed flame front progression modelling, interpretation of post blast burning patterns at nodes is difficult.
- The blast pressure front velocity is relatively low (compared to condensed explosives) but of significant duration. That is, significant displacement of objects will occur but little or no fragmentation of materials will be observed.
- Restrictions (objects within the roadways) will cause added turbulence and increase the velocity of propagation of the explosion front.
- The tunnels and objects within them will cause "shadowing" and blast/flame front reflections.

These dispersed (gas) explosion characteristics have produced a range of terminal effects on both material and personnel within the mine. However, most of the available information has been lost or obliterated due to an inadequate post blast investigation. Failure to properly examine and record in-situ the condition of the deceased miners, in particular, the presence of blast damage, fragment attack and flash burn has severely restricted subsequent explosion investigation.

NOTE:

Sub-sections	5.5.4	"Observed Personal Effects" and
	5.5.5	"Condition of Deceased Miners after Explosion"

have been deleted from the published report as they contain medical details which could cause unnecessary stress for relatives and friends of the deceased miners and persons in the coal mining industry.

Any person who has a legitimate need for the information may obtain it by writing to:

The Honourable K.H. Vaughan MLA
Minister for Resource Industries
61 Mary Street
BRISBANE Q 4000
AUSTRALIA.

5.5.6 Observed Material Effects

The following explosion effects were apparent:

. Displacement of Objects; and

. Flash burn/blast damage.

However, this examination of records is restricted to material WEST of 25 c/t and is limited by the previously stated inadequacies in post blast processing of the scene. It must be emphasised that the use of small, light objects as indicators of displacement (and therefore overpressure magnitude and direction) should not be undertaken where there exists the possibility of complex pressure wave interactions and venting paths. For this reason, significance has been placed on the displacement of large heavy objects whereas the general movement of smaller objects only has been regarded as indicative.

Displacement of Objects

It was noted that displacement of smaller objects has been EASTERLY (outbye) from the goaf and is indicative of explosion front progression in an EASTERLY (outbye) direction from the goaf. The displacement of heavy objects in No.4 Supply Road is indicative of explosion front progression in an EASTERLY (outbye) direction. In the region of the intersection of 26 c/t displacement of the crib room table is consistent with complex explosion front progression which had continued outbye on No.4 Supply Road turned SOUTH down 26 c/t and been initially hampered and turned by the stopping NORTH on 26 c/t (the probable crib room). The displacement of the mine rover indicates explosion front progression EAST (outbye).

The observed positions of s/c No.31 and s/c No.30 are consistent with explosion front progression in an EASTERLY (outbye) direction along No.3 Belt Road and SOUTH down 26 c/t causing s/c No.31 to rotate clockwise (when viewed from above) and pushing shuttle car 30 counter clockwise (when viewed from above).

Flash Burn/Blast Damage

Significant blast and flash burn damage was noted on the mine rover situated in No.4 Supply Road. The roof had been lifted and significant flash burning had occurred to the back of the seats. This damage was consistent with the explosion/flame front progressing in an EASTERLY (outbye) direction along No.4 Supply Road striking the front of the mine rover which has been lifted and pushed into the SOUTH wall of the tunnel. There was no evidence of significant explosion/flame front impingement to the rear of the vehicle.

The Flame Safety Lamp recovered from Moura No.4 Mine was examined. The body of the lamp displayed impact damage consistent with it having struck a hard object. Some blackening was present on the lamp body. The damage and blackening are consistent with the lamp having been subjected to a short duration explosion flame front. The damage did not appear to be consistent with the Flame Safety Lamp having initiated the explosion.

Examination of a Report on Examination of Two Gauzes from Flame Safety Lamp Moura No.4 Mine Explosion has revealed the following:

. The inner and outer gauze are microstructurally different.

. The grain size is not uniform between gauzes.

. The new gauzes are dissimilar to the gauzes removed from the Moura No.4 Mine flame safety lamp.

The presence of grain size variation in ferritic wire of the type shown may arise during manufacturing processing. The extent of grain growth present in the gauzes from the Flame Safety Lamp Moura No.4 Mine Explosion is not great and given the dissimilarities identified between each of the gauzes cannot be regarded as definitive.

It is considered that the absence of significant blast damage to the lamp, the inconclusive nature of the metallurgical examination of the gauzes removed from Flame Safety Lamp Moura No.4 Mine Explosion, and the explosion source indicators already discussed rule out the Flame Safety Lamp as the initiation point of the explosion.

5.6 Discussion

The terminal effects detailed may be explained by an explosion initiated within the goaf propagating outbye along No.3 Belt Road with the major explosion/flame front propagating outbye along No.4 Supply Road turning (in part) SOUTH down 26 c/t. Considerable turbulence would be experienced at the junction of No.4 Supply Road and 26 c/t initially due to the temporary obstruction caused by the stopping NORTH of the crib room and explains the extensive flash burn experienced by one of the deceased. The injuries sustained by victim No.9 are consistent with partial shielding by the mine rover. The injuries to and placement of the victim No.11 are consistent with his being in the vicinity of the crib room. The injuries to and placement of victims Nos.1 and 2 are consistent with their being projected outbye along No.3 Belt Road. The injuries to and placement of victims Nos.3, 4, 5, 6, 7, 8 and 12 are consistent with their being projected SOUTH down 26 c/t by the explosion pressure front.

There is no evidence to suggest the explosion was initiated either in or near the junction of No.3 Belt Road and 26 c/t or the junction of No.4 Supply Road and 26 c/t.

5.7 Summary

Explosion scene investigations are based on the premise that everything at the scene prior to the explosion is still, at least in part, in existence in some form. While the explosion can in some instances destroy material which was in close proximity to the seat of the explosion, most of the items that were present before the explosion will remain, although their size, shape and appearance may be altered radically. Explosion scenes are often difficult to secure due to their size, location or nature. However, experience has shown that providing sound explosion scene examination procedures are followed much significant information and evidence can be recovered. These procedures require the full cooperation of all emergency services attending and a dispassionate approach to all material and deceased personnel within the disaster scene.