CHAPTER 7

SOME FINDINGS ON RE-ANALYSIS OF MOURA EXPLOSION

By
A. Green, S. Leivesley

The aim of this Chapter is to discuss the analysis of the course of the explosion at Moura based on evidence which is detailed in the preceding two chapters.

Forensic science provides for the use of evidence from blast, heat air flow and observations of the victims. The use of modelling can assist with the interpretation of this evidence allowing discrimination between what is or is not plausible. These methods allow the establishment of the course of the explosion with the various factors providing corroboration or elimination.

With this method all the known information is used to establish or eliminate findings on the course of the explosion.

In the first part of the chapter, a critical data set is established. Various hypotheses are then tested against this data. Finally there is a discussion on the likely areas of ignition sources capable of having caused the Moura explosion.

7.1 The Critical Data Set

There is a critical data set which defines the course of the explosion and against which all hypotheses should be tested to see whether they give the same type of damage or flow effects and pathology as the data in this critical set. Table 7.1 is a compilation of this critical data set extracted from Chapters 3 and 4.

The items in the critical data set relate to pressure, air flow, heat and body damage. Not every piece of information has been included in this critical list. Items such as the movement of steel from the area of the "Taj Mahal" or the general movement of the conveyor outbye 24 c/t appear to be common to all scenarios tested and have therefore been deleted from the list. Small items such as helmets and seats are too small to form part of the critical set as they tend to be easily transported by every flow past them and so are not good indicators of the initial blast direction. Such items have also been omitted from the list. The items in the critical data set are:

- A low pressure is observed at the stopping in 27 c/t compared with other stoppings on the north side of the mine.
- A uniform increase in pressure is observed moving away from the goaf area on both the north and south side of the Main Dip Section.
- The pattern of the alignment of the bodies that is observed including the relationship of the bodies in relation to the shuttle cars and the pattern of blast damage to clothing and severe head injuries.
- The observed positions of the shuttle cars.

- The observed direction of flow in No.1A South Return Road is outbye with no sign of a flow into the goaf in that road.

- A fire had occurred at the corner of No.1A South Return Road and 25 c/t with associated high devolatilisation of coal dust in that area.

- A bi-directional movement of crib room material at 26 c/t towards the shuttle cars, mine rover and outbye along No.4 Supply Road was observed. The tool bench top was moved from a point about 5m outbye 26 c/t on No.4 Supply Road in to the back of the mine rover some 3m inbye 26 c/t. Related equipment from that area ended up near the mine rover while some material from the crib room ended up 50m along No.4 Supply Road.

- The MPV tray found at the junction of No.4 Supply Road and 25 c/t had been moved from the opposite side of No.4 Supply Road spilling it's load of timber props which ended up parallel to No.4 Supply Road.

- The MPV tray in 27 c/t between No.3 Belt Road and No.4 Supply Road had been tipped in a direction towards the goaf and towards No.3 Belt Road.

- High devolatilisation of coal and high heat on plastic materials was observed between the continuous miner and s/c 31 in No.3 Belt Road.

- A fire occurred in 24 c/t.

- High heat was observed around the mine rover.

- The mine rover vehicle shows directional flame information with the flow of the flame and blast being sharply angled from the direction of the goaf.

- The pattern of burning on the bodies with severe burning of one body in No.4 Supply Road.

- The observed movement of fire extinguishers and hook in No.3 Belt Road outbye 27 c/t was towards the goaf. The hook on which the extinguishers were hung was also pointing towards the goaf.

- The observed movement of fire extinguishers in No.3 Belt Road outbye 26 c/t was towards 25 c/t.

- The belt structure at 25 c/t had been displaced towards No.4 Supply Road.

These 17 observations form the critical data set. All hypotheses have to be tested against this critical set to see which can be eliminated and which are more likely to be valid.

7.2 The Flame Safety Lamp

The major finding in the re-analysis is that there are a number of facts which negate the hypothesis of a course of an explosion emanating from 26 c/t and No.3 Belt Road. A comparison of the flame safety lamp hypothesis with the critical data set suggests the following:

- The findings of the Inquiry did not identify or relate ignition sources to a course of explosion. Consequently alternative ignition sources are still possible and cannot be eliminated until the course of the explosion is fully detailed.

- The pressure damage to the stopping in 27 c/t which is that closest to the goaf, is not consistent with an ignition in the region of the shuttle cars. Such an ignition would have displaced the stopping further against the rib than was observed. The expected damage would have been the same or greater than that observed at the stopping in 26 c/t since the stopping at 26 c/t would have been the closest stopping. The explosion would have been less intense at 26 c/t than 27 c/t.

- The blast evidence is that pressure increases away from the goaf area in what appears to be a consistent manner. The course of an explosion from close to the shuttle cars in 26 c/t or between the shuttle cars and the miner would produce the stopping in 26 c/t with the lowest pressure and more severe blast damage to the stoppings in 27 c/t and 25 c/t. This is not observed. There would not be a uniform pressure increase away from the goaf and there would be some signs of pressure increase towards the goaf. This is not observed.

- The pathology of the victims is not consistent with an ignition in the vicinity of any of the 12 men since all have been affected by substantial blast and some to intense directional flame. The evidence would suggest that the majority of bodies were moved by the blast between 3 and 25 metres.

- There is no substantiation of a flow of blast pressure originating within the vicinity of the shuttle cars being able to cause the positions of the shuttle cars where No.31 has moved towards the rib and No.30 has also been moved towards the rib.

- The air flow pattern observed in No.1A South Return Road is not consistent with ignition in the vicinity of 26 c/t and No.3 Belt Road. The preliminary indications from modelling studies show that ignition around the shuttle cars leads to a flow in a direction which is contrary to the evidence observed in No.1A South Return Road.

- The heat evidence is that the flame safety lamp coking and fusion has been caused by factors external to the lamp. The critical data set shows a high heating between the miner and s/c No.31 which is close to the position the lamp was found. Consequently fusion of material on the outside and inside of the lamp is not clear cut - it could be from ignition or due to external factors. This means that the experimental findings on the flame safety lamp are not absolutely in accord with an ignition within the lamp being the sole factor which can account for coking and fusion of dust on the internal lamp glass.

- There is no substantiation that the maximum devolatilisation occurred in this area (where the lamp was found) due to the blast flow originating in this area. Maximum devolatilisation occurred because of recirculation and extended burnout around the continuous miner and shuttle cars as the explosion moved past them (Flame brush burnout).

- The physical evidence of the lamp suggested it had been picked up by the explosion and impacted at a high velocity causing indentation and deformation of the base of the lamp and bending of the bonnet top.

- The reasonably uniform pattern of dust deposition on the outside of the lamp together with the impact damage suggests that it is consistent with being immersed and travelling with the flow of the explosion.

- The dust within the lamp is consistent with it being forced into the lamp due to a difference in internal and external pressure either caused by the blast or relative windspeeds.

- The coking within the lamp cannot be reproduced in a simple explosion and this mechanism remains unexplained but could be due to flame passing over the lamp more than once. It has been established that dust adheres to the surface in a single explosion flow. Dust adhering to the surface in this way will be preferentially heated by radiation from a second flame front due to its high absorption coefficient compared with the glass or metal surfaces. Rapid conduction of heat to the glass or metal surface will fuse the particles to that surface. Conduction will only occur where there are particles. Consequently, heating of the glass or metal is also localised and general discolouration of the metal surface does not occur.

- International attempts to replicate the experimental data presented at the Inquiry have failed to replicate the effect and have suggested that the addition of oxygen in Golledge's experiments caused an unwitting decrease in the flame arresting capabilities of the lamp's gauzes. The only experiment where ignition took place with the bonnet on used a spray gun discharging a pure coal dust jet held about 200mm away from the bonnet orifices. The pressure drop across the spray outlet was approximately 140 kPa. This corresponds to an air velocity substantially higher than that likely to be obtained from a wind blast due to a goaf fall.

- The ignition mechanism proposed for the flame safety lamp involves the creation of a jet flame in the direction of the air flow. This frame contains a substantial energy (an order of magnitude calculation would suggest 100 kJ). This is some 4-5 orders of magnitude greater than that required to ignite an external coal dust air mixture. The violence of this event would have left an indication on the direction of the flow and this is not seen in the evidence available.

- The air flow patterns around the mine rover due to the explosion are not consistent with ignition in the vicinity of 26 c/t and No.3 Belt Road. The direction of flame over the mine rover is also inconsistent with the flow from this area.

- The preliminary experiments with the physical scale model have not replicated a flow pattern which is consistent with the critical data set. An ignition source in the vicinity of the shuttle cars caused flows in all directions away from the source of ignition. This is exactly the reverse of the flow from the crib room and from in front of the mine rover and the flow responsible for moving s/c No.31. It also did not replicate the flow in No.1A South Return Road and was in the reverse direction to that observed.

- A scenario for the flame safety lamp being at the centre of the explosion would give low pressures radiating from the region of the lamp over distances of 25 m, low blast pressure damage to the bodies, i.e., no shredding of clothing, serious translational injuries, radial effects of burns and pressure damage rapidly escalating away from the centre of the explosion.

- The reliance on differences in the crystal microstructure of the two gauzes as an indicator of an event inside the lamp is not definitive, Manufacturing processes could be responsible for this difference.

Comparison of the flame safety lamp hypothesis with the critical data set shows there are two points of definite agreement, two of partial agreement and six points of definite disagreement and possibly a further three other negating factors. Three points cannot be determined because of inadequate information - points that may be determined at a later stage with modelling.

7.3 The Course of the Explosion

The main thrust of this work is to determine the course of the explosion. After examination of the flame safety lamp area as one potential area for ignition, a number of alternative areas were examined as to how the explosion would be expected to develop relative to the critical factors:

- The Conveyor boot end.

- The fire in 24 c/t.

- The shuttle cars.

- The crib room and area immediately in front of the mine rover.

- The continuous miner.

- The northern section of the goaf adjacent to No.4 Supply Road and

No.3 Belt Road.

. The southern section of the goaf adjacent to 27 c/t and 26 c/t.

Each hypothesis is tabulated against the critical factors in Table 7.1 and discussed separately below.

7.3.1 The area in 24 c/t and from the direction of the Boot End

The positive relationships are:

- The movement of the fire extinguishers at 27 c/t and No.3 Belt Road is in the correct direction.

- High devolatilisation between the shuttle cars and the continuous miner is more than likely with a strong flow in this direction but further work on burnout times from modelling studies is required.

- The fire in 24 c/t can be explained if the explosion started in that vicinity, but it is unclear if ignition towards the boot end of the conveyor will produce a long residence time for a fire to occur here. Further work with models is required.

The negative relationships are:

- The stopping pressure at 27 c/t is too low compared with that observed at 26 c/t.

- The pressure gradient observed is in the wrong direction for ignition in this area.

- The alignment of bodies is inconsistent with a flow from this direction. Such a flow could conceivably account for the accumulation of bodies by the shuttle car if the alignment of the bodies is considered as coincident rather than due to the explosion, but this type of flow could not account for the positions or state of the bodies near the mine rover.

- The position of the shuttle cars can not be explained with a flow from this direction.

- The bidirectional movement of material from the crib room is not consistent. The flow along 26 c/t would have blown the stopping and scattered debris from this area behind it before a flow down No.4 Supply Road towards the goaf took debris in towards the goaf area. Debris would not have travelled up to 300m out along No.4 Supply Road with this scenario.

- The movement of the MPV tray in 25 c/t is inconsistent as the blast would have moved up 25 c/t towards No.4 Supply Road. This movement would not have picked up the MPV tray in the manner observed.

- The direction of flame over the mine rover is not consistent with a flow along 26 c/t toward No.4 Supply Road and then into the goaf, obtained from this hypothesis.

- The movement of fire extinguishers at 26 c/t and No.3 Belt Road is in the wrong direction for ignition in this area.

- The lateral movement of the belt structure at 25 c/t is not consistent with this hypothesis.

- The movement of the MPV tray in 27 c/t is probably inconsistent for a flow down No.3 Belt Road and along 27 c/t towards No.4 Supply Road. Although the MPV tray was tipped towards the inbye rib, it was also skewed in the wrong direction for this hypothesis to be likely.

- The severe burning of the body in 26 c/t and the high heating observed around the mine rover seems to be inconsistent with this hypothesis but further modelling is required.

This hypothesis agrees with 1 critical factor and possibly a further 2 factors. It disagrees with 9 factors and possibly a further 3 while one is unknown.

7.3.2 The Crib Room and Surrounding Area

The positive factors with this hypothesis:

- The alignment of the bodies near the shuttle cars and at the intersection of 26 c/t and No.4 Supply Road is consistent with a flow and blast from the crib room along 26 c/t towards the shuttle cars, although the bodies that moved along No.3 Belt Road outbye might not occur with this scenario.

- The position of the shuttle cars can be explained with a flow along 26 c/t towards these vehicles.

- The crib room material will be moved in a cone as observed. The movement of material 300m out along No.4 Supply Road is probably consistent but further modelling work is required.

- The pattern of burning on the body in 26 c/t would be consistent.

- The high degree of heat around the mine rover area is explained.

- The movement of the fire extinguisher at 26 c/t and No.3 Belt Road is in the correct direction.

- This hypothesis could possibly explain the movement of both the MPV tray's at 25 c/t and 27 c/t but further modelling work is required.

- Preliminary modelling indicates that the flow at No.1A South Return Road is in the correct direction.

There is inadequate information to explain the fires at 24 c/t and No.1A South Return Road, the high devolatilisation between the miners and shuttle cars, and the movement of fire extinguishers towards 27 c/t - this information may come from modelling studies.

The negative factors:

- The pressure observed at 27 c/t stopping is too low relative to that at 26 c/t.

- The uniform pressure increase away from the goaf is inconsistent.

- The direction of flame around the mine rover is incorrect.

- The lateral movement of the belt at 25 c/t is probably not in the correct direction for ignition here but further work is required to verify this point.

The hypothesis agrees with 5 critical factors and possibly a further 4. It disagrees with 3 factors and possibly a further 1. There are 2 neutral factors and 2 unknown.

If the source of ignition is moved from the crib room to around the mine rover, the negative factors with regard to the stopping at 27 c/t and the pressure gradient become less certain, tending to move towards the positive the further the area is moved along No.4 Supply Road towards the goaf. The direction of flame over the mine rover becomes consistent and the movement of the MPV tray in 27 c/t becomes more positive. All other factors remain the same as for the crib room scenario.

Within the crib room area there are several potential ignition sources such as the lights, the entonox bottle as a frictional ignition source and as a spontaneous ignition source from oxygen release. The mine rover cannot be ruled out either. It was not tested in a flameproof enclosure to eliminate it as a potential source although the testing done on the vehicle would suggest this to be unlikely.

7.3.3 The Area Around the Continuous Miner

The positive factors are:

- The stopping at 27 c/t has the correct relative pressure to that at 26 c/t.

- The uniform pressure gradient away from the goaf is consistent.

- The high devolatilisation between the shuttle and continuous miner is explained.

. The movement of fire extinguishers outbye 26 c/t is in the expected direction.

. The movement of MPV tray in 27 c/t is in the correct direction to tilt it but not to skew it in the direction observed. This requires further modelling.

. The lateral movement of the belt at 25 c/t may be consistent but further modelling is required.

There is one factor which is unknown until further modelling studies are undertaken.

. The movement of the MPV tray at 25 c/t and No.4 Supply Road.

The negative factors are:

. The alignment of the bodies around the shuttle cars is not consistent although the bodies at the junction of 26 c/t and roadway 4 could be consistent if flame went back towards 27 c/t and then outbye along No.4 Supply Road. Preliminary modelling would suggest that the flow would move along 26 c/t towards No.4 Supply Road rather than in the reverse direction.

. The position of the shuttle cars is inconsistent and needs explaining.

. The flow in No.1A South Return Road and the associated fire.

. The crib room material movements depend on the relative timing of flows arriving up 26 c/t and along No.4 Supply Road from the goaf. Preliminary indications from modelling are negative.

. The movement of the fire extinguishers and hook towards 27 c/t is unlikely as it is too near the source of the explosion to get a sustained drag effect on the hook and bend it in the manner observed.

The hypothesis agrees with 4 critical factors and possibly another 4. It disagrees with 3 factors and probably 3 others. There are no neutral factors and 3 unknowns.

The ignition source in the vicinity of the miner would have been an electrostatically charged hose of the trickle duster or frictional ignition in the goaf adjacent to the roadway.

7.3.4 The Northern Section of the Goaf

The positive factors for ignition in this area are:

- The stopping damage at 27 c/t is consistent with damage to the other stoppings.

- The pressure gradient is consistent with this ignition.

- The pattern of alignment of the bodies is consistent. The severe burning of the body in 26 c/t may be consistent but requires testing in modelling studies.

- The position of the shuttle cars can be explained.

- The crib room material would be directional as observed with material being taken along No.4 Supply Road.

- The movement of the MPV tray in 25 c/t can be explained.

- The direction of flame front over the mine rover is consistent.

- The movement of fire extinguishers at 26 c/t and No.3 Belt Road is in the correct direction.

- Preliminary tests in the scale model suggest that the direction of flow in No.1A South Return Road is as observed as being in one direction only and then outward from the goaf with a relatively long flame burnout time. This requires further testing of modelling.

- The movement of the MPV tray in 27 c/t can possibly be explained but this requires further modelling.

- The high heat around the mine rover may be explained but again needs further modelling.

Two items are unknown. The high devolatilisation between the miner and shuttle cars and the fire in 24 c/t need explanation.

There are two possible negative factors for this scenario both of which need testing:

- The movement of fire extinguishers at 27 c/t and No.3 Belt Road.

- The lateral movement of the belt at 25 c/t.

There could be other contra indications which will show up in modelling. The inclusion of fusion on glass requires detailed modelling.

This hypothesis agrees with 8 factors with further agreement with 4 other factors. It disagrees with a possible 2 factors and there are 2 other factors which are unknown.

The possible ignition sources in this area are frictional ignition of rock and piezoelectric ignition in either the rock as it collapsed or between rock and rock or between rock and steel roof bolting material as it collapsed.

7.3.5 The Southern Section of the Goaf

This hypothesis has the following positive factors:

- The stopping at 27 c/t and the uniform pressure increase is consistent for the major part of the southern section of the goaf. As the area is moved towards the line of 26 c/t the weaker these two factors become.

- The movement of the fire extinguishers at 26 c/t and No.3 Belt Road and the lateral movement of the belt at 25 c/t is consistent with this area of ignition.

The negative factors are:

- The position of shuttle car 30 might be explainable by a flow from this direction but the position of s/c No.31 is definitely inconsistent.

- Preliminary modelling shows that the flow in No.1A South Return Road and the high heat in this roadway is inconsistent. Two flows are observed in opposite directions which is not seen in the evidence.

- Preliminary modelling also suggests that neither the movement of material from the crib room nor the pattern of body alignment is consistent with the observed evidence.

- The movement of the MPV tray in 27 c/t is inconsistent as is the movement of fire extinguishers at 27 c/t. These negative factors become weaker as the area of ignition approaches the line of 26 c/t.

- Preliminary modelling suggests that the direction of flame over the mine rover is inconsistent with flame travelling along 26 c/t toward No.4 Supply Road into the goaf.

There are several unknown factors at the present time:

- The high devolatilisation between the miner and shuttle cars and the fire in 24 c/t.

- The effect of flow on the MPV tray in 25 c/t is not known.

- The high heat around the mine rover and the pattern of burning on the body in 26 c/t requires further modelling.

This hypothesis agrees with 4 factors. It disagrees with 4 factors and possibly a further 4. There are 5 unknowns.

The ignition sources in this area are the same as for the northern section of the goaf.

7.4 Discussion

Figure 7.1 plots a percentage probability of ignition for several hypothesised ignition zones. The scaling has been based on +2 for a positive factor, +1 for a positive factor that needs further testing, 0 for a neutral or unknown factor, -1 for a negative factor that needs further testing and -2 for a negative factor. This process results in a value for each hypothesis between +34 and -34. This range has been converted to a percentage probability.

It is clearly seen that the regions above 50% probability lie in an arc from the goaf area to the west of the continuous miner around to the crib room area. The maximum value occurs in the north goaf in front of No.4 Supply Road.

The area around the shuttle car, boot end conveyor and outbye towards 24 c/t on No.3 Belt Road and the south goaf have a probability below 50%.

The above analysis relies on giving equal weighting to the seventeen critical factors in Table 7.1. In reality certain factors should carry more weight than others. For example agreement with the position and alignment of twelve bodies over what appears to be two distinct areas together with an explanation of burn marks, drag marks and pressure effects on the bodies should carry more weight than the movement of the fire extinguishers which would be more easily moved in subsequent winds following the primary flow. Similarly events which are hard to explain or appear unusual should carry more weight such as the one way flow in 1A heading or the movement of the MPV tray at 25 c/t across No.4 Supply Road.

Applying this additional weighting, the critical data set is reduced to six factors, Nos.3, 4, 5, 7, 8 and 13 given in Table 7.1. This reduced set is also plotted in Figure 7.1.

The additional weighting increases the likelihood that ignition started in the north goaf as far round as in front of the mine rover. The crib room area still remains high but the area in the goaf adjacent to the continuous miner is much less likely and is now compatible with the likelihood of ignition having occurred in the south goaf. The other scenarios around the shuttle cars and outbye the boot end of the conveyor become substantially less and can be considered unlikely areas of ignition for this explosion.

Although further verification through the application of modelling techniques is required, the indications are that the explosion started in the vicinity of the north goaf adjacent to No.4 Supply Road of No.3 Belt Road and possibly as far round as the crib room. In this region of the mine there are a number of potential ignition sources that cannot be ruled out on the basis of evidence presented at the inquiry.

Frictional ignition of rock on rock is the most likely frictional ignition mechanism. Tests attempted by both Poppit and Green independently show that rock hitting metal is unlikely to have occurred. Poppit showed that under at least one set of circumstances rock rubbing on rock could rapidly ignite methane. This mechanism cannot be ruled out even though it is not known how rocks break up or how they hit or slide down one another as the roof collapses. It should also be noted that both quartzitic and pyritic strata occur on either side of the shear plain near 27 c/t.

An alternative mechanism for ignition could be a piezzo - electric effect in the rock. The roof rock at Moura did contain bands of quartz. Two such bands close together under pressure could produce such an effect if the rock sheared between them. As the rock is distressed an impedance is set up in the quartz which can build up sufficient charge to cause sparking. A similar effect can be caused by a quartz band and a steel plate or roof bolt.

An electrostatic discharge from the trickle duster hose cannot be ruled out. This hose was apparently not antistatic. A goaf fall could have produced sufficient dust flow over the hose at a high enough velocity to produce a charge on the surface of the hose, leading eventually to ignition.

The mine rover, although thoroughly checked and inspected after the incident was never tested in a flameproof enclosure to ensure that ignition could not have occurred at start up or after a few minutes running.

In the crib room, the fluorescent lights were destroyed by the explosion. Consequently these remain potential sources of ignition as a fault may have developed in the electrics.

There was also an entonox bottle constructed of aluminium containing 50% oxygen and 50% nitrous oxide. This mixture is equivalent to a 70% oxygen atmosphere. Although the valve had been sheared at the cylinder head, expert testimony at the inquiry stated that the valve had been sheared in a violent impact consistent with its being projected by the explosion rather than being dropped or manually thrown against a wall. Frictional ignition from this source is therefore unlikely. However, release of high oxygen atmospheres over oil mist and greases causes spontaneous ignition and many such causes of explosions are documented. It is possible that this auto ignition will occur with coal dusts particularly when they are in suspension, since it is in this state that they behave like oil mists. This hypothesis does however require further testing.

There remains the question of the availability of fuel for ignition. There is substantial evidence to suggest that methane, present in the goaf, would have been pushed out from the goaf towards both the north and south returns. Furthermore, roof and floor heave associated with destressing of the strata could have contributed methane from the seams above and below Main Dips Section. There were signs of floor heave immediately inbye 27 c/t. One or more roof falls over a short period of time would have short circuited the air flow which would have resulted in a flammable methane in coal dust mixture throughout a substantial volume of the mine inbye 25 c/t, and possibly further out along certain headings.

In spite of this, the critical indicators point to the seat of the explosion occurring inbye the mine rover and No.4 Supply Road.

What is the likelihood that the ignition source was remote from this area? The only way a remote ignition could produce agreement with those critical indicators is for the ignition to result in a laminar flame which tracks, due to the concentration gradients of methane and coal dust, to the northern area of the goaf. This is more likely within the goaf, where the ignition is relatively uncontained compared with the roadways. This degree of unconfinement would suggest that turbulence levels even after a roof fall, would be much less than in the headings.

The flame safety lamp could not be the source of ignition if it was in either No.3 Belt Road or 26 c/t as it produces a highly turbulent directional and energetic jet that would rapidly accelerate the explosion. This would have left contrary indicators to that observed unless the lamp at the time was in the goaf. But this assumption creates other difficulties particularly, how the lamp was moved to the position it was found. Being at the ignition point, it would not be moved by the initial blast and subsequent air movement would probably be in the wrong direction due to over expansion of the initial blast.

It cannot be ruled out, however, that another ignition source producing a weak ignition could have been present outbye 27 c/t along No.3 Belt Road, causing the indications observed. There are no obvious candidates for this hypothesis.

.5 Conclusion

The reanalysis into the Moura explosion has been based on information that was available to the inquiry and expert international and Australian experts who have been consulted by the team over the past 6 months.

The general response by forensic scientists, mining engineers, scientists working in the mining field, forensic pathologists and explosives experts is that the lack of detailed information gathering at the time of the incident and the failure to provide a systematically gathered data set does not allow a full reconstruction of the incident.

However, this re-examination of the incident has shown that:

- The flame safety lamp scenario for ignition is inconsistent with the determined course of the explosion.

- The highest probability for the ignition zone is from the north goaf adjacent to No.4 Supply Road but could have occurred as far as the crib room area.

- In this region of the mine, there were a number of ignition sources that could have caused ignition and about which further research is required to elucidate the mechanism for ignition.

- The fuel could have been methane or a mixture of methane and coal dust. The ignition zone in the north goaf is coincident with the natural area for migration of methane within the goaf. Sufficient methane could have accumulated without the need for coal dust to participate in the ignition process.

- The use of modelling in this reinvestigation has shown that both physical and mathematical modelling of the incident are useful tools to assist the forensic scientist in interpretation. Of the two methods, mathematical models are potentially the more powerful of the two methods as long as they have been calibrated against experimental data, because they can:

- Give details of pressure, velocities and temperature throughout the region of interest and with time.
- Allow the direct calculation of impulses and heat fluxes on objects. As a consequence the likely damage or movement of an object can readily be assessed.
- Can form a link between scaled physical models and the full scale event as it should predict phenomena in both scales.

Further research is necessary to develop modelling techniques.

Table 7.1 Critical Factors for Scenario of Ignition

Factor	Ignition Area					
	Boot End out Outbye Conveyor	Shuttle and Car	Crib Room	Continuous Miner	North Goaf	South Goaf
1) Relative Low Pressure at 27 c/t Stopping North Side	N	N	N	Y	Y	Y
2) Uniformly increasing pressure moving away from Goaf	N	N	N	Y	Y	Y
3) Pattern of alignment of bodies around shuttle cars & mine rover	N	N	Y?	N	Y	N
4) Position of Shuttle Cars	N	N	Y	N	Y	N
5) One way flow out of the goaf in No.1A South Return Road	-	N?	Y?	N?	Y?	N?
6) To a fire in this heading	-	N?	-	-	Y?	N?
7) The bidirectional movement of material from the Crib Room area	N	N	Y	N?	Y	N?
8) The movement & tipping of the MPV tray in 25 c/t	N	N?	Y?	-	Y	-
9) MPV tray movement in 27 c/t	N?	N?	Y?	Y?	Y?	N
10) High devolatilisation of coal around the continuous miner	Y?	Y?	?	Y	-	-
11) Fire in 24 c/t	Y?	-	-	-	-	-
12) High heat around the mne rover	N?	-	Y	Y?	Y?	-
13) Directional flame from front of the mine rover	N	N	N	N?	Y	N?

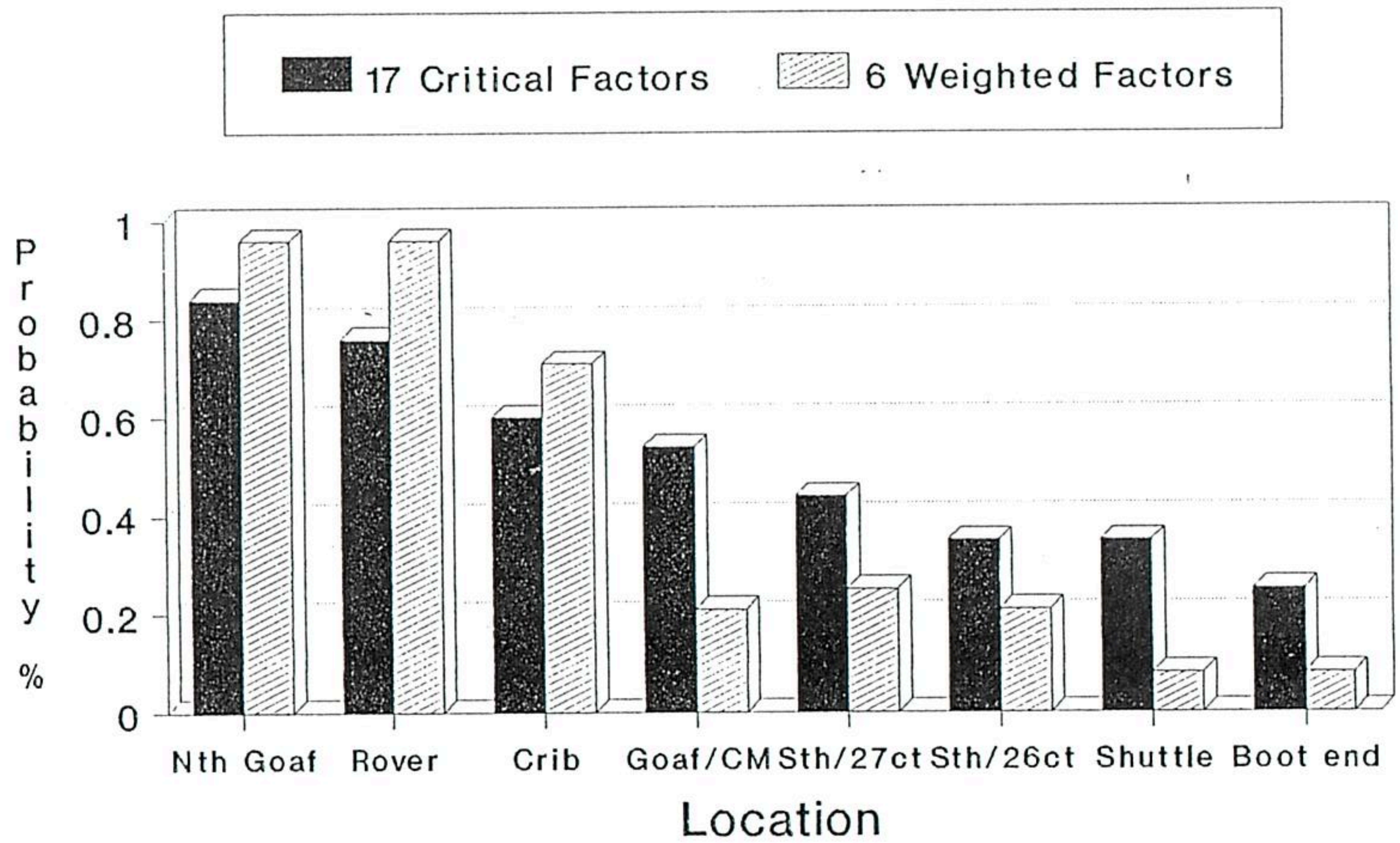
(Green/Leivesley)

Factor	Ignition Area					
	Boot End Out Outbye Conveyor	Shuttle and Car	Crib Room	Continuous Miner	North Goaf	South Goaf
14) Pattern of burning on body	N?	-	Y	Y?	Y?	-
15) Movement of fire extinguishers and hook outbye 27 c/t towards 27 c/t	Y	Y	?	N	N?	N
16) Movement of fire extinguishers and hook outbye 26 c/t towards 25 c/t	N	Y	Y	Y	Y	Y
17) Movement of belt structure at 25 c/t towards No.4 Supply Road	N	Y?	N?	Y?	N?	Y
No. Position factors (Y)	1	2	5	4	8	4
No. on Balance Position (Y?)	2	2	4	4	5	0
Neutral Factors (?)	0	0	2	0	0	0
No.on Balance Negative (N?)	3	4	1	3	2	4
No. Negative factors (N)	9	6	3	3	0	4
No. Unknown (-)	2	3	2	3	2	5

Note - The area around the shuttle car is assumed to be in the area of the interaction of 26 c/t and No.3 Belt Road rather than towards the continuous miner.

Figure 7.1 Ignition Sources

Probability for various locations



Note: Rover relates to area immediately in front of the vehicle.

ARG 15/5/90