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Our reference:	**2102027**
Prepared for:	**Queensland Coal Mining Board of Enquiry**
Client reference:	**RK:RK-181**
Date issued:	**19 March 2021**

FURTHER REPORT #1

in the matter of

Explosion and Fire at Grosvenor Mine

Moranbah QLD on 6 May 2020

EXPERT WITNESS DECLARATION

I certify that I have read the Expert Witness Code of Conduct UNIFORM CIVIL PROCEDURE RULES 1999 - REG 428 and agree to be bound by it. To the best of my ability, this report has been prepared in accordance with the Code. I have carried out all the enquiries which I consider to be necessary in this case.

Investigator: **James William MUNDAY** **MIFireE, FSSDip, IAAI-CFI, FCSFS**

Signed: [redacted]

Reviewed by: **Vithyaa Dayalan** **BSc, MSc, Grad Dip FI, IAAI-FIT, NAFI-CFEI**

Signed: [redacted]

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1 INTRODUCTION

1.1 Further to my report dated 11 March 2021, I have been provided with additional material and asked for further comments in a second letter of instruction (LOI 2) dated 16 March 2021. A copy of LOI 2 forms Appendix A to this report. Appendix One to LOI 2 comprises extracts from statements made by workers 1 and 2 to Mr Dobson and Mr Tolhurst of the Inspectorate on 18 December 2020 and 2 March 2021 respectively.

2 ADDITIONAL WITNESS ACCOUNTS

2.1 Worker 1 described a goaf fall which produced a pressure wave and reversed the ventilation, then another goaf fall followed by a 'pop' sound (also later described as a 'clap') immediately followed by another pressure wave and flames which surrounded him. The 'pop' and second pressure wave were '*nearly at the same time*'.

2.2 Worker 1 also described the power being lost after the first apparent goaf fall, before the second pressure wave and flames occurred. The time lag between the two pressure waves was an unknown number of seconds. During that period the ventilation did not resume.

2.3 Worker 2 had less detailed recall of the events, possibly due to having been rendered unconscious for at least part of the sequence, saying to Mr Tolhurst '*I can remember certain bits but I can't remember… in what order, you know*'. He described feeling one pressure wave followed by a sound like sprinklers and then being on fire. He did not see where the flame came from but thought '*it would have been minutes*' between the goaf fall and the flame.

3 INJURIES SUSTAINED

3.1 Workers 1 and 2 both sustained severe and widespread burns, described in the case of Worker 1 as full thickness and causing worker 2 to lose fingers. In my experience, injuries of this severity would be unlikely to result from the radiant heat of a transient gas-air flame front alone. Although a hybrid gas and coal dust fuel mixture would produce greater and more sustained radiant heating, this would still; be expected to pass the workers relatively quickly.

3.2 It is more likely that there was a significant contribution to the injuries from clothing and personal equipment, which was ignited by the deflagration and continued to burn after the pressure wave had passed.

4 RESPONSES TO QUESTIONS 1-5 OF LOI 2

4.1 Questions 1 and 2 will be addressed together.

1. What would be the net effect on the flame front velocity for an ignition that occurs deep within the caved goaf and the associated flame front propagating through the voids within the broken rock?

2. What would be the effect on the magnitude of the overpressure associated with the above scenario?

4.2 In general terms, flame propagation through voids within broken rock would be expected to proceed more slowly than through an unimpeded space but only if the voids were sufficiently narrow for the frictional drag effects and the heat losses to the rock surface to overcome the acceleration caused by turbulence. However, if the initial flame front was expanding within an open cavity and then encountered broken rock, the initial acceleration of the flame propagation due to the induced turbulence could be sufficient to overcome subsequent drag and heat losses.

4.3 In the first case, with slower flame propagation and greater heat losses to the surrounding rock, the overpressure would be reduced, and the pressure pulse extended over a longer period. In the second case, the reverse would apply; the acceleration of the flame propagation would be likely to increase the resulting overpressure.

4.4 Without very detailed information on the shape and size of the rock cavities and channels and the gas concentrations in various parts of the goaf, it is not possible to compute or model the possible outcomes. Therefore, in practical terms, I am unable to assist the Inquiry with a specific response to these questions.

4.5 Question 3

3. What is the potential time lag for a flame front to reach the face when the ignition point is 30 to 40 metres back within a caved goaf as per Question 1?

4.6 Assuming a flame propagation in a 10% methane concentration at 3.5 m/s[1] in open air with no intervening factors, the flame front could take approximately 10 seconds to travel the stated distance. In my experience, the turbulence induced by the pressure wave interacting with the surroundings generally causes acceleration to significantly greater speeds within 2-3m of the ignition point.

4.7 Typical flame speeds in structural gas explosions are in the order of 50-100 m/s but I am not aware of any research data relating specifically to mine situations involving broken rock voids.

4.8 Questions 4 and 5 will also be addressed together.

4. Is there a mechanism whereby an ignition can occur, and the associated overpressure carries an explosive mixture of gas some distance in front of the burning gas?

[1] Harris, RJ 1989; Investigation and Control of Gas Explosions table 1.2, p.6-7; E& F Spon

5. If such a mechanism is possible, would this explain a prolonged time lag between two overpressure events?

4.9 In a large but confined volume, such as a mine or tunnel, it is possible for localised variations in gas concentration to develop but this is much less likely to occur when forced ventilation and/or mechanical stirring is in progress (e.g. from machinery movements). If there are 'pockets' of gas-air mixture above LEL (lower explosive limit) remote from the area of ignition, then it is possible for them to be both carried and compressed by the pressure wave ahead of the flame front. When turbulent mixing takes place further away, for example by interaction of the wave with rocks or machinery, those 'pockets' can then ignite forming a second or subsequent deflagration epicentre. This is one of the mechanisms which can lead to multiple or cascade explosions.

4.10 Under these circumstances, there would be a time delay between the ignitions and hence between the observed pressure waves but the second or subsequent ignition would occur at a different location from the initial one. In this case, if it is assumed that the first ignition occurred in the goaf approximately 30-40m from the face, then the second ignition would be likely to occur much closer to or within the working area of the face. Worker 1 was facing towards the goaf when he saw the blue flame and worker 2 was facing the panline and tailgate; he did not see the flame coming towards him and thought it came from behind the chock.

4.11 There is a reference in LOI 2 to a '*suck back effect*' experienced at the maingate. Negative pressure waves are a common after effect of overpressure and may be caused by replacement of displaced air in a mechanical event or replacement of consumed oxygen in the case of a combustion event. I am unable to say with any certainty which was the case in this incident.

5 DISCUSSION

5.1 None of the witness descriptions seen mention any evidence of flame associated with the first pressure wave. Flame was only experienced when associated with the second pressure wave approximately 15 seconds later. Possible explanations for this are:

a. The first pressure wave was not caused by a deflagration but resulted from mechanical air compression, most likely caused by a rock fall.
b. The first pressure wave was caused by a deflagration, but it was so deep within the goaf that the methane gas was all consumed before the flame front reached the workers. In that case, the flame front could not have been an ignition source for a delayed second deflagration.
c. The first pressure wave was caused by a deflagration, but the flame propagation was sufficiently dispersed through cracked rock that no substantial flame front was visible to the workers.

5.2 In relation to the time taken for ignition in the goaf to propagate 30-40m to the face, taking structural data as a guide would indicate a potential time period of 1-2 seconds for flame propagation over the stated distance. If the 'pop' or 'clap' sound occurred at or close to the time of ignition, it would be consistent with the flame reaching worker 1 very soon afterwards as described.

5.3 Alternatively, the noise heard could have been from the approaching subsonic pressure wave although these are more commonly described by witnesses using terms such as 'whoosh, 'whoof' or 'boom' depending on the rate of pressure rise. Under these circumstances, the flame would have followed immediately after perception of the sound. Descriptions such as 'pop', 'clap', 'crack' or 'bang' are more commonly associated with high-speed subsonic pressure waves or supersonic detonations.

5.4 If there were two deflagrations, the first one being deep in the goaf and the second closer to or at the face, then:

a. the first deflagration would require an ignition source within the goaf; and
b. the second would require a separate volume of gas above its LEL near the face, in order to be ignited by the flame front from the first ignition.

5.5 The reported sequence of events with the first pressure wave being accompanied by no visible flame but the power going off immediately after it is, in my opinion, more suggestive of a mechanical cause for the first pressure wave (i.e. a substantial rock fall). If this damaged electrical equipment in the face area, methane released from the goaf as a result of the collapse there could flow towards the face area and be ignited by electrical activity at the damaged conductors. This would accord with the witness accounts of only one flame event, associated with the second pressure wave.

6 CONCLUSIONS

6.1 The additional material supplied does not alter the conclusions expressed at 7.1 and 7.2 of my original report.

6.2 The descriptions of injuries to workers 1 and 2 are more severe than I would expect from exposure to a deflagration flame front alone, even in a hybrid gas-coal dust combustion.

6.3 It is likely that clothing and/or personal equipment became ignited by the flame front, continued to burn and contributed significantly to the heat and duration of exposure experienced by the workers.

End of Further Report #1

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Appendix A – Letter of Instruction 2

Queensland Coal Mining Board of Inquiry

Your Ref:
In reply please quote: RK:RK-214

Mr James Munday
Founder / Senior Investigator
Fire Forensics Pty Ltd
PO Box 7007
SOUTH PENRITH NSW 2750

By Email: [redacted]

16 March 2021

Dear Mr Munday,

EXPERT EVIDENCE – FIRE AND EXPLOSION

Thank you very much for your report. The Board and Counsel Assisting the Board have considered it and it is very helpful.

The Board would be grateful if you would be willing to address some clarifying matters in an addendum report. Those matters involve three further questions and some additional material.

Further questions

Paragraph 2.8 describes the phenomenon of the flame front moving through a medium. The paragraph addresses the effect of obstructions and objects within the path of the flame front creating turbulence and an associated increase in flame front velocity.

Paragraph 2.9 adds the complication of heat loss and frictional drag on the flame front which opposes the turbulence induced acceleration.

The questions are:

1. What would be the net effect on the flame front velocity for an ignition that occurs deep within the caved goaf and the associated flame front propagating through the voids within the broken rock?
2. What would be the effect on the magnitude of the overpressure associated with the above scenario?

Paragraph 6.3 states that in the authors opinion, based on flame front speed, the time interval between the two pressure waves is too great for an initial methane or hybrid deflagration to have directly initiated a second event, in the manner of a cascade.

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The question is:

3. What is the potential time lag for a flame front to reach the face when the ignition point is 30 to 40 metres back within a caved goaf as per Question 1?

Reports from coal mine workers situated at the maingate reported a suck back effect after the first over pressure event.

The questions are:

4. Is there a mechanism whereby an ignition can occur, and the associated overpressure carries an explosive mixture of gas some distance in front of the burning gas?
5. If such a mechanism is possible, would this explain a prolonged time lag between two overpressure events?

Could we please have the benefit of your opinion on the above questions in an addendum report?

Additional material

Please find attached the final two excerpts from injured coal mine workers, namely injured coal mine workers 1 and 2 ([redacted]).

[redacted]

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[redacted]

The Board would be grateful if you could confirm, in an addendum, whether the attached excerpts or the above injury descriptions alter the opinions expressed in your report. If this material supports your opinions, the Board would appreciate you explaining this in the addendum also.

If you have any questions or wish to discuss this request, please contact me on 0477 312 075 or at renae.kirk@coalminesinquiry.qld.gov.au.

Yours faithfully

Renae Kirk
Special Counsel
Queensland Coal Mining Board of Inquiry