A RISK FRAMEWORK FOR ASSESSING THE POTENTIAL FOR A FRICTIONAL IGNITION

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SUMMARY

An increased occurrence of frictional ignitions in Queensland during the past year has seen the subject receive attention from both the industry and inspectorate. A generic risk assessment framework was developed by SIMTARS to assist the mines, as part of an ACARP project on frictional ignitions. Although the subject of frictional ignitions is not fully understood, sufficient information is available for a good evaluation of the probability of an ignition to be made using certain indicators. The framework is based on a fault tree of the causative factors leading up to an ignition and firstly identifies the critical issues that mines will have to know before such an evaluation could be embarked upon. Once this information is available, the framework leads the mine operators through a series of questions. The operator, by answering these questions, is able to identify those issues that could cause the probability of an ignition occurring to increase significantly. Knowledge of the issues that increase the risk enables the operators to focus their efforts at instituting the necessary preventative controls. It is foreseen that the use of this framework would assist mines to more readily assess their particular ignition risks and also develop cost effective solutions.

INTRODUCTION

The prevention of frictional ignitions in coal mines has received renewed attention during the past few years. Frictional ignitions can not only hurt people but can also lead to more catastrophic consequences if they are not contained. Despite significant research efforts into the causes and the necessary controls, it would seem that there has been little decrease in their occurrence in the last decade. In Queensland alone there have been a number of ignitions that have caused the subject to receive significant attention.

Frictional ignitions caused by picks striking stone have been widely researched and reported throughout the world. However there are still areas that are unclear and problems with the implementation of proposed controls are still prevalent. These issues include the influence of dust in the vicinity of the pick and micro ventilation in and around the picks. This second aspect is especially important in the light of the known fact that different temperatures as well as different heated surface areas have an effect on the ability to ignite the mixture. There is however sufficient knowledge and understanding to conduct a risk assessment that will enable mines to determine the potential for an ignition.

The Mining Research Centre at SIMTARS has been involved in an ACARP project on frictional ignitions. One part of this project was developing a risk framework that can be used to assess the frictional ignitions risk on a mine. It was anticipated that this risk framework would increase the understanding of the subject amongst the Australian coal mining industry as well as facilitate a more cost-effective process. As the major causative factors are known, a generic model and process was established which mines can use as part of their risk assessment process.

Although other forms of friction can cause ignitions or fires in mines, the area of investigation was restricted to frictional heat caused by the pick of a coal-cutting machine striking stone. Other forms of friction that occur in goafs or where steel rubs against steel or other materials are different in nature and were not included. A further reason for restricting efforts to frictional ignitions from pick on rock is because this area has been identified as having the most pressing need. The largest contribution to increasing safety on mines can be achieved by preventing such incidences.

USE OF THE PRINCIPLE OF FIXED CONSEQUENCE

The principle of fixed consequence was used in devising this risk framework to determine, even qualitatively, the probability of a hazard occurring. Risk has been defined as having two components, consequence and probability. Matters are usually complicated because there is a relationship between the probability and severity of the consequence. For example an incident with a small consequence could very easily occur with greater probability that one with a large consequence. This is quite possible in the area of frictional ignitions. The chance of friction causing a hotspot or a small kernel ignition is significantly higher than causing a methane explosion.

The fixed consequence principle is used to overcome this problem. This principle defines the consequence up front and the only issue under consideration is the probability of the hazard occurring. In the case of frictional ignitions the consequence is fixed as the ignition of methane by the frictional heat of a pick striking incendive material. For such an occurrence to happen the requirements of the fire triangle has to be complied with and thus the analysis is based on the probability of a fire triangle being formed. The size and scope of the ignition is not considered. The fact that such an ignition could occur is deemed to be serious enough without the consideration of a large accumulation of methane being present to cause an explosion to occur.

If there is a risk that a frictional ignition could occur, the principle of the progression of the explosion can be used to determine the most appropriate controls. This is performed with due regard to the possibility that the initial part of the ignition might be so small that it is not dangerous if it is contained. In other words the ignition is seen as a small initiating heat rather than an explosion which could lead to a further and larger explosion. By doing this, the consequence of the hazard is diminished as the probability of the hazard occurring is high (this is the underlying principle that is followed when suppression systems are introduced). If the controls on the mine were insufficient to keep an ignition from occurring then the controls to prevent an explosion from occurring would also be insufficient. This will require that additional controls be implemented to prevent ignitions from occurring. These controls could then range from closing the section, part of the mine or the implementation of advanced suppression systems.

CAUSATIVE FACTORS

A frictional ignition is an exothermic reaction, which requires three main components to exist simultaneously before it can happen. These three components are more commonly called the fire triangle, and consist of the fuel (reducing agent), oxygen in the air (the oxidising agent) and the heat caused by a frictional hotspot (initiating heat or entalphy of the reaction). These three components are used not only as the basis to determine the potential for a frictional ignition but are also used to devise controls to prevent an ignition from occurring.

The fuel for a frictional ignition is usually provided by the presence of methane. Methane is released from the coal or adjoining strata and is removed or diluted to safe levels through ventilation. Latter-day work has indicated that the presence of coal dust in the methane not only has an influence on the lower explosive limit of the methane but also takes part in the ignition. The effect that this coal dust has on the energy requirements to initiate the ignition is still to be determined. The outcome of this research could have a significant influence on the best method to control ignitions.

Oxygen in the air provides the oxygen for the reaction. As the oxygen is needed for humans to breathe, its presence is taken to be a given in any risk assessment to determine the potential for an ignition. It is only in certain cases where the risk is high due to the probability of the other two factors being present where the exclusion of oxygen is used in controlling an ignition. Therefore possibility of the both the fuel and oxygen can never be fully excluded from any coal mining situation. The third factor, which is the initiating heat, is however dependant on the prevailing conditions.

The initiating heat required to start the ignition is generated by the friction between the cutting picks and incendive sandstone. Research done locally and throughout the world has shown that it is only when a pick strikes a stone with specific characteristics that sufficient heat can be generated to ignite methane. Further it is only under specific cutting element conditions that a hotspot of sufficient size and temperature can be generated. These conditions relate to the speed and condition of the pick.

So for an ignition to occur there must methane present and the cutting elements must encounter the incendive stone under certain conditions. Only when this happens are all the requirements met for an ignition to occur. The probability of an ignition occurring can be determined using these conditions as the basis and determining the probability of these conditions occurring at the same time.

THE FRAMEWORK

The framework was developed by doing a problem or fault tree analysis of the conditions that would lead to a frictional ignition happening. An initial tree was used and then expanded to be fully comprehensive during a workshop held with authorities from both the industry and research environments. The following figure sets out the main headings of this fault tree.

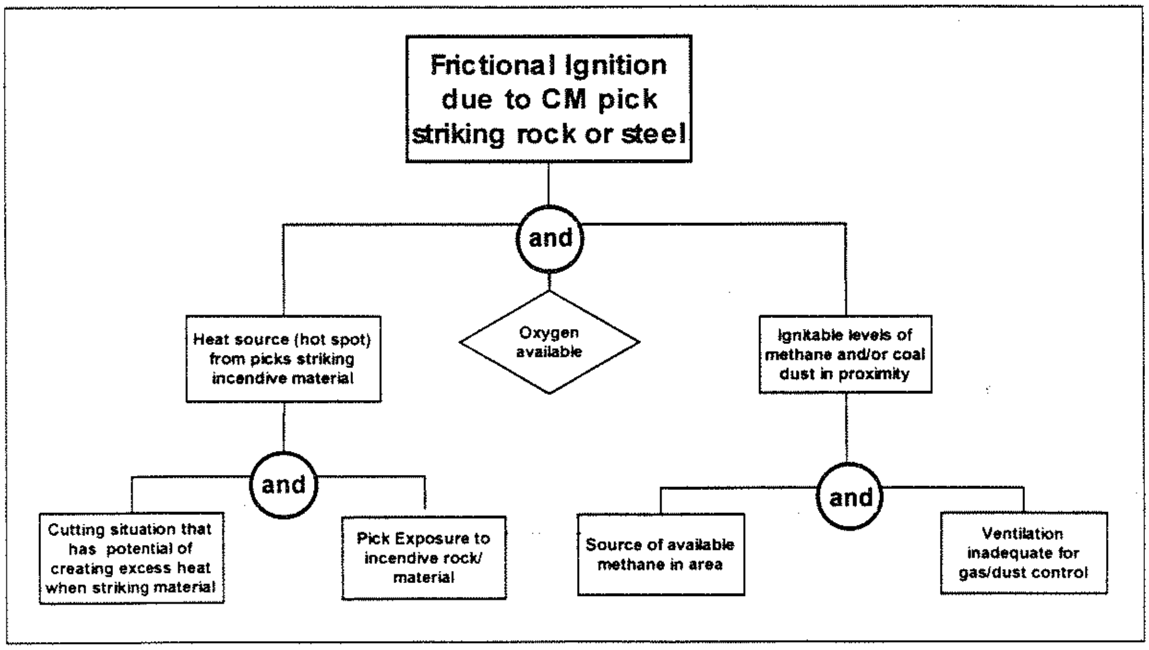

Figure 1: Fault tree for frictional ignition due to continuous miner pick striking rock or steel

The first line of this figure represents the fire triangle where it is shown that a heat source, oxygen and ignitable levels of methane all must be present at the same time to enable an ignition to occur. The lines below present those situations that lead to these three factors being present. As the presence of oxygen in the air cannot be prevented in the mining situation it has not been developed any further and attention is focused on the initiating heat and the presence of fuel.

The presence of fuel for an ignition is caused by a source of methane being present and at the same time having inadequate ventilation controls to dilute or remove this methane. The hotspot that forms the initiating heat is caused by exposing the cutting elements to incendive rock and at the same time having a cutting situation that has the potential for creating excess heat. Each of these basic causes were then developed further into more detailed contributing factors.

In Figure 2 sources of methane are identified. In an underground coal mine, except in very isolated instances, it can be safely assumed that there will always be methane present. The real issue with methane lies in how effectively the ventilation dilutes and removes it. The causes of inadequate dilution and/or removal of methane that can lead to an accumulation (of fuel) are presented in Figure 3. The main causes for inadequate control of methane are either the ventilation quantity is insufficient to dilute the methane to safe concentration or the ventilating air is directed in such a way that the air cannot reach the methane resulting in inadequate mixing and removal.

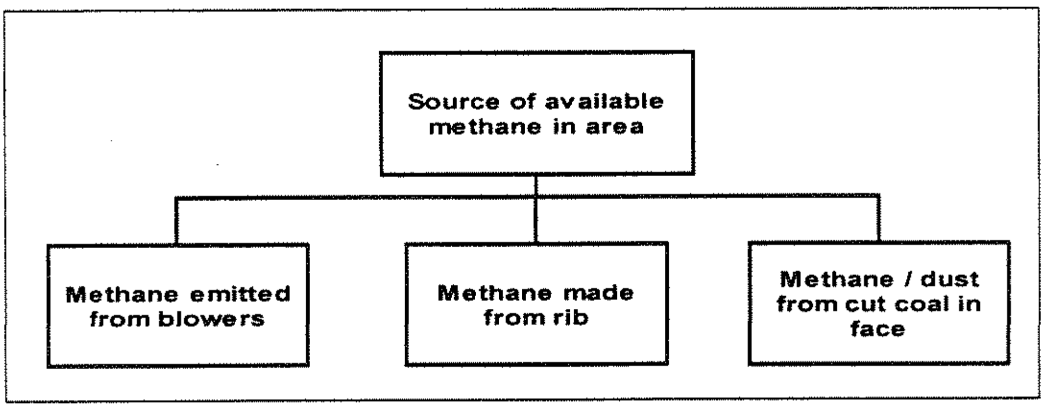

Figure 2: Sources of methane

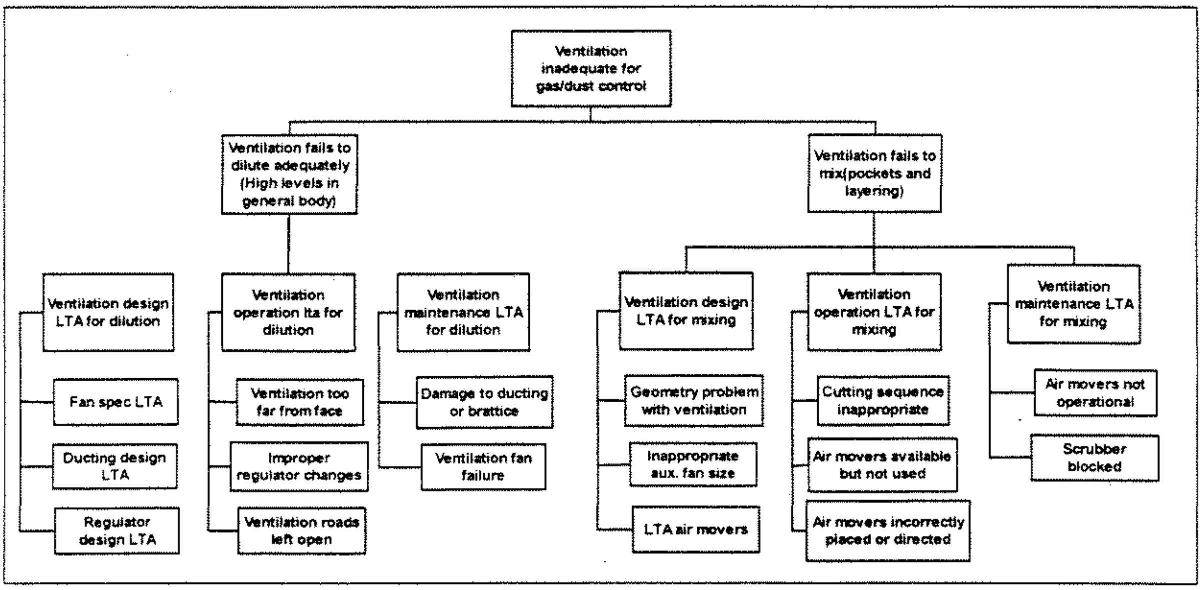

Figure 3: Causes for inadequate control of methane

The next consideration was the formation of a hotspot caused by a pick striking incendive material. Figure 4 shows that the picks can be exposed to such material in the roof, floor or in the seam being extracted. In the case of incendive materials in the seam being extracted, there is nothing that can be done to avoid this material if mining is to continue. But in the case of the roof and floor stone, inadequate horizon control could be the reason why the picks contact the stone.

The presence of incendive material and making contact with it is not the only reason a hotspot is generated. Coupled with the incendive stone the cutting conditions must also be such that excessive heat can be generated.

In Figure 5 the causative factors are described for excessive heat occurring in the cutting situation. The main reasons for the cutting situation to be problematic are:

(a) if the cutting drums and picks were designed inadequately to prevent the generation of frictional heat,
(b) the drum is operated wrongly, or more importantly,
(c) the maintenance of the drum, picks and water-sprays are not performed adequately.

This latter cause is one of the single most important causes of frictional ignitions. This is however not an easily defined criteria as it depends more on the actions of the operators than on a physical characteristic.

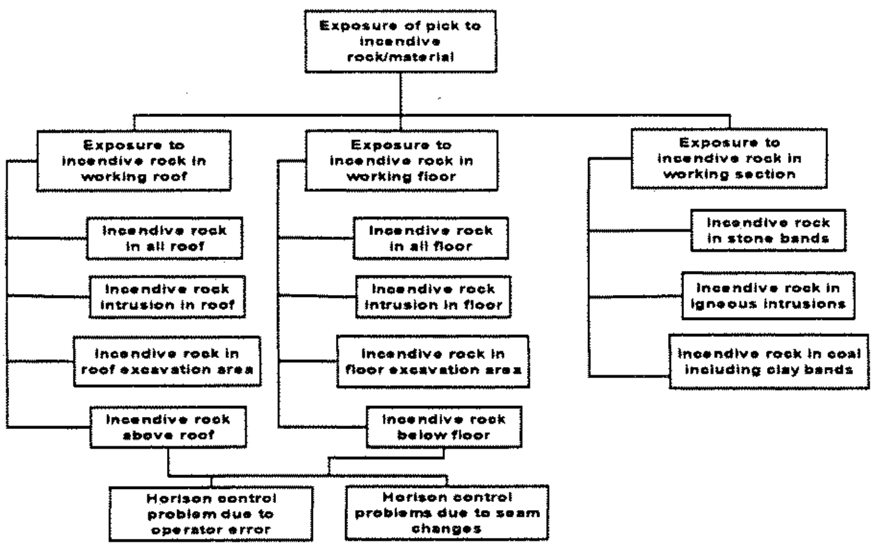

Figure 4: Causes for the exposure of the picks to incendive material

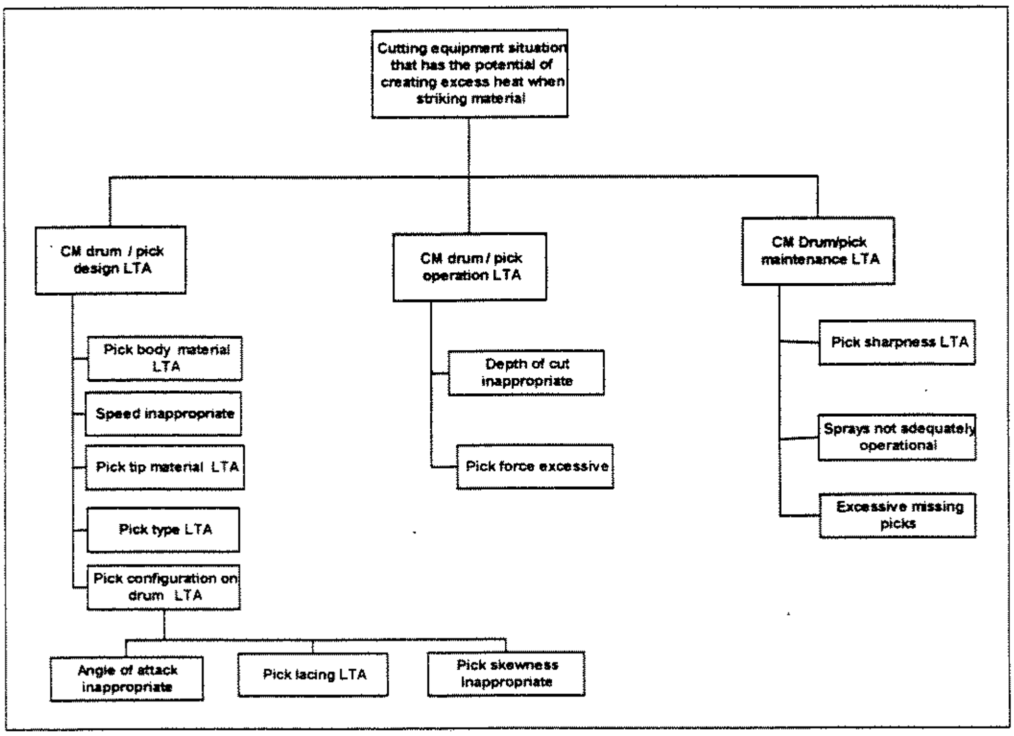

Figure 5: Causes leading to a cutting situation with the potential of creating excessive heat

The causative factors determined in the fault tree do not in themselves assist the mine to determine the risk of a frictional ignition occurring. The fault tree sets out the causes of a friction ignition but not the actual circumstances that have to prevail.

To make the framework more useable to management the factors have been transformed into a set of question structured in the same way as the logic diagram. A copy of the first page of questions is presented in Appendix A.

Structuring the causative factors in the form of questions serves two purposes.

Firstly it allows the mine to determine what information is required. Experience has shown that in the majority of cases mines do not know what is required to assess the potential for a frictional ignition and even when this is known the actual values required are difficult to obtain. A good example is the characteristics of incendive sandstone. Although the criteria according to which sandstone can be classified to be incendive has been well published, it still requires significant laboratory testing and evaluation. It is due to this lack of capability that another part of the present ACARP project is involved with the establishment of a method to test stone for its propensity to ignite methane when struck with a pick.

Secondly by obtaining the required information and then answering the questions mine management obtains a very good indication of the scope of causative factors that are present on their mine. The more possible alternative causes in such an evaluation the higher the potential for an ignition.

USE OF THE FRAMEWORK

The effectiveness of the framework was tested when it was used to determine the possible reasons for a frictional ignition that occurred in a Queensland mine as well as to identify shortcomings in present controls.

In the conducting of this pilot exercise the following benefits of the risk framework became evident:

- Allows for a speedy evaluation by directing attention to the pertinent issues.
- Identifies the problem issues that the mine has to focus on.
- Identifies the information gaps with relation to the potential for frictional ignitions on the mine.
- Allows the real problems leading to the potential for a frictional ignition to be identified.

- Identifies those factors that the mine has an influence over and those that can easily be solved.

- Enables a user driven transfer of knowledge and information because of the interactive nature of using the framework.

- Once the mine is familiar with the process it can very easily be used without outside assistance.

- Enables control indices to be identified.

DEVISING CONTROLS

When devising controls to manage the risk of frictional ignitions there are three main areas of action; preventative, engineering and training.

Preventative actions are those directed at preventing the conditions that cause a frictional ignition. These actions will include removing the methane, eliminating hybrid mixtures, keeping the picks in a good condition, not cutting in either roof or floor stone and using inert gases to prevent the oxygen being present. Preventative measures are also used when the risk, even when controls have been installed, is still too high and efforts must be directed at containing the effects of a frictional ignition. The use of active suppression systems in this case should form part of the preventative actions taken to ensure the safety of workers.

Engineering controls are those systems that are installed to reduce the risk of an frictional ignition occurring. These actions include the ensuring that there is adequate ventilation in the section, use of the right type of pick, use of machine controls to keep the cutting elements out of roof and floor stone, installation of the pick-path sprays and the installation of inert gas generators to supply inert gas to the cutting head area. These systems significantly reduce the risk of a frictional ignition occurring because they reduce the probability of one of the causative factors being present.

The final action that can be taken is training. Training should be directed at increasing the capability of the workforce by increasing awareness of the issues leading to a frictional ignition and by explaining the role of measures taken to reduce the probability of an ignition occurring. One of the areas that have been identified to be very important is training workers to recognise the importance of maintaining the installed engineering controls. Even a simple issue like the replacement of a worn pick is not easy due to the difficulty of recognising when a pick becomes worn down to a state where it can more easily produce a hotspot.

The available literature and engineering systems that have been developed throughout the world clearly indicate there is sufficient measures available to significantly reduce the probability of a frictional ignition occurring. If these measures have been installed on a mine and ignitions still occurring then there are only two logical outcomes: the installed systems are not used and maintained as intended, or the installed systems are inadequate. If the systems are not used according to design or insufficiently maintained then the mine should consider measures to ensure that the equipment is used so that they fulfil their purpose. If on the other hand the mine management is sure that the procedures were followed and equipment was well maintained and used according to specification, then it should consider additional measures like the installation of a suppression system which will safeguard workers in the mine even though it cannot prevent an ignition.

CONCLUSION

The exercises conducted and the discussion during the risk assessment held to establish this framework raised some key issues with regard to the occurrence of frictional ignitions in the industry.

There are some very knowledgeable persons in the industry on the subject of frictional ignitions, however on the whole there is lack of knowledge with regard to the issues that lead to, and are conducive to, frictional ignitions occurring.

Indicators, direct and indirect, of an increased risk of ignitions have been identified. For example, the increased occurrence of dust in the heading can become a valuable tool in determining a change in risk. Even though it is a known fact that an increase of airflow to dilute the methane could lead to increased dust pickup the presence of dust on the other hand indicates that there is insufficient air to stream the dust away from the face and that the pick maintenance is less than adequate (blunt picks always make more dust than sharp ones).

The frictional ignition risk framework holds some significant benefits for the industry. The use of this framework can greatly assist a mine to determine the potential for a frictional ignition. It also indicates if the present controls are sufficient, or whether further steps need to be taken to protect the mine and the workers in it. The framework also establishes if the mine has enough information to be able to properly assess their risk.

Other benefits of the risk framework process are that it is cost-effective in terms of the resources required. There is also an indirect benefit because it transfers information to the industry thereby increasing competency of people in the industry. The use of the framework to evaluate the probability of a frictional ignition at a mine, even though there has not been any previous incident, would serve to increase the knowledge of the people involved.

The framework also allows the identification of possible shortcomings in presently used controls and forms the basis for prioritising the implementation of controls according to those that represent the most effective expenditure of resources whilst ensuring the safety of the workforce.

Appendix 1 Example of questionnaire.

LOGICAL PROBLEM	ADJUDICATION CRITERIA	Remarks
Frictional ignitions due to pick striking incendive rock or steel	Has a frictional ignition occurred before on the mine? Previous history very strong evidence	
Are present controls adequate?	Has ignition occurred since installation of controls In the event of ignitions still occurring after installation of controls, present ones must be deemed as inadequate.	
IGNITABLE LEVELS OF METHANE /DUST IN PROXIMITY		
	Presence of methane to be primarily determined with no ventilation	
Source of available methane in area		
▪ Methane emitted from blowers	Visible bubbling Hear it Measure high concentrations close to	
▪ Methane make from ribs	High concentration measured when no ventilation flowing.	
▪ Methane made from cut coal/face	High concentration measured when no ventilation flowing.	
▪ Methane emitted due to unexpected geological occurrence	Audible and visible, noise of goaf or roof falls. Air blast or increase flow of ventilation Off scale or high levels of methane on monitors and other instruments.	
Ventilation inadequate for gas /dust control		
Ventilation fails to dilute		
Ventilation design LTA for dilution ▪ Fan spec LTA ▪ Ducting design LTA ▪ Regulator design LTA ▪ Ventilation not reaching methane	Increased incidence of on board monitors knocking power out. Increased levels of dust in heading Increased levels of methane in returns It should be noted that the local increase of methane at a point where no monitor or handheld instrument is present could possibly not be discerned	
Ventilation operation LTA for dilutions ▪ Ventilation too far from face ▪ Inappropriate regulator change ▪ Ventilation road left open	Same as above Incidences of high methane occurrences in cavities Lack of air on face	

▪ Airflow directed not to reach methane ▪ Cavities and roof such that ventilation cannot reach methane	It should be noted that the local increase of methane at a point where no monitor or handheld instrument is present could possibly not be discerned.	
Ventilation maintenance LTA for dilution ▪ Damage to tubes / brattice ▪ Ventilation fan failure	Lack of vent air in face Visible damage Short circuiting of air	
Ventilation fails to mix		
Ventilation LTA for mixing ▪ Geometry problem with ventilation ▪ Inappropriate aux. fan size ▪ LTA air movers ▪ Presence of cavities	Lack of air in heading Recirculation of air Incidences of high reading (handheld) Increased incidence of on board monitors knocking power out. Increased levels of dust in heading	
Ventilation operation LTA for mixing ▪ Cutting sequence inappropriate ▪ Air movers available but not used ▪ Air movers incorrectly located.	Increased incidence of on board monitors knocking power out. Increased levels of dust in heading Lack of visible spraying	
Ventilation maintenance LTA for mixing ▪ Air movers not operational ▪ Scrubbers blocked	Lower flow of air in heading Increased dust levels in heading Decreased dust levels in return	