Development and Application of a Risk-Based Online Body-of-Knowledge for the U.S. Underground Coal Mining Industry: RISKGATE-US COAL

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science
In
Mining Engineering

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December 1st, 2016
Blacksburg, Virginia

Keywords: Risk Management, Underground Mining, Coal, Occupational Health and Safety

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Abstract

The occurrence of multiple fatality events in the U.S. underground coal mining industry, such as the Upper Big Branch mine explosion, illustrates the need for improved methods of major safety hazard identification and control. While many solutions to reducing the risk of mine disasters have been proposed, including stricter regulation and improved technology, a comprehensive risk management approach has yet to be fully integrated in the U.S. mining industry.

Comprehensive risk management systems have been developed and implemented across a multitude of heavy industries, most notably the Australian minerals industry. This research examines the successful application of risk management in these industries, along with barriers towards U.S. implementation of risk management, which include the existence of competing safety models (e.g. behavior-based safety) and compliance regulation which consumes company resources, and limits incentive for beyond compliance safety measures. Steps towards the risk-based approach, including increased regulatory pressure and proactive initiation by high-ranking industry individuals, begin with the development of risk-based knowledge within the U.S. mining community.

This research reviews the development of mine safety regulation in the U.S., and identifies regulatory constraints which have affected the diffusion of risk management. The development of a risk-based online platform which could complement the existing safety systems of U.S. underground coal operations, based on the Australian RISKGATE tool, is the central work of this research. This online platform has been developed by the research participants and industry professionals whose total

underground coal mining experience exceeds 1,290 years. This joint effort has yielded a body-of-knowledge which may be used as a complementary safety control reference for U.S. mine operators who wish to employ risk management policies and practices at their own operations, or identify gaps within their own safety control systems.

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General Audience Abstract

Over the last century, the safety record of the U.S. coal mining industry has steadily improved, with annual fatal incidents reaching historically low values over the last decade. Advancements in mine safety are largely attributed to increased regulatory and enforcement efforts and the enhancement of mining technology. While fatal incidents have become more intermittent, the U.S. underground coal mining industry has yet to reach its zero harm goals through current industry standards and mining practices.

Risk management, the systematic mitigation of risk through proper identification, assessment, and control, has been successfully utilized by various heavy industries (chemical, aviation, military, nuclear energy, etc.) to improve worker health and safety outcomes. However, risk management has yet to be comprehensively adopted by and applied to the U.S. coal mining industry. This research examines the potential application of risk management in U.S. underground coal mining, and describes the development of a U.S.-based risk management body-of-knowledge, RISKGATE-US COAL, designed to assist U.S. coal mining operators (e.g. frontline workers, engineers, mine managers) in the identification and mitigation of the unique hazards encountered in the underground coal mine environment.

RISKGATE-US COAL is contained within an online platform (alpha.riskgate.org) devised as a reference tool for U.S. underground coal mining practitioners to identify gaps within their own safety control systems.

Acknowledgements

First and foremost, I would like to thank my advisor, Dr. Kray Luxbacher for her invaluable guidance and mentorship. She is an exemplary role model for me and other young engineers who have been given the opportunity to work with her. I would also like to thank my committee members, Dr. Erik Westman, Dr. Steven Schafrik, and Dr. Nino Ripepi, for the instrumental roles they played in this research project, and their continuous contributions to my education as a mining engineer. I am also grateful to the Virginia Tech Department of Mining and Minerals Engineering for the opportunities I've been afforded.

This research would not be possible without the contributions of our Australian research partners, the U.S. coal industry, and the companies and individuals who aided in the positive progress of this research. My appreciation for their time and effort cannot be overstated.

Most importantly, I could not have completed this research without the unending support of my family, which has given me every opportunity to succeed in life, and my greatest love, Laura.

Finally, I would like to thank the Alpha Foundation for the Improvement of Mine Safety and Health. This document was developed with a grant awarded to Virginia Tech researchers by the Alpha Foundation. The findings and conclusions in this report are those of the author and do not reflect the official policies of the Alpha Foundation. Additionally, the mention of trade names, commercial practices, or organizations does not imply endorsement by the Alpha Foundation.

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Chapter 1: Introduction

The International Organization of Standards defines risk as "*the effect of uncertainties on achieving objectives* (ISO 31000, 2009)." In general, many uncertainties can influence the outcome of personal or professional objectives. These uncertainties are often difficult to identify and predict. Risk management, the minimization and control of adverse effects from exposure to identified risks, is a well-established concept that can be summarized as "being smart about taking chances" (Hubbard, D.W. 2009). Risk management now consists of management processes unique to numerous organizations across many industries, as varying sectors encounter a variety of needs, including the analysis and mitigation of risks related to physical security, product liability, information security, various forms of insurance, regulatory compliance, and workplace safety (Hubbard, D.W. 2009).

The reoccurrence of multiple fatality events in the United States mining industry, especially the underground coal sector, suggests an opportunity for improved methods of major safety hazard identification, assessment, and mitigation (*Figure 1.1*). A risk management approach would include ready identification and mitigation of these risks, inclusive stakeholder engagement, and rapid integration. A risk management approach has already been implemented with success in Australia's minerals industry as part of a transition during the mid-1990s from a prescriptive based health and safety attitude to a more proactive, duty-of care [risk-based] philosophy (Iannacchione, A. et al. 2008, Joy, J. 2004, Kirsch, P.A., J. Harris, D. Sprott, and D. Cliff, 2014).

While many solutions to reducing the risk of mine disasters have been proposed including stricter regulation and improved technology, a comprehensive risk management approach has yet to be fully integrated in the U.S. mining industry. In December of 2006, R. Larry Grayson of the National Mining Association's Mine Safety Technology and Training Commission called for "*a new paradigm for ensuring safety in underground coal mines, one that focuses on systematic and comprehensive risk management as the foundation from which all life-safety efforts emanate* (Grayson, R.L. 2006)."

The research presented outlines the development process and application of an online risk control database – RISKGATE-US COAL – which addresses three key high-risk areas in U.S. underground coal mine safety: Fire and Explosion Prevention, Roof Control, and Moving Equipment. Information used to create the online body-of-knowledge was gathered through research workshops attended by industry professionals and technical experts in U.S. underground coal mining. The website was built in partnership with the School of Mining Engineering at the University of New South Wales and the Minerals Industry Safety and Health Center of the University of Queensland.

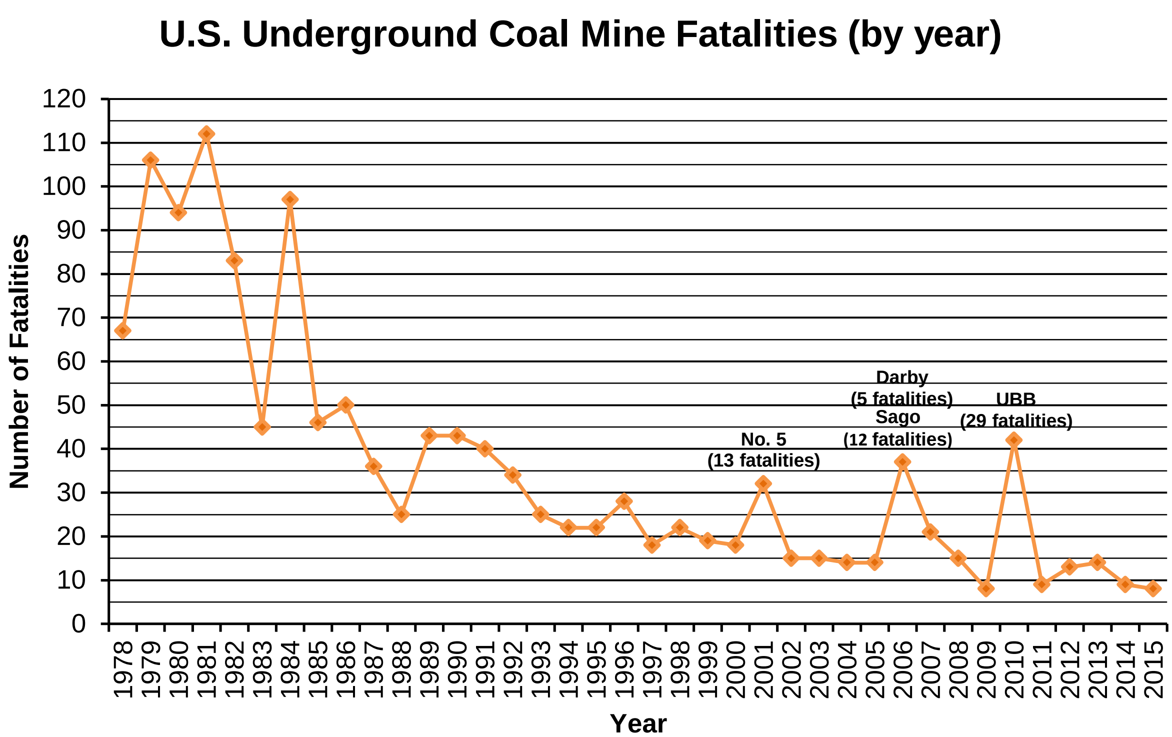

Figure 1.1 – High profile Multi-fatality events (Upper Big Branch mine event, Sago mine event, Darby mine event, No. 5 mine event) from recent years (U.S. Mine Safety and Health Administration, 2008, 2009, 2010b, 2011, 2012, 2013, 2014, 2015)

Chapter 2: Literature Review

2.1 Risk Management Techniques and Practices in Mining

The comprehensive application of a risk management framework in an underground coal mine operation requires an understanding of fundamental risk management principles and their applied outcomes in relevant industries. Balancing an awareness of U.S. mine safety culture, its origins, and current best practice in health and safety with this information is necessary to build a practical and accessible online platform to support the U.S mining industry's safety goals.

2.1.1 Fundamental Elements of Risk Management - Risk Assessment

The fundamental components of a comprehensive risk assessment/management program are well-established within the realm of mining health and safety. *Figure 2.1* depicts the elements of a typical mining risk management framework. The first step in any safety-based risk management system is to identify and assess hazards by their location, nature, and magnitude within a mine. Next, a decision is made about choosing to eliminate, mitigate, or tolerate each hazard. Ideally, a hazard will be eliminated during the design stages of mining, though dynamic mining conditions often require continuous improvement and reevaluation of existing hazard controls. If elimination is not possible, hazard mitigation actions can consist of methods, rules, equipment, competencies, or other mechanisms. If a hazard is simply tolerated, as many inherent mining hazards must be, then specialized administrative controls must be utilized to minimize losses. During this process, the performance of each action is monitored and modified as needed (Iannacchione, A. et al. 2008).

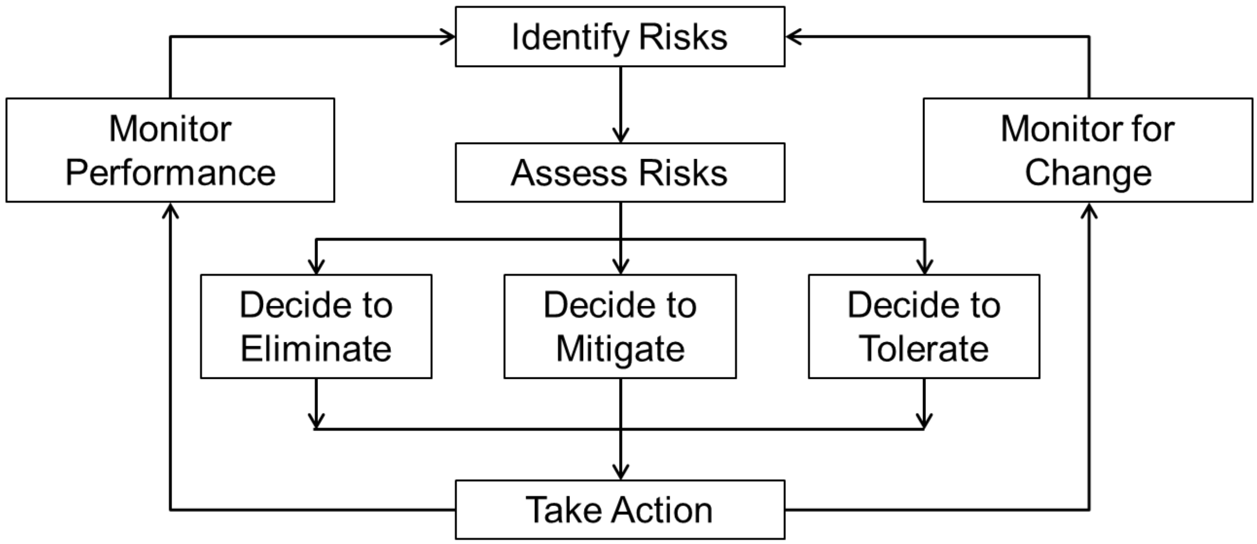

Figure 2.1 – Principal elements of a risk management framework in an industrial setting (Iannacchione, A. et al. 2008)

2.1.2 Determining Risk: Common Tools and Techniques

To determine risk, whether that determination is quantitative or qualitative, the risk must be defined in terms of the probability that an unwanted or uncontrolled event will occur as well as the subsequent consequences of that event occurring. Qualitative or semi-quantitative risk assessment, which is commonly used to assess occupational health and safety hazards, uses basic estimation to assign and rank the risk of unwanted events occurring from high to low. This form of risk assessment can also be referred to as Rapid Risk Ranking (RRR). The RRR methodology typically relies on a risk matrix which defines qualitative categories (e.g. unlikely-to-probable, low consequence-to-high consequence) with predetermined quantitative values (e.g. number of events per year, production lost in dollar amount) to rank risk (Iannacchione, A. et al. 2008).

Risk matrices usually consist of three sections of severity denoted by different colors. An event ranked in the red section (high risk) is characterized as unacceptable, and steps must be taken to improve control effectiveness and lower the probability or consequences of such an event occurring. The yellow or intermediate section is reserved for risks which require monitoring, but are usually tolerated and controlled as low as reasonably practicable (ALARP). Finally, the green section (low risk) is reserved for events that are both unlikely to occur and would result in little consequence. Generally, the risk of unwanted events in this section is considered to be controlled.

While risk matrices can be useful for ranking risks, they do not address the underlying causes of uncontrolled events. Risk matrices also do not define what controls an organization currently has in-place, and should not be used to make informed decisions about control effectiveness. An example of a generalized risk matrix is shown in *Figure 2.2*.

		Likelihood of Occurrence		
		High	Medium	Low
Consequence	High	High risk		
	Medium		Moderate risk	
	Low			Low risk

Figure 2.2 – A generalized risk matrix used to rank risk for priority unwanted events (Iannacchione, A. et al. 2008)

The Workplace Risk Assessment and Control (WRAC) tool is another rapid risk ranking method which allows the user to focus on the highest risk associated with a particular phase of mining, location within a mine, etc. (*Figure 2.3*). This is done by identifying and examining the high risk hazards encountered during each step of a specific mine process. Then, the unwanted events associated with these hazards are assigned a likelihood and consequence using some form of a risk matrix. The risk matrix is often used in conjunction with the WRAC tool to provide a general risk ranking prior to assessment of in-place controls, and then again to provide a lower risk ranking once specific controls are identified which provide further protection from the risk of an unwanted event. However, simply re-ranking risk based on limited control information does not necessarily provide a reliable assessment of control effectiveness. The likelihood and consequence values are used to calculate a risk rating (Iannacchione, A. et al. 2008). This risk rating is based on user-defined values for consequence and likelihood, which limits the application of risk matrices and the WRAC tool towards any quantifiable or probabilistic risk determination. Standardized scales which contain analogous consequence and likelihood values can be used to address the qualitative nature of these tools and assess different forms of loss/risk on a single WRAC risk ranking form.

Mining phase, location within mine, etc.	Potential unwanted event	Consequence	Likelihood	Risk rating
Longwall face	Coal outburst	High (5)	Likely (4)	(C x L) = 20
...	...	...	...	...

Figure 2.3 – A simple example of a WRAC risk ranking form (Iannacchione, A. et al. 2008)

Consequences must be ranked in a consistent and logical manner, with either the most probable or the most severe consequences considered for each event. A variable consequence scale can be developed to determine the maximum reasonable consequence for events across different consequence categories, including human safety, equipment damage, production loss, and destruction of the environment (*Figure 2.4*). A company may also wish to include less tangible consequences, which may include a loss of public trust in the company (loss of social license to operate), negative press coverage leading to increased public scrutiny, etc. following an unwanted event.

Consequences of Event				
Rank	Safety (human)	Equipment	Production	Environment
1	Multiple fatalities	> $5 M	1 Week	> $5 M
2	Single fatality	$1 M	1 Day	$1 M
3	Major lost-time injury (LTI)	$200 K	1 Shift	$200 K
4	Average LTI (4-5 days)	$50 K	1 Hour	$50 K
5	Minor Injury (≤ 1 day)	< $10 K	<1 Minute	< $10 K

Figure 2.4 – An example of a variable scale used to rank consequences associated with different forms of loss (Iannacchione, A. et al. 2008)

As with the consequences, the likelihood rating for each event should be assigned in a consistent manner. A variable scale can be developed for likelihood ratings based on criteria such as number of events per year, number of events per decade, etc. (*Figure 2.5*)

Rank	Based on Maximum Reasonable Consequence			Based on Events / Year
1	Common	Highly likely	Expected	> 10
2	It has happened	Likely	High	1 to 10
3	Possible	Possible	Moderate	0.1 to 1
4	Unlikely	Unlikely	Low	0.01 to 0.1
5	Almost impossible	Very unlikely	Not Likely	< 0.01

Figure 2.5 – An example of a variable scale used to rank the likelihood of an unwanted event occurring (Iannacchione, A. et al. 2008)

These risk assessment tools (RRR methodology) provide the user with broad-brush risk rankings for the priority hazards present at their mine, and semi-quantitative risk values. However, a more robust risk assessment tool focusing on the effectiveness of controls rather than risk ranking must be supplemented for a more comprehensive analysis of risk control. Simply ranking risk based on limited control information may not provide a reliable representation of tolerable risk for a mine site.

2.1.3 The Bowtie Analysis Tool (BTA)

The bowtie analysis tool approaches risk control by focusing on an unwanted initiating event, or the moment at which control effectiveness is lost (*Figure 2.6*). Bowtie diagrams visually illustrate the relationship between potential hazards, the unwanted event these hazards could lead to, the consequences of this event, and controls relating to both the causes and the effects of the event. The initiating event is represented by the center of the bowtie. A list of possible causes is presented to the left of the bowtie, each with its own specific preventive controls addressing its association with the initiating event. To the right of the bowtie is a list of potential consequences, as well as their own mitigating controls linked to the initiating event. Bowtie analysis allows the user to assign event-specific controls by addressing each identified cause or consequence of an unwanted event, and considering the range of controls that correspond to those causes and consequences. This distinction of controls (preventive versus mitigating) is the major organizational difference between bowtie analysis and the more informal risk assessment tools discussed earlier.

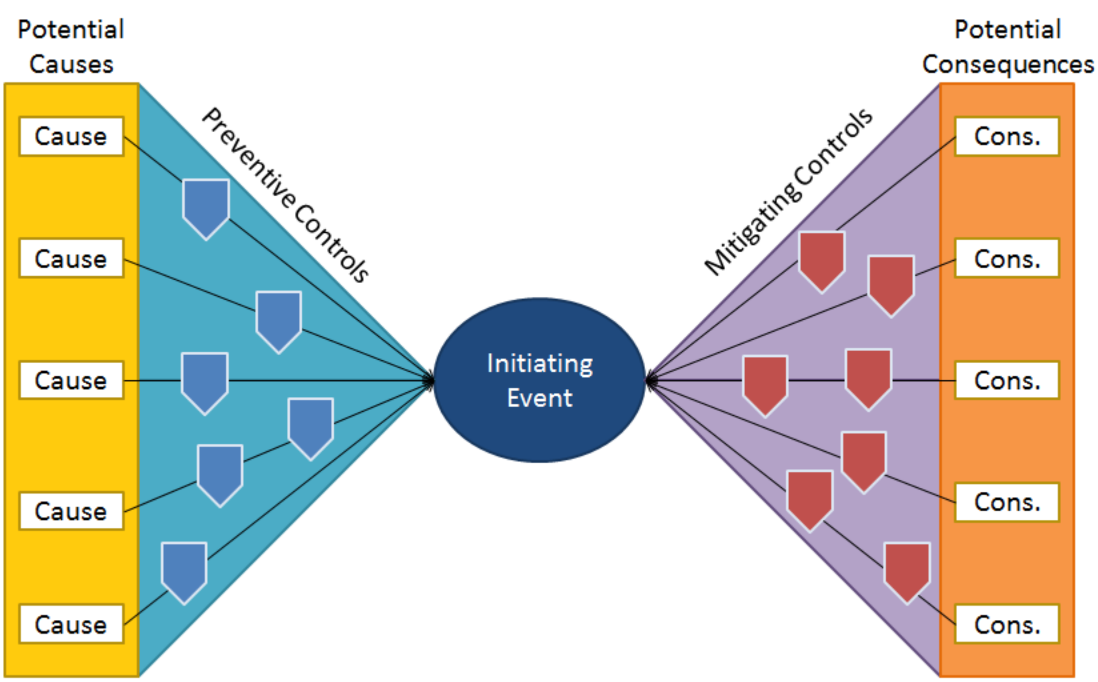

Figure 2.6 – A bowtie analysis diagram which presents the causes of and consequences arising from an initiating event and the corresponding controls

This innate feature of bowtie analysis allows the operator to focus on the relationship between cause and event, as well as event and consequence, instead of simply cause and consequence. Bowtie analysis offers its user a means for identifying gaps in their own system of preventive controls, and selecting mitigating controls to reduce the impact of an unwanted event. While it is intuitive to read a bowtie diagram from left to right (cause-event-consequence), it is important to note that the bowtie diagram is not chronological. Mitigating controls are designed in-place prior to failure of preventive controls and the occurrence of the unwanted event. For example, consider the initiating event: fire on a coal conveyor belt. A mitigating control for this event, an automatic fire suppression system, would be fitted prior to the event occurring. Additionally, an automatic fire suppression system could be a preventive control for another initiating event, a mine explosion.

While bowtie analysis focuses on control effectiveness rather than risk ranking, or more specifically, the number and quality of specific in-place controls associated with a certain unwanted event, the bowtie tool can be used in conjunction with the WRAC tool, risk matrices, and variable likelihood and consequence scales (RRR methodology) to offer a more accurate risk determination than each tool can provide individually. This combination of the traditional bowtie and RRR tools may be referred to as a Probability Bowtie (PBT). The PBT retains the bowtie structure (cause, preventive control, event, mitigating control, consequence) while incorporating RRR tools at each juncture of the event sequence to calculate a final risk rating for an unwanted consequence. A comprehensive PBT requires a spreadsheet in which the basis for each probability calculation is recorded and subsequently linked to the next phase of the sequence. This method provides the user with a semi-quantitative probability determination at each stage of the bowtie in a sequential manner which incorporates the probability calculated for the previous stage of the bowtie (i.e. the calculated probability of a preventive control failure is dependent upon the frequency of a cause and the probability of a previous control failure). Through this process of assigning probabilities for each control failure, the PBT offers a more robust interpretation of control effectiveness than the simple bowtie while considering the independence of any number of controls pertaining to an individual cause or initiating event. In practice, a typical PBT is constructed for individual strings of a bowtie, which provides a further breakdown of the bowtie for which a risk rating can be calculated for each of the consequences associated with an unwanted event (Cockshott, J.E. et al. 2005).

2.2 Historical Regulation of the U.S. Mining Industry

2.2.1: Introduction

The safety regulations of the U.S. mining industry rely heavily on the preexistence of standardized rules. This foundation is based on past experiences and current industry best practices, producing technically detailed regulations requiring constant review and occasional modification. However, these universal standards sometimes fail to identify and manage unique hazards associated with unconventional and dynamic mining conditions (Iannacchione, A. et al. 2008). In the United States, this methodology has led to a reactive approach towards hazards in which new regulation is often only imposed following major disasters. Such a standardized approach towards health and safety can de-incentivize the use of leading practices and create an industrywide culture of compliance. This is very consistent with the observations of an Australian mine manager made in 1998 prior to the introduction of risk-based regulation in Australia:

> *An emphasis on prescriptive regulation leads to mediocrity when a dose of realism is needed in this industry. Prescriptive operation and safety regulations lead to under-performance with everyone from the chief executive officer down abdicating their performance responsibilities and routinely filling in the required forms without addressing the real problem. Culture and attitude to safety must be widespread, with responsibility spread to everyone under a duty of care regime. A duty of care regime can reflect individual mine circumstances and places the onus on both mine management and employees to assess and manage safety risks within their sphere of control* (Foots, K. 1998).

2.2.2 Major Legislation Prior to the Mine Act

The Federal Mine Safety and Health Act of 1977, generally referred to as the Mine Act, is the legislation which currently governs all coal, metal, and non-metal mines in the United States, including surface and underground operations and mills. The Mine Act was preceded by both the Metal and Non-Metallic Safety Act of 1966 and the Federal Coal Mine Safety and Health Act of 1969, commonly recognized as the Coal Act. The Metal and Non-Metallic Safety Act was the first federal statute to directly regulate non-coal mines (U.S. House 1966). However, enforcement of the advisory standards created by Metal/Non-Metal Act was minimal due to vague and undefined language in the legislation (U.S. House 1977). The passage of the Coal Act was largely due to public uproar in response to a coal mine disaster in Farmington, West Virginia. The explosion and ensuing fire occurred on November 20, 1968, at the Consol No. 9 Mine killing 78 miners ("History of the Mining Program" 2012). This tragedy initiated a movement to standardize health and safety practices for U.S. coal mines and increase enforcement of these standards to prevent the occurrence of similar disasters in the future. As with previous legislation, widespread public criticism of the federal regulation of the coal industry pressured Congress to impose harsher penalties on mines and mine operators who failed to properly mitigate unsafe mining practices and hazards. The Coal Act pioneered many regulatory standards for the coal mining industry and was more stringent than any previous legislation governing the industry. Provisions of the Coal Act included increased federal enforcement authority, establishment of criminal penalties for violations, and the adoption of specific procedures for the development of mandatory health and safety standards (U.S. House 1969).

While the Coal Act was seen as a major step forward for health and safety standards in the coal mining industry, the non-coal mining sector still saw low enforcement of health and safety standards. After the Sunshine Mine disaster of 1972 killed 91 miners, the Secretary of the Interior created the Mining Enforcement and Safety Administration (MESA), a new departmental agency responsible for enforcing the safety and health standards promulgated by prior federal statutes ("Mining Disasters - An Exhibition" 2013). Although no major non-coal disasters occurred in the five years following the establishment of MESA, the average fatality rate for metal and non-metal miners (including underground mines, surface mines, and mills) increased to more than 75 percent of that for coal miners during this time period, up 25 percent from the previous five years (U.S. House 1977) suggesting that enforcement of statutory regulations was not achieving desired workforce safety outcomes.

2.2.3 The Mine Act and Mine Safety and Health Administration (MSHA)

The major thrust of the Mine Act was the consolidation of mandatory federal health and safety standards at U.S. coal and metal/nonmetal mines through a single piece of legislation. The Mine Act replaced the Coal Act and repealed the Metal and Non-Metallic Mine Safety Act of 1966, discontinuing advisory standards and state enforcement plans in the metal and non-metal sector ("Federal Mine Safety and Health Act (Mine Act)" 2008). The Mine Act effectively expanded the jurisdiction of the Coal Act to include metal and non-metal mines, improving legal provisions for non-coal miners, and increasing Federal enforcement power of safety standards for metal and non-metal mines. The Mine Act also transferred responsibility for the health and safety of miners from the Department of the Interior to the Department of Labor, establishing both the Mine Safety and Health Administration (MSHA) and the Federal Mine Safety Health and Review Commission to provide for the independent review of MSHA enforcement actions ("Legislative History" 2013). MESA was placed under the newly created MSHA in an effort to unify major federal safety and health programs in the Department of Labor. The passage of the Mine Act affected virtually every aspect of mine health and safety in the US.

Since its creation in 1978, MSHA has administered the provisions of the Mine Act, enforcing and facilitating compliance with the mandatory safety and health standards set forth by the act. The MSHA enforcement structure contains several divisions, including the Coal Mine Safety and Health (CMS&H) division, which is further divided into 11 district offices overseeing the separate coal mining regions across the nation (Marshall, R. 1981). Under the Mine Act, each underground coal mine in the United States must undergo at least four annual inspections by MSHA, during which mine compliance with Title 30, Part 75 of the Code of Federal Regulations (Mandatory Safety Standards Underground Coal Mines) is examined. Additionally, "gassy" mines and mines deemed particularly dangerous may receive supplementary inspections ("Federal Mine Safety and Health Act (Mine Act)" 2008).

MSHA is specifically prohibited from giving any advance notice to the mine regarding a routine inspection, and MSHA inspectors may enter the mine property without a warrant. All violations found during inspections must be cited, are subject to civil penalties, and must be corrected within an established timeframe. The MSHA penalizing inspection scheme was created to encourage compliance with the provisions and safety standards of the Mine Act.

2.2.4 The Prescriptive Approach to Mine Safety Regulation

Through years of modification, mine safety regulation in the U.S. has developed into a highly prescriptive system emphasizing tough enforcement and harsh penalties for violations. Despite this approach, several catastrophic accidents resulting in multiple fatalities have occurred since the passage of the Mine Act. In 2006, following the Sago Mine explosion in West Virginia which killed 12 miners, Congress enacted the Mine Improvement and New Emergency Response Act (MINER Act). The MINER Act established mine-specific emergency response plans in underground coal mines, created new regulations for the sealing of abandoned areas, and dramatically raised civil penalties for violating the law ("Legislative History" 2013). However, harsher penalties and increasingly prescriptive regulation did not prevent the Upper Big Branch disaster from occurring. The mine had been issued 76 orders concerning failures to comply with the approved ventilation plan in the four months prior to the explosion (Yang, B. 2012). This citation record indicates not only the failure of the mine to maintain its ventilation system, but the failure of any intervention by the U.S. enforcement system to effectively prevent unsafe conditions from recurring within the mine (Kuykendall, T. 2012).

In addition to propagation of the mandatory health and safety standards contained within 30 CFR 75 through the Coal Act and the Mine Act, further requirements and revisions have been proposed and implemented over the years. Additional safety requirements can be expected with emergent technologies and increasing sophistication in mining methods. For example, in 1996, MSHA issued final rules establishing new safety standards for the use of diesel-powered equipment in underground coal mines regarding allowable surface temperatures, and newly required methods for conducting methane tests in deep cuts due to improved testing methods ("Information Regarding Diesel Regulations" 1996). A major issue with this rulemaking procedure is that once a new rule or requirement is issued as part of the CFR, it becomes difficult to modify even when new knowledge or technology makes the final ruling moot or incorrect.

The issue of modification becomes especially salient when the rulemaking process is abbreviated due to pressure on MSHA to impose new health and safety standards following a major disaster (Harris, R.J. 2008). For instance, following the Sago Mine explosion, passage of the MINER Act required underground mines to implement wireless two-way communications and an electronic tracking system within three years. Unfortunately, ambiguous language in the regulation, particularly concerning the term "wireless", caused confusion among both mine operators and product manufacturers regarding the necessary performance requirements of such systems. Also, prescriptive regulation has led to reluctance by U.S. mine operators to implement best safety practice if variable mining conditions exist at their operation or if the practice may potentially affect future mine developments. Alteration of an MSHA approved mine plan (ventilation, roof control, etc.) is nearly impossible after submitted if any part of the resubmitted plan offers modification that might be perceived as providing less protection to miners than the previous version.

2.3 The Successful Application of Risk Management in Relevant Industries

2.3.1 Risk-Based Governance

Prescriptive regulations have long dominated governance of the hazardous working environment of underground coal mining in the U.S., due largely to two features of this system: 1) explicitly stated requirements, and 2) easily enforced legislation. However, there is an inherent disincentive for organizations to be innovative, as the compliance approach focuses on minimum federal standards rather than local industry best practice. These systems also may not consider that institutional management of work may introduce unforeseen hazards if inadequately organized (Cliff, D. 2012). A regulatory approach called risk-based governance has more recently emerged in the safety regulation of coal mining and other heavy industries around the world where various stakeholders (government, employers, workers, etc.) have become more comfortable eliminating compliance requirements. Risk-based governance, which emphasizes placing responsibility for controlling workplace hazards on those who create the hazards, coincides with the implementation of comprehensive risk management systems by employers to fulfill their operations' unique safety requirements (Yang, B. 2012). A milestone in global occupational health and safety legislation and practice occurred in 1972, when the Chair of the National Coal Board (NCB) in the UK, Lord Robens, delivered the Robens report. This report was in part a response to the Aberfan disaster of 1966 which resulted in the deaths of 116 children (109 of which were aged 7 to 10), after an impoundment failure. The findings of this report stated that there was too much law in occupational health and safety, and the area needed to be simplified, and should encourage self-regulation. Lord Robens found that a shift needed to occur in the balance between "prescriptive" and "goal-setting" legislation towards the latter, in order to encourage self-regulation (Robens, L. 1972). This report had a significant impact on health and safety approaches in the UK, and subsequently commonwealth countries including Australia.

Despite broad adoption in other high hazard industries, the dissemination of risk-based management techniques in the U.S. coal industry has been slow. In contrast, commercial aviation and defense have strong safety records with low accident rates. The U.S. Federal Aviation Administration (FAA) developed the Aviation Safety Reporting System (ASRS), a voluntary system which allows pilots and other airplane crew members to confidentially report near misses and accidental rule violations for the purpose of improving safety. This system provides incentives which waive operator liability for self-reporting of incidents, and has contributed to the identification and management of many safety hazards present in commercial aviation (Carmona, M. 2013). Today, the accident rate for the commercial aviation industry is relatively low considering that there are over 10 million commercial airplane flights domestically per year. In 2010, for example, U.S. Air Carriers flew 17.5 million miles with only one major accident (Leveson, N.G. 2011). In 1963, the United States Nuclear Navy instituted a “wildly successful” risk-based safety program called SUBSAFE (Leveson, N.G. 2011). Since the launch of SUBSAFE, not a single U.S. submarine has been lost.

Another heavy industry, the nuclear power industry, has used risk management methods for the development of new regulation. Following the Three Mile Island disaster of 1979, John G. Kemeny delivered a report on behalf of the Presidential Commission entitled The Kemeny Report. Just as the Robens Report had done for the UK coal industry, the Kemeny Report suggested the need for a major change in the nuclear industry’s attitude towards health and safety. The report recommended that the industry move towards self-policing to promote its own standard of excellence, while criticizing complacency in the United States Nuclear Regulatory Commission. Over the next few decades, risk-based management systems became the standard for the nuclear industry. The NRC developed the probabilistic risk assessment (PRA) plan in 1994, a risk-informed performance-based regulatory framework which has since evolved into the risk-informed, performance-based (RPP) plan in 2007. These plans have guided the NRC in its efforts to develop risk-informed regulation, or risk-based governance. This regulatory approach helps the NRC identify and support additional requirements or regulatory actions, while reducing unnecessary requirements found in purely deterministic approaches, like prescriptive regulation. These regulatory requirements don’t necessarily mandate risk-based approaches for occupational safety hazards, but they are designed to ensure that there is a low probability of accidents that could adversely affect the health and safety of the public ("History of the NRC's Risk-Informed Regulatory Programs” 2013). The safety success of risk-based approaches in these highly hazardous industries undermines the notion that accidents are inevitable and are the price of productivity in inherently dangerous industries like coal mining.

2.3.2 The Australian Mining Industry’s Risk Management Experience

Perhaps the most pertinent example of the successful implementation of risk-based governance in a heavy industry can be attributed to the Australian minerals industry. The Australian minerals industry began its movement towards risk-based management systems following two mine disasters: the Moura coal mine explosion of 1994 and the Gretley coal mine inundation of 1996 (Hopkins, A. 2000). The industry subsequently identified the capability of risk analysis methods to mitigate key hazards like fires, explosions, spontaneous combustions, etc. The varying state-controlled regulation that followed generally requires mines to regularly perform some style of risk assessment to prevent circumstances which may result in occupational injury or fatality. Mine managers are also expected to demonstrate competency in risk management systems through training and certification (Iannacchione, A. et al. 2008).

This shift to a risk-based approach saw the development of National Codes of Practice and Mining Design Guidelines (MDGs) in lieu of more prescriptive legislation. These codes of practice retain bodies of knowledge to promote flexibility in each mine's approach towards risk. The recommendations use a "may" rather than a "must" ideology allowing the expert user to determine their own needs. Codes of practice represent a key component of the OHS regulatory structure described by the Robens Committee in the Robens Report. Regulators commission these codes of practice through collaboration with representatives from the industry, unions, and the Australian mine inspectorate (a 'tripartite' body). Enforcement of Mine Operators is focused on system failures rather than minor infractions. Essentially, if a Mine Operator (in Australia) can legally establish that their risk management system equals or exceeds the standards proposed by Codes of Practice and MDGs, they cannot assume liability for incidents, promoting best safety practice. A failure to fulfill these obligations will result in prosecution of the operator. This methodology is an improvement for the individual miner, and focuses on what operators can control. In the case of an accident, recklessness (MSHA citation form 7000-1 uses the term gross negligence) must be proven, which limits overreaction of legal responses, particularly the promulgation of reactive legislation.

In the years following the adoption of a risk-based safety culture, Australia saw a drop in the number of fatal accidents at underground coal mines which was proportionally superior to the drop seen in the U.S. for the same time period (*Figure 2.7*).

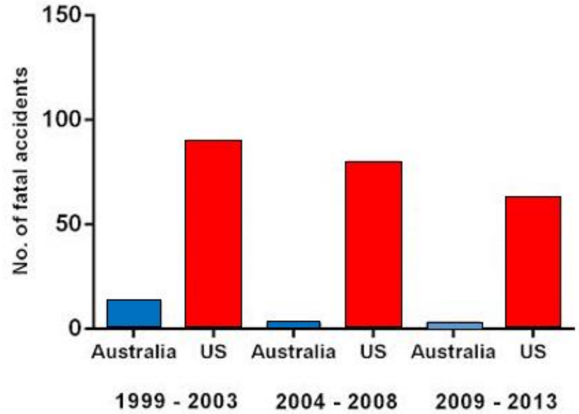

Figure 2.7 – Number of fatal accidents in underground coal mines for Australia and the US[1]

It is worth nothing that although the Australian metalliferous industry enacted "duty-of-care" legislation in 1994, a major drop in fatalities in this sector did not occur until several years later when risk management approaches began to see more application and maturity (Iannacchione, A. et al. 2008). During the five-year period between 2006 and 2010, there were 20 times more fatalities in the U.S. coal mining industry than in the Australian coal sector to produce only twice the volume of coal (Kirsch, P.A., J. Harris, M. Shi, and D. Cliff 2014). Following the adoption of risk-based governance by the Australian mining industry, fatality rates in Australian underground coal mines began to decrease at a larger rate than that of U.S. mines (*Figure 2.8*).

[1] The data in this figure was collected from publicly accessible documents made available by the Mine Safety and Health Administration (MSHA) and the Australian Bureau of Labor (ABS) for analysis

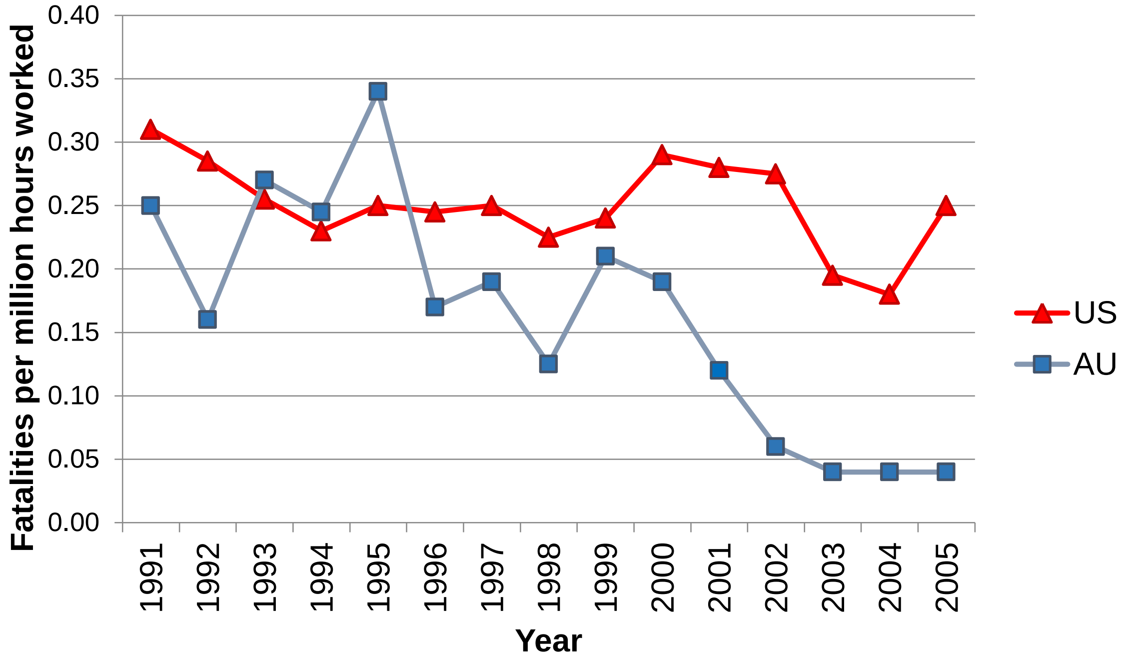

Figure 2.8 – Underground coal mine fatality rates for the U.S. and Australia (Iannacchione, A. et al. 2008)

The general downward trends in Australian underground mining fatality rates have been, in part, attributed to the industry acceptance of and obligation to employ risk-based management systems towards its safety goals. While risk-based governance has contributed largely to the Australian experience, it is unclear whether or not risk-based approaches would have been so rapidly adopted by companies without being mandated. Further, it has taken years of continuous improvement and extensive cooperation to develop today's acknowledged mutual respect among the mine inspectorate, the mining industry, and its labor force ('tripartite governance') with respect to implementation of OHS risk management.

There are limitations to all approaches. Risk management is not necessarily a "catch all" solution to preventing incidents, but an optimization of human well-being and overall system performance. Risk-based management systems provide guidelines for how risks are to be managed, who is responsible for implementing actions, what resources are required, and the level of training required to properly implement the plans. These systems also identify the monitoring and review requirements necessary to maintain the system's effectiveness and relevance. As expected, comprehensive risk management systems tend to produce a high level of administrative responsibility for mine operators, which can result in exorbitant amounts of paperwork and worker hours required to maintain the integrity of a system where continuous reassessments of risk are conducted for even the most menial operational procedures and worker tasks. Additionally, the concept that risk management approaches drive technological and practical innovation has yet to be demonstrated by the Australian mining industry under a risk-based regime. Counter to this idea, Australian development and adoption of several emergent mine technologies (e.g. the use of proximity detection, collision avoidance systems, and remote cameras on moving equipment, investment in the development of longer-term mine emergency refuge chambers, etc.) lags behind the progress and integration seen in U.S. underground mining practice, where these technologies are standard and in some cases mandated.

2.3.3 Barriers to Large-Scale Implementation of Risk Management in U.S. Coal Mining

So what has prevented the widespread adoption of comprehensive risk management systems by U.S. coal mining companies? Yang (2012) provides evidence of several barriers which have hindered the adoption of risk management in the U.S. coal industry (Yang, B. 2012). One potential barrier is the historical lack of a perceived "common fate" among various coal mining organizations operating in the U.S. (large versus small). Although the recent reoccurrence of major disasters has sparked an emerging recognition of common fate throughout the industry, reputational concerns still vary greatly across the diversely scaled operations of the U.S. Australia's industry reform was largely influenced by the consolidation and acquisition of small coal mining operations by larger corporations. There are currently only 33 underground coal mines in Australia's major coal producing regions, compared with 488 in the U.S. ("Annual 20 Coal Report" 2012, Kirsch, P.A., J. Harris, M. Shi, and D. Cliff 2014). The lack of small, low-production operations in Australia contributes to the industry's general acknowledgment of common fate among all stakeholders, including mine operators, the government, and labor unions. The Australian coal market is also export-driven, while the U.S. consumed approximately 93% of total coal production domestically in 2012 (Yang, B. 2012). The Australian coal industry is more integrated with the international coal market, and due to increasingly tough competition from low cost, high production coal-exporting nations like China and India, and the large contribution of coal products to the state's GDP (9% versus less than 0.5% in the U.S.), the Australian coal mining industry has seized the opportunity to establish itself as a global leader in mine health and safety performance (Yang, B. 2012)

Strict, prescriptive regulation and enforcement thereof with high-cost penalties and citations, is another barrier to the dissemination of risk management and adoption of best practices in the United States. U.S. company compliance with these regulations consumes company resources which could be utilized to develop a risk management framework, or explore other health and safety models which might better suit their organization's needs. Penalties can be as high as $68,000 for an individual offense based on the operator's history of offenses, whether or not the operator was deemed negligent, the gravity of the violation, and other factors. These criteria are evaluated using a points system which is converted into a dollar amount per infraction (U.S. House 1990). Costly penalties for violations have a particularly profound effect on the capacity of small-scale operations to invest in research and development of new safety models that go above and beyond what is required by law. As Yang points out, "such regulation creates a compliance mentality that is not compatible with the idea of risk management, which expects operators to proactively identify, analyze, and control hazards" (Yang, B. 2012). A competing safety model, behavior-based safety (BBS), is an additional factor restricting the acceptance of risk management in the U.S. coal industry. Yang (2012) attributes the widespread U.S. adoption of the BBS model to several key factors when compared to a risk management approach. These factors include a focus on worker performance for individual tasks, a "bottom-up" worker-driven thrust based on peer evaluation and employee feedback, and the observable benefits which include an improved safety culture and an increase in knowledge sharing from lessons-learned discussions between employees and management (Yang, B. 2012). Additionally, as BBS rises in popularity and more expertise is developed for the BBS process, these observable benefits become more apparent, the incentives for alternative (risk management) systems appear less appealing to mine operators, and the entry cost for a novel system (risk management) is much higher than that of a broadly adopted or accepted approach.

Chapter 3: Project Description

3.1 Alpha Foundation: Project Background and Objectives

Established in 2011, the Alpha Foundation for the Improvement of Mine Safety and Health, Inc. (Alpha Foundation) is a research trust created to fund research projects relating to improvements in mine safety and health. The trust was developed by Alpha Natural Resources as part of a Non-Prosecution Agreement following Alpha's acquisition of Massey Energy Company a year after the Upper Big Branch mine disaster. In 2013, the Alpha Foundation funded a research proposal for an examination of how risk management principles can be applied in a comprehensive manner to the U.S. underground coal mining industry to improve mine safety. This project is the joint effort of researchers from Virginia Tech and researchers from two Australian Universities (University of New South Wales and University of Queensland) whose contributions were integral to the development of the Australian RISKGATE tool, an online body-of-knowledge designed to assist Australian mine operators with risk management. The central aims of this project include:

1. Identification of factors that could contribute to a step change in the general application of risk management in the U.S.
2. Development of strategies for the implementation of risk management approaches in the U.S.
3. The application of these strategies to three high risk areas in U.S. underground mine safety: Fire and Explosion prevention, Roof Control, and Moving Equipment.
4. Dissemination of the research findings and recommendations for application of these strategies across the U.S. underground coal mining sector.

Another major objective of this project is the adaptation of the Australian RISKGATE web tool to a US-based platform which covers the three high-risk areas mentioned above (fires and explosions, roof control, and moving equipment). This objective requires a substantial amount of knowledge on U.S. mining practice, as well as discrepancies between standard operational practices in the U.S. and Australia. The gathering of technical information for this website was accomplished through research workshops attended by industry individuals representing several major U.S. coal companies.

3.2 StrengthsWeaknessesOpportunitiesThreats (SWOT) Analysis of Project Objectives

A StrengthsWeaknessesOpportunitiesThreats (SWOT) Analysis was necessary to identify factors that could contribute to the viability of a U.S.-based website which parallels the Australian RISKGATE database. The initial results of the SWOT Analysis indicate that the American mining industry is engaged in a transition towards increased risk management practice in the management of hazards (e.g. recent ICMM guideline). This fact suggests a great opportunity for the application of risk management in the U.S. The objective of this RISKGATE-U.S. exercise is to deliver a broad body of hazard control information, derived from leading industry practice, which becomes an essential platform for the U.S. Underground Coal Industry during this transition. The SWOT Analysis is designed to consider differences in mining practice, industrial safety culture, and regulatory methodology between the U.S. and Australia. *Figure 3.1* displays the outcomes of the SWOT analysis, highlighting the challenges associated with integrating such a system with the U.S. coal industry at its present state.

The noted strengths of the project include a general “no secrets in safety” atmosphere among U.S. operators, the uniqueness of the proposed body-of-knowledge, and the project’s emphasis on performance of engineering controls rather than worker behavior modification. Thanks in part to company-wide safety initiatives (e.g. BBS programs, NMA CORESafety) and the regulatory impacts of recent coal mine disasters, coal companies in the U.S. have shifted towards embracing the idea that they share a common fate with their competitors, and the sharing of safety information and minimization of harm to mine workers are beneficial to the industry as a whole.

Additionally, WRAC analysis, a fundamental risk-ranking tool discussed in *Chapter 2.1.2 Determining Risk: Common Tools and Techniques*, is compatible and has seen use with the CORESafety system model.

Significant opportunities include the relative immaturity (when compared with Australia) of risk management practice at U.S. coal mines. This lack of experience with risk management helps facilitate the prospect of rapid best practice transfer, as opposed to a more gradual best practice evolution. The project also provides the opportunity for continuous modification of the U.S. platform, which will ensure the adequacy and integrity of the material presented to the user.

	STRENGTHS	WEAKNESSES
INTERNAL	• Leaders in development of several key safety technologies • An evolved safety culture with heavy emphasis on BBS • A vision among companies – (e.g., CoreSafety) that is critical for developing an industry wide body of knowledge • Interest in Risk Management and early stage development in many companies • A general "no secrets in safety" atmosphere – willingness to share	• Limited experience with Risk Management for application to operational safety • Poor coal economy, limited resources • Large geographic area, several coal basins, all with distinct cultures and practices
EXTERNAL	• The relative immaturity of Risk Management does allow for best practice transfer (as opposed to a longer best practice evolution). • RISKGATE-U.S. can bring U.S. best practice to a single source: more rapid transfer of best technology and best practice	• Increased enforcement as a result of beyond compliance approach • Few regulatory incentives for using Risk Management approach • Comfort with Risk Management requires repeated exposure and training – fairly sizeable time commitment
	OPPORTUNITIES	THREATS

Figure 3.1 – SWOT analysis to determine feasibility of project objectives

In addition to the noted strengths and opportunities associated with the project, internal weaknesses and external threats were also determined.

Perhaps the most significant weakness of the project at this point in time is the current economic climate of the U.S. coal mining industry. Coal production during the first three months of 2016 was 173 million short tons (Park, B. 2016). This is the lowest quarterly level of production in the U.S. since a major coal strike curtailed production in the second quarter of 1981. The current woes facing the coal industry's production levels stem from a number of factors including a lack of electricity generation (partly due to above normal temperatures for the winter of 2015-16), competition from renewables and natural gas-fired electricity generation, and increased regulatory and political pressure to move away from coal-fired electricity generation as a nation (Park, B. 2016). These challenging market conditions have understandably decreased the willingness of many U.S. coal companies to volunteer employees to assist in the gathering of knowledge for the U.S. website by attending action research workshops. Additional weaknesses include a generally limited U.S. experience with comprehensive risk management systems in underground coal mining health and safety, and full inclusion of the diverse mining conditions and practices encountered throughout the country.

External threats include the lack of regulatory incentive for using a risk-based approach to mining health and safety, including a potentially increased level of enforcement during such a transition and an inability of coal producers to modify safety controls while maintaining strict adherence to statutory health and safety provisions. Furthermore, the industrial application of any novel system, particularly comprehensive risk management, requires a fairly sizeable time and financial commitment for the companies involved.

Chapter 4: RISKGATE

4.1 Introduction to RISKGATE

A central aim of this research is the development of a U.S.-based online risk management tool that adapts the Australian RISKGATE body-of-knowledge to assist U.S. mine operators. The RISKGATE tool was developed in part by researchers from the University of New South Wales (Bruce Hebblewhite, Rudra Mitra) and the University of Queensland (Philipp Kirsch, Meng Shi). A Virginia Tech led initiative funded by the Alpha Foundation project is the translation of this tool from an Australian tool to one focused on mining practices in the U.S.

4.1.1 ACARP, MISHC, and the Conception of RISKGATE

Established in 1992, the Australian Coal Association Research Program (ACARP) is a mining research program funded entirely by the Australian black coal industry. Funding for ACARP is allocated through a five-cents-per-metric-ton ($0.05/tonne) levy on saleable coal which all Australian black coal producers are required to pay (Graham, R.L. 1998). Research initiatives funded by ACARP focus on all aspects of black coal production and consumption, including occupational health and safety, environmental impacts of mining, and the investigation of new mining technologies. ACARP's unique funding scheme provides Australia's mining industry with input and expertise from individual coal companies on research initiatives that address the wider challenges the industry faces. The pooling of resources allows the industry to develop solutions in a way that a single coal producer's research and development division could not. Additionally, ACARP utilizes the assistance of research institutions such as the University of Queensland's MISHC (Minerals Industry Safety and Health Centre), the University of Wollongong, and the University of New South Wales to conduct its research undertakings.

In 2006, ACARP funded the development by MISHC of its largest occupational health and safety initiative to date. This initiative produced two risk management decision support platforms based on Incident Cause Analysis Method (ICAM), TYREgate and ISOLgate (Kirsch, P., S. Goater, J. Harris, D. Sprott, and J. Joy, 2012). Subsequently, in 2009 ACARP identified the need for a more comprehensive risk-based tool that could be utilized to improve health and safety outcomes across Australia's entire black coal industry. MISHC then developed a strategy for the development of this new platform through consultation with more than 25 industry leaders on the topic, including internationally renowned risk management expert, Jim Joy (Kirsch, P., S. Goater, J. Harris, D. Sprott, and J. Joy, 2012). From 2011 to 2014, through the use of "action research workshops" composed of industry experts nominated by the mining industry and its suppliers, MISHC's RISKGATE project team produced the body of knowledge contained within the RISKGATE online database, Riskgate.org.

4.1.2 RISKGATE – An Online Body of Knowledge

RISKGATE is an online interactive tool designed to help mining industry professionals identify, assess, and control the potential hazards encountered at their mining operations. Regarding these hazards, RISKGATE aims to provide both causal (hazard identification and assessment) and control (both preventive and mitigating) prompts with which the user can evaluate the effectiveness of their in-place risk management system.

To date, the information contained within the online RISKGATE platform covers 18 different topics related to high-risk hazard areas associated with coal mining (*Figure 4.1*), including fires, strata control, explosions, and fitness for work. Presented using a standard format and structure, RISKGATE defines each topic area in terms of what information is covered under that topic. Each topic also notes the related information not included within that topic, and references the appropriate topic to examine for that information. The intuitive RISKGATE interface uses the Bowtie Analysis method (BTA), which allows the user to select from multiple "initiating events" within each topic, and then carefully choose which prompts (causes, consequences, and related controls) are relevant to their site-specific risk management needs.

It is important to note that RISKGATE is not intended to assess risk for specific mine sites, but instead provide the user with a decision support tool to assist with the assessment and evaluation of their operation's particular key hazards and risk management practices. RISKGATE does not provide procedures, systems, or guidelines, but rather a series of prompts which the user can use to identify gaps within their own risk management system. At present, RISKGATE assists mine operators in Australia with various operational activities including new task risk assessments, incident investigations, and internal safety audits. A simple example in the following section illustrates how RISKGATE can be used at a mine site.

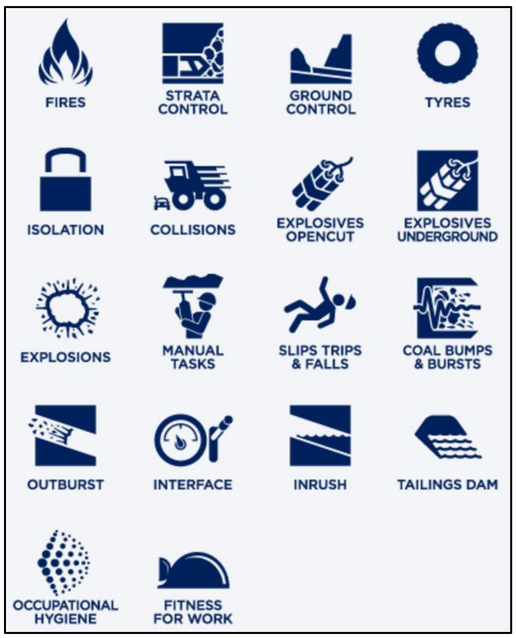

Figure 4.1 – Current RISKGATE topic areas (Riskgate.org)

4.2 RISKGATE Tutorial

The following tutorial illustrates how RISKGATE can be used to assist mine operators with a risk assessment at their site. For this example, the user will examine their operation's in-place controls for preventing or mitigating the consequences of a collision between mobile mining equipment and pedestrians in the mine environment.

To begin, the user must log-in to Riskgate.org with a username and password. The "Log-in" tab is located on the toolbar at the top of the website's home screen. The home screen is shown in *Figure 4.2*. Before logging in, the website prompts the user with a standard disclaimer reminding the user that RISKGATE is a database, and is not currently recommended as a single source for legal and technical advice (*Figure 4.3*).

Figure 4.2 – RISKGATE home screen (Riskgate.org)

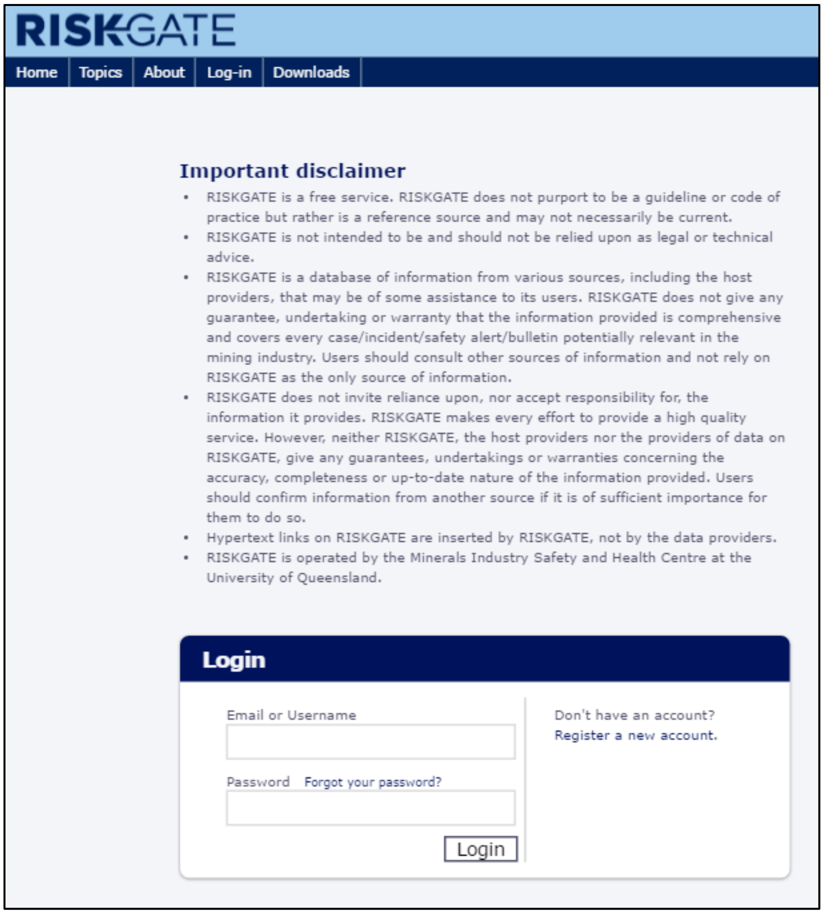

Figure 4.3 – RISKGATE log-in screen and site disclaimer (Riskgate.org)

After logging on to the website, the user can select a topic by clicking on the "Topics" tab on the home screen toolbar, or by simply clicking on the topic icon of their choice as presented on the home screen (*Figure 4.2*). For this example, the user has selected the "Collisions" topic by clicking on the icon. Selecting a topic brings the user to that topic's main page (*Figure 4.4*). This page contains a description of the information contained within the topic, the relevant information not addressed by the topic (and where to find that information), and the "Initiating Event Bowties" related to the topic. The topic page also contains an "Overview" section which lists the number of Bowties (Initiating events), causes, preventive controls, consequences, and mitigating controls contained within the topic (*Figure 4.4*). For example, the "Collisions" topic is comprised of 2 initiating event bowties, which contain 45 causes, 138 preventive controls, 4 mitigating controls, and 10 consequences across both events. A breakdown of these numbers by each initiating event is listed next to the “Initiating Event Bowties” links at the bottom of the “Collisions” topic’s main page (*Figure 4.4*).

Figure 4.4 – Example of RISKGATE topic page for “Collisions” topic (Riskgate.org)

This tutorial focuses on collisions between mobile equipment and pedestrians. To access information covering an unwanted interaction of this nature, the user has selected the initiating event bowtie, “Unexpected positioning of pedestrians in proximity to mobile equipment,” by clicking on the link at the bottom of the “Collisions” topic page (*Figure 4.4*). After selecting the appropriate initiating event, the user is presented with the “Bowtie Tool” screen, allowing the user to navigate the available causes, consequences, and controls for the indicated initiating event (*Figure 4.5*).

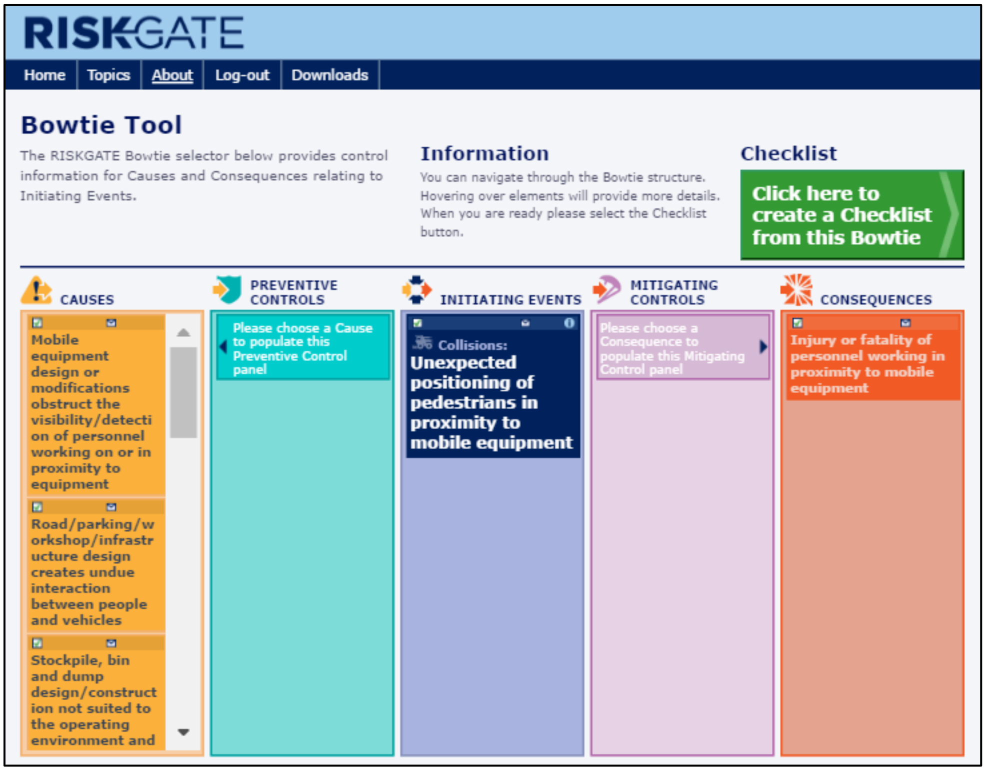

Figure 4.5 – Example of "Bowtie Tool" screen (Riskgate.org)

The "Bowtie Tool" screen allows the user to select from several drop-down menus which include the causes, consequences, and preventive and mitigating controls associated with the indicated initiating event. Once the user has selected the information needed, they can output a "Checklist" which consolidates the selected information into a single document.

To begin, the user examines the golden-colored "Causes" drop-down menu. The user can then select for analysis the causes related to their mine operation by clicking on the small, checked box in the upper left corner of each cause. Initially, each cause is selected for output to the checklist, but the user can unselect causes chosen for omission. By clicking on a specific cause, the user can populate the teal-colored "Preventive Controls" pane with the preventive controls that address the highlighted cause (*Figure 4.6*). This pane contains general control considerations which can be expanded upon by clicking on the small plus-sign icon in the upper right corner of each control (*Figure 4.7*), providing sub-controls which further describe the selected preventive control. In addition to selecting only the causes the user wishes to address, the user can choose which specific controls and sub-controls associated with each cause will be selected for output by clicking on the small, checked box in the upper left corner of each control. Selected controls can be further customized to omit the sub-controls the user does not find necessary for their purposes. *Figure 4.7* shows a highlighted cause, "Restricted visibility due to ventilation control devices in underground environment," and the related controls and sub-controls that the user has selected.

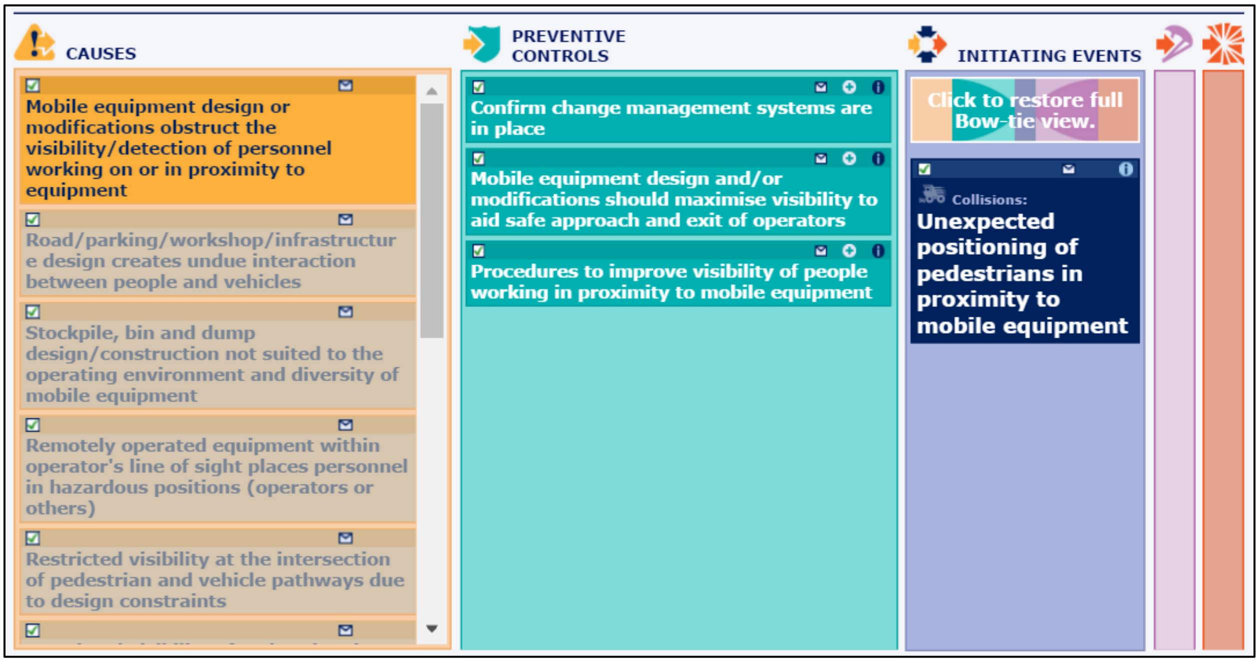

Figure 4.6 – Preventive controls pane addressing highlighted cause (Riskgate.org)

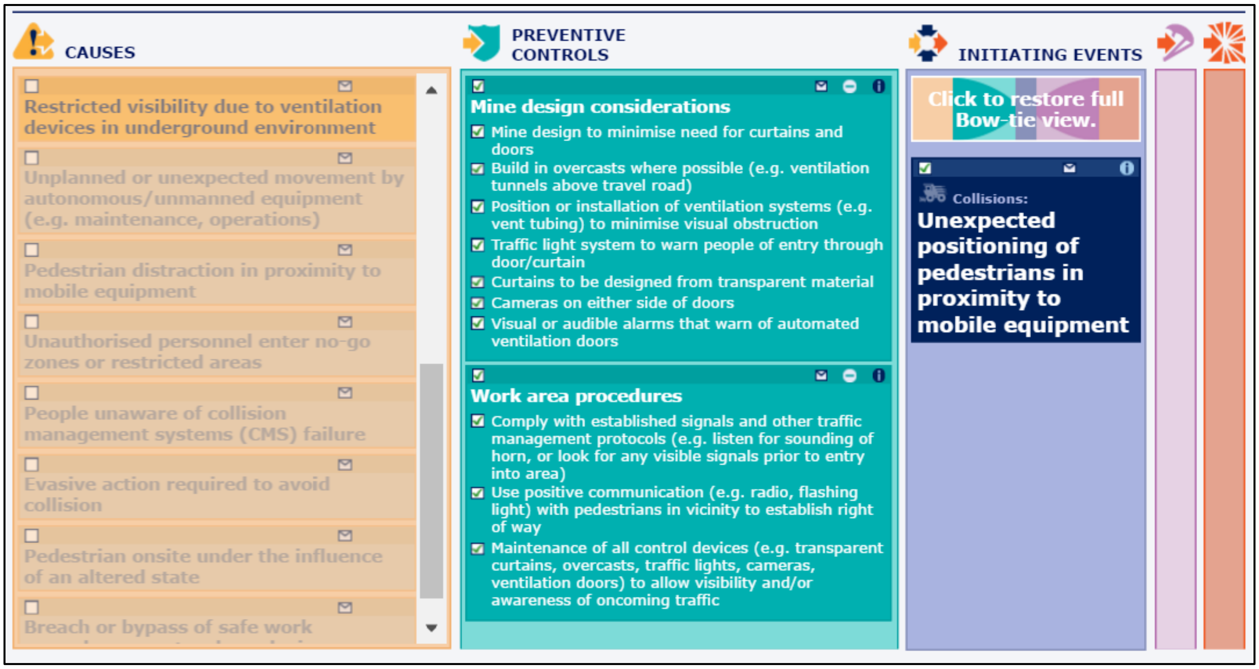

Figure 4.7 – Preventive control window expanded to show selected sub-controls for the highlighted cause (Riskgate.org)

If the user does not highlight a specific cause and unselect any of its associated controls, then all controls and sub-controls associated with the selected causes will be included in the checklist. Simply put, the user does not actually need to select and unselect cause, control, and consequence information. For an expedited checklist containing all control information for that initiating event, the user can simply click on the green box labeled, “Click here to create a Checklist from this Bowtie” (*Figure 4.5*).

It is important to identify both controls which are intended to prevent the initiating event from occurring and controls which mitigate loss once the event has occurred. Before creating a checklist, the user can also examine the consequences of the initiating event, and their respective mitigating controls on the right side of the diagram. The orange-colored “Consequences” pane is navigated in the same manner as the golden-colored “Causes” pane, with selection of relevant consequences activated by checking the small box in the corner of each listed consequence. Mitigating controls and sub-controls are selected and unselected at the user’s discretion using the purple-colored “Mitigating Controls” pane in a similar fashion to the “Preventive Controls” pane. *Figure 4.8* shows a consequence, “Injury or fatality of personnel working in proximity to mobile equipment," highlighted in the "Consequences" pane, along with the relevant mitigating controls and sub-controls expanded in the "Mitigating Controls" pane (all of which are selected for inclusion in the checklist).

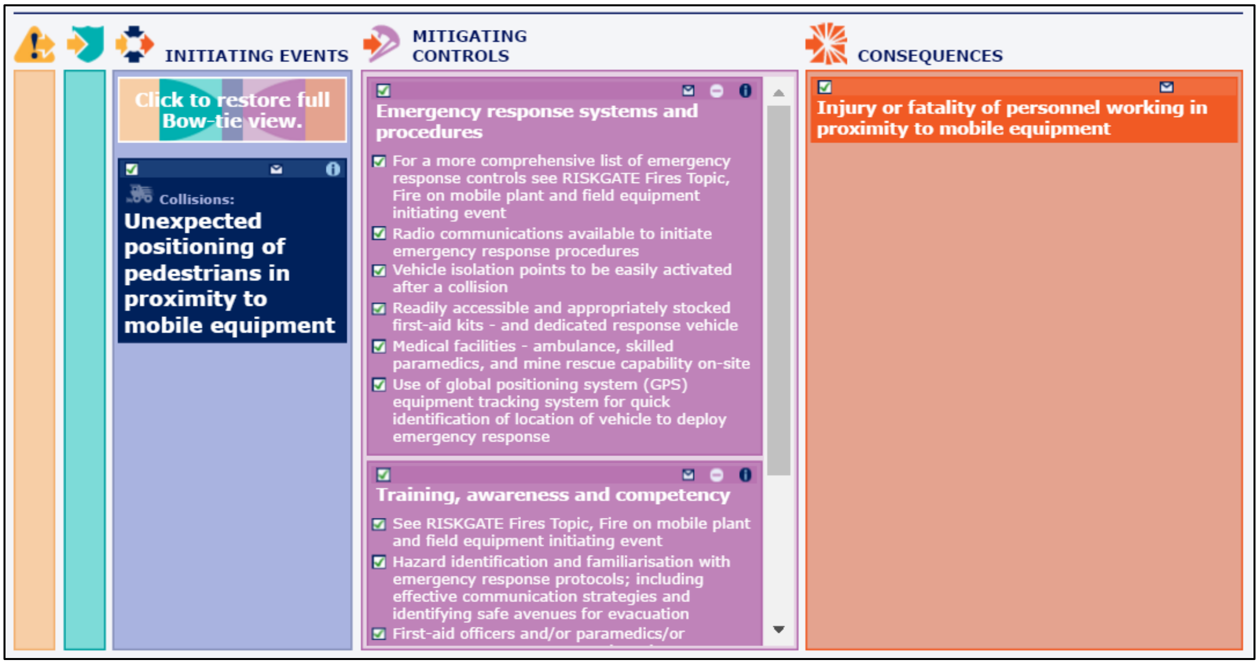

Figure 4.8 – Mitigating control window expanded to show selected sub-controls for the highlighted consequence (Riskgate.org)

Once the user has selected the customized information for their checklist, they can output a checklist in the available file formats. Upon clicking the green "Click here to create a Checklist from this Bowtie" button (*Figure 4.5*), the user is prompted with a message screen asking the user to select their desired file format and agree to the legal disclaimer before creating the checklist. The options for checklist formats include: 1) output to screen, 2) save as PDF file (for printing and distribution), 3) save as Microsoft Excel XML, and 4) save as Stature XML[2] .

For this example, the user has chosen to output the checklist to the screen (*Figure 4.9*). This checklist contains each control the user specified, as well as its

[2] "Stature" is a spreadsheet software tool used by several Australian mining companies. The software is utilized for record-keeping and consolidation of organization-wide risk management systems.

associated cause or consequence. In addition, the checklist provides information on the material presented by the topic and more specifically, the initiating event.

Figure 4.9 – RISKGATE checklist "Output to screen" format (Riskgate.org)

This checklist can now be utilized for assistance with a risk assessment, an incident investigation (determining the root cause(s) of an accident), an internal safety audit, training of new miners, etc. The bowties created in RISKGATE can be used to complement a company's existing risk assessment tools and practice. As described in *Chapter 2.1.3 Bowtie Analysis Tool (BTA)*, the control analysis offered by the bowtie tool can be used to influence or modify risk ratings calculated with a risk matrix or the WRAC tool and develop probability bowties. Careful consideration of actual in-place controls provides a higher level of certainty in risk calculations. In the case of an incident investigation, the large number of causes provided by RISKGATE may be used to assist with a root cause analysis while providing information about which controls were in place to address that cause and which controls may have prevented or mitigated the unwanted event. *Figure 4.10* illustrates the tiered format of the checklist, in which individual causes and consequences are enlarged with the corresponding controls and sub-controls directly following. The checklist format keeps information succinct and conveniently transferable for administrative or distributive purposes.

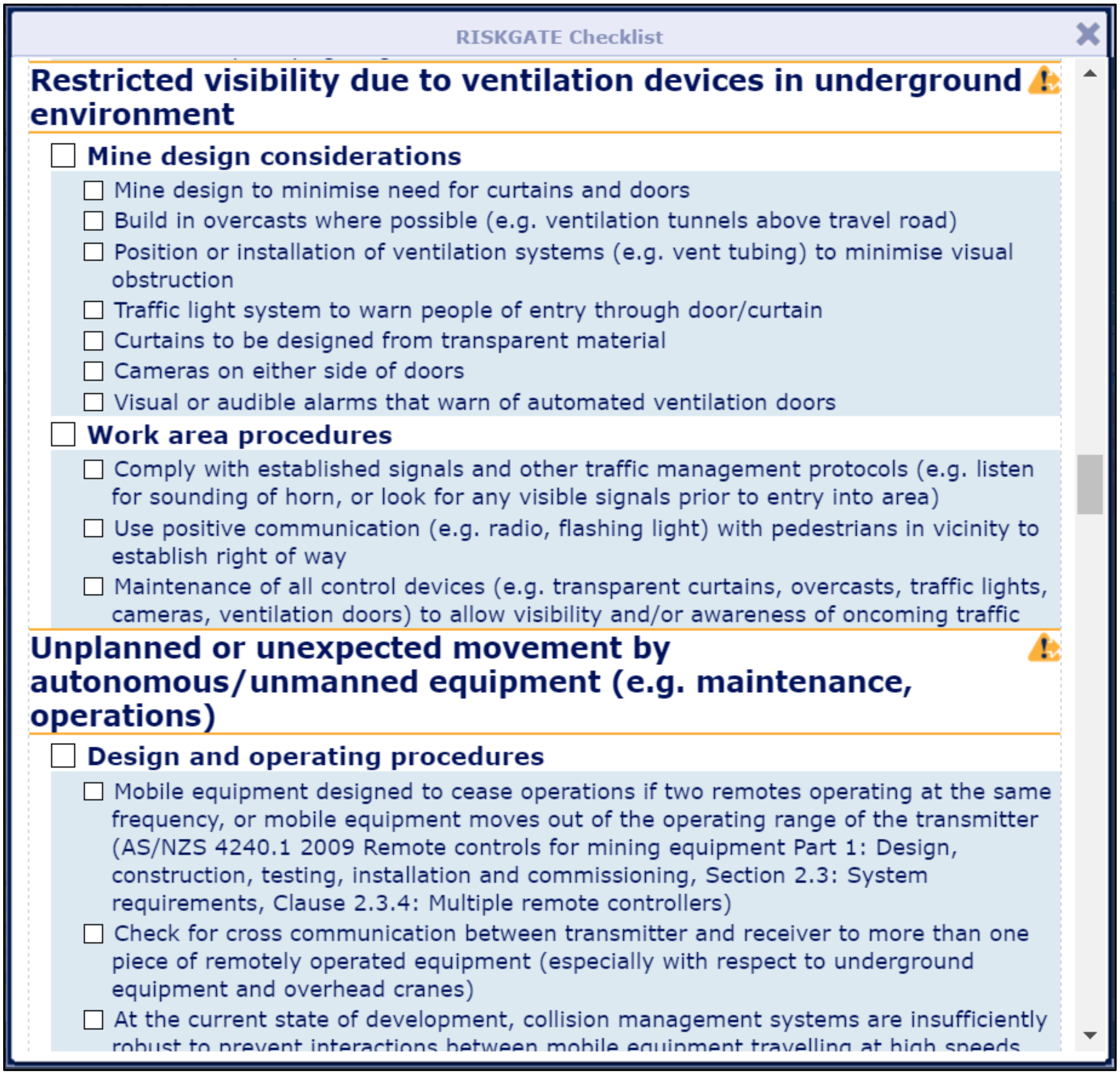

Figure 4.10 – RISKGATE checklist showing causes and controls (Riskgate.org)

4.3 Gap Analysis of RISKGATE Body-of-Knowledge

Conversion of the Australian RISKGATE body-of-knowledge to a usable platform based on U.S. mining practice requires a familiarity with the information RISKGATE provides the user, and the suitability of that information to address the contrasting mining standards (operational practice and techniques, government regulation, geological conditions, etc.) of the U.S. and Australian industries. This section examines the applicability of RISKGATE towards accident investigation in the U.S., and the feasibility of providing customizable control information which may not directly consider some strict provisions which mine operators are obligated to follow.

4.3.1 MSHA Accident Report Analysis

Prior to adapting RISKGATE for U.S. mine operators, a brief analysis of recent underground coal mine fatalities in the U.S. was conducted to determine the extent to which the information contained within the RISKGATE database could be used to determine both the root cause(s) of the fatal incidents and offer adequate control measures which address the root cause(s). For this analysis, only fatalities relating to fire and explosion prevention, roof control, and moving equipment were studied.

The Mine Safety and Health Administration (MSHA) provides publicly accessible "Preliminary Reports," brief incident overviews called "Fatalgrams," and finalized "Accident Reports" of reported mine fatalities that occur. These documents are a part of MSHA's program to promote best safety practice and provide incident transparency by sharing worker fatality information with both the mining community and the general public. Contained within each accident report is a brief overview of the accident, general information about the mine at which the accident occurred, a detailed description of the accident and the events prior to and afterwards, the investigation procedure, a root cause analysis, and conclusions and enforcement actions taken following the accident.

For the time period of Jan. 2010 through Dec. 2013 there were 78 fatalities at underground coal mines in the United States. Of those 78 fatalities, 61 (78 percent) were classified under the three high risk areas mentioned above. A further breakdown of the analyzed fatalities is shown in *Table 4.1*.

Table 4.1 – High-risk area U.S. underground coal mine fatalities, 2010 - 2014

Incident Classification	No. of fatal Incidents	No. of Fatalities	Percentage of high-risk area fatalities	Fatalities per Incident
Fires and Explosions	1	29	47.5	29
Roof Control	15	15	24.6	1
Moving Equipment	17	17	27.9	1
Totals:	33	61	100.0	

The high-risk area of fires and explosions accounted for almost half (47.5 percent) of the fatalities examined. However, it is important to note that a single incident (Upper Big Branch mine event) was responsible for these fatalities, highlighting the extreme severity of mine fire and mine explosion events. Moving equipment fatalities (17) accounted for 27.9 percent of the fatalities examined, while roof control fatalities (15) accounted for 24.6 percent of fatalities. Fatal incidents associated with moving equipment and roof control averaged one fatality per incident during the considered time period.

To conduct the accident report analysis, the root cause analyses provided within each MSHA fatal accident report were scrutinized, and then compared with a similar cause contained within a RISKGATE bowtie for a similar initiating event and subsequent consequence of the event (injury or fatality). Then, the RISKGATE recommended controls for each root cause and consequence were compared to the corrective actions MSHA provided to prevent and mitigate future events of the same nature.

The results of the analysis indicated that the MSHA-identified root cause(s) of each fatality that occurred could be addressed by existing RISKGATE controls. In addition to addressing the root cause(s) concluded by MSHA's investigations, RISKGATE provided multiple preventive and mitigating controls for each fatal accident that matched or exceeded the corrective actions given by MSHA. These results conclude that RISKGATE could be a viable option for incident investigation at U.S. underground coal mines. However, these results do not necessarily indicate that access to RISKGATE would have prevented any of these incidents from occurring. The outcomes of the accident report analysis can be found in *Appendix A*.

4.3.2 Primary Safety Requirements – 30 CFR 75

Title 30 Code of Federal Regulations (CFR) Part 75 (30 CFR 75) contains the statutory provisions which mandate the primary safety requirements for underground coal mines in the U.S. The bulk of the requirements contained within 30 CFR 75 do not offer mine operators the flexibility to customize their operation's safety practices (Jong, E.C. et al. 2016). This one-size-fits-all form of regulation, which has resulted in lengthy and rigid technical guidelines for U.S. mine development, highly contrasts with the Australian duty-of-care regulatory model, in which mine operators present to the regulator a risk management plan acknowledging the unique conditions of their mining operation.

RISKGATE was developed for the Australian coal industry under the premise that mine operators can and must tailor their risk management systems to address the distinct hazards they encounter. An adaptation of this body-of-knowledge to express the stringent nature of U.S. mining regulations must consider which existing RISKGATE control information can be utilized by U.S. mine operators, and which information fails to comply with the preordained safety requirements presented by 30 CFR 75.

This exercise requires an analysis of the mine safety provisions given by 30 CFR 75 and the compatibility of these rules with control recommendations that RISKGATE currently provides. For this analysis, only the provisions of 30 CFR 75 relating to fire and explosion prevention, roof control, and moving equipment were studied. This process required the categorization of each major area and sub-area from 30 CFR 75 into the defined hazard area (e.g. fire and explosion prevention) and control type (e.g. preventive versus mitigating, engineering versus administrative). This categorization allows the regulations to be tied to RISKGATE initiating events and controls. *Table 4.2* shows a sample of the spreadsheet created to classify the provisions of 30 CFR 75 into RISKGATE controls.

Table 4.2 – Sample categorization of "30 CFR 75 Subpart C – Roof Control" provisions as RISKGATE controls

Section	Subject	Subsection	Provisions	Engineering or Administrative Control	Preventive or Mitigating Control	Most Applicable RISKGATE Control
75.202	Protection from falls of roof, face, and rib	a	(a) The roof, face and ribs of areas where persons work or travel shall be supported or otherwise controlled to protect persons from hazards related to falls of the roof, face or ribs and coal or rock bursts.	Engineering	Preventive/ Mitigating	Training, competencies, assessment and review of operators with respect to site-based standards, management plans and awareness of strata control factors
		b	(b) No person shall work or travel under unsupported roof unless in accordance with this subpart.	Administrative	Preventive/ Mitigating	
75.203	Mining methods	a	(a) The method of mining shall not expose any person to hazards caused by excessive widths of rooms, crosscuts and entries, or faulty pillar recovery methods. Pillar dimensions shall be compatible with effective control of the roof, face and ribs and coal or rock bursts.	Engineering	Preventive	Adopt a level of conservatism that reflects the integrity of the data available
		b	(b) A sightline or other method of directional control shall be used to maintain the projected direction of mining in entries, rooms, crosscuts and pillar splits.	Engineering	Preventive	Eliminate variation in excavation dimensions (e.g. cutting, shooting) relative to design
		c	(c) A sidecut shall be started only from an area that is supported in accordance with the roof control plan.	Engineering	Preventive	Establish a strata management strategy for development roadways
		d	(d) A working face shall not be mined through into an unsupported area of active workings, except when the unsupported area is inaccessible.	Engineering	Preventive	
		e	(e) Additional roof support shall be installed where—			
		e1	(1) The width of the opening specified in the roof control plan is exceeded by more than 12 inches; and	Engineering	Preventive	Support design for widening roadways
		e2	(2) The distance over which the excessive width exists is more than 5 feet.	Engineering	Preventive	

This table shows the classification of 9 separate provisions from 2 sections of 30 CFR 75 Subpart C – Roof Control. These provisions, contained in blue cells, fall under the roof control hazard category. Not shown in *Table 4.2*, an additional 980 provisions from 30 CFR 75 were assigned RISKGATE controls. The full table displaying the 980 provisions assigned controls can be viewed in *Appendix B*. The assigned control recommendations offered by RISKGATE offered predominantly supplemental suggestions for improving safety without conflicting with the statutory provisions of 30 CFR 75.

These results indicate that RISKGATE can be adapted to be used by U.S. mine operators as a supplemental tool for risk-based safety practices. However, a number of discrepancies between RISKGATE controls and what is practicably allowed by 30 CFR 75 were noted. These incongruities must be considered to ensure that the U.S. version of RISKGATE offers control information which enhances safety, but does not fail to comply with statutory requirements.

Mandatory provisions which are too specific to be addressed by the RISKGATE platform include: prescribed methods for data presentation when submitting documentation to the regulator (MSHA), proper methods and specifications for installing bearing plates, ventilation control devices, etc., and specifications for the design of escapeways, mine fans, atmospheric monitoring systems, power distribution stations, roadway dimensions, etc. Since these specifications are strict and independent of site-specific mine conditions, they must be considered when determining which RISKGATE controls are appropriate for U.S. inclusion.

Certain control recommendations in RISKGATE are statutory requirements in the U.S. For example, the use of proximity detection systems is recommended as a control to prevent collisions between persons and moving equipment in RISKGATE, but is now required by law for certain equipment (continuous miners) in the U.S. However, proximity detection technology is considered immature by Australian standards, and is not mandated. This distinction is the based largely on differences in mining practice: the use of miner-bolter equipment for entry development in Australia versus the change-place method (alternating movement of continuous miner and roof bolter) in U.S. mines. RISKGATE's "Collisions" topic definition contains the following caution statement: "At the current state of development in the mining environment, collision management systems (CMS) are insufficiently robust to prevent interactions between mobile equipment. Here, 'collision management system' (CMS) is an umbrella term that includes both proximity detection technology (PDT) and collision avoidance systems (CAS). Proximity detection technology actively scans for other vehicles, infrastructure or personnel and warns of their presence but does not automatically take action to prevent a collision (e.g. simply triggers an alarm). In contrast, CAS makes use of various technologies to actively scan for other vehicles or personnel and take automatic action to render the equipment to a safe state (e.g. slowing or stopping the vehicle)" (RISKGATE, 2014).

Another RISKGATE control recommendation that does not comply with 30 CFR 75 is the use of booster fans to mitigate ventilation issues in underground coal mines. This recommendation should be excluded from the U.S. platform (Jong, E.C. et al. 2016). While some RISKGATE controls do consider legal requirements of the mine operator (e.g. "Accountability under legislation," "Consider using guidance from appropriate reference material – New South Wales Mine Design Guideline MDG," etc.) these broad-brush controls do not indicate to the operator what requirements are mandated by 30 CFR 75. A possible solution to this problem is the presentation of both mandated policies according to the subject area and applicable enhancements corresponding to the high-risk items (Jong, E.C. et al. 2016). Using this format, additional suggestions based on site-specific risk hazard assessments would be given only once operators acknowledge that primary requirements have been met (Jong, E.C. et al. 2016). However, this underlying problem could perhaps be a non-issue based on the obvious assumption that U.S. mine operators are already well aware of and have full access to the mandatory requirements of 30 CFR 75.

Chapter 5: RISKGATE-US COAL

5.1 Building a Body-of-Knowledge

The culmination of this project is the development of a U.S.-based risk platform analogous to the Australian RISKGATE database which focuses exclusively on underground coal mining: RISKGATE-US COAL. Information provided by the Australian RISKGATE platform addresses both surface and underground coal mining, covering 18 different topics related to high-risk hazard areas associated with coal mining, including coal bumps and bursts, interface, explosions, and manual tasks. Due to limited funding and scope of project, RISKGATE-US COAL focuses on only three principal hazards associated with underground coal mining in the U.S.: Fire and explosion prevention, roof control, and moving equipment.

5.1.1 Action Research Workshops

The development of the Australian RISKGATE database required contribution from several dozen AU coal industry experts and practitioners. This major task required a series of action research workshops conducted over the course of several months, revising and refining the information gathered to ensure essential industry knowledge, procedural documentation and practical user-functionality were built into the system. These workshops provided a mechanism for strengthening and contextualizing publicly available mine safety information while simultaneously collating this information an extensive reference library for use by the AU coal industry.

While RISKGATE-US COAL is built largely on the foundations developed for the AU RISKGATE (e.g. user interface, bowtie structure, checklist format, etc.), the information contained within each RISKGATE-US COAL topic is original, and was generated by U.S. industry participants. To assemble this body-of-knowledge, action research workshops were conducted with the help of several US coal industry players.

These workshops were facilitated by the research participants, and attended by U.S. mining practitioners who included frontline workers (whom these principal hazards most directly affect), safety officials, and technical experts, among others. These workshops focused on the identification of risk controls specific to U.S. operational standards, along with applying appropriate and necessary alterations to the existing Australian RISKGATE body of knowledge, including differences in language and terminology (e.g. goaf versus gob, bord and pillar versus room and pillar, etc.).

5.1.2 The Workshop Process

The action research workshops were conducted over a 14-month cycle and held at several different locations throughout the United States. The various locations were selected to reflect the varying nature of coal mining practice throughout the U.S., including differences in mining methods (longwall versus room and pillar), mining equipment, and geologic conditions (e.g. Western U.S. mines are more prone to spontaneous combustion of coal incidents). *Table 5.1* summarizes the locations of each workshop, the high-risk area of focus for each workshop, the number of participants, and the cumulative underground coal mining experience of the participants in years. The quality of the participants' experience varied from directly participating in coal production (miners, foreman, engineers, etc.) to experts and academic professionals.

Table 5.1 – Workshop dates, locations, topics, and participants

Date	Location	Workshop Topic	No. of Industry Participants
9/30/2014	Julian, W.Va.	Moving Equipment	24
10/2/2014	Harrisburg, Ill.	Moving Equipment	15
2/19/2015	Oak Creek, Co.	Spontaneous Combustion	10
2/23/2015	Julian, W.Va.	Moving Equipment	23
2/24/2015	Julian, W.Va.	Roof Control	19
11/17/2015	Bluefield, W.Va.	Roof Control	8
11/18/2015	Bluefield, W.Va.	Fires and Explosions	8
Cumulative mining experience of participants (years)			>1290

Each workshop generally begins with an introductory short course on risk management techniques and practices with an emphasis on the bowtie analysis tool to familiarize the participants with the bowtie method of analyzing risk. Additionally, the participants were introduced to the Australian RISKGATE tool and the AU experience with risk management and duty-of-care legislation.

To help the participants understand the bowtie tool, case studies of fatal mine incidents were presented to and examined by the participants. The participants were asked to generate a bowtie for the fatal incidents analyzed, distinguishing between key parts of the bowtie: causes, preventive controls, the initiating event, mitigating controls, and consequences. This practice proved to be beneficial in developing a fundamental understanding of the bowtie process for the participants, which led to greater participant involvement, and a more complete understanding of the workshop goals.

The next step in the workshop process was a “whiteboard” exercise during which the participants identified major initiating events and generated a list of causes relating to the topic of focus for that workshop. Since each workshop began with a new group of participants, the whiteboard approach allowed each group to essentially start from scratch, building their own initiating events, causes, consequences, and controls before reviewing the work done by previous groups at past workshops. While this approach was more time-consuming than simply expanding upon the work from previous workshops, it appeared to lead to more spontaneous conversation and innovative thinking. Once the list was deemed sufficient, the causes were addressed individually and assigned preventive controls. The same procedure was applied to assign mitigating controls to consequences identified by the participants.

Participants noted the strengths of developing a U.S. version of RISKGATE with the following feedback:

- “RISKGATE is on the right track – the availability of risk-based expertise in the U.S. would improve the general understanding of risk management and best practice in mining.”
- “There should be no secrets in safety. We are only as good as our worst actors. The biggest detriment to mining’s perception by the public is major disasters – multiple fatalities – fire and explosion issues.”

- “RISKGATE and the bowtie tool offer a very good analysis of specific hazards at the mine. I think there’s a need for it in the U.S. I definitely do.”

Several areas of the workshop process could be improved upon for future workshops. Inclusion of information from frontline workers is vital for a comprehensive body of control knowledge, and the formation of an accurate representation of the hazards encountered during mining. However, the frontline workers who attended the workshops at times seemed unwilling to participate in the conversation. This could be due to several factors, including the participants’ disassociation with the technical and participatory nature of the workshop, or a failure on the part of the researchers to adequately educate the participants prior to the workshop on the expectations and goals of the process. One solution to this problem is the addition of separate, on-site workshops for frontline workers with a limited number of academic and technical experts present. Additionally, the workshop process was at times tedious, and it was difficult to keep participants engaged for the entire 8-hour process. Adjustments should be made for future workshops to ensure all participants are fully aware of the goals of the workshop prior to attending. Smaller, group-based activities which focus on the workshop process may offer a solution to the lack of participation from individual attendees. Despite these flaws, participants noted value in attending the workshops, which offered attendees information on risk management principles and application, the bowtie analysis tool, and the opportunity to engage with fellow industry professionals on health and safety topics in a productive manner.

Following the workshop cycle, the research participants from Virginia Tech and Australia worked to distill the collected information for the synthesis of the U.S. website. This task focused on presenting the information gathered in a consistent and accessible manner. The challenges of this process included ensuring grammatical consistency (diction, syntax, consistent language, etc.), consolidation of similar causes, controls, consequences and initiating events, and confirmation through research and collaboration of current best practice standards. This task required careful consideration for including all of the information which the workshop participants had generated, without providing redundant or inconsistent control information. Once this task was completed, the information was uploaded to a prototype website, RISKGATE-US COAL (alpha.riskgate.org).

5.1.3 RISKGATE-US COAL: Current Status and Future Development

At its current state of development, RISKGATE-US COAL is ready to be utilized by coal mine operators in a manner similar to the original Australian RISKGATE. The website features three topic areas: "Ground Control" (which contains information concerning the high risk area of roof control), "Fires/Explosions," and "Moving Equipment." These topics are listed on the home page of RISKGATE-US COAL, displayed in *Figure 5.1*.

Figure 5.1 – Home page of RISKGATE-US COAL (alpha.riskgate.org)

Navigating RISKGATE-US COAL is exactly the same as with RISKGATE. The user can browse each topic, generating and outputting customizable checklists for conducting risk assessments, incident investigations, training workers, etc. *Figure 5.2* displays the topic page of RISKGATE-US COAL, which highlights the number of unique causes, preventive controls, initiating events (bowties), mitigating controls, and consequences contained within each topic.

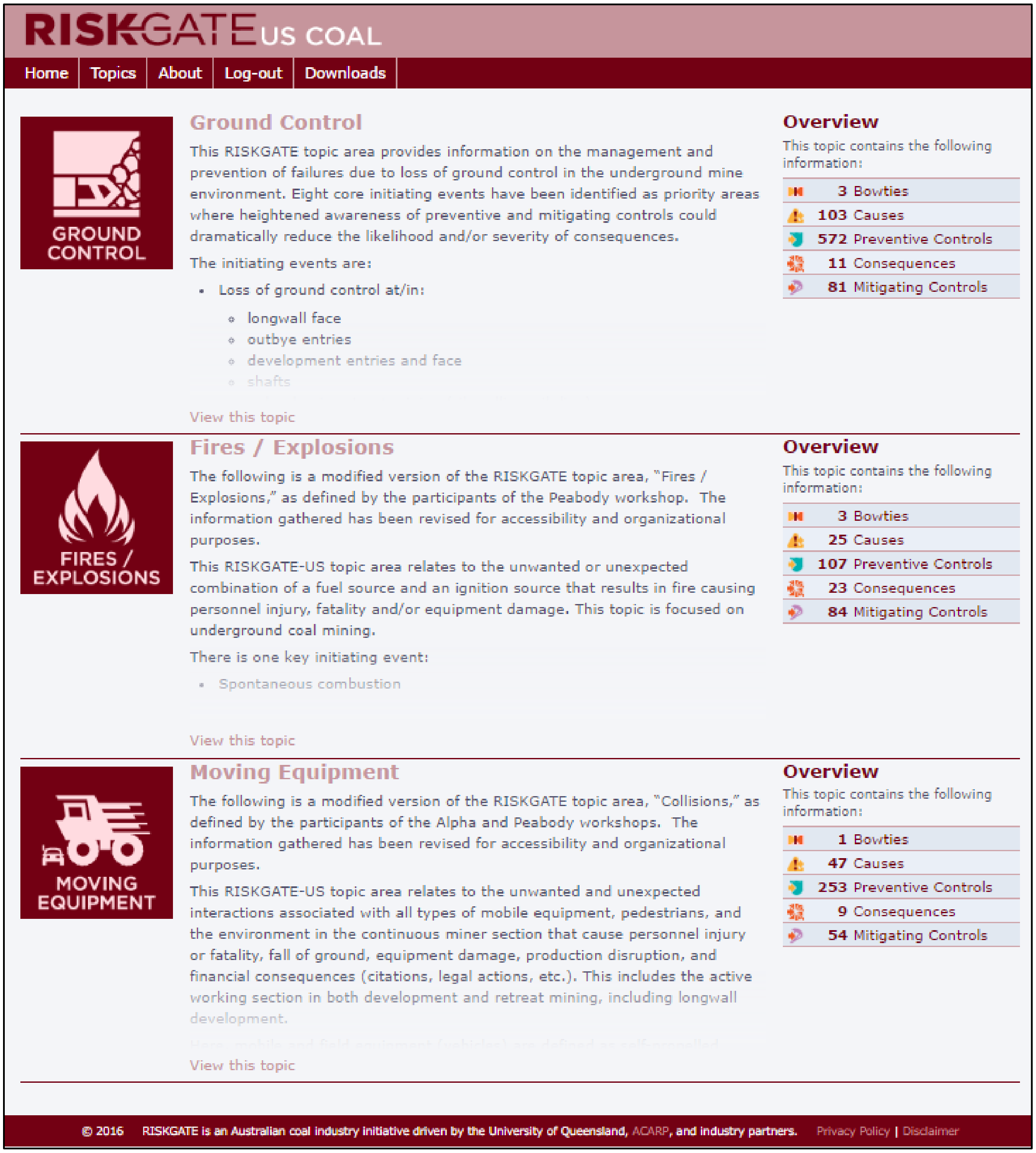

Figure 5.2 – RISKGATE-US COAL topic page (alpha.riskgate.org)

Across all three topic areas, RISKGATE-US COAL currently contains 7 bowties, with 175 causes, 932 preventive controls, 219 mitigating controls, and 43 consequences. These unique bowties and the information contained within were generated entirely from information collected through action research workshops and were not transferred or adapted from existing RISKGATE controls. *Figure 5.3* shows a sample bowtie, "Loss of control of mobile equipment (including events caused by less than adequate operation/design of equipment)," with a highlighted cause and its corresponding preventive controls expanded for selection.

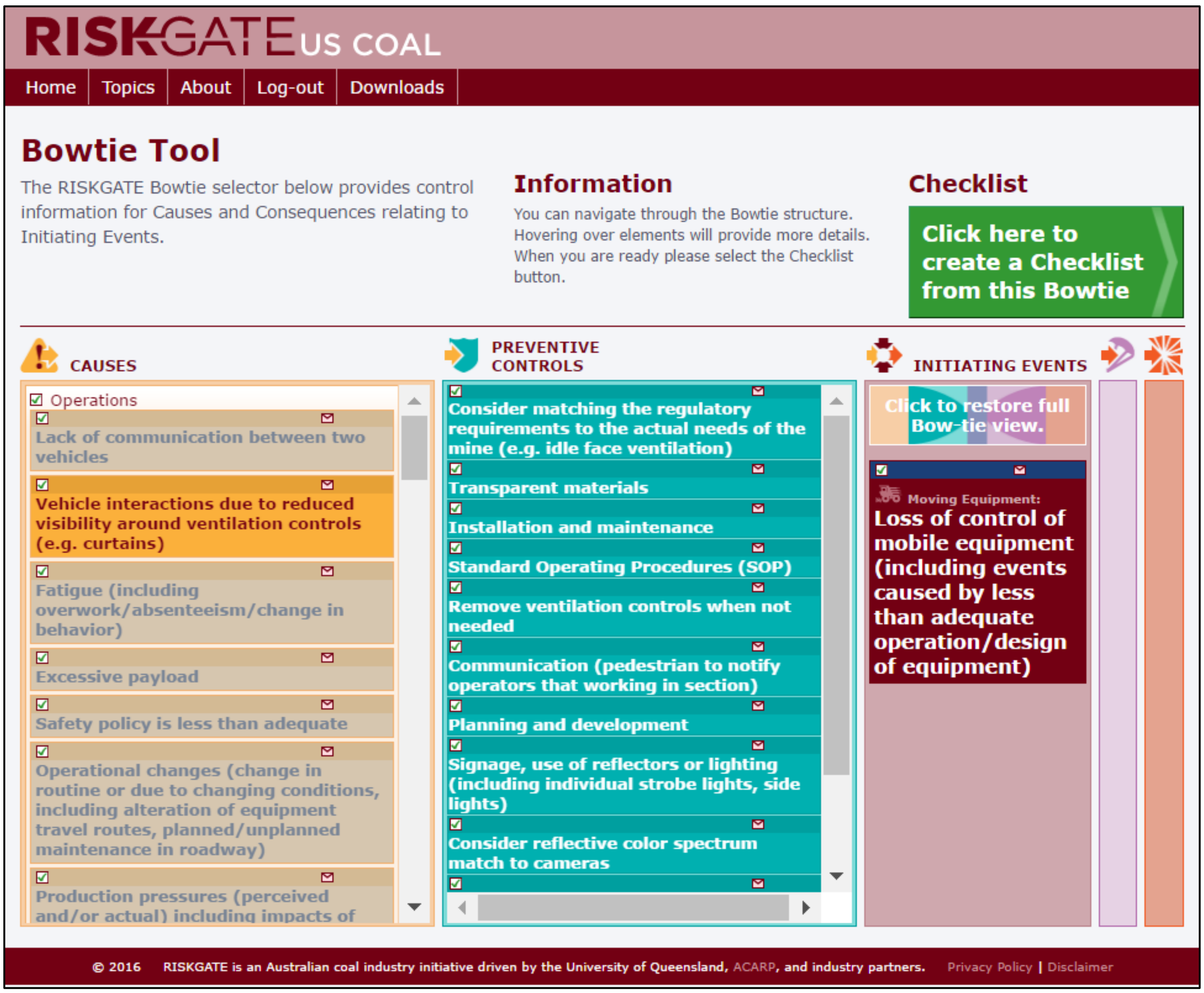

Figure 5.3 – Sample bowtie from RISKGATE-US COAL topic: Moving Equipment (alpha.riskgate.org)

The three RISKGATE-US COAL topics were developed with priority U.S. underground coal mining hazards in mind, due to comparatively limited development time, workshop opportunities, and resources information contained in the smaller U.S. project. However, this did not affect the quality and comprehensiveness of the controls developed.

The "Fires/Explosions" topic within RISKGATE-US COAL contains 3 bowties: "Spontaneous combustion," "Fire on/near conveyor belt," and "Methane ignition resulting in fire (face/gob) or explosion." These three bowties focus on known high-risk areas of a mine rather than individual tasks which may lead to mine fires/mine explosions.

Researchers were able to consolidate control information for the "Moving Equipment" topic into a single bowtie (*Figure 5.3*). Control information contained within this topic is divided into four categories: operations, equipment, environment, and behavior. The behavior category focuses on controls associated with worker behavior modification and improvement (e.g. the development and implementation of mentoring programs, adequate miner training, management leadership and commitment to culture that retains workforce, etc.). The inclusion of "behavior-based" controls may serve to facilitate the adoption of RISKGATE-US COAL as a supplementary safety control reference for U.S. mine operators, as the benefits of such controls may be more easily perceived by management and the workforce, in addition to the generally low cost of implementing such controls.

The "Ground Control" topic contains an additional 3 bowties: "Loss of roof control at advancing section (feeder inby), "Loss of roof control at longwall face," and "Burst of coal (at longwall face, development roadway, or outby roadway)." Control information contained within this topic is divided into three categories: geology, design, and operating practice (training, supervision, monitoring, audits, etc.). The full contents of RISKATE-US COAL are contained in *Appendix C*.

To date, pending revisions to the site include the topic definition for the "Ground Control" topic, which is borrowed from the original definition found in RISKGATE, the renaming of the "Ground Control" topic to the more colloquial "Roof Control," and a potential visual modification of the websites home page topic pages. The information contained within RISKGATE-US COAL is in no way absolute, and should be continuously modified to reflect the evolution of mining standards and best practice in U.S. underground coal mining.

It is recommended that the website be applied in a pilot study to test the overall usefulness and effectiveness of RISKGATE-US COAL towards improving mine safety. Such a study is appropriate to determine if any major modifications or revisions might be necessary before activating the site for free public use. The pilot study would require identifying and gaining access to an appropriate field site, training and educating the workforce from management to the frontline, and collecting anecdotal, survey, and quantitative data regarding the implementation of RISKGATE-US COAL. Ideally, the pilot site would be a small to medium size mine, preferably in the Central Appalachian Coal Basin near Virginia Tech. This would limit travel difficulties for the principal investigators from Virginia Tech undertaking this project. For data gathered from the pilot study to be of statistical significance, it is recommended the duration of the study be at least one year in length.

Chapter 6: Conclusions

The U.S. underground coal mining industry's steadily improving safety record continues to be marred by multi-fatality events. Prescriptive, compliance legislation, while influencing the development of new mining technologies which improve safety, is not robust enough to address the variable mining conditions facing the U.S. underground coal industry. The outcomes of this research project demonstrate that the risk management approach, a safety approach that has been successfully applied in numerous industries including the Australian mining industry, can at least provide supplemental health and safety support to U.S. mine operators, and possibly lead to a step-change which would see fatality rates approach the industry's ultimate zero-harm goal.

This research reviews the development of mine safety regulation in the U.S., and identifies regulatory constraints which have affected the widespread adoption of risk management, including: competing safety models (Behavior-based safety), a lack of available company resources, a lack of U.S. expertise in the area of risk management, and a historical, though recently wavering, lack of perceived common fate among competing coal companies. The development of a risk-based online platform, analogous to a subset of the Australian RISKGATE tool, was accomplished.

RISKGATE-US COAL was synthesized using the knowledge gathered by U.S. coal industry practitioners through 7 action research workshops conducted over a 14-month cycle. Workshop participants included frontline workers, as well as experienced engineers, and mine safety experts. The cumulative coal mining experience of those who participated totals over 1290 years.

The information addresses three high-risk areas of mining: fire and explosion prevention, roof control, and moving equipment. These three hazard areas were responsible for 78 percent of U.S. underground coal mine fatalities from 2010 to 2014. Across all three topic areas, RISKGATE-US COAL currently contains 7 bowties, with 175 causes, 932 preventive controls, 219 mitigating controls, and 43 consequences. The RISKGATE-US COAL topic, "Moving Equipment" contains 1 unique bowtie comprised of 47 causes, 253 preventive controls, 54 mitigating controls, and 9 consequences. The “Fires/Explosions” topic contains 3 bowties comprised of 25 causes, 107 preventive controls, 84 mitigating controls, and 23 consequences. The “Ground Control” topic contains 3 bowties comprised of 103 causes, 572 preventive controls, 81 mitigating controls, and 11 consequences.

It is recommended a pilot study be applied to RISKGATE-US COAL from which both qualitative (survey, anecdotal, behavioral) and quantitative (measured improvements in safety) data can be gathered and analyzed. This data would then be used to determine the primary ways which users utilize RISKGATE-US COAL at their own operations, and provide information necessary for modifications (design, interface, organization of material, content, etc.) to the website.

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Appendix A

MSHA Accident Report Analysis

Table A.1 – MSHA incident report analysis

MSHA-Identified Root Cause(s) of Incident as RISKGATE Cause(s)	RISKGATE Preventive Controls	RISKGATE Initiating Event	RISKGATE Mitigating Controls	Consequence(s) of Incident
Fatality 1: January 22, 2010				
Rib failure	Improve the characterization of the geotechnical and structural domain (e.g. update geological model, strata management plan)	**Loss of strata control in roadways under development**	Awareness, Training, and Assessment (separate personnel from unsupported roof/ poor strata conditions	Personnel Injury or Fatality
	Rib Support Design (e.g. review rib support requirements)			
	Monitoring of Rib Support (e.g. rib monitoring devices, visual roadway inspections)			
Incorrect selection or specification of strata support materials	Monitor the Performance of Installed Strata Support			
Fatalities 2-30: April 5, 2010				
Frictional ignition and incendiary sparking (pick hitting, fall of ground, roof fall, rock on rock, steel on rock, quartz on quartz, metal on metal, alloy on steel)	Risk assess the propensity for incendiary sparking: drum, pick, and spray design and site-based maintenance standards (e.g. wet head, ultra-fine sprays, spray curtains, venturi sprays)	**Fire or ignition on an extraction face (pillar and longwall)**	Develop an emergency response plan according to the risk assessment and regulatory requirements/guidelines that addresses firefighting, evacuation and medical treatment	Personnel Injury or fatality in the underground mine environment
	Confirm ventilation system mitigates dead spots or potential areas of gas accumulation (e.g. inspection, modelling, dead spots resulting from multiple fans or multiple shafts)			
	Establish an inspection and defect management system that identifies and reports defects, required corrective actions and close out			

	Pick or drill bit maintenance strategy (e.g. missing, blunt, missing pick blocks, worn or hot drill bit; pick speed/drum speed)			
Fatality 31: April 22, 2010				
Operator error leading to loss of control of mobile equipment	Comply with site based requirements and standards	**Loss of control of mobile equipment**	Collision avoidance system that automatically warns the operator when they are entering a Red Zone.	Injury or fatality of personnel operating mobile equipment
	Training, awareness, and competency in controls and procedures			
	Promotion of a safety culture			
Operator breaches or bypasses safety/ detection systems or procedures	Maintenance, testing, and calibration of safety/detection systems			
	Supervision, monitoring, and measuring behavior		Vehicle isolation points to be easily activated after a collision	
Fatality 32: April 28, 2010				
Unknown geologic anomalies	Improve characterization of the structural geology and geotechnical domain (e.g. review stress environment)	**Loss of strata control in roadways under development**	Training and awareness of safe operating procedures – communication of hazards and awareness to workforce	Personnel injury or fatality during roadway development
	Trigger Action Response Plans (TARPs) and inspection program			
Fatality 33: May 10, 2010				
Remotely operated equipment within operator's line of sight places personnel in hazardous positions (operators or others)	Personnel to be detected by collision avoidance systems that trigger shut down of equipment when no go zone/safety zone is breached	**Unexpected positioning of pedestrians in proximity to mobile equipment**	Hazard identification and familiarization with emergency response protocols; including effective communication strategies and identifying safe avenues for evacuation	Injury or fatality of personnel working in proximity to mobile equipment
	Promote a safety culture that encourages personnel to conduct a risk evaluation before each job			
Breach or bypass of safe work procedures, protocols, or devices	Supervision, monitoring, and measuring behavior (e.g. Safety observation/ audits by supervisors and managers			
Fatality 34: June 16, 2010				

Excessive stress conditions not addressed in design (including incorrect orientation) (e.g. local magnitude variations/rotations in tectonic stress environment)	Review all available stress data (measured, inferred, mapped)	**Loss of strata control in stress relief mining systems**	Training and awareness for recognition of impending system failure indicators and appropriate responses	Personnel injury or fatality due to failure of the stress relief mining system
	Incorporate stress data into mining system design			
Inadequate design methods for stress relief mining systems	Consider all geotechnical and geological factors relative to the geotechnical environment including other mining constraints (historical workings, weak floor or roof, slip planes, subsidence, structures, gradient, massive units, depth of cover)		Adoption of effective pillar and roadway monitoring systems and related trigger action response plans (TARPs) to warn of potential system failure	
Fatality 35: June 24, 2010				
Operator error leading to loss of control of mobile equipment	Comply with site based requirements and standards	**Loss of control of mobile equipment**	Collision avoidance system that automatically warns the operator when they are entering a Red Zone.	Injury or fatality of personnel operating mobile equipment
	Training, awareness, and competency in controls and procedures			
	Promotion of a safety culture			
Operator breaches or bypasses safety/ detection systems or procedures	Maintenance, testing, and calibration of safety/detection systems		Vehicle isolation points to be easily activated after a collision	
	Supervision, monitoring, and measuring behavior			
Fatality 36: July 1, 2010				
Mobile equipment design or modifications obstruct the visibility/	Safety critical modifications must be certified or approved by an authorized and competent person	**Unexpected positioning of pedestrians in proximity to mobile equipment**	Hazard identification and familiarization with emergency response protocols; including effective communication strategies and identifying safe avenues for evacuation	Injury or fatality of personnel working in proximity to mobile equipment
detection of personnel working on or in proximity to equipment	Use signs and procedures to warn workers of mobile equipment operator's restricted field of vision			
	Positive and effective two way communication			

	Training and awareness of risks associated with working near mobile equipment (e.g. field of vision		Vehicle isolation points to be easily activated after a collision	
	of operators, restricted/blind zones, vehicle hazard zones, truck stopping/braking distances, etc.)			
Fatality 37: July 9, 2010				
Restricted visibility at the intersection of pedestrian and vehicle pathways due to design constraints	Install warning signs in mine infrastructure areas to inform pedestrians of restricted/blind zones of mobile equipment	**Unexpected positioning of pedestrians in proximity to mobile equipment**	Hazard identification and familiarization with emergency response protocols; including effective communication strategies and identifying safe avenues for evacuation	Injury or fatality of personnel working in proximity to mobile equipment
	Use signs and procedures to warn workers of mobile equipment operator's restricted field of vision			
	Use pedestrian crossings and/ or traffic lights to manage flow of people in proximity to intersections			
	Segregate traffic or design one way traffic flow to avoid interactions between heavy vehicles and light vehicles, people and infrastructure			
Fatality 38: July 29, 2010				
Rib failure	Support design to consider deformation and failure mechanisms of roof, ribs, and floor under anticipated loading conditions	**Loss of strata control in roadways under development**	Select cut and bolt equipment that minimizes unsupported spans and time to installation	Personnel injury or fatality during roadway development
	Rib support design – review roof support requirements in areas where the rib has deteriorated			
Support installation equipment not fit for purpose	Equipment matched to planned support needs and geotechnical considerations		Training and awareness of safe operating procedures – communication of hazards and awareness to workforce	
	Correct support placement capability (e.g. rib support)			

<table>
<tr><th colspan="5">Fatality 39: October 11, 2010</th></tr>
<tr><td rowspan="2">Increasing the roadway height</td><td>Obtain additional lithological information, geotechnical testing, and data interpretation</td><td rowspan="5">Loss of strata control in roadways under development</td><td rowspan="3">Training and awareness of safe operating procedures – communication of hazards and awareness to workforce</td><td rowspan="5">Personnel injury or fatality during roadway development</td></tr>
<tr><td>Implement a change management strategy for design modifications</td></tr>
<tr><td rowspan="2">Non-conformance to approved excavation dimensions (e.g. height/width)</td><td>Geotechnical inspections/audits to check excavation conformance to design</td></tr>
<tr><td>Support design must counter changes that occur as a result of non-conforming excavation dimensions</td><td>Equipment design and selection to consider operator protection</td></tr>
<tr><td>Unknown geologic anomalies (e.g. brow formation)</td><td>Continuous update of geological model, panel hazard plan, and permits to mine in accordance with the Roof Control Plan.</td><td>Trigger Action Response Plans (TARPs)</td></tr>
<tr><th colspan="5">Fatality 40: October 27, 2010</th></tr>
<tr><td>Mobile equipment design or modifications obstruct the visibility/</td><td>Undertake a risk assessment for all new, modified or hired mobile equipment to determine impacts of modifications on the field of vision (relative to task, personnel, environment)</td><td rowspan="2">Unexpected positioning of pedestrians in proximity to mobile equipment</td><td rowspan="2">Hazard identification and familiarization with emergency response protocols; including effective communication strategies and identifying safe avenues for evacuation</td><td rowspan="2">Injury or fatality of personnel working in proximity to mobile equipment</td></tr>
<tr><td>detection of personnel working on or in proximity to equipment</td><td>Training and awareness of risks associated with working near mobile equipment (e.g. field of vision of operators, restricted/blind zones, vehicle hazard zones, truck stopping/braking distances, etc.)</td></tr>
</table>

<table>
<tr><td>Restricted visibility at the intersection of pedestrian and vehicle pathways due to design constraints</td><td>Use collision management systems that trigger an alarm when pedestrians or vehicles enter a hazardous zone (e.g. warning to both mobile equipment operator & personnel outside workshop as vehicle exits)</td><td rowspan="2"></td><td>Equipment design and selection to consider operator protection</td><td rowspan="2"></td></tr>
<tr><td>Breach or bypass of safe work procedures, protocols, or devices</td><td>Training in correct and safe operating practices</td><td>Trigger Action Response Plans (TARPs)</td></tr>
<tr><td colspan="5">Fatality 41: March 25, 2011</td></tr>
<tr><td rowspan="3">Operator error leading to loss of control of mobile equipment</td><td>Comply with site based requirements and standards</td><td rowspan="5">Loss of control of mobile equipment</td><td rowspan="3">Collision avoidance system that automatically warns the operator when they are entering a Red Zone.</td><td rowspan="5">Injury or fatality of personnel operating mobile equipment</td></tr>
<tr><td>Training, awareness, and competency in controls and procedures</td></tr>
<tr><td>Promotion of a safety culture</td></tr>
<tr><td rowspan="2">Operator breaches or bypasses safety/ detection systems or procedures</td><td>Maintenance, testing, and calibration of safety/detection systems</td><td rowspan="2">Vehicle isolation points to be easily activated after a collision</td></tr>
<tr><td>Supervision, monitoring, and measuring behavior</td></tr>
<tr><td colspan="5">Fatality 42: June 27, 2011</td></tr>
<tr><td rowspan="2">Compromised support integrity from erosion</td><td>Re-support or replace components of support systems</td><td rowspan="4">Loss of strata control in outby roadways</td><td rowspan="4">Training and awareness of safe operating procedures – communication of hazards and awareness to workforce</td><td rowspan="4">Personnel injury or fatality in outby districts</td></tr>
<tr><td>Design support patterns and system considering life cycle of the roadway</td></tr>
<tr><td rowspan="2">Inappropriate strata support design of outby roadway - people</td><td>Strata support designs conducted by competent (suitably technical/ qualified/ experienced) personnel</td></tr>
<tr><td>Strata support designs peer reviewed by competent (suitably technical/ qualified/ experienced) personnel</td></tr>
<tr><td colspan="5">Fatality 43: June 29, 2011</td></tr>
</table>

Rib failure	Periodically review and update relative to unexpected rib deterioration	**Loss of strata control in outby roadways**	Separate people from unstable strata in the outby district (as identified by inspection or TARPs)	Personnel injury or fatality in outby districts
	Visual inspection of roadways to detect rib deterioration (e.g. preshift inspections)			
	Rib support design – review roof support requirements in areas where the rib has deteriorated			
Deficient personnel skills and awareness	Hazard recognition and awareness (e.g. geotechnical hazard plans)		Training and awareness of safe operating procedures – communication of hazards and awareness to workforce	
	Ensure miners possess the ability to recognize changing strata conditions			
Fatality 44: July 11, 2011				
Contact between mobile plant and overhead infrastructure	Clear delineation of trafficable roads that do not require traversing under infrastructure	**Loss of control of mobile equipment**	Barrier height appropriate for typical traffic users (e.g. relative to vehicle type working in proximity to infrastructure)	Injury or fatality of personnel operating mobile equipment
	Training, awareness, and competency in controls and procedures (e.g. training in potential collisions and consequences)			
Operator breaches or bypasses safety/ detection systems or procedures	Maintenance, testing, and calibration of safety/detection systems		Vehicle isolation points to be easily activated after a collision	
	Supervision, monitoring, and measuring behavior			
Fatality 45: August 15, 2011				
Inadequate support during longwall take-off and/or inappropriate chock removal	Confirm compliance with longwall take-off plan/manual	**Loss of strata control at longwall face**	Limit the number of operators working on the face at any one time	Personnel injury or fatality on the longwall face
	Assess appropriateness of design and support plan to operating conditions			
	Scheduled monitoring of conditions as longwall approaches take-off			

Deviant practice (e.g. failure to follow safe operating procedures)	Disciplinary procedures – clearly understandable, regularly reviewed, enforced consistently		Automated equipment to maintain planned operating procedures and designed extraction geometry on the longwall face	
	Communicate the safety policy regularly			
Fatality 46: March 10, 2012				
Rib failure	Improve the characterization of the geotechnical and structural domain (e.g. update geological model, strata management plan)	**Loss of strata control in roadways under development**	Awareness, Training, and Assessment (separate personnel from unsupported roof/ poor strata conditions	Personnel Injury or Fatality
	Rib Support Design (e.g. review rib support requirements)			
	Monitoring of Rib Support (e.g. rib monitoring devices, visual roadway inspections)			
Incorrect selection or specification of strata support materials	Support design to consider deformation and failure mechanisms of roof, ribs and floor under anticipated loading conditions			
Fatality 47: June 25, 2012				
Rib failure	Periodically review and update relative to unexpected/expected rib deterioration	**Loss of strata control in outby roadways**	Training and awareness of safe operating procedures — communication of hazards and awareness to outby workforce	Personnel Injury or Fatality in outby districts
	Rib Support Design (e.g. review rib support requirements)			
	Monitoring of Rib Support (e.g. rib monitoring devices, visual roadway inspections)			
	Consider the life cycle of the roadway (install secondary rib support in a timely manner)			
Fatality 48: July 27, 2012				
Restricted visibility due to ventilation devices in underground environment	Traffic light system to warn people of entry through door/ curtain	**Unexpected positioning of pedestrians in proximity to**	Hazard identification and familiarization with emergency response protocols; including	Injury or fatality of personnel working in proximity to

	Curtains to be designed from transparent material	**mobile equipment**	effective communication strategies and identifying safe avenues for evacuation	mobile equipment
	Use positive communication (e.g. radio, flashing light) with pedestrians in vicinity to establish right of way			
Pedestrian distraction in proximity to mobile equipment	Use collision management systems that trigger an alarm when pedestrians or vehicles enter a hazardous zone (e.g. warning to both mobile equipment operator & personnel outside workshop as vehicle exits)		Vehicle isolation points to be easily deactivated after a collision	
Fatality 49: July 31, 2012				
Mobile equipment design or modifications obstruct the visibility/ detection of personnel working on or in proximity to equipment	Test and verify modifications prior to commissioning to assess the change outcomes (i.e. confirm the equipment or modifications maintain the safety, functionality and scope/objective of the change)	**Unexpected positioning of pedestrians in proximity to mobile equipment**	Hazard identification and familiarization with emergency response protocols; including effective communication strategies and identifying safe avenues for evacuation	Injury or fatality of personnel working in proximity to mobile equipment
	Consider installing secondary devices such as collision management systems that alert operators and workers (via lights, alarms, etc.) of people approaching or entering hazardous zones (e.g. blind zones) of mobile equipment			
Pedestrian distraction in proximity to mobile equipment	Rationalize the number of visual and audible alarms external to vehicle or in mine infrastructure area		Vehicle isolation points to be easily deactivated after a collision	
Fatality 50: September 11, 2012				

<table>
<tr><td rowspan="2">Mobile equipment design or modifications obstruct the visibility/ detection of personnel working on or in proximity to equipment</td><td>Test and verify modifications prior to commissioning to assess the change outcomes (i.e. confirm the equipment or modifications maintain the safety, functionality and scope/objective of the change)</td><td rowspan="4">Unexpected positioning of pedestrians in proximity to mobile equipment</td><td rowspan="2">Hazard identification and familiarization with emergency response protocols; including effective communication strategies and identifying safe avenues for evacuation</td><td rowspan="4">Injury or fatality of personnel working in proximity to mobile equipment</td></tr>
<tr><td>Consider installing secondary devices such as collision management systems that alert operators and workers (via lights, alarms, etc.) of people approaching or entering hazardous zones (e.g. blind zones) of mobile equipment</td></tr>
<tr><td>Pedestrian distraction in proximity to mobile equipment</td><td>Use of alarm or signal triggered by ambient noise level to alert personnel of hazardous work environment</td><td rowspan="2">Vehicle isolation points to be easily deactivated after a collision</td></tr>
<tr><td>Breach or bypass of safe work procedures, protocols, or devices</td><td>Training, awareness, and competency (e.g. field of vision of operators, blind spot areas, hazardous zones around each vehicle type)</td></tr>
<tr><td colspan="5">Fatality 51: September 13, 2012</td></tr>
<tr><td rowspan="2">Changes to stress environment</td><td>Develop a contingency plan (e.g. hydraulic props equipment/ gear/training)</td><td rowspan="3">Loss of strata control in outby roadways</td><td rowspan="3">Training and awareness of safe operating procedures – communication of hazards and awareness to outby workforce (e.g. no go zones, manager's support rules)</td><td rowspan="3">Personnel Injury or Fatality in outby districts</td></tr>
<tr><td>Installation of secondary supports in a timely manner</td></tr>
<tr><td>Deficient personnel skills and awareness</td><td>Functional understanding of support principles – ability to recognize changing strata conditions</td></tr>
</table>

<table>
<tr><td></td><td>Training, competencies, assessment and review of operators with respect to site-based standards – Installation of strata support products (placement)</td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Fatality 52: September 26, 2012</td></tr>
<tr><td rowspan="2">Deviant practice (i.e. short-cuts, work under unsupported roof, cultural norms, substandard performance and/or installation)</td><td>Disciplinary policy and procedures: clearly state the consequences of violating a safety rule/ manager’s support rules/ standard/ statutory regulation (formal and informal consequences), clearly communicated, enforced consistently</td><td rowspan="2">Loss of strata control in roadways under development</td><td rowspan="2">Awareness, Training, and Assessment (separate personnel from unsupported roof/ poor strata conditions</td><td rowspan="2">Personnel Injury or Fatality</td></tr>
<tr><td>Awareness of legislation concerning deviant behavior in underground mines (e.g. person working underneath an unsupported roof, contraband in underground mines, fitness of work)</td></tr>
<tr><td colspan="5">Fatality 53: November 17, 2012</td></tr>
<tr><td rowspan="3">Operator error leading to loss of control of mobile equipment</td><td>Comply with site based requirements and standards</td><td rowspan="5">Loss of control of mobile equipment</td><td rowspan="4">Collision avoidance system that automatically warns the operator when they are entering a Red Zone.</td><td rowspan="5">Injury or fatality of personnel operating mobile equipment</td></tr>
<tr><td>Training, awareness, and competency in controls and procedures</td></tr>
<tr><td>Promotion of a safety culture</td></tr>
<tr><td rowspan="2">Operator breaches or bypasses safety/ detection systems or procedures</td><td>Maintenance, testing, and calibration of safety/detection systems</td></tr>
<tr><td>Supervision, monitoring, and measuring behavior</td><td>Vehicle isolation points to be easily activated after a collision</td></tr>
<tr><td colspan="5">Fatality 54: November 30, 2012</td></tr>
<tr><td>Restricted visibility due to ventilation devices in underground</td><td>Traffic light system to warn people of entry through door/ curtain</td><td>Unexpected positioning of pedestrians in</td><td>Hazard identification and familiarization with emergency response</td><td>Injury or fatality of personnel working in</td></tr>
</table>

environment	Curtains to be designed from transparent material	**proximity to mobile equipment**	protocols; including effective communication strategies and identifying safe avenues for evacuation	proximity to mobile equipment
	Use positive communication (e.g. radio, flashing light) with pedestrians in vicinity to establish right of way			
Pedestrian distraction in proximity to mobile equipment	Use collision management systems that trigger an alarm when pedestrians or vehicles enter a hazardous zone (e.g. warning to both mobile equipment operator & personnel outside workshop as vehicle exits)			
Mobile equipment design or modifications obstruct the visibility/ detection of personnel working on or in proximity to equipment	Undertake a risk assessment for all new, modified or hired mobile equipment to determine impacts of modifications on the field of vision (relative to task, personnel, environment)		Vehicle isolation points to be easily deactivated after a collision	
Fatality 55: February 13, 2014				
Operator error leading to loss of control of mobile equipment	Comply with site based requirements and standards	**Loss of control of mobile equipment**	Collision avoidance system that automatically warns the operator when they are entering a Red Zone.	Injury or fatality of personnel operating mobile equipment
	Training, awareness, and competency in controls and procedures			
	Promotion of a safety culture			
Operator breaches or bypasses safety/ detection systems or procedures	Maintenance, testing, and calibration of safety/detection systems		Vehicle isolation points to be easily activated after a collision	
	Supervision, monitoring, and measuring behavior			
Fatality 56: February 19, 2014				
Mobile equipment design or modifications obstruct the visibility/	Safety critical modifications must be certified or approved by an authorized and competent person	**Unexpected positioning of pedestrians in proximity to mobile equipment**	Hazard identification and familiarization with emergency response protocols; including effective communication	Injury or fatality of personnel working in proximity to mobile equipment

detection of personnel working on or in proximity to equipment	Use signs and procedures to warn workers of mobile equipment operator's restricted field of vision		strategies and identifying safe avenues for evacuation	
	Positive and effective two way communication			
	Training and awareness of risks associated with working near mobile equipment (e.g. field of vision		Vehicle isolation points to be easily activated after a collision	
	of operators, restricted/blind zones, vehicle hazard zones, truck stopping/braking distances, etc.)			
Fatality 57: March 13, 2014				
Deficient personnel skills and awareness	Audit installation practice against manager's support rules (e.g. timing, sequence, location), original equipment manufacturers (OEMs) installation guidelines/standards	**Loss of strata control in outby roadways**	Separate people from unstable strata in the outby district (as identified by inspection or trigger action response plans, TARPs)	Personnel injury or fatality in outby districts
Deviant practice (i.e. short-cuts, work under unsupported roof, cultural norms, substandard performance and/or installation)	Competencies (e.g. roof/rib bolter operation competency) required for underground operators		Remote bolting capability — separate the operator from the equipment and the hazard zone	
	Awareness of legislation concerning deviant behavior in underground mines (e.g. person working underneath an unsupported roof, contraband in underground mines, fitness of work)			
Fatality 58: March 22, 2013				
Inappropriate strata support design of outby roadway - people	Strata support designs conducted by competent (suitably technical/ qualified/ experienced) personnel e.g. Registered Professional Engineers	**Loss of strata control in outby roadways**	Separate people from unstable strata in the outby district (as identified by inspection or trigger action response plans, TARPs)	Personnel injury or fatality in outby districts

Support installation equipment not fit for purpose	Correct support placement capability (e.g. close to center line, close to edge, distance from face)		Training and awareness of safe operating procedures — communication of hazards and awareness to outby workforce	
Incorrect selection or specification of strata support materials	Review and use monitoring results for ongoing design process to assess if installed support is fit for purpose			
Fatality 59: July 2, 2013				
Restricted visibility due to ventilation devices in underground environment	Traffic light system to warn people of entry through door/ curtain	**Unexpected positioning of pedestrians in proximity to mobile equipment**	Hazard identification and familiarization with emergency response protocols; including effective communication strategies and identifying safe avenues for evacuation	Injury or fatality of personnel working in proximity to mobile equipment
	Curtains to be designed from transparent material			
	Use positive communication (e.g. radio, flashing light) with pedestrians in vicinity to establish right of way			
Pedestrian distraction in proximity to mobile equipment	Use collision management systems that trigger an alarm when pedestrians or vehicles enter a hazardous zone (e.g. warning to both mobile equipment operator & personnel outside workshop as vehicle exits)		Vehicle isolation points to be easily deactivated after a collision	
Fatality 60: October 11, 2013				
Mobile equipment design or modifications obstruct the visibility/	Safety critical modifications must be certified or approved by an authorized and competent person	**Unexpected positioning of pedestrians in proximity to mobile equipment**	Hazard identification and familiarization with emergency response protocols; including effective communication strategies and identifying safe avenues for evacuation	Injury or fatality of personnel working in proximity to mobile equipment
detection of personnel working on or in proximity to equipment	Use signs and procedures to warn workers of mobile equipment operator's restricted field of vision			
	Positive and effective two way communication			

	Training and awareness of risks associated with working near mobile equipment (e.g. field of vision of operators, restricted/blind zones, vehicle hazard zones, truck stopping/braking distances, etc.)		Vehicle isolation points to be easily activated after a collision	
Fatality 61: November 4, 2013				
Deviant practice (e.g. failure to follow safe operating procedures)	Corporate audits to establish compliance with company standards and procedures	**Loss of strata control at longwall face**	Communication of hazards and awareness to longwall workforce: no go zones, manager's support rules; mine emergency plan (including mine egress procedures, communication methods, etc.)	Personnel injury or fatality on the longwall face
	Disciplinary procedures – clearly understandable, regularly reviewed, enforced consistently		Automated equipment to maintain planned operating procedures and designed extraction geometry on the longwall face	
	Communicate the safety policy regularly			

Appendix B

Categorization of Relevant "30 CFR 75" Provisions as RISKGATE Controls

Table Key (Provision Classification by Priority Hazard):

Explosions
Moving Equipment
Roof Control

Table B.1 – Categorization of “30 CFR 75 Subpart C – Roof Control” provisions as RISKGATE controls

Section	Subject	Sub-section	Provisions	Engineering or Administrative Control	Preventive or Mitigating Control	RISKGATE Control
75.202	Protection from falls of roof, face, and rib	a	(a) The roof, face and ribs of areas where persons work or travel shall be supported or otherwise controlled to protect persons from hazards related to falls of the roof, face or ribs and coal or rock bursts.	Engineering	Preventive	Training, competencies , assessment and review of operators with respect to site-based standards, management plans and awareness of strata control factors
		b	(b) No person shall work or travel under unsupported roof unless in accordance with this subpart.	Administrative	Preventive	
75.203	Mining methods	a	(a) The method of mining shall not expose any person to hazards caused by excessive widths of rooms, crosscuts and entries, or faulty pillar recovery methods. Pillar dimensions shall be compatible with effective control of the roof, face and ribs and coal or rock bursts.	Engineering	Preventive	Adopt a level of conservatism that reflects the integrity of the data available
		b	(b) A sightline or other method of directional control shall be used to maintain the projected direction of mining in entries, rooms, crosscuts and pillar splits.	Engineering	Preventive	Eliminate variation in excavation dimensions (e.g. cutting, shooting) relative to design
		c	(c) A sidecut shall be started only from an area that is supported in accordance with the roof control plan.	Engineering	Preventive	Establish a strata management strategy for development roadways
		d	(d) A working face shall not be mined through into an unsupported area of active workings, except when the unsupported area is inaccessible.	Engineering	Preventive	
		e	(e) Additional roof support shall be installed where—			
		e1	(1) The width of the opening specified in the roof control plan is exceeded by more than 12 inches; and	Engineering	Preventive	Support design for widening roadways
		e2	(2) The distance over which the excessive width	Engineering	Preventive	

			exists is more than 5 feet.			
75.204	Roof bolting	a	(a) For roof bolts and accessories addressed in ASTM F432–95, ‘‘Standard Specification for Roof and Rock Bolts and Accessories,’’ the mine operator shall—			
		a1	(1) Obtain a manufacturer’s certification that the material was manufactured and tested in accordance with the specifications of ASTM F432–95; and	Administrative	Preventive	Confirm original equipment manufacturer (OEM) has a thorough QA/QC process
		a2	(2) Make this certification available to an authorized representative of the Secretary and to the representative of miners.	Administrative	Preventive	
		b	(b) Roof bolts and accessories not addressed in ASTM F432–95 may be used, provided that the use of such materials is approved by the District Manager based on—			
		b1	(1) Demonstrations which show that the materials have successfully supported the roof in an area of a coal mine with similar strata, opening dimensions and roof stresses; or	Engineering	Preventive	Check or test (conducted by supplier or mine company) that components meet specification (e.g. stress strain graph for each batch of bolts, resin viscosity for hole size)
		b2	(2) Tests which show the materials to be effective for supporting the roof in an area of the affected mine which has similar strata, opening dimensions and roof stresses as the area where the roof bolts are to be used. During the test process, access to the test area shall be limited to persons necessary to conduct the test.	Engineering	Preventive	
		c1	(c)(1) A bearing plate shall be firmly installed with each roof bolt.	Engineering	Preventive	Inspection and monitoring
		c2	(2) Bearing plates used directly against the mine roof shall be at least 6 inches square or the equivalent, except that where the mine roof is firm	Engineering	Preventive	Appropriate selection of fit-for-purpose strata support materials - people and

			and not susceptible to sloughing, bearing plates 5 inches square or the equivalent may be used.			process, Equipment matched to planned support needs and geotechnical considerations, accountability under legislation
		c3	(3) Bearing plates used with wood or metal materials shall be at least 4 inches square or the equivalent.	Engineering	Preventive	
		c4	(4) Wooden materials that are used between a bearing plate and the mine roof in areas which will exist for three years or more shall be treated to minimize deterioration.	Engineering	Preventive	
		d	(d) When washers are used with roof bolts, the washers shall conform to the shape of the roof bolt head and bearing plate.	Engineering	Preventive	
		e1	(e)(1) The diameter of finishing bits shall be within a tolerance of plus or minus 0.030 inch of the manufacturer's recommended hole diameter for the anchor used.	Engineering	Preventive	
		e2	(2) When separate finishing bits are used, they shall be distinguishable from other bits.	Engineering	Preventive	
		f	(f) Tensioned roof bolts.			
		f1	(1) Roof bolts that provide support by creating a beam of laminated strata shall be at least 30 inches long. Roof bolts that provide support by suspending the roof from overlying stronger strata shall be long enough to anchor at least 12 inches into the stronger strata.	Engineering	Preventive	Select cut and bolt equipment that minimises unsupported spans and time to installation (e.g. continuous miners with the ability to install bolts within one meter of the face)
		f2	(2) Test holes, spaced at intervals specified in the roof control plan, shall be drilled to a depth of at least 12 inches above the anchorage horizon of mechanically anchored tensioned bolts being	Engineering	Preventive	Characterization of the roadway fall structural and geotechnical domain

			used. When a test hole indicates that bolts would not anchor in competent strata, corrective action shall be taken.			
		f3	(3) The installed torque or tension ranges for roof bolts as specified in the roof control plan shall maintain the integrity of the support system and shall not exceed the yield point of the roof bolt nor anchorage capacity of the strata.	Engineering	Preventive	Check or test (conducted by supplier or mine company) that components meet specification (e.g. stress strain graph for each batch of bolts, resin viscosity for hole size)
		f4	(4) In each roof bolting cycle, the actual torque or tension of the first tensioned roof bolt installed with each drill head shall be measured immediately after it is installed. Thereafter, for each drill head used, at least one roof bolt out of every four installed shall be measured for actual torque or tension. If the torque or tension of any of the roof bolts measured is not within the range specified in the roof control plan, corrective action shall be taken.	Engineering	Preventive	Verify adequacy of available torque in bolt installation equipment
		f5	(5) In working places from which coal is produced during any portion of a 24-hour period, the actual torque or tension on at least one out of every ten previously installed mechanically anchored tensioned roof bolts shall be measured from the outby corner of the last open crosscut to the face in each advancing section. Corrective action shall be taken if the majority of the bolts measured—	Administrative	Preventive	
		f5i	(i) Do not maintain at least 70 percent of the minimum torque or tension specified in the roof control plan, 50	Engineering	Preventive	

			percent if the roof bolt plates bear against wood; or			
		f5ii	(ii) Have exceeded the maximum specified torque or tension by 50 percent.	Engineering	Preventive	
		f6	(6) The mine operator or a person designated by the operator shall certify by signature and date that measurements required by paragraph (f) (5) of this section have been made. This certification shall be maintained for at least one year and shall be made available to an authorized representative of the Secretary and representatives of the miners.	Engineering	Preventive	Support design conducted by competent (technically qualified, experienced) personnel, All support designs signed-off by competent (technically qualified, experienced) personnel
		f7	(7) Tensioned roof bolts installed in the roof support pattern shall not be used to anchor trailing cables or used for any other purpose that could affect the tension of the bolt. Hanging trailing cables, line brattice, telephone lines, or other similar devices which do not place sudden loads on the bolts are permitted.	Engineering	Preventive	Accountability under legislation
		f8	(8) Angle compensating devices shall be used to compensate for the angle when tensioned roof bolts are installed at angles greater than 5 degrees from the perpendicular to the bearing plate.	Engineering	Preventive	Accountability under legislation
		g	(g) Non-tensioned grouted roof bolts. The first non-tensioned grouted roof bolt installed during each roof bolting cycle shall be tested during or immediately after the first row of bolts has been installed. If the bolt tested does not withstand at least 150 foot-pounds of torque without rotating in the hole, corrective action shall be taken.	Engineering	Preventive	Verify adequacy of available torque in bolt installation equipment

75.205	Installation of roof support using mining machines with integral roof bolters	a	When roof bolts are installed by a continuous mining machine with integral roof bolting equipment: (a) The distance between roof bolts shall not exceed 10 feet crosswise.	Engineering	Preventive	Develop and/or implement appropriate, reliable and sustainable integrated systems to increase awareness of strata conditions by all personnel (including both strata movement and installed support patterns and timing)
		b	(b) Roof bolts to be installed 9 feet or more apart shall be installed with a wooden crossbar at least 3 inches thick and 8 inches wide, or material which provides equivalent support.	Engineering	Preventive	
		c	(c) Roof bolts to be installed more than 8 feet but less than 9 feet apart shall be installed with a wooden plank at least 2 inches thick and 8 inches wide, or material which provides equivalent support.	Engineering	Preventive	
75.206	Conventional roof support	a	(a) Except in anthracite mines using non-mechanized mining systems, when conventional roof support materials are used as the only means of support—			
		a1	(1) The width of any opening shall not exceed 20 feet;	Engineering	Preventive	Permit to mine system - communication of operational requirements to workforce (e.g. height/width, sequencing and rate, strengths of horizon and roof)
		a2	(2) The spacing of roadway roof support shall not exceed 5 feet;	Engineering	Preventive	
		a3i	(3)(i) Supports shall be installed to within 5 feet of the uncut face;	Engineering	Preventive	
		a3ii	(ii) When supports nearest the face must be removed to facilitate the operation of face equipment, equivalent temporary support shall be installed prior to removing the supports;	Engineering	Preventive	Use of temporary roof support (TRS) or alternatives
		a4	(4) Straight roadways shall not exceed 16 feet wide where full overhead support is used and 14 feet wide where only posts are used;	Engineering	Preventive	Determine appropriate working section and grading requirement - within the
		a5	(5) Curved roadways shall	Engineering	Preventive	

			not exceed 16 feet wide; and			seam
		a6	(6) The roof at the entrance of all openings along travelways which are no longer needed for storing supplies or for travel of equipment shall be supported by extending the line of support across the opening.	Engineering	Preventive	
		b	(b) Conventional roof support materials shall meet the following specifications:	Engineering	Preventive	N/A
		b1	(1) The minimum diameter of cross-sectional area of wooden posts shall be as follows: (See 30 CFR)	Engineering	Preventive	Accountability under legislation
		b2	(2) Wooden materials used for support shall have the following dimensions:			
		b2i	(i) Cap blocks and footings shall have flat sides and be at least 2 inches thick, 4 inches wide and 12 inches long.	Engineering	Preventive	Appropriate selection of fit-for-purpose strata support materials - people and process, Quality assurance/quality control testing to validate materials conform to purchase specifications, mine requirements, relevant standards for materials
		b2ii	(ii) Crossbars shall have a minimum cross-sectional area of 24 square inches and be at least 3 inches thick.	Engineering	Preventive	
		b2iii	(iii) Planks shall be at least 6 inches wide and 1 inch thick.	Engineering	Preventive	
		b3	(3) Cribbing materials shall have at least two parallel flat sides.	Engineering	Preventive	
		c	(c) A cluster of two or more posts that provide equivalent strength may be used to meet the requirements of paragraph (b) (1) of this section, except that no post shall have a diameter less than 4 inches or have a cross-sectional area less than 13 square inches.	Engineering	Preventive	
		d	(d) Materials other than wood used for support shall have support strength at least equivalent to wooden material meeting the applicable provisions of this section.	Engineering	Preventive	
		e	(e) Posts and jacks shall be tightly installed on solid footing.	Engineering	Preventive	

		f	(f) When posts are installed under roof susceptible to sloughing a cap block, plank, crossbar or materials that are equally effective shall be placed between the post and the roof.	Engineering	Preventive	
		g	(g) Blocks used for lagging between the roof and crossbars shall be spaced to distribute the load.	Engineering	Preventive	
		h	(h) Jacks used for roof support shall be used with at least 36 square inches of roof bearing surface.	Engineering	Preventive	
75.207	Pillar recovery	a	Pillar recovery shall be conducted in the following manner, unless otherwise specified in the roof control plan: (a) Full and partial pillar recovery shall not be conducted on the same pillar line, except where physical conditions such as unstable floor or roof, falls of roof, oil and gas well barriers or surface subsidence require that pillars be left in place.	Engineering	Preventive	Extraction sequencing should take account of the location and impact of geological structures
		b	(b) Before mining is started in a pillar split or lift—			
		b1	(1) At least two rows of breaker posts or equivalent support shall be installed—			
		b1i	(i) As close to the initial intended breakline as practicable; and	Engineering	Preventive	Breaker-line support management plan addresses the traversing of geological structures
		b1ii	(ii) Across each opening leading into an area where full or partial pillar extraction has been completed.	Engineering	Preventive	
		b2	(2) A row of roadside-radius (turn) posts or equivalent support shall be installed leading into the split or lift.	Engineering	Preventive	
		c	(c) Before mining is started on a final stump—			
		c1	(1) At least 2 rows of posts or equivalent support shall be installed on not more than 4-foot centers on each side of the roadway; and	Engineering	Preventive	Develop a panel strata hazard plan for secondary extraction

		c2	(2) Only one open roadway, which shall not exceed 16 feet wide, shall lead from solid pillars to the final stump of a pillar. Where posts are used as the sole means of roof support, the width of the roadway shall not exceed 14 feet.	Engineering	Preventive	
		d	(d) During open-end pillar extraction, at least 2 rows of breaker posts or equivalent support shall be installed on not more than 4-foot centers. These supports shall be installed between the lift to be started and the area where pillars have been extracted. These supports shall be maintained to within 7 feet of the face and the width of the roadway shall not exceed 16 feet. Where posts are used as the sole means of roof support, the width of the roadway shall not exceed 14 feet.	Engineering	Preventive	Breaker-line support management plan
75.208	Warning devices	a	Except during the installation of roof supports, the end of permanent roof support shall be posted with a readily visible warning, or a physical barrier shall be installed to impede travel beyond permanent support.	Engineering	Preventive	Confirm suitable level of monitoring to detect change in strata behavior in a timely manner
75.209	Automated temporary roof support (ATRS) systems	a	(a) Except in anthracite mines and as specified in paragraphs (b) and (c) of this section, an ATRS system shall be used with roof bolting machines and continuous-mining machines with integral roof bolters operated in a working section. The requirements of this paragraph shall be met according to the following schedule:	Engineering	Preventive	Use of temporary roof support (TRS) or alternatives
		a1	(1) All new machines ordered after March 28, 1988.	Engineering	Preventive	N/A
		a2	(2) All existing machines operated in mining heights of 36 inches or more after March 28, 1989; and	Engineering	Preventive	N/A

		a3	(3) All existing machines operated in mining heights of 30 inches or more but less than 36 inches after March 28, 1990.	Engineering	Preventive	N/A
		b	(b) After March 28, 1990 the use of ATRS systems with existing roof bolting machines and continuous-mining machines with integral roof bolters operated in a working section where the mining height is less than 30 inches shall be addressed in the roof control plan.	Engineering	Preventive	Use of temporary roof support (TRS) or alternatives
		c	(c) Alternative means of temporary support shall be used, as specified in the roof control plan, when—			
		c1	(1) Mining conditions or circumstances prevent the use of an ATRS system; or	Engineering	Preventive	N/A
		c2	(2) Temporary supports are installed in conjunction with an ATRS system.	Engineering	Preventive	Use of temporary roof support (TRS) or alternatives
		d	(d) Persons shall work or travel between the support device of the ATRS system and another support, and the distance between the support device of the ATRS system and support to the left, right or beyond the ATRS system, shall not exceed 5 feet.	Engineering	Preventive	Accountability under legislation
		e	(e) Each ATRS system shall meet each of the following:			
		e1	(1) The ATRS system shall elastically support a deadweight load measured in pounds of at least 450 times each square foot of roof intended to be supported, but in no case less than 11,250 pounds.	Engineering	Preventive	Use of temporary roof support (TRS) or alternatives, accountability under legislation
		e2	(2) The controls that position and set the ATRS system shall be—			
		e2i	(i) Operable from under permanently supported roof; or	Engineering	Preventive	Use of remote control or automated

		e2ii	(ii) Located in a compartment, which includes a deck, which provides the equipment operator with overhead and lateral protection, and has the structural capacity to elastically support a deadweight load of at least 18,000 pounds.	Engineering	Preventive	mining methods
		e3	(3) All jacks affecting the capacity of the ATRS system and compartment shall have check valves or equivalent devices that will prevent rapid collapse in the event of a system failure.	Engineering	Preventive	
		e4	(4) Except for the main tram controls, tram controls for positioning the equipment to set the ATRS system shall limit the speed of the equipment to a maximum of 80 feet-per-minute.	Engineering	Preventive	
		f	(f) The support capacity of each ATRS system and the structural capacity of each compartment shall be certified by a registered engineer as meeting the applicable requirements of paragraphs (e)(1) and (e)(2) of this section. The certifications shall be made available to an authorized representative of the Secretary and representative of the miners.	Engineering	Preventive	Support design conducted by competent (technically qualified, experienced) personnel, Support design independently reviewed by competent (technically qualified, experienced) personnel (i.e. peer review), All support designs signed-off by competent (technically qualified, experienced) personnel
75.210	Manual installation of temporary support	a	(a) When manually installing temporary support, only persons engaged in installing the support shall proceed beyond permanent support.	Engineering	Preventive	
		b	(b) When manually installing temporary supports, the first temporary support shall be set no more than 5 feet from a permanent roof support and the rib. All temporary supports shall be set so that the person installing the supports remains between the temporary support being set and two other supports	Engineering	Preventive	

			which shall be no more than 5 feet from the support being installed. Each temporary support shall be completely installed prior to installing the next temporary support.			
		c	(c) All temporary supports shall be placed on no more than 5-foot centers.	Engineering	Preventive	Accountability under legislation, No-go zones for unsupported ground (e.g. place changing with narrow head miner)
		d	(d) Once temporary supports have been installed, work or travel beyond permanent roof support shall be done between temporary supports and the nearest permanent support or between other temporary supports.	Engineering	Preventive	
75.211	Roof testing and scaling	a	(a) A visual examination of the roof, face and ribs shall be made immediately before any work is started in an area and thereafter as conditions warrant.	Engineering	Preventive	
		b	(b) Where the mining height permits and the visual examination does not disclose a hazardous condition, sound and vibration roof tests, or other equivalent tests, shall be made where supports are to be installed. When sound and vibration tests are made, they shall be conducted—	Engineering	Preventive	
		b1	(1) After the ATRS system is set against the roof and before other support is installed; or	Engineering	Preventive	
		b2	(2) prior to manually installing a roof support. This test shall begin under supported roof and progress no further than the location where the next support is to be installed.	Engineering	Preventive	

		c	(c) When a hazardous roof, face, or rib condition is detected, the condition shall be corrected before there is any other work or travel in the affected area. If the affected area is left unattended, each entrance to the area shall be posted with a readily visible warning, or a physical barrier shall be installed to impede travel into the area.	Engineering	Preventive	
		d	(d) A bar for taking down loose material shall be available in the working place or on all face equipment except haulage equipment. Bars provided for taking down loose material shall be of a length and design that will allow the removal of loose material from a position that will not expose the person performing this work to injury from falling material.	Engineering	Mitigating	
75.212	Rehabilitation of areas with unsupported roof	a	(a) Before rehabilitating each area where a roof fall has occurred or the roof has been removed by mining machines or by blasting—			
		a1	(1) The mine operator shall establish the cleanup and support procedures that will be followed;	Engineering	Preventive	Adhere to the development roadway TARP based on monitoring data and visual inspections; that defines anomalous behavior and associated corrective actions, Mine emergency plan (including mine egress procedures, communication methods, etc.), Initial response to roadway/development fall,
		a2	(2) All persons assigned to perform rehabilitation work shall be instructed in the clean-up and support procedures; and	Administrative	Preventive	
		a3	(3) Ineffective, damaged or missing roof support at the edge of the area to be rehabilitated shall be replaced or other equivalent support installed.	Engineering	Preventive	
		b	(b) All persons who perform rehabilitation work shall be experienced in this work or they shall be supervised by a person experienced in rehabilitation work who is designated by the mine operator.	Administrative	Preventive	

		c	(c) Where work is not being performed to rehabilitate an area in active workings where a roof fall has occurred or the roof has been removed by mining machines or by blasting, each entrance to the area shall be supported by at least one row of posts on not more than 5-foot centers, or equally effective support.	Engineering	Preventive	Characterization of the roadway fall structural and geotechnical domain, Develop a specific recovery/support plan for area based on a risk assessment, Adhere to statutory requirement that strata support materials are available prior to commencement of mining
75.213	Roof support removal	a1	(a)(1) All persons who perform the work of removing permanent roof supports shall be supervised by a management person experienced in removing roof supports.	Administrative	Preventive	
		a2	(2) Only persons with at least one year of underground mining experience shall perform permanent roof support removal work.	Administrative	Preventive	
		b	(b) Prior to the removal of permanent roof supports, the person supervising roof support removal in accordance with paragraph (a)(1) of this section shall examine the roof conditions in the area where the supports are to be removed and designate each support to be removed.	Engineering	Preventive	
		c1	(c)(1) Except as provided in paragraph (g) of this section, prior to the removal of permanent supports, a row of temporary supports on no more than 5-foot centers or equivalent support shall be installed across the opening within 4 feet of the supports being removed. Additional supports shall be installed where necessary to assure safe removal.	Engineering	Preventive	
		c2	(2) Prior to the removal of roof bolts, temporary support shall be installed as close as practicable to each roof bolt being removed.	Engineering	Preventive	

		d	(d) Temporary supports installed in accordance with this section shall not be removed unless—			
		d1	(1) Removal is done by persons who are in a remote location under supported roof; and	Engineering	Preventive	Separate people from unsupported roof
		d2	(2) At least two rows of temporary supports, set across the opening on no more than 5-foot centers, are maintained between the miners and the unsupported area.	Engineering	Preventive	Use of temporary roof support (TRS) or alternatives
		e	(e) Each entrance to an area where supports have been removed shall be posted with a readily visible warning or a physical barrier shall be installed to impede travel into the area.	Engineering	Preventive	Training and awareness of safe operating procedures - communication of hazards and awareness to workforce
		f	(f) Except as provided in paragraph (g) of this section, permanent support shall not be removed where—			
		f1	(1) Roof bolt torque or tension measurements or the condition of conventional support indicate excessive loading;	Engineering	Preventive	Training, competencies, assessment and review of operators with respect to standards, management plans and awareness of strata control factors
		f2	(2) Roof fractures are present;	Engineering	Preventive	
		f3	(3) There is any other indication that the roof is structurally weak; or	Engineering	Preventive	
		f4	(4) Pillar recovery has been conducted.	Engineering	Preventive	
		g	(g) Permanent supports may be removed provided that:			
		g1	(1) Removal is done by persons who are in a remote location under supported roof; and	Engineering	Preventive	
		g2	(2) At least two rows of temporary supports, set across the opening on no more than 5-foot centers, are maintained between the miners and the unsupported area.	Engineering	Preventive	

		h	(h) The provisions of this section do not apply to removal of conventional supports for starting crosscuts and pillar splits or lifts except that prior to the removal of these supports an examination of the roof conditions shall be made.	Engineering	Preventive	
75.214	Supplemental support materials, equipment, and tools	a	(a) A supply of supplementary roof support materials and the tools and equipment necessary to install the materials shall be available at a readily accessible location on each working section or within four crosscuts of each working section.	[redacted]		
		b	(b) The quantity of support materials and tools and equipment maintained available in accordance with this section shall be sufficient to support the roof if adverse roof conditions are encountered, or in the event of an accident involving a fall.	Administrative	Preventive	Consider the changing stress environment (e.g. gate ends, intersections, niche, stubs - include secondary supports to address longwall stress changes, gate road pillar design)
75.215	Longwall mining systems	a	For each longwall mining section, the roof control plan shall specify— (a) The methods that will be used to maintain a safe travelway out of the section through the tailgate side of the longwall; and	Engineering	Preventive	Confirm support is adequate to prevent excessive convergence due to longwall abutment load (especially consider length and width of stub) and is compatible with shearer cutting regime
		b	(b) The procedures that will be followed if a ground failure prevents travel out of the section through the tailgate side of the longwall.	Engineering	Mitigating	Fall recovery plan, remedial action plan and development roadway and face

						stabilization plan
75.22	Roof Control Plan	a1	(a)(1) Each mine operator shall develop and follow a roof control plan, approved by the District Manager that is suitable to the prevailing geological conditions, and the mining system to be used at the mine. Additional measures shall be taken to protect persons if unusual hazards are encountered.	Engineering	Preventive	
		a2	(2) The proposed roof control plan and any revisions to the plan shall be submitted, in writing, to the District Manager. When revisions to a roof control plan are proposed, only the revised pages need to be submitted unless otherwise specified by the District Manager.	Administrative	Preventive	Accountability under legislation, Consult available technical literature, code of practice
		b1	(b)(1) The mine operator will be notified in writing of the approval or denial of approval of a proposed roof control plan or proposed revision.	Administrative	Preventive	
		b2	(2) When approval of a proposed plan or revision is denied, the deficiencies of the plan or revision and recommended changes will be specified and the mine operator will be afforded an opportunity to discuss the deficiencies and changes with the District Manager.	Administrative	Preventive	
		b3	(3) Before new support materials, devices, or systems other than roof bolts and accessories, are used as the only means of roof support, the District Manager may require that their effectiveness be demonstrated by experimental installations.	Engineering	Preventive	Consult available technical literature, code of practice (e.g. Safe Work Australia's Strata Control in Underground Mines Code of Practice, 2013, version 4)
		c	(c) No proposed roof control plan or revision to	Administrative	Preventive	

			a roof control plan shall be implemented before it is approved.			
		d	(d) Before implementing an approved revision to a roof control plan, all persons who are affected by the revision shall be instructed in its provisions.	Administrative	Preventive	Communicate change management outcomes to workforce and raise awareness of the impact of changes in support materials
		e	(e) The approved roof control plan and any revisions shall be available to the miners and representative of miners at the mine.	Administrative	Preventive	
75.221	Roof control plan information	a	(a) The following information shall be included in each roof control plan:			
		a1	(1) The name and address of the company.	Administrative	Preventive	Accountability under legislation, Awareness of legislation concerning deviant behavior in underground mines (e.g. person working underneath an unsupported roof, contraband in underground mines, fitness-for-work), Corporate audits to establish compliance with company standards and procedures, Obtain additional lithological information, geotechnical testing (e.g. core sample - series of tests), hydrological models and data interpretation, Develop a
		a2	(2) The name, address, mine identification number and location of the mine.	Administrative	Preventive	
		a3	(3) The name and title of the company official responsible for the plan.	Administrative	Preventive	
		a4	(4) A typical columnar section of the mine strata which shall—			
		a4i	(i) Show the name and the thickness of the coalbed to be mined and any persistent partings;	Engineering	Preventive	
		a4ii	(ii) Identify the type and show the thickness of each stratum up to and including the main roof above the coalbed and for distance of at least 10 feet below the coalbed; and	Engineering	Preventive	
		a4iii	(iii) Indicate the maximum cover over the area to be mined.	Engineering	Preventive	
		a5	(5) A description and drawings of the sequence of installation and spacing of supports for each method of mining used.	Engineering	Preventive	
		a6	(6) When an ATRS system is used, the maximum distance that an ATRS system is to be set beyond the last row of permanent support.	Engineering	Preventive	
		a7	(7) When tunnel liners or arches are to be used for roof support, specifications and installation procedures for the liners or arches.	Engineering	Preventive	

		a8	(8) Drawings indicating the planned width of openings, size of pillars, method of pillar recovery, and the sequence of mining pillars.	Engineering	Preventive	geotechnical model that collates all available data to establish a regional Characterization that includes the review of disparate data points
		a9	(9) A list of all support materials required to be used in the roof, face and rib control system, including, if roof bolts are to be installed—	Engineering	Preventive	
		a9i	(i) The length, diameter, grade and type of anchorage unit to be used;	Engineering	Preventive	
		a9ii	(ii) The drill hole size to be used; and	Engineering	Preventive	
		a9iii	(iii) The installed torque or tension range for tensioned roof bolts.	Engineering	Preventive	
		a10	(10) When mechanically anchored tensioned roof bolts are used, the intervals at which test holes will be drilled.	Engineering	Preventive	
		a11	(11) A description of the method of protecting persons—			
		a11i	(i) From falling material at drift openings; and	Engineering	Preventive	
		a11ii	(ii) When mining approaches within 150 feet of an outcrop.	Engineering	Preventive	
		a12	(12) A description of the roof and rib support necessary for the refuge alternatives.	Engineering	Preventive	
		b	(b) Each drawing submitted with a roof control plan shall contain a legend explaining all symbols used and shall specify the scale of the drawing which shall not be less than 5 feet to the inch or more than 20 feet to the inch.	Engineering	Preventive	
		c	(c) All roof control plan information, including drawings, shall be submitted on 8 1⁄2 by 11 inch paper, or paper folded to this size.	Administrative	Preventive	

75.222	Roof control plan-approval criteria	a	(a) This section sets forth the criteria that shall be considered on a mine-by-mine basis in the formulation and approval of roof control plans and revisions. Additional measures may be required in plans by the District Manager. Roof control plans that do not conform to the applicable criteria in this section may be approved by the District Manager, provided that effective control of the roof, face and ribs can be maintained.			
		b	(b) Roof Bolting.			
		b1	(1) Roof bolts should be installed on centers not exceeding 5 feet lengthwise and crosswise, except as specified in § 75.205.	Engineering	Preventive	Cutting and bolting equipment suitability for given conditions and support requirements design, Timing of installation of roof and cable bolt support - integrate with driving sequence, Check or test (conducted by supplier or mine company) that components meet specification (e.g. stress strain graph for each batch of bolts, resin viscosity for hole size), etc.
		b2	(2) When tensioned roof bolts are used as a means of roof support, the torque or tension range should be capable of supporting roof bolt loads of at least 50 percent of either the yield point of the bolt or anchorage capacity of the strata, whichever is less.	Engineering	Preventive	
		b3	(3) Any opening that is more than 20 feet wide should be supported by a combination of roof bolts and conventional supports.	Engineering	Preventive	
		b4	(4) In any opening more than 20 feet wide—	Engineering	Preventive	
		b4i	(i) Posts should be installed to limit each roadway to 16 feet wide where straight and 18 feet wide where curved; and	Engineering	Preventive	
		b4ii	(ii) A row of posts should be set for each 5 feet of space between the roadway posts and the ribs.	Engineering	Preventive	
		b5	(5) Openings should not be more than 30 feet wide.	Engineering	Preventive	
		c	(c) Installation of roof support using mining machines with integral roof bolters.	Engineering	Preventive	

		c1	(1) Before an intersection or pillar split is started, roof bolts should be installed on at least 5-foot centers where the work is performed.	Engineering	Preventive	
		c2	(2) Where the roof is supported by only two roof bolts crosswise, openings should not be more than 16 feet wide.	Engineering	Preventive	
		d	(d) Pillar recovery.			
		d1	(1) During development, any dimension of a pillar should be at least 20 feet.	Engineering	Preventive	Accountability under legislation, Width of extraction panel to prevent failure of massive units (sub critical) (new panel - reduce panel width; old panel - leave additional pillars)
		d2	(2) Pillar splits and lifts should not be more than 20 feet wide.	Engineering	Preventive	
		d3	(3) Breaker posts should be installed on not more than 4-foot centers.	Engineering	Preventive	
		d4	(4) Roadside-radius (turn) posts, or equivalent support, should be installed on not more than 4-foot centers leading into each pillar split or lift.	Engineering	Preventive	
		d5	(5) Before full pillar recovery is started in areas where roof bolts are used as the only means of roof support and openings are more than 16 feet wide, at least one row of posts should be installed to limit the roadway width to 16 feet. These posts should be—	Engineering	Preventive	
		d5i	(i) Extended from the entrance to the split through the intersection outby the pillar in which the split or lift is being made; and	Engineering	Preventive	
		d5ii	(ii) Spaced on not more than 5-foot centers.	Engineering	Preventive	
		e	(e) Unsupported openings at intersections. Openings that create an intersection should be permanently supported or at least one row of temporary supports should be installed on not more than 5-foot centers across the opening before any other work or travel in the intersection.	Engineering	Preventive	

		f	(f) ATRS systems in working sections where the mining height is below 30 inches. In working sections where the mining height is below 30 inches, an ATRS system should be used to the extent practicable during the installation of roof bolts with roof bolting machines and continuous-mining machines with integral roof bolters.	Engineering	Preventive	
		g	(g) Longwall mining systems.			
		g1	(1) Systematic supplemental support should be installed throughout—	Engineering	Preventive	N/A
		g1i	(i) The tailgate entry of the first longwall panel prior to any mining; and	Engineering	Preventive	Determine best method/strategy for safe recovery of fall, including selection of support and remedial methods (e.g. polyurethane resin - PUR, spiling, chemical cavity fillers, injection, grout, roof bolts, face take-off)
		g1ii	(ii) In the proposed tailgate entry of each subsequent panel in advance of the frontal abutment stresses of the panel being mined.	Engineering	Preventive	
		g2	(2) When a ground failure prevents travel out of the section through the tailgate side of the longwall section, the roof control plan should address—	Engineering	Preventive	
		g2i	(i) Notification of miners that the travelway is blocked;	Engineering	Preventive	Deputy to inspect fall, initiate trigger action response plan (TARP) and prevent personnel entry
		g2ii	(ii) Re-instruction of miners regarding escapeways and escape procedures in the event of an emergency;	Administrative	Preventive	Competencies (e.g. QLD: Black Coal Competency) required for underground operators
		g2iii	(iii) Re-instruction of miners on the availability and use of self-contained self-rescue devices;	Administrative	Preventive	Appropriate training in collection/operation of data

		g2iv	(iv) Monitoring and evaluation of the air entering the longwall section;	Engineering	Preventive	collection systems (e.g. interpretation, integration and communication of monitoring data - including leg pressures, convergence, face position, gate end roof movement)
		g2v	(v) Location and effectiveness of the two-way communication systems; and	Engineering	Preventive	
		gtvi	(vi) A means of transportation from the section to the main line.	Engineering	Preventive	Face gate transitions - consider snake distance, changes in horizon between longwall face and gate roads, minimising damage to standing support in tailgate, operation of anti-topple system
		g3	(3) The plan provisions addressed by paragraph (g) (2) of this section should remain in effect until a travelway is reestablished on the tailgate side of a longwall section.	Engineering	Preventive	
75.223	Evaluation and revision of roof control plan	a	(a) Revisions of the roof control plan shall be proposed by the operator—			
		a1	(1) When conditions indicate that the plan is not suitable for controlling the roof, face, ribs, or coal or rock bursts; or	Engineering	Preventive	Roadway dimensions (width, height) to consider the bump potential at the roof, face, ribs and floor (including cut-out distances relative to rib support installation)
		a2	(2) When accident and injury experience at the mine indicates the plan is inadequate. The accident and injury experience at each mine shall be reviewed at least every six months.	Engineering	Preventive	Conducted by incident management team/senior management team with appropriate technical experts (e.g. mine manager,

						cross section of workforce, geotechnical expert)
		b	(b) Each unplanned roof fall and rib fall and coal or rock burst that occurs in the active workings shall be plotted on a mine map if it—	Engineering	Preventive	Review stress environment and depth of cover measured stress data; map condition of roadways to evaluate the stress orientation
		b1	(1) Is above the anchorage zone where roof bolts are used;	Engineering	Preventive	
		b2	(2) Impairs ventilation;	Engineering	Preventive	
		b3	(3) Impedes passage of persons;	Engineering	Preventive	
		b4	(4) Causes miners to be withdrawn from the area affected; or	Engineering	Preventive	
		b5	(5) Disrupts regular mining activities for more than one hour.	Engineering	Preventive	
		c	(c) The mine map on which roof falls are plotted shall be available at the mine site for inspection by authorized representatives of the Secretary and representatives of miners at the mine.	Administrative	Preventive	Develop and/or implement appropriate, reliable and sustainable integrated systems to increase awareness of strata conditions by all personnel (including both strata movement and installed support patterns and timing)
		d	(d) The roof control plan for each mine shall be reviewed every six months by an authorized representative of the Secretary. This review shall take into consideration any falls of the roof, face and ribs and the adequacy of the support systems used at the time.	Administrative	Preventive	Support design independently reviewed by competent (technically qualified, experienced) personnel (i.e. peer review)

Table B.2 – Categorization of "30 CFR 75 Subpart D – Ventilation" provisions as RISKGATE controls

Section	Subject	Sub-section	Provisions	Engineering or Administrative Control	Preventive or Mitigating Control	RISKGATE Control
75.302	Main mine fans	a	Each coal mine shall be ventilated by one or more main mine fans. Booster fans shall not be installed underground to assist main mine fans except in anthracite mines. In anthracite mines, booster fans installed in the main air current or a split of the main air current may be used provided their use is approved in the ventilation plan.	Engineering	Preventive	Develop ability to control ventilation systems as required in the event of a fire (e.g. consider variable fan speed, reverse airflow direction)
75.310	Installation of main mine fans	a	(a) Each main mine fan shall be—	Engineering	Preventive	N/A
		a1	(1) Installed on the surface in an incombustible housing;	Engineering	Preventive	Develop ability to control ventilation systems as required in the event of a fire (e.g. consider variable fan speed, reverse airflow direction)
		a2	(2) Connected to the mine opening with incombustible air ducts;	Engineering	Preventive	
		a3	(3) Equipped with an automatic device that gives a signal at the mine when the fan either slows or stops. A responsible person designated by the operator shall always be at a surface location at the mine where the signal can be seen or heard while anyone is underground. This person shall be provided with two-way communication with the working sections and work stations where persons are routinely assigned to work for the majority of a shift;	Engineering	Preventive	Train personnel with respect to operation, maintenance, inspection/readiness of reticulation systems, gas docking stations, access points for safe delivery of inertization materials to the areas required (e.g. confirm functionality and readiness of gas generating unit/boilers)

		a4	(4) Equipped with a pressure recording device or system. Mines permitted to shut down main mine fans under § 75.311 and which do not have a pressure recording device installed on main mine fans shall have until June 10, 1997 to install a pressure recording device or system on all main mine fans. If a device or system other than a circular pressure recorder is used to monitor main mine fan pressure, the monitoring device or system shall provide a continuous graph or continuous chart of the pressure as a function of time. At not more than 7-day intervals, a hard copy of the continuous graph or chart shall be generated or the record of the fan pressure shall be stored electronically. When records of fan pressure are stored electronically, the system used to store these records shall be secure and not susceptible to alteration and shall be capable of storing the required data. Records of the fan pressure shall be retained at a surface location at the mine for at least 1 year and be made available for inspection by authorized representatives of the Secretary and the representative of miners;	Engineering	Preventive	N/A
		a5	(5) Protected by one or more weak walls or explosion doors, or a combination of weak walls and explosion doors, located in direct line with possible explosive forces;	Engineering	Preventive	Seals, stoppings and ventilation control device (VCD) design
		a6	(6) Except as provided under paragraph (e) of this section, offset by at least 15 feet from the nearest side of the mine opening unless an alternative method of protecting the fan and its associated components is	Engineering	Preventive	N/A

			approved in the ventilation plan.			
		b1	(b)(1) If an electric motor is used to drive a main mine fan, the motor shall operate from a power circuit independent of all mine power circuits.	Engineering	Preventive	Confirm installation category rating (e.g. AS 61010.1 2003 Safety requirements for electrical equipment for measurement, control and laboratory use, Part 1: General requirements, Section 6.7.4: Measuring circuits)
		b2	(2) If an internal combustion engine is used to drive a main mine fan—	Engineering	Preventive	N/A
		b2i	(i) The fuel supply shall be protected against fires and explosions;	Engineering	Preventive	N/A
		b2ii	(ii) The engine shall be installed in an incombustible housing and be equipped with a remote shut-down device;	Engineering	Preventive	Develop and use detailed commissioning sheets (e.g. inspection and test plans) that confirm that isolation device/procedures, labelling, guarding, barriers and interlocks are installed correctly and functional
		b2iii	(iii) The engine and the engine exhaust system shall be located out of direct line of the air current exhausting from the mine; and	Engineering	Preventive	
		b2iv	(iv) The engine exhaust shall be vented to the atmosphere so that the exhaust gases do not contaminate the mine intake air current or any enclosure.	Engineering	Preventive	
		c	(c) If a main mine fan monitoring system is used under § 75.312, the system shall—	Engineering	Preventive	
		c1	(1) Record, as described in paragraph (a) (4) the mine ventilating pressure;	Engineering	Preventive	Monitoring systems to confirm the quality of ventilation (e.g. measure potential for gas build-up: real time, gas

						monitoring and pressure)
		c2	(2) Monitor bearing temperature, revolutions per minute, vibration, electric voltage, and amperage;	Engineering	Preventive	Accountability under legislation
		c3	(3) Provide a printout of the monitored parameters, including the mine ventilating pressure within a reasonable period, not to exceed the end of the next scheduled shift during which miners are underground; and	Engineering	Preventive	
		c4	(4) Be equipped with an automatic device that signals when—	Engineering	Preventive	
		c4i	(i) An electrical or mechanical deficiency exists in the monitoring system; or	Engineering	Preventive	Monitoring systems to confirm the quality of ventilation (e.g. measure potential for gas build-up: real time, gas monitoring and pressure)
		c4ii	(ii) A sudden increase or loss in mine ventilating pressure occurs.	Engineering	Preventive	
		c5	(5) Provide monitoring, records, printouts, and signals required by paragraphs (c) (1) through (c) (4) at a surface location at the mine where a responsible person designated by the operator is always on duty and where signals from the monitoring system can be seen or heard while anyone is underground. This person shall be provided with two-way communication with the working sections and work stations where persons are routinely assigned to work for the majority of a shift.	Engineering	Preventive	
		d	(d) Weak walls and explosion doors shall have cross-sectional areas at least equal to that of the entry through which the pressure from an explosion underground would be relieved. A weak wall and explosion door combination shall have a	Engineering	Preventive	Seals, stoppings and ventilation control device (VCD) design

			total cross-sectional area at least equal to that of the entry through which the pressure from an explosion underground would be relieved.			
		e	(e) If a mine fan is installed in line with an entry, a slope, or a shaft—	Engineering	Preventive	Confirm ventilation system mitigates dead spots or potential areas of gas accumulation (e.g. inspection, modelling, dead spots resulting from multiple fans or multiple shafts)
		e1	(1) The cross-sectional area of the pressure relief entry shall be at least equal to that of the fan entry;	Engineering	Preventive	
		e2	(2) The fan entry shall be developed out of direct line with possible explosive forces;	Engineering	Preventive	
		e3	(3) The coal or other solid material between the pressure relief entry and the fan entry shall be at least 2,500 square feet; and	Engineering	Preventive	
		e4	(4) The surface opening of the pressure relief entry shall be not less than 15 feet nor more than 100 feet from the surface opening of the fan entry and from the underground intersection of the fan entry and pressure relief entry.	Engineering	Preventive	
		f	(f) In mines ventilated by multiple main mine fans, incombustible doors shall be installed so that if any main mine fan stops and air reversals through the fan are possible, the doors on the affected fan automatically close.	Engineering	Preventive	Accountability under legislation
75.311	Mine main fan operation	a	(a) Main mine fans shall be continuously operated, except as otherwise approved in the ventilation plan, or when intentionally stopped for testing of automatic closing doors and automatic fan signal devices, maintenance or adjustment of the fan, or to perform maintenance or repair work underground that cannot otherwise be made while the fan is operating.	Engineering	Preventive	Use equipment with alarms or engineered plant isolation controls that alert or prevent inappropriate equipment in a specific location (e.g. auto shutdown on fire protected vehicles

						moving beyond Negligible Explosion Risk Zone (NERZ))
		b	(b) Except as provided in paragraph (c) of this section, when a main mine fan is intentionally stopped and the ventilating quantity provided by the fan is not maintained by a back-up fan system—	Engineering	Preventive	N/A
		b1	(1) Only persons necessary to evaluate the effect of the fan stoppage or restart, or to perform maintenance or repair work that cannot otherwise be made while the fan is operating, shall be permitted underground;	Administrative	Preventive	Confirm that hot work is solely conducted by competent and authorized operators
		b2	(2) Mechanized equipment shall be shut off before stopping the fan; and	Administrative	Preventive	Accountability under legislation
		b3	(3) Electric power circuits entering underground areas of the mine shall be deenergized.	Engineering	Preventive	Remove batteries and/or disable generators and uninterruptable power supply (UPS) as they are a means of back feed (alternate power supply)
		c	(c) When a back-up fan system is used that does not provide the ventilating quantity provided by the main mine fan, persons may be permitted in the mine and electric power circuits may be energized as specified in the approved ventilation plan.	Engineering	Preventive	N/A

		d	(d) If an unusual variance in the mine ventilation pressure is observed, or if an electrical or mechanical deficiency of a main mine fan is detected, the mine foreman or equivalent mine official, or in the absence of the mine foreman or equivalent mine official, a designated certified person acting for the mine foreman or equivalent mine official shall be notified immediately, and appropriate action or repairs shall be instituted promptly.	Engineering	Preventive	Develop ability to control ventilation systems as required in the event of a fire (e.g. consider variable fan speed, reverse airflow direction)
		e	(e) While persons are underground, a responsible person designated by the operator shall always be at a surface location where each main mine fan signal can be seen or heard.	Administrative	Preventive	Confirm appropriate personnel are trained and competent with respect to mine re-entry plans, systems and capability, External personnel to be familiar with site emergency locations, communication protocols, procedures
		f	(f) The area within 100 feet of main mine fans and intake air openings shall be kept free of combustible material, unless alternative precautions necessary to provide protection from fire or other products of combustion are approved in the ventilation plan.	Engineering	Preventive / Mitigating	Confirm ventilation system mitigates dead spots or potential areas of gas accumulation (e.g. inspection, modelling, dead spots resulting from multiple fans or multiple shafts)
		g	(g) If multiple mine fans are used, the mine ventilation system shall be designed and maintained to eliminate areas without air movement.	Engineering	Preventive	
		h	(h) Any atmospheric monitoring system operated during fan stoppages shall be intrinsically safe.	Engineering	Preventive	

75.312	Main mine fan examination and records	a	(a) To assure electrical and mechanical reliability of main mine fans, each main mine fan and its associated components, including devices for measuring or recording mine ventilation pressure, shall be examined for proper operation by a trained person designated by the operator. Examinations of main mine fans shall be made at least once each day that the fan operates, unless a fan monitoring system is used. No examination is required on any day when no one, including certified persons, goes underground, except that an examination shall be completed prior to anyone entering the mine.	Engineering	Preventive	Design of adequate ventilation (e.g. monitor and manage methane accumulation, manage dust level - scrubber fans, venturis)
		b1	(b)(1) If a main mine fan monitoring system is used, a trained person designated by the operator shall—	Administrative	Preventive	Understanding site-based standards for inspecting, sampling and testing the integrity of seals, stoppings, VCDs and environment
		b1i	(i) At least once each day review the data provided by the fan monitoring system to assure that the fan and the fan monitoring system are operating properly. No review is required on any day when no one, including certified persons, goes underground, except that a review of the data shall be performed prior to anyone entering the underground portion of the mine. Data reviewed should include the fan pressure, bearing temperature, revolutions per minute, vibration, electric voltage, and amperage; and	Administrative	Preventive	
		b1ii	(ii) At least every 7 days—	Administrative		
		b1iiA	(A) Test the monitoring system for proper operation; and	Engineering	Preventive	
		b1iiB	(B) Examine each main mine fan and its associated components to assure electrical and	Engineering	Preventive	

			mechanical reliability of main mine fans.			
		b2	(2) If the monitoring system malfunctions, the malfunction shall be corrected, or paragraph (a) of this section shall apply.	Engineering	Preventive	
		c	(c) At least every 31 days, the automatic fan signal device for each main mine fan shall be tested by stopping the fan. Only persons necessary to evaluate the effect of the fan stoppage or restart, or to perform maintenance or repair work that cannot otherwise be made while the fan is operating, shall be permitted underground. Notwithstanding the requirement of § 75.311 (b) (3), underground power may remain energized during this test provided no one, including persons identified in § 75.311 (b) (1), is underground. If the fan is not restarted within 15 minutes, underground power shall be deenergized and no one shall enter any underground area of the mine until the fan is restarted and an examination of the mine is conducted as described in § 75.360 (b) through (e) and the mine has been determined to be safe.	Engineering	Preventive	

		d	(d) At least every 31 days, the automatic closing doors in multiple main mine fan systems shall be tested by stopping the fan. Only persons necessary to evaluate the effect of the fan stoppage or restart, or to perform maintenance or repair work that cannot otherwise be made while the fan is operating, shall be permitted underground. Notwithstanding the provisions of § 75.311, underground power may remain energized during this test provided no one, including persons identified in § 75.311 (b)(1), is underground. If the fan is not restarted within 15 minutes, underground power shall be deenergized and no one shall enter any underground area of the mine, until the fan is restarted and an examination of the mine is conducted as described in § 75.360 (b) through (e) and the mine has been determined to be safe.	Engineering	Preventive	
		e	(e) Circular main mine fan pressure recording charts shall be changed before the beginning of a second revolution.	Engineering	Preventive	
		f1	(f)(1) Certification. Persons making main mine fan examinations shall certify by initials and date at the fan or another location specified by the operator that the examinations were made. Each certification shall identify the main mine fan examined.	Administrative	Preventive	Accountability under legislation
		f2	(2) Persons reviewing data produced by a main mine fan monitoring system shall certify by initials and date on a printed copy of the data from the system that the review was completed. In lieu of certification on a copy of the data, the person reviewing the data	Administrative	Preventive	

			may certify electronically that the review was completed. Electronic certification shall be by handwritten initials and date in a computer system so as to be secure and not susceptible to alteration.			
		g1	(g)(1) Recordkeeping. By the end of the shift on which the examination is made, persons making main mine fan examinations shall record all uncorrected defects that may affect the operation of the fan that are not corrected by the end of that shift. Records shall be maintained in a secure book that is not susceptible to alteration or electronically in a computer system so as to be secure and not susceptible to alteration.	Administrative	Preventive	Accountability under legislation
		g2	(2) When a fan monitoring system is used in lieu of the daily fan examination—	Engineering	Preventive	
		g2i	(i) The certified copies of data produced by fan monitoring systems shall be maintained separate from other computer-generated reports or data; and	Administrative	Preventive	
		g2ii	(ii) A record shall be made of any fan monitoring system malfunctions, electrical or mechanical deficiencies in the monitoring system and any sudden increase or loss in mine ventilating pressure. The record shall be made by the end of the shift on which the review of the data is completed and shall be maintained in a secure book that is not susceptible to alteration or electronically in a computer system so as to be secure and not susceptible to alteration.	Administrative	Preventive	

		g3	(3) By the end of the shift on which the monthly test of the automatic fan signal device or the automatic closing doors is completed, persons making these tests shall record the results of the tests. Records shall be maintained in a secure book that is not susceptible to alteration or electronically in a computer system so as to be secure and not susceptible to alteration.	Administrative	Preventive	
		h	(h) Retention period. Records, including records of mine fan pressure and the certified copies of data produced by fan monitoring systems, shall be retained at a surface location at the mine for at least 1 year and shall be made available for inspection by authorized representatives of the Secretary and the representative of miners.	Administrative	Preventive	
75.313	Main mine fan stoppage with persons underground	a	(a) If a main mine fan stops while anyone is underground and the ventilating quantity provided by the fan is not maintained by a back-up fan system—	Engineering	Preventive	Design and implementation of effective methods for emergency sealing of the mine or parts of the mine (e.g. portals, panels, fan)
		a1	(1) Electrically powered equipment in each working section shall be deenergized;	Engineering	Preventive	
		a2	(2) Other mechanized equipment in each working section shall be shut off; and	Engineering	Preventive	
		a3	(3) Everyone shall be withdrawn from the working sections and areas where mechanized mining equipment is being installed or removed.	Administrative	Mitigating	Instigate training in competencies for fire fighting, evacuation procedures and the use of Self Contained Self Rescuers (SCSR)

		b	(b) If ventilation is restored within 15 minutes after a main mine fan stops, certified persons shall examine for methane in the working places and in other areas where methane is likely to accumulate before work is resumed and before equipment is energized or restarted in these areas.	Engineering		Undertake an initial risk assessment to identify hazards and scenarios associated with potential mine fires or explosions including the potential risks associated with mine evacuation
		c	(c) If ventilation is not restored within 15 minutes after a main mine fan stops—	Engineering	Preventive	
		c1	(1) Everyone shall be withdrawn from the mine;	Engineering	Mitigating	
		c2	(2) Underground electric power circuits shall be deenergized. However, circuits necessary to withdraw persons from the mine need not be deenergized if located in areas or haulageways where methane is not likely to migrate to or accumulate. These circuits shall be deenergized as persons are withdrawn; and	Engineering	Preventive	Correct testing procedure - prove verification device before and after isolation (e.g. check indicator, isolate and dissipate stored energy, check indicator, re-energise, check indicator, repeat)
		c3	(3) Mechanized equipment not located on working sections shall be shut off. However, mechanized equipment necessary to withdraw persons from the mine need not be shut off if located in areas where methane is not likely to migrate to or accumulate.	Engineering	Preventive	
		d1	(d)(1) When ventilation is restored—			
		d1i	(i) No one other than designated certified examiners shall enter any underground area of the mine until an examination is conducted as described in § 75.360 (b) through (e) and the area has been determined to be safe. Designated certified examiners shall enter the underground area of the mine from which miners have been withdrawn only after the fan has operated for at least 15 minutes	Administrative	Preventive	Confirm appropriate personnel are trained and competent with respect to mine re-entry plans, systems and capability

			unless a longer period of time is specified in the approved ventilation plan.			
		d1ii	(ii) Underground power circuits shall not be energized and nonpermissible mechanized equipment shall not be started or operated in an area until an examination is conducted as described in § 75.360 (b) through (e) and the area has been determined to be safe, except that designated certified examiners may use nonpermissible transportation equipment in intake airways to facilitate the making of the required examination.	Engineering	Mitigating	
		d2	(2) If ventilation is restored to the mine before miners reach the surface, the miners may return to underground working areas only after an examination of the areas is made by a certified person and the areas are determined to be safe.	Administrative	Mitigating	
		e	(e) Any atmospheric monitoring system operated during fan stoppages shall be intrinsically safe.	Engineering	Preventive	Confirm turnkey project and original plant and equipment manufacturers' (OEMs') component designs adhere to site-based selection and procurement standards (e.g. intrinsically safe and flameproof equipment)

		f	(f) Any electrical refuge alternative components exposed to the mine atmosphere shall be approved as intrinsically safe for use during fan stoppages. Any electrical refuge alternative components located inside the refuge alternative shall be either approved as intrinsically safe or approved as permissible for use during fan stoppages.	Engineering	Preventive	Emergency response systems (e.g. consider lifelines, fresh air bases. refuge bays, Compressed Air Breathing Apparatus CABA refilling stations, Self Contained Self Rescue [SCSR] cache, mine evacuation plans)
75.320	Air quality detectors and measurement devices	a	(a) Tests for methane shall be made by a qualified person with MSHA approved detectors that are maintained in permissible and proper operating condition and calibrated with a known methane-air mixture at least once every 31 days.	Administrative	Preventive	Monitoring systems to confirm the quality of ventilation (e.g. measure potential for gas build-up: real time, gas monitoring and pressure)
		b	(b) Tests for oxygen deficiency shall be made by a qualified person with MSHA approved oxygen detectors that are maintained in permissible and proper operating condition and that can detect 19.5 percent oxygen with an accuracy of ± 0.5 percent. The oxygen detectors shall be calibrated at the start of each shift that the detectors will be used.	Administrative	Preventive	
		c	(c) Handheld devices that contain electrical components and that are used for measuring air velocity, carbon monoxide, oxides of nitrogen, and other gases shall be approved and maintained in permissible and proper operating condition.	Engineering	Preventive	
		d	(d) An oxygen detector approved by MSHA shall be used to make tests for oxygen deficiency required by the regulations in this part. Permissible flame safety lamps may only be used	Engineering	Preventive	

			as a supplementary testing device.			
		e	(e) Maintenance of instruments required by paragraphs (a) through (d) of this section shall be done by persons trained in such maintenance.	Engineering	Preventive	
75.321	Air quality	a1	(a)(1) The air in areas where persons work or travel, except as specified in paragraph (a) (2) of this section, shall contain at least 19.5 percent oxygen and not more than 0.5 percent carbon dioxide, and the volume and velocity of the air current in these areas shall be sufficient to dilute, render harmless, and carry away flammable, explosive, noxious, and harmful gases, dusts, smoke, and fumes.	Engineering	Preventive	
		a2	(2) The air in areas of bleeder entries and worked-out areas where persons work or travel shall contain at least 19.5 percent oxygen, and carbon dioxide levels shall not exceed 0.5 percent time weighted average and 3.0 percent short term exposure limit.	Engineering	Preventive	
		b	(b) Notwithstanding the provisions of § 75.322, for the purpose of preventing explosions from gases other than methane, the following gases shall not be permitted to accumulate in excess of the concentrations listed below:	Engineering	Preventive	
		b1	(1) Carbon monoxide (CO)—2.5 percent	Engineering	Preventive	
		b2	(2) Hydrogen (H_2)—.80 percent	Engineering	Preventive	
		b3	(3) Hydrogen sulfide (H_2S)—.80 percent	Engineering	Preventive	
		b4	(4) Acetylene (C_2H_2)—.40 percent	Engineering	Preventive	
		b5	(5) Propane (C_3H_8)—.40 percent	Engineering	Preventive	
		b6	(6) MAPP (methyl-acetylene-propylene-	Engineering	Preventive	

			propodiene)—.30 percent			
75.322	Harmful quantities of noxious gases	All	Concentrations of noxious or poisonous gases, other than carbon dioxide, shall not exceed the threshold limit values (TLV) as specified and applied by the American Conference of Governmental Industrial Hygienists in ''Threshold Limit Values for Substance in Workroom Air'' (1972). Detectors or laboratory analysis of mine air samples shall be used to determine the concentrations of harmful, noxious, or poisonous gases. This incorporation by reference has been approved by the Director of the Federal Register in accordance with 5 U.S.C. 552 (a) and 1 CFR part 51. Copies are available from the Mine Safety and Health Administration, Department of Labor, 1100 Wilson Blvd., Room 2424, Arlington, Virginia 22209–3939 and at every MSHA Coal Mine Safety and Health district office. The material is available for examination at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202–741–6030, or go to: http://www.archives.gov/federallregister/codeloflfederallregulations/ibrllocations.html.	Engineering	Preventive	
75.323	Actions for excessive methane	a	(a) Location of tests. Tests for methane concentrations under this section shall be made at least 12 inches from the roof, face, ribs, and floor.	Engineering	Preventive	
		b	(b) Working places and intake air courses.			
		b1	(1) When 1.0 percent or more methane is present in a working place or an intake air course, including an air course in which a belt conveyor is located, or in an area	Engineering	Preventive	

			where mechanized mining equipment is being installed or removed—			
		b1i	(i) Except intrinsically safe atmospheric monitoring systems (AMS), electrically powered equipment in the affected area shall be deenergized, and other mechanized equipment shall be shut off;	Engineering	Preventive	
		b1ii	(ii) Changes or adjustments shall be made at once to the ventilation system to reduce the concentration of methane to less than 1.0 percent; and	Engineering	Preventive	
		b1iii	(iii) No other work shall be permitted in the affected area until the methane concentration is less than 1.0 percent.	Administrative	Preventive	
		b2	(2) When 1.5 percent or more methane is present in a working place or an intake air course, including an air course in which a belt conveyor is located, or in an area where mechanized mining equipment is being installed or removed—	Engineering	Preventive	
		b2i	(i) Everyone except those persons referred to in § 104 (c) of the Act shall be withdrawn from the affected area; and	Administrative	Preventive	
		b2ii	(ii) Except for intrinsically safe AMS, electrically powered equipment in the affected area shall be disconnected at the power source.	Engineering	Preventive	
		c	(c) Return air split.			
		c1	(1) When 1.0 percent or more methane is present in a return air split between the last working place on a working section and where that split of air meets another split of air, or the location at which the split is used to ventilate seals or worked-out areas changes or adjustments shall be	Engineering	Preventive	

			made at once to the ventilation system to reduce the concentration of methane in the return air to less than 1.0 percent.			
		c2	(2) When 1.5 percent or more methane is present in a return air split between the last working place on a working section and where that split of air meets another split of air, or the location where the split is used to ventilate seals or worked-out areas—	Engineering	Preventive	
		c2i	(i) Everyone except those persons referred to in § 104 (c) of the Act shall be withdrawn from the affected area;	Administrative	Preventive	
		c2ii	(ii) Other than intrinsically safe AMS, equipment in the affected area shall be deenergized, electric power shall be disconnected at the power source, and other mechanized equipment shall be shut off; and	Engineering	Preventive	
		c2iii	(iii) No other work shall be permitted in the affected area until the methane concentration in the return air is less than 1.0 percent.	Administrative	Preventive	
		d	(d) Return air split alternative.			
		d1	(1) The provisions of this paragraph apply if—			
		d1i	(i) The quantity of air in the split ventilating the active workings is at least 27,000 cubic feet per minute in the last open crosscut or the quantity specified in the approved ventilation plan, whichever is greater;	Engineering	Preventive	Develop ability to control ventilation systems as required in the event of a fire (e.g. consider variable fan speed, reverse airflow direction)
		d1ii	(ii) The methane content of the air in the split is continuously monitored during mining operations by an AMS that gives a visual and audible signal on the working section when the methane in the	Engineering	Preventive	

			return air reaches 1.5 percent, and the methane content is monitored as specified in § 75.351; and			
		d1iii	(iii) Rock dust is continuously applied with a mechanical duster to the return air course during coal production at a location in the air course immediately outby the most inby monitoring point.	Engineering	Preventive	Develop a stone dusting plan (SDP) and maintain compliance with statutory stone dusting requirements
		d2	(2) When 1.5 percent or more methane is present in a return air split between a point in the return opposite the section loading point and where that split of air meets another split of air or where the split of air is used to ventilate seals or worked-out areas—	Engineering	Preventive	Monitoring systems to confirm the quality of ventilation (e.g. measure potential for gas build-up: real time, gas monitoring and pressure)
		d2i	(i) Changes or adjustments shall be made at once to the ventilation system to reduce the concentration of methane in the return air below 1.5 percent;	Engineering	Preventive	
		d2ii	(ii) Everyone except those persons referred to in § 104 (c) of the Act shall be withdrawn from the affected area;	Administrative	Preventive	Develop an emergency response plan according to the risk assessment and regulatory requirements/ guidelines that addresses fire fighting, evacuation and medical treatment (Note, e.g. MDG 1020 Guidelines for underground emergency escape systems and the provisions of self-rescuers, October
		d2iii	(iii) Except for intrinsically safe AMS, equipment in the affected area shall be deenergized, electric power shall be disconnected at the power source, and other mechanized equipment shall be shut off; and	Engineering	Preventive	
		d2iv	(iv) No other work shall be permitted in the affected area until the methane concentration in the return air is less than 1.5 percent.	Administrative	Preventive	
		e	(e) Bleeders and other return air courses. The concentration of methane in a bleeder split of air immediately before the air in the split joins another	Engineering	Preventive	

			split of air, or in a return air course other than as described in paragraphs (c) and (d) of this section, shall not exceed 2.0 percent.			2010; MDG 1022 Guideline for determining withdrawal conditions from underground coal mines, October 2010)
75.324	Intentional changes in the ventilation system	a	(a) A person designated by the operator shall supervise any intentional change in ventilation that—	Engineering	Preventive	Change management process for change of mine plan (e.g. alterations to mine design plan, ventilation pressures, reduction in number of gate roads)
		a1	(1) Alters the main air current or any split of the main air current in a manner that could materially affect the safety or health of persons in the mine; or	Engineering	Preventive	Develop ability to control ventilation systems as required in the event of a fire (e.g. consider variable fan speed, reverse airflow direction)
		a2	(2) Affects section ventilation by 9,000 cubic feet per minute of air or more in bituminous or lignite mines, or 5,000 cubic feet per minute of air or more in anthracite mines.	Engineering	Preventive	
		b	(b) Intentional changes shall be made only under the following conditions:	Engineering	Preventive	N/A
		b1	(1) Electric power shall be removed from areas affected by the ventilation change and mechanized equipment in those areas shall be shut off before the ventilation change begins.	Engineering	Preventive	Design equipment to enable isolation in conformance with relevant standards, Consider isolation to a mining standard as a fundamental part of the design process, Device to be usable within mine
		b2	(2) Only persons making the change in ventilation shall be in the mine.	Engineering	Preventive	
		b3	(3) Electric power shall not be restored to the areas affected by the ventilation change and mechanized equipment shall not be restarted until a certified person has examined these areas for methane	Engineering	Preventive	

			accumulation and for oxygen deficiency and has determined that the areas are safe.			operating procedures to facilitate local mine practices and site-based standards
75.325	Air Quantity	a1	(a)(1) In bituminous and lignite mines the quantity of air shall be at least 3,000 cubic feet per minute reaching each working face where coal is being cut, mined, drilled for blasting, or loaded. When a greater quantity is necessary to dilute, render harmless, and carry away flammable, explosive, noxious, and harmful gases, dusts, smoke, and fumes, this quantity shall be specified in the approved ventilation plan. A minimum air quantity may be required to be specified in the approved ventilation plan for other working places or working faces.	Engineering	Preventive	Develop ability to control ventilation systems as required in the event of a fire (e.g. consider variable fan speed, reverse airflow direction)
		a2	(2) The quantity of air reaching the working face shall be determined at or near the face end of the line curtain, ventilation tubing, or other ventilation control device. If the curtain, tubing, or device extends beyond the last row of permanent roof supports, the quantity of air reaching the working face shall be determined behind the line curtain or in the ventilation tubing at or near the last row of permanent supports.	Engineering	Preventive	
		a3	(3) If machine mounted dust collectors or diffuser fans are used, the approved ventilation plan shall specify the operating volume of the dust collector or diffuser fan.	Engineering	Preventive	

		b	(b) In bituminous and lignite mines, the quantity of air reaching the last open crosscut of each set of entries or rooms on each working section and the quantity of air reaching the intake end of a pillar line shall be at least 9,000 cubic feet per minute unless a greater quantity is required to be specified in the approved ventilation plan. This minimum also applies to sections which are not operating but are capable of producing coal by simply energizing the equipment on the section.	Engineering	Preventive	
		c	(c) In longwall and shortwall mining systems—	Engineering	Preventive	
		c1	(1) The quantity of air shall be at least 30,000 cubic feet per minute reaching the working face of each longwall, unless the operator demonstrates that a lesser air quantity will maintain continual compliance with applicable methane and respirable dust standards. This lesser quantity shall be specified in the approved ventilation plan. A quantity greater than 30,000 cubic feet per minute may be required to be specified in the approved ventilation plan.	Engineering	Preventive	
		c2	(2) The velocity of air that will be provided to control methane and respirable dust in accordance with applicable standards on each longwall or shortwall and the locations where these velocities will be provided shall be specified in the approved ventilation plan. The locations specified shall be at least 50 feet but no more than 100 feet from the headgate and tailgate, respectively.	Engineering	Preventive	

		d	(d) Ventilation shall be maintained during installation and removal of mechanized mining equipment. The approved ventilation plan shall specify the minimum quantity of air, the locations where this quantity will be provided and the ventilation controls required.	Engineering	Preventive	
		e	(e) In anthracite mines, the quantity of air shall be as follows:	Engineering	Preventive	
		e1	(1) At least 1,500 cubic feet per minute reaching each working face where coal is being mined, unless a greater quantity is required to be specified in the approved ventilation plan.	Engineering	Preventive	
		e2	(2) At least 5,000 cubic feet per minute passing through the last open crosscut in each set of entries or rooms and at the intake end of any pillar line, unless a greater quantity is required to be specified in the approved ventilation plan.	Engineering	Preventive	
		e3	(3) When robbing areas where air currents cannot be controlled and air measurements cannot be obtained, the air shall have perceptible movement.	Engineering	Preventive	
		f	(f) The minimum ventilating air quantity for an individual unit of diesel-powered equipment being operated shall be at least that specified on the approval plate for that equipment. Such air quantity shall be maintained—	Engineering	Preventive	
		f1	(1) In any working place where the equipment is being operated;	Engineering	Preventive	
		f2	(2) At the section loading point during any shift the equipment is being operated on the working section;	Engineering	Preventive	
		f3	(3) In any entry where the equipment is being operated outby the section	Engineering	Preventive	

			loading point in areas of the mine developed on or after April 25, 1997;			
		f4	(4) In any air course with single or multiple entries where the equipment is being operated outby the section loading point in areas of the mine developed prior to April 25, 1997; and	Engineering	Preventive	
		f5	(5) At any other location required by the district manager and specified in the approved ventilation plan.	Engineering	Preventive	
		g	(g) The minimum ventilating air quantity where multiple units of diesel-powered equipment are operated on working sections and in areas where mechanized mining equipment is being installed or removed must be at least the sum of that specified on the approval plates of all the diesel-powered equipment on the working section or in the area where mechanized mining equipment is being installed or removed. The minimum ventilating air quantity shall be specified in the approved ventilation plan. For working sections such air quantity must be maintained—	Engineering	Preventive	
		g1	(1) In the last open crosscut of each set of entries or rooms in each working section;	Engineering	Preventive	
		g2	(2) In the intake, reaching the working face of each longwall; and	Engineering	Preventive	
		g3	(3) At the intake end of any pillar line.	Engineering	Preventive	
		h	(h) The following equipment may be excluded from the calculations of ventilating air quantity under paragraph (g) if such equipment exclusion is approved by the district manager and specified in the ventilation plan:	Engineering	Preventive	
		h1	(1) Self-propelled equipment meeting the			

			requirements of § 75.1908 (b);			
		h2	(2) Equipment that discharges its exhaust into intake air that is coursed directly to a return air course;	Engineering	Preventive	
		h3	(3) Equipment that discharges its exhaust directly into a return air course; and	Engineering	Preventive	
		h4	(4) Other equipment having duty cycles such that the emissions would not significantly affect the exposure of miners.	Engineering	Preventive	
		i	(i) A ventilating air quantity that is less than what is required by paragraph (g) of this section may be approved by the district manager in the ventilation plan based upon the results of sampling that demonstrate that the lesser air quantity will maintain continuous compliance with applicable TLV R's.	Engineering	Preventive	
		j	(j) If during sampling required by § 70.1900 (c) of this subchapter the ventilating air is found to contain concentrations of CO or NO2 in excess of the action level specified by § 70.1900 (c), higher action levels may be approved by the district manager based on the results of sampling that demonstrate that a higher action level will maintain continuous compliance with applicable TLV R's. Action levels other than those specified in § 70.1900 (c) shall be specified in the approved ventilation plan.	Engineering	Preventive	
		k	(k) As of November 25, 1997 the ventilating air quantity required where diesel-powered equipment is operated shall meet the requirements of paragraphs (f) through (j) of this section. Mine operators utilizing diesel-powered equipment in underground coal mines	Engineering	Preventive	

			shall submit to the appropriate MSHA district manager a revised ventilation plan or appropriate amendments to the existing plan, in accordance with § 75.371, which implement the requirements of paragraphs (f) through (j) of this section.			
75.326	Mean entry air velocity	All	In exhausting face ventilation systems, the mean entry air velocity shall be at least 60 feet per minute reaching each working face where coal is being cut, mined, drilled for blasting, or loaded, and to any other working places as required in the approved ventilation plan. A lower mean entry air velocity may be approved in the ventilation plan if the lower velocity will maintain methane and respirable dust concentrations in accordance with the applicable levels. Mean entry air velocity shall be determined at or near the inby end of the line curtain, ventilation tubing, or other face ventilation control devices.	Engineering	Preventive	
75.327	Air courses and trolley haulage systems	a	(a) In any mine opened on or after March 30, 1970, or in any new working section of a mine opened before that date, where trolley haulage systems are maintained and where trolley wires or trolley feeder wires are installed, an authorized representative of the Secretary shall require enough entries or rooms as intake air courses to limit the velocity of air currents in the haulageways to minimize the hazards of fires and dust explosions in the haulageways.	Engineering	Preventive	Accountability under legislation

		b	(b) Unless the district manager approves a higher velocity, the velocity of the air current in the trolley haulage entries shall be limited to not more than 250 feet per minute. A higher air velocity may be required to limit the methane content in these haulage entries or elsewhere in the mine to less than 1.0 percent and provide an adequate supply of oxygen.	Engineering	Preventive	
75.330	Face ventilation control devices	a	(a) Brattice cloth, ventilation tubing and other face ventilation control devices shall be made of flame-resistant material approved by MSHA.	Engineering	Preventive	Standards/procedures (e.g. construction and maintenance of seals, stoppings, ventilation control devices - VCDs, operation and maintenance of gas monitoring systems), Seals, stoppings and ventilation control device (VCD) design
		b1	(b)(1) Ventilation control devices shall be used to provide ventilation to dilute, render harmless, and to carry away flammable, explosive, noxious, and harmful gases, dusts, smoke, and fumes—	Engineering	Preventive	
		b1i	(i) To each working face from which coal is being cut, mined, drilled for blasting, or loaded; and	Engineering	Preventive	
		b1ii	(ii) To any other working places as required by the approved ventilation plan.	Engineering	Preventive	
		b2	(2) These devices shall be installed at a distance no greater than 10 feet from the area of deepest penetration to which any portion of the face has been advanced unless an alternative distance is specified and approved in the ventilation plan. Alternative distances specified shall be capable of maintaining concentrations of respirable dust, methane, and other harmful gases, in accordance with the levels specified in the applicable sections of this chapter.	Engineering	Preventive	

		c	(c) When the line brattice or any other face ventilation control device is damaged to an extent that ventilation of the working face is inadequate, production activities in the working place shall cease until necessary repairs are made and adequate ventilation is restored.	Engineering	Preventive	
75.331	Auxiliary fans and tubing	a	(a) When auxiliary fans and tubing are used for face ventilation, each auxiliary fan shall be—	Engineering	Preventive	Develop ability to control ventilation systems as required in the event of a fire (e.g. consider variable fan speed, reverse airflow direction)
		a1	(1) Permissible, if the fan is electrically operated;	Engineering	Preventive	
		a2	(2) Maintained in proper operating condition;	Engineering	Preventive	
		a3	(3) Deenergized or shut off when no one is present on the working section; and	Engineering	Preventive	
		a4	(4) Located and operated to avoid recirculation of air.	Engineering	Preventive	
		b	(b) If a deficiency exists in any auxiliary fan system, the deficiency shall be corrected or the auxiliary fan shall be deenergized immediately.	Engineering	Preventive	
		c	(c) If the air passing through an auxiliary fan or tubing contains 1.0 percent or more methane, power to electrical equipment in the working place and to the auxiliary fan shall be deenergized, and other mechanized equipment in the working place shall be shut off until the methane concentration is reduced to less than 1.0 percent.	Engineering	Preventive	Monitoring systems to confirm the quality of ventilation (e.g. measure potential for gas build-up: real time, gas monitoring and pressure)
		d	(d) When an auxiliary fan is stopped—	Engineering	Preventive	Seals, stoppings and ventilation control device (VCD) design
		d1	(1) Line brattice or other face ventilation control devices shall be used to maintain ventilation to affected faces; and	Engineering	Preventive	
		d2	(2) Electrical equipment in the affected working places shall be disconnected at the power source, and other mechanized equipment shall be shut off until	Engineering	Preventive	Develop and implement management plans (e.g. gas management, ventilation

			ventilation to the working place is restored.			management, electrical management)
75.332	Working sections and working places	a1	(a)(1) Each working section and each area where mechanized mining equipment is being installed or removed, shall be ventilated by a separate split of intake air directed by overcasts, undercasts or other permanent ventilation controls.	Engineering	Preventive	Develop and implement management plans (e.g. gas management, ventilation management, electrical management)
		a2	(2) When two or more sets of mining equipment are simultaneously engaged in cutting, mining, or loading coal or rock from working places within the same working section, each set of mining equipment shall be on a separate split of intake air.	Engineering	Preventive	
		a3	(3) For purposes of this section, a set of mining equipment includes a single loading machine, a single continuous mining machine, or a single longwall or shortwall mining machine.	Engineering	Preventive	
		b1	(b)(1) Air that has passed through any area that is not examined under §§ 75.360, 75.361 or 75.364 of this subpart, for through an area where second mining has been done shall not be used to ventilate any working place. Second mining is intentional retreat mining where pillars have been wholly or partially removed, regardless of the amount of recovery obtained.	Engineering	Preventive	Design of adequate ventilation (e.g. monitor and manage methane accumulation, manage dust level - scrubber fans, venturis)
		b2	(2) Air that has passed by any opening of any unsealed area that is not examined under §§ 75.360, 75.361 or 75.364 of this subpart, shall not be used to ventilate any working place.	Engineering	Preventive	
75.333	Ventilation Controls	a	(a) For purposes of this section, ‘‘doors’’ include	[redacted]		

			any door frames.			
		b	(b) Permanent stoppings or other permanent ventilation control devices constructed after November 15, 1992, shall be built and maintained—	Engineering	Preventive	Site-based standards/procedures (e.g. construction and maintenance of seals, stoppings, ventilation control devices - VCDs, operation and maintenance of gas monitoring systems), Develop understanding of the importance of construction, operation and maintenance of seals, stoppings, gas drainage systems, and VCDs (to control atmosphere), Understanding site-based standards for inspecting, sampling and testing the integrity of seals, stoppings, VCDs and environment
		b1	(1) Between intake and return air courses, except temporary controls may be used in rooms that are 600 feet or less from the centerline of the entry from which the room was developed including where continuous face haulage systems are used in such rooms. Unless otherwise approved in the ventilation plan, these stoppings or controls shall be maintained to and including the third connecting crosscut outby the working face;	Engineering	Preventive	
		b2	(2) To separate belt conveyor haulageways from return air courses, except where belt entries in areas of mines developed before March 30, 1970, are used as return air courses;	Engineering	Preventive	
		b3	(3) To separate belt conveyor haulageways from intake air courses when the air in the intake air courses is used to provide air to active working places. Temporary ventilation controls may be used in rooms that are 600 feet or less from the centerline of the entry from which the rooms were developed including where continuous face haulage systems are used in such rooms. When continuous face haulage systems are used, permanent stoppings or other permanent ventilation control devices shall be built and maintained to the outby most point of travel of the dolly or 600 feet from the point of deepest penetration in the	Engineering	Preventive	

			conveyor belt entry, whichever distance is closer to the point of deepest penetration, to separate the continuous haulage entry from the intake entries;			
		b4	(4) To separate the primary escapeway from belt and trolley haulage entries, as required by § 75.380 (g). For the purposes of § 75.380 (g), the loading point for a continuous haulage system shall be the outby most point of travel of the dolly or 600 feet from the point of deepest penetration, whichever distance is less; and	Engineering	Preventive	
		b5	(5) In return air courses to direct air into adjacent worked-out areas.	Engineering	Preventive	
		c	(c) Personnel doors shall be constructed of noncombustible material and shall be of sufficient strength to serve their intended purpose of maintaining separation and permitting travel between air courses, and shall be installed as follows in permanent stoppings constructed after November 15, 1992:	Engineering	Preventive	
		c1	(1) The distance between personnel doors shall be no more than 300 feet in seam heights below 48 inches and 600 feet in seam heights 48 inches or higher.	Engineering	Preventive	
		c2	(2) The location of all personnel doors in stoppings along escapeways shall be clearly marked so that the doors may be easily identified by anyone traveling in the escapeway	Engineering	Preventive	

			and in the entries on either side of the doors.			
		c3	(3) When not in use, personnel doors shall be closed.	Engineering	Preventive	
		c4	(4) An airlock shall be established where the air pressure differential between air courses creates a static force exceeding 125 pounds on closed personnel doors along escapeways.	Engineering	Preventive	
		d	(d) Doors, other than personnel doors, constructed after November 15, 1992, that are used in lieu of permanent stoppings or to control ventilation within an air course shall be:	Engineering	Preventive	
		d1	(1) Made of noncombustible material or coated on all accessible surfaces with flame-retardant materials having a flame-spread index of 25 or less, as tested under ASTM E162–87, ''Standard Test Method for Surface Flammability Source.'' This publication is incorporated by reference and may be inspected at any MSHA Coal Mine Safety and Health district office, or at MSHA's Office of Standards, Regulations, and Variances, 1100 Wilson Blvd., Room 2352, Arlington, Virginia 22209–3939, and at the National archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202–741–6030, or go to: http://www.archives.gov/federallregister/codeloflfederallregulations/ibrllocations.html. In addition, copies of the document can be purchased from the American Society for Testing (ASTM), 100 Barr Harbor Drive, PO Box C700, West	Engineering	Preventive	

			Conshohocken, PA 19428–2959; http://www.astm.org. This incorporation by reference was approved by the Director of the Federal Register in accordance with 5 U.S.C. 552 (a) and 1 CFR part 51.			
		d2	(2) Of sufficient strength to serve their intended purpose of maintaining separation and permitting travel between or within air courses or entries.	Engineering	Preventive	
		d3	(3) Installed in pairs to form an airlock. When an airlock is used, one side of the airlock shall remain closed. When not in use, both sides shall be closed.	Engineering	Preventive	

		e1i	(e)(1)(i) Except as provided in paragraphs (e)(2), (e) (3) and (e) (4) of this section all overcasts, undercasts, shaft partitions, permanent stoppings, and regulators, installed after June 10, 1996, shall be constructed in a traditionally accepted method and of materials that have been demonstrated to perform adequately or in a method and of materials that have been tested and shown to have a minimum strength equal to or greater than the traditionally accepted in-mine controls. Tests may be performed under ASTM E72–80, ''Standard Methods of Conducting Strength Tests of Panels for Building Construction'' (Section 12—Transverse Load—Specimen Vertical, load, only), or the operator may conduct comparative in-mine tests. In-mine tests shall be designed to demonstrate the comparative strength of the proposed construction and a traditionally accepted in-mine control. The publication ASTM E72–80, ''Standard Methods of Conducting Strength Tests of Panels for Building Construction'' is incorporated by reference and may be inspected at any MSHA Coal Mine Safety and Health district office, or at MSHA's Office of Standards, Regulations, and Variances, 1100 Wilson Blvd., Room 2352, Arlington, Virginia 22209–3939, and at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202–741–6030, or go to: http://www.archives.gov/federallregister/codeloflfederallregulations/ibrllocations.html. In addition, copies of	Engineering	Preventive	

			the document can be purchased from the American Society for Testing (ASTM), 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428–2959; http://www.astm.org. This incorporation by reference was approved by the Director of the Federal Register in accordance with 5 U.S.C. 552 (a) and 1 CFR part 51.			
		e1ii	(ii) All overcasts, undercasts, shaft partitions, permanent stoppings, and regulators, installed after November 15, 1992, shall be constructed of noncombustible material. Materials that are suitable for the construction of overcasts, undercasts, shaft partitions, permanent stoppings, and regulators include concrete, concrete block, brick, cinder block, tile, or steel. No ventilation controls installed after November 15, 1992, shall be constructed of aluminum.	Engineering	Preventive	

		e2	(2) In anthracite mines, permanent stoppings may be constructed of overlapping layers of hardwood mine boards, if the stoppings are a minimum 2 inches thick.	Engineering	Preventive	
		e3	(3) When timbers are used to create permanent stoppings in heaving or caving areas, the stoppings shall be coated on all accessible surfaces with a flame-retardant material having a flame-spread index of 25 or less, as tested under ASTM E162–87, ''Standard Test Method for Surface Flammability of Materials Using A Radiant Heat Energy Source.'' This publication is incorporated by reference and may be inspected at any MSHA Coal Mine Safety and Health district office, or at MSHA's Office of Standards, Regulations, and Variances, 1100 Wilson Blvd., Room 2352, Arlington, Virginia 22209–3939, and at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202–741–6030, or go to: http://www.archives.gov/federallregister/codeloflfederallregulations/ibrllocations.html. In addition, copies of the document can be purchased from the American Society for Testing (ASTM), 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428–2959; http://www.astm.org. This incorporation by reference was approved by the Director of the Federal Register in accordance with 5 U.S.C. 552 (a) and 1 CFR part 51.	Engineering	Preventive	

		e4	(4) In anthracite mines, doors and regulators may be constructed of overlapping layers of hardwood boards, if the doors, door frames, and regulators are a minimum 2 inches thick.	Engineering	Preventive	
		f	(f) When sealants are applied to ventilation controls, the sealant shall have a flame-spread index of 25 or less under ASTM E162–87, ‘‘Standard Test Method for Surface Flammability of Materials Using A radiant Heat Energy Source.’’ This publication is incorporated by reference and may be inspected at any MSHA Coal Mine Safety and Health district office, or at MSHA’s Office of Standards, Regulations, and Variances, 1100 Wilson Blvd., Room 2352, Arlington, Virginia 22209–3939, and at the National archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202–741–6030, or go to: http://www.archives.gov/federallregister/codeloflfederallregulations/ibrllocations.html. In addition, copies of the document can be purchased from the American Society for Testing (ASTM), 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428–2959; http://www.astm.org. This incorporation by reference was approved by the Director of the Federal Register in accordance with 5 U.S.C. 552 (a) and 1 CFR part 51.	Engineering	Preventive	

		g	(g) Before mining is discontinued in an entry or room that is advanced more than 20 feet from the inby rib, a crosscut shall be made or line brattice shall be installed and maintained to provide adequate ventilation. When conditions such as methane liberation warrant a distance less than 20 feet, the approved ventilation plan shall specify the location of such rooms or entries and the maximum distance they will be developed before a crosscut is made or line brattice is installed.	Engineering	Preventive	
		h	(h) All ventilation controls, including seals, shall be maintained to serve the purpose for which they were built.	Engineering	Preventive	
75.334	Worked out areas and ares where pillars are being recovered	a	(a) Worked-out areas where no pillars have been recovered shall be—	Engineering	Preventive	
		a1	(1) Ventilated so that methane-air mixtures and other gases, dusts, and fumes from throughout the worked-out areas are continuously diluted and routed into a return air course or to the surface of the mine; or	Engineering	Preventive	Confirm ventilation system mitigates dead spots or potential areas of gas accumulation (e.g. inspection, modelling, dead spots resulting from multiple fans or multiple shafts)
		a2	(2) Sealed.	Engineering	Preventive / Mitigating	
		b1	(b)(1) During pillar recovery a bleeder system shall be used to control the air passing through the area and to continuously dilute and move methane-air mixtures and other gases, dusts, and fumes from the worked-out area away from active workings and into a return air course or to the surface of the mine.	Engineering	Preventive	Implement ventilation management strategies to address methane accumulation, Risk assess the potential for unexpected source/gas dynamic event at the extraction face. Do not work in the
		b2	(2) After pillar recovery a bleeder system shall be maintained to provide ventilation to the worked-	Engineering	Preventive	

			out area, or the area shall be sealed.			return if there is high potential for an outburst, Develop and implement site-based stopping standards (especially design system that is not adversely affected by overpressure event e.g. large goaf fall/windblast; for example, consider flexible stoppings/sails that can effectively absorb without damage or failure)
		c	(c) The approved ventilation plan shall specify the following:	Engineering	Preventive	
		c1	(1) The design and use of bleeder systems;	Engineering	Preventive	
		c2	(2) The means to determine the effectiveness of bleeder systems;	Engineering	Preventive	
		c3	(3) The means for adequately maintaining bleeder entries free of obstructions such as roof falls and standing water; and	Engineering	Preventive	
		c4	(4) The location of ventilating devices such as regulators, stoppings and bleeder connectors used to control air movement through the worked-out area.	Engineering	Preventive	
		d	(d) If the bleeder system used does not continuously dilute and move methane-air mixtures and other gases, dusts, and fumes away from worked-out areas into a return air course or to the surface of the mine, or it cannot be determined by examinations or evaluations under § 75.364 that the bleeder system is working effectively, the worked-out area shall be sealed.	Engineering	Preventive	
		e	(e) Each mining system shall be designed so that each worked-out area can be sealed. The approved ventilation plan shall specify the location and the sequence of construction of proposed seals.	Engineering	Preventive	
		f	(f) In place of the requirements of paragraphs (a) and (b) of this section, for mines with a demonstrated history of spontaneous combustion, or that are located in a coal seam determined to be susceptible to spontaneous combustion, the approved ventilation	Engineering	Preventive	

			plan shall specify the following:			
		f1	(1) Measures to detect methane, carbon monoxide, and oxygen concentrations during and after pillar recovery, and in worked-out areas where no pillars have been recovered, to determine if the areas must be ventilated or sealed.	Engineering	Preventive	
		f2	(2) Actions that will be taken to protect miners from the hazards of spontaneous combustion.	Engineering	Preventive	
		f3	(3) If a bleeder system will not be used, the methods that will be used to control spontaneous combustion, accumulations of methane-air mixtures, and other gases, dusts, and fumes in the worked-out area.	Engineering	Preventive	
75.335	Seal strengths, design applications, and installations	a	(a) Seal strengths. Seals constructed on or after October 20, 2008 shall be designed, constructed, and maintained to withstand—	Engineering	Preventive	Site-based standards/procedures (e.g. construction and maintenance of seals, stoppings, ventilation control devices - VCDs, operation and maintenance of gas monitoring systems), Develop understanding of the importance of construction, operation and maintenance of seals, stoppings, gas drainage systems, and VCDs (to control atmosphere),
		a1i	(1)(i) At least 50-psi overpressure when the atmosphere in the sealed area is monitored and maintained inert and designed using a pressure-time curve with an instantaneous overpressure of at least 50 psi. A minimum overpressure of at least 50 psi shall be maintained for at least four seconds then released instantaneously.	Engineering	Preventive	
		a1ii	(ii) Seals constructed to separate the active longwall panel from the longwall panel previously mined shall be designed using a pressure-time curve with a rate of pressure rise of at least 50 psi in 0.1 second. A minimum overpressure of	Engineering	Preventive	

			at least 50 psi shall be maintained; or			Understanding site-based standards for inspecting, sampling and testing the integrity of seals, stoppings, VCDs, and environment, Consider the need for pressure balancing in mains, and/or nitrogen positive pressure sealing
		a2i	(2)(i) Overpressures of at least 120 psi if the atmosphere in the sealed area is not monitored, is not maintained inert, the conditions in paragraphs (a) (3) (i) through (iii) of this section are not present, and the seal is designed using a pressure-time curve with an instantaneous overpressure of at least 120 psi. A minimum overpressure of 120 psi shall be maintained for at least four seconds then released instantaneously.	Engineering	Preventive	
		a2ii	(ii) Seals constructed to separate the active longwall panel from the longwall panel previously mined shall be designed using a pressure-time curve with a rate of pressure rise of 120 psi in 0.25 second. A minimum overpressure of 120 psi shall be maintained; or	Engineering	Preventive	
		a3	(3) Overpressures greater than 120 psi if the atmosphere in the sealed area is not monitored and is not maintained inert, and	Engineering	Preventive	
		a3i	(i) The atmosphere in the sealed area is likely to contain homogeneous mixtures of methane between 4.5 percent and 17.0 percent and oxygen exceeding 17.0 percent throughout the entire area;	Engineering	Preventive	
		a3ii	(ii) Pressure piling could result in overpressures greater than 120 psi in the area to be sealed; or	Engineering	Preventive	
		a3iii	(iii) Other conditions are encountered, such as the likelihood of a detonation in the area to be sealed.	Engineering	Preventive	

		a3iv	(iv) Where the conditions in paragraphs (a) (3) (i), (ii), or (iii) of this section are encountered, the mine operator shall revise the ventilation plan to address the potential hazards. The plan shall include seal strengths sufficient to address such conditions.	Engineering	Preventive	
		b	(b) Seal design applications. Seal design applications from seal manufacturers or mine operators shall be in accordance with paragraphs (b) (1) or (b) (2) of this section and submitted for approval to MSHA's Office of Technical Support, Pittsburgh Safety and Health Technology Center, P.O. Box 18233, Cochrans Mill Road, Pittsburgh, PA 15236.	Engineering	Preventive	
		b1	(1) An engineering design application shall—	Engineering	Preventive	
		b1i	(i) Address gas sampling pipes, water drainage systems, methods to reduce air leakage, pressure-time curve, fire resistance characteristics, flame spread index, entry size, engineering design and analysis, elasticity of design, material properties, construction specifications, quality control, design references, and other information related to seal construction;	Engineering	Preventive	Develop understanding of the importance of construction, operation and maintenance of seals, stoppings, gas drainage systems, and VCDs (to control atmosphere), Develop and implement site-based standards for seals, pressure management, active inertization, monitoring, auditing, checks, sign-off on VCDs, Consider the need for pressure balancing in mains, and/or nitrogen
		b1ii	(ii) Be certified by a professional engineer that the design of the seal is in accordance with current, prudent engineering practices and is applicable to conditions in an underground coal mine; and	Engineering	Preventive	
		b1iii	(iii) Include a summary of the installation procedures related to seal construction; or	Engineering	Preventive	
		b2	(2) Each application based on full-scale explosion tests or equivalent means of	Engineering	Preventive	

			physical testing shall address the following requirements to ensure that a seal can reliably meet the seal strength requirements:			positive pressure sealing, Site-based standards/procedures (e.g. construction and maintenance of seals, stoppings, ventilation control devices - VCDs, operation and maintenance of gas monitoring systems)
		b2i	(i) Certification by a professional engineer that the testing was done in accordance with current, prudent engineering practices for construction in a coal mine;	Engineering	Preventive	
		b2ii	(ii) Technical information related to the methods and materials;	Engineering	Preventive	
		b2iii	(iii) Supporting documentation;	Engineering	Preventive	
		b2iv	(iv) An engineering analysis to address differences between the seal support during test conditions and the range of conditions in a coal mine; and	Engineering	Preventive	
		b2v	(v) A summary of the installation procedures related to seal construction.	Engineering	Preventive	
		b3	(3) MSHA will notify the applicant if additional information or testing is required. The applicant shall provide this information, arrange any additional or repeat tests, and provide prior notification to MSHA of the location, date, and time of such test(s).	Engineering	Preventive	
		b4	(4) MSHA will notify the applicant, in writing, whether the design is approved or denied. If the design is denied, MSHA will specify, in writing, the deficiencies of the application, or necessary revisions.	Engineering	Preventive	
		b5	(5) Once the seal design is approved, the approval holder shall promptly notify MSHA, in writing, of all deficiencies of which they become aware.	Administrative	Preventive	
		c	(c) Seal installation approval. The installation of the approved seal design shall be subject to approval in the ventilation plan. The mine operator	Engineering	Preventive	

			shall—			
		c1	(1) Retain the seal design approval and installation information for as long as the seal is needed to serve the purpose for which it was built.	Engineering	Preventive	
		c2	(2) Designate a professional engineer to conduct or have oversight of seal installation and certify that the provisions in the approved seal design specified in this section have been addressed and are applicable to conditions at the mine. A copy of the certification shall be submitted to the District Manager with the information provided in paragraph (c) (3) of this section and a copy of the certification shall be retained for as long as the seal is needed to serve the purpose for which it was built.	Engineering	Preventive	
		c3	(3) Provide the following information for approval in the ventilation plan—	Engineering	Preventive	
		c3i	(i) The MSHA Technical Support Approval Number;	[redacted]		
		c3ii	(ii) A summary of the installation procedures;	Engineering	Preventive	
		c3iii	(iii) The mine map of the area to be sealed and proposed seal locations that include the deepest points of penetration prior to sealing. The mine map shall be certified by a professional engineer or a professional land surveyor.	Engineering	Preventive	
		c3iv	(iv) Specific mine site information, including—	Engineering	Preventive	
		c3ivA	(A) Type of seal;	Engineering	Preventive	
		c3ivB	(B) Safety precautions taken prior to seal achieving design strength;	Engineering	Preventive	
		c3ivC	(C) Methods to address site-specific conditions that may affect the strength and applicability of the seal including set-	Engineering	Preventive	

			back distances;			
		c3ivD	(D) Site preparation;	Engineering	Preventive	
		c3ivE	(E) Sequence of seal installations;	Engineering	Preventive	
		c3ivF	(F) Projected date of completion of each set of seals;	Engineering	Preventive	
		c3ivG	(G) Supplemental roof support inby and outby each seal;	Engineering	Preventive	
		c3ivH	(H) Water flow estimation and dimensions of the water drainage system through the seals;	Engineering	Preventive	
		c3ivI	(I) Methods to ventilate the outby face of seals once completed;	Engineering	Preventive	
		c3ivJ	(J) Methods and materials used to maintain each type of seal;	Engineering	Preventive	
		c3ivK	(K) Methods to address shafts and boreholes in the sealed area;	Engineering	Preventive	
		c3ivL	(L) Assessment of potential for overpressures greater than 120 psi in sealed area;	Engineering	Preventive	
		c3ivM	(M) Additional sampling locations; and	Engineering	Preventive	
		c3ivN	(N) Additional information required by the District Manager.	Engineering	Preventive	
75.336	Sampling and monitoring requirements	a	(a) A certified person as defined in § 75.100 shall monitor atmospheres of sealed areas. Sealed areas shall be monitored, whether ingassing or outgassing, for methane and oxygen concentrations and the direction of leakage.	Engineering	Preventive	Auditing/inspection - records and schedules (e.g. job task analysis/observation, planned task observation, safety observation)
		a1	(1) Each sampling pipe and approved sampling location shall be sampled at least every 24 hours.	Engineering	Preventive	
		a1i	(i) Atmospheres with seals of 120 psi or greater shall be sampled until the design strength is reached for every seal used to seal the area.	Engineering	Preventive	

		a1ii	(ii) Atmospheres with seals less than 120 psi constructed before October 20, 2008 shall be monitored for methane and oxygen concentrations and maintained inert. The operator may request that the District Manager approve different sampling locations and frequencies in the ventilation plan, provided at least one sample is taken at each set of seals at least every 7 days.	Engineering	Preventive	Develop understanding of the importance of construction, operation and maintenance of seals, stoppings, gas drainage systems, and VCDs (to control atmosphere), Develop and implement site-based standards for seals, pressure management, active inertization, monitoring, auditing, checks, sign-off on VCDs, Consider the need for pressure balancing in mains, and/or nitrogen positive pressure sealing, Site-based standards/procedures (e.g. construction and maintenance of seals, stoppings, ventilation control devices - VCDs, operation and maintenance of gas monitoring systems), Understanding site-based standards for inspecting, sampling and testing the integrity of seals, stoppings,
		a1iii	(iii) Atmospheres with seals less than 120 psi constructed after October 20, 2008 shall be monitored for methane and oxygen concentrations and maintained inert. The operator may request that the District Manager approve different sampling locations and frequencies in the ventilation plan after a minimum of 14 days and after the seal design strength is reached, provided at least one sample is taken at each set of seals at least every 7 days.	Engineering	Preventive	
		a2	(2) The mine operator shall evaluate the atmosphere in the sealed area to determine whether sampling through the sampling pipes in seals and approved locations provides appropriate sampling locations of the sealed area. The mine operator shall make the evaluation immediately after the minimum 14-day required sampling, if the mine ventilation system is reconfigured, if changes occur that adversely affect the sealed area, or if the District Manager requests an evaluation. When the results of the evaluations indicate the need for additional sampling locations, the mine operator shall provide the	Engineering	Preventive	

			additional locations and have them approved in the ventilation plan. The District Manager may require additional sampling locations and frequencies in the ventilation plan.			VCDs and environment
		a3	(3) Mine operators with an approved ventilation plan addressing spontaneous combustion pursuant to § 75.334 (f) shall sample the sealed atmosphere in accordance with the ventilation plan.	Engineering	Preventive	
		a4	(4) The District Manager may approve in the ventilation plan the use of a continuous monitoring system in lieu of monitoring provisions in this section.	Engineering	Preventive	
		b1	(b)(1) Except as provided in § 75.336(d), the atmosphere in the sealed area is considered inert when the oxygen concentration is less than 10.0 percent or the methane concentration is less than 3.0 percent or greater than 20.0 percent.	Engineering	Preventive	
		b2	(2) Immediate action shall be taken by the mine operator to restore an inert sealed atmosphere behind seals with strengths less than 120 psi. Until the atmosphere in the sealed area is restored to an inert condition, the sealed atmosphere shall be monitored at each sampling pipe and approved location at least once every 24 hours.	Engineering	Preventive	

		c	(c) Except as provided in § 75.336 (d), when a sample is taken from the sealed atmosphere with seals of less than 120 psi and the sample indicates that the oxygen concentration is 10 percent or greater and methane is between 4.5 percent and 17 percent, the mine operator shall immediately take an additional sample and then immediately notify the District Manager. When the additional sample indicates that the oxygen concentration is 10 percent or greater and methane is between 4.5 percent and 17 percent, persons shall be withdrawn from the affected area which is the entire mine or other affected area identified by the operator and approved by the District Manager in the ventilation plan, except those persons referred to in § 104 (c) of the Act. The operator may identify areas in the ventilation plan to be approved by the District Manager where persons may be exempted from withdrawal. The operator's request shall address the location of seals in relation to: Areas where persons work and travel in the mine; escapeways and potential for damage to the escapeways; and ventilation systems and controls in areas where persons work or travel and where ventilation is used for escapeways. The operator's request shall also address the gas concentration of other sampling locations in the sealed area and other required information. Before miners reenter the mine, the mine operator shall have a ventilation plan revision approved by the District Manager	Engineering	Preventive	

			specifying the actions to be taken.			
		d	(d) In sealed areas with a demonstrated history of carbon dioxide or sealed areas where inert gases have been injected, the operator may request that the District Manager approve in the ventilation plan an alternative method to determine if the sealed atmosphere is inert and when miners have to be withdrawn. The mine operator shall address in the ventilation plan the specific levels of methane, carbon dioxide, nitrogen and oxygen; the sampling methods and equipment used; and the methods to evaluate these concentrations underground at the seal.	Engineering	Preventive	

		e1	(e) Recordkeeping. (1) The certified person shall promptly record each sampling result including the location of the sampling points, whether ingassing or outgassing, and oxygen and methane concentrations. The results of oxygen and methane samples shall be recorded as the percentage of oxygen and methane measured by the certified person and any hazardous condition found in accordance with § 75.363.	Engineering	Preventive	
		e2	(2) The mine operator shall retain sampling records at the mine for at least one year from the date of the sampling.	Engineering	Preventive	
75.337	Construction and repair of seals	a	(a) The mine operator shall maintain and repair seals to protect miners from hazards of sealed areas.	Engineering	Preventive	Defect management system that reports defects and associated corrective actions (e.g. loss of protective coating)
		b	(b) Prior to sealing, the mine operator shall—	Engineering	Preventive	
		b1	(1) Remove insulated cables, batteries, and other potential electric ignition sources from the area to be sealed when constructing seals, unless it is not safe to do so. If ignition sources cannot safely be removed, seals must be constructed to at least 120 psi;	Engineering	Preventive	Plant or infrastructure provided with capacity for external isolation of potential ignition sources (e.g. Isolation of power) and fuels
		b2	(2) Remove metallic objects through or across seals; and	Engineering	Preventive	
		b3	(3) Breach or remove all stoppings in the first crosscut inby the seals immediately prior to sealing the area.	Engineering	Preventive	
		c	(c) A certified person designated by the mine operator shall directly supervise seal construction and repair and—	Engineering	Preventive	Develop and implement site-based standards for seals, pressure

		c1	(1) Examine each seal site immediately prior to construction or repair to ensure that the site is in accordance with the approved ventilation plan;	Engineering	Preventive	management, active inertization, monitoring, auditing, checks, sign-off on VCDs, Training and awareness with respect to site-based procedures (e.g. construction and maintenance of seals, stoppings, ventilation control devices - VCDs, operation and maintenance of gas monitoring systems) and spontaneous combustion management plans (including propensity for spontaneous combustion; stowage rules), Awareness of past spontaneous combustion events within the goaf
		c2	(2) Examine each seal under construction or repair during each shift to ensure that the seal is being constructed or repaired in accordance with the approved ventilation plan;	Engineering	Preventive	
		c3	(3) Examine each seal upon completion of construction or repair to ensure that construction or repair is in accordance with the approved ventilation plan;	Engineering	Preventive	
		c4	(4) Certify by initials, date, and time that the examinations were made; and	Engineering	Preventive	
		c5	(5) Make a record of the examination at the completion of any shift during which an examination was conducted. The record shall include each deficiency and the corrective action taken. The record shall be countersigned by the mine foreman or equivalent mine official by the end of the mine foreman's or equivalent mine official's next regularly scheduled working shift. The record shall be kept at the mine for one year.	Engineering	Preventive	
		d	(d) Upon completion of construction of each seal a senior mine management official, such as a mine manager or superintendent, shall certify that the construction, installation, and materials used were in accordance with the approved ventilation plan. The mine operator shall retain the certification for as long as the seal is needed to serve the purpose for which it was built.	Engineering	Preventive	

		e	(e) The mine operator shall—	Engineering	Preventive	
		e1	(1) Notify the District Manager between two and fourteen days prior to commencement of seal construction;	Administrative	Preventive	
		e2	(2) Notify the District Manager, in writing, within five days of completion of a set of seals and provide a copy of the certification required in paragraph (d) of this section; and	Administrative	Preventive	
		e3	(3) Submit a copy of quality control results to the District Manager for seal material properties specified by § 75.335 within 30 days of completion of quality control tests.	Administrative	Preventive	
		f	(f) Welding, cutting, and soldering. Welding, cutting, and soldering with an arc or flame are prohibited within 150 feet of a seal. An operator may request a different location in the ventilation plan to be approved by the District Manager. The operator's request must address methods the mine operator will use to continuously monitor atmospheric conditions in the sealed area during welding or burning; the airflow conditions in and around the work area; the rock dust and water application methods; the availability of fire extinguishers on hand; the procedures to maintain safe conditions, and other relevant factors.	Engineering	Preventive	Implement operational practices to identify and prevent inappropriate use of hot work equipment (location and tools)
		g1	(g) Sampling pipes. (1) For seals constructed after April 18, 2008, one nonmetallic sampling pipe shall be installed in each seal that shall extend into the center of the first connecting crosscut inby the seal. If an open crosscut does not exist, the sampling pipe shall extend one-half of the distance of the open entry	Engineering	Preventive	Understandin g site-based standards for inspecting, sampling and testing the integrity of seals, stoppings, VCDs and environment, Develop and implement

			inby the seal.			site-based standards for monitoring the status of goaf areas (e.g. gas, pressure differential, heat in goaf areas, water temperature in sealed areas)
		g2	(2) Each sampling pipe shall be equipped with a shut-off valve and appropriate fittings for taking gas samples.	Engineering	Preventive	
		g3	(3) The sampling pipes shall be labeled to indicate the location of the sampling point when more than one sampling pipe is installed through a seal.	Engineering	Preventive	
		g4	(4) If a new seal is constructed to replace or reinforce an existing seal with a sampling pipe, the sampling pipe in the existing seal shall extend through the new seal. An additional sampling pipe shall be installed through each new seal to sample the area between seals, as specified in the approved ventilation plan.	Engineering	Preventive	
		h	(h) Water drainage system. For each set of seals constructed after April 18, 2008, the seal at the lowest elevation shall have a corrosion-resistant, nonmetallic water drainage system. Seals shall not impound water or slurry. Water or slurry shall not accumulate within the sealed area to any depth that can adversely affect a seal.	Engineering	Preventive	Fire fighting system including fire hydrants, fire depots, fire blankets, foams, water lines in fire resistant material, appropriate fire extinguishing agents for range of possible fire types
75.338	Training	a	(a) Certified persons conducting sampling shall be trained in the use of appropriate sampling equipment, procedures, location of sampling points, frequency of sampling, size and condition of the sealed area, and the use of continuous monitoring systems if applicable before they conduct	Engineering	Preventive	Auditing/inspection - records and schedules (e.g. job task analysis/observation, planned task observation, safety observation), Understanding site-based

			sampling, and annually thereafter. The mine operator shall certify the date of training provided to certified persons and retain each certification for two years.			standards for inspecting, sampling and testing the integrity of seals, stoppings, VCDs and environment
		b	(b) Miners constructing or repairing seals, designated certified persons, and senior mine management officials shall be trained prior to constructing or repairing a seal and annually thereafter. The training shall address materials and procedures in the approved seal design and ventilation plan. The mine operator shall certify the date of training provided each miner, certified person, and senior mine management official and retain each certification for two years.	Engineering	Preventive	
75.340	Underground electrical installations	a	(a) Underground transformer stations, battery charging stations, substations, rectifiers, and water pumps shall be housed in noncombustible structures or areas or be equipped with a fire suppression system meeting the requirements of § 75.1107–3 through § 75.1107–16.	Engineering	Preventive	Plant or infrastructure provided with capacity for external fire suppression activation
		a1	(1) When a noncombustible structure or area is used, these installations shall be—			
		a1i	(i) Ventilated with intake air that is coursed into a return air course or to the surface and that is not used to ventilate working places; or	Engineering	Preventive	Implement ventilation management strategies to address methane accumulation, Risk assess the potential for unexpected source/gas dynamic event at the extraction
		a1ii	(ii) Ventilated with intake air that is monitored for carbon monoxide or smoke by an AMS installed and operated according to § 75.351. Monitoring of intake air ventilating battery charging stations shall be	Engineering	Preventive	

			done with sensors not affected by hydrogen; or			face. Do not work in the return if there is high potential for an outburst, Develop and implement site-based stopping standards (especially design system that is not adversely affected by overpressure event e.g. large goaf fall/windblast; for example, consider flexible stoppings/sails that can effectively absorb without damage or failure)
		a1iii	(iii) Ventilated with intake air and equipped with sensors to monitor for heat and for carbon monoxide or smoke. Monitoring of intake air ventilating battery charging stations shall be done with sensors not affected by hydrogen. The sensors shall de-energize power to the installation, activate a visual and audible alarm located outside of and on the intake side of the enclosure, and activate doors that will automatically close when either of the following occurs:	Engineering	Preventive	
		a1iiiA	(A) The temperature in the noncombustible structure reaches 165 °F; or	Engineering	Preventive	
		a1iiiB	(B) The carbon monoxide concentration reaches 10 parts per million above the ambient level for the area, or the optical density of smoke reaches 0.022 per meter. At least every 31 days, sensors installed to monitor for carbon monoxide shall be calibrated with a known concentration of carbon monoxide and air sufficient to activate the closing door, or each smoke sensor shall be tested to determine that it functions correctly.	Engineering	Preventive	
		a2	(2) When a fire suppression system is used, these installations shall be—	Engineering	Preventive	
		a2i	(i) Ventilated with intake air that is coursed into a return air course or to the surface and that is not used to ventilate working places; or	Engineering	Preventive	

		a2ii	(ii) Ventilated with intake air that is monitored for carbon monoxide or smoke by an AMS installed and operated according to § 75.351. Monitoring of intake air ventilating battery charging stations shall be done with sensors not affected by hydrogen.	Engineering	Preventive	
		b	(b) This section does not apply to—			
		b1	(1) Rectifiers and power centers with transformers that are either dry-type or contain nonflammable liquid, if they are located at or near the section and are moved as the working section advances or retreats;			
		b2	(2) Submersible pumps;			
		b3	(3) Permissible pumps and associated permissible switchgear;			
		b4	(4) Pumps located on or near the section and that are moved as the working section advances or retreats;			
		b5	(5) Pumps installed in anthracite mines; and			
		b6	(6) Small portable pumps.			
75.341	Direct-fired intake air heaters	a	(a) If any system used to heat intake air malfunctions, the heaters affected shall switch off automatically.	Engineering	Preventive	Develop operating standards for monitoring the status of the development panel (e.g. gas, pressure differential, heat)
		b	(b) Thermal overload devices shall protect the blower motor from overheating.	Engineering	Preventive	
		c	(c) The fuel supply shall turn off automatically if a flame-out occurs.	Engineering	Preventive	
		d	(d) Each heater shall be located or guarded to prevent contact by persons and shall be equipped with a screen at the inlet to prevent combustible materials from passing over the burner units.	Engineering	Preventive	
		e	(e) If intake air heaters use liquefied fuel systems—	Engineering	Preventive	Plant or infrastructure provided with capacity for external
		e1	(1) Hydrostatic relief valves installed on	Engineering	Preventive	

			vaporizers and on storage tanks shall be vented; and			isolation of potential ignition sources (e.g. Isolation of power) and fuels
		e2	(2) Fuel storage tanks shall be located or protected to prevent fuel from leaking into the mine.	Engineering	Preventive	
		f	(f) Following any period of 8 hours or more during which a heater does not operate, the heater and its associated components shall be examined within its first hour of operation. Additionally, each heater and its components shall be examined at least once each shift that the heater operates. The examination shall include measurement of the carbon monoxide concentration at the bottom of each shaft, slope, or in the drift opening where air is being heated. The measurements shall be taken by a person designated by the operator or by a carbon monoxide sensor that is calibrated with a known concentration of carbon monoxide and air at least once every 31 days. When the carbon monoxide concentration at this location reaches 50 parts per million, the heater causing the elevated carbon monoxide level shall be shut down.	Engineering	Preventive	
75.342	Methane monitors	a1	(a)(1) MSHA approved methane monitors shall be installed on all face cutting machines, continuous miners, longwall face equipment, loading machines, and other mechanized equipment used to extract or load coal within the working place.	Engineering	Preventive	Develop trigger action response plan (TARP) that activates when gas levels exceed detection thresholds, Suitable face management

		a2	(2) The sensing device for methane monitors on longwall shearing machines shall be installed at the return air end of the longwall face. An additional sensing device also shall be installed on the longwall shearing machine, downwind and as close to the cutting head as practicable. An alternative location or locations for the sensing device required on the longwall shearing machine may be approved in the ventilation plan.	Engineering	Preventive	standards (e.g. stone dusting, web depth, cut profile, cutter head speed, cutting sequence), Confirm that original equipment manufacturers' (OEMs') designs adhere site-based standards
		a3	(3) The sensing devices of methane monitors shall be installed as close to the working face as practicable.	Engineering	Preventive	
		a4	(4) Methane monitors shall be maintained in permissible and proper operating condition and shall be calibrated with a known air-methane mixture at least once every 31 days. To assure that methane monitors are properly maintained and calibrated, the operator shall:	Engineering	Preventive	
		a4i	(i) Use persons properly trained in the maintenance, calibration, and permissibility of methane monitors to calibrate and maintain the devices.	Engineering	Preventive	
		a4ii	(ii) Maintain a record of all calibration tests of methane monitors. Records shall be maintained in a secure book that is not susceptible to alteration or electronically in a computer system so as to be secure and not susceptible to alteration.	Administrative	Preventive	
		a4iii	(iii) Retain the record of calibration tests for 1 year from the date of the test. Records shall be retained at a surface location at the mine and made available for inspection by	Administrative	Preventive	

			authorized representatives of the Secretary and the representative of miners.			
		b1	(b)(1) When the methane concentration at any methane monitor reaches 1.0 percent the monitor shall give a warning signal.	Engineering	Preventive	
		b2	(2) The warning signal device of the methane monitor shall be visible to a person who can de-energize electric equipment or shut down diesel-powered equipment on which the monitor is mounted.	Engineering	Preventive	
		c	(c) The methane monitor shall automatically de-energize electric equipment or shut down diesel-powered equipment on which it is mounted when—	Engineering	Preventive	
		c1	(1) The methane concentration at any methane monitor reaches 2.0 percent; or	Engineering	Preventive	
		c2	(2) The monitor is not operating properly.	Engineering	Preventive	
75.343	Underground shops	a	(a) Underground shops shall be equipped with an automatic fire suppression system meeting the requirements of § 75.1107–3 through § 75.1107–16, or be enclosed in a noncombustible structure or area.	Engineering	Mitigating	Plant and infrastructure provided with means to detect fire, alert personnel and trigger fire suppression system (e.g. smoke, CO, heat detector)
		b	(b) Underground shops shall be ventilated with intake air that is coursed directly into a return air course.	Engineering	Preventive	
75.344	Compressors	a	(a) Except compressors that are components of equipment such as locomotives and rock dusting machines and compressors of less than 5 horsepower, electrical compressors including those that may start automatically shall be:	Engineering	Preventive	

		a1	(1) Continuously attended by a person designated by the operator who can see the compressor at all times during its operation. Any designated person attending the compressor shall be capable of activating the fire suppression system and de-energizing or shutting off the compressor in the event of a fire; or,	Administrative	Preventive	Auditing/inspection - records and schedules (e.g. job task analysis/observation, planned task observation, safety observation), Understanding site-based standards for inspecting, sampling and testing the integrity of seals, stoppings, VCDs and environment
		a2	(2) Enclosed in a noncombustible structure or area which is ventilated by intake air coursed directly into a return air course or to the surface and equipped with sensors to monitor for heat and for carbon monoxide or smoke. The sensors shall deenergize power to the compressor, activate a visual and audible alarm located outside of and on the intake side of the enclosure, and activate doors to automatically enclose the noncombustible structure or area when either of the following occurs:	Engineering	Preventive / Mitigating	
		a2i	(i) The temperature in the noncombustible structure or area reaches 165 °F.	Engineering	Preventive	
		a2ii	(ii) The carbon monoxide concentration reaches 10 parts per million above the ambient level for the area, or the optical density of smoke reaches 0.022 per meter. At least once every 31 days, sensors installed to monitor for carbon monoxide shall be calibrated with a known concentration of carbon monoxide and air sufficient to activate the closing door, and each smoke sensor shall be tested to determine that it functions correctly.	Engineering	Preventive	
		b	(b) Compressors, except those exempted in paragraph (a), shall be equipped with a heat activated fire suppression system meeting the	Engineering	Preventive	

			requirements of 75.1107–3 through 75.1107–16.			
		c	(c) Two portable fire extinguishers or one extinguisher having at least twice the minimum capacity specified for a portable fire extinguisher in § 75.1100– 1(e) shall be provided for each compressor.	Engineering	Mitigating	
		d	(d) Notwithstanding the requirements of § 75.1107–4, upon activation of any fire suppression system used under paragraph (b) of this section, the compressor shall be automatically deenergized or automatically shut off.	Engineering	Preventive / Mitigating	Implement operator pre-start inspections for early detection of impending equipment failures (e.g. check fire suppression system pressure, check presence of appropriate fire extinguishers)
75.350	Belt air course ventilation	a	(a) The belt air course must not be used as a return air course; and except as provided in paragraph (b) of this section, the belt air course must not be used to provide air to working sections or to areas where mechanized mining equipment is being installed or removed.	Engineering	Preventive	Selection of materials suitable for the environment (e.g. fire resistant anti-static (FRAS) belts, inappropriate use of light alloys (aluminum, magnesium or titanium ignition)), Select equipment with monitoring devices (e.g. belt tracking detectors, belt under-speed, belt rip switches, belt tracking devices, vibration monitors),
		a1	(1) The belt air course must be separated with permanent ventilation controls from return air courses and from other intake air courses except as provided in paragraph (c) of this section.	Engineering	Preventive	
		a2	(2) Effective December 31, 2009, the air velocity in the belt entry must be at least 50 feet per minute. When requested by the mine operator, the district manager may approve lower velocities in the ventilation plan based on specific mine conditions.	Engineering	Preventive	

			Air velocities must be compatible with all fire detection systems and fire suppression systems used in the belt entry.			Training in awareness and response to alarms (e.g. belt tracking, excessive vibration, excessive temperature), Implement ventilation management strategies to address methane accumulation, Risk assess the potential for unexpected source/gas dynamic event at the extraction face. Do not work in the return if there is high potential for an outburst, Develop and implement site-based stopping standards (especially design system that is not adversely affected by overpressure event e.g. large goaf fall/windblast; for example, consider flexible stoppings/sails that can effectively absorb without damage or failure)
		b	(b) The use of air from a belt air course to ventilate a working section, or an area where mechanized mining equipment is being installed or removed, shall be permitted only when evaluated and approved by the district manager in the mine ventilation plan. The mine operator must provide justification in the plan that the use of air from a belt entry would afford at least the same measure of protection as where belt haulage entries are not used to ventilate working places. In addition, the following requirements must be met:	Engineering	Preventive	
		b1	(1) The belt entry must be equipped with an AMS that is installed, operated, examined, and maintained as specified in § 75.351.	Engineering	Preventive	
		b2	(2) All miners must be trained annually in the basic operating principles of the AMS, including the actions required in the event of activation of any AMS alert or alarm signal. This training must be conducted prior to working underground in a mine that uses belt air to ventilate working sections or areas where mechanized mining equipment is installed or removed. It must be conducted as part of a miner's 30 CFR part 48 new miner training (§ 48.5), experienced miner training (§ 48.6), or annual refresher training (§ 48.8).	Engineering	Preventive	
		b3i	(3)(i) The average concentration of respirable dust in the belt air course, when used as a section intake air course, must be	Engineering	Preventive	

			maintained at or below 1.0 mg/m3.			
		b3ii	(ii) Where miners on the working section are on a reduced standard below 1.0 mg/m3, the average concentration of respirable dust in the belt entry must be at or below the lowest applicable respirable dust standard on that section.	Engineering	Preventive	
		b3iii	(iii) A permanent designated area (DA) for dust measurements must be established at a point no greater than 50 feet upwind from the section loading point in the belt entry when the belt air flows over the loading point or no greater than 50 feet upwind from the point where belt air is mixed with air from another intake air course near the loading point. The DA must be specified and approved in the ventilation plan.	Engineering	Preventive	
		b4	(4) The primary escapeway must be monitored for carbon monoxide or smoke as specified in § 75.351 (f).	Engineering	Preventive	
		b5	(5) The area of the mine with a belt air course must be developed with three or more entries.	Engineering	Preventive	
		b6	(6) In areas of the mine developed after the effective date of this rule, unless approved by the district manager, no more than 50% of the total intake air, delivered to the working section or to areas where mechanized mining equipment is being installed or removed, can be supplied from the belt air course. The locations for measuring these air quantities must be approved in the mine ventilation plan.	Engineering	Preventive	

		b7	(7) The air velocity in the belt entry must be at least 100 feet per minute. When requested by the mine operator, the district manager may approve lower velocities in the ventilation plan based on specific mine conditions.	Engineering	Preventive	
		b8	(8) The air velocity in the belt entry must not exceed 1,000 feet per minute. When requested by the mine operator, the district manager may approve higher velocities in the ventilation plan based on specific mine conditions.	Engineering	Preventive	
		c	(c) Notwithstanding the provisions of § 75.380 (g), additional intake air may be added to the belt air course through a point-feed regulator. The location and use of point feeds must be approved in the mine ventilation plan.	Engineering	Preventive	
		d	(d) If the air through the point-feed regulator enters a belt air course which is used to ventilate a working section or an area where mechanized mining equipment is being installed or removed, the following conditions must be met:	Engineering	Preventive	
		d1	(1) The air current that will pass through the point-feed regulator must be monitored for carbon monoxide or smoke at a point within 50 feet upwind of the point-feed regulator. A second point must be monitored 1,000 feet upwind of the point-feed regulator unless the mine operator requests that a lesser distance be approved by the district manager in the mine ventilation plan based on mine specific conditions;	Engineering	Preventive	
		d2	(2) The air in the belt air course must be monitored for carbon monoxide or smoke upwind of the point-feed regulator. This sensor must be in the belt air course within 50 feet of	Engineering	Preventive	

			the mixing point where air flowing through the point-feed regulator mixes with the belt air;			
		d3	(3) The point-feed regulator must be provided with a means to close the regulator from the intake air course without requiring a person to enter the crosscut where the point-feed regulator is located. The point-feed regulator must also be provided with a means to close the regulator from a location in the belt air course immediately upwind of the crosscut containing the pointfeed regulator;	Engineering	Preventive	
		d4	(4) A minimum air velocity of 300 feet per minute must be maintained through the point-feed regulator;	Engineering	Preventive	
		d5	(5) The location(s) and use of a pointfeed regulator(s) must be approved in the mine ventilation plan and shown on the mine ventilation map; and	Engineering	Preventive	
		d6	(6) An AMS must be installed, operated, examined, and maintained as specified in § 75.351.	Engineering	Preventive	
75.351	Atmospheric monitoring systems	a	(a) AMS operation. Whenever personnel are underground and an AMS is used to fulfill the requirements of §75.323(d) (1) (ii), 75.340(a) (1) (ii), 75.340(a) (2) (ii), 75.350 (b), 75.350 (d), or 75.362 (f), the AMS must be operating and a designated AMS operator must be on duty at a location on the surface of the mine where audible and visual signals from the AMS must be seen or heard and the AMS operator can promptly respond to these signals.	Engineering	Preventive	Use designs where discharge storage devices automatically de-power or discharge when cabinet doors are open, when explosive atmospheres are detected, when failure of the storage device is detected, etc., Develop understandin

		b	(b) Designated surface location and AMS operator. When an AMS is used to comply with §75.323 (d) (1) (ii), 75.340 (a) (1) (ii), 75.340(a) (2) (ii), 75.350 (b), 75.350(d), or 75.362(f), the following requirements apply:	Engineering	Preventive	g of the importance of construction, operation and maintenance of seals, stoppings, gas drainage systems, and VCDs (to control atmosphere), Develop ability to control ventilation systems as required in the event of a fire (e.g. consider variable fan speed, reverse airflow direction), Design of adequate ventilation (e.g. monitor and manage methane accumulation, manage dust level - scrubber fans, venturis), Confirm ventilation system mitigates dead spots or potential areas of gas accumulation (e.g. inspection, modelling, dead spots resulting from multiple fans or multiple shafts)
		b1	(1) The mine operator must designate a surface location at the mine where signals from the AMS will be received and two-way voice communication is maintained with each working section, with areas where mechanized mining equipment is being installed or removed, and with other areas designated in the approved emergency evacuation and firefighting program of instruction (§ 75.1502).	Engineering	Preventive	
		b2	(2) The mine operator must designate an AMS operator to monitor and promptly respond to all AMS signals. The AMS operator must have as a primary duty the responsibility to monitor the malfunction, alert and alarm signals of the AMS, and to notify appropriate personnel of these signals. In the event of an emergency, the sole responsibility of the AMS operator shall be to respond to the emergency.	Engineering	Preventive	
		b3	(3) A map or schematic must be provided at the designated surface location that shows the locations and type of AMS sensor at each location, and the intended air flow direction at these locations. This map or schematic must be updated within 24 hours of any change in this information.	Engineering	Preventive	

		b4	(4) The names of the designated AMS operators and other appropriate personnel, including the designated person responsible for initiating an emergency mine evacuation under § 75.1501, and the method to contact these persons, must be provided at the designated surface location.	Engineering	Preventive	
		c	(c) Minimum operating requirements. AMSs used to comply with §75.323 (d) (1) (ii), 75.340 (a) (1) (ii), 75.340 (a) (2) (ii), 75.350 (b), 75.350 (d), or 75.362 (f) must:	Engineering	Preventive	
		c1	(1) Automatically provide visual and audible signals at the designated surface location for any interruption of circuit continuity and any electrical malfunction of the system. These signals must be of sufficient magnitude to be seen or heard by the AMS operator.	Engineering	Preventive	
		c2	(2) Automatically provide visual and audible signals at the designated surface location when the carbon monoxide concentration or methane concentration at any sensor reaches the alert level as specified in § 75.351(i). These signals must be of sufficient magnitude to be seen or heard by the AMS operator.	Engineering	Preventive	
		c3	(3) Automatically provide visual and audible signals at the designated surface location distinguishable from alert signals when the carbon monoxide, smoke, or methane concentration at any sensor reaches the alarm level as specified in § 75.351(i). These signals must be of sufficient magnitude to be seen or heard by the AMS operator.	Engineering	Preventive	

		c4	(4) Automatically provide visual and audible signals at all affected working sections and at all affected areas where mechanized mining equipment is being installed or removed when the carbon monoxide, smoke, or methane concentration at any sensor reaches the alarm level as specified in § 75.351 (i). These signals must be of sufficient magnitude to be seen or heard by miners working at these locations. Methane signals must be distinguishable from other signals.	Engineering	Preventive	
		c5	(5) Automatically provide visual and audible signals at other locations as specified in Mine Emergency Evacuation and Firefighting Program of Instruction (§ 75.1502) when the carbon monoxide, smoke, or methane concentration at any sensor reaches the alarm level as specified in § 75.351 (i). These signals must be seen or heard by miners working at these locations. Methane alarms must be distinguishable from other signals.	Engineering	Preventive	
		c6	(6) Identify at the designated surface location the operational status of all sensors.	Engineering	Preventive	
		c7	(7) Automatically provide visual and audible alarm signals at the designated surface location, at all affected working sections, and at all affected areas where mechanized mining equipment is being installed or removed when the carbon monoxide level at any two consecutive sensors alert at the same time. These signals must be seen or heard by the AMS operator and miners working at these locations.	Engineering	Preventive	
		d	(d) Location and installation of AMS sensors.	Engineering	Preventive	

		d1	(1) All AMS sensors, as specified in §§ 75.351 (e) through 75.351 (h), must be located such that measurements are representative of the mine atmosphere in these locations.	Engineering	Preventive	
		d2	(2) Carbon monoxide or smoke sensors must be installed near the center in the upper third of the entry, in a location that does not expose personnel working on the system to unsafe conditions. Sensors must not be located in abnormally high areas or in other locations where air flow patterns do not permit products of combustion to be carried to the sensors.	Engineering	Preventive	
		d3	(3) Methane sensors must be installed near the center of the entry, at least 12 inches from the roof, ribs, and floor, in a location that would not expose personnel working on the system to unsafe conditions.	Engineering	Preventive	
		e	(e) Location of sensors-belt air course.	Engineering	Preventive	
		e1	(1) In addition to the requirements of paragraph (d) of this section, any AMS used to monitor belt air courses under § 75.350 (b) must have approved sensors to monitor for carbon monoxide at the following locations:	Engineering	Preventive	
		e1i	(i) At or near the working section belt tailpiece in the air stream ventilating the belt entry. In longwall mining systems the sensor must be located upwind in the belt entry at a distance no greater than 150 feet from the mixing point where intake air is mixed with the belt air at or near the tailpiece;	Engineering	Preventive	
		e1ii	(ii) No more than 50 feet upwind from the point where the belt air course is combined with another	Engineering	Preventive	

			air course or splits into multiple air courses;			
		e1iii	(iii) At intervals not to exceed 1,000 feet along each belt entry. However, in areas along each belt entry where air velocities are between 50 and 100 feet per minute, spacing of sensors must not exceed 500 feet. In areas along each belt entry where air velocities are less than 50 feet per minute, the sensor spacing must not exceed 350 feet;	Engineering	Preventive	
		e1iv	(iv) Not more than 100 feet downwind of each belt drive unit, each tailpiece, transfer point, and each belt take-up. If the belt drive, tailpiece, and/or take-up for a single transfer point are installed together in the same air course, and the distance between the units is less than 100 feet, they may be monitored with one sensor downwind of the last component. If the distance between the units exceeds 100 feet, additional sensors are required downwind of each belt drive unit, each tailpiece, transfer point, and each belt take-up; and	Engineering	Preventive	
		e1v	(v) At other locations in any entry that is part of the belt air course as required and specified in the mine ventilation plan.	Engineering	Preventive	
		e2	(2) Smoke sensors must be installed to monitor the belt entry under § 75.350 (b) at the following locations:	Engineering	Preventive	
		e2i	(i) At or near the working section belt tailpiece in the air stream ventilating the belt entry. In longwall mining systems the sensor must be located upwind in the belt entry at a distance no greater than 150 feet from the mixing point where intake air is mixed with the belt air at	Engineering	Preventive	

			or near the tailpiece;			
		e2ii	(ii) Not more than 100 feet downwind of each belt drive unit, each tailpiece transfer point, and each belt take-up. If the belt drive, tailpiece, and/or take-up for a single transfer point are installed together in the same air course, and the distance between the units is less than 100 feet, they may be monitored with one sensor downwind of the last component. If the distance between the units exceeds 100 feet, additional sensors are required downwind of each belt drive unit, each tailpiece, transfer point, and each belt take-up; and	Engineering	Preventive	
		e2iii	(iii) At intervals not to exceed 3,000 feet along each belt entry.	Engineering	Preventive	
		2eiv	(iv) This provision shall be effective one year after the Secretary has determined that a smoke sensor is available to reliably detect fire in underground coal mines.	Engineering	Preventive	
		f	(f) Locations of sensors—the primary escapeway. When used to monitor the primary escapeway under § 75.350(b) (4), carbon monoxide or smoke sensors must be located in the primary escapeway within 500 feet of the working section and areas where mechanized mining equipment is being installed or removed. In addition, another sensor must be located within 500 feet inby the beginning of the panel. The point-feed sensor required by § 75.350(d) (1) may be used as the sensor at the beginning of	Engineering	Preventive	

			the panel if it is located within 500 feet inby the beginning of the panel.			
		g	(g) Location of sensors—return air splits.	Engineering	Preventive	
		g1	(1) If used to monitor return air splits under § 75.362 (f), a methane sensor must be installed in the return air split between the last working place, longwall or shortwall face ventilated by that air split, and the junction of the return air split with another air split, seal, or worked out area.	Engineering	Preventive	
		g2	(2) If used to monitor a return air split under § 75.323 (d) (1) (ii), the methane sensors must be installed at the following locations:	Engineering	Preventive	
		g2i	(i) In the return air course opposite the section loading point, or, if exhausting auxiliary fan(s) are used, in the return air course no closer than 300 feet downwind from the fan exhaust and at a point opposite or immediately outby the section loading point; and	Engineering	Preventive	
		g2ii	(ii) Immediately upwind from the location where the return air split meets another air split or immediately upwind of the location where an air split is used to ventilate seals or worked-out areas.	Engineering	Preventive	
		h	(h) Location of sensors—electrical installations. When monitoring the intake air ventilating underground transformer stations, battery charging stations, substations, rectifiers, or water pumps under 75.340 (a) (1) (ii) or § 75.340 (a) (2) (ii), at	Engineering	Preventive	

			least one sensor must be installed to monitor the mine atmosphere for carbon monoxide or smoke, located downwind and not greater than 50 feet from the electrical installation being monitored.			
		i	(i) Establishing alert and alarm levels. An AMS installed in accordance with the following paragraphs must initiate alert and alarm signals at the specified levels, as indicated:	Engineering	Preventive	
		i1	(1) For § 75.323 (d) (1) (ii) alarm at 1.5% methane.	Engineering	Preventive	
		i2	(2) For §§75.340(a) (1) (ii), 75.340(a) (2) (ii), 75.350 (b), and 75.350 (d), alert at 5 ppm carbon monoxide above the ambient level and alarm at 10 ppm carbon monoxide above the ambient level when carbon monoxide sensors are used; and alarm at a smoke optical density of 0.022 per meter when smoke sensors are used. Reduced alert and alarm settings approved by the district manager may be required for carbon monoxide sensors identified in the mine ventilation plan, § 75.371(nn).	Engineering	Preventive	
		i3	(3) For § 75.362 (f), alert at 1.0% methane and alarm at 1.5% methane.	Engineering	Preventive	
		j	(j) Establishing carbon monoxide ambient levels. Carbon monoxide ambient levels and the means to determine these levels must be approved in the mine ventilation plan (§ 75.371(hh)) for monitors installed in accordance with §75.340 (a) (1) (ii), 75.340 (a) (2) (ii), 75.350 (b), and 75.350 (d).	Engineering	Preventive	

		k	(k) Installation and maintenance. An AMS installed in accordance with §§75.323 (d) (1) (ii), 75.340(a) (1) (ii), 75.340(a) (2) (ii), 75.350 (b), 75.350 (d), or 75.362 (f) must be installed and maintained by personnel trained in the installation and maintenance of the system. The system must be maintained in proper operating condition.	Engineering	Preventive	
		l	(l) Sensors. Sensors used to monitor for carbon monoxide, methane, and smoke must be either of a type listed and installed in accordance with the recommendations of a nationally recognized testing laboratory approved by the Secretary; or these sensors must be of a type, and installed in a manner, approved by the Secretary.	Engineering	Preventive	
		m	(m) Time delays. When a demonstrated need exists, time delays may be incorporated into the AMS. These time delays must only be used to account for non-fire related carbon monoxide alert and alarm sensor signals. These time delays are limited to no more than three minutes. The use and length of any time delays, or other techniques or methods which eliminate or reduce the need for time delays, must be specified and approved in the mine ventilation plan.	Engineering	Preventive	
		n	(n) Examination, testing, and calibration.	Engineering	Preventive	
		n1	(1) At least once each shift when belts are operated as part of a production shift, sensors used to detect carbon monoxide or smoke in accordance with § 75.350 (b), and 75.350 (d), and alarms installed in accordance with § 75.350 (b) must be visually	Engineering	Preventive	

			examined.			
		n2	(2) At least once every seven days, alarms for AMS installed in accordance with §§ 75.350 (b), and 75.350 (d) must be functionally tested for proper operation.	Engineering	Preventive	
		n3	(3) At intervals not to exceed 31 days—	Engineering	Preventive	
		n3i	(i) Each carbon monoxide sensor installed in accordance with §§75.340 (a) (1) (ii), 75.340 (a) (2) (ii), 75.350 (b), or 75.350 (d) must be calibrated in accordance with the manufacturer's calibration specifications. Calibration must be done with a known concentration of carbon monoxide in air sufficient to activate the alarm;	Engineering	Preventive	
		n3ii	(ii) Each smoke sensor installed in accordance with §§75.340 (a) (1) (ii), 75.340(a) (2) (ii), 75.350 (b), or 75.350 (d) must be functionally tested in accordance with the manufacturer's calibration specifications;	Engineering	Preventive	
		n3iii	(iii) Each methane sensor installed in accordance with §§ 75.323(d) (1) (ii) or 75.362 (f) must be calibrated in accordance with the manufacturer's calibration specifications. Calibration must be done with a known concentration of methane in air sufficient to activate an alarm.	Engineering	Preventive	

		n3iv	(iv) If the alert or alarm signals will be activated during calibration of sensors, the AMS operator must be notified prior to and upon completion of calibration. The AMS operator must notify miners on affected working sections, areas where mechanized mining equipment is being installed or removed, or other areas designated in the approved emergency evacuation and firefighting program of instruction (§ 75.1502) when calibration will activate alarms and when calibration is completed.	Engineering	Preventive	
		n4	(4) Gases used for the testing and calibration of AMS sensors must be traceable to the National Institute of Standards and Technology reference standard for the specific gas. When these reference standards are not available for a specific gas, calibration gases must be traceable to an analytical standard which is prepared using a method traceable to the National Institute of Standards and Technology. Calibration gases must be within ± 2.0 percent of the indicated gas concentration.	Engineering	Preventive	
		o	(o) Recordkeeping.	Engineering	Preventive	
		o1	(1) When an AMS is used to comply with §§ 75.323 (d) (1) (ii), 75.340 (a) (1) (ii), 75.340 (a) (2) (ii), 75.350 (b), 75.350 (d), or 75.362 (f), individuals designated by the operator must make the following records by the end of the shift in which the following event(s) occur:	Engineering	Preventive	
		o1i	(i) If an alert or alarm signal occurs, a record of the date, time, location and type of sensor, and the cause for the	Engineering	Preventive	

			activation.			
		o1ii	(ii) If an AMS malfunctions, a record of the date, the extent and cause of the malfunction, and the corrective action taken to return the system to proper operation.	Engineering	Preventive	
		o1iii	(iii) A record of the seven-day tests of alert and alarm signals; calibrations; and maintenance of the AMS must be made by the person(s) performing these actions.	Engineering	Preventive	
		o2	(2) The person entering the record must include their name, date, and signature in the record.	Engineering	Preventive	
		o3	(3) The records required by this section must be kept either in a secure book that is not susceptible to alteration, or electronically in a computer system that is secure and not susceptible to alteration. These records must be maintained separately from other records and identifiable by a title, such as the 'AMS log.'	Engineering	Preventive	
		p	(p) Retention period. Records must be retained for at least one year at a surface location at the mine and made available for inspection by miners and authorized representatives of the Secretary.	Engineering	Preventive	
		q	(q) Training.	Engineering	Preventive	
		q1	(1) All AMS operators must be trained annually in the proper operation of the AMS. This training must include the following subjects:	Engineering	Preventive	
		q1i	(i) Familiarity with underground mining systems;	Engineering	Preventive	
		q1ii	(ii) Basic atmospheric monitoring system requirements;	Engineering	Preventive	
		q1iii	(iii) The mine emergency evacuation and firefighting program of instruction;	Engineering	Preventive	

		q1iv	(iv) The mine ventilation system including planned air directions;	Engineering	Preventive	
		q1v	(v) Appropriate response to alert, alarm and malfunction signals;	Engineering	Preventive	
		q1vi	(vi) Use of mine communication systems including emergency notification procedures; and	Engineering	Preventive	
		q1vii	(vii) AMS recordkeeping requirements.	Engineering	Preventive	
		q2	(2) At least once every six months, all AMS operators must travel to all working sections.	Engineering	Preventive	
		q3	(3) A record of the content of training, the person conducting the training, and the date the training was conducted, must be maintained at the mine for at least one year by the mine operator.	Engineering	Preventive	
		r	(r) Communications. When an AMS is used to comply with § 75.350 (b), a two-way voice communication system required by § 75.1600 must be installed in an entry that is separate from the entry in which the AMS is installed no later than August 2, 2004. The two-way voice communication system may be installed in the entry where the intake sensors required by § 75.350 (b) (4) or 75.350 (d) (1) are installed.	Engineering	Preventive	
75.352	Actions in response to AMS malfunction, alert, or alarm signals	a	(a) When a malfunction, alert, or alarm signal is received at the designated surface location, the sensor(s) that are activated must be identified and the AMS operator must promptly notify appropriate personnel.	Engineering	Mitigating	Develop understanding of the importance of construction, operation and maintenance of seals, stoppings, gas drainage systems, and VCDs (to control atmosphere), Develop ability to control ventilation
		b	(b) Upon notification of a malfunction, alert, or alarm signal, appropriate personnel must promptly initiate an investigation to determine the cause of the signal and take the required actions set forth	Engineering	Mitigating	

			in paragraphs (c), (d), or (e) of this section.			systems as required in the event of a fire (e.g. consider variable fan speed, reverse airflow direction), Design of adequate ventilation (e.g. monitor and manage methane accumulation, manage dust level - scrubber fans, venturis), Confirm ventilation system mitigates dead spots or potential areas of gas accumulation (e.g. inspection, modelling, dead spots resulting from multiple fans or multiple shafts), Confirm turnkey project and original plant and equipment manufacturer s' (OEMs') component designs adhere to site-based selection and procurement standards (e.g. intrinsically safe and flameproof equipment), Design to consider: rating and settings of
		c	(c) If any sensor installed in accordance with §75.340 (a) (1) (ii), 75.340 (a) (2) (ii), 75.350 (b), or 75.350 (d) indicates an alarm or if any two consecutive sensors indicate alert at the same time, the following procedures must be followed unless the cause of the signal(s) is known not to be a hazard to miners:	Engineering	Mitigating	
		c1	(1) Appropriate personnel must notify miners in affected working sections, in affected areas where mechanized mining equipment is being installed or removed, and at other locations specified in the § 75.1502 approved mine emergency evacuation and firefighting program of instruction; and	Engineering	Mitigating	
		c2	(2) All personnel in the affected areas, unless assigned other duties under § 75.1502, must be withdrawn promptly to a safe location identified in the mine emergency evacuation and firefighting program of instruction.	Engineering	Mitigating	
		d	(d) If there is an alert or alarm signal from a methane sensor installed in accordance with § 75.323 (d) (1) (ii) and 75.362 (f), an investigation must be initiated to determine the cause of the signal, and the actions required under § 75.323 must be taken.	Engineering	Mitigating	
		e	(e) If any fire detection components of the AMS malfunction or are inoperative, immediate action must be taken to return the system to proper operation. While the AMS component repairs are being made,	Engineering	Mitigating	

<table>
<tr><td></td><td></td><td></td><td>operation of the belt may continue if the following conditions are met:</td><td></td><td></td><td rowspan="6">protective devices, cable type/sizing, arc fault containment, vibration mounting, suitable separation between electrical and other components and ruggedness of components, limitations on external surface temperatures, etc., Establish a mechanism or system that provides continuous improvement of mine site specifications and will develop, review and feedback into the design/procurement process, Consider scheduling original equipment manufacturers' (OEMs') recommended maintenance inspections/services including life-cycle change-out (e.g. batteries, capacitors, switch gear, damaged cables or enclosures, bearings, rollers, exhaust manifolds,</td></tr>
<tr><td></td><td></td><td>e1</td><td>(1) If one AMS sensor malfunctions or becomes inoperative, a trained person must continuously monitor for carbon monoxide or smoke at the inoperative sensor.</td><td>Engineering</td><td>Mitigating</td></tr>
<tr><td></td><td></td><td>e2</td><td>(2) If two or more adjacent AMS sensors malfunction or become inoperative, a trained person(s) must patrol and continuously monitor for carbon monoxide or smoke so that the affected areas will be traveled each hour in their entirety, or a trained person must be stationed to monitor at each inoperative sensor.</td><td>Engineering</td><td>Mitigating</td></tr>
<tr><td></td><td></td><td>e3</td><td>(3) If the complete AMS malfunctions or becomes inoperative, trained persons must patrol and continuously monitor for carbon monoxide or smoke so that the affected areas will be traveled each hour in their entirety.</td><td>Engineering</td><td>Mitigating</td></tr>
<tr><td></td><td></td><td>e4</td><td>(4) The trained person(s) monitoring under this section must, at a minimum, have two-way voice communication capabilities with the AMS operator at intervals not to exceed 2,000 feet and report contaminant levels to the AMS operator at intervals not to exceed 60 minutes.</td><td>Engineering</td><td>Mitigating</td></tr>
<tr><td></td><td></td><td>e5</td><td>(5) The trained person(s) monitoring under this section must report immediately to the AMS operator any concentration of the contaminant that reaches either the alert or alarm level specified in § 75.351 (i), or the alternate alert and alarm levels specified in paragraph (e) (7) of this section, unless the source of the contaminant is</td><td>Engineering</td><td>Mitigating</td></tr>
</table>

			known not to present a hazard.			thermographic profiles), Establish an auditing process to confirm adherence to and evaluate the effectiveness of the maintenance strategy (e.g. periodically verify protection settings, ratings of protective devices - adhere to approved ratings or settings)
		e6	(6) Detectors used to monitor under this section must have a level of detectability equal to that required of the sensors in § 75.351 (l).	Engineering	Mitigating	
		e7	(7) For those AMSs using sensors other than carbon monoxide sensors, an alternate detector and the alert and alarm levels associated with that detector must be specified in the approved mine ventilation plan.	Engineering	Mitigating	
		f	(f) If the minimum air velocity is not maintained when required under § 75.350 (b) (7), immediate action must be taken to return the ventilation system to proper operation. While the ventilation system is being corrected, operation of the belt may continue only while a trained person(s) patrols and continuously monitors for carbon monoxide or smoke as set forth in § 75.352 (e) (3) through (7), so that the affected areas will be traveled each hour in their entirety.	Engineering	Mitigating	
		g	(g) The AMS shall automatically provide both a visual and audible signal in the belt entry at the point-feed regulator location, at affected sections, and at the designated surface location when carbon monoxide concentrations reach:	Engineering	Mitigating	
		g1	(1) The alert level at both point-feed intake monitoring sensors; or	Engineering	Mitigating	
		g2	(2) The alarm level at either pointfeed intake monitoring sensor.	Engineering	Mitigating	

75.360	Preshift examination at fixed intervals	a1	(a)(1) Except as provided in paragraph (a) (2) of this section, a certified person designated by the operator must make a preshift examination within 3 hours preceding the beginning of any 8- hour interval during which any person is scheduled to work or travel underground. No person other than certified examiners may enter or remain in any underground area unless a preshift examination has been completed for the established 8-hour interval. The operator must establish 8-hour intervals of time subject to the required preshift examinations.	Engineering	Preventive	Accountability under legislation, Auditing/inspection - records and schedules (e.g. rib inspection for cracks/fissures/odors), Develop an outbye roadway TARP based on monitoring data and visual inspections, Visual inspection of roadways to detect stress induced change, Conducted by competent (technically qualified, experienced) personnel, Supervised by suitably competent person (as per statutory requirements and tickets), Resourcing the task correctly with competent people and planning, Competencies (e.g. QLD: Black Coal Competency) required for underground operators
		a2	(2) Preshift examinations of areas where pumpers are scheduled to work or travel shall not be required prior to the pumper entering the areas if the pumper is a certified person and the pumper conducts an examination for hazardous conditions and violations of the mandatory health or safety standards referenced in paragraph (b) (11) of this section, tests for methane and oxygen deficiency, and determines if the air is moving in its proper direction in the area where the pumper works or travels. The examination of the area must be completed before the pumper performs any other work. A record of all hazardous conditions and violations of the mandatory health or safety standards found by the pumper shall be made and retained in accordance with § 75.363 of this part.	Administrative	Preventive	

		b	(b) The person conducting the preshift examination shall examine for hazardous conditions and violations of the mandatory health or safety standards referenced in paragraph (b) (11) of this section, test for methane and oxygen deficiency, and determine if the air is moving in its proper direction at the following locations:	Administrative	Preventive	
		b1	(1) Roadways, travelways and track haulageways where persons are scheduled, prior to the beginning of the preshift examination, to work or travel during the oncoming shift.	Engineering	Preventive	
		b2	(2) Belt conveyors that will be used to transport persons during the oncoming shift and the entries in which these belt conveyors are located.	Engineering	Preventive	
		b3	(3) Working sections and areas where mechanized mining equipment is being installed or removed, if anyone is scheduled to work on the section or in the area during the oncoming shift. The scope of the examination shall include the working places, approaches to worked-out areas and ventilation controls on these sections and in these areas, and the examination shall include tests of the roof, face and rib conditions on these sections and in these areas.	Engineering	Preventive	

		b4	(4) Approaches to worked-out areas along intake air courses and at the entries used to carry air into worked-out areas if the intake air passing the approaches is used to ventilate working sections where anyone is scheduled to work during the oncoming shift. The examination of the approaches to the worked-out areas shall be made in the intake air course immediately inby and outby each entry used to carry air into the worked-out area. An examination of the entries used to carry air into the worked-out areas shall be conducted at a point immediately inby the intersection of each entry with the intake air course.	Engineering	Preventive	
		b5	(5) Seals along intake air courses where intake air passes by a seal to ventilate working sections where anyone is scheduled to work during the oncoming shift.	Engineering	Preventive	
		b6i	(6)(i) Entries and rooms developed after November 15, 1992, and developed more than 2 crosscuts off an intake air course without permanent ventilation controls where intake air passes through or by these entries or rooms to reach a working section where anyone is scheduled to work during the oncoming shift; and,	Engineering	Preventive	
		b6ii	(ii) Entries and rooms developed after November 15, 1992, and driven more than 20 feet off an intake air course without a crosscut and without permanent ventilation controls where intake air passes through or by these entries or rooms to reach a working section where anyone is scheduled to work during the oncoming shift.	Engineering	Preventive	

		b7	(7) Areas where trolley wires or trolley feeder wires are to be or will remain energized during the oncoming shift.	Engineering	Preventive	
		b8	(8) High spots along intake air courses where methane is likely to accumulate, if equipment will be operated in the area during the shift.	Engineering	Preventive	
		b9	(9) Underground electrical installations referred to in § 75.340 (a), except those pumps listed in § 75.340 (b) (2) through (b) (6), and areas where compressors subject to § 75.344 are installed if the electrical installation or compressor is or will be energized during the shift.	Engineering	Preventive	
		b10	(10) Other areas where work or travel during the oncoming shift is scheduled prior to the beginning of the preshift examination.	Engineering	Preventive	
		b11	(11) Preshift examinations shall include examinations to identify violations of the standards listed below:	Engineering	Preventive	
		b11i	(i) § 75.202 (a) and 75.220 (a) (1)—roof control;	Engineering	Preventive	
		b11ii	(ii) § 75.333(h) and 75.370(a) (1)—ventilation, methane;	Engineering	Preventive	
		b11iii	(iii) § 75.400 and 75.403—accumulations of combustible materials and application of rock dust;	Engineering	Preventive	
		b11iv	(iv) § 75.1403—other safeguards, limited to maintenance of travelways along belt conveyors, off track haulage roadways, and track haulage, track switches, and other components for haulage;	Engineering	Preventive	
		b11v	(v) § 75.1722 (a)—guarding moving machine parts; and	Engineering	Preventive	
		b11vi	(vi) § 75.1731 (a)—maintenance of belt conveyor components.	Engineering	Preventive	

		c	(c) The person conducting the preshift examination shall determine the volume of air entering each of the following areas if anyone is scheduled to work in the areas during the oncoming shift:	Engineering	Preventive	
		c1	(1) In the last open crosscut of each set of entries or rooms on each working section and areas where mechanized mining equipment is being installed or removed. The last open crosscut is the crosscut in the line of pillars containing the permanent stoppings that separate the intake air courses and the return air courses.	Engineering	Preventive	
		c2	(2) On each longwall or shortwall in the intake entry or entries at the intake end of the longwall or shortwall face immediately outby the face and the velocity of air at each end of the face at the locations specified in the approved ventilation plan.	Engineering	Preventive	
		c3	(3) At the intake end of any pillar line—	Engineering	Preventive	
		c3i	(i) If a single split of air is used, in the intake entry furthest from the return air course, immediately outby the first open crosscut outby the line of pillars being mined; or	Engineering	Preventive	
		c3ii	(ii) If a split system is used, in the intake entries of each split immediately inby the split point.	Engineering	Preventive	
		d	(d) The person conducting the preshift examination shall check the refuge alternative for damage, the integrity of the tamper-evident seal and the mechanisms required to deploy the refuge alternative, and the ready availability of compressed oxygen and air.	Engineering	Preventive	

		e	(e) The district manager may require the operator to examine other areas of the mine or examine for other hazards and violations of other mandatory health or safety standards found during the preshift examination.	Engineering	Preventive	
		f	(f) Certification. At each working place examined, the person doing the preshift examination shall certify by initials, date, and the time, that the examination was made. In areas required to be examined outby a working section, the certified person shall certify by initials, date, and the time at enough locations to show that the entire area has been examined.	Engineering	Preventive	
		g	(g) Recordkeeping. A record of the results of each preshift examination, including a record of hazardous conditions and violations of the nine mandatory health or safety standards and their locations found by the examiner during each examination, and of the results and locations of air and methane measurements, shall be made on the surface before any persons, other than certified persons conducting examinations required by this subpart, enter any underground area of the mine. The results of methane tests shall be recorded as the percentage of methane measured by the examiner. The record shall be made by the certified person who made the examination or by a person designated by the operator. If the record is made by someone other than the examiner, the examiner shall verify the record by initials and date by or at the end of the shift for which the	Engineering	Preventive	

			examination was made. A record shall also be made by a certified person of the action taken to correct hazardous conditions and violations of mandatory health or safety standards found during the preshift examination. All preshift and corrective action records shall be countersigned by the mine foreman or equivalent mine official by the end of the mine foreman's or equivalent mine official's next regularly scheduled working shift. The records required by this section shall be made in a secure book that is not susceptible to alteration or electronically in a computer system so as to be secure and not susceptible to alteration.			
		h	(h) Retention period. Records shall be retained at a surface location at the mine for at least 1 year and shall be made available for inspection by authorized representatives of the Secretary and the representative of miners.	Engineering	Preventive	
75.361	Supplemental examination	a1	(a)(1) Except for certified persons conducting examinations required by this subpart, within 3 hours before anyone enters an area in which a preshift examination has not been made for that shift, a certified person shall examine the area for hazardous conditions and violations of the mandatory health or safety standards referenced in paragraph (a) (2) of this section, determine whether the air is traveling in its proper direction and at its normal volume, and test for	Engineering	Preventive	Visual inspection of roadways to detect stress induced change, Conducted by competent (technically qualified, experienced) personnel, Supervised by suitably competent person (as per statutory requirements and tickets), Resourcing

			methane and oxygen deficiency.			the task correctly with competent people and planning, Competencies (e.g. QLD: Black Coal Competency) required for underground operators
		a2	(2) Supplemental examinations shall include examinations to identify violations of the standards listed below:	Engineering	Preventive	
		a2i	(i) § 75.202 (a) and 75.220 (a) (1)—roof control;	Engineering	Preventive	
		a2ii	(ii) § 75.333 (h) and 75.370(a) (1)—ventilation, methane;	Engineering	Preventive	
		a2iii	(iii) § 75.400 and 75.403—accumulations of combustible materials and application of rock dust;	Engineering	Preventive	
		a2iv	(iv) § 75.1403—other safeguards, limited to maintenance of travelways along belt conveyors, off track haulage roadways, and track haulage, track switches, and other components for haulage;	Engineering	Preventive	
		a2v	(v) § 75.1722 (a)—guarding moving machine parts; and	Engineering	Preventive	
		a2vi	(vi) § 75.1731 (a)—maintenance of belt conveyor components.	Engineering	Preventive	
		b	(b) Certification. At each working place examined, the person making the supplemental examination shall certify by initials, date, and the time, that the examination was made. In areas required to be examined outby a working section, the certified person shall certify by initials, date, and the time at enough locations to show that the entire area has been examined.	Engineering	Preventive	

75.362	On-shift examination	a1	(a)(1) At least once during each shift, or more often if necessary for safety, a certified person designated by the operator shall conduct an on-shift examination of each section where anyone is assigned to work during the shift and any area where mechanized mining equipment is being installed or removed during the shift. The certified person shall check for hazardous conditions and violations of the mandatory health or safety standards referenced in paragraph (a) (3) of this section, test for methane and oxygen deficiency, and determine if the air is moving in its proper direction.	Engineering	Preventive	
		a2	(2) A person designated by the operator shall conduct an examination to assure compliance with the respirable dust control parameters specified in the mine ventilation plan. In those instances when a shift change is accomplished without an interruption in production on a section, the examination shall be made anytime within 1 hour of the shift change. In those instances when there is an interruption in production during the shift change, the examination shall be made before production begins on a section. Deficiencies in dust controls shall be corrected before production begins or resumes. The examination shall include air quantities and velocities, water pressures and flow rates, excessive leakage in the water delivery system, water spray numbers and orientations, section ventilation and control device placement, and any other dust	Engineering	Preventive	

			suppression measures required by the ventilation plan. Measurements of the air velocity and quantity, water pressure and flow rates are not required if continuous monitoring of these controls is used and indicates that the dust controls are functioning properly.			
		a3	(3) On-shift examinations shall include examinations to identify violations of the standards listed below:	Engineering	Preventive	
		a3i	(i) § 75.202 (a) and 75.220 (a) (1)—roof control;	Engineering	Preventive	
		a3ii	(ii) § 75.333 (h) and 75.370 (a) (1)—ventilation, methane;	Engineering	Preventive	
		a3iii	(iii) § 75.400 and 75.403—accumulations of combustible materials and application of rock dust;	Engineering	Preventive	
		a3iv	(iv) § 75.1403—other safeguards, limited to maintenance of travelways along belt conveyors, off track haulage roadways, and track haulage, track switches, and other components for haulage;	Engineering	Preventive	
		a3v	(v) § 75.1722 (a)—guarding moving machine parts; and	Engineering	Preventive	
		a3vi	(vi) § 75.1731 (a)—maintenance of belt conveyor components.	Engineering	Preventive	

		b	(b) During each shift that coal is produced, a certified person shall examine for hazardous conditions and violations of the mandatory health or safety standards referenced in paragraph (a) (3) of this section along each belt conveyor haulageway where a belt conveyor is operated. This examination may be conducted at the same time as the preshift examination of belt conveyors and belt conveyor haulageways, if the examination is conducted within 3 hours before the oncoming shift.	Engineering	Preventive	
		c	(c) Persons conducting the on-shift examination shall determine at the following locations:	Engineering	Preventive	
		c1	(1) The volume of air in the last open crosscut of each set of entries or rooms on each section and areas where mechanized mining equipment is being installed or removed. The last open crosscut is the crosscut in the line of pillars containing the permanent stoppings that separate the intake air courses and the return air courses.	Engineering	Preventive	
		c2	(2) The volume of air on a longwall or shortwall, including areas where longwall or shortwall equipment is being installed or removed, in the intake entry or entries at the intake end of the longwall or shortwall.	Engineering	Preventive	
		c3	(3) The velocity of air at each end of the longwall or shortwall face at the locations specified in the approved ventilation plan.	Engineering	Preventive	
		c4	(4) The volume of air at the intake end of any pillar line—	Engineering	Preventive	
		c4i	(i) Where a single split of air is used in the intake entry furthest from the return air course	Engineering	Preventive	

			immediately outby the first open crosscut outby the line of pillars being mined; or			
		c4ii	(ii) Where a split system is used in the intake entries of each split immediately inby the split point.	Engineering	Preventive	
		d1	(d) (1) A qualified person shall make tests for methane—	Engineering	Preventive	
		d1i	(i) At the start of each shift at each working place before electrically operated equipment is energized; and	Engineering	Preventive	
		d1ii	(ii) Immediately before equipment is energized, taken into, or operated in a working place; and	Engineering	Preventive	
		d1iii	(iii) At 20-minute intervals, or more often if required in the approved ventilation plan at specific locations, during the operation of equipment in the working place.	Engineering	Preventive	
		d2	(2) Except as provided for in paragraph (d) (3) of this section, these methane tests shall be made at the face from under permanent roof support, using extendable probes or other acceptable means. When longwall or shortwall mining systems are used, these methane tests shall be made at the shearer, the plow, or the cutting head. When mining has been stopped for more than 20 minutes, methane tests shall be conducted prior to the startup of equipment.	Engineering	Preventive	
		d3	(3) As an alternative method of compliance with paragraph (d) (2) of this section during roof bolting, methane tests may be made by sweeping an area not less than 16 feet inby the last area of permanently supported roof, using a probe or other acceptable means. This method of testing is conditioned on meeting the following requirements:	Engineering	Preventive	

		d3i	(i) The roof bolting machine must be equipped with an integral automated temporary roof support (ATRS) system that meets the requirements of 30 CFR 75.209.	Engineering	Preventive	
		d3ii	(ii) The roof bolting machine must have a permanently mounted, MSHA-approved methane monitor which meets the maintenance and calibration requirements of 30 CFR 75.342 (a) (4), the warning signal requirements of 30 CFR 75.342 (b), and the automatic deenergization requirements of 30 CFR 75.342 (c).	Engineering	Preventive	
		d3iii	(iii) The methane monitor sensor must be mounted near the inby end and within 18 inches of the longitudinal center of the ATRS support, and positioned at least 12 inches from the roof when the ATRS is fully deployed.	Engineering	Preventive	
		d3iv	(iv) Manual methane tests must be made at intervals not exceeding 20 minutes. The test may be made either from under permanent roof support or from the roof bolter's work position protected by the deployed ATRS.	Engineering	Preventive	
		d3v	(v) Once a methane test is made at the face, all subsequent methane tests in the same area of unsupported roof must also be made at the face, from under permanent roof support, using extendable probes or other acceptable means at intervals not exceeding 20 minutes.	Engineering	Preventive	
		d3vi	(vi) The district manager may require that the ventilation plan include the minimum air quantity and the position and placement of ventilation controls to be maintained during roof bolting.	Engineering	Preventive	

		e	(e) If auxiliary fans and tubing are used, they shall be inspected frequently.	Engineering	Preventive	
		f	(f) During each shift that coal is produced and at intervals not exceeding 4 hours, tests for methane shall be made by a certified person or by an atmospheric monitoring system (AMS) in each return split of air from each working section between the last working place, or longwall or shortwall face, ventilated by that split of air and the junction of the return air split with another air split, seal, or worked-out area. If auxiliary fans and tubing are used, the tests shall be made at a location outby the auxiliary fan discharge.	Engineering	Preventive	
		g	(g) Certification.	Engineering	Preventive	
		g1	(1) The person conducting the on-shift examination in belt haulage entries shall certify by initials, date, and time that the examination was made. The certified person shall certify by initials, date, and the time at enough locations to show that the entire area has been examined.	Engineering	Preventive	
		g2	(2) The certified person directing the on-shift examination to assure compliance with the respirable dust control parameters specified in the mine ventilation plan shall certify by initials, date, and time that the examination was made.	Engineering	Preventive	
75.364	Weekly	a	(a) Worked-out areas.	Engineering	Preventive	

	examination	a1	(1) At least every 7 days, a certified person shall examine unsealed worked-out areas where no pillars have been recovered by traveling to the area of deepest penetration; measuring methane and oxygen concentrations and air quantities and making tests to determine if the air is moving in the proper direction in the area. The locations of measurement points where tests and measurements will be performed shall be included in the mine ventilation plan and shall be adequate in number and location to assure ventilation and air quality in the area. Air quantity measurements shall also be made where the air enters and leaves the worked-out area. An alternative method of evaluating the ventilation of the area may be approved in the ventilation plan.	Administrative	Preventive	
		a2	(2) At least every 7 days, a certified person shall evaluate the effectiveness of bleeder systems required by § 75.334 as follows:	Administrative	Preventive	
		a2i	(i) Measurements of methane and oxygen concentrations and air quantity and a test to determine if the air is moving in its proper direction shall be made where air enters the worked-out area.	Engineering	Preventive	
		a2ii	(ii) Measurements of methane and oxygen concentrations and air quantity and a test to determine if the air is moving in the proper direction shall be made immediately before the air enters a return split of air.	Engineering	Preventive	

		a2iii	(iii) At least one entry of each set of bleeder entries used as part of a bleeder system under § 75.334 shall be traveled in its entirety. Measurements of methane and oxygen concentrations and air quantities and a test to determine if the air is moving in the proper direction shall be made at the measurement point locations specified in the mine ventilation plan to determine the effectiveness of the bleeder system.	Engineering	Preventive	
		a2iv	(iv) In lieu of the requirements of paragraphs (a) (2) (i) and (iii) of this section, an alternative method of evaluation may be specified in the ventilation plan provided the alternative method results in proper evaluation of the effectiveness of the bleeder system.	Engineering	Preventive	
		b	(b) Hazardous conditions and violations of mandatory health or safety standards. At least every 7 days, an examination for hazardous conditions and violations of the mandatory health or safety standards referenced in paragraph (b) (8) of this section shall be made by a certified person designated by the operator at the following locations:	Engineering	Preventive	
		b1	(1) In at least one entry of each intake air course, in its entirety, so that the entire air course is traveled.	Engineering	Preventive	
		b2	(2) In at least one entry of each return air course, in its entirety, so that the entire air course is traveled.	Engineering	Preventive	
		b3	(3) In each longwall or shortwall travelway in its entirety, so that the entire travelway is traveled.	Engineering	Preventive	

		b4	(4) At each seal along return and bleeder air courses and at each seal along intake air courses not examined under § 75.360 (b) (5).	Engineering	Preventive	
		b5	(5) In each escapeway so that the entire escapeway is traveled.	Engineering	Preventive	
		b6	(6) On each working section not examined under § 75.360 (b) (3) during the previous 7 days.	Engineering	Preventive	
		b7	(7) At each water pump not examined during a preshift examination conducted during the previous 7 days.	Engineering	Preventive	
		b8	(8) Weekly examinations shall include examinations to identify violations of the standards listed below:	Administrative	Preventive	
		b8i	(i) § 75.202 (a) and 75.220 (a) (1)—roof control;	Engineering	Preventive	
		b8ii	(ii) § 75.333 (h) and 75.370 (a) (1)—ventilation, methane;	Engineering	Preventive	
		b8iii	(iii) § 75.400 and 75.403—accumulations of combustible materials and application of rock dust; and	Engineering	Preventive	
		b8iv	(iv) § 75.1403—maintenance of off track haulage roadways, and track haulage, track switches, and other components for haulage;	Engineering	Preventive	
		b8v	(v) § 75.1722 (a)—guarding moving machine parts; and	Engineering	Preventive	
		b8vi	(vi) § 75.1731 (a)—maintenance of belt conveyor components.	Engineering	Preventive	
		c	(c) Measurements and tests. At least every 7 days, a certified person shall—	Administrative	Preventive	
		c1	(1) Determine the volume of air entering the main intakes and in each intake split;	Engineering	Preventive	
		c2	(2) Determine the volume of air and test for methane in the last open crosscut in any pair or set of developing entries or rooms, in the return of each split of air	Engineering	Preventive	

			immediately before it enters the main returns, and where the air leaves the main returns; and			
		c3	(3) Test for methane in the return entry nearest each set of seals immediately after the air passes the seals.	Engineering	Preventive	
		d	(d) Hazardous conditions shall be corrected immediately. If the condition creates an imminent danger, everyone except those persons referred to in section 104 (c) of the Act shall be withdrawn from the area affected to a safe area until the hazardous condition is corrected. Any violation of the nine mandatory health or safety standards found during a weekly examination shall be corrected.	Engineering	Preventive	
		e	(e) The weekly examination may be conducted at the same time as the preshift or on-shift examinations.	Engineering	Preventive	
		f1	(f) (1) The weekly examination is not required during any 7 day period in which no one enters any underground area of the mine.	Engineering	Preventive	
		f2	(2) Except for certified persons required to make examinations, no one shall enter any underground area of the mine if a weekly examination has not been completed within the previous 7 days.	Engineering	Preventive	
		g	(g) Certification. The person making the weekly examinations shall certify by initials, date, and the time that the examination was made. Certifications and times shall appear at enough locations to show that the entire area has been examined.	Engineering	Preventive	

		h	(h) Recordkeeping. At the completion of any shift during which a portion of a weekly examination is conducted, a record of the results of each weekly examination, including a record of hazardous conditions and violations of the nine mandatory health or safety standards found during each examination and their locations, the corrective action taken, and the results and location of air and methane measurements, shall be made. The results of methane tests shall be recorded as the percentage of methane measured by the examiner. The record shall be made by the person making the examination or a person designated by the operator. If made by a person other than the examiner, the examiner shall verify the record by initials and date by or at the end of the shift for which the examination was made. The record shall be countersigned by the mine foreman or equivalent mine official by the end of the mine foreman's or equivalent mine official's next regularly scheduled working shift. The records required by this section shall be made in a secure book that is not susceptible to alteration or electronically in a computer system so as to be secure and not susceptible to alteration.	Engineering	Preventive	
		i	(i) Retention period. Records shall be retained at a surface location at the mine for at least 1 year and shall be made available for inspection by authorized representatives of the Secretary and the representative of miners.	Engineering	Preventive	

75.380	Escapeways; bituminous and lignite mines	a	(a) Except in situations addressed in § 75.381, § 75.385 and § 75.386, at least two separate and distinct travelable passageways shall be designated as escapeways and shall meet the requirements of this section.	Engineering	Mitigating	
		b1	(b) (1) Escapeways shall be provided from each working section, and each area where mechanized mining equipment is being installed or removed, continuous to the surface escape drift opening or continuous to the escape shaft or slope facilities to the surface.	Engineering	Mitigating	Develop an emergency response plan according to the risk assessment and regulatory requirements/ guidelines that addresses fire fighting, evacuation and medical treatment (Note, e.g. MDG 1020 Guidelines for underground emergency escape systems and the provisions of self-rescuers, October 2010; MDG 1022 Guideline for determining withdrawal conditions from underground coal mines, October 2010)
		b2	(2) During equipment installation, these escapeways shall begin at the projected location for the section loading point. During equipment removal, they shall begin at the location of the last loading point.	Engineering	Mitigating	
		c	(c) The two separate and distinct escapeways required by this section shall not end at a common shaft, slope, or drift opening, except that multiple compartment shafts or slopes separated by walls constructed of noncombustible material may be used as separate and distinct passageways.	Engineering	Mitigating	
		d	(d) Each escapeway shall be—			
		d1	(1) Maintained in a safe condition to always assure passage of anyone, including disabled persons;	Engineering	Mitigating	Develop an emergency response plan according to the risk assessment and regulatory requirements/
		d2	(2) Clearly marked to show the route and direction of travel to the surface;	Engineering	Mitigating	

		d3	(3) Maintained to at least a height of 5 feet from the mine floor to the mine roof, excluding the thickness of any roof support, except that the escapeways shall be maintained to at least the height of the coalbed, excluding the thickness of any roof support, where the coalbed is less than 5 feet. In areas of mines where escapeways pass through doors, the height may be less than 5 feet, provided that sufficient height is maintained to enable miners, including disabled persons, to escape quickly in an emergency. In areas of mines developed before November 16, 1992, where escapeways pass over or under overcasts or undercasts, the height may be less than 5 feet provided that sufficient height is maintained to enable miners, including disabled persons, to escape quickly in an emergency. When there is a need to determine whether sufficient height is provided, MSHA may require a stretcher test where 4 persons carry a miner through the area in question on a stretcher;	Engineering	Mitigating	guidelines that addresses fire fighting, evacuation and medical treatment (Note, e.g. MDG 1020 Guidelines for underground emergency escape systems and the provisions of self-rescuers, October 2010; MDG 1022 Guideline for determining withdrawal conditions from underground coal mines, October 2010), Awareness and competency in self and aided escape, Train relevant mine personnel with respect to mine emergency response and management (especially incident management teams, mine managers/Senior Site Executives, control room operators e.g. New South Wales Mines Rescue Mine Emergency Preparedness
		d4	(4) Maintained at least 6 feet wide except—	Engineering	Mitigating	
		d4i	(i) Where necessary supplemental roof support is installed, the escapeway shall not be less than 4 feet wide; or	Engineering	Mitigating	
		d4ii	(ii) Where the route of travel passes through doors or other permanent ventilation controls, the escapeway shall be at least 4 feet wide to enable miners to escape quickly in an emergency, or	Engineering	Mitigating	

		d4iii	(iii) Where the alternate escapeway passes through doors or other permanent ventilation controls or where supplemental roof support is required and sufficient width is maintained to enable miners, including disabled persons, to escape quickly in an emergency. When there is a need to determine whether sufficient width is provided, MSHA may require a stretcher test where 4 persons carry a miner through the area in question on a stretcher, or	Engineering	Mitigating	Course/Queensland Mine Emergency Management System), Emergency response systems (e.g. consider lifelines, fresh air bases. refuge bays, Compressed Air Breathing Apparatus CABA refilling stations, Self Contained Self Rescue [SCSR] cache, mine evacuation plans), Undertake an initial risk assessment to identify hazards and scenarios associated with potential mine fires or explosions including the potential risks associated with mine evacuation, Develop ability to monitor and use changes in gas levels as triggers for personnel evacuation in the event of a fire or potential explosion, Instigate training in competencies for fire fighting, evacuation procedures and the use of Self Contained Self Rescuers (SCSR),
		d4iv	(iv) Where mobile equipment near working sections, and other equipment essential to the ongoing operation of longwall sections, is necessary during normal mining operations, such as material cars containing rock dust or roof control supplies, or is to be used for the evacuation of miners off the section in the event of an emergency. In any instance, escapeways shall be of sufficient width to enable miners, including disabled persons, to escape quickly in an emergency. When there is a need to determine whether sufficient width is provided, MSHA may require a stretcher test where 4 persons carry a miner through the area in question on a stretcher;	Engineering	Mitigating	
		d5	(5) Located to follow the most direct, safe and practical route to the nearest mine opening suitable for the safe evacuation of miners; and	Engineering	Mitigating	
		d6	(6) Provided with ladders, stairways, ramps, or similar facilities where the escapeways cross over obstructions.	Engineering	Mitigating	
		d7	(7) Provided with a continuous, durable directional lifeline or	Engineering	Mitigating	

			equivalent device that shall be—			Awareness of evacuation procedures in cases of potential major fires and explosions
		d7i	(i) Installed and maintained throughout the entire length of each escapeway as defined in paragraph (b) (1) of this section;	Engineering	Mitigating	
		d7ii	(ii) Flame-resistant in accordance with the requirements of part 18 of this chapter upon replacement of existing lifelines; but in no case later than June 15, 2009;	Engineering	Mitigating	
		d7iii	(iii) Marked with a reflective material every 25 feet;	Engineering	Mitigating	
		d7iv	(iv) Located in such a manner for miners to use effectively to escape;	Engineering	Mitigating	
		d7v	(v) Equipped with one directional indicator cone securely attached to the lifeline, signifying the route of escape, placed at intervals not exceeding 100 feet. Cones shall be installed so that the tapered section points inby;	Engineering	Mitigating	
		d7vi	(vi) Equipped with one sphere securely attached to the lifeline at each intersection where personnel doors are installed in adjacent crosscuts;	Engineering	Mitigating	
		d7vii	(vii) Equipped with two securely attached cones, installed consecutively with the tapered section pointing inby, to signify an attached branch line is immediately ahead.	Engineering	Mitigating	
		d7viiA	(A) A branch line leading from the lifeline to an SCSR cache will be marked with four cones with the base sections in contact to form two diamond shapes. The cones must be placed within reach of the lifeline.	Engineering	Mitigating	
		d7viiB	(B) A branch line leading from the lifeline to a refuge alternative will be marked with a rigid spiraled coil at least eight inches in length. The spiraled coil must be	Engineering	Mitigating	

			placed within reach of the lifeline			
		e	(e) Surface openings shall be adequately protected to prevent surface fires, fumes, smoke, and flood water from entering the mine.	Engineering	Mitigating	
		f	(f) Primary escapeway.	Engineering	Mitigating	
		f1	(1) One escapeway that is ventilated with intake air shall be designated as the primary escapeway. The primary escapeway shall have a higher ventilation pressure than the belt entry unless the mine operator submits an alternative in the mine ventilation plan to protect the integrity of the primary escapeway, based on mine specific conditions, which is approved by the district manager.	Engineering	Mitigating	
		f2	(2) Paragraphs (f) (3) through (f) (7) of this section apply as follows:	Engineering	Mitigating	
		f2i	(i) To all areas of a primary escapeway developed on or after November 16, 1992;	Engineering	Mitigating	
		f2ii	(ii) Effective as of June 10, 1997, to all areas of a primary escapeway developed between March 30, 1970 and November 16, 1992; and	Engineering	Mitigating	
		f2iii	(iii) Effective as of June 10, 1997, to all areas of the primary escapeway developed prior to March 30, 1970 where separation of the belt and trolley haulage entries from the primary escapeway existed prior to November 16, 1992.	Engineering	Mitigating	
		f3	(3) The following equipment is not permitted in the primary escapeway:	Engineering	Mitigating	
		f3i	(i) Mobile equipment hauling coal except for hauling coal incidental to cleanup or maintenance of the primary escapeway.	Engineering	Mitigating	
		f3ii	(ii) Compressors, except—	Engineering	Mitigating	

		f3iiA	(A) Compressors necessary to maintain the escapeway in safe, travelable condition;	Engineering	Mitigating	
		f3iiB	(B) Compressors that are components of equipment such as locomotives and rock dusting machines; and	Engineering	Mitigating	
		f3iiC	(C) Compressors of less than five horsepower.	Engineering	Mitigating	
		f3iii	(iii) Underground transformer stations, battery charging stations, substations, and rectifiers except—	Engineering	Mitigating	
		f3iiiA	(A) Where necessary to maintain the escapeway in safe, travelable condition; and	Engineering	Mitigating	
		f3iiiB	(B) Battery charging stations and rectifiers and power centers with transformers that are either dry-type or contain nonflammable liquid, provided they are located on or near a working section and are moved as the section advances or retreats.	Engineering	Mitigating	
		f3iv	(iv) Water pumps, except—	Engineering	Mitigating	
		f3ivA	(A) Water pumps necessary to maintain the escapeway in safe, travelable condition;	Engineering	Mitigating	
		f3ivB	(B) Submersible pumps;	Engineering	Mitigating	
		f3ivC	(C) Permissible pumps and associated permissible switchgear;	Engineering	Mitigating	
		f3ivD	(D) Pumps located on or near a working section that are moved as the section advances or retreats;	Engineering	Mitigating	
		f3ivE	(E) Pumps installed in anthracite mines; and	Engineering	Mitigating	
		f3ivF	(F) Small portable pumps.	Engineering	Mitigating	
		f4	(4) Mobile equipment operated in the primary escapeway, except for continuous miners and as provided in paragraphs (f) (5), (f) (6), and (f) (7) of this section, shall be equipped with a fire suppression system installed according to § 75.1107–3 through	Engineering	Mitigating	

			75.1107–16 that is—			
		f4i	(i) Manually operated and attended continuously by a person trained in the systems function and use, or	Engineering	Mitigating	
		f4ii	(ii) A multipurpose dry chemical type capable of both automatic and manual activation.	Engineering	Mitigating	
		f5	(5) Personnel carriers and small mobile equipment designed and used only for carrying people and small hand tools may be operated in primary escapeways if—	Engineering	Mitigating	
		f5i	(i) The equipment is provided with a multipurpose dry chemical type fire suppression system capable of both automatic and manual activation, and the suppression system is suitable for the intended application and is listed or approved by a nationally recognized independent testing laboratory, or,	Engineering	Mitigating	
		f5ii	(ii) Battery powered and provided with two 10 pound multipurpose dry chemical portable fire extinguishers.	Engineering	Mitigating	
		f6	(6) Notwithstanding the requirements of paragraph (f) (3) (i), mobile equipment not provided with a fire suppression system may operate in the primary escapeway if no one is inby except those persons directly engaged in using or moving the equipment.	Engineering	Mitigating	
		f7	(7) Notwithstanding the requirements of paragraph (f) (3) (i), mobile equipment designated and used only as emergency vehicles or ambulances, may be operated in the primary escapeway without fire suppression systems.	Engineering	Mitigating	

		g	(g) Except where separation of belt and trolley haulage entries from designated escapeways did not exist before November 15, 1992, and except as provided in §75.350 (c), the primary escapeway must be separated from belt and trolley haulage entries for its entire length, to and including the first connecting crosscut outby each loading point except when a greater or lesser distance for this separation is specified and approved in the mine ventilation plan and does not pose a hazard to miners.	Engineering	Mitigating	
		h	(h) Alternate escapeway. One escapeway shall be designated as the alternate escapeway. The alternate escapeway shall be separated from the primary escapeway for its entire length, except that the alternate and primary escapeways may be ventilated from a common intake air shaft or slope opening.	Engineering	Mitigating	
		i	(i) Mechanical escape facilities shall be provided and maintained for—	Engineering	Mitigating	
		i1	(1) Each shaft that is part of a designated escapeway and is greater than 50 feet in depth; and	Engineering	Mitigating	
		i2	(2) Each slope from the coal seam to the surface that is part of a designated escapeway and is inclined more than 9 degrees from the horizontal.	Engineering	Mitigating	
		j	(j) Within 30 minutes after mine personnel on the surface have been notified of an emergency requiring evacuation, mechanical escape facilities provided under paragraph (i) of this section shall be operational at the bottom of shaft and slope openings that are part of escapeways.	Engineering	Mitigating	

		k	(k) Except where automatically activated hoisting equipment is used, the bottom of each shaft or slope opening that is part of a designated escapeway shall be equipped with a means of signaling a surface location where a person is always on duty when anyone is underground. When the signal is activated or the evacuation of persons underground is necessary, the person shall assure that mechanical escape facilities are operational as required by paragraph (j) of this section.	Engineering	Mitigating	
		l1	(l)(1) Stairways or mechanical escape facilities shall be installed in shafts that are part of the designated escapeways and that are 50 feet or less in depth, except ladders may be used in shafts that are part of the designated escapeways and that are 5 feet or less in depth.	Engineering	Mitigating	
		l2	(2) Stairways shall be constructed of concrete or metal, set on an angle not to exceed 45 degrees from the horizontal, and equipped on the open side with handrails. In addition, landing platforms that are at least 2 feet by 4 feet shall be installed at intervals not to exceed 20 vertical feet on the stairways and equipped on the open side with handrails.	Engineering	Mitigating	
		l3	(3) Ladders shall be constructed of metal, anchored securely, and set on an angle not to exceed 60 degrees from the horizontal.	Engineering	Mitigating	
		m	(m) A travelway designed to prevent slippage shall be provided in slope and drift openings that are part of designated escapeways, unless mechanical escape facilities are installed.	Engineering	Mitigating	

75.381	Escapeways; anthracite mines	a	(a) Except as provided in § 75.385 and 75.386, at least two separate and distinct travelable passageways shall be designated as escapeways and shall meet the requirements of this section.	Engineering	Mitigating	
		b	(b) Escapeways shall be provided from each working section continuous to the surface.	Engineering	Mitigating	
		c	(c) Each escapeway shall be—			
		c1	(1) Maintained in a safe condition to always assure passage of anyone, including disabled persons;	Engineering	Mitigating	
		c2	(2) Clearly marked to show the route of travel to the surface;	Engineering	Mitigating	
		c3	(3) Provided with ladders, stairways, ramps, or similar facilities where the escapeways cross over obstructions; and	Engineering	Mitigating	
		c4	(4) Maintained at least 4 feet wide by 5 feet high. If the pitch or thickness of the coal seam does not permit these dimensions to be maintained other dimensions may be approved in the ventilation plan.	Engineering	Mitigating	
		c5	(5) Provided with a continuous, durable directional lifeline or equivalent device that shall be—	Engineering	Mitigating	
		c5i	(i) Installed and maintained throughout the entire length of each escapeway as defined in paragraph (b) of this section;	Engineering	Mitigating	
		c5ii	(ii) Flame-resistant in accordance with the requirements of part 18 of this chapter upon replacement of existing lifelines; but in no case later than June 15, 2009;	Engineering	Mitigating	
		c5iii	(iii) Marked with a reflective material every 25 feet;	Engineering	Mitigating	
		c5iv	(iv) Located in such a manner for miners to use effectively to escape;	Engineering	Mitigating	

		c5v	(v) Equipped with one directional indicator cone securely attached to the lifeline, signifying the route of escape, placed at intervals not exceeding 100 feet. Cones shall be installed so that the tapered section points inby;	Engineering	Mitigating	
		c5vi	(vi) Equipped with one sphere securely attached to the lifeline at each intersection where personnel doors are installed in adjacent crosscuts;	Engineering	Mitigating	
		c5vii	(vii) Equipped with two securely attached cones, installed consecutively with the tapered section pointing inby, to signify an attached branch line is immediately ahead.	Engineering	Mitigating	
		c5viiA	(A) A branch line leading from the lifeline to an SCSR cache will be marked with four cones with the base sections in contact to form two diamond shapes. The cones must be placed within reach of the lifeline.	Engineering	Mitigating	
		c5viiB	(B) A branch line leading from the lifeline to a refuge alternative will be marked with a rigid spiraled coil at least eight inches in length. The spiraled coil must be placed within reach of the lifeline.	Engineering	Mitigating	
		d	(d) Surface openings shall be adequately protected to prevent surface fires, fumes, smoke, and flood water from entering the mine.	Engineering	Preventing / Mitigating	
		e	(e) Primary escapeway. One escapeway that shall be ventilated with intake air shall be designated as the primary escapeway. The primary escapeway shall have a higher ventilation pressure than the belt entry unless the mine operator submits an alternative in the mine ventilation plan to protect the integrity of the primary	Engineering	Mitigating	

			escapeway, based on mine specific conditions, which is approved by the district manager.			
		f	(f) Alternate escapeway. One escapeway that shall be designated as the alternate escapeway shall be separated from the primary escapeway for its entire length.	Engineering	Mitigating	
		g	(g) Mechanical escape facilities shall be provided—	Engineering	Mitigating	
		g1	(1) For each shaft or slope opening that is part of a primary escapeway; and	Engineering	Mitigating	
		g2	(2) For slopes that are part of escapeways, unless ladders are installed.	Engineering	Mitigating	
		h	(h) Within 30 minutes after mine personnel on the surface have been notified of an emergency requiring evacuation, mechanical escape facilities shall be operational at the bottom of each shaft and slope opening that is part of an escapeway.	Engineering	Mitigating	
		i	(i) Except where automatically activated hoisting equipment is used, the bottom of each shaft or slope opening that is part of a primary escapeway shall be equipped with a means of signaling a surface location where a person is always on duty when anyone is underground. When the signal is activated or the evacuation of personnel is necessary, the person on duty shall assure that mechanical escape facilities are operational as required by paragraph (h) of this section.	Engineering	Mitigating	

75.382	Mechanical escape facilities	a	(a) Mechanical escape facilities shall be provided with overspeed, overwind, and automatic stop controls.	Engineering	Preventive / Mitigating	Develop an emergency response plan according to the risk assessment and regulatory requirements/ guidelines that addresses firefighting, evacuation and medical treatment (Note, e.g. MDG 1020 Guidelines for underground emergency escape systems and the provisions of self-rescuers, October 2010; MDG 1022 Guideline for determining withdrawal conditions from underground coal mines, October 2010), Awareness and competency in self and aided escape, Train relevant mine personnel with respect to mine emergency response and management (especially incident management teams, mine managers/Senior Site Executives, control room operators e.g. New South Wales Mines
		b	(b) Every mechanical escape facility with a platform, cage, or other device shall be equipped with brakes that can stop the fully loaded platform, cage, or other device.	Engineering	Preventive / Mitigating	
		c	(c) Mechanical escape facilities, including automatic elevators, shall be examined weekly. The weekly examination of this equipment may be conducted at the same time as a daily examination required by § 75.1400–3.	Administrative	Preventive	
		c1	(1) The weekly examination shall include an examination of the headgear, connections, links and chains, overspeed and overwind controls, automatic stop controls, and other facilities.	Administrative	Preventive	
		c2	(2) At least once each week, the hoist shall be run through one complete cycle of operation to determine that it is operating properly.	Administrative	Preventive	
		d	(d) A person trained to operate the mechanical escape facility always shall be available while anyone is underground to provide the mechanical escape facilities, if required, to the bottom of each shaft and slope opening that is part of an escapeway within 30 minutes after personnel on the surface have been notified of an emergency requiring evacuation. However, no operator is required for automatically operated cages, platforms, or elevators.	Administrative	Preventive	
		e	(e) Mechanical escape facilities shall have rated capacities consistent with the loads handled.	Engineering	Preventive	

		f	(f) Manually-operated mechanical escape facilities shall be equipped with indicators that accurately and reliably show the position of the facility.	Engineering	Preventive	Rescue Mine Emergency Preparedness Course/Queensland Mine Emergency Management System), Emergency response systems (e.g. consider lifelines, fresh air bases. refuge bays, Compressed Air Breathing Apparatus CABA refilling stations, Self-Contained Self Rescue [SCSR] cache, mine evacuation plans), Undertake an initial risk assessment to identify hazards and scenarios associated with potential mine fires or explosions including the potential risks associated with mine evacuation, Develop ability to monitor and use changes in gas levels as triggers for personnel evacuation in the event of a fire or potential explosion, Instigate training in competencies for fire fighting, evacuation procedures and the use of Self
		g	(g) Certification. The person making the examination as required by paragraph (c) of this section shall certify by initials, date, and the time that the examination was made. Certifications shall be made at or near the facility examined.	Administrative	Preventive	

						Contained Self Rescuers (SCSR), Awareness of evacuation procedures in cases of potential major fires and explosions
75.384	Longwall and shortwall travelways	a	(a) If longwall or shortwall mining systems are used and the two designated escapeways required by § 75.380 are located on the headgate side of the longwall or shortwall, a travelway shall be provided on the tailgate side of that longwall or shortwall. The travelway shall be located to follow the most direct and safe practical route to a designated escapeway.	Engineering	Preventive	Communication of hazards and awareness to longwall workforce: no-go zones, manager's support rules, mine emergency plan (including mine egress procedures, communication methods, etc.)
		b	(b) The route of travel shall be clearly marked.	Engineering	Preventive	Clear road traffic signals and protocols that conform to national road rules
		c	(c) When a roof fall or other blockage occurs that prevents travel in the travelway—	[redacted]		
		c1	(1) Work shall cease on the longwall or shortwall face;	Engineering	Preventive	Consider design of development panels to account for the possibility of a blocked roadway
		c2	(2) Miners shall be withdrawn from face areas to a safe area outby the section loading point; and	Engineering	Preventive	Separate people from unstable strata in the outbye district (as identified by inspection or trigger action response plans, TARPs)
		c3	(3) MSHA shall be notified.	Administrative	Mitigating	Accountability under

		d	(d) Work may resume on the longwall or shortwall face after the procedures set out in §§ 75.215 and 75.222 are implemented.	Engineering	Preventive	legislation

Table B.3 – Categorization of "30 CFR 75 Subpart E – Combustible Materials" provisions as RISKGATE controls

Section	Subject	Sub-section	Provisions	Engineering or Administrative Control	Preventive or Mitigating Control	RISKGATE Control
75.400	Accumulation of combustible materials	All	Coal dust, including float coal dust deposited on rock-dusted surfaces, loose coal, and other combustible materials, shall be cleaned up and not be permitted to accumulate in active workings, or on diesel-powered and electric equipment therein.	Engineering	Preventive	Design of adequate ventilation (e.g. monitor and manage methane accumulation, manage dust level - scrubber fans, venturis)
75.401	Abatement of dust; water or water with a wetting agent	All	[STATUTORY PROVISION] Where underground mining operations in active workings create or raise excessive amounts of dust, water or water with a wetting agent added to it, or other no less effective methods approved by the Secretary or his authorized representative, shall be used to abate such dust. In working places, particularly in distances less than 40 feet from the face, water, with or without a wetting agent, or other no less effective methods approved by the Secretary or his authorized representative, shall be applied to coal dust on the ribs, roof, and floor to reduce dispersibility and to minimize the explosion hazard.	Engineering	Preventive / Mitigating	SDP to include means to prevent build-up of float dust (e.g. continuous introduction of incombustible dust to prevent hazardous accumulations of coal float dust)
75.401-1	Excessive amounts of dust	All	The term ''excessive amounts of dust'' means coal and float coal dust in the air in such amounts as to create the potential of an explosion hazard.	[redacted]		

75.402	Rock dusting	All	[STATUTORY PROVISION] All underground areas of a coal mine, except those areas in which the dust is too wet or too high in incombustible content to propagate an explosion, shall be rock dusted to within 40 feet of all working faces, unless such areas are inaccessible or unsafe to enter or unless the Secretary or his authorized representative permits an exception upon his finding that such exception will not pose a hazard to the miners. All crosscuts that are less than 40 feet from a working face shall also be rock dusted.	Engineering	Preventive / Mitigating	Develop a stone dusting plan (SDP) and maintain compliance with statutory stone dusting requirements
75.403	Maintenance of incombustible content of rock dust	All	Where rock dust is required to be applied, it shall be distributed upon the top, floor, and sides of all underground areas of a coal mine and maintained in such quantities that the incombustible content of the combined coal dust, rock dust, and other dust shall be not less than 80 percent. Where methane is present in any ventilating current, the percent of incombustible content of such combined dust shall be increased 0.4 percent for each 0.1 percent of methane.	Engineering	Preventive / Mitigating	

Table B.4 – Categorization of "30 CFR 75 Subpart F – Electrical Equipment" provisions as RISKGATE controls

Section	Subject	Sub-section	Provisions	Engineering or Administrative Control	Preventive or Mitigating Control	RISKGATE Control
75.500	Permissible electric equipment	N/A	On and after March 30, 1971:			
		a	(a) All junction or distribution boxes used for making multiple power connections inby the last	Engineering	Preventive / Mitigating	Design equipment to enable isolation in

			open crosscut shall be permissible;			conformance with relevant standards, Consider isolation to a mining standard as a fundamental part of the design process, Device to be usable within mine operating procedures to facilitate local mine practices and site-based standards
		b	(b) All handheld electric drills, blower and exhaust fans, electric pumps, and such other low horsepower electric face equipment as the Secretary may designate on or before May 30, 1970, which are taken into or used inby the last open crosscut of any coal mine shall be permissible;	Engineering	Preventive	
		c	(c) All electric face equipment which is taken into or used inby the last open crosscut of any coal mine classified under any provision of law as gassy prior to March 30, 1970, shall be permissible; and	Engineering	Preventive	
		d	(d) All other electric face equipment which is taken into or used inby the last crosscut of any coal mine, except a coal mine referred to in § 75.501, which has not been classified under any provision of law as a gassy mine prior to March 30, 1970, shall be permissible.	Engineering	Preventive	
75.500-1	Other low horsepower electric face equipment	All	Other low horsepower electric face equipment designated pursuant to the provisions of § 75.500 (b) is all other electric-driven mine equipment, except low horsepower rock dusting equipment, and employs an electric current supplied by either a power conductor or battery and consumes not more than 2,250 watts of electricity and which is taken into or used inby the last open crosscut.	Engineering	Preventive	Selection of verification devices appropriate to voltages and equipment use on site

75.501	Permissible electric face equipment; coal seams above water table	All	On and after March 30, 1974, all electric face equipment, other than equipment referred to in paragraph (b) of § 75.500, which is taken into and used inby the last open crosscut of any coal mine which is operated entirely in coal seams located above the water table and which has not been classified under any provision of law as a gassy mine prior to March 30, 1970, and in which one or more openings were made prior to December 30, 1969, shall be permissible.	Engineering	Preventive	Design equipment to enable isolation in conformance with relevant standards, Consider isolation to a mining standard as a fundamental part of the design process, Device to be usable within mine operating procedures to facilitate local mine practices and site-based standards
75.501-1	Coal seams above the water table	All	As used in § 75.501, the phrase ''coal seams above the water table'' means coal seams in a mine which are located at an elevation above a river or the tributary of a river into which a local surface water system naturally drains.			
75.501-2	Permissible electric face equipment	a	(a) On and after March 30, 1971, in mines operated entirely in coal seams which are located at elevations above the water table:			
		a1	(1) All junction or distribution boxes used for making multiple power connections inby the last open crosscut shall be permissible; and	Engineering	Preventive	Compliance with relevant Australian Standards e.g. 600mm clearance around switchboards (AS/NZS 3000 2007 Electrical installations

		a2	(2) All handheld electric drills, blower and exhaust fans, electric pumps, and all other electric-driven mine equipment, except low horsepower rock dusting equipment, that employs an electric current supplied by either a power conductor or battery and consumes not more than 2,250 watts of electricity, which is taken into or used inby the last open crosscut shall be permissible.	Engineering	Preventive	(known as the Australian/New Zealand Wiring Rules), Part 2: Installation practices, Sections 2.9.2.2: Accessibility and emergency exit facilities, 4.2.2.6: Prevention of spread of fire)
		b	(b) On and after March 30, 1974, in mines operated entirely in coal seams which are located at elevations above the water table, all electric face equipment which is taken into or used inby the last crosscut shall be permissible.	Engineering	Preventive	
75.504	Permissibility of new, replacement, used, reconditioned, additional, and rebuilt electric face equipment	All	On and after March 30, 1971, all new, replacement, used, reconditioned, and additional electric face equipment used in any mine referred to in §§ 75.500, 75.501, and 75.503 shall be permissible and shall be maintained in a permissible condition, and in the event of any major overhaul of any item of electric face equipment in use on or after March 30, 1971, such equipment shall be put in, and thereafter maintained in, a permissible condition, unless in the opinion of the Secretary, such equipment or necessary replacement parts are not available.	Engineering	Preventive	
75.505	Mines classed gassy; use and maintenance of permissible electric face equipment	All	Any coal mine which, prior to March 30, 1970, was classed gassy under any provision of law and was required to use permissible electric face equipment and to maintain such equipment in a permissible condition shall continue to use such equipment and to maintain	Engineering	Preventive	

			such equipment in such condition.			
75.506	Electric face equipment; requirements for permissibility	a	(a) Electric-driven mine equipment and accessories manufactured on or after March 30, 1973, will be permissible electric face equipment only	Engineering	Preventive	
		a1	(1) if they are fabricated, assembled, or built under an approval, or any extension thereof, issued by the Bureau of Mines or the Mine Safety and Health Administration in accordance with schedule 2G, or any subsequent Bureau of Mines schedule promulgated by the Secretary after March 30, 1970, which amends, modifies, or supersedes the permissibility requirements of schedule 2G, and	Engineering	Preventive	
		a2	(2) If they are maintained in a permissible condition.	Engineering	Preventive	
		b	(b) Except as provided in paragraph (c) of this § 75.506 electric-driven mine equipment and accessories manufactured prior to March 30, 1973, will be permissible electric face equipment	Engineering	Preventive	
		b1	(1) if they were fabricated, assembled, or built under an approval, or any extension thereof, issued by the Bureau of Mines in accordance with the schedules set forth below, and	Engineering	Preventive	Accountability under legislation (permissibility not directly referenced in RISKGATE
		b2	(2) if they are maintained in a permissible condition. Bureau of Mines Schedule 2D, May 23, 1936; Bureau of Mines Schedule 2E, February 15, 1945; Bureau of Mines Schedule 2F, August 3, 1955; and Bureau of Mines Schedule 2G, March 19, 1968. Copies of these schedules are available at all MSHA	Engineering	Preventive	

			Coal Mine Safety and Health district offices.			
		c	(c) Electric driven mine equipment and accessories bearing the Bureau of Mines approval numbers listed in Appendix A to this subpart are permissible electric face equipment only if they are maintained in a permissible condition.	Engineering	Preventive	
		d	(d) The following equipment will be permissible electric face equipment only if it is approved under the appropriate parts of this chapter, or former Bureau of Mines' approval schedules, and if it is in permissible condition:	Engineering	Preventive	
		d1	(1) Multiple-Shot Blasting Units, part 7 subpart D;	Engineering	Preventive	
		d2	(2) Electric Cap Lamps, part 19;	Engineering	Preventive	
		d3	(3) Electric Mine Lamps Other than Standard Cap Lamps, part 20;	Engineering	Preventive	
		d4	(4) Flame Safety Lamps;	Engineering	Preventive	
		d5	(5) Portable Methane Detectors, part 22;	Engineering	Preventive	
		d6	(6) Telephone and Signaling Devices, part 23;	Engineering	Preventive	
		d7	(7) Single-Shot Blasting Units;	Engineering	Preventive	
		d8	(8) Lighting Equipment for Illuminating Underground Workings;	Engineering	Preventive	
		d9	(9) Methane-Monitoring Systems, part 27; and	Engineering	Preventive	
		d10	(10) Continuous Duty, Warning Light,	Engineering	Preventive	

75.506-1	Electric face equipment; permissibility condition; maintenance requirements	a	(a) Except as provided in paragraph (b) of this section, electric face equipment which meets the requirements for permissibility set forth in § 75.506 will be considered to be in permissible condition only if it is maintained so as to meet the requirements for permissibility set forth in the Bureau of Mines schedule under which such electric face equipment was initially approved, or, if the equipment has been modified, it is maintained so as to meet the requirements of the schedule under which such modification was approved.	Engineering	Preventive	
		b	(b) Electric face equipment bearing the Bureau of Mines approval number listed in Appendix A of this subpart will be considered to be in permissible condition only if it is maintained so as to meet the requirements for permissibility set forth in Bureau of Mines Schedule 2D or, if such equipment has been modified, it is maintained so as to meet the requirements of the schedule under which the modification was approved.	Engineering	Preventive	
		c	(c) Notwithstanding the provisions of paragraphs (a) and (b) of this section, where the minimum requirements for permissibility set forth in the appropriate Bureau of Mines schedule under which such equipment or modifications were approved have been superseded by the requirements of this Part 75, the latter requirements shall be applicable. Except where permissible power connection units are used, all power-connection points outby the last open crosscut	Engineering	Preventive	

			shall be in intake air.			
75.507-1	Electric equipment other than power-connection points; outby the last open crosscut; return air; permissibility requirements	a	(a) All electric equipment, other than power-connection points, used in return air outby the last open crosscut in any coal mine shall be permissible except as provided in paragraphs (b) and (c) of this section.	Engineering	Preventive	
		b	(b) Notwithstanding the provisions of paragraph (a) of this section, in any coal mine where nonpermissible electric face equipment may be taken into or used inby the last open crosscut until March 30, 1974, such nonpermissible electric face equipment may be used in return air outby the last open crosscut.	Engineering	Preventive	
		c	(c) Notwithstanding the provisions of paragraph (a) of this section, in any coal mine where a permit for noncompliance is in effect, nonpermissible electric face equipment specified in such permit for noncompliance may be used in return air outby the last open crosscut for the duration of such permit.	Engineering	Preventive	
75.522	Lighting devices	All	No device for the purpose of lighting any coal mine which has not been approved by the Secretary or his authorized representative shall be permitted in such mine.	Engineering	Preventive	

75.522-1	Incandescent and fluorescent lamps	a	(a) Except for areas of a coal mine inby the last open crosscut, incandescent lamps may be used to illuminate underground areas. When incandescent lamps are used in a track entry or belt entry or near track entries to illuminate special areas other than structures, the lamps shall be installed in weather-proof sockets located in positions such that the lamps will not come in contact with any combustible material. Lamps used in all other places must be of substantial construction and be fitted with a glass enclosure.	Engineering	Preventive	
		b	(b) Incandescent lamps within glass enclosures or fluorescent lamps may be used inside underground structures (except magazines used for the storage of explosives and detonators). In underground structures lighting circuits shall consist of cables installed on insulators or insulated wires installed in metallic conduit or metallic armor.	Engineering	Preventive	
75.523	Electric face equipment; deenergization	All	An authorized representative of the Secretary may require in any mine that electric face equipment be provided with devices that will permit the equipment to be deenergized quickly in the event of an emergency.	Engineering	Preventive	Develop decommissioning task that de-energizes complete system with verification prior to removal of gauges and other instrumentation
75.523-1	Deenergization of self-propelled electric face equipment installation requirements	a	(a) Except as provided in paragraphs (b) and (c) of this section, all self-propelled electric face equipment which is used in the active workings of each underground coal mine on and after March 1, 1973, shall, in accordance with the schedule of time specified in paragraphs (a) (1) and	Engineering	Preventive	Use safe guarding mechanisms that take control of, or dissipate, mechanical energies which are de-activated when personnel

			(2) of this section, be provided with a device that will quickly deenergize the tramming motors of the equipment in the event of an emergency. The requirements of this paragraph (a) shall be met as follows:			enter a hazardous situation (e.g. light curtains, proximity detection systems, motion sensors, limit switches on gates)
		a1	(1) On and after December 15, 1974, for self-propelled cutting machines, shuttle cars, battery-powered machines, and roof drills and bolters;	Engineering		
		a2	(2) On and after February 15, 1975, for all other types of self-propelled electric face equipment.	Engineering		
		b	(b) Self-propelled electric face equipment that is equipped with a substantially constructed cab which meets the requirements of this part, shall not be required to be provided with a device that will quickly deenergize the tramming motors of the equipment in the event of an emergency.	Engineering	Mitigating	Design of operator cabin and restraints to be robust to prevent injury to operator during an event such as nose-to-tail collision, roll-over, etc.
		c	(c) An operator may apply to the Director of Technical Support, Mine Safety and Health Administration, Department of Labor, 1100 Wilson Blvd., Room 2329, Arlington, Virginia 22209– 3939 for approval of the installation of devices to be used in lieu of devices that will quickly deenergize the tramming motors of self-propelled electric face equipment in the event of an emergency. The Director of Technical Support may approve such devices if he determines that the performance thereof will be no less effective than the performance requirements specified in § 75.523–2.			

75.523-2	Deenergization of self-propelled electric face equipment; performance requirements	a	(a) Deenergization of the tramming motors of self-propelled electric face equipment, required by paragraph (a) of § 75.523–1, shall be provided by:	Engineering		
		a1	(1) Mechanical actuation of an existing pushbutton emergency stopswitch,	Engineering	Mitigating	Use safe guarding mechanisms that take control of, or dissipate, mechanical energies which are de-activated when personnel enter a hazardous situation (e.g. light curtains, proximity detection systems, motion sensors, limit switches on gates)
		a2	(2) Mechanical actuation of an existing lever emergency stopswitch, or	Engineering	Mitigating	
		a3	(3) The addition of a separate electromechanical switch assembly.	Engineering	Mitigating	
		b	(b) The existing emergency stopswitch or additional switch assembly shall be actuated by a bar or lever which shall extend a sufficient distance in each direction to permit quick deenergization of the tramming motors of self-propelled electric face equipment from all locations from which the equipment can be operated.	Engineering	Mitigating	
		c	(c) Movement of not more than 2 inches of the actuating bar or lever resulting from the application of not more than 15 pounds of force upon contact with any portion of the equipment operator's body at any point along the length of the actuating bar or lever shall cause deenergization of the tramming motors of the self-propelled electric face equipment.	Engineering	Mitigating	
75.523-3	Automatic emergency-parking brakes	a	(a) Except for personnel carriers, rubber- tired, self-propelled electric haulage equipment used in the active workings of underground coal mines shall be equipped with automatic emergency parking brakes in accordance with the following schedule.	Engineering	Preventive / Mitigating	Pre-start checks to establish correct functioning of mechanical or electrical components and systems (e.g. brake check)
		a1	(1) On and after May 23, 1989—			

		a1i	(i) All new equipment ordered; and	Engineering	Preventive	
		a1ii	(ii) All equipment originally furnished with or retrofitted with automatic emergency-parking brakes which meet the requirements of this section.	Engineering	Preventive	Change management process for in-cab retrofits (consider all of the above)
		a2	(2) On and after May 23, 1991, all other equipment.			
		b	(b) Automatic emergency-parking brakes shall—	Engineering	Preventive	N/A
		b1	(1) Be activated immediately by the emergency deenergization device required by 30CFR75.523–1 and 75.523–2;	Engineering	Mitigating	
		b2	(2) Engage automatically within 5.0 seconds when the equipment is deenergized;	Engineering	Mitigating	
		b3	(3) Safely bring the equipment when fully loaded to a complete stop on the maximum grade on which it is operated;	Engineering	Preventive	
		b4	(4) Hold the equipment stationary despite any contraction of brake parts, exhaustion of any non-mechanical source of energy, or leakage; and	Engineering	Preventive	
		b5	(5) Release only by a manual control that does not operate any other equipment function.	Engineering	Preventive	
		c	(c) Automatic emergency-parking brakes shall include a means in the equipment operator's compartment to—	Engineering	Preventive	
		c1	(1) Apply the brakes manually without deenergizing the equipment; and	Engineering	Preventive	
		c2	(2) Release and reengage the brakes without energizing the equipment.	Engineering	Preventive	
		d	(d) On and after November 24, 1989, rubber-tired, self-propelled electric face equipment not covered by paragraph (a) of this section shall be equipped with a means incorporated on the equipment and operable from each tramming station to hold the	Engineering	Preventive	

			equipment stationary—			
		d1	(1) On the maximum grade on which it is operated; and	Engineering	Preventive	
		d2	(2) Despite any contraction of components, exhaustion of any non-mechanical source of energy, or leakage.	Engineering	Preventive	
		e	(e) The brake systems required by paragraphs (a) or (d) of this section shall be applied when the equipment operator is not at the controls of the equipment, except during movement of disabled equipment.	Engineering	Preventive	

Table B.5 – Categorization of "30 CFR 75 Subpart G – Trailing Cables" provisions as RISKGATE controls

Section	Subject	Sub-section	Provisions	Engineering or Administrative Control	Preventive or Mitigating Control	RISKGATE Control
75.605	Clamping of trailing cables to equipment	All	[STATUTORY PROVISIONS] Trailing cables shall be clamped to machines in a manner to protect the cables from damage and to prevent strain on the electrical connections.	Engineering	Preventive	Establish an electrical and mechanical maintenance strategy or equivalent for mobile equipment (no trailing cable reference in RISKGATE)
75.606	Protection of trailing cables	All	[STATUTORY PROVISIONS] Trailing cables shall be adequately protected to prevent damage by mobile equipment.	Engineering	Preventive / Mitigating	

Table B.6 – Categorization of "30 CFR 75 Subpart I – Underground High-Voltage Distribution" provisions as RISKGATE controls

Section	Subject	Sub-section	Provisions	Engineering or Administrative Control	Preventive or Mitigating Control	RISKGATE Control
75.828	Trailing cable pulling	All	The trailing cable must be de-energized prior to being pulled by any equipment other than the continuous mining machine. The cable manufacturer's recommended pulling procedures must be followed when pulling the trailing cable with equipment other than the continuous mining machine.	Engineering	Preventive	Establish an electrical and mechanical maintenance strategy or equivalent for mobile equipment (no trailing cable reference in RISKGATE)
75.829	Tramming continuous mining machines in and out of the mine and from section to section	a	(a) Conditions of use. Tramming the continuous mining machine in and out of the mine and from section to section must be done in accordance with movement requirements of high-voltage power centers and portable transformers (§ 75.812) and as follows:	Engineering	Preventive / Mitigating	
		a1	(1) The power source must not be located in areas where permissible equipment is required;	Engineering	Preventive	Remove mains power by physical separation
		a2	(2) The continuous mining machine must not be used for mining or cutting purposes, unless a power center is used in accordance with § 75.823 through 75.828 and § 75.830 through 75.833;	Administrative	Preventive	Accountability under legislation
		a3	(3) Low-, medium-, and high-voltage cables must comply with § 75.600–1, 75.907, and 75.826, as applicable; and	Engineering	Preventive	
		a4	(4) The energized high-voltage cable must be mechanically secured onboard the continuous mining machine. This provision applies only when using the power sources specified in paragraphs (c) (2) and (c) (3) of this section.	Engineering	Preventive	

		b	(b) Testing prior to tramming. Prior to tramming the continuous mining machine,	Administrative	Preventive	Establish pre-use inspection regime
		b1	(1) A qualified person must activate the ground-fault and ground-wire monitor test circuits of the power sources specified in paragraph (c) of this section to assure that the corresponding circuit-interrupting device opens the circuit. Corrective actions and recordkeeping resulting from these tests must be in accordance with § 75.832 (f) and (g).	Administrative	Preventive	Accountability under legislation, Undertake periodic specialist maintenance/inspections that take into account the site functional specifications and expectations under various operating conditions, Document and report damage to appropriate personnel for corrective action (e.g. reporting structure categorized by priority)
		b2	(2) Where applicable, a person designated by the mine operator must activate the test circuit for the grounded- phase detection circuit on the continuous mining machine to assure that the detection circuit is functioning properly. Corrective actions resulting from this test must be in accordance with § 75.832 (f).	Engineering	Preventive	
		c	(c) Power sources. In addition to the power center specified in § 75.825, the following power sources may be used to tram the continuous mining machine.	Engineering	Preventive	
		c1	(1) Medium-voltage power source. A medium-voltage power source is a source that supplies 995 volts through a trailing cable (See Figure 1 of this section) to the continuous mining machine. The medium-voltage power source must—			
		c1i	(i) Not be used to back-feed the high voltage circuits of the continuous mining machine; and	Engineering	Preventive	
		c1ii	(ii) Meet all applicable requirements for medium-voltage circuits in 30 CFR 75.	Engineering	Preventive	

Appendix C

Contents of RISKGATE-US COAL – All Current Bowties including Causes, Preventive Controls, Mitigating Controls, and Consequences

Table C.1 – RISKGATE-US COAL bowtie: Spontaneous combustion

Initiating Event: Spontaneous combustion		
Cause: Air leakage (negative pressure) through mine seal causes coal heating in sealed gob area	Control: Inertization of gob atmosphere through inert gas (nitrogen) injection	
	Control: Conduct regular visual inspections and gas monitoring to expose seal deficiencies	Sub Control: Maintenance or reconstruction of damaged or deficient seals
		Sub Control: Injection of grout to repair seal fractures
		Sub Control: Gas monitoring of gob area enclosed by seals rated to less than 50 psi (e.g. use of boreholes to monitor gob area)
	Control: Ensure underlying panel locations protect mainline seals (in the case of over mining)	
Cause: Air leakage through caving of underlying mined out area causes coal heating in sealed gob area	Control: Inertization of gob atmosphere through inert gas (nitrogen) injection	
	Control: Conduct regular visual inspections and gas monitoring to expose seal deficiencies	Sub Control: Maintenance or reconstruction of damaged or deficient seals
		Sub Control: Injection of grout to repair seal fractures
		Sub Control: Gas monitoring of gob area enclosed by seals rated to less than 50 psi (e.g. use of boreholes to monitor gob area)
	Control: Modification of mining near underlying mine	Sub Control: Alternative panel geometry (e.g. reduce panel width)
Cause: Seal failure from seismic event causes coal heating in sealed gob area	Control: Conduct a detailed seal inspection immediately following a seismic event	Sub Control: Replace damaged seals following a seismic event
		Sub Control: Install new mine seal if damaged seal is inaccessible following a seismic event
	Control: Ensure underlying panel locations protect mainline seals (in the case of over mining)	
Cause: Air leakage through fracture coals or rock around a seal causes coal heating in sealed gob area	Control: Inertization of gob atmosphere through inert gas (nitrogen) injection	
	Control: Conduct regular visual inspections and gas monitoring to expose seal deficiencies	Sub Control: Maintenance or reconstruction of damaged or deficient seals
		Sub Control: Injection of grout to repair seal fractures
		Sub Control: Gas monitoring of gob area enclosed by seals rated to less than 50 psi (e.g. Use of boreholes to monitor gob area)
	Control: Ensure underlying panel locations protect mainline seals (in the case of over mining)	

<table>
<tr><td></td><td colspan="2">Control: Modify seal design to ensure air leakage does not occur</td></tr>
<tr><td rowspan="3">Cause: Air leakage through gas monitoring borehole causes coal heating in sealed gob area</td><td colspan="2">Control: Inertization of gob atmosphere through inert gas (nitrogen) injection</td></tr>
<tr><td colspan="2">Control: Injection of grout to seal borehole</td></tr>
<tr><td colspan="2">Control: Modify borehole drainage design/location to prevent or limit air leakage</td></tr>
<tr><td rowspan="7">Cause: Oxygen from longwall face moves into the gob causing coal heating</td><td colspan="2">Control: Ventilation design limits oxygen flow through/around gob area (e.g. U-system layout, limited bleeder/fringe system)</td></tr>
<tr><td colspan="2">Control: Modify mining rate (e.g. stop mining, shorter shifts, slower, faster, etc.))</td></tr>
<tr><td colspan="2">Control: Cross-cut panel seals</td></tr>
<tr><td colspan="2">Control: Continuously monitor explosive gas levels at longwall face</td></tr>
<tr><td colspan="2">Control: Ensure gate road design limits airflow through the longwall face (e.g. yield pillar)</td></tr>
<tr><td colspan="2">Control: Maximize extraction percentage of the coal seam</td></tr>
<tr><td colspan="2">Control: Inject nitrogen</td></tr>
<tr><td rowspan="7">Cause: Oxygen from tailgate/previous panel moves into gob causing coal heating</td><td colspan="2">Control: Ventilation design limits oxygen flow through/around gob area (e.g. U-system layout, limited bleeder/fringe system)</td></tr>
<tr><td colspan="2">Control: Alter retreat mining rate (1/2 days)</td></tr>
<tr><td colspan="2">Control: Cross-cut panel seals</td></tr>
<tr><td colspan="2">Control: Continuously monitor gas levels at longwall face</td></tr>
<tr><td colspan="2">Control: Ensure gate road design limits airflow through the longwall face (e.g. yield pillar)</td></tr>
<tr><td colspan="2">Control: Maximize extraction percentage of the coal seam</td></tr>
<tr><td colspan="2">Control: Reduce panel width</td></tr>
<tr><td>Cause: Oxygen from borehole in the longwall face moves into gob area causing coal heating</td><td>Control: Monitor and seal the borehole</td><td>Sub Control: Verify or stop oxygen intake through borehole into gob area</td></tr>
<tr><td rowspan="2">Cause: Oxygen from fringe area of bleeder system moves into gob area causing coal heating</td><td colspan="2">Control: Continuously monitor gas levels in fringe area</td></tr>
<tr><td colspan="2">Control: Ensure ventilation design can regulate or shut-down the bleeder system if dangerous atmospheric conditions are encountered</td></tr>
<tr><td rowspan="5">Consequence: Fire in sealed gob area</td><td rowspan="3">Control: Monitoring to determine the extent of the affected area</td><td>Sub Control: Evacuation of mine employees</td></tr>
<tr><td>Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust</td></tr>
<tr><td>Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)</td></tr>
<tr><td rowspan="2">Control: Implement comprehensive emergency response plan</td><td>Sub Control: Mobilize mine rescue team</td></tr>
<tr><td>Sub Control: Notify the proper authorities/agencies immediately following an incident</td></tr>
</table>

<table>
<tr><td rowspan="2"></td><td colspan="2">Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)</td></tr>
<tr><td colspan="2">Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies</td></tr>
<tr><td rowspan="9">Consequence: Explosion in sealed gob area</td><td colspan="2">Control: Use seals which provide maximum resistance to explosive force (e.g. 120 psi seals)</td></tr>
<tr><td colspan="2">Control: Ensure roadways are properly rock dusted</td></tr>
<tr><td rowspan="3">Control: Monitoring to determine the extent of the affected area</td><td>Sub Control: Evacuation of mine employees</td></tr>
<tr><td>Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust</td></tr>
<tr><td>Sub Control: Alteration/management of ventilation system (e.g. move fresh air to trapped miners)</td></tr>
<tr><td rowspan="2">Control: Implement comprehensive emergency response plan</td><td>Sub Control: Mobilize mine rescue team</td></tr>
<tr><td>Sub Control: Notify the proper authorities/agencies immediately following an incident</td></tr>
<tr><td colspan="2">Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)</td></tr>
<tr><td colspan="2">Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies</td></tr>
<tr><td rowspan="2">Consequence: Regulatory action imposed due to coal heating in sealed gob area</td><td colspan="2">Control: Ensure compliance with federal, state, and site-specific mining rules and regulations</td></tr>
<tr><td colspan="2">Control: Notify the proper authorities/agencies immediately following a heating incident</td></tr>
<tr><td rowspan="6">Consequence: Fire in gob area at active longwall face</td><td rowspan="3">Control: Monitoring to determine the extent of the affected area</td><td>Sub Control: Evacuation of mine employees</td></tr>
<tr><td>Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, or jet engine exhaust</td></tr>
<tr><td>Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)</td></tr>
<tr><td rowspan="2">Control: Implement comprehensive emergency response plan</td><td>Sub Control: Mobilize mine rescue team</td></tr>
<tr><td>Sub Control: Notify the proper authorities/agencies immediately following an incident</td></tr>
<tr><td colspan="2">Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)</td></tr>
</table>

	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Explosion in gob area at active longwall face	Control: Use seals which provide maximum resistance to explosive force (e.g. 120 psi seals)	
	Control: Ensure roadways are properly rock dusted	
	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. move fresh air to trapped miners)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident
	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Regulatory action imposed due to coal heating in gob area at active longwall face	Control: Ensure compliance with federal, state, and site-specific mining rules and regulations	
	Control: Notify the proper authorities/agencies immediately following a heating incident (note: there are no incentives for self-reporting heating events. Heating events do not need to be reported by law.)	
Consequence: Coal loss due to coal heating in gob area at active longwall face	Control: Modification of mine plan/mining method (e.g. switch from longwall mining to room and pillar mining)	
	Control: Secure mine insurance policy for lost mineral assets	
	Control: Ensure water spray system is in place to minimize coal loss	
Consequence: Equipment damage or loss due to coal heating in gob area at active longwall face	Control: Secure equipment insurance policy for major mine equipment	
	Control: Ensure water spray system is in place to minimize damage to equipment	
	Control: Implement an emergency equipment recovery plan	
Consequence: Accumulation of toxic gases in mine atmosphere due to coal heating in gob area at active longwall face	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)

<table>
<tr><td rowspan="4"></td><td rowspan="2">Control: Implement comprehensive emergency response plan</td><td>Sub Control: Mobilize mine rescue team</td></tr>
<tr><td>Sub Control: Notify the proper authorities/agencies immediately following an incident</td></tr>
<tr><td colspan="2">Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)</td></tr>
<tr><td colspan="2">Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies</td></tr>
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</table>

Table C.2 – RISKGATE-US COAL bowtie: Fire on/near Conveyor Belt

<table>
<tr><th colspan="3">Initiating Event: Fire on/near conveyor belt</th></tr>
<tr><td rowspan="7">Cause: Buildup of combustible materials on belt</td><td colspan="2">Control: Consider use of alternate coal transportation (e.g. ram cars, battery-operated shuttle cars, etc.)</td></tr>
<tr><td colspan="2">Control: Prevent buildup of combustible material on/near the conveyor belt</td></tr>
<tr><td>Control: Ensure belt design parameters and location are appropriate for maintenance, belt examination, housekeeping, travel, etc.</td><td>Sub Control: Parameters for consideration include: clearance, alignment, geometry, sizing, etc.</td></tr>
<tr><td colspan="2">Control: Adjust wipers to prevent coal-roller interaction</td></tr>
<tr><td colspan="2">Control: Third party examination to ensure conveyor belt is constructed appropriately</td></tr>
<tr><td colspan="2">Control: Regulate feed rate and feed size</td></tr>
<tr><td colspan="2">Control: Consider roof/skin control measures to prevent additional material from falling on belt</td></tr>
<tr><td>Cause: Belt is misaligned near/in takeup</td><td>Control: Ensure belt design parameters and location are appropriate for maintenance, belt examination, housekeeping, travel, etc.</td><td>Sub Control: Parameters for consideration include: clearance, alignment, geometry, sizing, etc.</td></tr>
</table>

	Control: Install and maintain instrumentation to monitor belt performance	Sub Control: Overload sensor, fault sensor, slippage sensor, etc.
Cause: Improper maintenance of belt rollers	Control: Provide belt operator training to identify faulty/worn rollers	
	Control: Undertake preventive maintenance program to ensure equipment functionality	
	Control: Install and maintain instrumentation to monitor belt performance	Sub Control: Overload sensor, fault sensor, slippage sensor, etc.
	Control: Confirm belt splice conditions meet appropriate operating standards	Sub Control: Consider vulcanization of belt splice
Cause: Wiper malfunction	Control: Provide belt operator training to identify irregular wiper performance	
	Control: Undertake preventive maintenance program to ensure equipment functionality	
	Control: Confirm wipers are in the proper position	
Cause: Plugged chutes	Control: Prevent buildup of combustible material on/near the conveyor belt	
	Control: Ensure belt design parameters and location are appropriate for maintenance, belt examination, housekeeping, travel, etc.	Sub Control: Parameters for consideration include: clearance, alignment, geometry, sizing, etc.
	Control: Develop/confirm appropriate chute design	
	Control: Use magnetic removal system for metallic objects including bolts, etc.	
Cause: Inadequate ventilation to belt	Control: Inertization of combustible atmosphere through automated system	
	Control: Consider installation of belt temperature monitor (e.g. infrared gun for distribution sensing)	
	Control: Ensure air flow/quantity adheres to design specifications	
	Control: CO monitoring to detect fire	
	Control: Monitor for combustible atmosphere while undertaking welding/cutting procedures	
Cause: Belt control equipment (PLC) malfunction	Control: Undertake preventive maintenance program to ensure equipment functionality	
	Control: Electro-mechanical belt monitoring	Sub Control: Appropriate sequence design (PLC)
		Sub Control: Automated spillage switch
Cause: Damage to friction drive	Control: Provide adequate protection to friction drive	Sub Control: Isolation from loose material (e.g. belt flaps)
	Control: Undertake preventive maintenance program to ensure equipment functionality	
	Control: Ensure belt design parameters and location are appropriate for maintenance, belt examination, housekeeping, travel, etc.	Sub Control: Parameters for consideration include: clearance, alignment, geometry, sizing, etc.

	Control: Electro-mechanical belt monitoring	Sub Control: Appropriate sequence design (PLC)
		Sub Control: Automated spillage switch
	Control: Install and maintain instrumentation to monitor belt performance	Sub Control: Overload sensor, fault sensor, slippage sensor, etc.
Cause: Roller failure (e.g. damaged/worn bearing)	Control: Provide belt operator training to identify irregular roller performance	
	Control: Undertake preventive maintenance program to ensure roller functionality	Sub Control: Appropriate roller maintenance (e.g. prohibit improper bearing lubrication)
Cause: Slippage of belt (e.g. hydraulic failure at takeup)	Control: Undertake preventive maintenance program to ensure equipment functionality	
	Control: Ensure belt design parameters and location are appropriate for maintenance, belt examination, housekeeping, travel, etc.	Sub Control: Parameters for consideration include: clearance, alignment, geometry, sizing, etc.
	Control: Electro-mechanical belt monitoring	Sub Control: Appropriate sequence design (PLC)
		Sub Control: Automated spillage switch
	Control: Install and maintain instrumentation to monitor belt performance	Sub Control: Overload sensor, fault sensor, slippage sensor, etc.
Consequence: Fire on/near belt resulting in injury or fatality	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident
	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Regulatory action imposed due to fire	Control: Ensure compliance with federal, state, and site-specific mining rules and regulations	

<table>
<tr><td>on/near belt</td><td colspan="2">Control: Notify the proper authorities/agencies immediately following a heating incident (note: there are no incentives for self-reporting heating events. Heating events do not need to be reported by law.)</td></tr>
<tr><td rowspan="2">Consequence: Coal loss due to fire on/near belt</td><td colspan="2">Control: Secure mine insurance policy for lost mineral assets</td></tr>
<tr><td colspan="2">Control: Ensure water spray system is in place to minimize coal loss</td></tr>
<tr><td rowspan="3">Consequence: Equipment damage or loss due to fire on/near belt</td><td colspan="2">Control: Secure equipment insurance policy for major mine equipment</td></tr>
<tr><td colspan="2">Control: Ensure water spray system is in place to minimize damage to equipment</td></tr>
<tr><td colspan="2">Control: Implement an emergency equipment recovery plan</td></tr>
<tr><td rowspan="7">Consequence: Accumulation of toxic gases in mine atmosphere due to fire on/near belt</td><td rowspan="3">Control: Monitoring to determine the extent of the affected area</td><td>Sub Control: Evacuation of mine employees</td></tr>
<tr><td>Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust</td></tr>
<tr><td>Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)</td></tr>
<tr><td rowspan="2">Control: Implement comprehensive emergency response plan</td><td>Sub Control: Mobilize mine rescue team</td></tr>
<tr><td>Sub Control: Notify the proper authorities/agencies immediately following an incident</td></tr>
<tr><td colspan="2">Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)</td></tr>
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</table>

Table C.3 – RISKGATE-US COAL bowtie: Methane ignition resulting in fire (face/gob) or explosion

Initiating Event: Methane ignition resulting in fire (Face/Gob) or explosion		
Cause: Accumulation of methane due to: poor ventilation, infiltration from adjacent seam (stratigraphic interactions), geologic anomaly, change in barometric pressure, coal burst, leakage in gathering system, borehole/gas well interaction with mine, seismic event, or unknown source	Control: Inertization of gob atmosphere through inert gas (nitrogen) injection	
	Control: Conduct regular visual inspections and gas monitoring to expose seal deficiencies	Sub Control: Maintenance or reconstruction of damaged or deficient seals
		Sub Control: Injection of grout to repair seal fractures
		Sub Control: Gas monitoring of gob area enclosed by seals rated to less than 50 psi (e.g. use of boreholes to monitor gob area)
	Control: Ensure underlying panel locations protect mainline seals (in the case of over mining)	
	Control: Modification of mining near underlying mine	Sub Control: Alternative panel geometry (e.g. reduce panel width)
	Control: Conduct a detailed seal inspection immediately following a seismic event	Sub Control: Replace damaged seals following a seismic event
		Sub Control: Install new mine seal if damaged seal is inaccessible following a seismic event
	Control: Ensure underlying panel locations protect mainline seals (in the case of over mining)	
	Control: Ventilation design limits oxygen flow through/around gob area (e.g. U-system layout, limited bleeder/fringe system)	
	Control: Continuously monitor gas levels in fringe area	
	Control: Ensure ventilation design can regulate or shut-down the bleeder system if dangerous atmospheric conditions are encountered	
	Control: Alter retreat mining rate (1/2 days)	
	Control: Cross-cut panel seals	
	Control: Continuously monitor explosive gas levels at longwall face	
	Control: Ensure gate road design limits airflow through the longwall face (e.g. yield pillar)	
	Control: Maximize extraction percentage of the coal seam	
	Control: Monitor and seal the borehole	Sub Control: Verify or stop oxygen intake through borehole into gob area
Cause: Spark generated by: dull/missing bits on shearer, electrical fault/arc (DC trolley), lightning, roof fall, roof bolt shear/general roof bolting process, shearer interaction with Sulphur ball	Control: Ensure equipment meets/exceeds regulatory permissibility standards (e.g. use of non-sparking equipment, diesel equipment, hydraulic equipment, etc.)	
	Control: Equip shearer with water spray system to reduce probability of ignition	
	Control: Consider use of plow if mining conditions allow	

	Control: Ensure ventilation design can regulate or shut-down the bleeder system if dangerous atmospheric conditions are encountered	
	Control: Alter mining rate to prevent sparking	
	Control: Ensure proper isolation of electrical energy from distribution stations/battery charging stations	
	Control: Confirm shield advance procedure is designed to prevent shield scraping	
	Control: Mapping of abandoned or previous mine workings to prevent interaction with active mining	
	Control: Halt mining during inclement weather (high-intensity electrical storm)	
Cause: Belt friction	Control: See Initiating Event: Fire on/near conveyor belt	
Cause: Inadequate ventilation to active face/battery charging stations	Control: Inertization of combustible atmosphere through automated system	
	Control: Consider installation of temperature monitor for working face equipment (e.g. infrared gun for distribution sensing)	
	Control: Ensure air flow/quantity adheres to design specifications	
	Control: CO monitoring to detect fire	
	Control: Monitor for combustible atmosphere while undertaking welding/cutting procedures	
	Control: Ensure equipment meets/exceeds regulatory permissibility standards	
Cause: Collision between moving equipment	Control: See RISKGATE Topic: Moving Equipment, Initiating Event: Loss of control of mobile equipment (including events caused by less than adequate operation/design of equipment)	
	Control: Ensure equipment meets/exceeds regulatory permissibility standards	
Cause: Blasting	Control: Provide adequate training and supervision to blasting crews	
	Control: Use of permissible blasting equipment	
	Control: Isolation of combustible material when blasting (e.g. compressed cylinders containing explosive chemicals)	
	Control: Take measures to prevent unplanned caving/falls of roof while blasting	
Consequence: Fire in sealed gob area	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident

	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Explosion due to methane ignition	Control: Use seals which provide maximum resistance to explosive force (e.g. 120 psi seals)	
	Control: Ensure roadways are properly rock dusted	
	Control: Optimization of rock dust characteristics to prevent propagation of explosive force	
	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. move fresh air to trapped miners)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident
	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Regulatory action imposed due to methane ignition	Control: Ensure compliance with federal, state, and site-specific mining rules and regulations	
	Control: Notify the proper authorities/agencies immediately following a heating incident (note: there are no incentives for self-reporting heating events. Heating events do not need to be reported by law.)	
Consequence: Methane ignition at longwall face	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an

		incident
	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Methane ignition in gob area at active longwall face	Control: Use seals which provide maximum resistance to explosive force (e.g. 120 psi seals)	
	Control: Ensure roadways are properly rock dusted	
	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. move fresh air to trapped miners)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident
	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Regulatory action imposed due to methane ignition	Control: Ensure compliance with federal, state, and site-specific mining rules and regulations	
	Control: Notify the proper authorities/agencies immediately following a heating incident (note: there are no incentives for self-reporting heating events. Heating events do not need to be reported by law.)	
Consequence: Coal loss due to methane ignition	Control: Modification of mine plan/mining method (e.g. switch from longwall mining to room and pillar mining)	
	Control: Secure mine insurance policy for lost mineral assets	
	Control: Ensure water spray system is in place to minimize coal loss	
Consequence: Equipment damage or loss due to methane ignition	Control: Secure equipment insurance policy for major mine equipment	
	Control: Ensure water spray system is in place to minimize damage to equipment	
	Control: Implement an emergency equipment recovery plan	
Consequence: Accumulation of toxic gases in mine atmosphere	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees

due to methane ignition and resulting fire/explosion		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident
	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
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Table C.4 – RISKGATE-US COAL bowtie: Loss of roof control at advancing section (feeder inby)

Initiating Event: Loss of roof control at advancing section (feeder inby)		
Cause Category: Geology		
Cause: Changing geology/roof conditions, including known anomalies	Control: Forecasting methods	Sub Control: Projection from known geology (own or adjacent mines, historical data)
		Sub Control: Identification (boreholes, bore scopes, core drilling, e-logs)
		Sub Control: Mine mapping

	Control: Develop mine geological model (hazard maps, geological influence, and mapping)	
	Control: Modify design of support system to address changing conditions	
	Control: Schedule independent audit of mine geological model	
Cause: Strata transition causing weak bedding plane/laminations (e.g. shale-shale, limestone-shale, rider seams, rider faults, stack rocks)	Control: Forecasting methods	Sub Control: Projection from known geology (own or adjacent mines, historical data)
		Sub Control: Identification (boreholes, bore scopes, core drilling, e-logs)
		Sub Control: Mine mapping
	Control: Develop mine geological model (hazard maps, geological influence, and mapping)	
	Control: Modify design of support system to address strata transition	
	Control: Schedule independent audit of mine geological model	
Cause: Insufficient characterization of geology	Control: Secondary exploration drilling to update the mine geological model	
	Control: Targeted drilling	
	Control: Consider surface lineament mapping	
Cause: Changes in overburden, depth of cover leading to variation in vertical stress conditions	Control: Mine mapping of topography and depth of cover	
	Control: Recognition of impact of overburden variation on mining conditions	
	Control: Modify design of support systems to address changes	
Cause: Insufficient understanding of rock and coal properties (strength and susceptibility to water; including soft bottom leading to rib failure)	Control: Characterize rock layer strength (laboratory testing)	
	Control: Rock mass classification	
	Control: Integrate findings into the mine geological model and mine design	
Cause: Cleat pattern, orientation, spacing	Control: In situ geological mapping (swillies)	
	Control: Integrate findings into the mine geological model and mine design	
Cause: Known geological structures (faults, dykes, slickensides, rolls, swillies, washouts, intrusions, channels)	Control: Exploration drilling	
	Control: In situ geological mapping	
	Control: Geophysical surveys	
	Control: Consider surface lineament mapping	
	Control: Integrate findings into the mine geological model and mine design	
Cause: Kettlebottoms	Control: In situ observation	
	Control: Obtain and review historical data from parallel panels	
Cause: Horizontal stress (including valley bottom stress effects)	Control: Consider stress outcomes from mining in adjacent mines	
	Control: Mapping of in situ features (e.g. cutters)	
	Control: Mine mapping of topography to consider alignment of valleys, lineaments	
	Control: Measurement of horizontal stress direction and magnitude	
	Control: Design of support system	
	Control: Mine planning and orientation	

Cause: Water bearing layer	Control: Permeability and piezometer tests on targeted water bearing horizons	
	Control: Forecasting methods	Sub Control: Projection from known geology (own or adjacent mines, historical data)
		Sub Control: Identification methods (boreholes, core drilling, e-logs)
		Sub Control: Mine mapping
	Control: Develop mine geological model (hazard maps, geological influence mapping)	
	Control: Update geological model with observations from mining	
	Control: Schedule independent audit of mine geological model	
Cause Category: Design		
Cause: Inadequate roof support/roof control results in fall of ground	Control: Identify weak and competent strata	
	Control: Consideration for conditions and effective intervention methods in adjacent mines, historical data	
	Control: Consider abutment stress	
	Control: Select appropriate modeling approach (e.g. FLAC, ARBS, ALPS, STOP)	
	Control: Consult with bolt suppliers (provide rock strength properties)	
	Control: Develop roof support plan	
	Control: Consider life cycle requirements (time/length of support required)	
	Control: Apply adequate safety factors to account for purpose of entry	
	Control: Revise and/or update roof support plans with input from operational roof conditions (driller reports, etc.)	
	Control: Consider regulatory agency recommendations	
	Control: Schedule independent audit of roof support design	
Cause: Insufficient characterization of geology	Control: Increase safety factors to compensate for unknown geological conditions	
Cause: Changes in overburden and/or depth of cover	Control: Design base plan for maximum cover that could be encountered	
	Control: Design base plan for actual cover (e.g. variation in support plan that matches specific stress conditions)	
	Control: Develop designs that identify and communicate changes in cover depth to operations personnel (e.g. triggers that lead to modification in mining practice)	
Cause: Valley bottom stress effects	Control: Identify areas with expected valley bottoms (e.g. topography, degree of gradient change between low and high coverage)	
	Control: Consider roof type (eg. laminated shale vs massive sandstone) and fracturing	
	Control: Consider orientation	
	Control: Re-evaluate primary roof support	

	Control: Consider supplemental roof support to manage elevated horizontal stresses
	Control: Consider potential for increased floor and rib problems (e.g. heave, rib sloughing)
Cause: Mining under/around water	Control: Identify bodies of water (e.g. historical records - overlying map and elevation of water; aquifers marked on geological model; inseam horizontal drilling to confirm absence of water)
	Control: Orient mining to minimize interaction with water bodies
	Control: Routine preshift and onshift inspections/monitoring for water hazards
	Control: Establish monitoring wells for water hazards
	Control: Consider dewatering
	Control: Establish and model barriers to calculate stability
Cause: Insufficient consideration for rock and coal properties (strength and susceptibility to water; including soft bottom leading to rib failure; strata mineralogy - especially clay minerals)	Control: Select appropriate bolt length
	Control: Select appropriate pillar size
	Control: Incorporate outcomes from models, sensitivity analysis
	Control: Increase factor of safety
	Control: Consider rib bolting
	Control: Integrate findings into the mine geological model and mine design
	Control: Install pumping and drainage systems to manage water on floor or face
	Control: Remove thin clay layer (cutting out) as part of mining process
	Control: Select appropriate equipment for floor bearing pressure and water usage
	Control: Consider using wetting agents in water supply to reduce volume of water used
	Control: Floor treatment (e.g. lime)
	Control: Use rail instead of rubber tires for transportation
Cause: Inadequate pillar dimensions (size, shape) by design	Control: Consider overburden depth and variation
	Control: Reevaluate all design parameters (e.g. stress, geology, abutment stresses, mine layout)
	Control: Review and select appropriate modeling software and approach
	Control: Consider prior experience in the same seam (own or adjacent mining)
	Control: Consider future mining activity (e.g. retreat mining or longwall) when selecting dimensions
	Control: Schedule peer or independent audit/review of pillar design
Cause: Cleat pattern, orientation, spacing	Control: Consider rib support
	Control: Consider primary production method in selection of orientation
Cause: Known geological structures (faults, dykes, slickensides, rolls, swillies, washouts, etc.)	Control: Adjust mine geometry and panel orientation
	Control: Include geological structures within the mine geological model

	Control: Consider structures in development planning, equipment selection and scheduling
	Control: Adjust bolting, strapping, grouting, secondary support activities to manage known structures
Cause: Excessive depth of cut or unsupported standing time relative to roof conditions	Control: Adjust depth of cut, review of depth of cut relative to geological conditions
	Control: Reduce maximum standing times
	Control: Adjust the cutting height (e.g. incompetent layer, different equipment to cut down)
	Control: Narrow the entry width
Cause: Inadequate bolt selection and anchorage relative to geology	Control: Detailed characterization of geotechnical and geological domain
	Control: Consider geotechnical domain when selecting appropriate support mechanism (e.g. beams building, anchorage)
	Control: Consider roof geology when selecting appropriate anchorage horizon
	Control: Consider full or partial encapsulation
	Control: Calculate appropriate bolt pattern (spacing and height)
	Control: Consider horizontal stress factors
	Control: Calculate maximum potential load on bolts and consider known failure rates
Cause: Horizontal stress (magnitude and orientation)	Control: Consider mining outcomes in adjacent mines
	Control: Mine mapping of topography to consider alignment of valleys, lineaments
	Control: Measure horizontal stress direction and magnitude
	Control: Consider horizontal stress in design of support system (primary and secondary)
	Control: Mine planning and orientation
Cause Category: Operating practice (training, supervision, monitoring, audits, etc.)	
Cause: Deviation from bolt pattern - installation/design, bolt anchorage	Control: Bolt crew training (type of bolts, speed of glue, etc.)
	Control: Train section foreman
	Control: Provide section plan
	Control: Monitor and supervise bolt installation
	Control: Audit and disciplinary action for deviation from bolt pattern
Cause: Insufficient characterization of geology on the section (not drilling test	Control: Characterize strata and match/overlay with mine map
	Control: Provide training regarding drilling location and depth

holes to confirm)/inadequate test holes (not deep enough, etc.)	Control: Confirm transfer of information from bolt crew to section boss	
	Control: Monitor and report any changes in strata data	
	Control: Independent visual or auditory inspection/check of test holes	
Cause: Failure to recognize changing vertical stress (changes in overburden, depth of cover)	Control: Increase number of core holes	
	Control: Horizontal drilling when laying out panels	
	Control: Integrate core hole drilling information into overlay maps	
	Control: Establish triggers and communicate support changes	
	Control: Confirm and maintain continuous feedback from bolt crew	
Cause: Valley bottom stress effects	Control: Review past mining history in same seam	
	Control: Train operators to identify this type of hazard	
	Control: Highlight valley bottoms in topography map and consider mine plan adjustments	
Cause: Mining under/around water (water make at face/probe drilling/ground water)	Control: Review past mining history in same seam	
	Control: Train operators to identify this hazard	
	Control: Highlight water bodies on topography map	
	Control: Undertake directional drilling as needed	
	Control: Confirm availability of discharge line/sumps for dewatering	
Cause: Mining off center line	Control: Select equipment to achieve planned pillar size	
	Control: Provide miner operator training	
	Control: Audit and replace miner operator if required	
	Control: Provide foreman training	
	Control: Audit and replace foreman if required	
	Control: Maintain spads (survey markers) at current or reasonable distances	
	Control: Use laser sights (or sight rods) to orient mining direction	
	Control: Update maps to communicate section progress	
	Control: Ensure good center transition or entries when changing pillar size	
	Control: Designate different center line colors for different shifts	
	Control: Paint center lines and guidance lines	
	Control: Increase roof and/or rib support as required	
	Control: Provide adequate training for turning angles (you don't learn till you mess up)	
Cause: Excessive span or reduced pillar width due to rib sloughing	Control: Consider effect of rib sloughing when developing entries	Sub Control: Reduce entry width so the final is acceptable
	Control: Ensure initial bolt pattern is tight to the rib to decrease sloughage	
	Control: Implement secondary support as required	Sub Control: Rib bolting
		Sub Control: Pillar wrap, wire mesh, polyfabric
		Sub Control: Timbering, cribs
		Sub Control: Wooden strap supports

		Sub Control: Jacks
	Control: Increase safety factor	
	Control: Maintain square instead of angled/rectangular pillars	
Cause: Excessive cutting height	Control: Provide miner operator training	
	Control: Audit and replace miner operator if required	
	Control: Provide foreman training	
	Control: Audit and replace foreman if required	
	Control: Install height indicators (e.g. sight onto the face, using laser)	
	Control: Increase or maintain supervision	
	Control: Select equipment to achieve desired entry height	
	Control: Characterize the roof geology to determine if different cutting heights are required	
	Control: Consider cutting the height out of the bottom	
Cause: Improper application of bolt torque	Control: Confirm manufacturer specifications for bolt installation	
	Control: Select bolt type for geological conditions	
	Control: Consider alternate bolt types (eg. glue/tension); and/or consider changing glue	
	Control: Establish test procedure to validate bolt performance	
	Control: Provide bolter training	
	Control: Audit and replace bolter operator if required	
	Control: Test and calibrate that bolt installation equipment can achieve full torque	
	Control: Monitor and supervise bolt installation	
	Control: Train foremen with respect to bolt quality control or replacement	
Cause: Cutting too low, equipment damage	Control: Provide miner operator training	
	Control: Audit and replace miner operator if required	
	Control: Provide foreman training	
	Control: Audit and replace foreman if required	
	Control: Take the height out of the bottom when required	
	Control: Match bit selection to the rock type	
	Control: Install height indicator if needed	
	Control: Assign difficult travelling to one shift	
	Control: Drill and shoot	
	Control: Match miner operator to height of cutting	
Cause: Abutment stress/barrier width inadequate	Control: Reduce number of entries	
	Control: Install supplementary support	
	Control: Build a barrier	
	Control: Install standing support	
	Control: Change adjacent pillar size	
	Control: Reduce entry width or height	
	Control: Rib support including grouting into barrier to stabilize	
Cause: Deviation from cleat	Control: Install rib support	

pattern, orientation, spacing, penetration rate	Control: Reduce height	
	Control: Provide miner crew training	
	Control: Audit and replace with faster mining crew if conditions require	
	Control: Reduce number of idle shifts	
	Control: Match bit type to geologic conditions	
	Control: Change orientation of entries (e.g. orient pillars perpendicular to face cleat)	
	Control: Advance belt sooner, reduce haulage distance to increase cutting rate (i.e. less down-time waiting for shuttle cars due to long travel distances)	
Cause: Nonconformance to development procedure (e.g. mining speed, advance rate, depth of cut, bolt installation timeframe)	Control: Review and/or adjust depth of cut relative to geological conditions	
	Control: Reduce maximum standing times	
	Control: Adjust the cutting height (e.g. incompetent layer, different equipment to cut down)	
	Control: Narrow the entry width	
	Control: Increase speed of bolt installation (e.g. select bolts with shorter install times)	
Cause: Geological structures (faults, dykes, slickensides, rolls, swillies), known/unknown	Control: Map the geology and the extent of structure interference	
	Control: Communication of geological/structural conditions	
	Control: Ensure availability of sufficient supplies (e.g. support materials) and additional equipment	
	Control: Install supplementary support	
	Control: Match entry width to conditions (e.g. narrow entries)	
	Control: Reduce the number of entries	
	Control: Reduce depth of cut	
	Control: Lengthen the pillars	
	Control: Preplan to identify optimal location to start grading	
	Control: Consider alternate bolt types including cables, torque-tension, glue	
	Control: Relocate the section	
Cause: Bottom conditions, soft undercut affecting ribs	Control: Use lighter equipment	
	Control: Reduce number of entries	
	Control: Install pumping and drainage system to manage water on floor	
	Control: Relocate the section	
	Control: Mine the bottom	
	Control: Temporarily increase pillar size	
	Control: Install additional rib support at the base of the rib	
	Control: Adjust or relocate hauling route	
	Control: Program off sequence belt move	
Cause: Rib failure leading to roof failure	Control: Install supplementary rib support including mesh	Sub Control: Including mesh
		Sub Control: Straps
		Sub Control: Standing support
		Sub Control: Cribs

	Control: Reduce entry width	
	Control: Bolt closer to the rib	
	Control: Relocate the section	
	Control: Reduce the number of entries	
	Control: Increase pillar size	
Cause: Equipment and supplies not available or not compatible with mine plan or mine conditions	Control: Selection of mining equipment and supplies that match mining conditions	
	Control: Purchase supplemental or new equipment if required to match mine plan or mine conditions	
	Control: Modification of mine plan to match available equipment and supplies	
	Control: Undertake preventive maintenance program to ensure equipment availability	
	Control: Adjust availability of equipment and supplies	
	Control: Improve or maintain communication between miners and support team (e.g. procurement, maintenance, warehouse, operations)	
	Control: Do not mine if equipment is not fit for conditions	
Consequence: Roof fall at advancing section resulting in injury or fatality	Control: Remove personnel from potential secondary fall zones after a primary failure while remediation activities are in-progress at the working face	
	Control: Define high risk areas for roof falls and barricade against entry in the working section with exception to personnel responsible for roof control remediation (e.g., roof control crews, foreman, etc.)	
	Control: Ensure that the number of operators working on the section at any one time is not excessive	
	Control: Automate equipment to maintain planned operating procedures and designed extraction geometry	Sub Control: Automate horizon control equipment to maintain designed cutting height
		Sub Control: Automate chock and armored face conveyor (AFC) advance to maintain designed shield and AFC advance sequence and timing
	Control: Implement remotely operated equipment (e.g., roof bolters, shuttle cars, etc.) to physically separate the operator from the working face (red zone)	
	Control: Design drilling and support installation equipment to maximize distance and create physical barriers between the operator and the roof to allow operators to work in safe zone (e.g., under protective canopy)	
	Control: Equipment design and selection to consider operator protection	
	Control: Personnel protective equipment (PPE) beyond minimum standard	Sub Control: Full face masks/hardhat for protection from dust and flyrock - specific to site conditions
		Sub Control: Metatarsal boots
	Control: Training and awareness of safe operating procedures including safe zones and accepted operational practices in the working section	

	Control: Training on roof control plan and operating sequence under varying roof conditions	
	Control: Communication of hazards to personnel (e.g., red zones, roof control plan, mine emergency plan including mine escape procedures, communication methods, etc.)	
	Control: Establish active section roof failure remediation plan (i.e., re-supporting roof, fall cleanup, equipment recovery, etc.)	Sub Control: Define safe practices (e.g., use of temporary support, etc.)
	Control: Ensure that local agreements are in-plan for medical services and transport. If practical, implement on-site medical personnel (i.e., mine workers who are EMT certified, etc.) and transportation	
	Control: Minimize emergency response time	
	Control: Ensure availability of first-aid and emergency response resources across all shifts (e.g. equipment, kits)	
Consequence: Frictional ignition at working face, see RISKGATE Fires / Explosions Topics	Control: Implement fire suppression systems, gas monitoring, temperature sensors, etc.	
Consequence: Equipment damage or loss at working face	Control: Design equipment to withstand impact from rock fall	
	Control: Ensure equipment insurance policies are in place	
	Control: Ensure availability of equipment recovery resources	
Consequence: Production disruption and/or loss of resources	Control: Spare equipment and parts readily available to continue operations	
	Control: Relocate to alternative mining area for production supplementation	
	Control: Design roof fall response plan to minimize disruption	
	Control: Ensure personnel are trained to implement response plans in a timely manner	
	Control: Agreements in place to guarantee the availability of specialized services and resources - consolidation products, teams and suppliers, consultants	
	Control: Ensure insurance policies are in place	
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Table C.5 – RISKGATE-US COAL bowtie: Loss of roof control at longwall face

Initiating Event: Loss of roof control at longwall face		
Cause Category: Geology		
Cause: Changing geology/roof conditions, including known anomalies	Control: Forecasting methods	Sub Control: Projection from known geology (own or adjacent mines, historical data)
		Sub Control: Identification (boreholes, bore scopes, core drilling, e-logs)
		Sub Control: Mine mapping
	Control: Develop mine geological model (hazard maps, geological influence, and mapping)	
	Control: Modify design of support system to address changing conditions	
	Control: Schedule independent audit of mine geological model	
Cause: Strata transition causing weak bedding plane/laminations (e.g. shale-shale, limestone-shale, rider seams, rider faults, stack rocks)	Control: Forecasting methods	Sub Control: Projection from known geology (own or adjacent mines, historical data)
		Sub Control: Identification (boreholes, bore scopes, core drilling, e-logs)
		Sub Control: Mine mapping
	Control: Develop mine geological model (hazard maps, geological influence, and mapping)	
	Control: Modify design of support system to address strata transition	
	Control: Schedule independent audit of mine geological model	
Cause: Insufficient characterization of geology	Control: Secondary exploration drilling to update the mine geological model	
	Control: Targeted drilling	
	Control: Consider surface lineament mapping	
Cause: Changes in overburden, depth of cover leading to variation in vertical stress conditions	Control: Mine mapping of topography and depth of cover	
	Control: Recognition of impact of overburden variation on mining conditions	
	Control: Modify design of support systems to address changes	
Cause: Insufficient understanding of rock and coal properties (strength and susceptibility to water; including soft bottom leading to rib failure)	Control: Characterize rock layer strength (laboratory testing)	
	Control: Rock mass classification	
	Control: Integrate findings into the mine geological model and mine design	
Cause: Cleat pattern, orientation, spacing	Control: In situ geological mapping (swillies)	
	Control: Integrate findings into the mine geological model and mine design	
Cause: Known geological structures (faults, dykes, slickensides, rolls, swillies, washouts, intrusions, channels)	Control: Exploration drilling	
	Control: In situ geological mapping	
	Control: Geophysical surveys	

	Control: Consider surface lineament mapping	
	Control: Integrate findings into the mine geological model and mine design	
Cause: Kettlebottoms	Control: In situ observation	
	Control: Obtain and review historical data from parallel panels	
Cause: Horizontal stress (including valley bottom stress effects)	Control: Consider stress outcomes from mining in adjacent mines	
	Control: Mapping of in situ features (e.g. cutters)	
	Control: Mine mapping of topography to consider alignment of valleys, lineaments	
	Control: Measurement of horizontal stress direction and magnitude	
	Control: Design of support system	
	Control: Mine planning and orientation	
Cause: Water bearing layer	Control: Permeability and piezometer tests on targeted water bearing horizons	
	Control: Forecasting methods	Sub Control: Projection from known geology (own or adjacent mines, historical data)
		Sub Control: Identification methods (boreholes, core drilling, e-logs)
		Sub Control: Mine mapping
	Control: Develop mine geological model (hazard maps, geological influence mapping)	
	Control: Update geological model with observations from mining	
	Control: Schedule independent audit of mine geological model	
Cause Category: Design		
Cause: Inadequate roof support/roof control results in fall of ground	Control: Identify weak and competent strata	
	Control: Consideration for conditions and effective intervention methods in adjacent mines, historical data	
	Control: Consider abutment stress	
	Control: Select appropriate modeling approach (e.g. FLAC, ARBS, ALPS, STOP, etc.)	
	Control: Consult with bolt suppliers (provide rock strength properties)	
	Control: Develop roof support plan	
	Control: Consider life cycle requirements (time/length of support required)	
	Control: Apply adequate safety factors to account for purpose of entry	
	Control: Revise and/or update roof support plans with input from operational roof conditions (driller reports, etc.)	
	Control: Consider regulatory agency recommendations	
	Control: Schedule independent audit of roof support design	
Cause: Insufficient characterization of geology	Control: Increase safety factors to compensate for unknown geological conditions	
	Control: Targeted drilling	

	Control: Consider surface lineament mapping
Cause: Changes in overburden and/or depth of cover	Control: Design base plan for maximum cover that could be encountered
	Control: Design base plan for actual cover (e.g. variation in support plan that matches specific stress conditions)
	Control: Develop designs that identify and communicate changes in cover depth to operations personnel (e.g. triggers that lead to modification in mining practice)
Cause: Valley bottom stress effects	Control: Identify areas with expected valley bottoms (e.g. topography, degree of gradient change between low and high coverage)
	Control: Consider roof type (e.g. laminated shale vs massive sandstone) and fracturing
	Control: Consider orientation
	Control: Re-evaluate primary roof support
	Control: Consider supplemental roof support to manage elevated horizontal stresses
	Control: Consider potential for increased floor and rib problems (e.g. heave, rib sloughing)
Cause: Mining under/around water	Control: Identify bodies of water (e.g. historical records – overlying map and elevation of water; aquifers marked on geological model; inseam horizontal drilling to confirm absence of water)
	Control: Orient mining to minimize interaction with water bodies
	Control: Routine preshift and onshift inspections/monitoring for water hazards
	Control: Establish monitoring wells for water hazards
	Control: Consider dewatering
	Control: Establish and model barriers to calculate stability
Cause: Insufficient consideration for rock and coal properties (strength and susceptibility to water; including soft bottom leading to rib failure; strata mineralogy – especially clay minerals)	Control: Select appropriate bolt length
	Control: Select appropriate pillar size
	Control: Incorporate outcomes from models, sensitivity analysis
	Control: Increase factor of safety
	Control: Consider rib bolting
	Control: Integrate findings into the mine geological model and mine design
	Control: Install pumping and drainage systems to manage water on floor or face
	Control: Remove thin clay layer (cutting out) as part of mining process
	Control: Select appropriate equipment for floor bearing pressure and water usage
	Control: Consider using wetting agents in water supply to reduce volume of water used
	Control: Floor treatment (e.g. lime)
	Control: Use rail instead of rubber tires for transportation
Cause: Inadequate pillar dimensions (size, shape) by design	Control: Consider overburden depth and variation
	Control: Reevaluate all design parameters (e.g. stress, geology, abutment stresses, mine layout)
	Control: Review and select appropriate modeling software and approach

	Control: Consider prior experience in the same seam (own or adjacent mining)	
	Control: Consider future mining activity (e.g. retreat mining or longwall) when selecting dimensions	
	Control: Schedule peer or independent audit/review of pillar design	
Cause: Cleat pattern, orientation, spacing	Control: Consider rib support	
	Control: Consider primary production method in selection of orientation	
Cause: Known geological structures (faults, dykes, slickensides, rolls, swillies, washouts, etc.)	Control: Adjust mine geometry and panel orientation	
	Control: Include geological structures within the mine geological model	
	Control: Consider structures in development planning, equipment selection and scheduling	
	Control: Adjust bolting, strapping, grouting, secondary support activities to manage known structures	
Cause Category: Operating Practice (training, supervision, monitoring, audits, etc.)		
Cause: Excessive cutting height	Control: Provide miner operator training	
	Control: Audit and replace miner operator if required	
	Control: Provide foreman training	
	Control: Audit and replace foreman if required	
	Control: Install height indicators (e.g. sight onto the face, using laser)	
	Control: Increase or maintain supervision	
	Control: Select equipment to achieve desired entry height	
	Control: Characterize the roof geology to determine if different cutting heights are required	
	Control: Consider cutting the height out of the bottom	
Cause: Failure of one or multiple shields	Control: Undertake preventive maintenance program to ensure shield functionality	
	Control: Confirm shield specifications meet requirements for mining conditions /mine plan	Sub Control: Size, load capacity, shield reach, shield width, etc.
	Control: Selection of mining equipment and supplies that match mining conditions	
	Control: Purchase supplemental or new equipment if required to match mine plan or mine conditions	
	Control: Modification of mine plan to match available equipment and supplies	
	Control: Correct shield advance procedure	
	Control: Consider manual shield setting	
Cause: Cutting too low, equipment damage	Control: Provide miner operator training	
	Control: Audit and replace miner operator if required	
	Control: Provide foreman training	
	Control: Audit and replace foreman if required	
	Control: Take the height out of the bottom when required	
	Control: Match bit selection to the rock type	

	Control: Install height indicator if needed
	Control: Assign difficult travelling to one shift
	Control: Drill and shoot
	Control: Match miner operator to height of cutting
Cause: Abutment stress/barrier width inadequate	Control: Reduce number of entries
	Control: Install supplementary support
	Control: Build a barrier
	Control: Install standing support
	Control: Change adjacent pillar size
	Control: Reduce entry width or height
	Control: Rib support including grouting into barrier to stabilize
Cause: Failure to recognize changing vertical stress (changes in overburden, depth of cover)	Control: Increase number of core holes
	Control: Horizontal drilling when laying out panels
	Control: Integrate core hole drilling information into overlay maps
	Control: Establish triggers and communicate support changes
	Control: Confirm and maintain continuous feedback from bolt crew
Cause: Valley bottom stress effects	Control: Review past mining history in same seam
	Control: Train operators to identify this type of hazard
	Control: Highlight valley bottoms in topography map and consider mine plan adjustments
Cause: Mining under/around water (water make at face/probe drilling/ground water)	Control: Review past mining history in same seam
	Control: Train operators to identify this hazard
	Control: Highlight water bodies on topography map
	Control: Undertake directional drilling as needed
	Control: Confirm availability of discharge line/sumps for dewatering
Cause: Deviation from cleat pattern, orientation, spacing, penetration rate	Control: Install rib support
	Control: Reduce height
	Control: Provide miner crew training
	Control: Audit and replace with faster mining crew if conditions require
	Control: Reduce number of idle shifts
	Control: Match bit type to geologic conditions
	Control: Change orientation of entries (e.g. orient pillars perpendicular to face cleat)
	Control: Advance belt sooner, reduce haulage distance to increase cutting rate (i.e. less down-time waiting for shuttle cars due to long travel distances)
Cause: Nonconformance to development procedure (e.g. mining speed, advance rate, depth of cut, bolt installation timeframe)	Control: Review and/or adjust depth of cut relative to geological conditions
	Control: Reduce maximum standing times
	Control: Adjust the cutting height (e.g. incompetent layer, different equipment to cut down)
	Control: Narrow the entry width
	Control: Reduce panel width

	Control: Increase speed of bolt installation (e.g. select bolts with shorter install times)
Cause: Geological structures (faults, dykes, slickensides, rolls, swillies), known/unknown	Control: Map the geology and the extent of structure interference
	Control: Communication of geological/structural conditions
	Control: Ensure availability of sufficient supplies (e.g. support materials) and additional equipment
	Control: Install supplementary support
	Control: Match entry width to conditions (e.g. narrow entries)
	Control: Reduce the number of entries
	Control: Reduce depth of cut
	Control: Lengthen the pillars
	Control: Preplan to identify optimal location to start grading
	Control: Consider alternate bolt types including cables, torque-tension, glue
	Control: Relocate the section
Cause: Bottom conditions, soft undercut affecting face	Control: Use lighter equipment
	Control: Reduce number of entries
	Control: Install pumping and drainage system to manage water on floor
	Control: Relocate the section
	Control: Mine the bottom
	Control: Adjust or relocate hauling route
	Control: Program off sequence belt move
	Control: Reestablish face to suitable conditions (scaling, supplemental support, etc.)
Cause: Equipment and supplies not available or not compatible with mine plan or mine conditions	Control: Selection of mining equipment and supplies that match mining conditions
	Control: Purchase supplemental or new equipment if required to match mine plan or mine conditions
	Control: Modification of mine plan to match available equipment and supplies
	Control: Undertake preventive maintenance program to ensure equipment availability
	Control: Adjust availability of equipment and supplies
	Control: Improve or maintain communication between miners and support team (e.g. procurement, maintenance, warehouse, operations)
	Control: Do not mine if equipment is not fit for conditions
Cause: Excessive width of headgate, tailgate, or setup room	Control: Reduce number of entries
	Control: Install supplementary support
	Control: Build a barrier
	Control: Install standing support
	Control: Change adjacent pillar size
	Control: Reduce entry width or height

	Control: Rib support including grouting into barrier to stabilize	
Consequence: Roof fall at longwall face resulting in injury or fatality	Control: Separate personnel from potential fall zones on the longwall face	
	Control: Establish red zones on longwall (e.g. in front of spill plates on the armored face conveyor, AFC)	
	Control: Authorized access to red zones	
	Control: Limit the number of operators working on the face at any one time	
	Control: Automated equipment to maintain planned operating procedures and designed extraction geometry on the longwall face	Sub Control: Automate horizon control equipment to maintain designed cutting height
		Sub Control: Automated chock and armored face conveyor (AFC) advance to maintain designed shield and AFC advance sequence and timing
	Control: Remotely operated equipment to physically separate the operator from the working face (red zone)	
	Control: Design drilling and support installation equipment to maximize distance and create physical barriers between the operator and the face and allow operators to work in safe zone (e.g. under shield canopy and behind AFC spill plate)	
	Control: Remote controlled shearer equipment removes operator from face area where flyrock hazards exist	
	Control: Equipment design and selection to consider operator protection	Sub Control: Side shields reduce probability of roof material falling between the shields into work area
	Control: Guards on transfer point of conveyor prevents coal falling off and also access to block side of conveyor on headgate	
	Control: Personnel protective equipment (PPE) beyond minimum standard	Sub Control: Full face masks/helmet for protection from dust and flyrock - specific to site conditions
		Sub Control: Metatarsal boots
	Control: Training and awareness of safe operating procedures including safe zones and operational practice on longwall face	
	Control: Training on face management plan and operating sequence and under varying roof / face conditions	
	Control: Awareness and establishment of safe operational zones when there is potential for equipment interaction/impact (e.g. potential for impact between shearer drum and shield in thin seam or early advance of shields over shearer)	
	Control: Communication of hazards and awareness to longwall workforce: red zones, roof control plan, mine emergency plan (including mine escape procedures, communication methods, etc.)	
	Control: Face recovery plan - contingency actions related to safe recovery of face fall (e.g. use of temporary support if accessing red zone)	
	Control: On-site medical services and transport	

	Control: Minimized response time and likelihood of elevated consequence
	Control: First-aid and emergency response resources across all shifts (e.g. equipment, procedures, suitably trained personnel)
	Control: Emergency response plan to prevent further consequences from face fall (injury to fatality)
Consequence: Frictional ignition at longwall face, see RISKGATE Fires / Explosions Topics	Control: Fire suppression systems and monitoring
	Control: Statutory gas level monitoring
Consequence: Equipment damage or loss at longwall face	Control: Equipment designed to minimize the extent of face fall and withstand impact from rock fall
	Control: Design of systems to consider sprags, longwall gob shields, canopies, spill plate height, cable and hose protection, side shields, position of controls
Consequence: Production disruption, loss of resources, dilution	Control: Equipment designed to minimize the extent of face fall and withstand impact from rock fall (e.g. sprags, longwall gob shields, canopies, spill plate height, cable and hose protection, side shields, position of controls)
	Control: Spare equipment and parts on-site - to continue operations
	Control: Alternative mining area or stockpile - production substitution
	Control: Response plan to minimize disruption time during operation
	Control: Fall recovery plan and face stabilization plan
	Control: Equipment, skilled people and materials on site to implement above plans in a timely manner
	Control: Agreement in place to guarantee the availability of specialist services and resources - consolidation products, teams and suppliers, consultants (i.e. to reduce down time)
	Control: Ensure equipment insurance policies are in place

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Table C.6 – RISKGATE-US COAL bowtie: Burst of coal (at longwall face, development roadway, or outby roadway)

Initiating Event: Burst of Coal (at longwall face, development roadway, or outby roadway)		
Cause Category: Geology		
Cause: Changing geology/roof conditions	Control: Implement forecasting methods	Sub Control: Projection from known geology (e.g., from historical data)
		Sub Control: Detailed geologic characterization (boreholes, bore scopes, core drilling, e-logs)
		Sub Control: Historical mine mapping
	Control: Develop mine geological model	
	Control: Modify design of support system to address changing conditions	
	Control: Schedule independent audit of mine geological model	
Cause: Strata transition causing weak bedding plane/aminations (e.g., shale-shale, limestone-shale, rider seams, rider faults, stack rocks)	Control: Implement forecasting methods	Sub Control: Projection from known geology (e.g., from historical data)
		Sub Control: Detailed geologic characterization (boreholes, bore scopes, core drilling, e-logs)
		Sub Control: Historical mine mapping
	Control: Develop mine geological model	
	Control: Modify design of support system to address changing conditions	
	Control: Schedule independent audit of mine geological model	
Cause: Insufficient characterization of geology	Control: Secondary exploration drilling to update the mine geological model	
	Control: Targeted core-hole drilling of suspect areas	
Cause: Changes in overburden depth of cover leading to variations in vertical stress conditions	Control: Mine mapping of topography and depth of cover	
	Control: Recognizing the impact of overburden variation on mining conditions	
	Control: Modify design of support systems to address changes in depth (e.g., additional roof and rib supports, adjusting pillar design, etc.)	
Cause: Insufficient understanding of rock and coal properties (strength and susceptibility to water; including conditions that lead to rib failure)	Control: Characterize rock layer strength and composition (e.g., laboratory testing)	
	Control: Integrate findings into the mine geological model and mine design	
Cause: Cleat pattern, orientation, spacing	Control: In-situ geological mapping	
	Control: Integrate findings into the mine geological model and mine design	

Cause: Seismic event	Control: Characterization of proximal seismic activity (i.e., location, magnitude, and extent)	
	Control: Design of support system to minimize damage from seismic event	
Cause: Known geological structures (faults, dykes, slickensides, rolls, washouts, intrusions, channels)	Control: Exploration drilling	
	Control: In-situ geological mapping	
	Control: Geophysical surveys	
	Control: Consider surface lineament mapping	
	Control: Integrate findings into the mine geological model and mine design	
Cause: Horizontal stress (including the valley bottom stress effects)	Control: Consider stress outcomes from mining in adjacent mines	
	Control: Mapping of in-situ features (e.g., cutters)	
	Control: Mine mapping of topography to consider alignment of valleys and lineaments	
	Control: Measurement of horizontal stress direction and magnitude	
	Control: Design of support system sufficient to manage stress variations	
	Control: Mine planning and orientation	
Cause: Water bearing layer	Control: Permeability and piezometer tests on targeted water bearing horizons	
	Control: Implement forecasting methods	Sub Control: Projection from known geology (e.g., from historical data)
		Sub Control: Detailed geologic characterization (boreholes, bore scopes, core drilling, e-logs)
		Sub Control: Historical mine mapping
	Control: Develop mine geological model	
	Control: Modify design of support system to address changing conditions	
	Control: Schedule independent audit of mine geological model	
Cause Category: Design		
Cause: Inadequate roof support and increase in abutment stress	Control: Identify weak strata	
	Control: Consider conditions and effective intervention methods in adjacent mines, historical data	
	Control: Consider abutment stress	
	Control: Consider alarm gauge system which indicates excessive load on mobile roof supports	
	Control: Select appropriate modeling approach (e.g. FLAC, ARBS, ALPS, STOP, etc.)	
	Control: Consult with bolt suppliers (provide rock strength properties)	
	Control: Develop roof support plan	
	Control: Targeted drilling to relieve stress	
	Control: Consider life cycle requirements of mine workings (time/length of support required)	
	Control: Apply adequate factor of safety to design	
	Control: Revise and/or update roof support plans based on roof conditions (driller reports, etc.)	

	Control: Consider regulatory agency recommendations
	Control: Schedule independent audit of roof support design
Cause: Insufficient characterization of geology	Control: Increase factor of safety to compensate for unknown geological conditions
	Control: Targeted drilling
Cause: Changes in overburden and/or depth of cover	Control: Design roof control plan to account for variations in cover (e.g., match specific stress conditions)
	Control: Communicate changes in cover depth to personnel (e.g., conditions that lead to modification in mining practice)
Cause: Valley bottom stress effects	Control: Identify areas with expected valley bottoms (e.g., topography, degree of gradient change between low and high coverage)
	Control: Consider roof composition (e.g., laminated shale vs massive sandstone) and fracturing
	Control: Consider orientation of stress
	Control: Re-evaluate primary roof support
	Control: Consider supplemental roof support to manage elevated horizontal stresses
	Control: Consider potential for increased floor and rib problems (e.g., heaving, rib sloughing)
Cause: Mining under and around water	Control: Identify bodies of water (e.g., historical records - overlying map and elevation of water; aquifers marked on geological model; inseam horizontal drilling to confirm absence of water)
	Control: Orient mining to minimize interaction with water bodies
	Control: Routine preshift and onshift inspections/monitoring for water hazards
	Control: Establish monitoring wells for water hazards
	Control: Consider dewatering small bodies of water
	Control: Identify and model barriers to calculate stability
Cause: Insufficient consideration for rock and coal properties (strength and susceptibility to water; including soft bottom leading to rib failure; strata mineralogy - especially clay minerals)	Control: Select appropriate bolt length
	Control: Select appropriate pillar size
	Control: Incorporate outcomes from computer models, sensitivity analysis to design
	Control: Increase factor of safety
	Control: Consider rib bolting
	Control: Integrate findings into the mine geological model and mine design
	Control: Install pumping and drainage systems to manage water
	Control: Remove hazardous thin clay layers as part of mining process
	Control: Select appropriate equipment for floor bearing pressure
	Control: Consider using wetting agents in water supply to minimize volume of water used
	Control: Floor treatment (e.g., lime)
	Control: Use rail instead of rubber tired vehicles for transportation
Cause: Inadequate pillar dimensions (size, shape) by design	Control: Consider overburden depth
	Control: Reevaluate all design parameters (e.g., stress, geology, abutment stresses, mine layout)

	Control: Review and select appropriate modeling software and approach	
	Control: Consider prior experience in the same seam (i.e., adjacent mining)	
	Control: Consider future mining activity (e.g., retreat mining or longwall) when selecting pillar dimensions	
	Control: Schedule peer or independent audit/review of pillar design	
Cause: Cleat pattern, orientation, spacing	Control: Consider rib support	
	Control: Consider orientation of mine working with respect to cleat properties	
Cause: Known geological structures (faults, dykes, slickensides, rolls, washouts, etc.)	Control: Adjust mine geometry and panel orientation	
	Control: Include geological structures within the mine geological model	
	Control: Consider structures in development planning, equipment selection and scheduling	
	Control: Adjust bolting, strapping, grouting, secondary support activities to manage known structures	
Cause Category: Operating Practices (training, supervision, monitoring, audits, etc.)		
Cause: Excessive mining height	Control: Provide miner operator training	
	Control: Audit and replace miner operator if required	
	Control: Provide foreman training	
	Control: Audit and replace foreman if required	
	Control: Install height indicators (e.g., sight onto the face, lasers)	
	Control: Increase or maintain supervision	
	Control: Select equipment to achieve desired entry height	
	Control: Characterize the roof geology to determine if different mining heights are required	
	Control: Consider cutting the floor instead of the top to achieve necessary height	
Cause: Failure of one or multiple shields	Control: Undertake preventive maintenance program to ensure shield functionality	
	Control: Confirm shield specifications meet requirements for mining conditions/mine plan	Sub Control: Size, load capacity, shield reach, shield width, etc.
	Control: Selection of mining equipment and supplies that match mining conditions	
	Control: Purchase new equipment if required to match mine plan or mine conditions	
	Control: Refine shield advance procedure	
	Control: Manually operate shields when needed	
Cause: Insufficient mining height to remove unstable strata	Control: Provide miner operator training	
	Control: Audit and replace miner operator if required	
	Control: Provide foreman training	
	Control: Audit and replace foreman if required	
	Control: Match bit selection to rock type	
	Control: Install height indicator if needed	
	Control: Match equipment to height of cutting	

Cause: Abutment stress/pillar size inadequate	Control: Reduce number of entries
	Control: Install supplementary support
	Control: Change adjacent pillar size
	Control: Reduce entry width or height (i.e., increase pillar size)
	Control: Rib support including grouting in the pillar to stabilize
	Control: Targeted drilling to relieve stress
Cause: Failure to recognize changing vertical stress (changes in overburden, depth of cover)	Control: Increase number of core holes to map stress distribution
	Control: Horizontal drilling when laying out panels
	Control: Integrate core hole drilling information into mine design
	Control: Communicate support changes to mine personnel
	Control: Maintain continuous feedback from roof support crew
Cause: Valley bottom stress effects	Control: Review past mining history in the same seam
	Control: Train operators to identify this type of hazard
	Control: Highlight valley bottoms in topography map and consider mine plan adjustments
Cause: Mining under/around water (water make at face/probe drilling/ground water)	Control: Review past mining history in the same seam
	Control: Train operators to identify this hazard
	Control: Highlight water bodies on topographic map
	Control: Undertake directional drilling as needed for dewatering
	Control: Maintain discharge line/sumps for dewatering
Cause: Deviation from expected cleat pattern, orientation, spacing	Control: Install rib support
	Control: Reduce mining height
	Control: Provide personnel training
	Control: Reduce the time that unsupported roof is left unsecured
	Control: Match bit type to geologic conditions
	Control: Change orientation of entries (e.g., orient pillars perpendicular to face cleat)
Cause: Noncompliance to development procedure (e.g., mining speed, advance rate, depth of cut, bolt installation timeframe)	Control: Review or revaluate development procedures with employees
	Control: Increase the presence of supervisors
	Control: Disciplinary action if noncompliance becomes habitual
Cause: Geological structures (faults, dykes, slickensides, rolls), known/unknown	Control: Map the geology and surrounding structure
	Control: Communication of geological/structural conditions to mine personnel
	Control: Ensure availability of sufficient roof support supplies and equipment
	Control: Install supplementary supports
	Control: Match entry width to conditions
	Control: Reduce the number of entries
	Control: Reduce depth of cut
	Control: Increase pillar size
	Control: Consider alternate bolt types including cable, torque-tension, and resin grouted
	Control: Relocate the active section
Cause: Bottom conditions, soft	Control: Use lighter equipment

undercut affecting face	Control: Reduce number of entries	
	Control: Install pumping and drainage system to manage water on floor	
	Control: Relocate the active section	
	Control: Mine the bottom	
Cause: Equipment and supplies not available or not compatible with mine plan or mine conditions	Control: Select mining equipment and supplies that match mining conditions	
	Control: Purchase new equipment if required to match mine plan or mine conditions	
	Control: Modify mine plan to match available equipment and supplies	
	Control: Undertake preventive maintenance program to reduce downtime	
	Control: Improve or maintain communication between miners and support teams (e.g., purchasing, maintenance, warehouse, operations)	
	Control: Do not use if equipment is not fit for conditions	
Cause: Excessive entry width of headgate, tailgate, or setup room	Control: Reduce entry width	
	Control: Install supplemental support	
	Control: Change adjacent pillar size	
	Control: Rib support including grouting into pillar to stabilize	
Consequence: Injury or fatality	Control: Remove personnel from area until further risk is assessed	
	Control: Minimize the number of personnel working in potential outburst areas	
	Control: Automate equipment to maintain planned operating procedures on the longwall face	Sub Control: Automate horizon control equipment to maintain designed cutting height
		Sub Control: Automate chock and armored face conveyor (AFC) advance to maintain designed shield and AFC advance sequence and timing
	Control: Implement remotely operated equipment to separate the operator from the working face	
	Control: Design drilling and support installation equipment to protect operators from exposure	
	Control: Implemented remote shearer equipped with video monitoring to remove operator from face area where flyrock hazards exist	
	Control: Equipment design and selection to consider operator protection from outbursts	
	Control: Personnel protective equipment (PPE) beyond minimum standard	Sub Control: Full face masks/hardhat for protection from dust and flyrock - specific to site conditions
	Control: Training on safe operating procedures around outburst prone areas	
	Control: Training and awareness of indications of danger including noise (coal bumps), acceptable load on mobile roof support, acceptable load on supplemental roof support, floor heave, and other environmental anomalies	

	Control: Communication of hazards to mine personnel: roof control plan, mine emergency plan (including mine escape procedures, communication methods, etc.)
	Control: Ensure that local agreements are in-plan for medical services and transport. If practical, implement on-site medical personnel (i.e., mine workers who are EMT certified, etc.) and transportation
	Control: Minimize emergency response time
	Control: Ensure availability of first-aid and emergency response resources across all shifts (e.g. equipment, kits)
Consequence: Equipment damage or loss	Control: Design equipment to withstand impact from outburst
	Control: Design of systems to consider longwall gob shields, canopies, spill plate height, cable and hose protection, side shields, position of controls
	Control: Ensure that adequate insurance policies are in-place
Consequence: Production disruption, loss of resources	Control: Design equipment to withstand impact from outburst
	Control: Spare equipment and parts on-site to continue operations
	Control: Design response plan to minimize downtime after outburst
	Control: Institute outburst response plan
	Control: Ensure personnel are available to implement response plans in a timely manner
	Control: Agreement in place to guarantee the availability of specialized services and resources - consolidation products, teams and suppliers, consultants (i.e. to reduce down time)
	Control: Ensure equipment insurance policies are in place

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Table C.7 – RISKGATE-US COAL bowtie: Loss of control of mobile equipment (including events caused by less than adequate operation/design of equipment)

Initiating Event: Loss of control of mobile equipment (including events caused by less than adequate operation/design of equipment)	
Cause Category: Operations	
Cause: Lack of communication between two vehicles	Control: Radio communications
	Control: Dispatch (especially rail)
	Control: Block lights
	Control: Equipment tracking
	Control: Proximity detection systems
	Control: Transparent ventilation controls
	Control: Visual barriers (including maintenance)
	Control: Lighting (including directional, reflective)
	Control: Training, including default when system fails
	Control: Shut down when proximity detection fails
	Control: Light signals
Cause: Vehicle interactions due to reduced visibility around ventilation controls (e.g. curtains)	Control: Consider matching the regulatory requirements to the actual needs of the mine (e.g. idle face ventilation)
	Control: Transparent materials
	Control: Installation and maintenance
	Control: Standard Operating Procedures (SOP)
	Control: Remove ventilation controls when not needed
	Control: Communication (pedestrian to notify operators that working in section)
	Control: Planning and development
	Control: Signage, use of reflectors or lighting (including individual strobe lights, side lights)
	Control: Consider reflective color spectrum match to cameras
	Control: Training, awareness, compliance
	Control: High visibility personal protective equipment (PPE) (including strobe lights)
Cause: Fatigue (including overwork/absenteeism/change in behavior)	Control: Consideration for automation and mechanization
	Control: Consideration for monitoring/early warning technology
	Control: Integration of fatigue management within workforce health and wellbeing programs
	Control: Achieve effective balance between work load and staffing
	Control: Establish and implement site-based standards with respect to fatigue management
	Control: Consider guidance materials from other high-risk industries
Cause: Excessive payload	Control: Standard Operating Policies for supplies/payloads and loading on equipment
	Control: Buy-in from management regarding load limits
	Control: Clear communication and training regarding impacts of overloading (loss during travel, damage to mine infrastructure, increased maintenance)
	Control: Overload/height indicators

	Control: Understanding of impact of material density (e.g. coal vs rock; braking distance and braking capacity)	
	Control: Weight sensor	
	Control: Clear communication between CM operator and load operators	
	Control: Consideration for auto-stop sensors/technology when payload exceeds operating limits	
Cause: Safety policy is less than adequate	Control: Appropriate and effective policies	
	Control: Development of equipment and operations standards and policies that consider impacts on vehicle interactions (e.g. transport rules)	
	Control: Stakeholder engagement (feedback) in development of policies	
	Control: Audit, regular review/measurement (all stakeholders) and update of policies	
	Control: Compliance and enforcement - management leadership and limits	
Cause: Operational changes (change in routine or due to changing conditions, including alteration of equipment travel routes, planned/unplanned maintenance in roadway)	Control: Planning and development to consider change management	
	Control: Consider impacts of change to mining sequence/procedures (depth of cut, panel design, etc.) on existing travel conditions	
	Control: Establish communication protocols for changes	Sub Control: Routine tool-box talks
		Sub Control: From site level to individual sections
		Sub Control: Thorough communication of change across all workers within a section
		Sub Control: Accurate communication between shifts
	Control: Standard Operating Procedures (e.g. trigger action response) to worsening conditions	Sub Control: Shut down/stop work
		Sub Control: Recognize that the smallest routine changes can result in catastrophic accident)
	Control: Supervision and on-the-job training with respect to managing changes in conditions and/or routines	
Cause: Production pressures (perceived and/or actual) including impacts of corporate culture, generational factors, absenteeism, insufficient size of workforce (increased personal stress, individual workload)	Control: Corporate culture: e.g. do not run if something is wrong	
	Control: Management leadership and commitment to culture that retains workforce	
	Control: Continuous process improvement supported by proactive management	
	Control: Development and communication of clear workforce expectations and accountabilities	
	Control: Employee selection, with consideration for impact/integration of prior workplace cultures	
	Control: Adaptation of workplace culture to engage with younger workers	
	Control: Engagement of seasoned workforce in adaptation and implementation of new technology	

Cause: Incompetent operator (e.g. lack of training, inexperience)	Control: Develop and implement Standard operating procedures (SOPs), safe work procedures that are appropriate for site and workforce	
	Control: Appropriate and effective training	Sub Control: Consider use of advanced training methods (e.g. virtual reality)
		Sub Control: Include adequate training of the trainer
		Sub Control: Standard Operating Procedures (SOPs)
		Sub Control: Safe work procedures
		Sub Control: Confirm equipment operating competency
	Control: Ensure that operator is adequately trained to safely function in designated work zone	Sub Control: Mine layout
		Sub Control: Mine conditions
		Sub Control: Hazards
		Sub Control: Requirements for specific equipment
	Control: Develop and implement mentoring programs	Sub Control: Matching experienced operators to novice operators
		Sub Control: Matching less experienced foremen (e.g. red hat mentors) to those with experience
	Control: Train supervisors to maximize operator competency and identify/manage operators that do not meet required performance levels	
Cause: Mechanical failure (braking system, dynamic conditions of road/rail and load)	Control: Preventive maintenance	
	Control: Pre-op inspection	
	Control: Regular inspection and testing	
	Control: Track maintenance	
	Control: Adequate braking technology	
	Control: Intentional derail	
	Control: Operator training - gentle touch	
Cause: Deviation from planned haulage route (e.g. when running battery, diesel, scoop operators)	Control: Communication	
	Control: Call the road before proceeding (radio communication)	
	Control: Planning and development	
	Control: Change management	
	Control: Signage, use of reflectors/lighting/other to mark routes	
	Control: Standard Operating Procedures (SOP, protocols for scoops, haulers, pedestrians)	
	Control: Training, awareness, compliance	
	Control: High visibility clothing	
Cause: Environmental factors (uphill, downhill, rolling), ambient (rock dusting)	Control: Schedule rock dusting to minimize dust impact on operations	
	Control: Communication of schedules	
	Control: Operate efficiently in challenging conditions to minimize time in those conditions	

	Control: Traffic management plan, sectional access controls to manage environmental factors	
	Control: Mine design	
Cause: Travelling speed exceeds safe level (different road surface, roadway conditions, visibility)	Control: Mechanical limits	
	Control: Optimize distance to feeder, increase belt moving	
	Control: Consider impact of roadway watering on different road surfaces (e.g. clay)	
	Control: Gravel and grading of roadways	
	Control: Water management plan (pumping)	
	Control: Application of calcium for dust	
	Control: Intentional derails	
Cause: Aging workforce	Control: Consider the time that long-time workers may need to adapt to new technology	
	Control: Correct body movement/posture training for operators	
	Control: Consideration for diminished eyesight, hearing, flexibility in task design (appropriate corrective devices)	
Cause: Congestion/high traffic areas (including new/additional vehicles)	Control: Planning and development	Sub Control: Change out locations
		Sub Control: Right of ways
		Sub Control: Detailed schedule for longwall or other equipment moves
	Control: People management	Sub Control: Asynchronous schedules (e.g. crews start/return at different times)
		Sub Control: Limits on visitors, survey crews, etc.
	Control: Increase sensory awareness	Sub Control: Lights (both mobile and fixed plant, directional lights)
		Sub Control: Signs
		Sub Control: Audible warnings (e.g. back-up horn)
	Control: Develop and implement communication protocols	Sub Control: Dispatch and block light system
		Sub Control: Changed conditions
		Sub Control: Visitors
	Control: Travel way maintenance	
	Control: Proximity detection systems	
Cause: Inadequate or improper signage	Control: Develop and implement site-based signage standards	Sub Control: Choice of materials
		Sub Control: Consideration for impact of rock dusting
		Sub Control: Maintenance plan, including cleaning
		Sub Control: Locate signs where equipment damage to sign is minimized
		Sub Control: Locate signs where they can be seen
	Control: Keep signage current with changes in section	

	Control: Consideration for color-blindedness in workforce	
Cause: Dynamics and congestion of longwall move (including complexity, size, quantity and diversity of equipment, additional new vehicles in traffic flow)	Control: Planning and development	Sub Control: Detailed schedule for longwall or other equipment moves
		Sub Control: Allocation of best operators to the equipment, maximize efficiency and reduce time
		Sub Control: Pre-move audit of haulage system (track, switches, components, clearance)
		Sub Control: Pre-operation checklist on equipment (mules, changes, hooks, etc.)
		Sub Control: Change out locations
		Sub Control: Right of ways
		Sub Control: Longwall move has complete priority over right of way
		Sub Control: Control non-longwall travel during move (e.g. not allowed on track during move, post man at every switch during move to control traffic)
	Control: People management	Sub Control: Asynchronous schedules (e.g. crews start/return at different times)
		Sub Control: Limits on visitors, survey crews, etc.
	Control: Increase sensory awareness	Sub Control: Lights (both mobile and fixed plant, directional lights)
		Sub Control: Signs
		Sub Control: Audible warnings (e.g. back-up horn)
	Control: Develop and implement communication protocols	Sub Control: Dispatch and block light system
		Sub Control: Increased communication and heightened awareness regarding exclusion from area of move
		Sub Control: Transfer dispatch duties underground to near longwall move; or one dispatch for move, and one for remainder of mine; separate radios
		Sub Control: Manage changed conditions
		Sub Control: Manage/preclude visitors
	Control: Travel way maintenance	
	Control: Proximity detection systems	

Cause: Capacity of available workforce is limited due to geography or demographics	Control: Consideration for automation/mechanization	
	Control: Build talent pool of suitable workforce in local community	Sub Control: Investment in community education (high school, community college, youth/adults)
	Control: Adapt mine operations to characteristics of workforce (e.g. times of shift for farmers, car pooling for people with no license, work release, school bus times)	
	Control: Recruitment/HR practice that engages available workers (e.g. consideration for local factors)	
	Control: Consideration and accommodation for worker literacy (e.g. color coding buttons)	
	Control: Consideration and accommodation for ESL employees (e.g. Hispanic)	
	Control: Make GED/other education available as a sign of corporate commitment to individual employees	
	Control: Develop and implement corporate culture that retains workforce	
Cause: Prescriptive regulation may increase risk for certain operations	Control: Prescriptive regulation may preclude an adaptive risk-based approach that considers the unique requirements of each site	
	Control: Notification to operators of visitors could be construed as prior notice for inspections	
	Control: Required minimum air quantities -> unnecessary ventilation controls -> creates risk	
	Control: Differences between regulatory requirements (e.g. red zone interpretation)	
	Control: Prescriptive proximity detection systems may not be fit for purpose	
Cause: Personnel working in red zone	Control: Define red zone for all equipment (continuous miner, roof bolter, haulage equipment, etc.)	Sub Control: Consider undertaking risk assessment to define red zone for all equipment based on operating conditions and procedures (operating, moving, maintenance, etc.)
		Sub Control: Establish high risk areas for each activity (e.g. pinch points, warning areas)
		Sub Control: Document outcomes in roof control plans, tramming procedures, personnel training programs
	Control: Adequate training, awareness, and competency of all personnel with respect to red zones	
	Control: Provide personnel supervision	Sub Control: Voice/audio communication with others
		Sub Control: Communication by signaling
	Control: Ensure adequate engineering controls for tramming	Sub Control: Remote control
		Sub Control: Dual controls
		Sub Control: Operator guards

	Control: Use of proximity detection systems (e.g. CMS)	Sub Control: Ensure comprehensive coverage of all personnel with respect to red zones
		Sub Control: Calibrate proximity detection systems to abide by red zone criteria
		Sub Control: Ensure proximity detection equipment is reliable and tamper-proof
Cause: Failure of proximity detection system (also see “Cause: Personnel working in red zone”)	Control: Ensure collision management systems (CMS) are not a primary control technology for interactions between personnel and mobile equipment	
	Control: Ensure mine road design, traffic management plans, operating and maintenance practices, etc. are in place prior to integration of personal detection devices	
	Control: System setup based on outcomes of risk assessment for red zone delineation, and individual units maintained and calibrated	
	Control: Confirm comprehensive coverage - all pedestrians in the CM section are equipped with transmitters/receivers	
Cause: Noise level due to mining environment interferes with personnel ability to perceive hazards	Control: Redesign/reengineer moving equipment with objective to reduce noise generation	
	Control: Ensure adequate visibility in all roadways (see “Cause: Equipment operator has restricted visibility”)	Sub Control: Measures to increase visibility
		Sub Control: High viz PPE, directional lighting, signage, clear curtains, lights on pagers, beacons
	Control: Hearing PPE (including moulded silicone earplugs)	
	Control: Implementation of other communication modes to compensate for noise impacts	
	Control: Enhanced visibility (e.g. mirrors at turns)	
	Control: Dosimeter readings on equipment	
	Control: Wear strips, noise damping blankets	
Cause: Poor ground conditions affect traverse capability (excess water, slippery floor, etc.)		
Cause: Deviant practice of personnel (short-cuts, recklessness, etc.)		
Cause Category: Equipment		
Cause: Failure of communication system between two vehicles (including failure of communication devices, radios, lights, horns, etc.)	Control: Dispatch (especially rail)	Sub Control: Communication alert
	Control: Proximity detection systems	Sub Control: Equipment tracking with automated/triggered warning, shut down
		Sub Control: Shut down when proximity detection down/fails
	Control: Improved visibility	Sub Control: Lighting (including directional, reflective, light signals)
		Sub Control: Transparent ventilation controls

		Sub Control: Highly visible protective barriers (including durability and maintenance)
	Control: Routine maintenance and verification of communications systems	Sub Control: Check and maintain radios, lights
		Sub Control: Block lights
	Control: Training in use of communication protocols	Sub Control: Including default procedures when system fails (e.g. standby, shut down)
Cause: Equipment operator has restricted visibility (equipment design and/or modifications/retrofit)	Control: Conduct design risk assessment of vehicle visibility for all mobile equipment, and any equipment modifications or retrofit	Sub Control: Identify and map blind spots
		Sub Control: Include engineering, and equipment operators in risk assessment
		Sub Control: Modify or optimize equipment design to maximize visibility
	Control: Ensure adequate visibility from cab for equipment operators	Sub Control: Provide adequate lighting on equipment
		Sub Control: Mirrors
		Sub Control: Install directional lighting on mobile equipment
		Sub Control: Install LED lights on mobile equipment
		Sub Control: Install cameras on mobile equipment
		Sub Control: Schedule routine verification and maintenance for all visibility-related devices
	Control: Maximize visibility of mine environment to equipment operator	Sub Control: Use of reflective/high visibility clothing
		Sub Control: Provide personnel with strobe lights
		Sub Control: Ensure rock dust is sufficiently applied to roadways
		Sub Control: Adequate ventilation controls, including water sprays, transparent fly pads, etc.
		Sub Control: Schedule routine verification and maintenance for lighting and other controls
	Control: Proximity detection systems	Sub Control: Equipment tracking with automated/triggered warning, shut down
		Sub Control: Shut down when proximity detection down/fails
Cause: Operational changes (e.g. deployment of different equipment, downtime due to planned/unplanned maintenance, retrofit)	Control: Planning and development to in response to equipment changes	Sub Control: Consider impact of equipment changes on travel plan and modify travel plan as required
		Sub Control: Workforce training in adaptation to equipment

		changes
	Control: Establish communication protocols for changes	Sub Control: Routine tool-box talks
		Sub Control: From site level to individual sections
		Sub Control: Thorough communication of change across all workers within a section
		Sub Control: Accurate communication between shifts
	Control: Modification of Standard Operating Procedures (e.g. trigger action response) for unplanned/planned equipment change	Sub Control: Shut down/stop work
		Sub Control: Recognize that the smallest routine changes can result in catastrophic accident
		Sub Control: Different routes
	Control: Supervision and on-the-job training with respect to managing changes in conditions and/or routines	
Cause: Mechanical failure (braking system, dynamic conditions of road/rail and load, load not properly secure)	Control: Schedule routine equipment inspections	Sub Control: Pre-op inspection
		Sub Control: Regular inspection and testing
	Control: Establish preventive maintenance program	Sub Control: Consider supplier guidelines
		Sub Control: Adapt maintenance schedule in response to operating conditions and outcomes (e.g. increased maintenance if increased wear and tear on equipment)
		Sub Control: Track maintenance programs are essential in rail environments
		Sub Control: Roadway maintenance programs enhance operability of mobile equipment
	Control: Undertake risk assessment regarding equipment braking requirements and operating environment	Sub Control: Ensure selection of braking technology that is fit for purpose
	Control: Operator training	Sub Control: Gentle touch
		Sub Control: Importance of inspections and maintenance - awareness of required schedules
		Sub Control: Ensure that operators understand correct procedures for securing loads
		Sub Control: Conditions and procedures for intentional derail (equipment out of control, mechanical failure)

	Control: Operator supervision, audit, spot-checking	
Cause: Equipment not fit for purpose (inappropriate design, dynamic mining conditions, geologic anomalies, grandfathered equipment, “that’s all we got”)	Control: Conduct mobile equipment risk assessment (including equipment modifications or retrofit) to identify operating requirements	Sub Control: Develop procurement specifications that incorporate risk assessment outcomes
		Sub Control: Include engineering, and equipment operators in risk assessment
		Sub Control: Procurement to purchase equipment for optimal performance in mine operating conditions
	Control: Modify or optimize equipment design to maximize safe operations	Sub Control: Consider retrofitting equipment in the field
		Sub Control: Changing drums, bit patterns, tire size, sideboards, canopy heights
		Sub Control: Add cameras
		Sub Control: Add proximity detection systems
		Sub Control: Switch to LED lighting
		Sub Control: Adapt operator seat height/position to conditions
		Sub Control: Directional lighting or illumination
	Control: Select equipment appropriate to task	
	Control: Redesign roadway layout, dimensions in mine plan (e.g. new section) to match the requirement available equipment	
Cause: Personnel working in red zone	Control: Accurately define red zone for all equipment (continuous miner, roof bolter, haulage equipment, etc.)	Sub Control: Consider undertaking risk assessment to define red zone for all equipment based on operating conditions and procedures (operating, moving, maintenance, etc.)
		Sub Control: Establish high risk areas for each activity (e.g. pinch points, warning areas)
		Sub Control: Document outcomes in roof control plans, tramming procedures, personnel training programs
	Control: Ensure adequate engineering controls for tramming	Sub Control: Remote control
		Sub Control: Dual controls (e.g. operator with flexibility to drive equipment by remote controls or controls on vehicle)
		Sub Control: Operator guards

	Control: Use of proximity detection systems (e.g. CMS)	Sub Control: Ensure comprehensive coverage of all personnel with respect to red zones
		Sub Control: Calibrate proximity detection systems to abide by red zone criteria
		Sub Control: Ensure proximity detection equipment is reliable and tamper-proof
Cause: Failure of proximity detection system (also see "Cause: Personnel working in red zone")	Control: Ensure collision management systems (CMS) are not a primary control technology for interactions between personnel and mobile equipment	
	Control: Ensure mine road design, traffic management plans, operating and maintenance practices, etc. are in place prior to integration of personal detection devices	
	Control: System setup based on outcomes of risk assessment for red zone delineation	
	Control: Individual proximity detection units maintained and calibrated	
	Control: Remove equipment from operations until proximity detection units are fully repaired and verified	
Cause: Noise level due to mining environment interferes with personnel ability to perceive hazards	Control: Redesign/reengineer/retrofit moving equipment with objective to reduce noise generation	
	Control: Enhanced visibility (e.g. mirrors at turns)	
	Control: Dosimeter readings on equipment	
	Control: Wear strips to reduce vibration/breakdown of bolts/bits	
	Control: Noise damping blankets	
Cause Category: Environment		
Cause: Equipment operator or pedestrian has restricted visibility (low seam/confined mining space, roadway design, etc.)	Control: Ensure adequate visibility in all roadways, intersections	Sub Control: Provide adequate area lighting
		Sub Control: Use of reflective/high visibility clothing
		Sub Control: Provide personnel with strobe lights
		Sub Control: Install directional lighting on mobile equipment
		Sub Control: Ensure rock dust is sufficiently applied to roadways
		Sub Control: Install LED lights on mobile equipment
		Sub Control: Install cameras on mobile equipment
		Sub Control: Adequate ventilation controls, including water sprays, transparent fly pads, etc.
	Control: Conduct risk assessment of mobile equipment procedures for traffic interactions when moving where	Sub Control: Develop and implement procedures and controls determined pertinent by the risk assessment

	pedestrians in area	Sub Control: Consider equipment tag out, use of spotters, communication protocols, etc.
	Control: Establish equipment tramming speed limits that are consistent with prevailing visibility and environmental conditions	
Cause: Vehicle interactions due to reduced visibility around ventilation controls (e.g. curtains, flypads)	Control: Conduct risk assessment of mobile equipment procedures for traffic interactions around ventilation controls	
	Control: Develop and implement procedures and controls determined pertinent by the risk assessment	Sub Control: Consider equipment tag out, use of spotters, communication protocols, etc.
		Sub Control: Consider matching the regulatory requirements to the actual needs of the mine (e.g. idle face ventilation)
		Sub Control: Communication (pedestrian to notify operators that working in section)
		Sub Control: Remove ventilation controls when not needed
	Control: Use of transparent materials for ventilation controls	
	Control: Standard Operating Procedures (SOP) for navigating ventilation controls	Sub Control: Appropriate speeds
		Sub Control: Communication (visual/lights, noise/horn) prior to passing through
		Sub Control: Positive communication and confirmation with others on section
		Sub Control: Training of all personnel with respect to SOPs
		Sub Control: Supervision, auditing, compliance with SOPs
	Control: Determine optimum location of ventilation controls to minimize unwanted interactions	Sub Control: Do not install where mobile equipment is required to turn
	Control: Visibility, signage, use of reflectors or lighting on both equipment and personnel including individual strobe lights, side lighting	Sub Control: Consider reflective color spectrum match to cameras
		Sub Control: High visibility PPE (including strobe lights)
Cause: Operational changes due to changing environmental conditions (including geological conditions, water, etc.)	Control: Planning and development to consider change management	
	Control: Consider impacts of change to mining procedures on existing travel conditions	
	Control: Establish communication protocols for changes	Sub Control: Routine tool-box talks
		Sub Control: From site level to individual sections

		Sub Control: Thorough communication of change across all workers within a section
		Sub Control: Accurate communication between shifts
	Control: Adapt Standard Operating Procedures (e.g. trigger action response) to worsening conditions	Sub Control: Shut down/stop work
		Sub Control: Recognize that the smallest routine changes can result in catastrophic accident
		Sub Control: Implement and audit reduced speed limits
	Control: Supervision and on-the-job training with respect to managing changes in conditions and/or routines	
Cause: Environmental factors (uphill, downhill, rolling), ambient conditions (rock dusting)	Control: Supervision and on-the-job training with respect to managing changes in environmental conditions and changed routines	Sub Control: Training with respect to reduced visibility inherent to uphill, downhill, rolling roadways
		Sub Control: Audit operator performance in difficult conditions
	Control: Schedule rock dusting to minimize impact on visibility while traveling	Sub Control: Communication of rock dusting schedules
	Control: Traffic management plan	Sub Control: Establish sectional access controls in response to environmental factors
		Sub Control: Operate efficiently in challenging conditions to minimize time in those conditions
	Control: Modify mine design to account for environmental factors	
	Control: Dispatch to recognize specific zones of environmental challenge	Sub Control: Communication alert
	Control: Proximity detection systems	Sub Control: Equipment tracking with automated/triggered warning, shut down
		Sub Control: Shut down when proximity detection down/fails
	Control: Lighting (including directional, reflective, light signals)	
Cause: Roadway conditions require reduced speeds (different road surface, roadway conditions, visibility, water, gravel, uneven/broken surface, slants)	Control: Adapt/modify mechanical limits (e.g. governor) for changed roadway conditions	
	Control: Consider impact of roadway watering on different road surfaces (e.g. clay)	
	Control: Maintain drivability of roadways	Sub Control: Gravel and grading of roadways
		Sub Control: Water management plan (pumping, dewatering)
		Sub Control: Application of calcium for dust
	Control: Supervision and on-the-job training with respect to	Sub Control: Training with respect to reduced visibility

	changes in roadway conditions	Sub Control: Audit operator performance in difficult conditions
	Control: Dispatch to recognize specific zones of environmental challenge	Sub Control: Communication alert
	Control: Proximity detection systems	Sub Control: Equipment tracking with automated/triggered warning, shut down
		Sub Control: Shut down when proximity detection down/fails
	Control: Lighting (including directional, reflective, light signals)	
Cause Category: Behavior		
Cause: Lack of communication between two vehicles (e.g. distraction, inattention, not looking)	Control: Establishment, training, monitoring of safety culture	
	Control: Training, including default when system fails	
	Control: Dispatch (especially rail)	Sub Control: Communication alert
	Control: Proximity detection systems	Sub Control: Equipment tracking with automated/triggered warning, shut down
		Sub Control: Shut down when proximity detection down/fails
	Control: Lighting (including directional, reflective, light signals)	
Cause: Working under the influence (drugs, alcohol)	Control: Development and communication of workplace standards or policies	
	Control: Compliance with mandatory state regulations	
	Control: Compliance with workplace standards or policies	Sub Control: Develop approach to situations issues where choice made to keep good worker, ignore substance usage
	Control: Consideration for routine drug and alcohol monitoring programs (e.g. start of shift)	
	Control: Integration of drug/alcohol education within workforce health and wellbeing programs	
	Control: Availability of rehabilitation programs	
	Control: Random testing	
	Control: Consider guidance materials from other high-risk industries	
Cause: Fatigue (including overwork/absenteeism/change in behavior)	Control: Consideration for automation and mechanization	
	Control: Consideration for monitoring/early warning technology	
	Control: Integration of fatigue management within workforce health and wellbeing programs	
	Control: Achieve effective balance between work load and staffing	
	Control: Establish and implement site-based standards with respect to fatigue management	
	Control: Consider guidance materials from other high-risk industries	
Cause: Excessive payload	Control: Standard Operating Policies from suppliers for payloads and loading on equipment	
	Control: Training and clear communication	Sub Control: Training regarding payloads

		Sub Control: Training regarding impacts of overloading (loss during travel, damage to mine infrastructure, increased maintenance)
		Sub Control: Impact of material density (e.g. coal vs rock, braking distance and braking capacity)
	Control: Buy-in from management regarding load limits	
	Control: Overload/height indicators	Sub Control: Weight sensor - dynamic in cab
		Sub Control: Labeling equipment with weight/height limits
		Sub Control: Maintain visibility of labels in operating environment
		Sub Control: Consideration for 'auto-stop' sensors/technology when payload exceeds operating limits
		Sub Control: Validate operating performance of overload/height indicators
		Sub Control: Ensure overload/height indicators are reliable and tamper-proof
	Control: Clear communication between CM operator and load operators	
Cause: Production pressures (perceived and/or actual) including impacts of corporate culture, generational factors, absenteeism, insufficient size of workforce (increased personal stress, individual workload)	Control: Corporate culture: "do not run if something is wrong"	
	Control: Management leadership and commitment to culture that retains workforce	
	Control: Human resources to ensure sufficient workforce availability, including personnel redundancy in critical positions (e.g. continuous miner operator)	
	Control: Development and communication of clear workforce expectations and accountabilities	
	Control: Selection/hiring of employees to consider impact/integration of prior workplace cultures	
	Control: Adaptation of workplace culture to engage with younger/new workers	
Cause: Mechanical failure (braking system, dynamic conditions of road/rail and load)	Control: Operator training	Sub Control: Gentle touch
		Sub Control: Importance of inspections and maintenance - awareness of required schedules
		Sub Control: Conditions and procedures for intentional derail (equipment out of control, mechanical failure)
	Control: Pre-op inspection	
	Control: Regular inspection and testing	
	Control: Operator supervision, audit, spot-checking	

Cause: Travelling speed exceeds safe level (different road surface, roadway conditions, visibility)	Control: Operator training	Sub Control: Clear communication of operating speed limits
		Sub Control: Consequences of exceeding operating speed limits
	Control: Operator supervision, audit, spot-checking	
	Control: Mechanical limits	Sub Control: Regular inspection
		Sub Control: Validation of governor performance
		Sub Control: Ensure mechanical limiting equipment is reliable and tamper-proof
	Control: Promote safe operating speeds	Sub Control: Optimize distance to feeder, move belt more frequently
	Control: Roadway maintenance	Sub Control: Grading of roadways
Cause: Aging workforce	Control: Open communication between management and workforce	
	Control: Consider the time that long-time workers may need to adapt to new technology	
	Control: Correct body movement/posture training for operators	
	Control: Consideration and accommodation for diminished eyesight, hearing, flexibility in task design (appropriate corrective devices)	
Cause: Incompetent operator (e.g. lack of training, inexperience)	Control: Develop and implement Standard operating procedures (SOPs), safe work procedures that are appropriate for site and workforce	
	Control: Appropriate and effective training	Sub Control: Consider use of advanced training methods (e.g. virtual reality)
		Sub Control: Include adequate training of the trainer
		Sub Control: Standard operating procedures (SOPs)
		Sub Control: Safe work procedures
		Sub Control: Confirm equipment operating competency
	Control: Ensure that operator is adequately trained to safely function in designated work zone	Sub Control: Mine layout
		Sub Control: Mine conditions
		Sub Control: Hazards
		Sub Control: Requirements for specific equipment
	Control: Develop and implement mentoring programs	Sub Control: Matching experienced operators to novice operators
		Sub Control: Matching less experienced foremen (e.g. Red hat mentors) to those with experience

	Control: Train supervisors to maximize operator competency and identify/manage operators that do not meet required performance levels	
Cause: Safety policy is less than adequate	Control: Develop and implement appropriate and effective training	Sub Control: Consider use of advanced training methods (e.g. virtual reality)
		Sub Control: Include adequate training of the trainer
		Sub Control: Standard operating procedures (SOPs)
		Sub Control: Safe work procedures
		Sub Control: Confirm equipment operating competency
	Control: Consider impacts of equipment and operations standards and policies on vehicle interactions (e.g. transport rules)	
	Control: Stakeholder engagement (feedback) in development of policies	
	Control: Audit, regular review/measurement (all stakeholders) and update of policies	
	Control: Compliance and enforcement - management leadership and limits	
Cause: At risk behavior (e.g. personnel working in red zone; including deliberate override/shutdown of safety controls)	Control: Define red zone for all equipment (continuous miner, roof bolter, haulage equipment, etc.)	Sub Control: Consider undertaking risk assessment to define red zone for all equipment based on operating conditions and procedures (operating, moving, maintenance, etc.)
		Sub Control: Establish high risk areas for each activity (e.g. pinch points, warning areas)
		Sub Control: Document outcomes in roof control plans, tramming procedures, personnel training programs
	Control: Adequate training, awareness, and competency of all personnel with respect to red zones	
	Control: Provide personnel supervision	Sub Control: Voice/audio communication with others
		Sub Control: Communication by signaling
	Control: Ensure adequate engineering controls for tramming	Sub Control: Remote control
		Sub Control: Dual controls
		Sub Control: Operator guards
	Control: Use of proximity detection systems (e.g. CMS)	Sub Control: Ensure comprehensive coverage of all personnel with respect to red zones
		Sub Control: Calibrate proximity detection systems to abide by red zone criteria

		Sub Control: Ensure proximity detection equipment is reliable and tamper-proof
Consequence: Fire and explosions	Control: Emergency response plan (ERP)	Sub Control: Emergency response procedures
		Sub Control: Training
		Sub Control: Mine Emergency Response Development (MERD) exercise
	Control: Fire extinguishers	
	Control: First responder	
	Control: EMT/first aid/AEDs	
	Control: Increased/supplementary first aid supplies	
	Control: Fire suppression equipment	
	Control: Fire detection sensors	
	Control: Mine rescue	
	Control: Fire brigade	
	Control: Relationship with emergency services	
Consequence: Injury and fatality	Control: Emergency response plan (ERP)	Sub Control: Emergency response procedures
		Sub Control: Training
		Sub Control: Mine Emergency Response Development (MERD) exercise
	Control: First responder	
	Control: Ensure availability of EMT/first aid/AEDs	
	Control: Increased/supplementary first aid supplies	
	Control: Availability of tools for entrapment (e.g. Jaws of Life)	
	Control: Risk management of employees that are accident prone (increased supervision, class, training, letter of intent to discharge if no improvement)	
	Control: Reinforced operator compartment (canopy, cages, protection)	
	Control: Personal Protective Equipment (PPE)	
	Control: Seat belts	
	Control: Medical, rehabilitation services	
	Control: Emergency medical transport facilities (helicopter, ambulance) and established relationships with service providers; agreement with local hospitals/facilities to accept patient from the mine	
	Control: Notification during transport to hospital of injury type	
	Control: Communication protocols for mine dispatch	
	Control: Within mine transportation of injured personnel	Sub Control: Stretchers available throughout mine to move injured personnel
		Sub Control: Consider modifying transport equipment to deliver smooth ride out of mine for prone injured personnel

	Control: Use non-energy retaining ropes to prevent whipping cable injuries on winches	
Consequence: Job loss	Control: Consider retraining	
	Control: Replacement worker	
	Control: Consider different duties/part-time duties	
Consequence: Equipment damage or loss	Control: Ensure availability of replacement equipment	
	Control: Ensure adequate supplies stock/personnel for workshop repair	
	Control: Guarding to minimize damage to or from mobile equipment impact	
	Control: Fire extinguishers	
	Control: Availability of tools for recovery of entrapped equipment	
	Control: Permitting in place for recovery of entrapped equipment	
Consequence: Reportable incident	Control: Training in reporting compliance	
	Control: Timely compliance	
Consequence: Increased regulatory pressure, POV (pattern of violations)	Control: Compliance and safety officers	
	Control: Internal audits	
	Control: Maintain high safety standards and awareness	
Consequence: Lost production (including delay due to equipment out of service)	Control: Alternative source for coal, standby production panel	
	Control: Alternative schedules following an accident	
	Control: Stockpile/storage, coal from a different mine to meet contract delivery	
	Control: Reduce the downtime disruption from damaged equipment (accelerate repair time: retrackers on motors, service jacks on shuttle cars; airbags)	
	Control: Specific to longwall moves, observation at switches to see if cars are tracking correctly and stop all other cars if an event happens	
Consequence: Family hardship	Control: Corporate training on communication/liaison with impacted family	
	Control: Counseling and support services	
	Control: Compensation arrangements	
	Control: Corporate insurance policies	
	Control: Management of information (containment process)	
	Control: Incorporate above points within Emergency Response Plan (ERP)	Sub Control: Emergency response procedures
		Sub Control: Training
		Sub Control: Mine Emergency Response Development (MERD) exercise
Consequence: Loss of operation (e.g. close part or all of mine)/social license to operate/regulatory closure	Control: Emergency Response Plan (ERP)	Sub Control: Emergency response procedures
		Sub Control: Training
		Sub Control: Mine Emergency Response Development (MERD) exercise
	Control: Effective media communications, public relations	

<table>
<tr><td rowspan="4"></td><td rowspan="3">Control: Management of information</td><td>Sub Control: Establish and implement incident communication protocols</td></tr>
<tr><td>Sub Control: Test and validate communication protocols in mock events</td></tr>
<tr><td>Sub Control: Ensure all tiers of corporation and related stakeholders are familiar and confident with required communication protocols</td></tr>
<tr><td colspan="2">Control: Legal counsel, legal defense</td></tr>
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