DISCUSSION PAPER

Process Safety Management

Application and relevance to mining

Queensland Commissioner for Resources Safety and Health

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noeticgroup.com

Contact

Noetic Solutions Pty Ltd
Locked Bag 3001
Deakin West ACT 2600 Australia

Equinox Business Park, Level 2, Equinox 3
70 Kent Street, Deakin ACT 2600 Australia

T +61 2 6234 7777

Peter Wilkinson
Principal Associate

T +61 2 6234 7777
peter.wilkinson@noeticgroup.com

Matthew Tuohy
Director

T +61 2 9657 0999
matthew.tuohy@noeticgroup.com

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Executive Summary

The Queensland Coal Mining Board of Inquiry recommended, among other things, that the mining industry "adopts strategies to address process safety and personal safety separately".[1] This discussion paper explains what is meant by process safety, assesses the approaches currently in place in mining comparable to process safety and identifies what might be needed for the mining industry to adopt "process safety strategies".[2]

Process safety is usually understood as preventing incidents with the potential for catastrophic consequences from the loss of containment of hazardous material (for example, from a process vessel or pipeline) including loss of life as well as significant environmental, financial, social and reputational damage. As a result, the term process safety is aimed at more than just safety consequences. However, this traditional approach, focusing on a loss of *containment* has tended to limit its application in the mining sector to processing and transporting hazardous substances such as in minerals processing, smelting and refining. A more recent definition from the Australian Institute of Health and Safety describes process safety as "the prevention and mitigation of incidents that have the potential for a loss of *control* of a hazardous material or energy".[3] The concept of a loss of control is more applicable to mining, as it is not restricted to loss of containment of materials. This definition is used as the basis for this paper.

A distinction between process and personal safety already exists in the mining sector. This is evident in legislation, where principal hazards are distinguished from other hazards, and in many companies, where process safety type hazards (catastrophic hazards) are distinguished from more frequent personal safety incidents (personal injury and single fatality type incidents).

The distinction between process and personal safety in mining looks different to other industries. The differences reflect mining industry and regulatory changes that occurred in parallel to similar developments in 'major hazards' sectors. Moreover, it reflects some important distinctions of the mining environment compared to typical process safety industries. Mining is inherently uncertain, as the characteristics and behaviour of rock is more difficult to predict than fluids and chemical. Mining is dynamic, as the location and conditions of activity change constantly as development and production cycles occur. Mining hazards are varied, meaning that the modes of control are specialised and not comparable across hazards.

Most of the elements required to adopt a process safety type approach in the mining industry are, to some extent, also established practices in mining organisations. However, due to the distinctions above, effective implementation of process safety type approaches as understood in the chemical and process industries will require a more focused and integrated approach from industry.

In contrast to conventional process safety, there is no mining industry wide definition of what is meant by a catastrophic hazard nor the tools and techniques necessary to manage these hazards. Guidance on the differences between the causation and management of catastrophic hazards compared with personal safety hazards is lesser in mining than in other sectors such as oil and gas. Although the differences between catastrophic hazards and personal safety are clear in many companies' documents, this is not pervasive in all companies or all practices visible on sites. In our experience, reporting on personal safety incidents, due to their frequency, is often more visible than the potential for the much rarer catastrophic hazards, even in organisations with established methodologies for monitoring and reporting on the

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[1] Martin, T & Clough, A, *Queensland Coal Mining Board of Inquiry: Report Part I*, State of Queensland, Brisbane, 2020, p. 14

[2] Ibid.

[3] Kerin, T 'Managing Process Safety' in AIHS (Australian Institute of Health and Safety), *The Core Body of Knowledge for Generalist OHS Professionals*, 2nd Ed, Australian Institute of Health and Safety, Tullamarine, 2019, p. 3

control of catastrophic risks. Communicating the importance of process safety by leaders requires a different approach to personal safety. Where leading practice exists on this approach, it is not widely established.

Process safety is seen as a distinct capability in the chemical and process industries, requiring specific professional training over and above their specialist engineering discipline. This tends also to provide recognition and status for these roles. Training for process safety roles is typically provided by professional institutions, such as the various national and international chemical engineering institutions. Perhaps the most important difference between the mining industry and the process industries is the degree of intellectual or institutional support provided by bodies such as the Institute of Chemical Engineers (IChemE) Safety Centre. This industry funded not-for-profit organisation provides a focus for information, guidance, incident reporting and training on process safety.

In summary, most of the elements to adopt process safety strategies already exist, but without the institutional focus which exists in the process industries.

The discussion paper's findings are:

Finding 1: Queensland's mining legislation (and more widely Australia's) is suitable for regulating major hazards (and therefore process safety) without the need for fundamental change.

Finding 2: A definition of catastrophic mining hazards which is comparable to process safety but specifically targeted at the mining industry will aid in adopting process safety concepts.

Finding 3: There are a range of options for providing greater institutional focus from academia, government and professional institutions on the mining equivalents to process safety hazards.

Finding 4: There is a lack of guidance aimed at mining senior leaders on catastrophic hazards, as exists in other sectors.

Finding 5: Other sectors benefit from a specialist capability in the management of the process safety hazards, and a mining equivalent could be established.

Finding 6: Low probability but high consequence events in mining are not adequately captured by aggregated health and safety measures and therefore must be treated differently than other safety hazards.

Introduction

Background

Finding 76 of Queensland Coal Mining Board of Inquiry (BoI) into the serious accident that occurred at the AngloAmerican Grosvenor Mine on 6 May 2020 says, "An appropriate focus on catastrophic risk requires consideration of process safety strategies" [4] and recommends that the "industry adopts strategies and performance measures to address process safety and personal safety separately" [5] (Recommendation 18). Noetic Solutions Pty Limited (Noetic) was contracted by the Commissioner for Resources Safety and Health to provide a discussion paper on process safety, its origins and relevance to the mining industry.

Purpose

This paper seeks to explain what is meant by process safety, assess the approaches currently in place in mining comparable to process safety and identify what might be needed for the mining industry to adopt "process safety strategies."

[4] Martin, T & Clough, A, *Queensland Coal Mining Board of Inquiry: Report Part I*, State of Queensland, Brisbane, 2020, p. 14

[5] Ibid.

Process safety concepts

What is process safety?

In the BoI, process safety is defined as "Safety strategies designed to address the risk of fatalities and catastrophic events".[6] There are a variety of definitions of process safety produced by professional institutions, regulators and individual companies, all with a similar focus. Process safety usually implies a set of tools, techniques and practices associated with preventing incidents that have the *potential* for catastrophic consequences. The definition of 'catastrophic' in this context means more than the safety of people and includes other adverse outcomes, including environmental and social impacts, reputational damage and loss of value.

The question of how to define process safety has recently received expert attention in Australia from the **Australian Institute of Health and Safety** (AIHS). In a published and peer reviewed paper, the AIHS provides this definition:

> Process safety is about managing the integrity of operating systems by applying inherently safer design principles, engineering and disciplined operating practices. It deals with the prevention and mitigation of incidents that have the potential for a loss of control of a hazardous material or energy. Such loss of control may lead to severe consequences with fire, explosion and/or toxic effects, and may ultimately result in loss of life, serious injury, extensive property damage, environmental impact and lost production with associated financial and reputational impacts.[7]

The AIHS draws on an earlier similar definition prepared by the Centre for Chemical and Process Safety (CCPS) in the USA under the auspices of the American Institute of Chemical Engineers (AIChE). The key difference between the recent AIHS definition and the CCPS definition is that the AIHS definition refers to a **loss of control** of a hazardous material or energy, rather than a loss of containment. The AIHS definition recognises that the loss of containment definition, while relevant to much of the processing industries where an important goal is to keep the hazardous materials contained inside a pipe or vessel, has less relevance to other sectors seeking to apply process safety principles. As Judith Hackitt (former Chair of the UK Health and Safety Executive), pointed out in a 2013 speech, there is much to learn about preventing catastrophe by looking at what lessons can be learned from other industries to apply to one's own.[8]

For these reasons, Noetic applies the AIHS definition in this paper.

Process Safety Management

The term process safety is used to cover a wide range of concepts including inherent safer design principles, engineering and operating practices. In addition to this general term, the more specific term Process Safety Management (PSM) is also used to refer to documented management systems intended to manage process safety hazards. These systems contain PSM "**elements**", although these elements vary depending on the organisation publishing them. The Energy Institute (the UK), CCPS (USA), the Canadian Society for Chemical Engineering and the US Department of Labor's Occupational Safety and Health

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[6] Martin, T & Clough, A, p. 200

[7] Kerin, T 'Managing Process Safety' in AIHS (Australian Institute of Health and Safety), *The Core Body of Knowledge for Generalist OHS Professionals*, 2nd Ed, Australian Institute of Health and Safety, Tullamarine, 2019, p. 3

[8] Dame Judith Hackitt is a chemical engineer who held a variety of positions in ExxonMobil prior to becoming Chair of the UK's Health and Safety Executive. She is also a past president of IChemE. More recently she led the independent review into fire safety and building regulations following the 2017 Grenfell Tower disaster in London in which 72 people died.

Administration (OSHA) have all produced PSM elements and descriptors, with typically 14-20 elements. An example of one of these is shown in Figure 1.

Figure 1. 14 elements of Process Safety Management as originally described by OSHA[9]

Although PSM standards are all broadly similar in scope, their stated purpose varies. For example, the stated overarching purpose of the Canadian PSM standard is "…to identify the performance requirements that can be audited by an organization or a third party to recognize and address gaps that may exist in the overall management system."[10] In contrast, the OSHA Standard is explicitly a regulatory requirement. Naturally, each PSM Standard reflects the context in which they were produced and none can be adopted 'as is' in the mining industry. Where such frameworks do exist and are applied in mining, it is to assets or operational processes that involve hazardous materials in processing, smelting and refining.

Many companies have their own standards which tend to be customised for their operating environment while ensuring coverage of established PSM elements. For instance, Rio Tinto makes its Process Safety Standard publicly available.[11] This standard incorporates minimum expectations for its operations based on 16 elements. These elements are similar to many of those in established PSM frameworks but include additional elements focused on the project/asset lifecycle that is applicable to their minerals processing, smelting and refining operations.

These types of PSM Standards are not without criticism, being labelled "activity-based" standards. While they may encourage work on the elements contained in the standard, they do not explicitly incorporate the requirement to reduce risk. This is a feature of "major hazard" and other similar regulatory

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[9] Adapted from Jeffress, CN, *Process Safety Management*, US Department of Labor: Occupational Safety and Health Administration, Washington, 2000, pp. 3-4

[10] Canadian Society for Chemical Engineering, *Process Safety Management Standard*, 1st Ed, Canadian Society for Chemical Engineering, 2012, p. iii

[11] Rio Tinto, *Group Standard: D6 – Process Safety*, HSEC-B-25, 2015, accessed 5 May 2022, https://www.riotinto.com/-/media/Content/Documents/Sustainability/Corporate-policies/RT-Process-safety-standard.pdf

approaches that use a "safety case". These regulatory requirements encompass all aspects of how risk is reduced, including specifying the control measures that will be implemented and how they will be maintained. More detail on safety cases is provided later in this section and at Annex A.

While the most commonly described PSM elements are necessary to effectively reduce risk, the overall objective of these elements is to ensure necessary control measures are put in place and remain working as intended to achieve risk reduction. This issue is often addressed in contemporary standards. For example, in the Rio Tinto Standard, the concept of critical controls is used to address the gap in the PSM standards on risk reduction.

Regardless of the PSM standard applied, the capabilities and competencies that underpin each element must also be highlighted. Whilst the PSM Standards produced by organisations such as CCPS and Energy Institute are highly visible, it is the high-quality guidance, training, competence schemes, tools and techniques, developed by these organisations and others such as IChemE which give practical effect to implementing process safety. IChemE does not promulgate any particular standard but its focus on process safety and the material it has produced is very influential.

Process safety in legislation

The term "process safety" is not generally used in Australian legislation. However, "major hazards" or "major accident events" are used in regulatory regimes where process safety concepts are applicable. At the same time, mining legislation, such as Queensland coal mining legislation, has adopted "principal hazards" to achieve a similar approach.

Although companies have played an important role in the development of process safety (often in conjunction with the chemical engineering institutions), government has also played an important role. For instance, in the US, OSHA developed and applied a 14 element PSM Standard. Initially in the UK and then more broadly in the European Union, the development of regulatory approaches took a different direction which was largely followed in Australia. The UK/European approach led to the establishment of the safety case regime, which requires operators to:

- Identify the major hazards for the facility
- Assess and analyse risks to health and safety that could occur
- Implement control measures to eliminate and/or minimise the risk of a major incident
- Prepare an emergency plan
- Develop a Safety Management System (SMS) for the operation of the MHF
- Prepare a Safety Case to demonstrate to the regulator that the risks will be controlled.

More detail on how the major hazards regulatory regime developed is provided at Annex A.

Major hazards in Australian legislation

Process safety is generally restricted in meaning to preventing losses of containment of hazardous materials from processing plant, process vessels and associated pipework. Under Australian work health and safety laws, the safety case approach is applied based on a threshold amount of specific hazardous materials that would require a safety case to be provided to the regulator and accepted in order to operate.

However, major hazards can have a wider meaning to that described above. For example, the collapse of a large structure such as an iron ore loader at a port, might be regarded as a major hazard but would not be a process safety hazard because it did not involve a loss of containment of hazardous materials. Broader definitions of a major hazard are a feature of offshore oil and gas regulation in Australia under the *Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009.* These regulations require the identification and control of all hazards that have the potential to cause a "major accident event" (i.e. multiple fatalities at or near a facility). The regulation does not prescribe in detail any PSM elements, even though process safety concepts and approaches are implemented to meet the regulatory requirements.

Australian mining legislation

Australian mining legislation in most States and Territories is based on similar principles as described above in relation to major hazards. They generally require the identification and control of hazards that may lead to multiple fatalities. There are some procedural distinctions; for instance, there is no requirement for the regulator to accept or approve hazard management arrangements prior to operating (as is required for a safety case). However, there are important similarities in place. Looking at Queensland coal mining legislation specifically:

- A general duty exists to reduce risk to an "acceptable level" using control measures.
- There must be a safety and health management system in place.
- The management of specific hazards is documented and made available to the regulator (in principal hazard management plans).

Principal hazards (or principal mining hazards in other jurisdictions) and the requirement to produce principal hazard management plans are conceptually similar to the requirements to prepare a safety case in major hazard regulatory regimes. In other words, the process safety relevant sectors and the mining industry already have similar regulatory requirements, which provide the capability to effectively regulate process safety. However, in Queensland mining legislation, the requirement to produce principal hazard management plans is restricted solely to the safety of people, reflecting the statutory responsibility of Resources Safety and Health Queensland. In practice, most process safety definitions include catastrophic consequences in terms of the environment, plant and equipment, financial loss and reputational damage.

Finding 1: Queensland's mining legislation (and more widely Australia's) is suitable for regulating major hazards (and therefore process safety) without the need for fundamental change.

Process safety in the mining industry

Principal hazards, in terms of how they can lead to incidents and how they are controlled, differ from other potentially fatal hazards encountered in mining workplaces. As a result, a distinction exists between process safety and personal safety in many aspects of mining along the lines of the AIHS process safety definition. For instance, managing ventilation underground involves the following competences:

- Technical design (understanding air flow and designing overall ventilation system capable of providing it).
- Engineering and operational (installation of fans, VCDs and ducts as designed to ensure air flow and minimise losses).
- Monitoring and assurance (ensuring that air flow is being delivered as intended and reconcile ventilation models).

The above example differs significantly from personal safety hazards. For example, a worker driving a vehicle or working at height can directly observe and interact with the controls for the risks presented by these activities. By comparison, many principal hazards are not immediately visible, and workers cannot always observe or influence their control.

The following section highlights analogues between typical process safety hazards (or major hazards) and principal hazards in mining. There are also some aspects of the mining environment that mean direct application of process safety concepts is not straightforward.

What is in common?

The PSM elements previously described overlap considerably with existing practices in mining. Management systems such as permit to work, management of change, maintenance, training, and emergency response are all prevalent in the mining industry. The design, operational disciplines and ongoing monitoring for risk controls are also a feature of hazard management in mining. A case study in the similarity between management of a principal mining hazard and the description of process safety described by AIHS is provided.

PREVENTION OF FALL OF GROUND/STRATA – A PROCESS SAFETY PARALLEL

Ground/strata failure has the potential to cause multiple fatalities in most underground operations. In addition to the potential for harm to people, major ground/strata failures can also cause significant disruption to mine production and environmental damage. The management of this hazard is based on comprehensive analysis, engineering and ongoing monitoring.

While experienced underground workers are sometimes able to observe inadequate or failing ground/strata support, this is often not the case in practice. Workers rely on the systems documented in the ground/strata control management plan being adequate and implemented as intended. Implementing the ground/strata control management plan requires the following technical practices.

Design of ground/strata control considers how the hazard must be addressed:

- Development of design requirements deal with ground/strata conditions and mine design requirements.
- Analysis of how risk may eventuate and ensure ground/strata control will reduce this risk to an acceptable level.

Engineering and operational practices to implement the design and controls:

- Installation of the ground/strata support correctly and according to the right design.
- Validation of installation to confirm that it is suitable and add support if necessary (e.g. spot bolts, mesh, etc).

Monitoring and assurance to maintain integrity and control:

- Ensuring ground/strata support is functioning as intended using inspections, pull testing and other quality assurance tools.
- Rehabilitation or reinforcement of ground/strata support when required.

Effective ground/strata control is also supported by management systems akin to the **PSM elements** mentioned previously. Some examples include:

- **Management of change** processes to ensure that operational changes are assessed for their effect on the hazard and its control.
- **Training and competency** management for operators, technicians and engineers to implement the ground/strata control management plan effectively.
- **Incident investigations** to analyse ground/strata failure events and use learning to improve controls and systems.
- **Emergency Response** to be ready and able to respond to foreseeable consequences of a ground/strata control failure.

Another similarity is company focus on catastrophic hazards. A well-known example of this is Glencore's catastrophic hazard management approach. It defines a catastrophic hazard as events that–though unlikely–could cause widespread loss of life or result in significant environmental harm, reputational damage or financial impact.[12] This is distinct from the Glencore SafeWork system, which is focused on the prevention of fatal accidents (including some principal hazards).

Vale has a similar focus on prevention of catastrophic accidents as distinct from fatality prevention under its Hazard Identification and Risk Assessment (HIRA) approach.[13] Apart from considering these events more broadly than safety, these approaches cover the entirety of their operations. They are **not limited** to areas such as minerals processing, smelting and refining where process safety concepts traditionally apply.

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[12] *2021 Sustainability Report*, Glencore, Baar, 2022, accessed 23 May 2022, https://www.glencore.com/.rest/api/v1/documents/67a0543aca31dec0a4dba8e30e5b1b96/GLEN_2021_sustainability_report.pdf

[13] HIRA involves detailed review of material operational risks and establishment of company-wide critical controls. See: *Integrated Report 2021*, Vale, Rio de Janeiro, 2022, p. 87, accessed 23 June 2022 http://www.vale.com/PT/sustainability/relato-integrado-2021/Documents/Integrated_Report_2021.pdf

What is not common?

While some similar systems in companies exist, there is no common approach to deal with catastrophic hazards across the mining industry. Equally, approaches to managing principal hazards (many of which are in practice managed similarly to process safety hazards) do not always adopt process safety methods. There are often different approaches applied to different hazards, or to different parts of the supply chain. For example, some mining companies have a process safety standard that is only applicable to instances of hazardous chemical release. They often have domain-specific standards, such as geotechnical, engineering, gas or ventilation that deal with other similarly catastrophic hazards.

Understandably, these approaches are highly specialised and incorporate technical knowledge. However, they have similar aims as process safety type approaches (i.e. to prevent major accidents). They involve common management systems to function effectively (management of change, training, incident investigation, emergency response). A subtle distinction of organisations with mature process safety approaches is that they apply a common lens to risks and maintaining controls. They ensure that the personnel with appropriate technical expertise manage this system, but the nature of monitoring, assurance and reporting on the management of major (or catastrophic) hazards is comparable.

Why does this distinction exist?

There are some clear reasons why process safety type approaches differ from mining approaches (i.e. principal hazard management), despite seeking the same outcomes. The most obvious is that both approaches emerged from two fundamentally different industries to deal with different but similarly catastrophic events. Regulatory frameworks and the development of best practices naturally developed in parallel to achieve this in mining and in other industries such as chemical, petrochemical, nuclear, and oil and gas industries. Beyond the differences, in management and regulatory approaches, there are some characteristics of mining operations that must be considered in the adoption of process safety concepts.

Mining is uncertain

The nature of mining hazards comes from the features of an ore deposit/coal seam, such as the rock types and structures of the environment and how a mine must be designed to manage these issues effectively. Drilling to understand a rock mass and infer information about a resource is inherently uncertain. From this uncertain information a mining engineer must construct a model of the environment and design a mine. Often it is only once mining commences that the accuracy of the model is understood.

In comparison, chemical and processing industries are more precise. Inputs to a processing plant are more predictable and controlled, fluids behave more predictably than rock, and the parameters of processes can be more tightly specified.

Mining is dynamic

Once in production and drilling is complete, oil and gas operations are in a relatively steady state. Refining, chemical manufacturing and other typical process safety relevant industries are similarly fixed. Modifications to facilities have a clear 'before' and 'after' in terms of design and implementation.

Mines are (mostly) continuously in development and production simultaneously. The location of production moves, conditions change and designs are revised. The nature of hazards is also dynamic. In coal mining, methane levels must be kept below the explosive range at the face while they can be above it in the goaf. In hard rock mining, block caves must have even production so that they avoid inducing extreme rock stress. However, too much production might influence the risk of an air blast.

Mining has diverse hazards

Catastrophic hazards in mining are varied, as are their means of control. Approaches to managing tailings dams, highwall stability and underground explosions are specialised in nature and are handled by domain experts. As a result, there is little commonality between hazards on the nature of precursor events, control failures or near miss incident definitions. Consolidated data or aggregate statistics provide little information on these hazards, meaning there is not as much visibility on these hazards in comparison to others.

In process safety industries, hazards have more in common as they are typically related to preventing a loss of containment from pipes, tanks and other vessels. As a result, conventional process safety industries can develop common indicators beyond typical incident/near miss reporting. Consolidated data on process upsets, loss of containment and control failures provides more visibility on how well hazards are managed.

PSM lessons and benefits

Despite these important distinctions, there are still many relevant and applicable aspects of process to mining. After all, the nature of the hazards is similar, and many of the elements of PSM are already present in some capacity.

When applied effectively, PSM encourages a focused approach to catastrophic hazards and how they are managed. The wide range of catastrophic hazards in the mining environment requires significant domain expertise. However, critical information on the nature of this hazard, its controls and how they function is contained in documents such as ground (or strata) control management plans or ventilation control plans. With a process safety lens, this information can be comparably reported so that senior leaders can understand how hazards are controlled and how controls are performing on a regular basis. In process safety sectors this is usually achieved by reporting on losses of control in terms of the performance of specific controls (also referred to as ‘barriers’ or ‘safety critical elements’ in other industries) across the range of hazards. It is also a feature of major hazards legislation, which requires performance criteria and indicators to be established for controls for major incident hazards. In mining, this is the intent of existing ‘Critical Control’ approaches, which could provide a framing for reporting on the potential for ‘loss of control’ in the same way. The International Council on Mining and Metals guidance on Critical Control Management is heavily influenced by process safety and major hazards approaches, although it is applied more broadly across the sector.

PSM also acknowledges how the effectiveness of underlying management systems influences management of catastrophic hazards. Mature process safety organisations have disciplined management of change processes, and they take great care when deviating from safe operating parameters. While management of change systems are prevalent in mining, their applicability varies and there is often not an explicit focus on how changes may affect a catastrophic hazard or influence critical controls.

The above issues have long been identified in the sector, and many companies have already made significant changes to address these issues. Learning from PSM can provide another prescription for continual improvement of the management of principal and other catastrophic hazards.

Giving effect to the BoI recommendation

The previous section highlights that strategies employed to manage process safety type risks differ from personal safety risks. This section seeks to identify what would give practical effect to the BoI recommendation. Most of the elements already exist, but are not organised in such a way to give a coherent identity to the causes, consequences and countermeasures to catastrophic mining hazards.

Define catastrophic hazards

Currently there is no equivalent to the AIHS definition (or similar definitions) of process safety for catastrophic mining hazards. The definitions of process safety from CCPS, AIHS and major companies such as Shell vary slightly. But at their core is a common understanding that process safety can result in catastrophic consequences. Importantly, these catastrophic consequences are defined more widely than just safety. The causation of catastrophic events can have widespread and long-lasting impacts which might include multiple fatalities, serious environmental consequences, financial losses to companies and communities as well as serious reputational impacts. For example, five workers were seriously injured in the 2020 Grosvenor mine incident. In contrast, no workers were hurt in the North Goonyella fires and explosions in 2018 but there were substantial financial losses.

It is often a matter of the circumstances and chance whether one or more of the potential consequences are realised. The process safety approach to defining catastrophic hazards recognises this and more importantly the definition is based on the knowledge that the causes of catastrophic incidents are different to personal safety incidents. The AIHS in its discussion of process safety has pointed out:

> Two key factors in the causation of process safety incidents have been identified as:
>
> + A failure to distinguish the need for different approaches to managing hazards associated with low-likelihood, high-consequence incidents.
> + Assumptions that strategies for managing personal safety would similarly create safe conditions in process safety, and that metrics used to monitor personal safety also provide information on the status of process safety.[14]

Most mining accidents are not the result of low-likelihood, high consequence (or catastrophic) incidents as defined by the process safety definitions. Without seeking to minimise the unacceptable burden of ill-health and personal safety incidents (which include most fatal accidents), different strategies are needed for personal safety and preventing events with the potential for catastrophic consequences.

It could be argued that the existing definition of a Principal Hazard in Section 20 of the Queensland *Coal Mining Safety and Health Act 1999*[15] is sufficient in the context of developing an approach equivalent to process safety for the mining industry. However, the definition is restricted to safety. This may be appropriate for the requirements of the mining safety regulator, but is arguably inappropriate in the context of implementing an approach equivalent to process safety. This is because from a company perspective, as opposed to the regulators, catastrophic hazards have similar causes whatever the actual consequences (e.g. Grosvenor versus North Goonyella). From a practical management perspective, it is important that a company has a single coordinated approach to all catastrophic hazards and not separate ones to safety, the environment and other potential catastrophic consequences. Ultimately these are consequences of a "loss of control", as the AIHS puts it.

This is not new and was discussed more fully in a Noetic report published by the Queensland Resources Council which pointed out (in the context of High Reliability Organisations):

> …HROs are not just focused on safety but look more widely at how their systems are designed and implemented to deliver reliable outcomes. HRO systems typically help to avoid unwanted outcomes in terms of events which can have negative consequences for any of the following: health, safety,

[14] AIHS (Australian Institute of Health and Safety), p. 51

[15] "A hazard at the coal mine with the potential to cause multiple fatalities"

> environment, finance and reputation. In other words, they enable companies to deliver all their goals more reliably. [16]

It is not possible to assess how well or widely the concept of catastrophic hazards as a distinct area of loss prevention[17] practice is understood. Noetic's perception is that among specialist health and safety professionals it is well understood. During a recent piece of work for the Queensland Resources Council, Noetic found that most senior managers intuitively knew that strategies aimed at workplace health and safety were not entirely relevant to the causes of catastrophic events. It is possible the absence of a mining definition of catastrophic incidents, equivalent to the process safety approach contributes to a lack of identity around catastrophic hazards.

Finding 2: A definition of catastrophic mining hazards which is comparable to process safety but specifically targeted at the mining industry will aid in adopting process safety concepts.

Institutional focus on catastrophic hazards

In major hazard industries, the tools, techniques and practices of PSM have a distinct presence (or brand) and professional identity as a result of the work done by the IChemE, AIChE and others. These institutions are typically produced by industry-funded organisations often working in partnership with professional bodies such as the chemical engineering institutions. For example, the CCPS is an industry funded and led organisation which works in conjunction with the AIChE to "…bring together manufacturers, government agencies, consultants, academia and insurers to lead the way in improving industrial process safety."[18]

Mining has comparable organisations, including industry organisations, professional bodies such as the Australasian Institute of Mining and Metallurgy, and research institutions such as the University of Queensland's Sustainable Minerals Institute (SMI) and Australian Coal Association Research Program (ACARP). It also has tripartite advisory committees and other fora that focus on the improvement of health and safety in entirety. These organisations acknowledge the distinction in causation and managerial approaches between personal safety hazards and most principal hazards. However, they typically do not have separate organisations explicitly focused on the disciplines and knowledge for management of catastrophic hazards.

There is an opportunity for more focus on process safety type approaches in mining, leveraging off existing expertise in academia, industry and research institutions on the management of principal hazards (such as at SMI, ACARP and in mining engineering faculties). This should also include support from and collaboration with industry bodies, trade unions, professional bodies and regulators.

Finding 3: There are a range of options for providing greater institutional focus from academia, government and professional institutions on the mining equivalents to process safety hazards.

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[16] Noetic, *High Reliability Organisations: Benchmarking Summary Report*, Queensland Resources Council, Brisbane, 2021, p. 6 accessed 11 May 2022, https://www.qrc.org.au/wp-content/uploads/2021/10/Noetic-HRO-Benchmarking-Project-Report-Final.pdf

[17] "Loss prevention" is a term used for anticipatory measures in place to prevent incidents accidents due to loss of containment or other process interruption. The term is used similarly to process safety but is broader in scope to consider losses of all kinds, not only safety or those with potentially catastrophic consequences.

[18] Center for Chemical Process Safety, Process Safety Integrity, 2022, accessed 6 May 2022, https://processsafetyintegrity.com/org/ccps/

Briefing and guidance for mining senior leaders

Implementing process safety concepts requires supporting leaders to develop a high level of understanding of the different approaches to, and challenges of, managing the prevention of catastrophic incidents compared with workplace health and safety.

Currently, there is little guidance provided to mining senior leaders on the differences and overlaps between managing catastrophic hazards and personal safety. This is sometimes reflected in organisational structures, where reporting on principal hazards and their controls is part of the health and safety functions.

This is in marked contrast with the guidance available in the process safety industries:

- OECD has published guidance for senior leaders on governance of process safety issues.[19]
- *Principles for Process Safety Leadership*, published by a process safety leadership group representing the UK offshore oil and gas industry (regulators, the peak industry body and Step Change for Safety, which involves oil and gas producers, contractors, trade unions and regulators).[20]
- Guidance and/or training produced by professional associations such as AIChE and IChemE.

These are examples of organisations which recognise that process safety hazards present significant material risks to businesses. Securities exchanges and shareholders expect this to be recognised and managed.

Finding 4: There is a lack of guidance aimed at mining senior leaders on catastrophic hazards, as exists in other sectors.[21]

Process Safety - a specialist capability

In the process industries, it is usual to find personnel who have a specialist capability in process safety. These are typically personnel who in addition to their "base" skills (mostly but not always in the engineering disciplines) have process safety expertise obtained from attending training organised by professional associations and their associated organisations (e.g. ISC and CCPS). The ISC for example, has developed a process safety competency framework. This specialist capability provides expertise and focus on process safety which generalist workplace health and safety personnel are not always well equipped to do because of capability or resources (or a mixture of the two). Within leadership teams, specialists in process safety often have a separate but equally senior "voice" to health and safety in operational leadership, given the different nature of the hazards and the requirement for engineering domain expertise.

Specialisation in mining disciplines (geotechnical/geomechanical, ventilation, production specialisations) often comes with focus on the management of specific hazards with bespoke approaches. However, there are common features in managing all these hazards, such as hazard identification, monitoring, assurance and reporting. Developing a specialisation in the management of mining hazards could produce stronger capabilities and greater consistency in managing mining hazards.

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[19] OECD Environment, Health and Safety: Chemical Accidents Programme, *Corporate Governance for Process Safety: Guidance for Senior Leaders in High Hazard Industries*, Organisation for Economic Cooperation and Development, 2012, accessed 23 May 2022, https://www.oecd.org/chemicalsafety/chemical-accidents/corporate%20governance%20for%20process%20safety-colour%20cover.pdf

[20] *Principles of Process Safety Leadership for the offshore UKCS Oil & Gas Industry*, Offshore Energies UK, accessed 23 May 2022, https://oeuk.org.uk/wp-content/uploads/2021/06/Principles-of-Process-Safety-Leadership-OGUK.pdf

[21] A similar observation was made in Noetic, *High Reliability Organisations: Benchmarking Summary Report*, p. 23

Finding 5: Other sectors benefit from a specialist capability in the management of the process safety hazards, and a mining equivalent could be established.

Organisational practices

As discussed earlier in this paper, the management of catastrophic hazards is for the most part unconnected with general health and safety events. Hazards or control failures for personal safety can be more readily observed by workers and reported from the face or in the field. For example, a control failure for working at height can be detected at the point of planning or pre-start checks for the work. By contrast, many controls relevant to catastrophic hazards must be actively monitored to understand failure. Otherwise, failure of the control may go undetected until a low probability but high consequence incident occurs.

However, injury frequency rates and other lagging measures tend to dominate safety reporting and therefore governance systems. While lagging measures are needed, there needs to be at least as much attention placed on prevention of potentially catastrophic process safety type incidents. In particular, monitoring the health of "critical controls" (often referred to as barriers or Safety Critical Elements in other industries) for low probability but high consequence events. In the case of critical controls, mining has guidance in place (published in 2015)[22] consistent with (and drawing upon) process safety and major hazards concepts. However, there are significant opportunities to improve its implementation. As the QRC HRO report pointed out:

> At some sites there seemed to be a greater focus on compliance with a target for critical control verifications rather than to learn about how well the controls are implemented. Few sites had a method of communicating what was done well in critical control implementation nor what the weaknesses were. As a result, we frequently saw graphs illustrating compliance with targets for verifications but little more qualitative information about how well the control was working and what if any improvements were needed.[23]

Monitoring the amount of control activity (i.e. the number of verifications or their aggregate compliance) is often less valuable than communicating specific information about the health of controls for specific hazards. This more qualitative feature of active monitoring controls acknowledges that mining hazards are varied and their means of control are often not common across hazards. Unlike traditional process industries, where most hazards involve loss of containment from vessels or pipes and therefore have related controls, management of one catastrophic mining hazard is often unrelated to another. Aggregating information on incidents, control monitoring or other activity metrics tends to provide less actionable feedback for leaders in comparison to both personal safety hazards and conventional process safety industries.

Finding 6: Low probability but high consequence events in mining are not adequately captured by aggregated health and safety measures and therefore must be treated differently than other safety hazards.

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[22] International Council on Mining and Metals (ICMM), *Critical Control Management: Implementation Guide*, International Council on Mining and Metals, London, accessed 23 May 2022, https://www.icmm.com/website/publications/pdfs/health-and-safety/2015/guidance_ccm-implementation.pdf

[23] Noetic, *High Reliability Organisations: Benchmarking Summary Report*, p. 12

Conclusion

The mining industry already has most but not all the elements of the PSM type approach which exists in in other industries with comparable catastrophic hazards. However, some elements are not well-established or have not been brought together as a readily identifiable, integrated and coherent set of practices. Such practices include research, professional competencies, leadership focus, and reporting and analysis.

A key lesson of process industries such as chemical and oil and gas production is that traditional approaches to managing and reporting on personal safety hazards are not suitable for process safety type hazards. In mining, approaches to managing process safety type hazards tend to be in specialised technical and engineering teams or reported under general health and safety teams. Our findings suggest that a process safety type discipline could provide a way to ensure these risks and their controls are given due attention distinct from personal safety, while still incorporating the expertise of technical teams. This will help managers and senior executives to be better informed on how process safety strategies differ from personal safety, and how leaders can better support the management of those strategies.

Next steps

Following on from this paper's conclusion that the mining industry has many of the resources available to enable a process safety type of approach to catastrophic hazards, Noetic recommends some initial steps. These include developing an inventory of the resources currently available on the management of catastrophic hazards in the mining sector. This inventory could include the name of the organisation or institution and its capabilities or services relevant to the management of catastrophic hazards. Although this represents a useful first step, it will not of itself illustrate what is *not* currently available compared with process safety. To help assess the nature of the gap, we also suggest a sample of available process safety resources in other sectors is also collated. These topics could include guidance material (including for example on leadership in process safety), training resources developed by professional institutions and regulatory guidance produced in jurisdictions with comparable legal regimes. Taken together, these two initial steps will help to inform further discussion on applying process safety type approaches in mining.

The following findings are made to support the development of an equivalent to process safety management in the Queensland mining sector:

Finding 1: Queensland's mining legislation (and more widely Australia's) is suitable for regulating major hazards (and therefore process safety) without the need for fundamental change.

Finding 2: A definition of catastrophic mining hazards which is comparable to process safety but specifically targeted at the mining industry will aid in adopting process safety concepts.

Finding 3: There are a range of options for providing greater institutional focus from academia, government and professional institutions on the mining equivalents to process safety hazards

Finding 4: There is a lack of guidance aimed at mining senior leaders on catastrophic hazards, as exists in other sectors.

Finding 5: Other sectors benefit from a specialist capability in the management of the process safety hazards, and a mining equivalent could be established.

Finding 6: Low probability but high consequence events in mining are not adequately captured by aggregated health and safety measures and therefore must be treated differently than other safety hazards.

Annex A: Process safety in legislation

The term "process safety" is not generally used in Australian legislation. However, "major hazards" or "major accident events" are used in regulatory regimes where process safety concepts are applicable. At the same time, mining legislation, such as Queensland coal mining legislation, has adopted "principal hazards" to achieve a similar approach. This section describes how the "major hazards" approach has come about.

Although companies have played an important role in the development of process safety (often in conjunction with the chemical engineering institutions), in parallel, government has also played an important role. For instance, in the US, OSHA developed and applied the PSM Standard, referred to earlier. Initially in the UK and then more broadly in the European Union, the development of regulatory approaches took a different direction which was largely followed in Australia.

Two incidents played a pivotal role in the development of process safety. Firstly, the 1974 explosion at Flixborough UK and then the Italian Seveso incident. The effect of these incidents and how they affected Australian law are briefly described below.

Flixborough, UK 1974

An explosion in June 1974 at the Flixborough works of Nypro killed 28 people and injured a further 36, which was described in the official report as "an explosion of warlike dimensions".[24] The incident led to the formation of the Advisory Committee on Major Hazards (ACMH), which inquired over several years into how best to regulate this category of events – henceforth typically referred to as "major hazards." The catastrophic consequences mentioned in the earlier definitions of process safety are much the same as "major hazards."

The Flixborough explosion occurred just after the Government introduced the Health and Safety at Work Act into parliament which implemented the Robens Committee recommendations of general goal setting duties on all persons involved at work and a framework for more specific regulations and codes of practice where needed. ACMH considered the impact of the Robens Report and concluded that the best approach (in relation to major hazards) was to retain the Robens-inspired structure, but add further regulations to require companies handling specified amounts of hazardous substances to notify this fact to the regulator. ACMH also foreshadowed the possibility of further regulations once "…we see how the proposed regulations are working."[25] However, the proposed regulatory changes were overtaken by the Seveso incident in 1976.

Seveso, Italy 1976

In July 1976 a bursting disc on a chemical reactor ruptured at the Icmesa chemical company's works in northern Italy, releasing a cloud of vapour which drifted offsite. Among the substances in the white cloud was 2,3,7,8-Tetrachlorodibenzo-p-dioxin ('TCDD' or 'dioxin'), a highly toxic material. The release lasted for some twenty minutes. The nearby town of Seveso, near Milan, had some 17,000 inhabitants. No human deaths were attributed to TCDD, but many individuals fell ill. 26 pregnant women exposed to the release had abortions. Thousands of animals in the contaminated area died and many thousands more were slaughtered to prevent TCDD entering the food chain. The major public outcry led to a European Directive, ("Seveso Directive") implemented in all European Union countries.

In the UK the recommendations from the ACMH Reports, and the requirements of the Seveso Directive, came together in a regulatory structure within HSE which focused on the substances listed in the Seveso

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[24] *Flixborough Disaster: Report of the Court of the Inquiry*, UK Department of Employment, 1975, p. 1 accessed 5 May 2022, https://www.icheme.org/media/17752/the-flixborough-disaster-report-of-the-court-of-inquiry.pdf

[25] Health and Safety Commission *Advisory Committee on Major Hazards: second report*. Her Majesty's Stationery Office, London, 1979, p. 26

Directive and the requirement for companies to produce a safety report. The safety report (referred to as a safety case in many jurisdictions) required companies to:

- Identify the major hazards for the facility
- Assess and analyse risks to health and safety that could occur
- Implement control measures to eliminate and/or minimise the risk of a major incident
- Prepare an emergency plan
- Develop a Safety Management System (SMS) for the operation of the MHF
- Prepare a Safety Case to demonstrate to the regulator that the risks will be controlled.

This safety case approach was subsequently adopted in most Australian states and territories. The US Chemical Safety Board's report on the Chevron Richmond Refinery accident suggests safety case-type "regimes are considered to provide more opportunity to adapt to best practices and changing technologies".[26] Safety cases enable companies to tailor their approach to the specific circumstances of their operations while requiring them to describe how they will control specific risks and maintain the effectiveness of controls.

Conventionally, both process safety and major hazards (where this term is used in the context of the EU Seveso Directives) apply to scenarios that can affect both people and the environment, such as in the Seveso incident. While the underlying event is a loss of containment, the responsibility for regulating safety and the environment risks can reside in different regulators requiring collaborative working to deliver the intent of the regulation. For example, in the UK the workplace health and safety regulator, the HSE and the Environment Agency in England and its equivalents in Scotland and Wales have common objectives for loss of containment to deliver their desired regulatory outcomes.

[26] For a full discussion on this point see US Chemical Safety and Hazard Investigation Board, *Regulatory Report:* Chevron Richmond Refinery Pipe Rupture and Fire, Richmond, California, August 6 2012, Report No. 2012-03-I-CA, 2014, pp. 38-39, accessed 5 May 2022, https://www.csb.gov/file.aspx?DocumentId=5912

Locked Bag 3001
Deakin West ACT 2600 Australia

Equinox Business Park, Level 2, Equinox 3
70 Kent Street, Deakin ACT 2600 Australia

T +61 2 6234 7777

noeticgroup.com