A Management System to Develop Occupational Health & Safety in Ground Control Operations of Underground Mines

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ABSTRACT

Falls of ground have historically been the main cause for fatalities in underground mines. Although recent advances in technology have reduced the number of such accidents, when failures occur they usually result in severe consequences. Risks of rock falls, use of heavy machinery and electrical apparatus, entry to confined spaces, working in noisy and dusty environments, and working on unstable platforms are some of the hazards in ground control operations. Managing these risks requires a management regime involving strict adherence to operational codes of practice and an enshrined culture of safety. These should be subsequently reinforced through active participation of management, systematic training, and stringent internal and third party auditing.

Accident reports show that the major contributing factor in most rock fall accidents is the failure to adequately manage known risks due to the lack of a systematic process. OHSAS 18001 (Occupational Health and Safety Assessment Series) is an international occupational health and safety management standard specification to develop occupational health and safety at the workplace.

This standard is intended to help mine operators control occupational health and safety risks. Addressing the requirements of OHSAS 18001 can be a complex and demanding task. A comprehensive guide for efficient and accurate implementation of this standard is provided in this paper. The discipline can be used to establish an accountable management system foreground control activities in underground coal mines. The paper also provides guidelines for preparing necessary documents, devising safety policies, procedures, performing risk assessment, and handling instructions. Finally, the paper concludes by providing a sound analytical basis in terms of the creation of a robust safety management system foreground control operations in underground mines. Full benefits of implementing an effective and systematic operational health and safety management system are illustrated. The procedure adopted and prescribed in this paper can be used in all underground coal mines where lack of appropriate ground control practices can create deficiencies in both safety and productivity.

INTRODUCTION

Mining can be a dangerous occupation with many potential health hazards: more than 104,000 miners have died in mining accidents in the United Stated since 1900 (Sherard, 2011). Approximately 631,000 U.S. soldiers and other Americans were killed in wars during the same period (Fischer, 2007). It is therefore conceivable to think that a silent war has been taking place in mines during the last century. Most of these fatalities occurred from 1900 to 1978 when laws and control system were ineffective (Sherard, 2011).

Coal provides 30% of primary energy needs, and over 7 million people are employed in this sector globally. Some of the worst human disasters have occurred in this industry, and even to date, mining is performed in very dangerous conditions in some countries. Most of the mining fatalities nowadays occur in developing countries where occupational health and safety rules are neglected.

Continuous technological advances and a highly skilled workforce have allowed the coal mining industry to provide a safer workplace in developed countries. Since 1970, coal production has increased nearly 75%, and fatal injuries have decreased by approximately 93% in the United States (MSHA, 2010). Nevertheless, underground mining still has one of the highest fatal injury rates of any U.S. industry—more than five times the national average compared to other industries (NIOSH, 2011).

Historically, roof and rib falls have been the greatest cause of fatalities in underground coal mines, and they remain the greatest safety problem in underground coal mining to date. Between 1999 and 2008, nearly 40% of all underground fatalities were attributed to roof, rib, and face falls (NIOSH, 2011). Poor roof and rib conditions lead operators in many mines to use roof support systems to prevent accidents. Although recent advances in technology have reduced the total number of such accidents drastically, when failures occur, they usually result in severe consequences. Risks of rock falls, use of heavy machinery and electrical apparatus, entry to confined spaces, working in noisy and dusty environments, and working on unstable platforms are only some of the hazards associated with ground control operations. Ground control operators are arguably the hardest working persons in the mine (Compton, 2007). They are constantly lifting, bending, pulling and carrying materials that they need to control the roof of the mine. Adding support installation to this already labor-intensive job increases the risk of stress and strain injury to the operators.

Managing these risks requires a management regime that includes strict adherence to operational codes of practice and an enshrined culture of safety. Accident reports show that the major contributing factor in most rock fall accidents is the failure to adequately manage known risks due to the lack of a systematic process. Occupational Health and Safety Assessment Series 18001 (OHSAS) is an international occupational health and safety management standard specification to develop occupational health and safety at the workplace.

OHSAS 18001

OHSAS 18001 is an assessment model for the management of health and safety in systems that were developed to promote effective health and safety management. It is intended to help an organization control occupational health and safety risks. OHSAS 18001 has been developed to be compatible with the ISO 9001:2000 (Quality) and ISO 14001:2004 (Environmental) management systems standards so that it facilitates the integration of quality, environmental, and occupational health and safety management systems by organizations. OHSAS complies with applicable legal requirements, though compliance with this Standard does not confer immunity from legal obligations. It was developed by a selection of leading trade bodies and international standards and certification bodies to address a gap where no third-party certifiable international standard exists.

Occupational health and safety (OHS) measures take into account all conditions and factors that affect, or could affect, the health and safety of employees or other workers (including temporary workers and contractor personnel), visitors, or any other person in the workplace. An OHS management system is part of the overall organization's management. A management system is a set of inter-related elements used to establish objectives, and a policy to achieve those objectives. A management system includes an organizational structure, planning activities (for example, risk assessment and the setting of objectives), responsibilities, practices, procedures, processes, and resources. The OHSAS Standard is based on the methodology known as Plan-Do-Check-Act (PDCA). The basis of the approach is shown in Figure 1.

The main elements of OHSAS 18001 are given in Table 1.

Scope and Objectives

The scope of the OHS management system defines the objectives and its boundaries (such as physical boundaries). It does not state specific health and safety performance criteria, nor does it give detailed specifications for the design of a management system. The scope has been prepared to ensure that the mine operator at an underground mine has provided adequate consideration of all ground control aspects relevant to the safe design and operation of the mine they are responsible for.

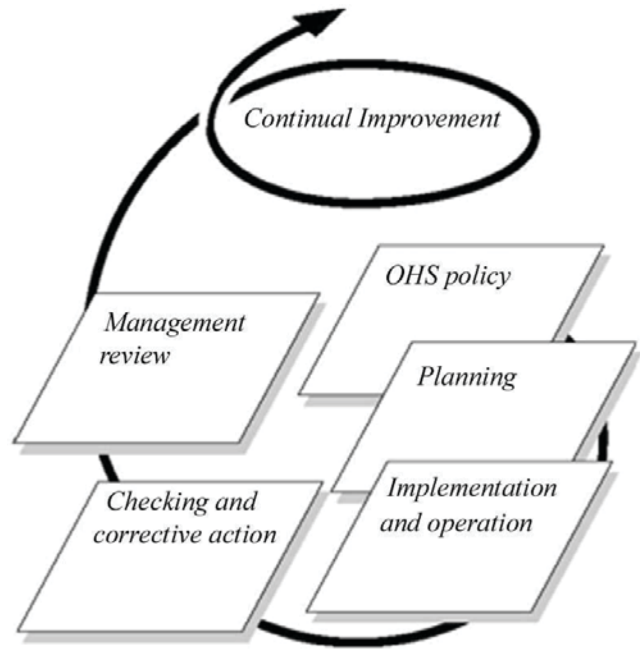

Figure 1. Operational heath and safety management system model for the OHSAS Standard.

POLICY

The ultimate goal and direction operating to an entity's OHS performance is set out in the OHS policy, which is formally expressed by top management. The OHS policy provides an appropriate framework, within the defined scope, for the nature and scale of the OHS risks to all persons working under the control of the organization. The framework also helps with setting tasks, action, and setting OHS objectives. The objectives should be consistent with the OHS policy and be specific, measurable, achievable, reasonable, and time bounded.

PLANNING

Planning is the organizational process of creating and maintaining a plan regarding the activities required to create the OHS objectives. The procedures for the ongoing hazard identification, risk assessment, and determination of necessary controls are the most important aspects of planning (see Figure 2).

An OHS Risk Assessment is the structured and systematic identification and analysis of workplace hazards, with the aim of reducing the risks of exposure to hazards. The OHS Risk Assessment is a decision making process that involves considering the consequences of accidents combined with the probability of exposure to risks. Furthermore, it includes analyzing and comparing alternative methods and to select among activities that may be less harmful. Various risk assessment techniques are available. Operators utilize many different risk assessment techniques such as what if, fault tree analysis, failure mode, and effects analysis.

Table 1. The main elements of OHSAS 18001.

Clause	Description	Clause	Description	Clause	Description
—	Introduction	4.4	Implementation and operation (title only)	4.5.3	Incident investigation, nonconformity, corrective action and preventive action (title only)
1	Scope	4.4.1	Resources, roles, responsibility, accountability and authority	4.5.3.1	Incident investigation
2	Normative references	4.4.2	Competence, training and awareness	4.5.3.2	Nonconformity, corrective and preventive action
3	Terms and definitions	4.4.3	Communication, participation and consultation	4.5.4	Control of records
4	OHS management system elements (title only)	4.4.4	Documentation	4.5.5	Internal audit
4.1	General requirements	4.4.5	Control of documents	4.6	Management review
4.2	OHS policy	4.4.6	Operational control		
4.3	Planning (title only)	4.4.7	Emergency preparedness and response		
4.3.1	Hazard identification, risk assessment and determining controls	4.5	Checking (title only)		
4.3.2	Legal and other requirements	4.5.1	Performance measurement and monitoring		
4.3.3	Objectives and programme(s)	4.5.2	Evaluation of compliance		

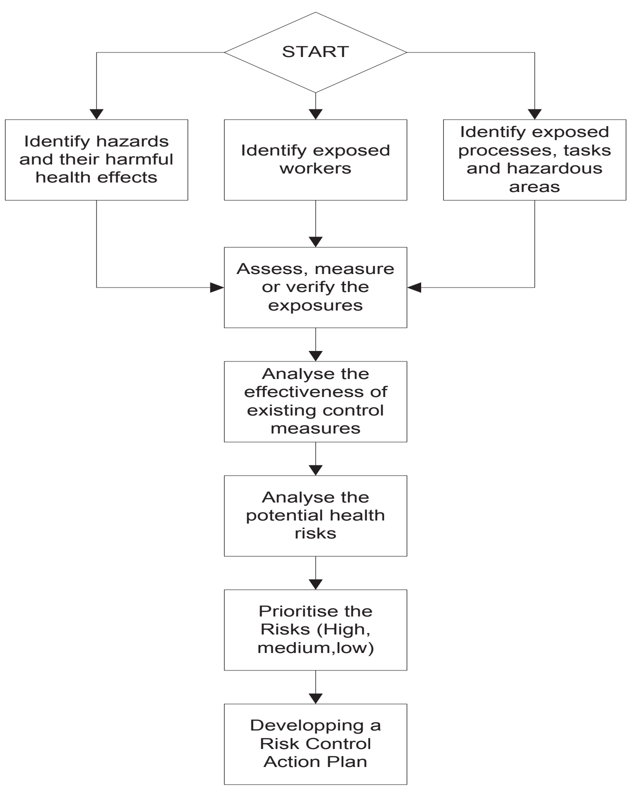

Figure 2. Risk management flowchart.

Mines are complex workplaces and the range of hazards and potential exposures to hazards are extensive. Identifying health hazards is the first step in an OHS risk assessment process. Compiling incident reports, audit reports, occupational illness and injury reports, fault reports of equipment, and Material Safety Data Sheets (MSDS) may be useful for documenting such risks.

It is suggested that conducting a survey of the workplaces will help harmonize, consolidate, and finalize the identification of health hazards. Some key aspects to be considered are as follows:(suggest including topics directly associated with 'ground control' rather noise, vibration, radiation, heat, cold, mist, gases, fibers etc.)

- Physical potential hazards (noise, vibration, lighting, radiation, heat, and cold)
- Chemical potential hazards (dusts, fumes, vapors, mists, liquids, gases, and fibers)
- Safety issues (rock fall, electrical shock, machinery accident, fire and explosion, working at height, and accident involving hydraulic pressure).

Assessing exposure levels is the next step after identifying health hazards in an OHS risk assessment process. It characterizes exposures in terms of their intensity and duration for processes, tasks, and areas. Exposures can be estimated qualitatively or quantified by measurement. A risk assessment worksheet provides the necessary tools to assess risk and therefore avoid it, or to reduce the possibility and percentage of accidents and other risk related incidents. A worksheet for identifying potential hazards and assessment of the risks is provided in Table 2.

Table 2. Checklist for identifying potential hazards and assessing the risks.

Potential Hazard	Likely to be found Yes/No/Not Sure	Details of specific hazard	Likely harmful effects	Acute/Long latency	Hazard rating	Where located (area/process/task)
Rock fall	Yes	falls of small rocks from the mine roof	Injury or dead	Acute	100	between roof bolts
High pressure of hydraulics fluid	Yes	The rupture of the high pressure hose	Injury or dead	Acute	100	Near power support systems

Risk rating is calculated based on the potential health consequence of each identified health hazard with the likely levels of exposures to it, and by the likelihood of the hazard occurring or being present. With a predefined numerical ranking, these risks can be quantified by using the following formula:

$$Risk rating = Consequence \times Probability of exposure \times Period of exposure \times Uncertainty$$

The numeric values for each function of the equation can be found in Tables 3,4,5,6, and 7.

Table 3. Consequence and numerical rating.

Consequence	Numerical Rating
Exposure at this level is unlikely to lead to harm.	1
Non-life threatening reversible health effects.	15
Adverse health effects that are permanent but do not significantly affect quality of life or longevity.	50
Adverse health effects that are generally permanent and could lead to a significant reduction in quality of life and/or longevity.	100

Table 4. Probability of exposure.

Probability of exposure	Numerical Rating
Low	3
Medium	6
High	10

Table 5. Period of exposure.

Period of exposure	Numerical Rating
Rare (Once per year)	0.5
Unusual (a few times year)	1
Short periods of time (a few times per month)	2
Continuous for between 2 and 4 hours per shift	6
Continuous for 8 hours shift	10

Upon completion of hazard identification and risk assessment, it should be ensured that risks are eliminated or minimized; an ounce of prevention is better than a pound of cure. There are several levels of control to deal with adverse exposures. In order of reliability, effectiveness, and likelihood of reducing exposures they are as follow: elimination, substitution, engineering (including isolation), administration (including education and training), and personal protective equipment.

Mines of all kinds are increasingly concerned with achieving and demonstrating sound occupational health and safety performance, but the range of potential exposures is extensive in mining ground control operations. The OHS management system includes all such risks and determined control. Due to the lack of a systematic management, operators cannot adequately prioritize and address the risks that lead to most accidents. OHSAS provides easy to use guidance and a proven method that will assist in developing a systematic approach to managing hazards that cause accidents. The operator should document and keep the results of identification of hazards, risk assessments, and determined controls up-to-date.

Some determined controls of ground control operations are:

Contact With Live Electrical Conductors or Energized Machine Parts

Electric shocks are a serious problem in the mining environment. Electrical accidents are not restricted to some activities but cover the entire spectrum of mining such as ground control operations. Many ground control machines such as modern bolting rigs, scaling machines, and T.B.M are often powered by electricity. They work at the harsh environment and any fault or unsafe electrical condition may make fatal accidents.

- Inspect all cables for damage including nearby cables. Test all circuits to ensure that they have been de-energized before beginning work.
- Take electrical measurements to identify any stray electrical currents.
- Conduct repair work at a safe distance from any energized cables.
- Familiarize workers with the work area, and be aware of any hazards.

Table 6. Uncertainty in extent of hazard.

Uncertainty in extent of hazard	Numerical Rating
Certain	1
Uncertain	2
Very Uncertain	3

Table 7. Calculated risk rating, classification of risk, and action.

Calculated risk rating	Classification of risk	Action
400 and above	Intolerable risk	Requires immediate discontinuation/shutdown
200–399	Very high risk	Requires immediate mitigation action with a program to develop a permanent solution
70–199	High risk	Requires mitigation action as soon as possible
20–69	Potential risk	Requires mitigation action and/or monitoring
Under 20	Tolerable risk	Requires monitoring

Potential Accidents Involving the High Pressure of Hydraulics

Hydraulic systems are popular on many types of ground control equipment such as power support systems and hydraulic jacks. Hydraulic systems must store fluid under high pressure more than thousands pounds per square inch. The fluid, under tremendous pressure is hot.

The rupture of the high pressure hose or the residual hydraulic fluid while the hose releases from circuit may spray into the miners' eyes and lead to chemical injuries or strikes to body.

- Disconnect the high pressure circuit on each shield with high pressure valves and electro-hydraulic isolation control buttons.
- Work on a circuit after the pressure is turned off and any locked in pressures have been released.
- Work on a shield component after it is blocked against inadvertent motion.
- Look for damaged hoses or controls.
- Do not place high pressure hoses in travel ways or in areas where miners would be regularly exposed to them.
- Educate miners that certain cylinders contain high pressure after shutting off the valves.
- Check valves keep the pressure in the cylinders to keep the roof supported.

Rock Fall

The result of the hazard of a loose rock falling from a roof or sidewall and striking someone can be fatal if direct physical contact is made.

- The design and installation of ground support and reinforcement systems must be capable of withstanding static and dynamic loads.
- Identify and remove loose roof material from a safe position.
- Always conduct a thorough visual examination of the roof, face, and ribs immediately before work is performed and thereafter as conditions dictate.
- Always stay alert for changing conditions in the work area.
- Release and remove roof support jacks remotely.
- Install breaker post from the outby side of the remaining pillar block toward the pillared out areas.
- Prevent of bounce/outburst on the active longwall face.
- Keep the boom of a scaling machine to a minimum angle to reduce the risk of a rock bouncing into the cab.
- Scale any loose or hazardous roof material using proper equipment and scale from a safe location.
- Know and follow the approved roof control plan including the approved pillaring procedures.
- Be alert to any change of roof conditions.
- Mine personnel not essential to the specific activity should remain outside the work zone.
- Never travel inby supported areas.
- Use roof screen to prevent falls of small pieces of rock from between roof bolts.
- Check roof bolting machines for proper torque settings. Abnormally high torque may also add to the problem of distorted expansion shells.
- Re-instruct roof bolting machine operators as to proper installation procedures, such as proper drill hole depth, resin cartridge length, and installed torque.
- Install and examine test holes regularly for changes in roof strata.
- Use "hands off" drilling method while rock bolt installation operations.
- Assess the suitability of ground controls in variable ground conditions (e.g., expansion shell bolts are generally ineffective in soft rock, as are friction bolts where the correct hole diameter cannot be maintained).
- Be sure that the correct hole length is drilled and holes are flushed clean of all drilling sludge.
- Ensure that the orientation of the hole is appropriate for the excavation geometry and expected block movement. Axial tensile loading of the steel elements installed in the rock is generally preferred; shear loading should be avoided.
- Drill hole nearly perpendicular to the rock surface; use of hemispherical ball and domed plates may be required where this cannot be achieved.

- Appropriately match the load capacity of the anchorage method, bar, or tendon and surface restraint fittings to prevent the premature failure of any one component.
- Ensure that all steel and other components designed to be encapsulated in resin or cement grout are clean of all oil, grease, fill, loose or flaking rust, and any other materials deleterious to the grout.
- Where full grout encapsulation of the steel elements is required, the method of grouting should show a grout return at the collar of the hole; other methods that can demonstrate complete hole filling may also be appropriate.
- Use correct tensioning or loading procedures for the various rock support and reinforcement systems.
- Ensure that plates and/or straps against the rock surface have the required thickness to prevent nuts or barrel and wedge anchors from being pulled through the plate and/or strap at the ultimate tensile strength of the tendon when loaded against the rock surrounding the bore hole.
- Recognize and remedy corrosion issues.
- Check that blast vibrations have not loosened threaded reinforcement systems.
- Regularly carry out load tests on point anchored rock bolts and friction anchored rock bolts.
- Check fully grouted reinforcement systems on a regular basis to ensure that the grout strength and encapsulated length of the bar or tendon is adequate.
- Implement an action plan when it is found that the load capacity of the installed support or reinforcement system, grout strength, and/or encapsulated length does not meet specifications.
- Store resin grouts at the temperature range recommended by manufacturer.
- Use resin grouts before their "use by" date, or within a specified period of time.
- Mix resin grouts for the recommended time and at the recommended speed; these should not be exceeded.
- Mix cement grout at the recommended water cement ratio and at the recommended angular speed in the specified equipment for the required time.
- Ensure that water used for cement grout mixing is of the required quality or the cement used should be able to develop the required uniaxial compressive strength with the run of mine water supply.
- Ensure that any additives (e.g. retarders, accelerators, fluidizers, etc.) to the cement grout mix are added in the recommended amounts and at the specified time in the mixing and pumping process.
- Clean and maintain all grout mixing and pumping equipment on a regular basis.
- Regularly maintain any pumping equipment used to pressurize rock support and reinforcement and operate it at the recommended pressure.
- In shotcrete mix specifications, state the slump of the mix, the uniaxial compressive strength, and a measure of the toughness of the product at specified time intervals prior to or following mine application, as appropriate.
- Collect samples of the mine shotcrete mix at specified intervals, under normal mine operating conditions, and test the mix by a registered concrete testing laboratory for compliance with the shotcrete design specifications.
- Test shotcrete thickness regularly during placement to ensure that the specified thickness has been applied; a means of permanently marking the shotcrete surface with a depth gauge probe may be appropriate.

Working at Height

Rock reinforcement is included in some activities such as scaling, bolting and screening. These activities involve generally working at height.

Steps, platforms, walkways, handrails, handholds, and guardrails must be designed to provide safe entry to, and exit from, a machine operating station and areas where maintenance is performed.

- Use proper fall protection equipment such as the full body harness.
- Make sure ladders, steps, and platforms are securely anchored and well maintained.
- Make sure boarding ladders and travel ways are well illuminated and unobstructed.
- Make positive contact with the machine operator before mounting or dismounting equipment.

Measures for risk management should reflect the principle of the elimination of hazards where practicable, followed in turn by risk reduction (either by reducing the likelihood of occurrence or the potential severity of injury or damage), with the adoption of personal protective equipment (PPE) as a last resort. The legal and other OHS applicable requirements relevant to ground control are taken into account in the OHS management system.

IMPLEMENTATION AND OPERATION

Resources, Roles, Responsibility, Accountability, and Authority

Top management shall take ultimate responsibility for the OHS management system. Management commits to providing resources including human resources and specialized skills, organizational infrastructure, and technology and financial resources, as well as defining roles, allocating responsibilities, and delegating authorities to facilitate effective OHS management in accordance with this OHSAS Standard.

Competence, Training, and Awareness

Each person who has an impact on OHS is competent on the basis of appropriate education, training, or experience. The operator shall provide training to meet the training needs of personnel, which should take into account differing levels of responsibility, ability, language skills, and literacy. The effectiveness of the training should be evaluated thereafter. Safety subjects relevant to ground conditions and control must be included in training programs and the training required must be provided to miners before they begin work at a mine, or before they receive new work tasks or assignments. Each worker must have a sound understanding of identifying hazardous ground conditions and safe mining practices to keep them safe.

The people who are working under an operator's control should be aware of the actual or potential consequences of OHS to their work activities and their roles and responsibilities in OHS management system.

OHSAS requires mine operators to provide information to miners concerning hazards. It is based on two safety and health principles: (1) miners have a right to know about the hazards where they work, and (2) miners have the responsibility to know about hazards at workplace.

Communication, Participation, and Consultation

Safety begins with teamwork; therefore, communication among various levels, participation from workers, and consultation are essential to implement the OHS management system. An example of the minimum contribution by workers to reduce ground control accidents is the examination of the roof in the work area prior to commencing work and being alert of changing roof conditions.

Documentation

Documentation provides evidence. Documentation is proportional to the level of complexity, hazards, and risks concerned and is kept to the minimum required for effectiveness and efficiency. The basis of the documentation is shown in Figure 3.

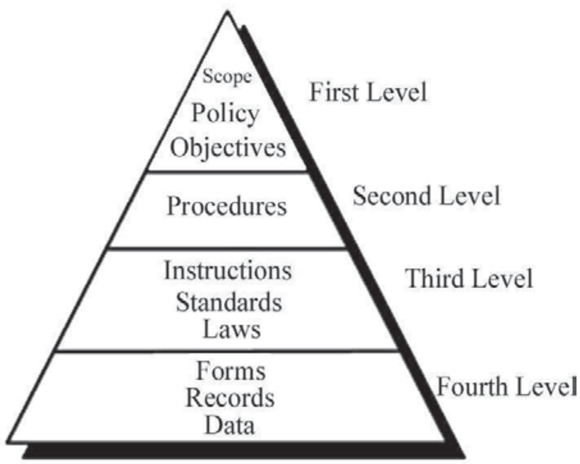

Figure 3. Documentation pyramid for OHSAS Standard.

All aspects of ground control are included in the ground control plan. It outlines the system used to manage ground control. All supporting documentation shall be readily available and reviewed regularly.

Control of Documents

Documents required by the OHSAS Standard shall be controlled. The producers of control of documents shall provide approval of documents for adequacy prior to being issued, and revise them if necessary. A competent authority is generally authorized to control the ground control plan.

Operational Control

The operator shall apply operational controls over the identified hazards to manage the OHS risks. Operational control includes controls related to purchased goods, equipment, services, contractors, and other visitors to the workplace.

Emergency Preparedness and Response

The operator shall establish that the producers identify the potential for emergency situations and response to such emergency situations to prevent or mitigate associated adverse health and safety consequences.

Being prepared for emergencies means ensuring that the necessary equipment and supplies are readily available and that all employees know what to do when an unplanned event occurs, such as a roof collapse. These procedures should be in writing, and employees should have the opportunity to practice their emergency response skills regularly. An emergency plan should include the needs of relevant interested parties, for instance, those of emergency services and neighbors.

CHECKING

Performance Measurement and Monitoring

OHSAS 18001 requires that OHS performance be monitored on a regular basis. The monitoring mechanism shall control both qualitative and quantitative proactive and reactive measures of performance (conformity with the OHS programs, operational criteria, and incidents) and the effectiveness of prevention methods.

Ground support and monitoring of ground control issues used must be implemented in a suitable manner in relation to the particular mining environment at any location in a mine. The monitoring data needs to be systematically recorded to build up a good understanding of how the mine is performing with time. Monitoring data also needs to be conveyed to the employees in a timely and clear method, explaining the risks and actions required to be taken.

Evaluation of Compliance

OHSAS 18001 requires that compliance with applicable legal and other requirements is monitored and records maintained.

Governments authorize the formulation of the code of regulations for mine safety, and parliaments legislate laws relevant to mining. International organizations such as International Labor Organization and the World Health Organization have offered OHS recommendations. Governments employ many inspectors to ensure that operators observe the national and international laws. The establishment of OHSAS 18001 satisfies governments on operators' adherence to OHS codes.

Incident Investigation, Nonconformity, Corrective Action, and Preventive Action

OHSAS 18001 requires incident investigation, nonconformity, corrective action, and preventive action. The wording of this requirement has been enhanced to ensure that incidents are investigated and that results are recorded and analyzed.

Nowhere is this more evident than in effective incident investigation, where prejudices, preconceptions, and value judgments predominate, along with limiting beliefs such as "most accidents are caused by human error/unsafe acts." Such models subconsciously restrict the flow of information and result in many relevant factors in an incident being overlooked.

Control of Records

OHSAS 18001 requires an operator to ensure that the mine develops a procedure for identifying, maintaining, and disposing of safety-related records. The procedure for the control of records should require that records be legible, protected, and readily retrievable. Records are essential to demonstrate the satisfactory operation of the safety management system.

Internal Audit

An organization confirms through internal audit that their OHS management system complies with intentions and with the requirements of OHSAS 18001.

Rock mass characteristics change during the process of mining; consequently, it is necessary during operation that the operator undertakes regular audits of ground control systems to ensure continued validity of all components within the system and formally modify the process as indicated by the audit.

MANAGEMENT REVIEW

Top management shall review the organization's OHS management system at planned intervals to ensure its continuing suitability, adequacy, and effectiveness. Reviews shall include assessing opportunities for improvement and the need for changes to the OHS management system, including the OHS policy and OHS objectives.

CONCLUSION

The goal of all mine safety professionals is to make mines a safer place to work. Nearly every mine eventually encounters poor roof conditions and the need to control ground at some point. Reducing the number of rock falls and other hazards during ground control operation injuries by establishing an OHS management system will help. It has been appreciated for many years that effective management of occupational health and safety can significantly reduce risk exposure and potentially improve an organization's profitability and sustainability. Leading studies have recognized that implementing a formal occupational health and safety management system based on OHSAS 18001 is an excellent means of achieving this business aim.

The OHSAS specification is applicable to any mining operator from small-scale mine to mining multinational consortium. All of De Beers Group's diamond mining operations and Rio Tinto's sites acquired prior to 2005 are certified to OHSAS 18001 standard.

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