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Best Practices for Ensuring Safety in Field Studies: A Comprehensive Guide for Mining Researchers and Operators

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ABSTRACT

In an effort to advance the science underlying ground control engineering, researchers with the National Institute for Occupational Safety and Health (NIOSH) are frequently involved in field studies at collaborating mines. Often, these field studies involve visiting the mine site, instrumentation installation, and data acquisition. Each of these aspects involve potential risks to NIOSH employees. As an organization whose mission it is to promote the health and safety of mine workers, the health and safety of our workforce is paramount.

This paper provides documentation of the best practices followed by NIOSH employees who are tasked with visiting and conducting work at underground and surface mines. This includes Mine Safety and Health Administration (MSHA) approved training, mine site specific training, and hazards associated with all aspects of mining that could be encountered by the employee. Additionally, this paper details best practices associated specifically with instrumentation installation including the mitigation of hazards associated with the proper equipment handling, drilling, and the mine environment.

The information showcased in this paper can be used as considerations for industry practitioners such as mine operators, consultants, and academic researchers engaged in the installation of instrumentation in the field. Furthermore, the best practices detailed in this paper can be used as a foundation for agreements made between mine operators and researchers to ensure safety procedures will be followed while on mine property. This will result in enhanced safety of both researchers involved in field studies as well as mine employees tasked with assisting and accompanying those researchers.

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is at the forefront of advancing the science of ground control engineering, often requiring its researchers to conduct field studies at collaborating mines. These studies, while essential, expose NIOSH employees to potential risks inherent in the mining environment. As NIOSH is an organization dedicated to the health and safety of mine workers, ensuring the well-being of its own workforce is of utmost importance.

This paper presents the best practices adopted by NIOSH employees during their visits and work at underground mines. From training to addressing specific hazards related to instrumentation installation, this paper provides a comprehensive guide to safe operations.

The insights presented in this paper are not just limited to NIOSH operations. They serve as valuable considerations for industry partners, including mine operators, consultants, and academic researchers. By highlighting the importance of collaboration between mine operators and researchers, the paper underscores the collective responsibility of ensuring a safe working environment.

TRAINING

Prior to identifying the hazards that researchers and operators need to recognize and identify while conducting field studies, it is important to start with the discussion of training. Training is the starting point for all underground worker safety, as it provides crucial information for new and experienced personnel working underground to stay safe.

Before any field studies can be completed, researchers and operators should complete training and refreshers to stay up to date on important safety guidelines and material.

Site-specific safety training is also essential, as hazards can vary from mine to mine. Below is a list of some of the safety training that researchers and operators conducting field studies underground should receive ((Training and Retraining of Miners, 2015; Training and Retraining of Miners Engaged in Shell Dredging or Employed at Sand, Gravel, Surface Stone, Surface Clay, Colloidal Phosphate, or Surface Limestone Mines, 2015).

- Underground New Miner Training
- Annual Refresher Training (up to date and current)
- Site-specific Safety Training
- Task Training (if equipment is to be operated)

POTENTIAL SAFETY HAZARDS IN MINES

Researchers are involved in numerous field projects across a variety of mines throughout the United States. Projects can range from surveying and scanning to large scale instrumentation installations, including but not limited to Hollow Inclusion (HI) Cells, Borehole Pressure Cells (BPCs), and Roof/Rib Extensometers. Field projects are faced with many hazards that come with working in underground mining.

In addition to the general hazards of working underground, there are also hazards that are specific to the task itself. Before beginning to identify what potential safety hazards researchers can be exposed to in mines, it is important to define the meaning of a hazard. A hazard is a condition or activity that, if not mitigated, can cause injury or illness.

There are many different categories of hazards. Safety hazards include slip, trip, and falls; working on ladders; working around heavy equipment. Physical hazards deal with the environment to which researchers can be exposed including noise, dust, or roof/rib conditions (See Figure 1). There are ergonomic hazards as well, which would include lifting, repeated movements, and vibration (OSHA, 2002).

This section will review some general underground and task-specific activity hazards that have the potential to cause injury/illness to researchers and operators during field studies. The section breaks down and explains what hazards each condition or activity can present to researchers and operators working at the mine.

General Underground

There are general underground hazards that are not specific to a particular task but are present with working in an underground mining environment. The first of these is slip, trip, and fall hazards (NIOSH, 2022). Underground mines can have uneven terrain that can make the prevalence of slip, trip, and fall hazards more common and can possibly endanger researchers in the mine. Standing water is also another hazard that can be posed to researchers while working underground. Stepping in standing water and not knowing the underlying surface can lead to slip, trip, and fall hazards.

Figure 1. Example of potential rib hazards including rib sloughage and damaged supports

Struck-by hazards also represent a significant proportion of hazards encountered underground. There are numerous different pieces of heavy equipment and machinery moving underground. The combination of moving and repositioning of heavy equipment (roof bolters, continuous miners, shuttle cars, man trips, etc.), poor visibility, and confined working conditions can subject researchers to struck-by hazards (See Figure 2).

The underground environment can present tight conditions with the addition of working in close proximity to heavy equipment which means that caught in/between hazards are also present (See Figure 3). Additionally, some underground equipment have pinch points associated with them, particularly scoops, and conveyor belts have multiple moving components that are capable of being caught in.

Both struck by and caught in/between hazards are most prominent when employees are conducting research on the

Figure 2. Example of tramming a continuous miner representing a potential struck-by hazard

active working section. This was recently experienced by NIOSH researchers tasked with instrumentation installations at the Maple Eagle Mine where instrumentation was being installed outby the pillar line of the working retreat section (McElhinney et al., 2023). Additionally, being on the active working section is common for researchers anytime they are making observations, scoping the roof, or collecting data. Respiratory hazards that researchers can be exposed to are also possible. Dusty conditions can be present from operations and field study activities while working underground (See Figure 4). Additionally, some of the epoxy, glue, and resin that researchers use have the potential for respiratory injuries.

A prime example of researchers potentially being exposed to respiratory hazards would be during data collection, particularly in longwall tailgates and other return air courses. The final data collection and data logger retrieval at a longwall mine in Central Utah is a recent example where this hazard was encountered by NIOSH researchers (Minoski et al., 2020). In this case, researchers were required to traverse the tailgate as it was not accessible from the longwall face. This occurred during the mine-through of a fault resulting in increased exposure to dust from cutting the surrounding rock.

In underground mining, roof and rib falls are serious safety concerns. These falls happen when the roof or walls of the mine become unstable due to factors like stress, changes in lithology, and weathering effects. These incidents have the potential to injure both mine researchers and operators. These hazards include loose or detached material from the roof or rib, rib brows due to excessive sloughing, and potentially damaged supports.

Figure 3. Example of a tramming continuous miner depicting the tight spaces associated with underground equipment and potential for caught between hazards

Figure 4. Example of drilling operations resulting in the production of dust

In addition to the general underground hazards, researchers conducting field studies have the potential to be exposed to a number of hazards specific to underground research. The following section discusses these specific hazards that researchers are likely to encounter in the field. Although some of the following hazards can be encountered in other aspects of mining, this discussion focuses on the impact of these hazards to mine researchers.

RESEARCH-SPECIFIC HAZARDS

Material Handling Hazards

Material handling is a major component of field studies as there are multiple pieces of equipment, instrumentation, and tools that researchers must handle during instrumentation installations. Material handling includes lifting, carrying, pushing, and pulling of materials (California DIR, 2007). Improper lifting mechanics and lifting items too heavy are just some of the material handling hazards that can result in injury to personnel while working underground. Depending on specific work areas in the mine, researchers may need to manually carry tools and equipment across long distances to get to active working areas. Trekking across these distances can fatigue researchers who need to carry tools and equipment. Fatigue can cause improper lifting mechanics and excessive stress and strain on the researchers working underground.

Drilling Hazards

Drilling, whether to install BPCs, extensometers, or other instrumentation, typically utilizes a roof bolting machine that not only has many moving and rotating parts but also has drill steel that requires handling by both researchers and operators (Sammarco et al., 2016). The drill steel could have sharp edges exposing researchers and operators to cuts, lacerations, abrasions, and punctures. Since boreholes need to be drilled at an extensive depth, drill steel needs to be constantly added to the bolt machine.

From handling this drill steel after drilling, researchers' and operators' hands can be exposed to burns from hot drill steel and bits (See Figure 5). Additional hazards due to drilling such as collapsing boreholes and stuck or broken drill steel can be encountered particularly under deep cover (Minoski et al, 2020) or where multiple-seam stresses are encountered (McElhinney et al., 2023).

Ladder Hazards

Ladders are an essential piece of equipment for researchers during instrument installation where the mining height is beyond reach of the average person (See Figure 6). Installing extensometers and running instrumentation cables are common tasks that can require researchers to use a ladder to reach the roof of the mine.

The usage of ladders is widely encountered during instrumentation installations as most mines are mining thicker partings, weaker immediate roof, or mining for equipment clearance. Selecting the wrong ladder for the job, ladder misuse, or using damaged/defective ladders are some hazards that can pose a danger to researchers working underground. Another hazard is falling tools and material striking personnel working underneath a ladder.

Borehole Pressure Cell (BPC) Installation Hazards

The installation of BPCs has numerous hazards that can endanger researchers and operators. BPCs are a hydraulic pressure cell used to measure changes in rock stress (Minoski et al., 2024).

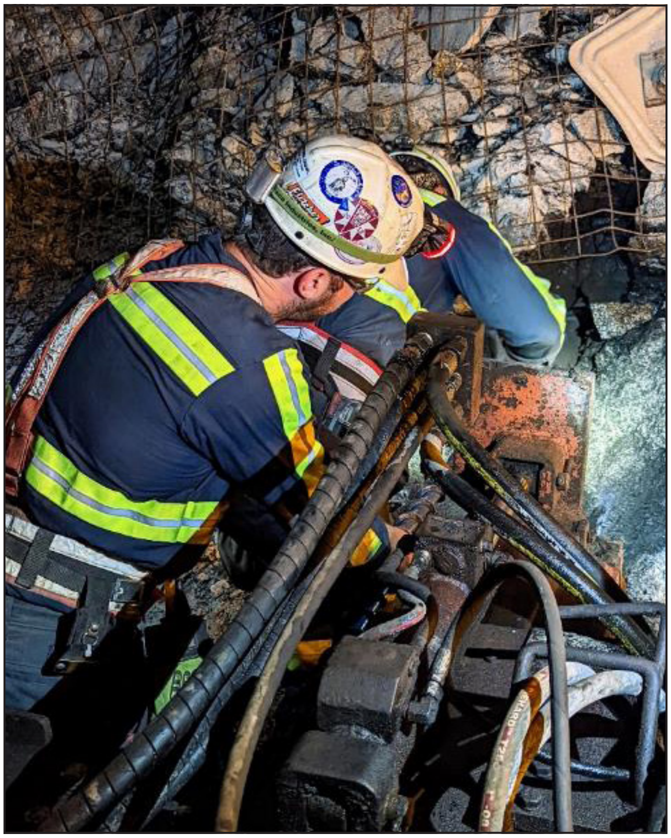

Figure 5. Photo depicting two researchers involved in the process of adding drill steel during drilling operations

While installing BPCs, researchers and operators work together in close proximity to a roof bolting machine. Working close to heavy equipment carries the hazard of personnel being struck by and caught in/between. In addition to the hazards of heavy equipment, BPCs are installed into the coal pillar, which can lead to material sloughing from the rib or brow and striking personnel working in close proximity to the BPCs.

Drilling is a critical stage of installing BPCs. Drilling depths vary, and researchers and operators need to repetitively add/subtract auger steel to/from the roof bolting machine. This activity can lead to injuries and illnesses from rotating and moving parts. Auger steel and drill bits also have the potential to be hot, which can lead to burn injuries to the personnel handling this equipment. Cuts, lacerations, and abrasions are also a concern due to auger steel having the potential to have sharp and jagged edges. Repetitively adding or subtracting auger steel on or off of the roof bolting machine also carries the risk of hazards associated with manual handling injuries. Connecting

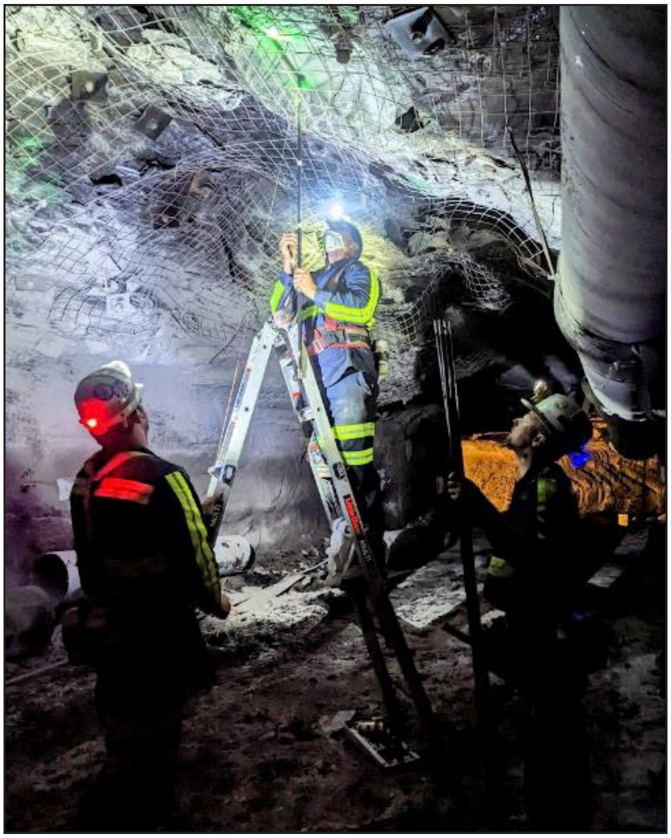

Figure 6. Photo depicting researchers safely using a ladder to install instrumentation

Figure 7. Photo depicting a researcher beginning the installation of a BPC using a set of insertion/setting rods

auger steel together for drilling BPC holes also carries the risk of pinch points for personnel changing auger steel.

Auger steel is connected together by using roll pins or nails. Common practice involves using a hammer and pin or pliers to add or remove these nails or pins. Line of fire and hand injuries from knocking the nail or pin in or out of place is a hazard while completing this step of the task. In addition to this, flying debris while hammering can cause eye damage.

This situation was encountered recently by a NIOSH researcher that was attempting to remove stuck drill steel at a mine under deep cover (Klemetti et al., 2019). In this example, the researcher was using a pair of channel locks on the drill steel when the steel was rotated by the bolt machine operator. This caused the channel locks to disengage the steel, flying up and hitting the researcher in the face. No injuries were received as the researcher was wearing proper PPE at the time including hard hat and safety glasses.

Following completion of boreholes being drilled, the BPCs are now ready to be installed. This stage carries additional hazards that can affect researchers during installation. Insertion rods are utilized to install the BPC itself into the borehole. Researchers must connect these pieces together to be able to set the BPC at the maximum depth of the hole (See Figure 7).

Connecting these setting rods, the hands of the researcher are continually exposed to pinch points. In some cases, resistance is encountered inserting the BPC requiring the researcher to apply excessive force to the drill steel if the hole is collapsing or contains excessive debris (McElhinney et al., 2023). After the BPC is positioned, hydraulic fluid is used to fill the BPCs to setting pressures up to as much as 3,000 psi, resulting in the potential for exposure to high pressure hydraulic fluid (See Figure 8).

MULTIPOINT ROOF/RIB EXTENSOMETER INSTALLATION HAZARDS

Like BPCs, installation of multipoint roof/rib extensometers have multiple hazards that can put both researchers and operators at risk. Extensometers are used to monitor movement of roof/rib and separation between the varying strata (Minoski, 2024). A roof-bolting machine is used during installation of roof/rib extensometers. The drilling hazards associated with extensometer installation is very similar to that discussed in the section on BPCs. The primary

Figure 8. Photo of a researcher pressurizing the BPC to its initial setting pressure using a hydraulic pump

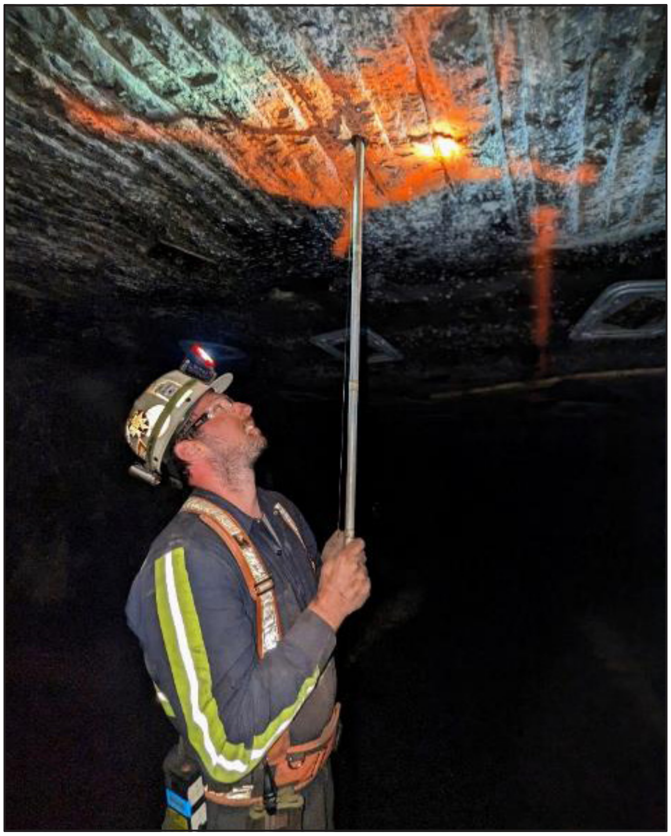

Figure 9. Photo of a researcher beginning the process of installing anchors for a roof extensometer

difference being that the borehole is drilled with the mine's standard drill steel and dusthog type bits.

After drilling is completed, the instrumentation installation begins, and it starts with installing anchors into the pre-drilled hole. Insertion rods are utilized to install these anchors at pre-determined depths.

As previously noted with the use of insertion rods for BPCs, hand injuries and pinch points are a major concern when connecting or disconnecting rods (See Figure 9).

In addition to hand injuries from the insertion rods, the anchors have stainless steel wire connected to them. Hand injuries (cuts, abrasions, etc.) can occur while tensioning the wires during installation.

Once the anchors are set to the correct depth, installation of the extensometer device itself begins. To achieve this step, the researcher adds an adhesive to the pipe connected to the extensometer. The pipe connected to the extensometer is then placed into the drilled hole. The adhesive that is placed on the pipe has hazards associated with it, including the potential for burns if it contacts skin.

While setting the extensometer, wedges are typically utilized to ensure a snug fit in the drilled hole. Researchers will use a hammer to set the wedges, and there is a hazard of both hand and line-of-fire injuries (See Figure 10).

Generally, NIOSH researchers do not typically encounter significant issues while installing roof extensometers. One of the more challenging installations required modification of the spring anchors that are typically installed in a 1 3/8" hole for installation in a 1" hole due to

Figure 10. Photo of a researcher completing the installation of a roof extensometer using epoxy and wooden wedges.

drilling limitation at the mine (McElhinney et al., 2023). This required cutting the spring end on each anchor to be installed which resulted in the additional hazard of cutting metal with wire cutters. The researcher tasked with this job wore safety glasses and gloves at all times and no injuries occurred.

While both rib and roof extensometers share many of the same installation hazards, they also present distinct risks. A rib extensometer is installed within the pillar, much like a BPC. On the other hand, a roof extensometer, as its name suggests, is installed in the mine roof. The installation of a roof extensometer often necessitates the use of a ladder, bringing along with it the ladder-related hazards mentioned earlier.

MULTI-POINT BOREHOLE EXTENSOMETER (MPBX) INSTALLATION HAZARDS

A multi-point borehole extensometer (MPBX) is used to measure displacement at specific anchor depths in a borehole (See Figure 11).

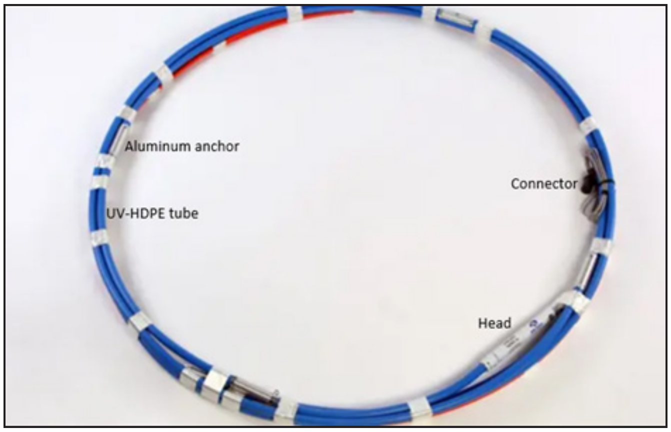

Figure 11. Example of a multi-point borehole extensometer typically grouted in place in the rib to measure horizontal displacement

Similar to the multipoint roof/rib extensometer installation, the MPBX installation utilizes a roof bolting machine to drill boreholes typically into the rib for the instrumentation to be placed.

Working in close proximity to the roof bolting machine carries the hazards of being struck by the equipment and caught in/between rotating parts during drilling. In addition to the hazards of the roof bolting machine, there are roof and rib hazards.

Another major step in the process of installing MPBX is grouting the instrumentation in the holes. While completing this step, researchers can be exposed to skin burns, eye irritation, and respiratory hazards. The safe installation of 6 MPBXs in addition to other instrumentation was recently completed by NIOSH researchers (Rashed et al., 2021).

STANDING-SUPPORT LOAD CELL INSTALLATION HAZARDS

Standing-support load cells are used to measure the loading performance of standing support in the mine (See Figure 12). Hazards associated with the installation of a standing-support load cell include manual handling hazards and slip, trip, and fall hazards.

Figure 12. An example of a standing-support load cell installed on top of a can type standing support between two sheets of plywood.

Manual handling hazards are of concern due to the size and weight of the instrumentation where improper lifting techniques and fatigue from prolonged handling can cause injuries to the researcher. Slip, trip, and fall hazards are also present, due to the environment of the mine and having to physically carry the load cells to the study site.

An example of the material handling hazards associated with standing support load cells was encountered by NIOSH researchers during the instrumentation installation in the bleeder entries at a longwall mine in Southwestern Virginia (Klemetti et al., 2018).

At this installation site, it was required that 23 prefilled loadcells be carried by hand from the end of the track to the installation located in the longwall bleeder entries. This required multiple trips by multiple researchers carrying these heavy 28” and 36” load cells.

Roof/Rib Load Cell Installation Hazards

Roof/rib bolt load cells are devices containing strain gauges used to measure the load on rock bolts (Minoski et al., 2024). Hazard associated with the installation of these load cells include working around heavy equipment, manual handling, and pinch points. A roof bolting machine is utilized to install the load cell. Similar to the installation of BPCs and extensometers, working in close proximity to a roof bolting machine will present the same hazards to researchers and operators. Part of the installation of cable bolt load cells involves sandwiching a 1" plate, a load cell, another 1" plate, and a roof bolt plate on a roof bolt (See Figure 13). The hazard for researchers and operators completing this task is pinch points and hand injuries.

Figure 13. Example of an installed roof bolt load cell

Because the installation of roof/rib bolt load cells requires a hands-on approach as the bolt is being installed, there is the potential for significant injuries. Recently, 6 rib bolt load cells were installed by NIOSH researchers (Rashed et al., 2021). The employees tasked with this install wore metacarpal gloves and no injuries occurred.

Hollow Inclusion (HI) Cell Installation Hazards

Hollow inclusion (HI) Cells (See Figure 14) are instrumentation used for three-dimensional stress measurements in rock and other material (Minoski et al., 2024). The installation process requires a collaborative effort between researchers and operators. While researchers handle instrument preparation and the actual installation, operators utilize a roof bolting machine to drill holes to a predetermined depth for the HI Cell.

Drilling these holes involves constant addition and subtraction of drill steel. This activity presents risks such as pinch points, hand injuries, and manual handling injuries to personnel. As highlighted earlier, working adjacent to the roof bolting machine comes with inherent dangers.

Figure 14. Example of a Hollow Inclusion (HI) Cell

Once drilling is completed, the next phase is the preparation of the HI Cell instrumentation.

This involves adding a corrosive epoxy resin, which can irritate the skin, and cleaning the drilled hole using insertion rods. The cleaning process poses hazards for researchers, including potential hand injuries and pinch points.

After the holes are cleaned and the instrumentation is ready, the HI Cell is installed. This step requires the use of insertion rods to set the HI Cell at the maximum drilled depth. The manual effort to push the HI Cell vertically into the roof can lead to muscle strains. Additionally, as mentioned earlier, researchers face risks of pinch points and hand injuries during this phase.

Securing the HI Cell is the final step. Depending on the mining height, researchers might need a ladder to reach the roof and secure the insertion rod, ensuring the HI Cell sets properly. Using a ladder introduces risks such as falls, being in the line of fire, and potential misuse of the ladder, all of which can result in injuries to the researchers.

Perhaps the most intensive HI Cell installation occurred at a longwall mine in Southwestern Virginia (Klemetti et al., 2019). Here, NIOSH researchers attempted to install 6 HI Cells at various angles into the roof over the pillars. The shallower the angle, the more difficult these were to drill. This resulted in broken drill steel, water swivels, and worn bits. This required researchers to add and remove steel to a very heavy drill string up to 30 ft. into the roof. This installation was completed with no injuries reported. However, the weight of such a long drill string, especially at the steeper angles was problematic from a material handling standpoint.

Cables/Wire Installation Hazards

Following completion of installing the required instrumentation at a field site, researchers are required to run cables from the instruments to the dataloggers located a distance outby. Cables are typically hung directly from the roof by attaching the cables to roof bolt plates or roof mesh. This ensures the cables are protected from damage by mobile equipment.

Depending on mining height, ladders are essential for researchers to complete this task. Hazards associated with ladder use include falls, struck-by falling tools/materials, ladder misuse, and pinch points.

This was most prominently encountered during the previously mentioned installation at a longwall mine in Central Utah (Minoski et al., 2020) where extreme deformation was expected during the mining process. In this case, all excess cable, BPC pressure gauges, and data loggers were anchored to the mine roof (See Figure 15).

This resulted in both material handling and potential ladder hazards particularly when associated with the uneven mine floor.

While understanding the hazards associated with underground research is paramount, it is equally crucial to recognize and implement best practices that can mitigate these risks. The following section delves into the best practices that researchers, operators, and mine personnel can adopt to ensure safety while conducting and facilitating underground research studies. These practices not only address the specific hazards discussed but also provide a holistic approach to ensuring the well-being of everyone involved in the research process.

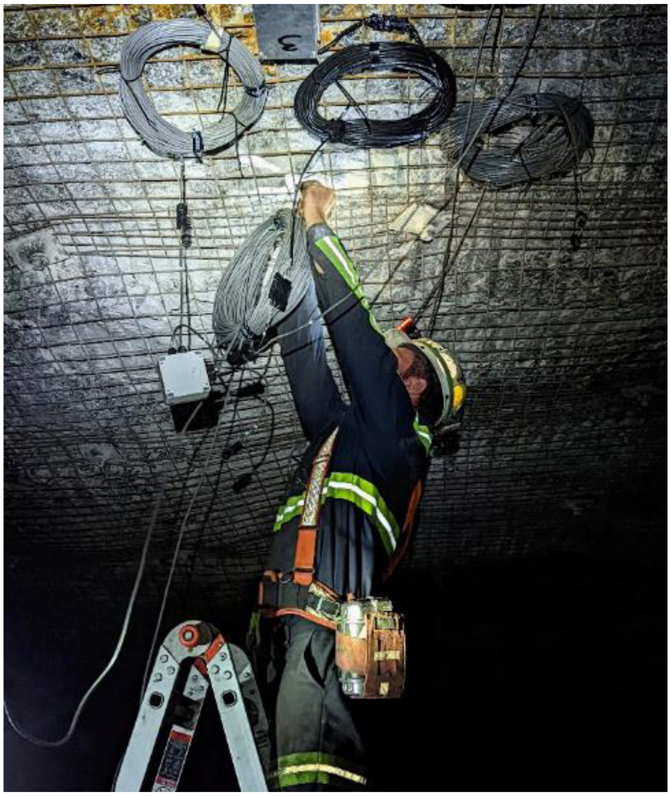

Figure 15. Example of a researcher safely using a ladder to hang cable from the mine roof.

BEST PRACTICES

Best practices in the context of safety refer to the set of guidelines, procedures, and standards that have been identified as the most effective and reliable methods to ensure the well-being and protection of individuals and assets. These practices are derived from both empirical evidence and expert consensus, often developed after thorough analysis of past incidents, near misses, and extensive research. By adhering to safety best practices, organizations and individuals can proactively mitigate risks, prevent accidents, and create an environment where safety is a paramount concern. These practices are dynamic and evolve over time, reflecting new insights, technological advancements, and changing environments, ensuring that safety measures remain relevant and up to date.

General Underground Best Practices

As previously presented, general underground best practices start with training. Underground new miner training, annual refresher training, and site-specific hazard training should be completed before conducting underground field studies. Prior to the start of underground field studies, it is important for researchers to familiarize themselves with mine ventilation, the mine map, and the location of areas where the researchers will be visiting.

Researchers must also familiarize themselves with key locations in the mine including the primary and secondary escapeways, self-contained self-rescuer (SCSR) caches, refuge alternatives, etc. Compliance with mine-specific safety protocols (i.e., proximity detectors, tracking systems, communications, Lite Tracker, etc.) is also essential for the safety of researchers and operators conducting field studies underground.

Personal Protective Equipment (PPE) Best Practices

Although considered the last line of defense in the hierarchy of controls, personal protective equipment (PPE) is a very effective control when it comes to minimizing the effects of hazards on personnel. Prior to field studies taking place underground, it is of the utmost importance to ensure that researchers have the correct PPE for the task to be completed. Researchers must also have a good understanding of the PPE that they will be utilizing during field studies.

Proper selection, knowledge of donning/doffing procedures, knowledge of PPE limitations, and careful observation of damage/defects are some of the details that researchers should take into consideration when using PPE. Researchers should proactively inspect PPE for damage/defects prior to use. If PPE is damaged or defective, discard and replace it before continuing research activities. Some of the PPE that is likely to be worn during field studies include:

- Hard hat (6 square inches of reflective tape/paint/material on each side and back)
- High-visibility/reflective clothing
- Safety glasses
- Protective footwear
- Hearing protection
- Hand protection
- Self-contained self-rescuer (SCSR)
- Respiratory protection (as long as individual is properly fit-tested for specific respirator).

Slip, Trip, and Fall Best Practices

Mitigation of slip, trip, and fall hazards starts with mindfulness of the environment in which researchers and operators are working. While working underground, there are many slip, trip, and fall hazards. Everything from uneven terrain and standing water to materials and objects can pose a trip hazard.

Researchers and operators need to identify slip, trip, and fall hazards to ensure mitigation. Eliminate the hazard by removing objects and materials that can possibly cause a slip, trip, and fall (NIOSH, 2022). Plan an appropriate travel path and watch foot placement while commuting throughout the mine (See Figure 16).

Mitigating the slip, trip, and fall hazards that standing water can cause starts with avoiding standing water and choosing an alternate path while commuting in the mine. If unavoidable, careful foot placement is essential while walking through this unknown terrain.

Multiple instances of slip, trip, and fall hazards have been encountered by NIOSH researchers in the past. One example is of a researchers who was tasked with installing a BPC into the rib. As the researcher was completing the task, the researcher stepped backwards and tripped over a cinderblock that was located behind them. Other instances involved traversing a longwall tailgate with significant standing water to retrieve data (Klemetti et al., 2019) and during observation and data collection at mines with significant floor heave (Sears et al., 2018).

Figure 16. Example of some slip, trip, and fall hazards including wet and uneven terrain, water line, rib sloughage

Heavy Equipment Best Practices

Working underground with the addition of heavy mining equipment can lead to a tight working condition for researchers and operators. Whether researchers and operators are working in close proximity to heavy equipment or just commuting past equipment, it is important to be aware of the hazards that equipment can present.

As previously mentioned, researchers can be exposed to struck-by hazards due to the prevalence of heavy equipment, traffic, and the environment itself. General awareness of your surroundings is important to avoid struck-by injuries.

Researchers working underground should consistently maintain heightened situational awareness. Maintaining good communication with the operator of the heavy equipment is imperative when working in close proximity. When in doubt, step out of the way of mobile heavy equipment and into a crosscut to ensure clearance. Researchers should never position themselves between a piece of mobile equipment and the rib unless the equipment is shut off and positive communication with the operator has been established (See Figure 17).

Material Handling Best Practices

Material handling is a major part of not only completing instrumentation installs but of day-to-day tasks and the hazards that are associated with them that can have a major impact on researchers and operators. Best practices when it comes to manual handling and mitigating the hazards associated with that activity include (California DIR, 2007):

- Knowing the dangers of improper lifting

Figure 17. Example of a mine employee making positive contact with a shuttle car operator to inform them of additional employees and researchers working in the area

- Utilizing proper lifting techniques
  - Lifting with your legs and not your back
  - Keeping a heavy load close to your body while lifting
  - Avoiding twisting and turning while lifting
  - Ensuring grip and feet are secure when lifting
- Utilizing the buddy system for lifting heavy loads
- Utilizing mechanical equipment for lifting and transporting heavy loads if available
- Taking breaks as needed to avoid overexertion and fatigue.

Drilling Best Practices

Drilling, whether to install borehole pressure cells (BPCs) or roof/rib extensometers, involves moving and rotating parts but also using drill steel that could have sharp edges. Hands-off drilling is an excellent practice for researchers and operators to utilize to stay safe during drilling operations (MSHA, 2013). Watching hand placement and identifying pinch points is essential for researchers when adding/subtracting drill steel.

Researchers should also use hand protection (gloves) when handling drill steel to avoid hand injuries such as cuts, abrasions, and lacerations. Safety glasses shall be worn while drilling and connecting or disconnecting drill steel to avoid flying debris that could cause eye injuries.

Ladder Best Prectices

Ladder safety is very important, and it all begins with selection of the correct ladder. Selecting a ladder not suited for the work that is to be completed can result in injuries to the user. Inspecting the ladder before and during use is another way researchers can mitigate hazards of working on ladders (Whitson and Kocher, 2020). If the ladder is damaged and not safe to use, inform mine personnel and request a safe operable ladder to use during installation activities.

Figure 18. Example of best practices for ladder usage including maintaining three points of contact, ensuring the ladder is level, and having additional employees securing the ladder during use

Always maintain three points of contact when using a ladder. Ensure the ladder is level and secure when in use and have assistance to secure the ladder while climbing up and down (See Figure 18).

Researchers must also be aware of their surroundings and personnel below them while working on a ladder. Researchers must ensure tools and equipment are secure and keep personnel out of the line of fire of falling tools and material. Never stand on the top step of ladder. If ladder is not of the correct height, do not use the ladder and request a suitable ladder for the task.

- Items to look for while inspecting a ladder:
  - Steps – Ensure they are not loose, cracked, bent, or missing.
  - Rails – Check that they are not cracked or bent.
  - Spreader – Check that it is not loose, bent, or broken.
  - Top – Ensure that it is not cracked, loose, or missing.
  - General – Inspect for rust, loose components, bracing, shoes, rivets.

Roof and Rib Best Practices

In underground mining, ensuring safety from roof and rib falls is vital. Researchers should make regular inspections of the work area to identify areas of potential weakness. Before work begins, loose material should be removed through effective scaling using a bar of an appropriate length. Researchers should be trained to recognize and respond to hazards quickly. It's advised to be attentive to changes in rock layers, which can introduce instability. Being alert to signs of unsupported roof, typically reflectors on the next to last row of bolts, and areas that have been dangered off is vitally important to for both researchers and operators.

In evaluating underground mines for potential roof and rib hazards key warning signs include visible cracks or separations in the roof, sagging rock layers, loosening rock blocks, and increased water seepage. Bulging areas, signs of damage to support systems, and unusual amounts of drilling dust can further denote vulnerabilities. Additionally, auditory cues such as cracking or popping noises and areas with a history of past falls should be approached with caution. Recognizing these signs, especially at transition zones where rock types change or appear weathered, is crucial for ensuring safety.

Instrumentation Installation Best Practices

Installation of the instrumentation itself results in a different set of hazards compared to actively drilling the borehole. As mentioned previously, typical hazards include roof or rib hazards, pinch points associated with insertion tools, and exposure to the various adhesives used to secure the instrument. Best practices for the installation of instruments are summarized as follows.

Researchers should inspect the work area for loose roof or rib material after drilling has been completed and prior to performing installation. This helps ensure that no additional movement has occurred in the work area during the drilling process (See Figure 19). Additionally, care should be taken when handling insertion tools to ensure hands are placed well away from the connection points. When handling grout, epoxy, or other adhesives, take care that skin contact does not occur and consider the use of additional PPE such as rubber gloves during application.

LIMITATIONS

While this paper provides a comprehensive overview of the best practices followed by NIOSH employees during their visits and work at underground and surface mines, there are several limitations that should be acknowledged.

The findings and recommendations presented in this paper are based on the experiences and practices of NIOSH Mining Program employees. This paper is not intended to be inclusive of all hazards associated with mining, only those most commonly encountered by research personnel while installing instrumentation in underground coal mines described in this paper.

The mining environment is dynamic, with conditions changing rapidly. The hazards identified in this paper may evolve, and new hazards may emerge over time. This is particularly true with advancements in both mining equipment and ground control instrumentation. Additionally, hazards can vary depending on the type of mining being conducted. The majority of installations take place during development. However, researchers are often making observations or collecting data longwall mining or pillar recovery. Full extraction mining alters the stress field, conditions can change rapidly, and may not be what was encountered on a previous visit. Therefore, continuous assessment and updating of safety practices are essential.

External factors such as regulatory changes, economic pressures, or advancements in mining technology can influence the safety practices and hazards in mines. These factors were not extensively covered in this paper. While the paper emphasizes the importance of training, it is crucial to note that the effectiveness of training can vary based on its delivery method, content, and the engagement level of participants.

While this paper offers valuable insights into the best practices followed by NIOSH employees in mining environments, it is essential for readers to approach the findings with an understanding of the mentioned limitations. Continuous evaluation and adaptation of safety practices

Figure 19. Example of rib sloughage, loose rib bolts, and the potential for brow formation of a coal rib

are crucial to address the ever-evolving challenges in the mining industry.

CONCLUSIONS

NIOSH plays a pivotal role in advancing ground control engineering through field studies at collaborating mines. While these studies are essential, they expose researchers to potential risks inherent in the mining environment. This paper has highlighted the best practices adopted by NIOSH to ensure the safety of its employees during fieldwork. These practices encompass comprehensive training, awareness of general and task-specific hazards, and the implementation of safety measures during instrumentation installation.

The insights presented here are invaluable not only for NIOSH but also for industry partners, including mine operators, consultants, and academic researchers. Collaboration between mine operators and researchers is emphasized, underscoring the collective responsibility of ensuring a safe working environment. Researchers working alongside operators and other mine personnel must be proactive when combating hazards that are and have the potential to be present.

Safety is an ever-evolving process, and striving to continually improve the safety of research activities is paramount. By adhering to these best practices, we can enhance the safety of researchers and mine employees alike, fostering a culture of safety and diligence in the field of ground control engineering.

DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of any company or product does not constitute endorsement by NIOSH.

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Can Fly Ash Pond Closure Expertise be Applied to Mine Tailings?

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ABSTRACT

In recent years, several geotechnical methods have been successfully applied to ash pond closure. These include modified dewatering techniques with wellpoints and wells to physically drain the material, soil mixing to create a soil-concrete material for improved accessways as well as improved ground structures within ponds to act as barriers or gravity dams, and geotechnical instrumentation to serve as an early warning of the potential for liquefaction. Given the parallels between fly ash and sluiced in place mine tailings, the application of fly ash remediation method to mine tailings shows significant potential, as illustrated in this paper.

SHARED ORIGINS

In 2008, a fly ash containment stack containing millions of cubic yards of coal ash from a Kingston, Tennessee coal-fired plant failed, resulting in the release of over five million cubic yards of ash into an adjacent river, disruption to electrical power, natural gas, and water lines, and covering local roadways and a rail track. Community and environmental damages were widespread. This was the biggest environmental disaster in the history of the United States.

In 2014, a drainage pipe burst at a coal ash containment pond, part of a closed coal-fired plant in Eden, North Carolina. Thirty-nine thousand tons of coal ash and 27 million gallons of wastewater was released into the Dan River before the event ended. Ash containing metals was deposited up to 70 miles (110 km) from the spill site.

The sheer magnitude and far-reaching consequences of these two events precipitated the 2015 enactment of "The Disposal of Coal Combustible Residuals (CCRs) from Electric Utilities Rule," the purpose of which was to provide a comprehensive set of requirements for the safe disposal of CCRs from coal-fired power plants. The ruling addressed the risk from unregulated coal ash disposal, such as the leaking of contaminants into the groundwater and the potential for catastrophic failure of surface impoundments.

CCRs consist primarily of fly ash but also include bottom ash and what we will refer to as "superfine" ash. A typical pond is probably 80% fly ash (Figure 1a), with approximately 80% silt-sized particles, and is absolutely non-cohesive. Although the particles are predominantly silt-sized, the material tends to behave more like a fine uniform sand than a silt. Ash does not consolidate like a natural silt or a clay. Bottom ash (probably 10% of a typical pond) is a coarse sand, free draining, with more angular particles (Figure 1b). From an earthwork perspective, it's an excellent, problem free material to work with and within. Superfine ash (Figure 1c) is the finest ash that finds its way to the far end of the pond. It is so fine that it will hold onto water and will not respond to drainage methods (such as dewatering). Superfine ash constitutes probably 10% of the typical pond.

Depending upon the condition of the impoundment or if ash is stored in a sensitive area, pond closure may require the complete excavation and removal of the CCRs, partial excavation and consolidation of ash over a smaller footprint, or just regrading and capping. The specific requirements for closure are in part dictated by the CCR Rule and in part decided by each state.

The experience gained in CCRs since the ruling was first enacted is directly applicable to tailings storage facilities of similar characteristics. The similarity starts with their origins, considering only the mine tailings that, like CCRs, are sluiced in place. They have similar resulting traits. If the sluice pipe never moves over the life of a pond, coarser particles would, predictably, settle first and the finer particles would travel further in the pond. Many ponds are intended to be filled evenly, so the pipe is moved around the periphery of the pond to achieve this. This creates a