Session No. 753

Safety Improvements for Roof Bolter Operators

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Introduction

There has been significant progress in reducing the risk of serious injury or death for those who work in underground coal mines (Figure 1). In 2003, there were 15 fatalities, which was the lowest recorded number since coal mining began in the United States. Even so, there is still room for improvement and a need for systematic research. The risk of serious injury in mines will always exist as workers are still exposed to hazards due to the inherent nature and challenges of underground coal mining.

From 1998 to 2003, 17% of all underground coal mining injuries happened during roof bolting activities, which is the most high-risk job of all face worker activities. Excluding fatalities, 66% of these injuries involved days lost with an average of 38 actual days lost per injury. In response to these losses, there is a focused attention on reducing the risk of injury to roof bolter operators.

This paper describes, in three different sections, the efforts of safety researchers and machine manufacturers to reduce the number of injuries to roof bolter operators affected by three factors: worker decisions and actions, the condition of the underground working environment, and machine technology. The first section gives an explanation of effective innovations in roof bolter training that integrate safety, production, and maintenance. The second section discusses research findings on how to reduce rock fall injuries, which are the number one cause of roof bolter operator injuries. Finally, the third section presents advancements in roof bolting technology that increase the safety of roof bolter operators.

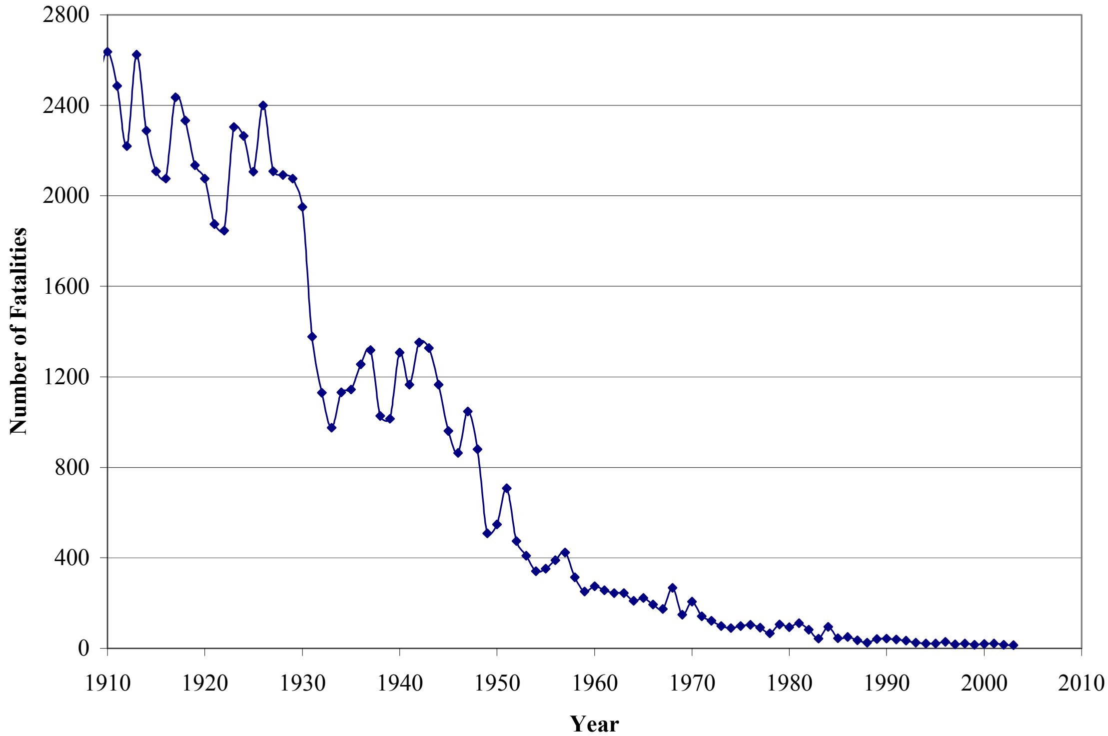

Figure 1. Throughout the history of U.S. coal mining, the number of underground fatalities has been dramatically reduced.

Innovations in Roof Bolter Training: Using Job Training Analysis to Structure On-the-Job Training to Integrate Safety and Production Skills

This section summarizes a process for quickly developing information that is useful for skills training. The process described is called Job Training Analysis (JTA). The JTA procedure is grounded within the military research on Instructional Systems Design (ISD). The JTA process has been refined into its current form by the National Institute for Occupational Safety and Health (NIOSH) and the Mine Safety and Health Administration (MSHA[a]), who worked in early collaboration with the Navy and mining companies and manufacturers of mining equipment. The JTA process has demonstrated potential for adding significant value to mining organizations, seeking to connect safety, production, and maintenance.

The roof bolting JTA described herein is one example of the JTA process. It is based on NIOSH collaborative work with personnel from Twentymile Coal Company, J.H. Fletcher and Co, and MSHA. It provides structure for skills training as it is built on lessons learned from experienced

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[a]Appreciation is expressed for the technical collaboration of James Baugher and Donald Conrad (MSHA) for building the JTA process. Appreciation is also expressed to Twentymile Coal Company and J.H. Fletcher and Co. for technical collaborations in applying the JTA process to roof bolting, thus helping improve the JTA process.

workers and connects their experience with technical expertise from original equipment manufacturers (OEMs), researchers, and safety professionals. The JTA process involves three main activities: (1) planning, (2) a 1-3 day workshop, and (3) follow up. A JTA for a particular job (e.g., roof bolting) is developed during the 1-3 day workshop.

On-the-Job Training (OJT)

OJT is a very natural and common method used by all industries to develop job skills for workers who are new to a task. On-the-job training is often considered informal training, and across industries, organizations invest significantly more money in informal training than they do in formal training. Some researchers (Carnevale and Gainer, 1989) estimate the ratio to be from 3:1 to 6:1. That is, for every dollar invested in the classroom, three to six dollars are invested in informal training in the workplace. Experienced workers and supervisors normally conduct this training.

In mining, job *safety* training is required to follow federal task training guidelines under 30 Code of Federal Regulations (30 CFR). These mandates require mining companies to provide instruction to workers on hazards related to task performance. How mining firms comply with these regulations is quite varied. The training normally consists of developing and using "job safety documentation" to support compliance with the task training requirements under 30 CFR, Part 48 or 46.

How much structure is necessary for OJT to effectively reduce risk does not have a clear answer. The level of structure is often based on a decision maker's perception of risk and the risk of self-instruction vs. casual on-the-job learning vs. a more formal system where experienced workers transfer their skills to someone new to the job. In this last case, it would make sense for the OJT coach to be proficient in effective methods for teaching and evaluating job skills. It makes equally good sense for these experienced workers to have an outline (a useful plan) to aid in their teaching to make sure that key points are not skipped. A practical JTA is the start of a useful training strategy for teaching and evaluating job skills.

Figure 2 offers a conceptual model for comparisons between informal and structured OJT. Structured OJT, with follow-up, can serve to accelerate learning and reduce performance variability. Performance variability is natural within any job classification. When the consequences are too high, opportunities exist to reduce variability via combinations of job design, training, or supervision. Variability in performance can affect production, safety, and equipment availability (Wiehagen, et al., 1996). In a practical sense, training should be connected to performance. Training can reduce performance variability within a work system. One should also consider how the system can be designed to foster desirable, effective performance.

Job Training Analysis

There are different ways of analyzing a job and most of it depends on how the information will be used. In a generic sense, job analysis is critical to production activities, including job training. It is a tool for planning, solving problems, and examining options for good ways to do a job.

Performing a job or task analysis, to help structure training, is not new. It is often considered part of a training needs assessment and is an essential first step in preparing a functional plan for training (i.e., developing skills).

The concept of a JTA can be thought of as road map for teaching, evaluating, and learning new skills. Road maps save time and energy when the route has not been traveled recently or when the destination is not exactly known. The destination of training – acceptable performance – is often difficult to quantify. However, JTA can help define envelopes of acceptable performance to help the on-the-job trainer organize the job into teachable components and then use the JTA as a guideline for teaching and a checklist for evaluating (offering feedback).

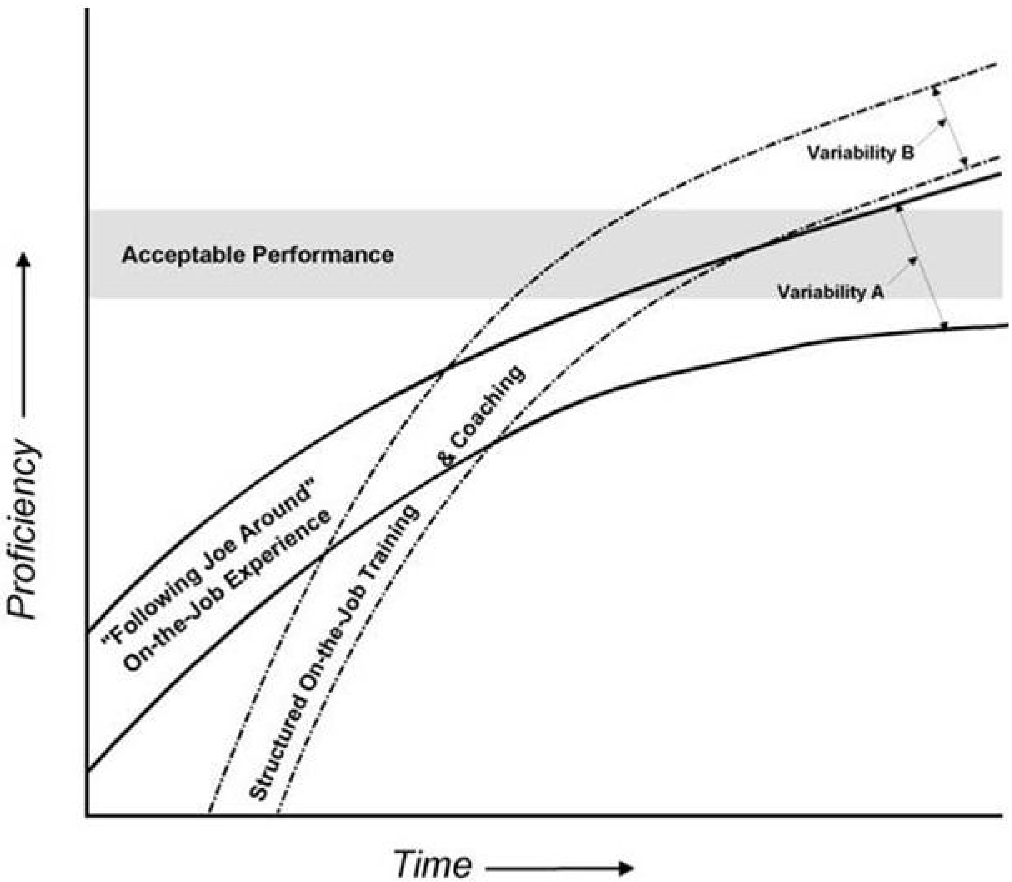

Figure 2. There is difference between informal training and structured on-the-job training (from Wiehagen et al., 2002).

OJT involves a transfer of skills from the experienced performer to individuals with significantly less experience in the job. In one respect, the JTA is a checklist to help the experienced worker cover all aspects of the job and the JTA should help the trainee understand job requirements.

For roof bolting, job requirements not only include operating the equipment in a productive manner, but also aspects of equipment availability and a worker's risk of serious injury. Taken together, effective training of roof bolter operators considers aspects of safety, production, and equipment availability *within* the context of the working environment (conditions).

In this context, JTA is much different than Job Safety Analysis (JSA). JSA is limited to safety and health aspects of the work. JTA is far more holistic in concept and approach; it does not treat safety and health as an "add-on" consideration to a production process.

The JTA process has shown potential providing continuity among experienced workers concerning proper methods of doing a job. Experienced workers often indicate that there is more than one “right” way to do a job. The JTA workshop and follow-up activities offer the opportunity for structured discussions of different ways of doing the job *and* the relative risk. Risk, in this context is generic. It can affect production output, injury risk, and unexpected maintenance. Therefore, the JTA process can be used as a way of strengthening or reinforcing the skills of experienced workers and affords them the opportunity to problem solve the “work process”. JTA assumes that safety is a skill and as a skill it should be integrated with production, maintenance, and crew communication and coordination.

There is a three-level hierarchy for analyzing a job: a job consists of (a) *duties*; (b) *tasks* that need to be performed to satisfy the duty; and (c) *steps* that are performed to complete the task[b]. Skills are involved in performing steps that complete a work task. The completion of several work tasks can satisfy a job duty. Developing a simple but practical hierarchy is a key concept in a JTA. It is the basis on which everything else is grounded and built.

Roof Bolting JTA

Table 1 is an example of one duty of a JTA for a standard, twin-boom bolting machine. This JTA was developed by a mine site JTA team. The JTA team involved a facilitator, recorder, and a number of Subject Matter Experts (SME). The SME were experienced miners, i.e., roof bolter operators, mechanics who service/repair the bolters, technical representatives of the equipment manufacturer, and mine site supervisory personnel. NIOSH and MSHA facilitated the meetings.

During the meetings, the recorder documented the information discussed by the SME then inputted that information into a worksheet. The worksheet was projected for the SME group to view and make comment. As a result, the roof bolting JTA team examined this job and broke it down into 6 primary duties:

1. Walk around Inspection,
2. Tramming,
3. Drilling roof and rib,
4. Installing bolts,
5. End-of-shift activities, and
6. Responding to unusual events.

Each of those duties had a set of “tasks” that were connected to the duty with steps connected to each task. This resulted in a three-level outline (hierarchy). Table 1 summarizes the JTA format and content for Duty 2 – Tramming a roof bolter.

[b] In reality, there is *no* standard, widely accepted terminology for describing and analyzing jobs (see McCormick, 1982). Nonetheless, the important point *is the need for a logical and systematic hierarchy* to help break a job into teachable and manageable components. This helps the OJT trainer coach and the trainee learn.

Table 1. Duty 2: Tramming the roof bolter.

Tasks/Steps	Importance---Consider Safety, Production, and Maintenance	Importance: 1=important 2=very important 3=critical
Walk roadway before tramming	Two people are needed for moves: one to walk and one to tram the bolter. This helps reduce risk in tramming (e.g., avoiding cables). Communication is essential (e.g., lamp signals). This is also a good time to check and make sure no other equipment is parked in blind spots, e.g., on other side of curtains.	2-3 Depends on conditions
Preparing to tram Collapse ATRS Bring booms in Lower canopy Position drop mast Position drill head	Skipping or not performing these job steps can affect safety and production, and could result in avoidable equipment damage.	3
Communicate intention to tram and cable reel coming on Use cap lamp or verbal communications	Include telling trainee importance of position in relation to cable and bolter. Note that splices can get hung up in the reel that can potentially affect maintenance and fire risk.	3
Positioning	Watch for roof contact	1
Tramming the machine Note bottom conditions and clearance Location of helper – communicate Watch for other workers - if another miner needs to pass by the bolter, stop tramming. Cable management	Take your time. If not sure of conditions, get out and check. Before ANYONE gets in between the bolter and the rib – they should NOTIFY the bolter operator and tramming should be stopped BEFORE they get in between the machine and the rib Prohibit standing on booms when tramming Watch for proper cable reel function when picking up and paying out. Is there enough cable? Go over methods for handling and hanging cable.	2

<u>Traditional roof bolter operator training vs. a method based on the JTA Process</u>

Based on work at Twentymile Coal Co. and later with an underground salt mine, the JTA process was refined to illustrate three distinct activities. The process involved (1) planning; (2) a 1-3 day workshop; and (3) follow-up. While this paper does not detail the JTA process, each of these activities took place in developing the roof bolter JTA. Table 2 illustrates a comparison of traditional vs. an improved method for conducting on-the-job (skills) training using JTA.

Table 2 - Existing roof bolter operator training vs. training using the JTA process.

Traditional roof bolter operator training	Improved method for roof bolter operator training based on the JTA process
Characteristics	**Characteristics**
Focus on compliance with task training requirements under 30 CFR, Parts 48 and 46. Often makes use of Job Safety Analyses to satisfy above requirements.	Focus on roof bolting skills and practices which integrate safety, production, and maintenance. JTA treats safety as a skill.
Existing skills training for new roof bolter operators is left more to chance (more variable). The quality of training often depends on who is conducting the training and whether or not those individuals are prepared to teach (e.g. having access to a training outline and are skilled in good methods for teaching and evaluating).	JTA is planned, leaving less to chance. JTA can be used to reduce the variability in teaching and evaluating skills. It can increase the odds of providing quality training. JTA makes direct use of the knowledge and skills residing at a specific mine site. It couples expertise with outside experts (e.g. OEM representatives). The JTA process is fluid and only requires small, layered time investments.
Makes use of generic training materials developed by the public and private sectors. Existing materials may be difficult to update and customize to conditions at a specific site.	JTA is make and model specific, and fits the operating conditions at the mine site. It is based on developing a job outline with specific duties, tasks, and steps. The JTA is fluid and can be easily updated as new information is learned or when new equipment / machines are purchased.
Is not likely based on a job analysis which connects training with performance within the context of the working environment and the specific make and model roof bolter.	JTA is based on a practical job analysis which considers safety, production, crew coordination, and maintenance (equipment availability). The JTA process seeks to connect training with job performance within the mining system.
Experienced workers are not likely to have been trained in good methods for coaching and teaching in an on-the-job environment.	Mine sites have the option of offering training in teaching their experienced workers good practices in coaching in an on-the-job environment. This is a natural follow-up to the JTA process. It requires small layered time investments.

Discussion

Traditional ways of training and evaluating performance are often based on time studies (a production measure) and adherence to safe work procedures (a safety measure). Often, these measures are *examined and treated in isolation*. For example, if shortcuts are taken in the drilling and bolting cycle (to reduce cycle times), it does not appear in the time study data. Thus, "saving" a few seconds in a production process could end up "costing" lost time down the road. Time "lost" could be evidenced via an injury to an employee, unnecessary production downtime due to improper installation of bolts, or machine downtime (reduced machine availability). As this example demonstrates, there is a difference between efficiency and effectiveness. That difference is *not intuitive* without discussion among those who perform or have a stake in the task.

JTA seeks to integrate safety, production, and maintenance and takes a holistic view of the job within the mining system and how job procedures and equipment might be designed to encourage effective performance. JTA should consider the working conditions unique to the mine site. Worker skills are a key element in that process. The structure of the roof bolting JTA is fluid and becomes a practical guide (or lesson plan) for conducting on-the-job training. It is also useful for follow-up observations and discussions on better ways to approach a task or perform the work. Conceptually, JTA is a method of learning from an experienced workforce and using their combined and shared knowledge to develop a reasonable road map for teaching those who are new to a job. It also serves to unify experienced task performers with respect to how a job might be done, or done better.

The structure and content of a JTA is designed to change as new information is learned and workers (e.g., bolter operators, supervisors, mechanics, and safety / training personnel) discuss how the process can be improved to help reduce risk. The training of new bolter operators can then be built on lessons learned from an experienced workforce.

Use of Roof Screening to Create a Safer Working Environment

Coal miners, especially roof bolter operators, work in a hazardous environment where they are frequently exposed to poor roof conditions that put them at risk of a rock fall injury. Over the past eight years, there were over 450 reported injuries each year resulting from rock falls; 99% of those reported were not caused by a major roof collapse, but from falls of smaller rocks from the mine roof where the average rock size was 30 x 18 x 4 inches (Molinda et al., 2002). This type of rock fall has been termed "skin fall" by the National Institute for Occupational Safety and Health (NIOSH). The immediate roof from where these skin falls occur is called the "roof skin" and does not extend more than one or two feet upwards into the roof.

Forty-four percent of these skin fall injuries happen to roof bolter operators. These operators have the responsibility of installing roof bolts to a freshly cut face and can be often exposed to poor roof conditions. Their bolting activities, especially the drilling process, disturb the mine roof and can cause pieces of rock to fall. Most rocks fall from an unprotected space on the mine roof that is located between the Automated Temporary Roof Support (ATRS) and the bolter canopy. Therefore, it is important to protect these workers as quickly and as much as possible, especially before and during the drilling and bolt installation process.

One way to prevent these skin falls is to control the coal mine roof skin by using skin supports. These supports are designed to increase the surface area coverage of the mine roof. Basically, the more the roof is covered by supports, the less chance of a rock falling and injuring a miner. Coal mines make use of various skin supports such as steel straps, header boards, large bearing plates, and steel screen or mesh. Each control has its own application and effectiveness depending on the geology of the roof, moisture sensitivity of the rock, and the life of the entry in which it was installed.

NIOSH has been investigating the use of roof screen because it can provide a large amount of roof skin coverage and has been proven to reduce rock fall injuries (Robertson et al., 2003). Currently, only a handful of coal mines are routinely roof screening in the Eastern U.S., compared to a greater acceptance of screening in the Western and Midwestern U.S. Therefore, NIOSH continues to work with the mining industry about the safety, production, and cost issues and benefits of roof screening along with providing some best practices to follow for screen installation. These matters, along with a J.H. Fletcher and Co. machine innovation that addresses material handling concerns, will be discussed in this section.

Skin Control

A number of mines with poor roof conditions were visited to document their experience and methods used to control poor roof skin conditions. Some mines using partial skin supports, such as large bearing plates (e.g., pizza pans) or roof straps, had difficulty keeping rocks from falling in between the supports. Mines that used roof screen were better able to control the roof skin.

The main advantage of using the roof screen over other supports is the large amount of roof coverage attainable – close to 100% can be achieved. A recent NIOSH study compared the roof coverage of roof mats versus roof screen. As shown in Figure 3, a mine with 18-ft entries that installed 16 ft x 10 in steel straps every 4 ft of advance achieved 18% roof coverage. If this same mine had installed 16 x 5 ft sheets of screen instead of the roof straps, it could have achieved 89% roof coverage. Hence, the use of roof screen provided five times more roof coverage than the steel straps. Besides this large amount of roof coverage, roof screen can also support a substantial amount of roof rock as shown in Figure 4. The amount depends upon the gage of the steel wire. Currently, most mines use a screen with 8-gage steel wires that can hold up to two feet of rock (Robertson et al., 2003).

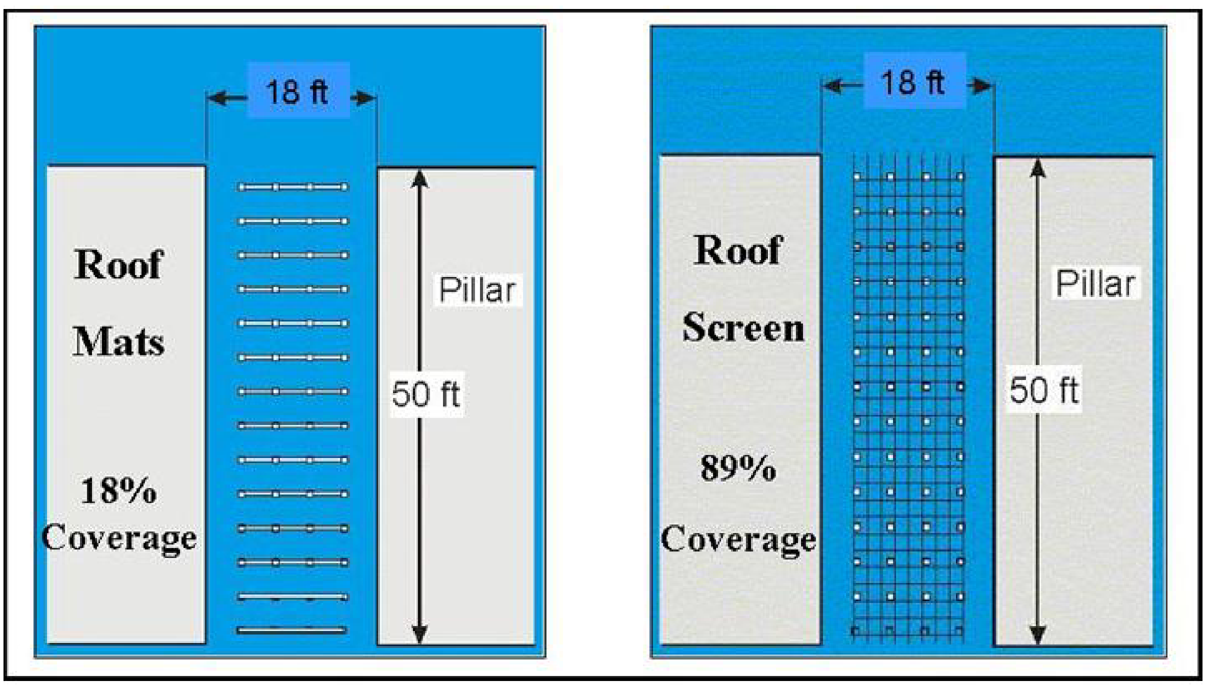

Figure 3. Mine roof coverage increases when using roof screen instead of roof mats.

Figure 4. Roof screen can hold up large pieces of broken roof.

Roof screen can be designed with reinforcing wires, with extra rows of wire along the width and length of the screen. For example, a typical piece of screen is designed with a 4 x 4 in wire grid pattern. With reinforced screen, extra rows of wire are fabricated into the screen resulting in a 2 x 4 in grid pattern. This reinforcement serves two purposes: it prevents wires from breaking around roof bolt plates as the roof rock loads onto the screen, and it provides a visual marker to operators for positioning the roof bolts. The latter also helps operators to achieve the desired bolt spacing (Robertson et al., 2003).

Safety Issues

An analysis of injury data from two eastern U.S. coal mines showed that when roof screen was used, the number of rock fall injuries reduced dramatically. The first, located in northern Maryland, began roof screening routinely and on-cycle in 1997 because of very poor roof skin conditions and a high occurrence of small rock falls. Before the mine started installing roof screen, there was an average of fourteen rock fall injuries per year, but after 1997, injuries dropped to an average of two per year. At another mine in the Illinois basin, similar geologic circumstances were encountered that also required roof screening. Rock fall injuries subsequently dropped from an average of eight to less than one per year (Robertson et al., 2003). These injury reductions were attributed to the overhead protection provided to operators throughout the entire bolt installation process. The roof screen covered the unprotected space on the mine roof that was mentioned earlier in this section.

One disadvantage of roof screening is that it may increase the risk of material handling injuries. Screen handling can be a challenge for the operators because it often requires overhead lifts and awkward positioning, i.e., lifting, pulling, and twisting movements. In addition, the weight of the screen can be quite heavy depending on the size of the screen, amount of reinforcing wires, and the gage of the steel. It was observed, during an investigation, that a mine in the western U.S. installed 8-gage steel sheets of screen that were 20 feet long and 5.5 feet wide weighing over 50 pounds.

There is substantial evidence that work-related physical factors can lead to musculoskeletal injuries such as sprains and strains. This is especially true when there are high levels of exposure to a combination of physical factors such as a repetitive lifting of heavy objects in extreme or awkward postures (Bernard, 1997). Ergonomic analyses of roof screen installation procedures can be used to identify high-risk activities and to develop work methods that reduce exposures to physical factors that can lead to musculoskeletal injuries.

A good practice that can reduce the likelihood of cut and puncture injuries is to purchase roof screen with flush-cut edges that have no wires protruding from the edges of the screen. Wires that are not cut flush along the edge can be quite sharp. Also, these wires can get tangled with other sheets of screen or bolting supplies making it difficult to separate them from each other. This can also contribute to sprain and strain types of injuries (Robertson et al., 2003).

<u>Material Cost</u>

The material cost of the roof screen is somewhat higher than most other skin supports, but this cost may be outweighed by the even larger increase in roof coverage. NIOSH recently compared the material cost of roof mats and roof screen. Roof mats were chosen for comparison because they are a commonly used skin support to combat poor roof conditions. It was found that the material cost of a 16 x 5 ft steel screen (8-gage steel) was close to 30 percent higher per linear foot of entry than a 16 ft x 10 in roof mat (14-gage steel). However, as noted earlier, in an 18-ft wide entry, the roof coverage using the roof mats was 18%, compared to a roof covering of 89% using the roof screens. Therefore, even though the roof screen costs close to 30% more than the roof mats, the increase in roof coverage using the roof screen was 5 times greater (Robertson et al., 2003). A number of mine managers who use roof screen report that they consider this extra cost negligible compared to the increased safety to the miners.

<u>Bolting Advance Rates</u>

Mine operators are often reluctant to install roof screen because they are aware that additional time and extra labor are required, but they commonly do not know the kinds of delays to expect. Therefore, NIOSH performed five in-mine production studies to document the impact of roof screening on bolting advance rates and the required labor. Roof screen load times, installation times, and total handling times were noted as well as the number of roof bolter operators used to install the screen. In these studies, there were either two or three operators.

Three types of twin-boom bolting machines were observed: a standard (non walk-thru) bolter, a walk-thru bolter, and a walk-thru bolter retrofitted with a material handling system (MHS). With the standard bolter, operators installed bolts from the sides of the machine; on a walk-thru bolter, operators installed bolts from the center of the machine. The MHS, shown if Figure 5, has many machine innovations that reduce material handling and address ergonomic concerns. Most notable is a separate and mechanized screen tray that moves in eight different directions including tilt. The system eliminates the hand-loading of screen by means of a winch rope and remote control operations. This tray can be raised so that operators can handle and install screen from an ergonomically friendly elevation (around shoulder height). It can also be lowered and moved toward the center of the machine to avoid material damage while tramming around corners. The results of the study were as follows (Robertson et al., 2003):

1. Roof screening added between 5 and 25 percent to normal bolt installation times.
2. The addition of the third operator reduced roof screen load and installation times close to 40 percent.
3. Installation times reduced by half as operators gained more experience installing roof screen.

4. Roof screen installations were 30 percent quicker using a walk-thru compared to the standard bolter.
5. Operator maneuverability while installing roof screen was easier using a walk-thru compared to the standard bolter.
6. The walk-thru bolter retrofitted with the MHS was better designed to store roof screen compared to the regular walk-thru bolter.
7. The total screen handling times, especially the load times, were 40 percent quicker using the walk-thru retrofitted with the MHS compared to the regular walk-thru bolter.

Figure 5. The J.H. Fletcher walk-thru bolting machine, with a material handling system (MHS), addresses material handling issues.

Best Practices for Roof Screening

To assist mines with roof screening installation, a list of best practices was developed during the course of this investigation. These suggestions or practices were obtained through underground observations, meetings with mine management, and working with equipment manufacturers (Robertson et al., 2003).

1. Roof screens with flush-cut edges will help avoid material handling difficulties and lessen the risk of cut and puncture types of injury.
2. Roof screens with reinforcing wires can help sustain the integrity of the screen under load and aid in proper bolt spacing.

3. Anti-fatigue mats on top of the bolting machine walkway will provide a more comfortable surface for operators to stand, resulting in less foot and shin fatigue.
4. An ergonomic analysis of installation procedures will determine the safest and most efficient installation procedures (e.g., how many persons, best positioning, safest method).
5. Design or engineering innovations of bolting machines will aid with installation speed and material handling. Some examples are the following:
   - Rounded edges on bolter canopy tops that reduce material snagging and decrease the physical effort required to move the screen into place.
   - Clamps or a wire assembly built onto ATRS designed to hold the screen in place while being raised against the roof.
   - The use of a separate screen tray for easier handling of roof screen and bolting supplies.
   - Remote control operations, winch ropes, material pods, or any other machine innovation that will eliminate or reduce material handling difficulties.

Roof Bolting Machine Innovations

Today, mining equipment manufacturers strive to produce technology that not only increases mining output, but creates a much safer situation for the equipment operator. This section of the paper gives an example of one mining equipment manufacturer that improved the safety conditions for roof bolter operators. J.H. Fletcher & Co. has developed machine innovations to lessen the risk of injury from safety concerns such as falling rocks from the roof and rib along with equipment pinch point areas. These machine innovations to the mining equipment have evolved slowly, but effectively, through successful communications between mine operators and owners, equipment manufactures, and mine safety professionals.

There have been a number of machine technology improvements that reduce the risk of injury from rock falls. One of which is a deflector pad that can be adapted to the ATRS system. When the ATRS is raised, this pad is also raised against the mine roof and acts as an additional shield providing protection from rocks falling inby the ATRS of the bolting machine. This design, shown in Figure 6, reduces the risk of rocks falling into the operator(s) work area.

Figure 6. The ATRS deflector pad reduces the chance of a rock falling inby the ATRS and into the operator area.

Another option available to mine operators that will reduce rock fall injury risk is adding larger bolter canopies or increasing the size of existing canopies without actually increasing the fixed width of the boom and machine. Recent developments in pull-out canopies, shown in Figure 7, allow the operator to manually extend the width of the canopy when needed. To more easily pull out the canopy extension, hand-holds placed underneath the extension, have been added. These hand-holds serve multiple purposes. First, they make it easier for the bolting machine operator to move the canopy extension. Second, hanging onto the hand-holds during operation may serve as a way to reduce operator fatigue. When operators are influenced by excessive fatigue, the result may be complacency with respect to job safety. And finally, these hand-holds serve as a safe location for bolting machine operators to place a hand instead of places where there is a potential for a hand to be crushed by falling objects or located in a pinch point area.

Figure 7. ATRS pull-out canopy extension pads provide additional protection to roof bolter operators.

New models of equipment have also evolved, such as the walk-thru chassis roof drill that protects the operator from roof and rib hazards. Traditionally, roof bolting machine operators installed roof bolts while positioned outside of the bolting machine on each side. This location did not provide optimal protection from rocks and coal falling from the rib and/or edges of the mine roof. With the walk-thru model, operators install bolts while positioned in the center of the machine, thus providing greater protection against falling objects. In addition, there is a walkway up the center of the machine and offset booms that improve operator egress and ingress from the work area.

Manufacturers have also addressed safety issues associated with fast-changing or unexpected mining conditions. In some instances, the mining height may change and exceed the height in which the machine was designed to operate. One problem this creates with regards to installing the roof bolt resin is that the operator cannot reach the roof while standing on the mine floor. Thus, some operators have been reported to stand on the drill head or mast, raising themselves toward the roof in order to reach the roof to install the resin. This is not a safe practice and it is not an intended or proper use of the roof bolting machine.

Standing on the drill head or mast creates at least three serious safety hazards: 1. Falling from the drill head onto the floor; 2. Getting caught in a pinch point area; 3. Being unnecessarily exposed to the mine roof and ribs. Any of these could lead to serious injury or death. In addressing these problems, J. H. Fletcher & Co. has developed and evaluated four resin inserter concepts (Figure 8). These tools allow the operator to stand on the mine floor and within the protection of the drill canopy while installing the roof bolt resin. A similar problem exists when installing angle and rib bolts. In these cases, the problem centers on the difficulty in reaching the roof or rib while remaining in the operator's platform. Resin inserters were also developed (Figure 9) to address these situations.

Figure 8. J.H. Fletcher and Co. has been investigating and evaluating different resin inserters, including a manual resin inserter.

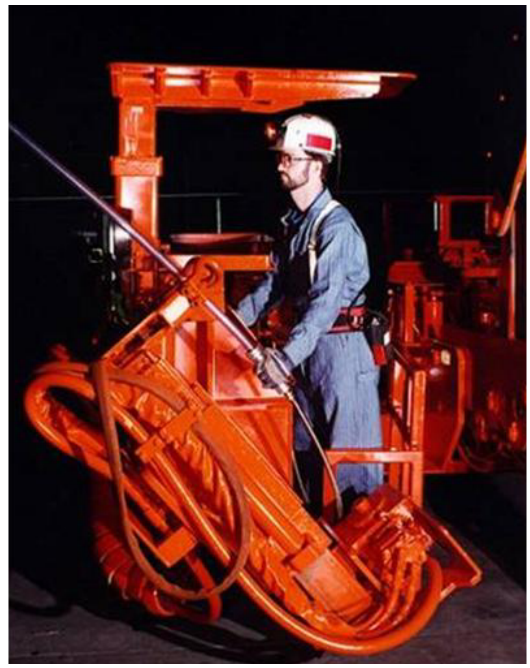

Figure 9. A hydraulic resin inserter better enables the roof bolter operator to reach the rib while remaining in the platform.

To adapt to advancing and accepted technologies used in today's society, innovations in valve handle design have taken place by combining multiple functions into one control lever (joystick). During the design process, a detailed hazard analysis considering many factors, including operator opinions, was performed. In addition, roof bolting machine operator training and education was an important aspect of the manufacturer's introduction of this new design. The newer, younger roof bolting machine operator quickly adapted to the use of a joystick due to previous exposure to this technology (through the "game boy era"). However, to the older, more experienced roof bolting machine operator, a new design such as the joystick was not quickly accepted and required additional training of its operation and demonstration of its abilities and safety features. The single-lever joystick, shown in Figure 10, is now regarded as the preferred method of operating a roof bolting machine.

Even with this joystick design, operators are still providing valuable input that has led to newer handle designs, such as the hydraulic/electric joystick, currently being developed by J.H. Fletcher & Co. This joystick will combine the feel of the hydraulic lever that most roof bolting machine operators say they need, with the permissible electrical safety interlock that MSHA, manufacturers, and operators desire.

Figure 10. This new, single-lever joystick handle function is regarded as the preferred method for operating a roof bolter.

Even with improved technology and product evolution, J.H. Fletcher and Co. continually strives to educate operators concerning proper use of its products. Equipment and mine operators must know how to handle the unexpected and to take a personal responsibility for safety. For the safety features on the machine to be effective, they must be properly maintained following the guidelines set forth by the equipment manufacturer. The machine is only a part of that equation and can never be a substitute for individual operator diligence to the ever-changing environment.

Summary

There have been great gains over the years in the field of coal mining safety. Even so, safety professionals and machine manufacturers are continually striving to reduce injury risks. Much of this attention has been given to roof bolter operators due to their injury rates. Practical training methods using an experienced work force that combine safety, production, and maintenance offer a holistic view to roof bolter training.

The use of roof screening has been found to be an effective method for controlling poor roof skin conditions. Data analyses have shown that roof screening can significantly reduce rock fall injuries, but there is a concern about an increased risk of material handling injuries. Ergonomic analyses can be a useful tool for reducing these injury risks. Researchers have answered many questions about safety, production, and material costs and have provided some best practices to help with roof screening.

Finally, the roof bolter operator must be aware of changes to roof, rib, and floor conditions continuously and take advantage of the safety features available on the roof bolting machine to avoid injury. J.H. Fletcher and Co. has added advancements and innovations to roof bolting machines that have increased efficiency and created safer working conditions for roof bolter operators. They continually consider, when designing equipment, human factors elements and the harsh and sometimes brutal conditions of underground mining environment.

References

Bernard, B., ed. (1997). Musculoskeletal Disorders and Workplace Factors. Cincinnati, OH: DHHS (NIOSH) Publication 97-141.

Carnevale, A., and Gainer, L. (1989). The Learning Enterprise. ASTD and the Dept. of Labor / Employment and Training Administration, Alexandria, VA.

McCormick, E.J. (1982). Job And Task Analysis. In: Handbook of Industrial Engineering, Editor: G. Salvendy. John Wiley and Sons, pp 2.4.1-2.4.21.

Molinda, G.M., Dolinar, D.R. and Robertson, S.B. (2002). Reducing Injuries from the Fall of Roof in U.S. Coal Mines. SME Annual Meeting, Phoenix, AZ, February 25-27, 7 pp.

Robertson, S.B., Molinda, G.M., Dolinar, D.R., Pappas, D.M., and Hinshaw, G.E. (2003). Best Practices and Bolting Machine Innovation for Roof Bolting. Pre-print 03-158, SME Annual Meeting, Cincinnati, OH, February 24-26, 8 pp.

Wiehagen, W.J., Lineberry, G.T., and Rethi, L.L. (1996). The Work Crew Performance Model: A Method For Defining And Building Upon The Expertise Within An Experienced Work Force. Society of Mining, Metallurgy and Exploration, Inc., Transactions Vol. 298.

Wiehagen, W., Conrad, D., Friend, T., Rethi, L. (2002). Considerations in Training On-the-Job Trainers. In: Strategies for Improving Miners' Training. Editor: Peters, R.H. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health Publication No. 2002-156, *Information Circular* 9463, pp. 27-34.