REDUCING MATERIALS HANDLING INJURIES IN UNDERGROUND MINES

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ABSTRACT

Back injuries from handling materials in underground mines continue to be a major safety problem. In spite of the ingenuity of many people and the development of numerous mechanized aids, the number of materials-handling injuries remains second only to the number of roof fall injuries in underground coal mines. Relocation and repositioning of electrical cable, conveyor belt parts, and roof bolt supplies in particular are the sources of significant numbers of back injuries.

To help reduce such injuries, researchers at the Spokane Research Laboratory of the National Institute for Occupational Safety and Health are examining Mine Safety and Health Administration accident data to determine correlations between materials-handling tasks and the number of back injuries. Also being investigated are new technologies used in underground mines in the United States. Equipment is being developed or modified that would replace the necessity of doing lifting tasks manually. A Coleman manipulator was tested, and modifications were made to make it more suitable for underground mine use. To reduce or eliminate the need to manually clean off materials that commonly plug grizzly openings, a track-guided pincher arm device was developed. Oversized rock can be broken with the pincher arms in the up position, and the arms can be lowered to grab and remove debris. The arm can also be used in a sweeping action to remove cohesive fines that may bridge grizzly openings.

INTRODUCTION

Materials-handling problems in underground mines and injuries associated with underground materials handling have been well documented (Peay 1983; Gallagher et al. 1990). Although lost-workday injury rates related to materials handling in mines decreased between 1988 and 1997 (Mine Safety and Health Administration [MSHA] 1999; National Institute for Occupational Safety and Health [NIOSH] 2000), the number of lost workdays was still significant, and the cost to the mining industry each year was tremendous. During that time, there were 58,661 lost-workday cases resulting in an average of 34 days lost (including restricted days) per case. Over 21,000 of the lost-workday cases were in underground mines.

A review of 1999 data from underground mines in the United States indicated that materials handling is still one of the leading causes of reportable injuries. Accident report narratives show numerous and varied materials-handling activities that result in injuries. This finding is not much different from what was reported in 1989 in an extensive investigation of back injuries in underground coal mines (Stoble et al. 1989). Stoble et al. found “considerable diversity in the situations which produce back injuries. Of the 156 scenarios which produced back injuries, 130 occurred only once, 17 occurred twice, 4 occurred three times, 1 occurred six times, 2 occurred eight times, and 2 occurred 10 or more times.”

The number of such injuries is directly

related to the number of manual tasks. Hundreds of these tasks are performed in underground mines each day. They involve pulling, hanging, pushing, and lifting objects of different weights, shapes, and sizes. Many times, handling tasks are done in confined areas, on uneven ground, in slippery conditions, and without assistance. Thus, given the nature of the underground environment (poor lighting, poor footing, confined spaces, etc.), the amount of supplies and equipment needed daily, and the diversity of tasks, injuries resulting from materials handling will probably never be eliminated.

Large underground mines have fewer materials-handling accidents than smaller mines, because in large mines, there is room for mechanized equipment. However, most underground mines have limited space. Numerous materials-handling tasks can only be done manually, and lifting and re-lifting supplies several times before they are used is not uncommon.

In the 1980's, several inexpensive, easy-to-construct materials-handling devices were developed and tested for underground mines (Conway and Unger 1989). These devices included a scoop-mounted lift boom for transporting and maneuvering heavy machine components, a swing arm boom to lift components on and off transport vehicles, a floor-type maintenance jack for lifting heavy machine parts, a mine mud car to aid in moving supplies from storage areas to the point of use, a container workstation vehicle to transport tools and supplies on a daily basis, and a timber car for installing crossbeams for roof support. All of these devices were designed to reduce materials-handling injuries. Research to reduce injuries from specific materials-handling tasks, such as hanging cables, building stoppings, and handling bags of rock dust, was also conducted (Unger and Bobick 1986).

The goal of the current research project is to reduce materials-handling injuries by reducing manual materials-handling tasks and to propose design considerations for underground materials handling safety training and technological innovations. This paper describes the development and testing of specialized equipment to help achieve this goal.

DESCRIPTION OF PROJECT

The research approach is to investigate common underground materials-handling tasks or activities that frequently result in injuries. Only underground mines are included in this research, and the emphasis is on manual tasks. Specific targets were determined by reviewing MSHA accident report narratives, personal discussions with mine safety officers, and mine tours to witness materials-handling activities.

Back injuries are a significant percentage of the materials-handling injuries in underground mine accidents. Some types of accidents are unique to metal mines, some to coal mines, and some are common in both types of mines. Underground coal mines have a much higher percentage of materials-handling back injuries than do underground metal/nonmetal mines. A breakdown by activity is shown in the MSHA Underground Accident Data Summary (table 1), and incident rates are shown in table 2. To determine changes in materials-handling accidents, accidents in 1989 were compared to those in 1999.

With the extensive reduc-tion in workforce over the past 10 years, incident rate is a better indicator of safety performance than total number of workers. Incident rates are calculated on the total number of hours worked *associated with mine type* (underground, surface) and not to the number of hours worked while *actually handling materials*.

Table 1.—MSHA Underground Accident Data Summary

Category	1989		1999	
	No. of injuries	Causes of back injuries, percent	No. of injuries	Causes of back injuries, percent
METAL/NONMETAL:				
Handling material, total	401		194	
Back injuries while handling materials:[1]	131	[1]33	47	[1]24
Handling supplies	65	50	20	43
Move power cable	11	8	2	4
Handle timber	9	7	3	6
Move equipment	9	7	6	13
Machine maintenance . . .	8	6	10	21
COAL:				
Handling material, total	3,661		1,390	
Back injuries while handling materialsl:[1]	1,737	[1]47	548	[1]39
Handling supplies	808	47	257	47
Move power cable	265	15	105	19
Machine maintenance . . .	90	5	44	8
Hand load hand shoveling	126	7	33	6
Move equipment	98	6	29	5
Handling coal, rock, waste	80	5	25	5
Handling timber	148	9	21	4

[1]The category of "injuries while handling materials" is divided into subsets by body part, of which back injuries is one. Handling supplies, etc., are subsets of "back injuries while handling materials." Percentages are calculated accordingly.

Because of budget and time constraints, it was not possible to develop and/or test solutions to all common materials-handling problems. The detailed investigations described in this paper include methods to reduce injuries from manually moving objects (single lifting event) and from cleaning debris from grizzlies. Investigations included the use of existing equipment, modifications of existing equipment, and development of new equipment.

SINGLE LIFTING EVENT

A significant percentage of back injuries is the result of lifting and pulling activities associated with materials handling. Most of these back injuries are thought to have occurred in a situation where, for reasons of expediency and in the absence of help, the worker tried to lift materials or handle equipment that were too heavy.

Assisted lift devices (manipulators) are currently used in many manufacturing sectors to reduce injuries associated with manual equipment and materials handling. Manipulators allow workers to lift and maneuver heavy objects throughout a work area, yet require that the operator exert only a few pounds of force. Underground shops where a variety of lifting activities occur in the course of performing maintenance activities are particularly good candidates for assisted lifting devices. In the mining environment, attachments are being included on many pieces of underground equipment to lift objects. Examples include

Table 2.—MSHA Underground Incident Rates Summary[1]

Category	1989	1999	Percentage of decrease in incident rate, 1989-1999
METAL/NONMETAL:			
Handling materials, total	2.72	1.71	37
Back injuries while handling materials:	0.89	0.41	54
Handling supplies	0.44	0.18	60
Move power cable	0.07	0.02	76
Handle timber	0.06	0.03	57
Move equipment	0.06	0.05	14
Machine maintenance	0.05	0.09	-62
COAL:			
Handling materials, total	5.60	3.61	36
Back injuries while handling materials:	2.66	1.42	47
Handling supplies	1.24	0.67	46
Move power cable	0.41	0.27	33
Machine maintenance	0.14	0.11	17
Hand load hand shoveling	0.19	0.09	56
Move equipment	0.15	0.08	50
Handling coal, rock, waste	0.12	0.06	47
Handling timber	0.23	0.05	76

[1] Incident rate = Injuries times 200,000 ÷ Total hours worked.

grabbers on roof bolters for picking up flat sheets of wire mesh; attachments on longwall shearers for moving small parts, tools, etc., down the longwall face; small revolving chain hoists fitted on stageloaders for moving parts over the stageloader; and grabbers for lifting and setting timbers and cribs.

Activities in which assisted lifting devices might reduce injuries include—

• Handling large pneumatic wheel-lug wrenches and changing out hydraulic motors, which are examples of maintenance-related lifting activities that involve lifting, positioning, and sometimes holding heavy objects.

• Getting needed materials from the surface to underground laydown areas. Currently, such work is done with forklifts or other mechanized devices. The materials are generally placed on a pallet and tied together. Once in the laydown area, however, materials are separated and must be handled manually by workers to get them to the active work area.

• Maintenance of heavy equipment where no overhead lifting system is in place, such as conveyor belt systems in underground mines, which are often manually disassembled, moved, and reassembled.

• Installing bulkheads, overcasts, and stoppings and hanging supply lines (waterlines, ventilation tubes, etc.) from the mine back.

INNOVATIVE WAYS TO IMPROVE MATERIALS HANDLING

Several innovative designs, procedures, and equipment for reducing materials-handling injuries were observed during mine visits. Many of these involved the use of mechanized equipment to aid in lifting.

Can Cribs

General improvements in materials handling in underground ore deposits in the western United States include replacing wood cribs with can cribs for roof control. Can cribs allow stress release, as do wood cribs. The can is a few inches shorter than seam height and consists of a metal jacket approximately 76 cm in diameter with a wall thickness of 1 cm filled with lightweight grout (figure 1). The can is fabricated off-site and shipped to the mine in predetermined lengths so it can be transported horizontally. It is rotated to upright in place, capped with wood, and wedged into place. The use of cans reduces lifting and pinch-point exposures. An attachment adapted for existing equipment is used to grip and lift the can off the floor or trailer and rotate it into position (figure 2). Much less manual labor is required to set a can crib support than is required to set a wood crib support because only the caps and wedges are placed manually, resulting in fewer materials-handling injuries.

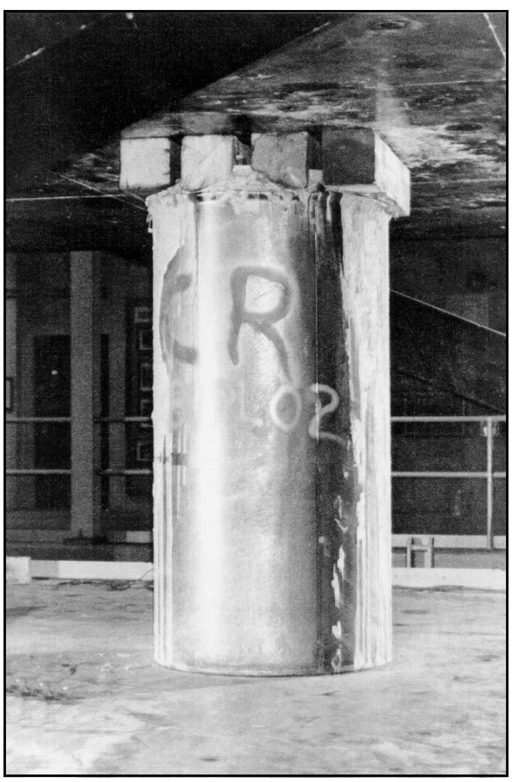

Figure 1.–Can crib used to replace wood crib in underground coal mines.

Figure 2.– Attachment used to pick up and maneuver can cribs.

Engineered Timber

In the eastern United States, engineered timber is replacing conventional timber in some mines. Engineered timber offers the same advantage as can cribs. Engineered timbers are wood posts that have steel bands and wedges added to increase post strength. Mechanized setting attachments similar to those used with the can crib can be used. Engineered timber has less strength than a can crib, thus requiring more trips, so it has fewer economic advantages.

Conveyor Belts

Labor-intensive handling of belt structures has become commonplace. The phenomenal production gains experienced by mining companies in the past few years has resulted in wider and faster conveyor belts. The weight of materials handled by workers has doubled as a result of using the wider belts, and this has increased the potential for back injuries. Belt weight as a function of width is shown in figure 3. Belt suppliers and mine personnel are coping with the demands of increased weight in several ways, as discussed below.

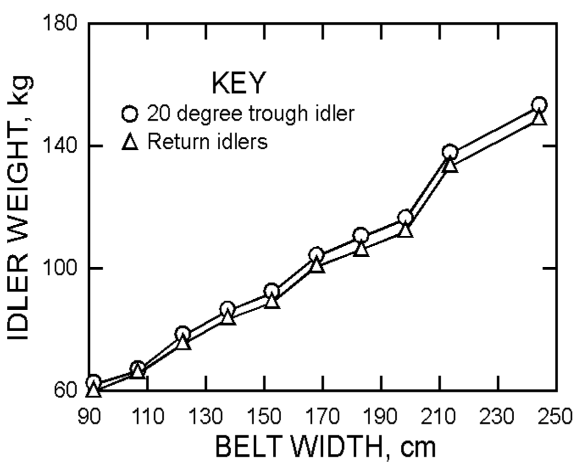

Figure 3.–Belt weight as a function of width.

Increasing Space

Mechanization of belt installation underground is an engineering challenge. The working space is narrow and uneven. A wider working space beside the belt in the same entry as the belt would greatly enhance materials handling for installation, removal, and maintenance of the belt line. However, in most cases, belt entries cannot be widened without jeopardizing roof control.

There are two approaches to creating more working space without widening total entry width. One is better utilization of present working space through the use of smaller equipment. Underground mines are using small loaders to meet this demand. Manufacturers have an assortment of attachments that have worked very satisfactorily with few modifications for underground settings.

However, new diesel particulate regulations are challenging the gains made by smaller equipment by restricting the use of surface loaders underground. Another concern presented by regulatory constraints is the type of air in which the equipment is operating. Because of the dangers of explosive charges and MSHA regulations, small nonpermissable loaders cannot be used in return air or beyond the last open crosscuts. Small, permissible loaders can be purchased as an option to replace standard-sized loaders, but none were observed on any of the mine trips.

A second approach is to eliminate space on the nonworking side (off side) of the belt by installing the belt closer to the off-side rib (figure 4). Because the belt line must be straight, the offside space is used to compensate for developing an entry that is not straight. However, with the use of lasers and with better training, miner operators can eliminate errors in cutting the entry and thus reduce the offside width, which can permit the use of smaller equipment designed for belt work. Moving the belt closer to the off-side rib and using smaller equipment has resulted in keeping entry widths under 6 m, and, in some cases, under 5.5 m.

Having a roadway beside the belt in the same entry has several materials-handling accessibility advantages. These include—

- Increasing the likelihood of having a piece of equipment available for lifting materials during installation.

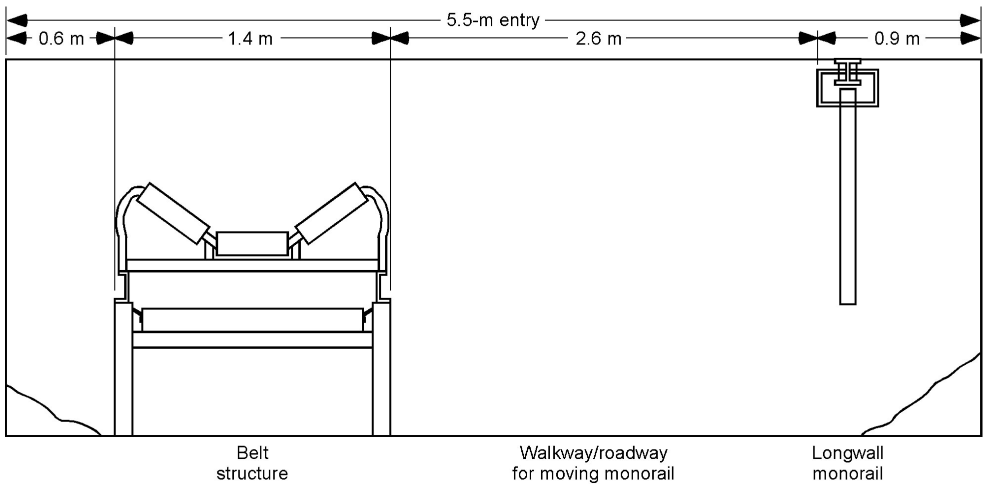

Figure 4.–Layout for belt entry to accommodate materials-handling equipment.

- Eliminating the need to carry materials between crosscuts during maintenance.

- Allowing better inspection of the belt for maintenance and during a belt shutdown.

- Allowing better access for cleaning underneath the belt with mechanized equipment.

- Allowing more thorough rock dusting.

A disadvantage is that clearance is limited when belt repairs are needed on the off side.

Placing and Removing Belt Rollers

The process of placing and removing rollers in belt extensions on continuous miner advance, during longwall retreat, and for maintenance change-out involves bending and manually lifting the heavy rollers. Innovative methods have been developed to separate the belt for removing rollers on the longwall. In one mine, the last top belt roller is mounted to one end of two H-beams, and two hydraulic jacks are mounted to the other end. The H-beams are pinned to the tailpiece near the middle of the beam. Through a lever-type arrangement, when the two hydraulic jacks push one end of the beam down, the top roller and belt are lifted. When the belt roller is lifted, the distance between the belts is increased, and the belt is completely lifted up from the second roller from the tailpiece. Lifting the top belt makes the second roller accessible for removal and eliminates the need to lift the belt manually. The tailpiece uses hydraulics for normal operation. This method could be used on any tailpiece and reduces the potential for accidents when removing the roller.

Another technique is to use an air bag to separate the belt to facilitate adding rollers in the belt advance process. Access to compressed air is necessary, but a mine may be able to utilize this in combination with other techniques.

A very successful approach for lifting the top belt for adding the roller has been to use small loaders with an attachment bar (a standard hard-roll steel bar bolted horizontally to the bucket). The advantage of the loader is that it can be employed to carry the roller and lift the belt. The loader is faster and eliminates the process of a worker lifting and bending while holding a come-along and chains or manually placing an air bag prior to inflating it.

Conveyor Belt Cleaning

Underground coal mines in the United States utilize belt conveyors to transport coal from the working face to the portal. Fine coal particles stick to the belt beyond the discharge point. Residual materials (carryback) stick to the bottom belt. Belt cleaners are installed at the head roller area to remove the sticky materials. If in good mechanical condition, the cleaners clean off approximately 95% of the carryback. The remainder is jarred and scraped off as the belt returns to the tail roller. In a three-shift per day operation, it is not uncommon for 2 tonnes or more of carryback to be deposited on the mine floor per week of belt operation. The carryback is usually wet when deposited, but dries over time. This becomes very dangerous. Coal dust particles are very small and, if ignited, burn very quickly, to the point of exploding. U.S. regulations require cleaning belt lines to remove the danger from the carryback exploding.

The standard method of cleaning the carryback is to use a long-handled, flat shovel to pick up coal dust and place it back on the belt. However, the coal dust is sticky and clings to the shovel blade. Cleaning is time consuming, and workers are prone to back injuries while twisting and dumping. To reduce costs and accidents, some mines have purchased specialty scoops to clean under the belts. The scoops must be small to operate in narrow spaces and should have an extended flat bucket to reach under the belt line. A roadway along the belt lines must also be present to operate the scoops. Hanging the belt from the roof allows better access for cleaning.

Industrial vacuums can also be used to clean the area around conveyor belts. In most cases, the vacuums are used to clean high-spillage areas, such as dumping points and the bottom of declines. Vacuum suppliers and underground mines are working to develop a lower-profile, mobile version for belt lines.

Washing material from under the belt with a high pressure hose, once an unacceptable practice, is becoming accepted. In the past, the washed material was picked up in solution with sludge pumps and placed back on the belt. The wet material caused further cleanup problems down the belt line. Now the washed material is being channeled into a concrete sump large enough to allow the coal to settle. The water is reused, and the material is allowed to dry and put back on the belt. Other operations using cyclones to separate the water and material to eliminate putting high-moisture material on the belt line[1]. All these procedures eliminate the need to shovel material and lift material manually.

Reduction of Materials Rehandling

Innovative approaches to reducing materials rehandling include loading skids and specialty trailers on the surface and using face equipment to take the loaded skids and trailers directly to an underground worksite. The trailer should be designed to haul different items efficiently. Skids and trailers are loaded with all the material needed to complete a specific job. Loading outside can be done in better light, with better footing, and with better use of equipment, all of which can reduce the potential for accidents. Job-specific trailers or skids can have special racks for hauling large water jugs and hydraulic hoses or specially designed skids for moving conveyor belt parts or cable bolting components.

The use of lightweight materials is another means of reducing the exertion required in manual materials-handling tasks. For example, aluminum can be used instead of steel bars for monorail systems on which high-voltage cable is transported in longwall mines, lightweight concrete blocks can be used for ventilation stoppings, and lightweight rollers can be

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[1]MSHA's home page contains useful tips on controlling spillage around conveyor belts.

incorporated as conveyor components.

Application of Sport Conditioning Principles to the Workplace

It is generally accepted that a period of warm-up exercises should take place before an exertion in a sports environment. That same philosophy is being followed in the work place. At one mine visited, miners were trained on correct stretching techniques. Plastic-protected cards showing the appropriate stretching techniques and that were easy to place in a shirt pocket or lunch box were given to the miners. To prepare workers for physical tasks, the mines are allowing time for stretching exercises before work starts and after long breaks. The stretching exercises are a good first step to reducing musculo-skeletal injuries. The other part of the warm up, a moderate exercise to increase the mechanical properties of muscles, was not observed.

MECHANICAL LIFTING AID INVESTIGATIONS

Manipulators

After purchasing a standard manipulator (figure 5), Spokane Research Laboratory personnel conducted a series of typical lifting activities to determine the manipulator's base-line performance. The device operated as intended with regard to lifting; however, several functional limitations and operational capabilities were identified as needing improvement before the device would be practical. The most significant limitation was its lack of mobility. With a weighted pallet jack base of 680 kg, the manipulator was too heavy for one person to move and position. A second limitation was the manipulator's lack of stability and leveling capability; that is, the device would rock on two of its four contact pads if the floor had any uneven or low spots. The manipulator arm would also list to the low side of a flat but inclined floor. A third limitation was the height and length of the unit, which made it difficult to move from one work area to another. Doorways were difficult to pass through because of the height, and corners were hard to navigate around because of the length.

Thus, researchers decided to modify the manipulator to improve its basic function. For the device to be practical, it would have to be self-propelled, compact enough to fit through openings and around corners, and stable and level once positioned. Also, the device should be self-contained with regard to the air and electrical supply for the lifting/driving/leveling system. An integrated design incorporating the manipulator was designed and named the mobile manipulator system (MMS).

The MMS is currently in the engineering design phase. Designs will involve modifications to the manipulator arm and the develop-

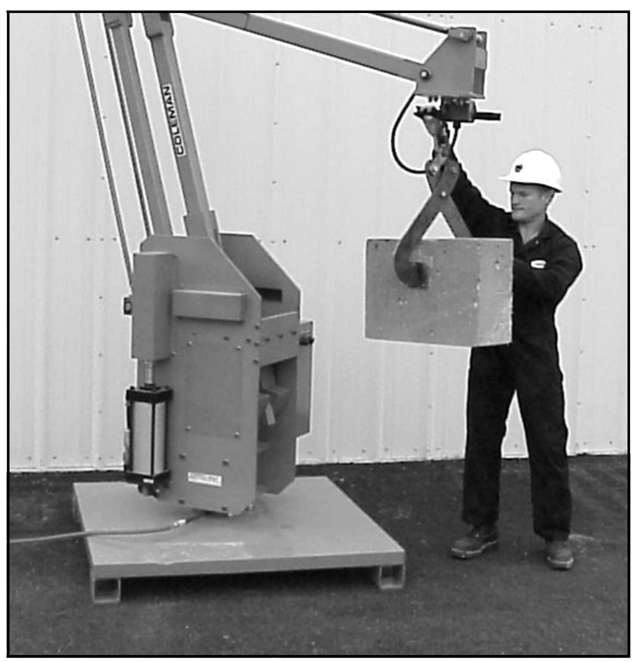

Figure 5.– Laboratory tests on Coleman manipulator as received from factory.

Figure 6.– Artist's concept of mobile manipulator after modifications.

ment of several subsystems that form the basis of the MMS. These subsystems will form the basis of an integrated lifting system. When completed, the MMS will be composed of a manipulator mounted on a mobile base. The base will be equipped with telescoping outrigger stabilizers and independently controlled leveling legs. In addition, an air compressor, inverter, and battery system will also be mounted on the mobile unit. The resulting MMS will tram to the location needed, deploy outriggers, level the base unit, then operate via the self-contained air-hydraulic system, all in a timely manner and requiring only a single user/operator. An artist's concept of the MMS is shown in figure 6. If the baseline performance is satisfactory, then the device will undergo a series of tests designed to approximate the manual materials handling and maintenance activities in mining environments.

Track-Guided Pincher Arm

Grizzlies are used in underground mines to prevent large boulders from entering ore passes and obstructing them. Some grizzlies are installed at ground level and others are recessed below ground level to accommodate sidecar or truck dumping. Typically, grizzly surfaces become clogged by the oversized boulders they are designed to retain; by fine cohesive materials that bridge openings; and by roof bolts, timbers, wire mesh, and other debris that have broken away and mixed with the mined ore. A recent search of an MSHA database to obtain information on accidents associated with ore passes showed that 20% of these accidents were caused by manually breaking and cleaning rock off of grizzlies.

Impact hammers are effective in breaking oversized rock, but they are very limited in their ability to clean off fines and are incapable of removing debris. In some hard-rock mines, especially those with recessed grizzlies, oversized rock is broken using permanently mounted hydraulic impact hammers. The hammer head is mounted on a backhoe-type arm and is controlled remotely from a control panel. In mines with accessible ground-level grizzlies, oversized rock is scooped from the grizzly and broken by secondary blasting and/or crushing. In some mines without impact hammers, the rock is broken manually with a double-jack sledgehammer. Roof bolts, timbers, wire mesh, and other debris are generally removed by a worker who climbs onto the grizzly and throws the debris off to the side, which is especially difficult in recessed grizz-lies. The materials then have to be picked up, placed in the trash, and hauled to the surface or other underground disposal area.

In cooperation with Gonzaga University, Spokane, WA, a device was designed, constructed, and tested to pick debris from grizzlies mechanically (figure 7). The device, called a track-guided pincher arm (TGPA), can be attached to any existing impact hammer. It employs two arms that come together at the end of their travel to create a clamp. The TGPA is designed so that the arms can extend into the clamping position, pick up debris, and retract out of the way of the hammer pick, which breaks up oversized rock. The arms can open wide to accommodate large objects. The device is capable of withstanding the daily pounding of the impact hammer and is fully functional in a mine environment.

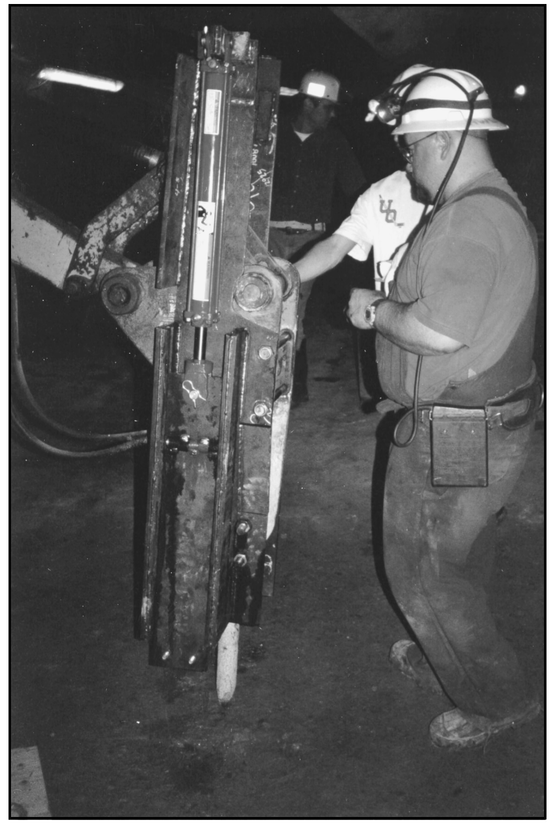

Figure 7.– Track-guided pincher arm attached to hydraulic impact hammer head.

The impact head for the TGPA was a hammer being used in an underground mine in northern Idaho. Measurements were obtained from both the mine and the manufacturer. To build the TGPA, detailed AutoCAD drawings of TGPA parts were prepared and sent to a machine shop for cutting into the necessary shapes. After the steel was cut, holes for the attachment bolts were bored through the steel, and the components were welded and assembled. After attaching the hydraulic cylinders for extending and retracting the pincher arms, the entire assembly was welded onto mounting plates. The TGPA was taken to the mine, installed on the impact hammer, and tested. The installation, including hydraulic hose hookup to the impact hammer control box, took about 1 hour.

During the initial test, the operator of the device ran the equipment in a slower, more-deliberate manner than usual. Under these slower operating conditions, the test was very successful. The pincher arms extended and retracted by moving the hydraulic lever at the control panel as designed. Several pieces of debris, including wire mesh, pipe (figure 8), wood pieces, and roof bolting pressure plates, were picked up from the recessed grizzly by the TGPA and dropped onto the ground. The impact hammer appeared to operate normally, and several rocks were broken with the arms of the TGPA in the retracted position. A bonus was the increased sweeping capability of the device. The TGPA has 30 cm (15 cm on each side) of base plate metal that can be used to sweep or pull back fines over the grizzly openings. Without the TGPA attached, only the hammer pick can be used for sweeping. Removing cohesive fines was probably three times faster with the TGPA.

After the initial test, the TGPA was left at the mine for long-term tests under typical

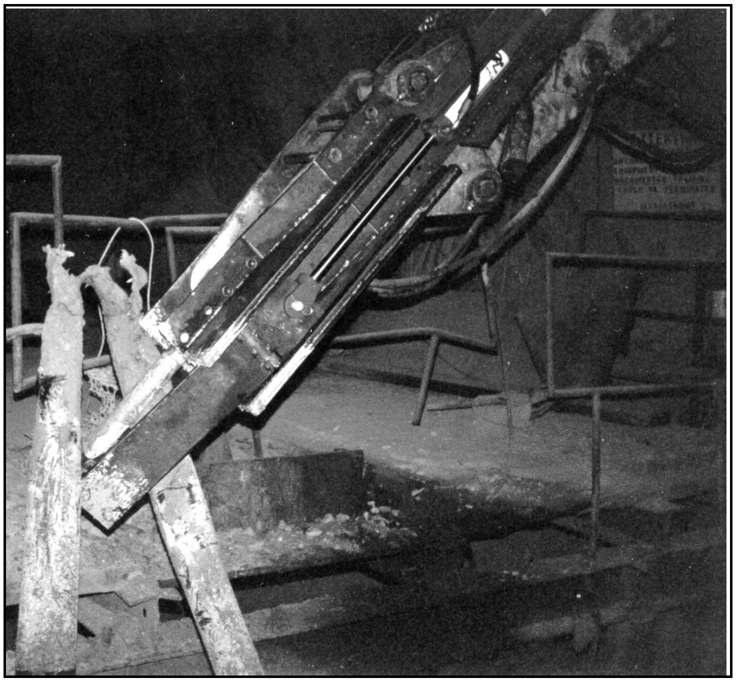

Figure 8.–Track-guided pincher arm picking up pipe debris from recessed grizzly.

operating conditions. Problems during this 3-month test included breakage of hydraulic fittings, less control of boom swing because of the additional weight of the TGPA attachment, exceeding relief valve pressures during maximum boom extension, and difficulty in reaching boulders in the corners of the recessed grizzly because of the added width of the TGPA.

Better protection of the hydraulic fittings and making the attachment lighter so that it does not affect the action and movement of the hammer are problems currently being addressed. The impact hammer operators appeared to be satisfied with the picking and sweeping capabilities of the TGPA.

CONCLUSIONS

The research described in this paper is not new. For years, underground miners, mine foremen, safety engineers, researchers, and others have been designing, developing, and testing innovative equipment and tools that can be used to make jobs easier and reduce injuries.

Yet, in spite of the ingenuity of many people and the development of many mechanized aids, materials handling continues to be the MSHA category with the highest percentage of accidents and injuries in underground mines. Hundreds of materials-handling tasks are performed in underground mines each day. It would be hard to find one of these tasks that has not resulted in an injury at least once.

Some solutions are simple, such as reducing "package" weight. Other solutions are not so simple, such as hanging objects overhead and moving trailing cables. Because of the diversity of materials-handling tasks, no single solution exists to eliminate materials-handling injuries. It is neither technically or economically feasible to mechanize all underground materials-handling tasks. Some tasks need to be done manually. The individual performing any materials-handling task, no matter how large or small, must take special precautions and get into the habit of thinking about the lift prior to doing it. No one likes to get hurt, and there is always a better, less strenuous way to lift a heavy object.

Research and development of materials-handling tools and equipment should continue with an emphasis on those tasks that result in numerous materials-handling injuries, such as moving roof bolt supplies, hanging waterlines and ventilation tubes, and moving cables. One approach is to have mine safety officers identify those tasks that cause frequent injuries at a given mine and conduct specialized materials-handling safety training to individuals performing these tasks. This would be valuable for new miners because they frequently get jobs involving supplies and materials. Constant (daily) safe materials-handling reminders from safety managers and shift foremen will aid in getting miners into the habit of not only "thinking before they lift," but also thinking before they carry, pull, hang, or push supplies and materials.

Improvements in production as well as safety have been accomplished over the past 10 years. The makeup of the work force has remained unchanged but is getting older. The mottos of the industry have been Think safety, Work smarter, Quality first, Production and safety go hand in hand, Team building, Quality circles, Employee empowerment. Future productivity and safety gains will be driven by technological improvements as it has been in the past 10 years. Those technologies will be developed by better-trained and coordinated organizations. University and research groups such as NIOSH have industrial advisory boards to help coordinate training and research efforts. The mining industry has been successful in reducing materials-handling injuries over the past 10 years. Continuation of this trend will be the challenge of the future.

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