# Materials Handling Accident Reduction in Underground Mines

Bill M. Stewart, Curtis Clark, and Phil Patton
Spokane Research Laboratory, National Institution for Occupational Safety and Health, E. 315 Montgomery, Spokane, WA 99207
(509)354-8021 office
(509)354-8099 fax
Bgs4@cdc.gov

# Synopsis

Handling materials in underground mines continues to be a major safety problem. To help reduce materials-handling injuries, the National Institute for Occupational Safety and Health (NIOSH) at the Spokane Research Laboratory is developing, modifying, and testing equipment to replace the necessity of doing lifting tasks manually. To reduce single-event lift injuries, equipment having mechanical automatic weight sensing and balancing control was investigated. The Coleman manipulator was selected for testing. Modifications to the Coleman manipulator to make it more suitable for underground mine use included mobilization, self-containment, all-purpose gripper attachment, and support jacks.

To reduce or eliminate the need to clean off manually the materials that commonly plug grizzly openings (timbers, wire mesh, roof bolts, and other debris), a track-guided pincher arm device was developed. The TGPA attaches to an impact hammer head, and the pincher arms are controlled by the operator of the hammer. Oversized rock can be broken with the pincher arms in the up position; the arms can then be lowered to grab and remove debris. Sweeping action to remove cohesive fines bridging grizzly openings is also greatly improved. This device is especially useful in recessed grizzlies.

An industrial gun was tested to evaluate its effectiveness in breaking oversized rock. Boulders up to 76 cm in diameter were successfully broken to minus-33 cm. Although methods to control flyrock need to be developed, an industrial gun may be a safe and inexpensive alternative to breaking oversized rock in certain underground mining situations.

**Keywords:** Mining, materials handling, overexertion, injuries

# Introduction

Materials-handling problems in underground mines and injuries associated with underground materials handling have been well documented[1, 2]. Although lost-workday injury rates related to materials handling in mines decreased between 1988 and 1997[3,4], 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.

Reviewing data from 1998-1999 from the 20 underground mines investigated in this study indicated that materials handling was still the leading cause of reportable injuries. Accident report narratives showed numerous and varied materials-handling activities that resulted 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[5]. The authors of that report 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."

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. 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.

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 relifting 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[6]. 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[7].

The goal of this research project is to reduce materials-handling injuries by reducing manual materials-handling tasks. This paper describes the development and testing of specialized equipment to help achieve that goal.

## Description of Problems

The research approach is to investigate common underground materials-handling tasks or activities that frequently result in injuries and that occur in several different mines. Only coal and metal underground mines were included in this research. Emphasis was placed on manual tasks. The focus areas were determined by reviewing MSHA accident report narratives, personal discussions with mine safety officers, and mine tours to witness materials-handling activities. The 10 most common materials-handling activities that resulted in reportable injuries numerous times in 1999 and the approximate number of occurrences are shown in Table 1. Some are unique to metal mines, some to coal mines, and some are common in both types of mines. Because of budget and time constraints, it was not possible to develop and/or test solutions to all common materials-handling problems. Detailed investigations described in this paper include methods to reduce injuries from three activities: single lifting event, cleaning debris from grizzlies, and breaking oversized rocks. Investigations included the use of existing equipment, modifications of existing equipment, and development of new equipment.

Table 1– Underground materials-handling activities and number of injuries in 1999 (MSHA, 2000)

| Activity | No. of occurrences |
|---|---|
| Moving cable (primarily trailing cable) . . . . . . . . . . . . . . . . . . . . | 117 |
| Moving roof bolt supplies . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 85 |
| Moving conveyor belt parts . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 69 |
| Loading/unloading supplies in and out of carriers . . . . . . . . . . . | 50 |
| Moving roof support supplies (timbers, beams, cribs, etc.) . . . . | 25 |
| Construction activities (stopping, bulkheads, overcasts, etc) . . . | 25 |
| Moving rock dust supplies . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 23 |
| Lifting, hanging, pulling objects overhead . . . . . . . . . . . . . . . . | 23 |
| Moving, shoveling rock, coal, debris . . . . . . . . . . . . . . . . . . . . | 16 |
| Moving pumps . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 11 |

### Single Lifting Event

Lifting and pulling activities associated with materials handling in underground mines continue to account for a significant percentage of back injuries. This is depicted graphically in Figure 1. 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 was 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 envelope, yet require that the operator exert only a few pounds of force. Underground shop areas where a variety of lifting activities occur in the course of performing maintenance activities are particularly good candidates for assisted lifting devices. Handling large pneumatic wheel-lug wrenches and changing out hydraulic motors are examples of maintenance-related lifting activities and involve lifting, positioning, and sometimes holding heavy objects.

Handling materials being dispersed from laydown areas to the work areas is a good candidate for assisted lift devices. In most underground mines, getting needed materials from the surface to underground laydown areas 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 for each shift.

Other applications of assisted lifting involve 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. Use of manipulators for bulkheads, overcasts, and stopping construction and for hanging supplies (waterlines, ventilation tubes, etc.) from the mine back is another possibility.

### Cleaning Debris from Grizzlies

Grizzlies are used in underground mines to prevent large boulders from entering ore passes and causing obstructions. 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. Impact hammers are effective in breaking oversized rock, but are very limited in cleaning 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 grizzlies. The materials then has to be picked up, placed in the trash, and hauled to the surface or other underground disposal area.

### Rock Breaking

Manually breaking oversize rock and removing debris from grizzlies is a hazardous task and has resulted in many injuries. A recent MSHA database search (1987 to 1996) for accidents and fatalities associated with ore passes in underground metal mines identified 78 accidents (of 392, or 20 per cent) as being caused by manually breaking and cleaning rock from grizzlies. These accidents included cuts and abrasions requiring stitches because of fragmentation of rock and metal pieces (12 incidents); injuries to the back, neck, and arm muscles (13 incidents); slip and falls (11 incidents, one of which resulted in a permanent disability); rock movements that caused pinched and broken feet, fingers, hands ankles, and head injuries (26 incidents); and bar and hammer ricochet injuries (16 incidents).

Unless drilling and applying a breaking agent can be done remotely, oversized rock has to be removed from the ore prior to dumping, removed from the grizzly after dumping (not feasible in recessed grizzlies), or drilled by a miner going onto the grizzly. These alternatives, although effective, can be time consuming, hazardous (if person has to go onto grizzly to drill), or expensive.

On the basis of this information, it is apparent that breaking rock and cleaning grizzlies should be done by machinery and that a worker be allowed to work on a grizzly in an active pass only as a last resort.

## Investigations at the Spokane Research Laboratory

### Manipulators

After purchasing a standard manipulator (Figure 2), Spokane Research Laboratory (SRL) personnel conducted a series of typical lifting activities to determine baseline 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 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 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 would need to 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).

Engineering design for the MMS involved modifications to the manipulator arm and the development of several subsystems that form the basis of the MMS. 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.

These individual components will form the basis of an integral lifting system. The resulting MMS will be trammed 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 3. 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.

### Industrial Gun

There are numerous secondary blasting methods that break oversized rock effectively. Most require a hole to be drilled part way through the rock in which the breaking agent is applied. At least two commercial machines have been developed that can drill and blast rock remotely or from the end of a boom at some distance from the rock. One is the "Weasel," a remote-controlled hole drilling and blasting vehicle manufactured by Marcotte Mining,[1] Sudbury, ON. The other is the Ro-Bust System, manufactured by McCarthy Industries, Ltd., Denver, CO, which uses a percussive drill and a Ro-Bust pulse generator mounted on a heavy-duty boom assembly to drill and blast rock.

A method to break oversize rock remotely using an industrial gun was tested at SRL. Industrial guns have been used to reestablish production flow in rotary kilns, to tap electric furnaces, to break up bridges in silos, and to descale industrial boiler tubes. They have also been used to dislodge or break up dangerous rock projections and hard-to-reach overhangs in open-pit mines and quarries.

Prior to the tests, a 3- by 3-m grizzly with 33- by 33-cm openings was constructed and placed in an open bunker at the test site. A truck load of rock from a quarry near an underground mine in northern Idaho was dumped at the test site and pushed onto the

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[1] Mention of specific products or manufacturers does not imply endorsement by the National Institute for Occupational Safety and Health.

grizzly with a front-end loader. A metal shield with a shooting window was constructed on top of the bunker (Figure 4). Maximum shooting distance was 7 m.

The industrial gun used was an 8-gauge Ringblaster Mark II manufactured by Winchester Olin Corp., East Alton, IL. The gun was loaned to SRL by Winchester free of charge for a 60-day trial period. It weighed about 22 kg and was hung from a sling inside the shield while firing. Winchester also supplied three different types of ammunition for the tests: 85-g, SX magnum, lead slug; 85-g, reduced-velocity, lead slug; and 50-g frangible slugs (metal unknown). There was also an 85-g zinc slug available, but this was not tested. All slugs were cylindrical so energy would be applied to the rock as a smashing blow rather than penetrating the rock and were designed to resist fragmentation. The frangible slugs were designed to disintegrate on impact. Very little recoil was noticed.

Rock sizes ranged from plus-33 cm to minus-152 cm. Twelve tests (shooting sessions) were performed. In all tests, rocks up to 76 cm were broken into pieces small enough to fall through the grizzly openings in eight shots or less. In one test, basalt rock measuring 61 by 51 by 43 cm required 13 shots to break into pieces small enough to fall through the grizzly openings. The type of slug used did not seem to matter, although in one case, the 50-g frangible slug required eight shots before breaking a 76-cm rock, and the 85-g lead SX magnum slug required only six shots for rock of the same size. The larger the rock, the more shots required. Generally, two, three, or four shots were required to break a 61-cm rock, and six, seven, or eight shots were required to break a 76-cm rock. In one test, a 160-cm boulder was shot 50 times with different slugs. The boulder chipped but did not break.

The effectiveness of using an industrial gun depended on rock hardness, size, and brittleness. The gun was very effective in breaking rock up to 76 cm in diameter from a distance of 7 m at an angle of about 25° from horizontal. It was not effective at breaking a very large boulder (160 cm) at the same distance and angle. Longer distances and different trajectories were not tested. The industrial gun is an alternative that can be used in mines currently breaking rock manually and for reasons of economics or space cannot use hydraulic impact hammers or other remote rock breaking options. One example may be block caving operations where ore feeds directly to ore pass grizzlies at several drawpoints in a crosscut. Protection of the shooter and mine personnel during shooting, noise, flyrock control, and gun management are all required safety considerations.

## Track-Guided Pincher Arm

In cooperation with Gonzaga University, a device was designed, constructed, and tested to pick debris from grizzlies mechanically (Figure 5). 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 accomodate large objects. The device is capable of withstanding the daily pounding of the impact hammer and is fully functional in a mine environment.

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 6), 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 operating conditions. Problems during this 3-month test included the hydraulic fittings to the cylinders that activated the pincher arms braking when bumped, the additional weight of the TGPA attachment causing the boom to swing more freely, pressures exceeding relief valve settings when the boom was extended all the way out because of the added weight, and the extended width of the attachment making it difficult to get to boulders in the corners of the recessed grizzly.

Better protection of the hydraulic fittings and making the attachment lighter so that it does not effect 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.

## 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 materials handling improvements in underground ore deposits in the western United States include replacing wood cribs with can cribs for roof control. 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 7). The can is fabricated off-site and shipped to the mine in predetermined lengths so it can be transported horizontally. It is rotated upright in place, capped with wood, and wedged into place. The use of cans reduces lifting and pinch-point exposures. They allow stress release, as does the wood crib. An attachment adapted for existing equipment is used to grip and lift the can off the floor or a trailer and rotate it into position (Figure 8). Much less manual labor is required to set a can crib support verses a wood crib support, resulting in fewer materials-handling injuries.

## Conveyor Belts

Labor-intensive handling of belt structures has become commonplace. The weight of materials handled by workers has doubled over the past few years as a result of using wider belts, which has increased the number of back injuries. Belt suppliers and mine personnel are coping with the demands of increased weight in several ways.

*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 the present working space by using 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. 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 9). Moving the belt closer to the off-side rib and using smaller equipment has resulted in keeping entry width under 6 m, and, in some cases, under 5.5 m. These roadways are not main roadway widths, but with smaller equipment designed for belt work, the roadways are adequate and have been very successful.

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

- Allowing a piece of equipment to be available for lifting materials during installation.
- 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.

*Placing and Removing Belt Rollers.* The manual process of placing and removing rollers in belt extensions on continuous miner advancement, longwall retreat removal, and roller maintenance change-out involves bending and 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 in 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 inflation.

*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 per cent 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 ftom 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 minor back injuries while twisting and dumping. To reduce costs and accidents, one mine operation has 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.

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. The vacuum system is new to underground mines, but has been proven in many other industrial situations. Vacuum suppliers and underground mines are working to develop a lower-profile, mobile version for belt lines.

### Other Techniques

Innovative approaches to reducing manual materials-handling tasks 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 and designing attachments for existing pieces of equipment so that materials can be lifted without manual labor. Such attachments include an arm on a roof bolter for picking up flat sheets of wire mesh, a longwall shearer attachment for moving parts down the longwall face, and small revolving chain hoists fitted on a stageloader for moving parts over the stageloader and down the longwall face. Other equipment includes special racks for hauling 19-L water jugs and hydraulic hoses, and specially designed skids for moving conveyor belt parts. Special “metacarpal gloves” for hand protection are also being required by some mines, and mine standards sometimes exceed federal and state requirements for protecting workers.

Using lightweight materials is another means of reducing the exertion required in manual materials-handling tasks, for example, the use of aluminum instead of steel bars for monorail systems on which high-voltage cable is transported in longwall mines and the use of lightweight blocks for ventilation stoppings and lightweight rollers for conveyor components. To prepare workers for physical tasks, mines are allowing time for stretching exercises before starting work and after long breaks.

## Conclusions

The research described in this paper is not new. For years, underground miners, mine foreman, 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 need to 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.

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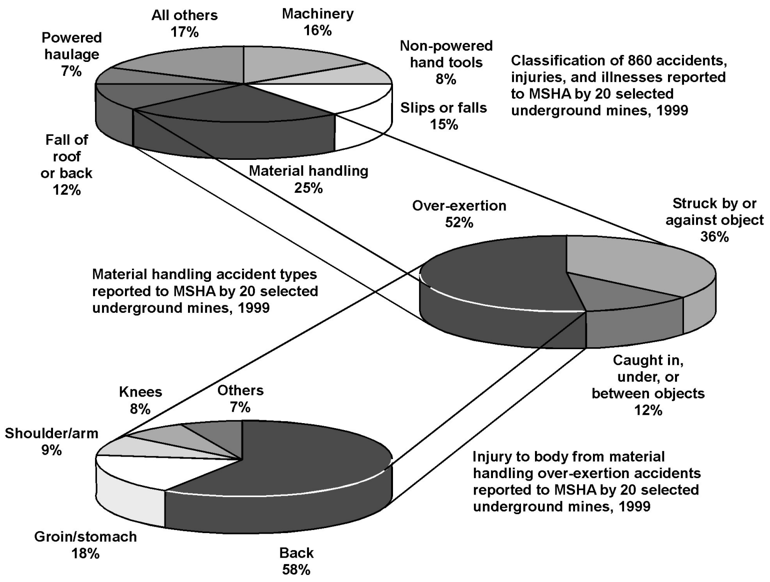
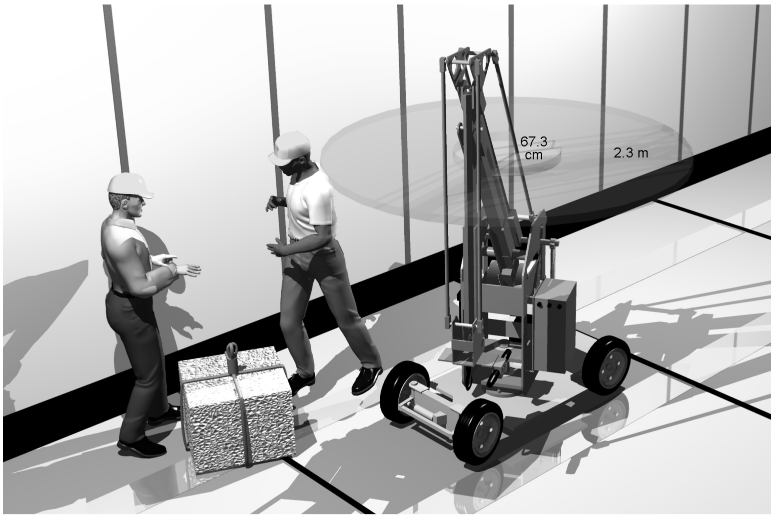


Figure 1.–Materials-handling back injuries from 20 underground mines, 1999.

Figure 2.– Laboratory tests on Coleman manipulator as received from factory.



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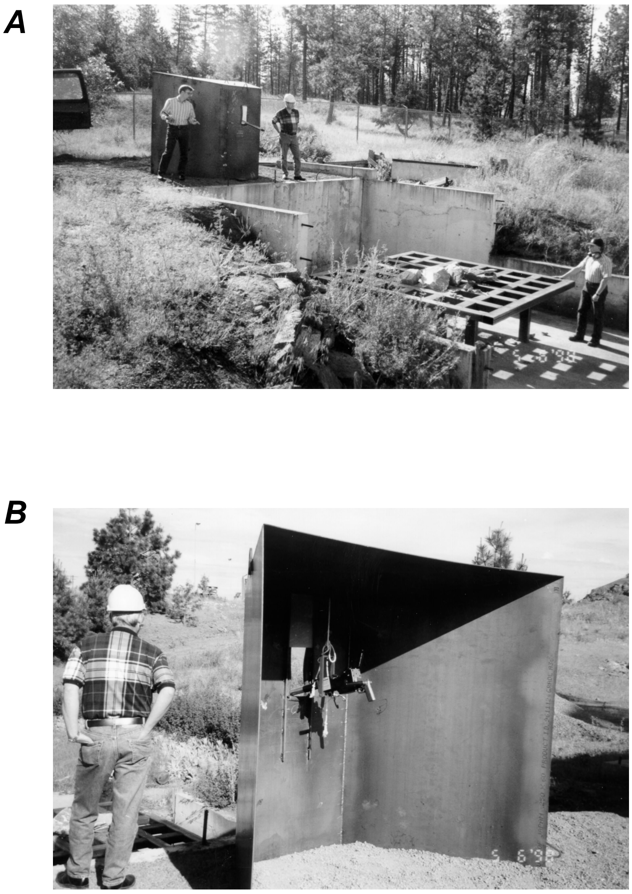

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Figure 5.– Track-guided pincher arm attached to hydraulic impact hammer head.

Figure 6.– Track-guided pincher arm picking up pipe debris from recessed grizzly

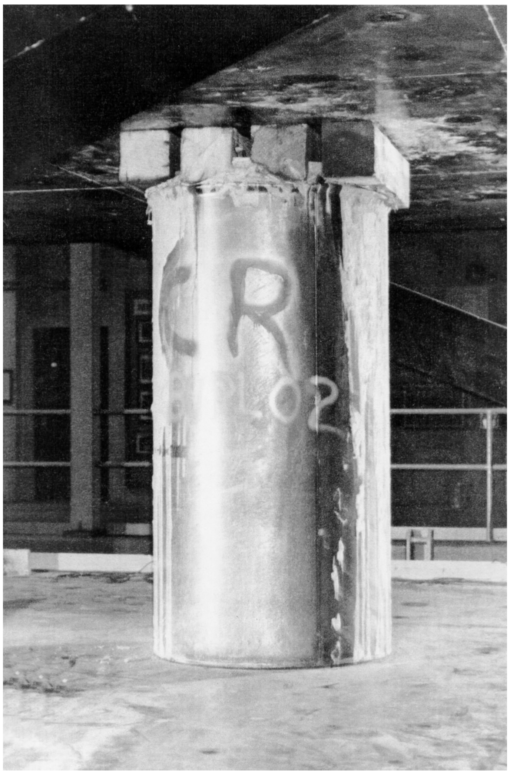

Figure 7.– Can crib used to replace wood crib in underground coal mines.

Figure 8.– Attachment used to pick up and maneuver can cribs.

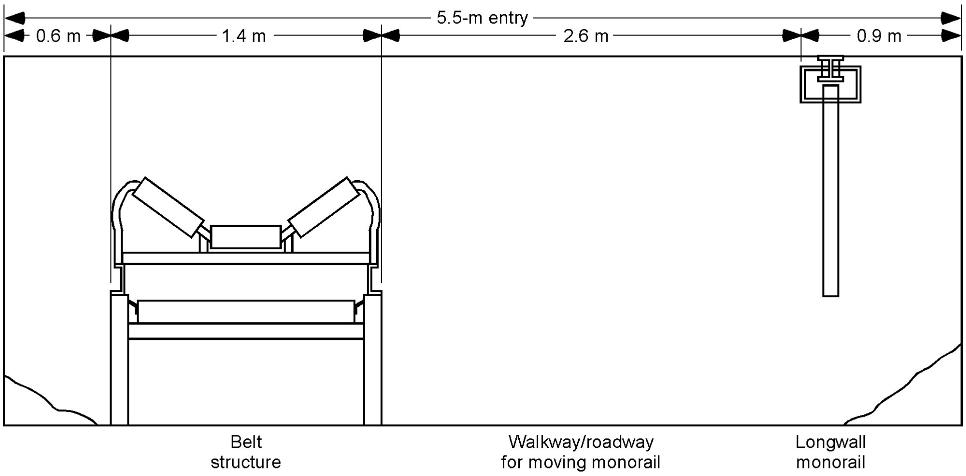

Figure 9.–Layout for belt entry to accommodate materials-handling equipment.