INEXPENSIVE, EASY TO CONSTRUCT MATERIALS-HANDLING DEVICES FOR UNDERGROUND MINES

By Richard L. Unger[1] and Kirk Conway[2]

ABSTRACT

The U.S. Bureau of Mines (USBM) has developed and tested designs for six materials-handling devices for use in underground mines to reduce materials-handling injuries. Particular attention was focused on making the designs practical, low cost, and easily fabricated to be broadly applicable in underground operations. Where possible, the designs were simplified so that off-the-shelf components could be used to permit fabrication by mine personnel on site. The six devices include scoop-mounted lift boom, swing-arm boom, heavy component lift-transport, mine mud cart, container-work station cart, and timber car.

This paper presents a brief discussion of that work and the six devices. It is intended for mine operators who wish to make use of the design concepts to manufacture similar devices for use in their mines.

INTRODUCTION

Manual materials handling represents a critical and persistent source of personnel injuries in underground coal mining operations. On an annual basis, such injuries represent the largest category of nonfatal, lost-time injuries, accounting for 35% of all lost-time injuries in 1983 and 1984, according to an analysis of U.S. Mine Safety and Health Administration (MSHA) data. Approximately 26% of all injuries related to manual materials handling are associated with the performance of mine maintenance or equipment maintenance tasks (fig. 1).

In the mid-1980's, as part of its program to improve health and safety conditions in mines, the USBM conducted a research program that addressed the materials-handling problems of mine maintenance and equipment maintenance. During the course of the project, a detailed analysis of mine- and machine-related tasks was completed and sources of injuries were identified. Concepts for simple materials-handling devices that could replace manual handling were then developed and evaluated. Six of these devices were fabricated and delivered to operational underground coal mines for testing and evaluation. Complete plans for the devices are available in USBM Information Circular (IC) 9212.[3]

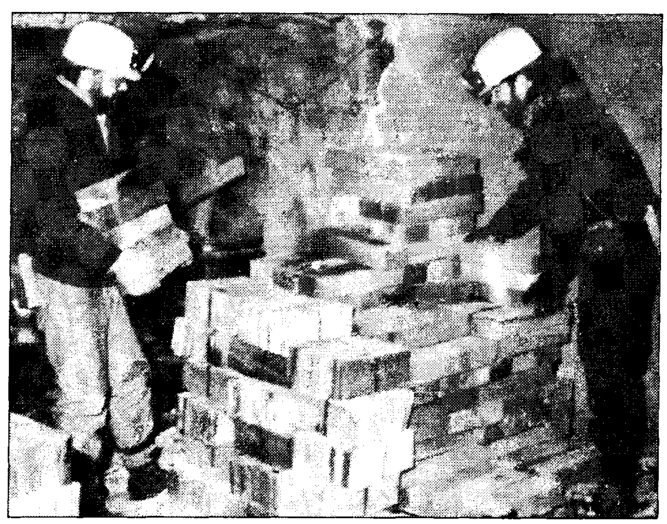

Figure 1.—Most materials handling is done manually in underground coal mines, which is part of the reason it is the leading cause of injuries year after year.

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[3]Conway, E. J., and R. L. Unger. Material Handling Devices for Underground Mines. BuMines IC 9212, 1989, 48 pp.

SUMMARY OF DESIGN RATIONALE

The work described in USBM IC 9212 specifically addressed materials-handling tasks related to mine maintenance and equipment maintenance performed in underground coal mines. Surface materials-handling tasks and the transporting of supplies or materials from the surface to the operating section were outside the scope of this effort.

MINE AND EQUIPMENT MAINTENANCE

Representative mine maintenance tasks included—

1. Installation or removal of ventilation, electrical, communications, or compressed-air systems.
2. Installation of timbers, cribbing, and other supplemental materials used in roof or rib control.
3 Track installation, repair, and retrieval.
4. Rock dusting, installation of air-control screens, and electrical wiring installation of warning or other systems.

Typical machine maintenance tasks falling within the scope of this project included—

1. Removal or replacement of belt drives, head, pumps, drive motors, and other major machine parts on stationary equipment.
2. Assembly, installation, and repair to mine equipment, including mobile face equipment.
3. Routine servicing of mining equipment.

All underground coal mine seam heights were included in this study. However, emphasis was placed on midseam to lower seam coal mines (under 147-cm (58-in) seam height) because preliminary data suggested that the highest risks of manual materials-handling injuries were to be found in those seam heights. The study included a review of relevant materials-handling literature and past USBM programs, visits to six operating coal mines, and an extensive analysis of MSHA's accident database.

The mine maintenance and equipment maintenance tasks investigated involved, by their very nature, the manual handling of supplies and equipment components. Individual modules of items handled might range in weight from a few to several thousand kilograms. Because of the operational constraints in underground coal mines, these materials and components often have to be manually moved from the supply dropoff point to the place where they will actually be used or installed.

Components used in equipment maintenance are typically hoisted onto a railroad car, scoop bucket, or maintenance jeep on the surface. They are then transported to the section where the disabled machine is located. At that point, they are manually lifted off the rail car or jeep or ejected out of the scoop bucket and manually carried to the installation position. Occasionally, hoists or come-alongs are attached to roof bolts to aid in this process. Replaced components are then manually loaded into the transport vehicle for shipment to the surface.

Mine maintenance materials (e.g., timbers, rock dust bags, roof bolts, etc.) are typically loaded in bales or via pallets onto railcars or into scoop buckets for shipment to or near the working section. At the end of the rail line, the bales or pallets are broken down for manual loading into scoops or onto other transport vehicles for delivery to work locations. (One mine visited had rubber-tire-equipped railcars that could be detached at the end of the rail line and towed by battery-powered vehicle to the work locations or section supply areas.) Once the materials are dumped near the work location, miners manually carry them to the maintenance point for use. These maintenance personnel may lift materials weighing 23 to 226 kg (50 to 500 lb) continually on a daily basis. They handle materials (sections of rail or steel arches) weighing 454 kg (1,000 lb) or more on a monthly or more frequent basis.

Analyses of materials-handling injuries in the six mines visited indicated that—

1. Thirty-nine percent of all mine maintenance and 35% of all machine maintenance injuries involved the lower back.
2. Forty-five percent of all mine and 39% of all machine maintenance accidents were the result of overexertion.
3. Sixty-eight percent of mine maintenance injuries involved handling timbers, posts, caps, and cribbing materials, while 32% of the machine-related accidents involved handling metal machine components.

MECHANIZATION REQUIREMENTS

The design implications of these and other findings revealed during studies of materials-handling tasks related to mine and equipment maintenance can be summarized by the following mechanization needs:

1. Devices to lift or lower and rotate machine components weighing up to 1,361 kg (3,000 lb) for removal from and replacement on mining equipment.
2. Devices to lift or lower components of up to 226 kg (500 lb) in and out of scoops, off railcars, and on or off other mobile vehicles.
3. Carts or other devices to transport small quantities of materials weighing up to 226 kg (500 lb) from storage areas or railheads to working sections.
4. A device to raise and support crossbeams for temporary roof support while permanent roof supports are installed.

Six materials-handling devices were developed to fulfill these needs. Particular attention was focused on making the designs practical, low cost, and easily fabricated so as to be broadly applicable in underground operations. Where possible, the designs were simplified and off-the-shelf components used to permit fabrication of the devices by mine personnel on site.

The devices discussed in this paper are not intended to be final designs. Rather, they are working prototypes that have been field evaluated and are presented herein in the hopes of stimulating other innovative designs on the part of mine personnel.

The six devices include—

1. Scoop-mounted lift boom.
2. Swing-arm boom.
3. Heavy component lift-transport.
4. Mine mud car.
5. Container-work station vehicle.
6. Timber car.

Functions performed by, and design specifications for, each of these devices are discussed in the following section.

PROTOTYPE MATERIALS-HANDLING DEVICES

SCOOP-MOUNTED LIFT BOOM

One of the major identified needs was for a simple boom device to lift and transport components weighing up to 1,361 kg (3,000 lb) in the underground environment. The device had to be mounted on a powered mobile machine and installed and removed quickly to minimize production down time for the machine. This tool would be used for transporting and maneuvering heavy machine components such as a continuous miner head.

A quick-mount-dismount lift boom device was developed for installation on the front of a small scoop with its bucket removed (figs. 2-3).

The design features of the scoop-mounted lift boom include—

1. A 1,361-kg (3,000-lb) lift capacity.
2. Manual or powered lift capability.
3. Installation and removal in 5 min or less.
4. Ready storage in working section or on mobile machinery.

Four attachment points secure the lift boom to the scoop lift mechanism by means of four pins. The pins correspond in size and location to the pins used to secure the scoop bucket. The overhead design of the lift boom permits lifting or lowering of components being handled. The bucket tilt mechanism provides up and down maneuvering of the components, while the scoop's normal steering permits lateral and forward and reverse maneuvering.

SWING-ARM BOOM

Accident and biomechanical analyses suggested the need for a simple swivel crane or boom device to lift components on and off transport vehicles and to assist in maneuvering heavy machine components in confined spaces. To address these requirements, a lightweight, removable, storable lift boom was designed (figs. 4-5). This boom can be installed at various locations on maintenance carts or on mining machines themselves. The height of the boom can be varied by quickly changing the boom leg. The inexpensive mounts can be permanently welded at various locations on the machine frame and are designed to

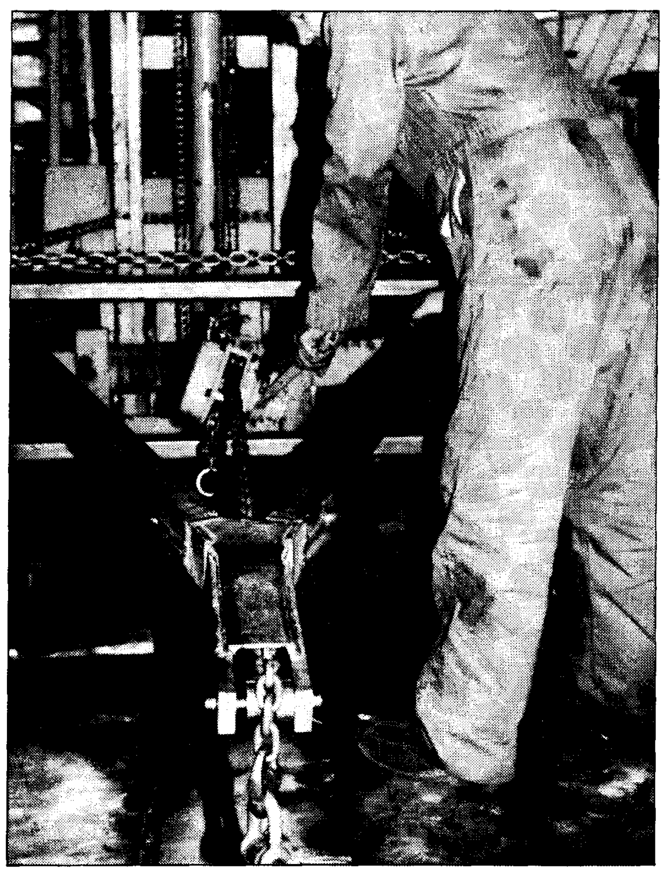

Figure 2.—Testing scoop-mounted lift boom at Pittsburgh Research Center.

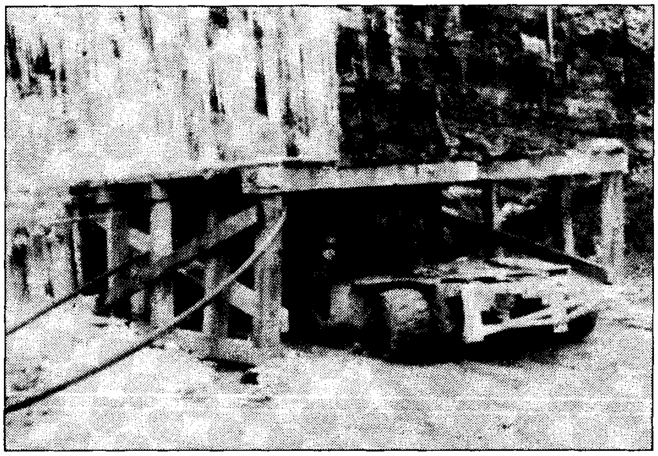

Figure 3.—Scoop-mounted lift boom during surface tests.

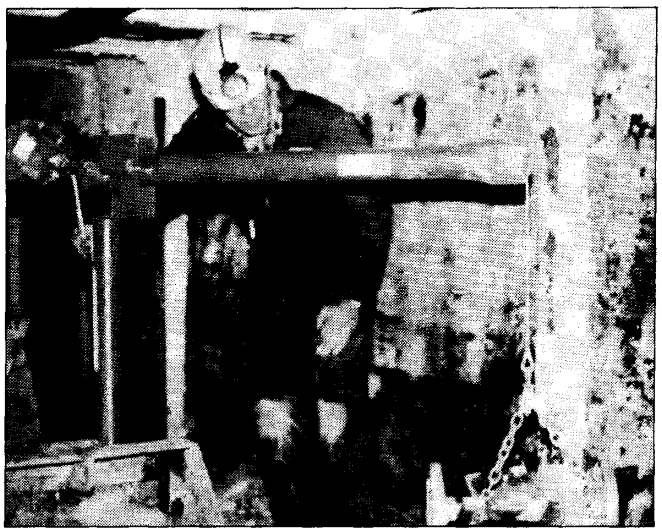

Figure 4.—Machine-mounted swivel crane during underground tests.

resist damage during normal machine operation. Two or more quick mounts can be installed on the same machine to permit access to all machine locations.

Design features of the swing-arm boom include—

1. Load capacity of 227 kg (500 lb).
2. Boom height range from 61 to 173 cm (24 to 68 in), depending on leg length.
3. Arm radius of 61 to 122 cm (24 to 48 in).
4. Mounting and stowing without tools.
5. Light weight for carrying by one person.

HEAVY COMPONENT LIFT-TRANSPORT

Another identified need was for a floor-type maintenance jack that could be used to lift heavy machine components from the bottom, transport them over short distances, and lift them into position for installation. Saddles on the lift point could be designed to permit additional maneuvering of the component during actual installation. This type of device could be used, for example, to install drive motors under the nonremovable fenders in shuttle cars.

Figure 5.—Crane is easily mounted in its removable base.

The heavy component lift-transport prototype is shown in figures 6 and 7. The device utilizes a standard hydraulic floor jack to provide the lift mechanism. The jack head itself is tiltable and rotatable to permit close-in maneuvering. The jack mechanism travels along the device frame by means of a sump drive mechanism. This motion permits forward-backward movement of handled components and balancing of components over the lift-transport device wheels during travel. The long handle permits the use leverage by which to maneuver loads up and down or sideways, as required. Dual tires or oversized balloon tires increase the device's stability and permit easy movement over uneven floors.

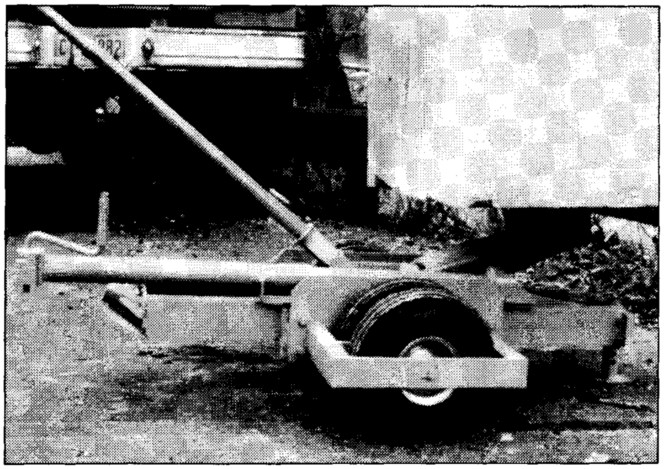

Figure 6.—Heavy component lift-transport during testing with 680-kg (1,500-lb) concrete block.

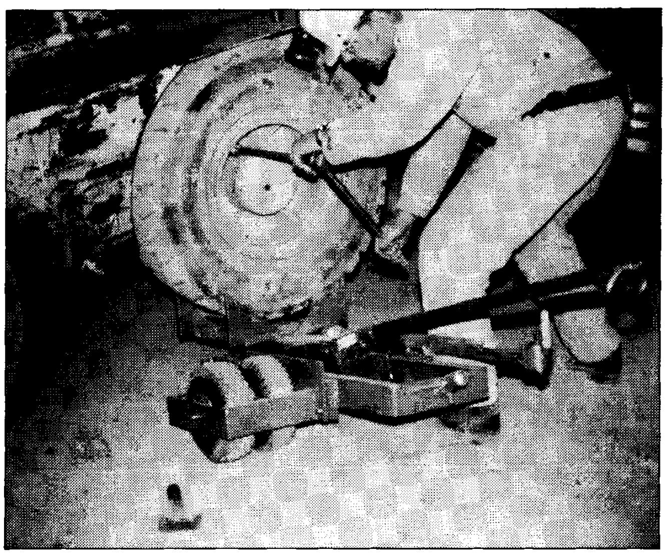

Figure 7.—Tire-changing attachment eliminates manual handling of heavy wheels during replacement.

The design features of the heavy component lift-transport include—

1. Up to 454-kg (1,000-lb) lift capacity.
2. Balloon tires for ease of transporting manually.
3. A standard automotive floor jack for the lift mechanism.
4. Ability to lift and maneuver a heavy component as it is being removed or replaced on a mining machine.
5. Jack head that can be trammed forward or back on the frame for close-in maneuvering or for load balancing.

MINE MUD CART

One of the basic problems faced by all miners is that of moving machine components or supplies such as concrete blocks from the supply storage area to the point of use. If a powered vehicle is not available, the task must be accomplished manually. The intent of this concept was to design a small, manually pulled cart that could transport up to 408 kg (900 lb) of materials over a short distance.

The mine mud cart has the following design features:

1. Narrow width to permit passage by a parked mining machine.
2. Tandem design to prevent tipover if one unit is loaded and the second is empty.
3. Balloon tires for transit through mud or water and over mine floors.
4. Handle designed for pulling by one or two people.

Figure 8 illustrates a tandem cart concept using eight wheels. The vehicle can also be fabricated as a single cart.

CONTAINER-WORK STATION VEHICLE

Hand tools and supplies required to perform most maintenance tasks in a section can be mounted on a transportable container. This concept is for a device that allows a single manually powered mechanism to lift and transport such containers (figs. 9-10). There are many uses for the containers themselves, such as tool station, lubrication module, rock dust unit, fire and safety equipment storage, repair work station, and cable-splicing module.

To move the container around the working section, the transporter is positioned around the container and a lift mechanism raises it off the floor and positions the load sightly ahead of the axle. The load is carried by the wheels while the operator controls motion by pulling, steering, and balancing the unit on its axle.

Design features of the container-work station include—

1. Rapidly interchangeable containers that can be picked up or dropped off as required.
2. Containers that can be used as secured storage units when dismounted from the vehicle.
3. Up to 454-kg (1,000-lb) load capacity.
4. Adjustable ground clearance.
5. Balloon-type tires for easy transporting on unimproved mine floor.
6. A tow bar that can be adapted for towing behind utility vehicles.

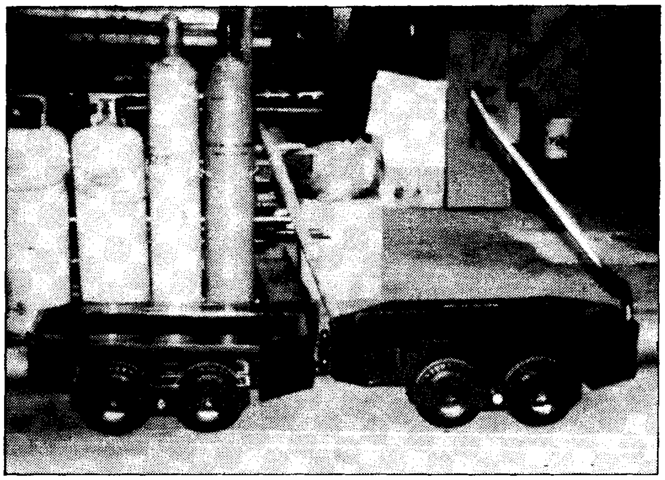

Figure 8.—Mine mud cart.

Figure 9.—Container-work station vehicle.

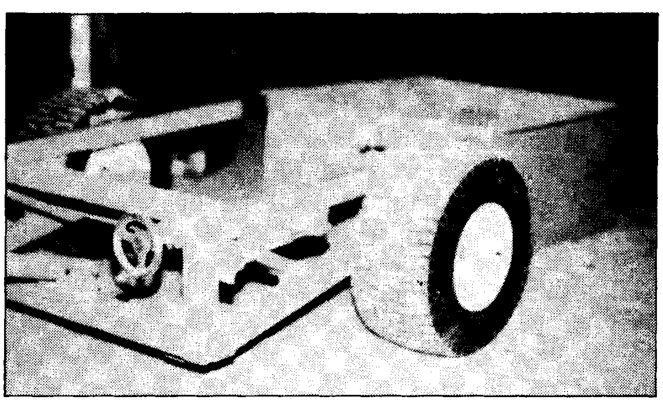

Figure 10.—Container is easily removed from frame of vehicle. Containers with specialized functions may then be attached.

TIMBER CAR

One of the most hazardous materials-handling tasks in underground mining is that of installing crossbeams for roof support. A need was identified for a mechanism to lift beams weighing up to 227 kg (500 lb) to the roof, where they could be held in place until permanent supports could be installed (figs. 11-12). The device shown in the figures utilizes a modified hydraulic floor jack to provide the lift. The jack mechanism is moved manually along a track down the center of the car. This forward-backward movement permits easy positioning of the load. In addition, the jack head rotates to ease positioning of extra-long members.

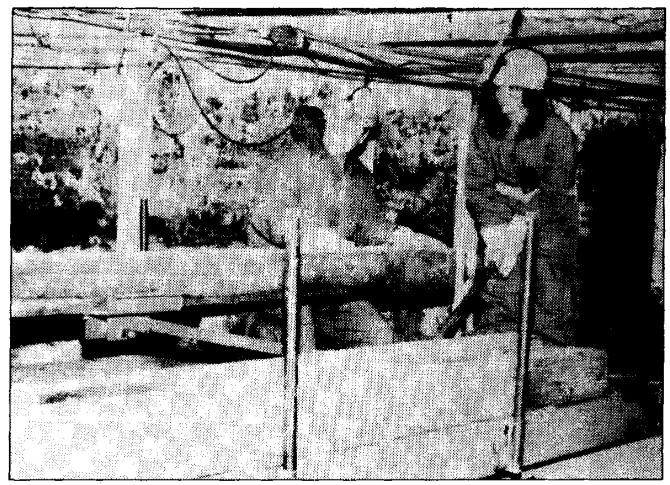

Figure 11.—Timber car during underground tests at Pittsburgh Research Center's safety research coal mine.

Figure 12.—Miners using timber car to raise 39-kg (85-lb) rail for roof support in an eastern Ohio coal mine.

Design features of the timber car include—

1. Up to 227-kg (500-lb) lift capacity with a 152-cm (60-in) lift height (suitable for low- to medium-seam mines).
2. Mounting on a low-profile flatcar, which serves double duty as a 36,287-kg (40-st) capacity supply car.
3. A modified automotive floor jack for the lift mechanism.
4. Jack that can be maneuvered forward or back in its track for close-in maneuvering.

CONCLUSIONS AND RECOMMENDATIONS

On-site visits, task analyses, and interviews suggest that the majority of the risk exposure associated with materials handling in underground coal mines results from the lack of properly designed and easily accessible materials-handling tools, devices, and vehicles. Mine personnel traditionally rely on a "couple of extra hands" or on crowbars, come-alongs, and other makeshift tools to handle even the largest components of mining machinery. Similarly, due to the lack of appropriate tools, carts, and other handling devices, mine personnel manually move timbers, posts, beams, and other heavy materials on a continual basis. In most instances, tools are simply not available for these heavy lifting, transporting, and positioning tasks.

These investigations also revealed that what is needed is not another complex, powered vehicle designed to perform any and all maintenance jobs. Rather, what is required is a series of simple, task-specific tools, aids, and devices to be housed and used in the working sections and maintenance areas. Mine personnel tend not to wait 30 to 60 min while a special vehicle or tool is brought in from another area of the mine. The materials-handling hardware should be relatively easy to fabricate and should, where possible, utilize off-the-shelf components. The hardware should be relatively inexpensive and designed for fabrication in mine shops. The prototypes of six such devices that were developed and tested by the USBM are described in this paper.

There appears to be a sincere interest on the part of mine management and safety and production personnel in reducing injuries related to materials handling. There is also a need for exposure to new ideas, products, and materials-handling mechanization concepts to assist mine personnel in identifying their own unique handling requirements and developing appropriate mechanical solutions to these problems. The concepts presented here were designed to stimulate the development of other mechanization concepts to address mine-specific materials-handling problems.

Three major recommendations are suggested with respect to development of materials-handling devices:

1. *Systems Approach to Materials Handling*.—Many larger mines have developed so-called systems for moving huge quantities of supplies and materials from surface storage areas to in-mine drop points or supply depots. These systems, however, have many missing elements and built-in problems. For example, pallets are utilized to load quantities of 41-kg (90-lb) cement blocks or 45-kg (100-lb) bags of rock dust from the storage onto the supply train. Forklifts or hoists may be used to offload the pallets at the dropoff points. However, personnel must manually load these supplies onto battery-powered vehicles or physically lug them to the point of use. This systems-approach thinking has failed to account for the fact that the blocks still weigh 41 kg (90 lb) and the bags 45 kg (100 lb) apiece when they get into the mine. These loads are too heavy for personnel working in confined workspaces and on unimproved mine floors. If a systems approach is to be used, it should start with the end user or task and work backward from there.

2. *Task-Specific Tools*.—As in any industry, the design of special tools to perform specific tasks is often overlooked. In underground mining, few if any tools or devices have been developed to cope with specific materials-handling tasks. Exposure to high-risk tasks could be substantially reduced if appropriate task-specific tools were available. For example, the transporting of materials through a 91- by 91-cm (3- by 3-ft) door requires the miner to lift a 23- to 45-kg (50- to 100-lb) (or heavier) object, rotate his or her body, and heave the object through the door opening. Exposure to overexertion-type injuries is very high. If a simple slide or materials conveyor was available, the miner could simply pass the material through the opening. Similar aids and mechanical tools are required for handling rail sections, timbers, posts, cribbing materials, etc.

3. *New Technologies*. The search for new technologies is an ongoing process in any industry. In underground mining, however, it is even more important since so little completely new technology has been introduced to this sector. With respect to materials-handling, this search should focus on new, low-cost, reduced-weight materials for mine maintenance and safety applications. It should address improved designs and packaging for manual handling in operational environments. It should cover improved methods of installation and maintenance of the mine and the mining equipment. It should focus on ways of reducing mine maintenance (e.g., cleaning up along belt lines) and machine maintenance (e.g., autolubing systems). It should attempt to replace muscle power (particularly back muscles) with mechanical or hydraulic power.

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Compiled by Robert H. Peters

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