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Improved Personnel Access for Surface Mining Equipment

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CONTENTS

	<u>Page</u>
Abstract.....	1
Introduction.....	2
Safety hazard assessment.....	2
Haulage trucks and front-end loaders.....	3
Access design problems.....	3
Improved ladders.....	7
Development.....	7
Description and use.....	12
Track dozers and shovels.....	13
Access design problems.....	13
Powered safety steps.....	14
Development.....	14
Description and use.....	16
Summary and economic considerations.....	18
References.....	19
Appendix.....	20

ILLUSTRATIONS

1. Typical ladder on off-highway haulage truck.....	3
2. Ladder located at right front of truck.....	4
3. Truck bumper as part of ladder system.....	5
4. Damaged truck ladder.....	6
5. Cable ladder showing height of first step.....	8
6. Cable ladder showing lack of rigidity when stepped on.....	9
7. Pre-tensioned spring step design.....	10
8. Spring step retrofitted to truck ladder.....	11
9. Spring step during collision.....	12
10. Track dozer.....	14
11. Loading shovel.....	15
12. Powered safety step on loading shovel.....	16
13. Powered safety step on track dozer.....	17

TABLES

1. Recommended design dimensions for ladder systems on large haulage trucks and front-end loaders.....	7
2. Pre-tensioned spring specifications.....	10
A-1. Field test locations for pre-tensioned spring step.....	20
A-2. Equipment used for evaluating pre-tensioned spring step.....	20
A-3. Field test locations for powered safety step.....	20
A-4. Equipment used for evaluating powered safety step.....	20

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

deg	degree	lb	pound
ft	foot	pct	percent
in	inch	yr	year

IMPROVED PERSONNEL ACCESS FOR SURFACE MINING EQUIPMENT

By Dennis A. Long¹

ABSTRACT

Slip and fall accidents are a major cause of lost-time injuries associated with large mobile equipment in surface mines. An evaluation of the safety hazards associated with getting on and off large surface mining vehicles showed that most of the accidents occur at the point where personnel attempt to mount or dismount the machine at ground level. The major hazardous design conditions were identified as excessively flexible supports for lower steps or rungs, inappropriate ground-level-to-first-step distances, poor step designs, access designs that use vehicle components as steps or walkways, and inadequate hand-rail and guardrail designs. Additional hazards are introduced by the lack of proper maintenance of ladder hardware and the work practices of operators in carrying articles while mounting and dismounting the vehicle. This Bureau of Mines report describes the design and in-mine testing of improved access systems for large mobile mining equipment.

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INTRODUCTION

Mobile equipment manufacturers and mining companies recognize the difficulty of getting on and off the large mining equipment. Overall, there is a lack of effective guidance and design standards, and access systems appear to have been added as an afterthought in mobile equipment design. Thus, the stringent system design concepts employed for most of the machine features are not generally applied in ladder access designs.

On-site reviews were conducted to identify design deficiencies of access ladders being used in surface mines. These reviews focused on handrail specifications, step and ladder design, step and ladder placement, ground clearance, environment-induced problems, and human factors. General design problems were identified along with numerous specific safety problems.

Design diversity and lack of good safety analysis may be a direct cause of the high slip and fall rates associated with mobile mining equipment. For example, drivers and maintenance personnel must usually work with various types of vehicles, creating a "transfer of training" problem associated with ladders of different designs. In moments of inattention or carelessness, or in emergencies, people react according to how they "expect" to find access hardware. When designs deviate from these expectations (e.g., a step is only half as wide as the one above or below it), the potential for accidents increases.

A review of a large number of mine mobile equipment (1)² identified the following significant design deficiencies:

- Inadequate handrail and guardrail designs, which increase the

difficulty of mounting and dismounting the vehicle.

- Excessively flexible lower section supports for lower steps or rungs on ladders, making ascent or descent difficult.
- Inappropriate ground-level-to-first-step distances, which create hazards.
- Poor step designs that permit accumulations of mud, snow, ice, grease, and oil and create hazardous footing.
- Access paths that require use of equipment components as primary steps, such as the tracks on dozers and shovels.
- Work practices of operators in carrying personal articles on and off the equipment introduce additional hazards.

The access problem involves two types of mobile equipment. The first category includes haulage trucks and front-end loaders. These vehicles have vertical or near vertical ladders in the vicinity of the cab. Analysis has shown that the chief hazards are found in the first few steps of the ladder where the operator mounts or dismounts the machine (2). The second category includes tracked vehicles, such as dozers, shovels, and draglines. These vehicles have one common hazard: the primary access path usually involves using the track as a step, walkway, or both.

The Bureau conducted this investigation to determine and reduce the hazards associated with mounting and dismounting large mine mobile equipment. This report summarizes the research results for each of the two types of equipment, and includes recommendations for alleviating the access problem.

SAFETY HAZARD ASSESSMENT

Evaluation of the safety hazards associated with mobile equipment in surface

mines confirmed that slip and fall accidents account for a substantial proportion of vehicle related accidents. According to 1978-79 data from the Mine Safety and Health Administration (MSHA), U.S. Department of Labor, slips and falls

²Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

while mounting and dismounting machines constitute over one-third of all lost-time accidents associated with the operation of haulage trucks, front-end loaders, track dozers, shovels, and draglines (2). These five types of equipment account for 80 pct of the mobile equipment operating in U.S. surface mines. An average slip and fall results in 15.3 lost worker days and the characteristic injuries resulting from getting on and off mobile equipment are cuts, lacerations, contusions, fractures, sprains, and strains. The hands, fingers, back, legs, and feet are most frequently injured in these accidents (2).

The slip and fall accident reports were further analyzed to determine where in the process of mounting or dismounting the machine people are getting hurt. The analysis revealed that 40 pct of all surface mine equipment slip and fall accidents occurred at the first step on the vehicle; that is, during the operator's initial attempt to mount or dismount the vehicle, with the accident occurring at the zone between the equipment and the ground (2). Nearly 60 pct of all slip and fall accidents involving track dozers occur at this point.

HAULAGE TRUCKS AND FRONT-END LOADERS

ACCESS DESIGN PROBLEMS

Off-highway haulage trucks usually have ladders mounted on the front of the truck

adjacent to the left side of the engine compartment (figs. 1-2), with the angle of inclination between 75° to 90° (vertical). On some model trucks, the bumper



FIGURE 1. - Typical ladder on off-highway haulage truck.

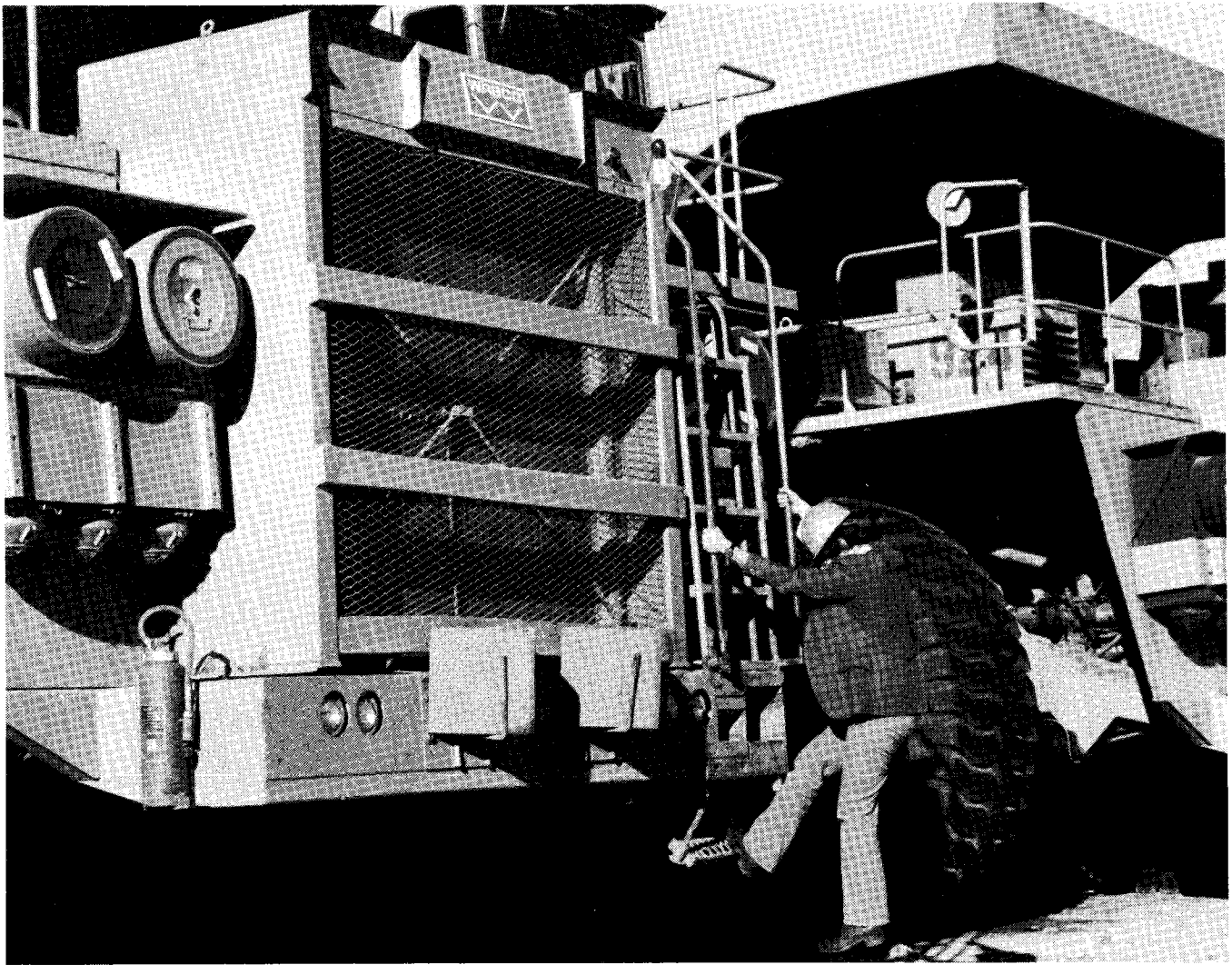


FIGURE 2. - Ladder located at right front of truck.

is used as part of the ladder structure (fig. 3). Most of the designs have lower steps supported by flexible material such as wire rope, chain, or a rubber belting material.

The ladders used on almost all front-end loaders are located directly alongside the cab. This design forces the operator to change direction in the middle of the ladder in order to open the door. He must also negotiate a difficult transition from the ladder into the cab. Some front-end loaders have a movable or retractable ladder that the operator must pull down to mount the vehicle.

Ladders provided as original equipment are often easily damaged once the vehicle

operates in the mine environment, and even slight damage can render them inoperable. A damaged ladder represents a safety hazard (fig. 4). In many cases, after making numerous repairs, the mine maintenance shop personnel will construct a ladder from available scrap steel, cable, and grip-strut material. Consequently, a wide range of ladder designs exists throughout the mining industry. Ladder reliability is directly related to the complexity, placement, and quality of installation.

The most significant problem or deficiency of the primary ladder system is the lower steps. Within the open pit mine environment, the problem of vehicle ground clearance is critical; the truck

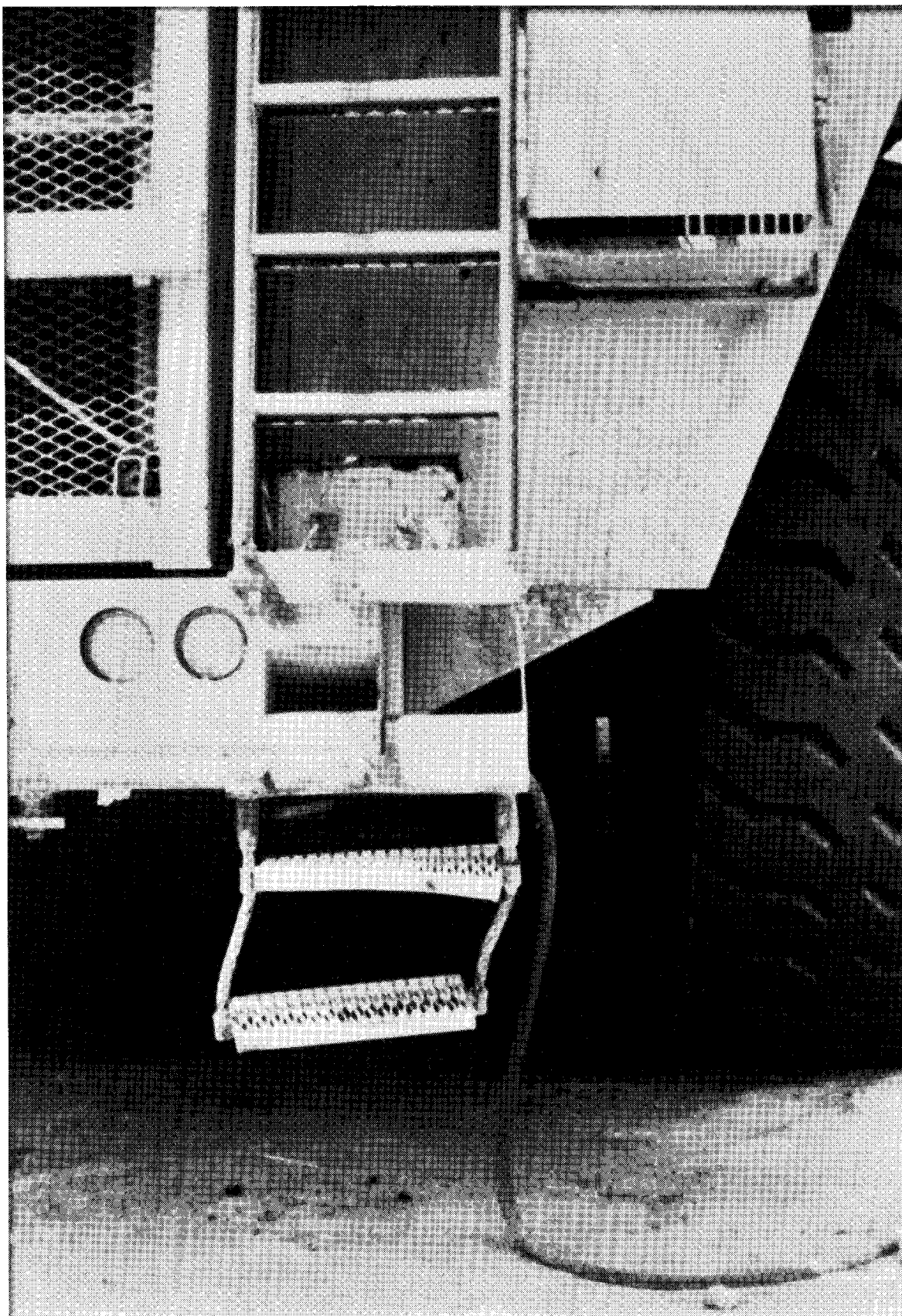


FIGURE 3. - Truck bumper as part of ladder system.

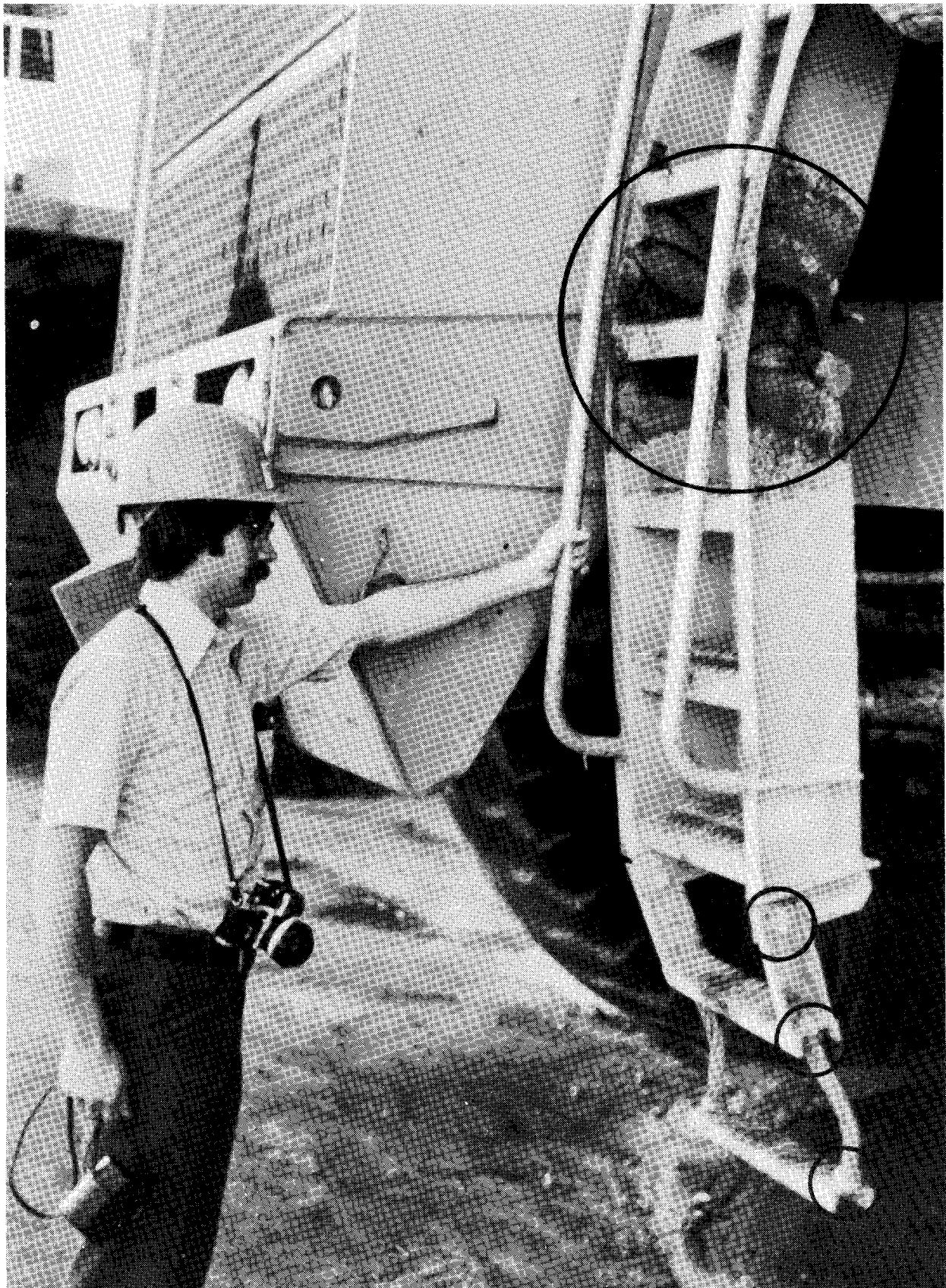


FIGURE 4. - Damaged truck ladder.

is designed to ensure the maximum possible ground clearance. The lower portion of the primary ladder assembly must be below this level for the operator to reach the first step, placing the first two steps in a vulnerable position. As a result, the ladders are subjected to continual impacts from the objects in the roadway.

To minimize damage, lower ladder supports are usually constructed from a very flexible material. Usually this means suspending the lower one or two steps on a cable which is then mounted to the bumper or the ladder. These wire rope or cable ladders are invariably knocked out of position, and do not return to their initial configuration (figs. 5-6). The height of the lower rung is usually about 36 to 42 in above the ground. Drivers and other personnel ascending or descending the vehicle using these damaged lower steps are subject to knee and shin bruises, scrapes, or worse. The flexibility of the ladder supports for the lower steps and the fact that the steps are too high for the operator to mount and dismount the machine safely contributes to the slip and fall accidents.

IMPROVED LADDERS

Development

In 1978, the Bureau of Mines began to design and develop improved ladder designs for haulage trucks and loaders. Several alternative designs were subjected to human-factor field evaluation and structural testing demonstrations in various surface mines. The effort was first focused on off-highway haulage trucks, and design recommendations were developed for improved total access systems. Table 1 summarizes the recommended ladder dimension systems for large haulage trucks and loaders (3). Field investigations showed that the most serious design deficiencies were at the lower end of the ladders; further Bureau of Mines research focused on solving the problem of the lower ladder design.

Several primary lower ladder designs were subjected to use by mine personnel and field evaluation, and structural-testing demonstrations. As a result of the initial field demonstrations, it was concluded that the four-spring design (figs. 7-8) could appreciably reduce slip

TABLE 1. - Recommended design dimensions for ladder systems on large haulage trucks and front-end loaders (3)

Parameter	Specification	
	Minimum	Maximum
Angle of inclination.....deg..	76	90
Step dimensions, in:		
First-step height above ground.....	None	28
Distance between steps ¹	10	12
Distance from top step to platform.....	10	12
Ladder depth ²	8	10
Step width.....	12	16
Step depth ³	4-3/4	7-1/2
Handrail dimensions, in:		
Diameter.....	3/4	1-1/2
Height above ground.....	28	56
Width between at ground level.....	18	21
Hand clearance.....	3	None
Height above landing.....	33	36

¹Measured vertically from top of step to top of step.

²To provide a minimum of 3 in from back of step to pan for toe clearance and a passage for debris to drop through.

³Standard dimensions for grip-strut step material.



FIGURE 5. - Cable ladder showing height of first step.



FIGURE 6. - Cable ladder showing lack of rigidity when stepped on.

and fall accidents on haulage trucks and loaders. The first-generation spring steps were evaluated for operator acceptability and structural performance at the Cyprus Pima Mine, south of Tucson, AZ, in 1978, and at the Bingham Canyon Mine, near Salt Lake City, UT, in 1979 (4).

The prototype lower steps substantially reduced the height of the first step and were much more rigid when stepped on, or off. Because of their high stiffness coefficient and the pre-tensioning of the springs, the prototype lower steps closely maintained the step distance and the angular inclination of the ladder. However, the pre-tensioned springs used in the first step proved to be too brittle to withstand the rugged mine environment.

The test program demonstrated that proper installation techniques were important for the survivability of the spring step. These techniques include good welding practices and proper

placement of the spring step on the mine vehicle. For example, a step mounted either directly on the bumper or on the side of the vehicle is likely to have limited survivability.

As a result of the in-mine testing, a second-generation pre-tensioned spring step was developed. The second-generation design parameters are listed in table 2. The most significant change was to adopt a modular design; rather than a one-piece welded unit, the grip-strut steps and each two-spring set are replaceable as individual parts. Further development has made the pre-tensioned springs more durable, using more rigid spring steel and different welding techniques.

A followup testing program was conducted at seven surface mines, where various types of haulage trucks larger than 100-ton capacity were fitted with ladders of the new design (2). The

TABLE 2. - Pre-tensioned spring specifications

Material.....	Chrome-nickel steel, 17-7 pH (ASTM 3-313 or AMS 5678)
Rockwell hardness.....	47-52, C-scale
Spring, OD.....in..	1.75±0.030
Wire size.....in..	0.312
Type of ends.....	Ground, plain
Direction of helix.....	LH, optional
Pre-tension.....lb..	150±10
Free length.....in..	11-1/8

NOTE.--Tensile test coupons 8 in long should be taken of wire before winding each spring lot and also of each heat lot and shipped with springs for quality control.

ladders were subjected to normal operating use for at least 1 yr, during which evaluations were made of the safety, maintenance, and driver acceptance of the spring step. Further field testing of the pre-tensioned spring step is being conducted at six additional mines using a

variety of mobile equipment. The mines and equipment are listed in the appendix tables. Table A-1 identifies the mines where the spring step has been field tested, and table A-2 lists the surface mining equipment on which spring steps have been installed.

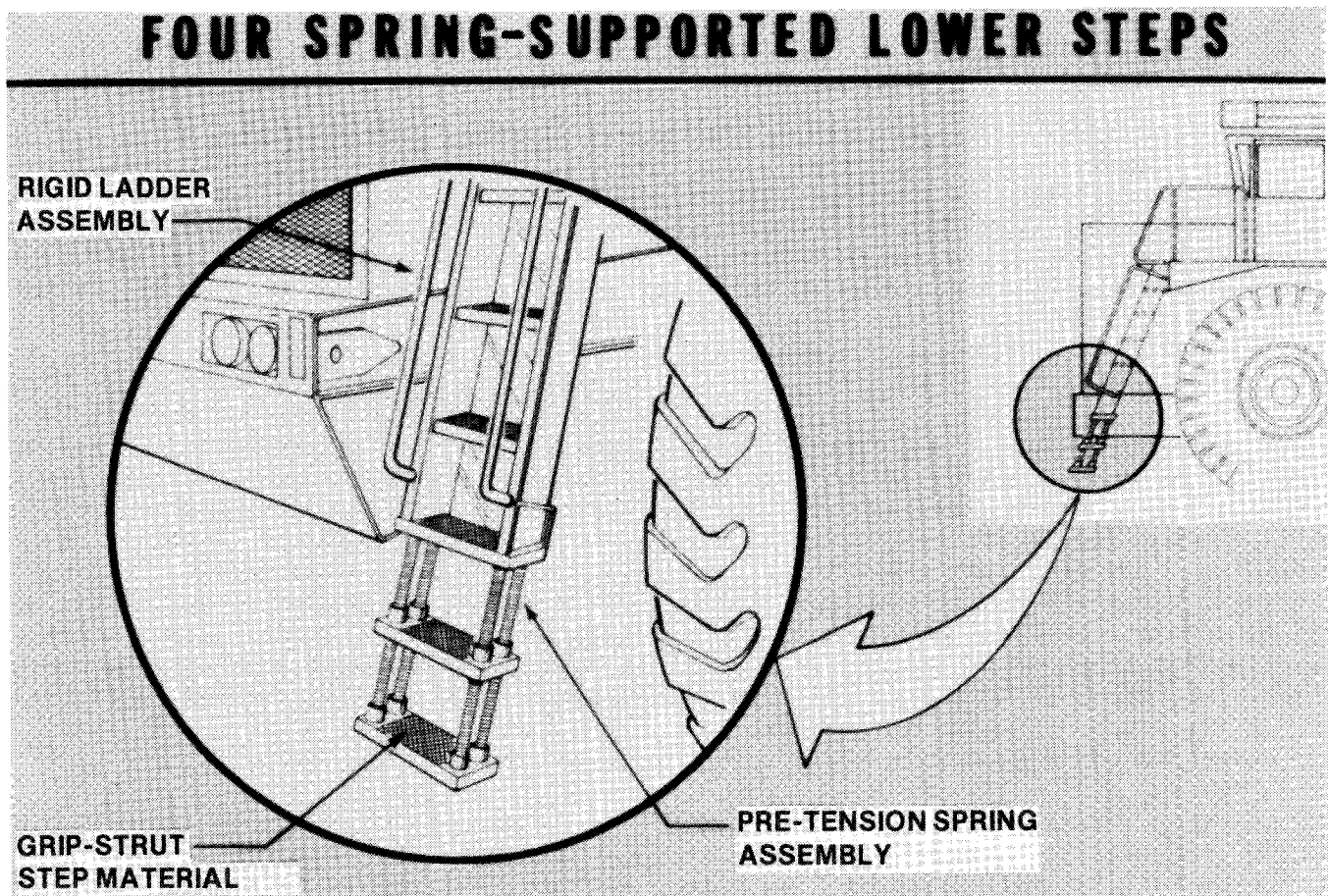


FIGURE 7. - Pre-tensioned spring step design.



FIGURE 8. - Spring step retrofitted to truck ladder.

Since 1978, about 30 spring steps were field tested at 13 mines on 27 vehicles. The results of the field testing indicate that the pre-tensioned spring step can help prevent first-step accidents. However, the testing also shows that proper installation techniques, correct vehicle applications, and management support for proper maintenance are important for long life of the spring step. Spring-step failure occurred for a variety of reasons, and the damage inflicted on the spring ladders varied greatly from mine to mine. At some mines, the ladders sustained damage after 3 or 4 weeks; at others, ladders remained on the trucks with little or no damage for more than a year. The most common reasons for failure included shear at the point where the step is welded to the ladder, spring failure resulting from low ground clearance, and lack of operator or supervisory acceptance. Some damage seemed to be a

result of a misconception that the Bureau of Mines spring step is indestructible. In several cases, the vehicle operator may have been experimenting to see how much punishment the spring step could withstand.

In summary, the following include the results from the long-term field tests. These points should be considered in all future spring step applications:

1. The ladders should be mounted higher than they were in most of the test installations. The spring failures occurred mostly at the connection of the upper supporting springs and the collar. By mounting it higher, this connection would be more protected. Although Society of Automotive Engineers (SAE) standards advise a 28-in minimum ground clearance, best results will occur at heights greater than 30 in. In mines

that have parking ditches or extraordinary ground clearance problems (soft, muddy haulroads or special guide berms), the operator should ensure that the bottom of the step will not undergo continuous ground impact.

2. Never install the spring step directly on the bumper. This causes large shear forces to develop at the top of the step.

3. Proper welding and installation techniques are important. Normally, installation will take around 2 worker hours, and should be supervised.

4. The spring step should only be installed perpendicular to primary vehicle movement; e.g., never install the spring step on the side of a haulage truck.

5. Where possible, the complete three-step unit (as shown in figure 7) should be used, even if part of the existing ladder must be cut off to maintain sufficient ground clearance.

6. Keep the step weight as low as possible by using lighter gauge metal.

7. Spring step width should correspond to the overall ladder width; and a 15-in step width for front-end loaders and rubber-tired dozers.

Description and Use

The spring ladder concept is shown in figure 9. The design is to provide the operator with basic human-factor design and to minimize damage to the lower steps on the primary ladder system. The

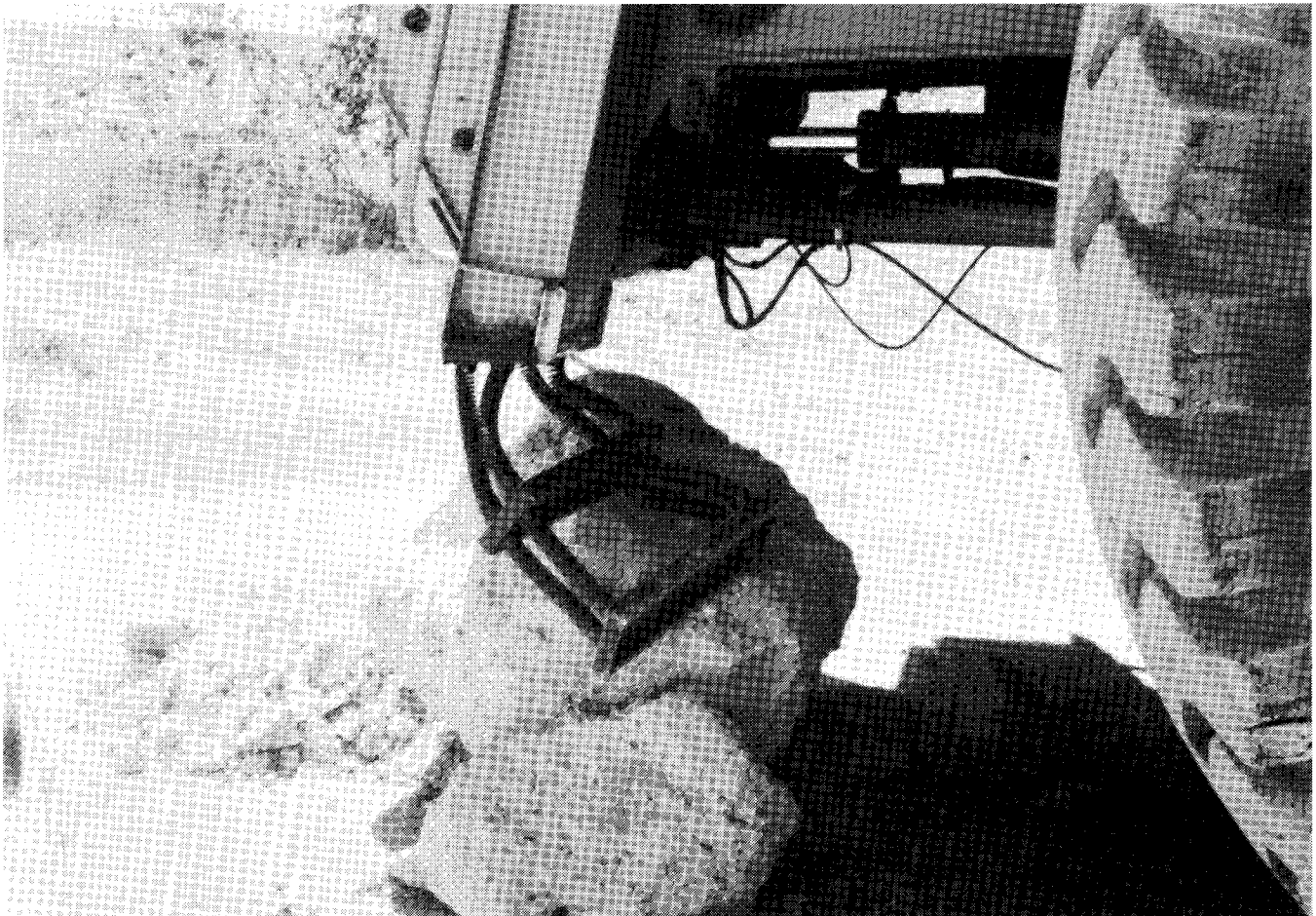


FIGURE 9. - Spring step during collision.

ladders are designed to deflect with minimal damage when impacting an object, but support the weight of the operator with minimal deflection (less than 2 in).

The steps are highly resistant to collision damage because they yield on impact if rammed into obstructions such as rocks or berms. The ground clearance required for rigid ladders mounted on large mining equipment is commonly 36 to 42 in. The flexibility of the durable spring-mounted supports allows the new ladders to be mounted with the bottom step between 24 and 36 in above the ground, depending on the application.

The spring step is a totally passive system; i.e., it needs no activation by the operator. The unit consists of two steps constructed with grip-strut material to minimize the accumulation of debris and provide an antiskid surface for good footing. The steps are joined with two pairs of spring assemblies and mounting brackets. The mounting brackets consist of a flat plate and a collar to support the spring, which is welded to the flat plate. The springs are fabricated

from stainless steel and pre-tensioned to 150 lb. The best results will be obtained by following the specifications developed in Bureau of Mines contract (2). The entire primary ladder assembly, including the spring ladder, should conform to the SAE requirements (3). These SAE recommendations cover access systems for large construction and mining machines, and specify ladder inclination, handrail dimensions and clearance, rung spacing, rung width, and other features.

There are other options available for using the spring step. On some trucks, a single-step spring ladder was installed in place of the standard oil check step. These ladders underwent no damage during the course of the program, but these steps were in a more protected area mounted under the engine compartment. On certain front-end loaders and smaller haulage trucks, a single-step ladder (one-half of ladder shown in figure 7) was installed at the bottom of the ladder. However, wherever possible, the double spring step should be used for optimum survivability.

TRACK DOZERS AND SHOVELS

ACCESS DESIGN PROBLEMS

Over the past decade, the size of track dozers in surface mines has increased substantially. Today the operator must climb 4 ft or more to mount the dozer, usually stepping onto or climbing over the track assembly. Because of the harsh working environment encountered by the dozer, the tracks are usually covered by mud, snow, or ice, making them an unsatisfactory accessway.

On some dozers, the track assembly is the only way to mount the vehicle (fig. 10). In this situation, the operator must use the track grips to mount the dozer at the rear of the machine, then walk on the track to reach the cab. On certain large dozers, the person must mount the machine at the front by stepping onto the blade arm and then walking along the track to enter the cab. On

some machines, the person uses a toe-hole in the side track frame, then steps up to the track. In any event, the distance from the ground to the track usually exceeds 48 in, presenting a challenge under any environmental condition.

The ladders and stair systems used on mining shovels and draglines vary in quality of design and safety. Many of the larger excavators use electricity or hydraulically operated stairways for access to the main decking or cab. Small to medium machines often utilize several variations of the pull-down and counterbalanced-stair systems (fig. 11).

The Bureau's work determined that the design area requiring the most work was the zone where the operator mounts or dismounts the piece of equipment. Almost all models require the operator to climb over the track assembly. An improved

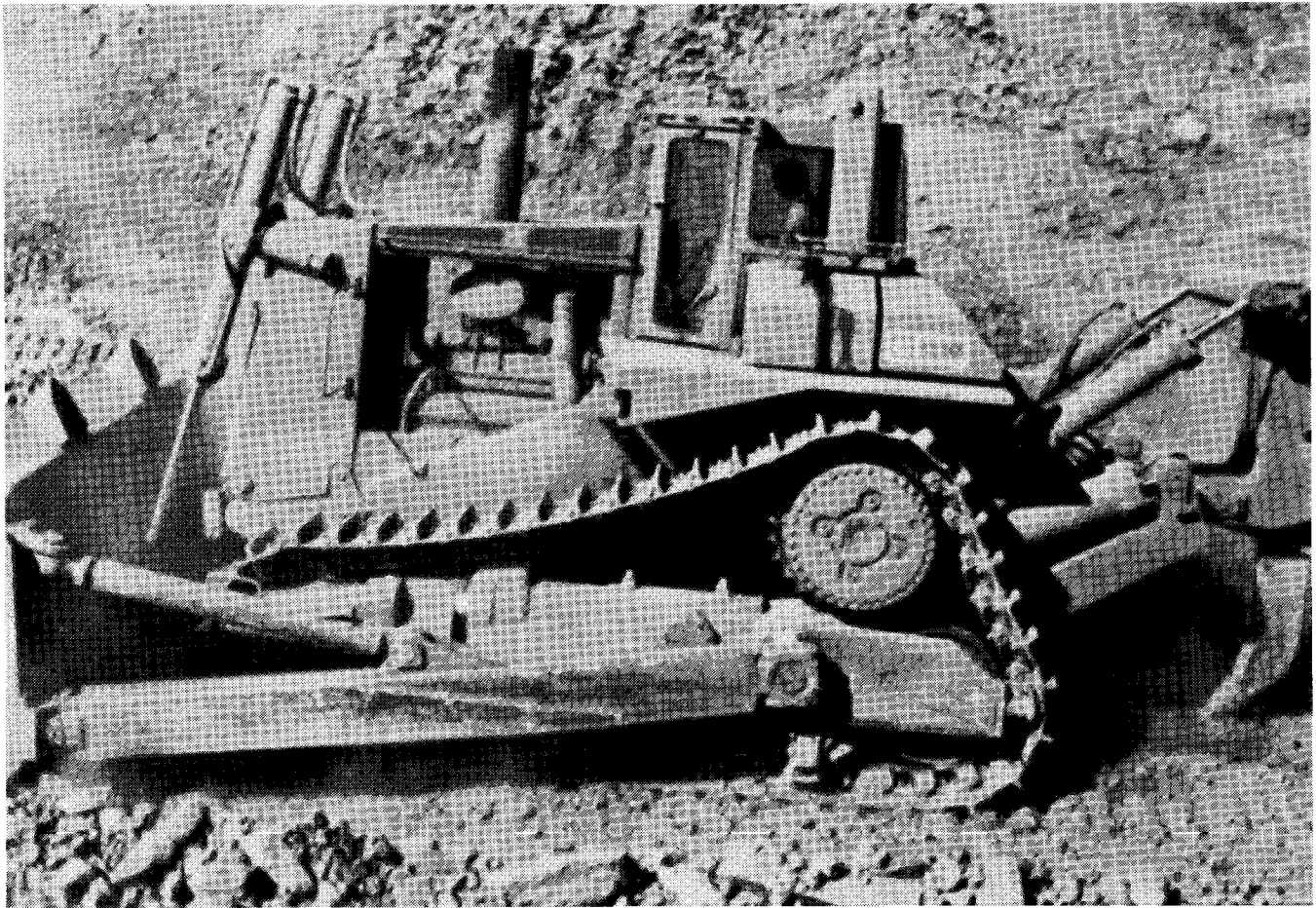


FIGURE 10. - Track dozer.

system would result in a safer method of transporting operators and materials up and over the track assembly.

There have been several efforts to devise alternative entry systems for track dozers and shovels. One method used a ladder extending out over the tracks. A second method entailed the use of a loading berm that the dozer pulled up next to, permitting the operator to exit via the berm, rather than having to climb down the tracks. A third method, sponsored by the Bureau of Mines on a cost-sharing basis, uses a hydraulic lift "power step" to transport the person from the ground level to the cab. This development has proved to be a practicable solution to the access problem on track dozers and shovels.

POWERED SAFETY STEP

Development

The powered safety step was designed in 1975. A prototype unit was installed on a Caterpillar 16G grader at Consolidation Coal Co.'s Glenharold Mine, near Stanton, ND. This unit is still in operation after 7 yr of continuous service. In view of its potential to reduce the number of accidents caused by slips and falls from large mining equipment, in 1978 the Bureau of Mines began working with the powered step on a cost-sharing basis to make the technology more mine-worthy. This work included developing and fabricating step-design alternatives, and conducting in-mine tests to determine

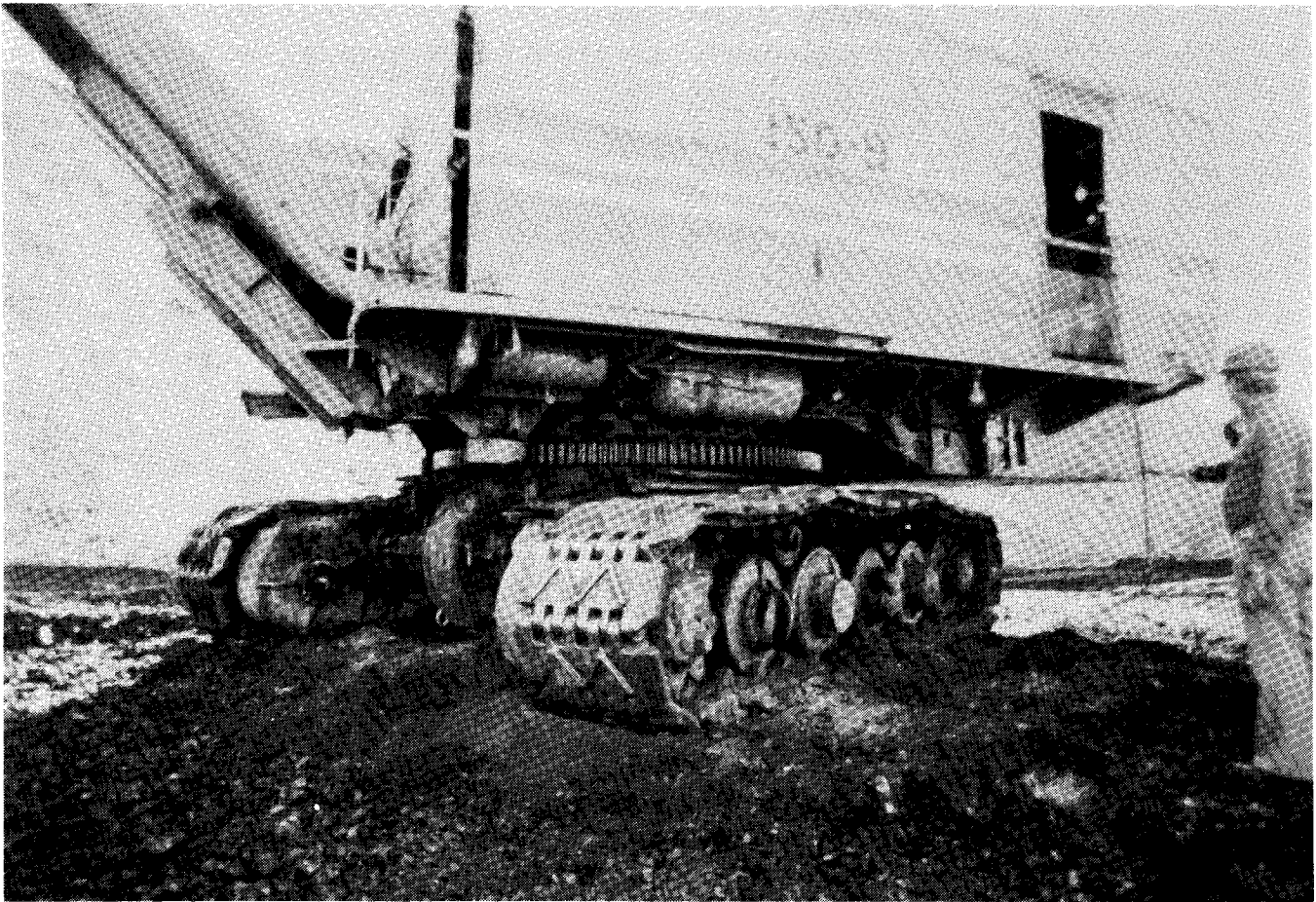


FIGURE 11. - Loading shovel.

survivability of the step in the rugged mine environment.

Since 1978, the powered step has been field tested at different mines in North Dakota, Indiana, Illinois, Wyoming, and Tennessee. Thirty of the test units are still in operation and many more have been sold commercially during the past 2 yr. Current installations of the powered step include loading shovels, track dozers, draglines, haulage trucks, and graders. Table A-3 lists the field test locations, and table A-4 lists the mining equipment on which the powered steps have been installed.

The results of the field testing have proved conclusively that the powered safety step can solve the problem of mounting and dismounting tracked mining vehicles. Almost 90 pct of the powered step units are still in use today on the

original machines; several step units have been in continual use for more than 5 yr. The mines have reported that maintenance is surprisingly low and survival is high.

Almost without fail, installations on shovels, draglines, and dozers have proved successful over the long-term. More recently, installations on haulage trucks, graders, and scrapers have shown promising results. The following comments were made by the mine personnel involved with the field testing of the powered steps:

- "The safety steps that we have on our equipment are well accepted by employees and management."

- "We feel that slip and fall accidents have been virtually zero since we installed these steps. They have been

accepted by the mining crews, and they would not be without them."

- "It is the best method for getting on and off large shovels that I have ever seen. We plan to install similar apparatus on all our shovels. We have not had any accidents with the powered steps. Very well accepted by all employees."

- "I have been associated with these powered steps from the very beginning. We have had very few maintenance problems with the step."

Description and Use

The powered safety step is a hydraulically powered device to lift personnel and materials from the ground to working levels on large equipment (figs. 12-13). The primary application of the powered step is for the large track dozers, shovels, and draglines. It eliminates

hazardous blind steps, and makes it unnecessary for the operator to climb on irregular surfaces such as the track or push arm (5).

The step is activated by a self-contained electric-hydraulic unit. Power comes either from the vehicle's auxiliary power supply or from its own battery source, depending on the application. When the step is in the "down" position, it rests approximately 15 in from ground level. When the machine is operating, the step automatically locks in the "up" position, protecting it against damaging obstructions. Visual alarms and machine interlocks are provided where necessary to prevent machine operation when the step is in the "down" position. On rotating machines, such as draglines and shovels, an electrical interlock is provided to prevent operation of the swing motors when the step is down (5).

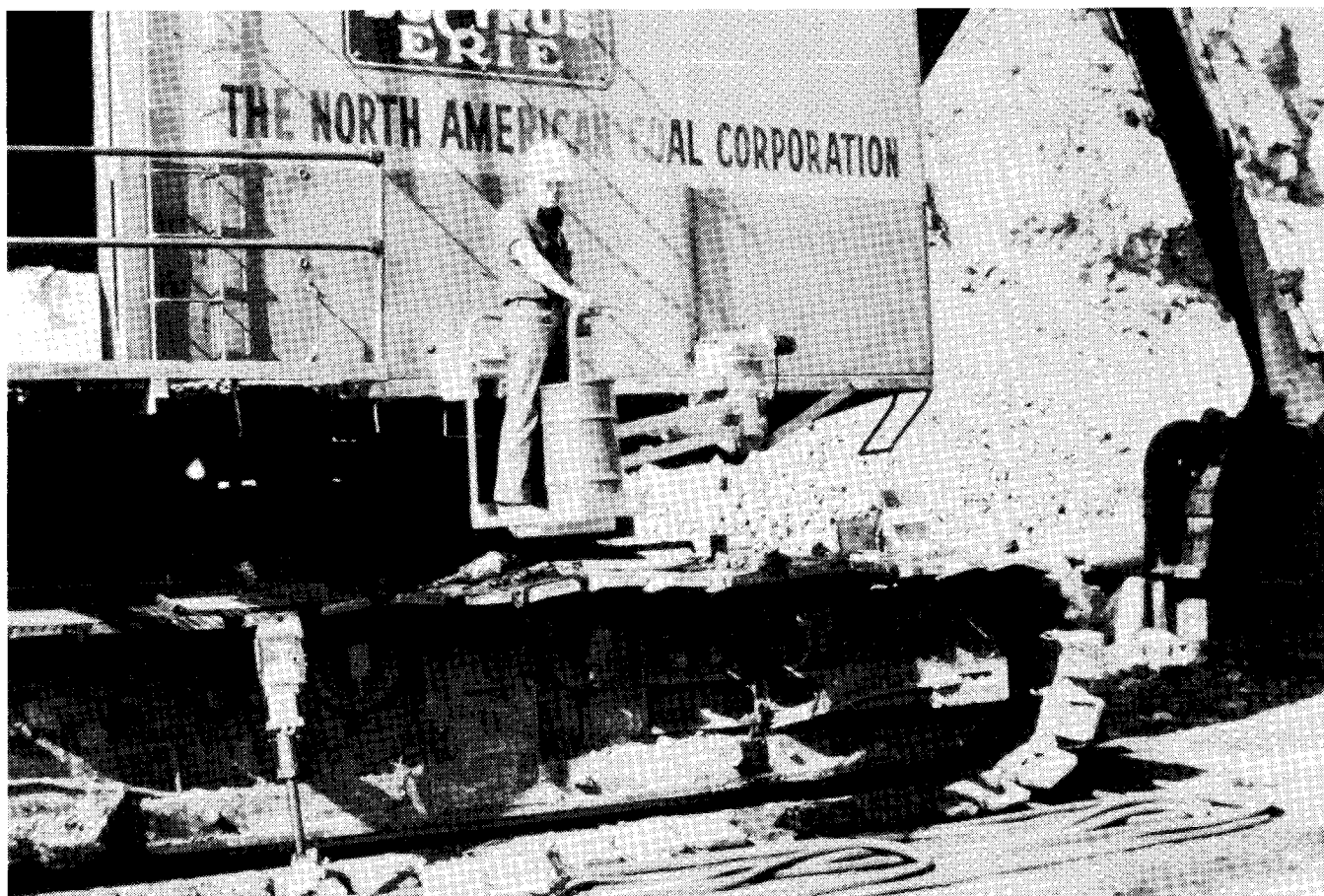


FIGURE 12. - Powered safety step on loading shovel.

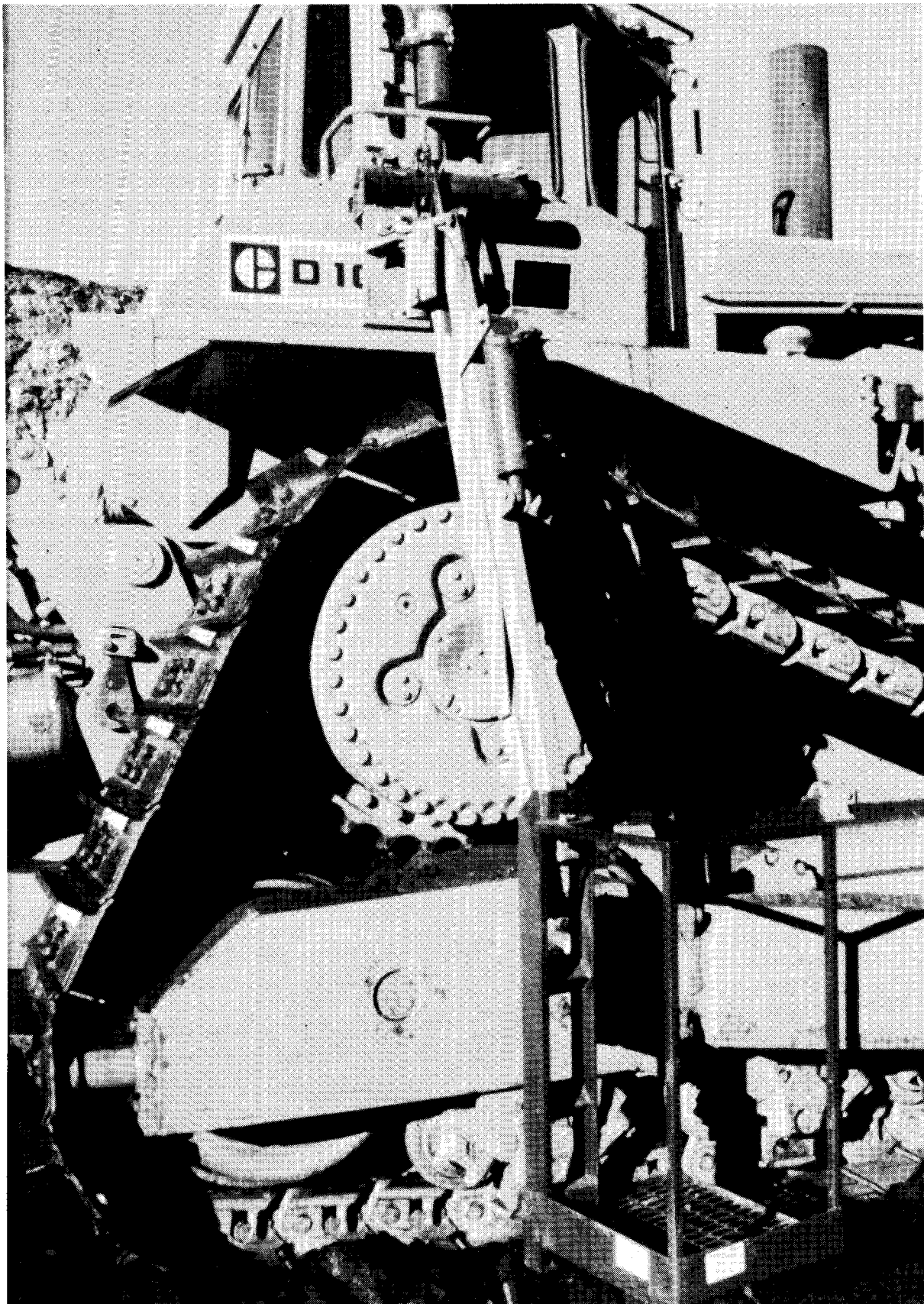


FIGURE 13. - Powered safety step on track dozer.

During step operation, when the power unit is activated with an electrical switch located on the step, a single cylinder attached between two lifting arms smoothly lifts the step. The step is lowered by activating a pressure-release solenoid, bypassing the hydraulic pump. The hydraulic fluid is released through an in-line orifice, controlling the downward speed and preventing free fall. On most machines, additional control switches are located at ground level and in the cab.

There are two basic designs of the powered safety step. One operates only in the "up" and "down" directions. The second design, using a linkage and bearing arrangement on the mounting end of the lift arms, rotates the step toward the machine in conjunction with the lifting motion. Thus, the step moves in an arc from ground level to platform level. Each design is suited for specific applications. With minor modifications, a powered step can be adapted to any type or model of large machinery.

SUMMARY AND ECONOMIC CONSIDERATIONS

Evaluation of the safety hazards associated with large mobile mining equipment has confirmed that slip and fall accidents account for a substantial proportion of vehicle-related accidents. Slips and falls while ascending or descending equipment constitute over one-third of all lost-time accidents associated with the operation of haulage trucks, front-end loaders, track dozers, shovels, and draglines. As a result, the Bureau of Mines initiated a program to develop and in-mine test improved access systems to reduce the hazards associated with mounting and dismounting large equipment.

For haulage trucks and front-end loaders, the Bureau of Mines developed a pre-tensioned step. The spring steps are designed to rigidly support the weight of the operator as he or she steps up onto the equipment, and are highly resistant to collision damage because they yield on impact if rammed into obstructions such as rocks or berms. Because the spring-mounted supports are flexible and durable, the improved ladders can be mounted with the bottom step 30 in above the ground.

The improved spring steps can be installed on existing haulage trucks or new ones at reasonable cost; they cost more than the current cable steps, but maintenance and repair costs are substantially less, with individual replaceable parts. The complete step would cost around \$400 under large-scale production

and marketing. Although the spring-step units are commercially available, the Bureau recommends that individual mines operators construct their own spring steps using the design concepts developed in this project. The pre-tensioned springs can be purchased in bulk quantity, and the step unit could be constructed by mine personnel and using locally available material.

In order to reach the cab of track dozers, shovels, and draglines, the operator must climb up and over the tracks; the tracks are usually a part of the primary access system. Because of the environment in which the equipment must operate, those tracks are usually covered by mud, snow, or ice, making them an unsatisfactory accessway. The most hazardous area is the zone where the operator mounts or dismounts the dozer or shovel. The height of the first step is most significant in all cases where the track assembly must be climbed over.

Through a cost-sharing agreement, the Bureau has helped to develop and test a hydraulic lift safety step to transport people and supplies from the ground to working levels on large surface mining equipment. The powered step has proved to be a safe, effective method of transporting operators and material over the track assembly. The primary application of the powered step is for the large track dozers, shovels, and draglines. It eliminates hazardous blind steps and

makes it unnecessary to climb on irregular surfaces, such as the track or push arm.

The cost of the powered step ranges from \$2,000 to \$5,000, depending on the equipment application. The low-maintenance record should justify the installation of the powered step, especially when compared to the overall cost of

shovels, draglines, or dozers. Installations are recommended for most large dozers except at mines where the dozer must work in close, confining conditions. The powered step has proved to be a reliable, maintenance-free safety improvement in mobile surface mining equipment, and mine operators are encouraged to investigate the application of this new technology.

REFERENCES

1. Gavan, G. A., D. P. Strassel, and D. A. Johnson. The Development of Improved Ingress/Egress Systems for Large Haulage Trucks. Pres. at SAE Earthmoving Industry Conf. (Peoria, IL, Apr. 14-16, 1980). SAE Tech. Paper 800680, 1980, 7 pp.
2. Gavan, G. A., P. Mote, D. P. Strassel, and K. Conway. Development and Demonstration of Improved Truck Ladders (contract H0282001, Woodward Associates, Inc.). BuMines OFR 87-81, 1979, 332 pp.; NTIS PB 81-223406.
3. Society of Automotive Engineers. Access Systems for Off-Road Machines. SAE J185, June 1981, 6 pp.
4. Johnson, D. A. Improved Ingress/Egress Systems For Large Haulage Trucks: Development and In-Mine Testing. Paper in Surface Mine Truck Safety. Proceedings: Bureau of Mines Technology Transfer Seminars, Minneapolis, MN, June 25, 1980; Birmingham, AL, July 9, 1980; and Tucson, AZ, July 24, 1980, Comp. by Staff, Bureau of Mines. BuMines IC 8828, 1980, pp. 40-51.
5. Winters, K. Analysis of the Powered Safety Step Ingress/Egress System for the Caterpillar D10 Crawler Tractor (contract P3391232, Woodward Associates, Inc.). BuMines Final Report, 1979, 65 pp.; available upon request from D. A. Long, BuMines, Minneapolis, MN.

APPENDIX

TABLE A-1. - Field test locations for pre-tensioned spring step

Mine	Operator	State
Bingham Canyon.....	Kennecott.....	Utah.
Bonner Springs Quarry	Lone Star.....	Kansas.
Cyprus Pima.....	AMOCO Minerals....	Arizona.
Detroit Salt.....	International Salt	Michigan.
Erie.....	Pickands Mather...	Minnesota.
Georgetown.....	CONSOL.....	Ohio.
Hibbing Taconite.....	Pickands Mather...	Minnesota.
Indianhead.....	North American....	North Dakota.
Leahy.....	AMAX.....	Illinois.
Martiki.....	MAPCO.....	Kentucky.
Minntac.....	U.S. Steel.....	Minnesota.
Minorca.....	Inland Steel.....	Do.
Pinto Valley.....	Newmont.....	Arizona.
Tilden.....	Cleveland-Cliffs..	Michigan.
White Pine.....	Copper Range.....	Do.

TABLE A-2. - Equipment used for evaluating pre-tensioned spring step

Equipment	Manufacturer and model
Bottom dump coal hauler.....	Dart 4120, 4150.
Loader.....	Caterpillar 988B.
	Michigan 275B.
Rear dump truck.....	Caterpillar 777.
	Dart 2085.
	Euclid R-85, R-170.
	Terex 170.
	Unit Rig M36.
	Wabco 120 C, 120 D, 170.
Scraper.....	Caterpillar 657 B.

TABLE A-3. - Field test locations for powered safety step

Mine	Operator	State	Mine	Operator	State
Ayshire....	AMAX.....	Indiana.	Delta.....	AMAX.....	Illinois.
Belle Ayr..	...do.....	Wyoming.	Falkirk....	North American.	North Dakota.
Beulah....	Knife River....	North Dakota.	Glenharold.	CONSOL.....	Do.
Black Butte	Black Butte....	Wyoming.	Hooker.....	Hooker Chemical	Tennessee.
Center.....	Baukol Noonan..	North Dakota.	Indianhead.	North American.	North Dakota.
Chinook....	AMAX.....	Indiana.	Minnehaha..	AMAX.....	Indiana.
Cordero....	Sunoco.....	Wyoming.	Seminole....	Arch Mineral...	Wyoming.

TABLE A-4. - Equipment used for evaluating powered safety step

Equipment	Manufacture and model	Equipment	Manufacture and model
Haulage truck	Unit Rig BD-180.	Scraper.....	Caterpillar 657.
Dozer.....	Caterpillar D7-G, D9-L, D10.	Shovel.....	Bucyrus Erie 155 B, 190 B, 195 B, 290 B, 295 B.
	Fiat-Allis HD41 B.		Marion 151 M, 182 M, 192 M, 201 M.
	Komatsu D455A-1.		P & H 2300.
Dragline.....	Bucyrus Erie 1570 W.		
Grader.....	Caterpillar 16G.		