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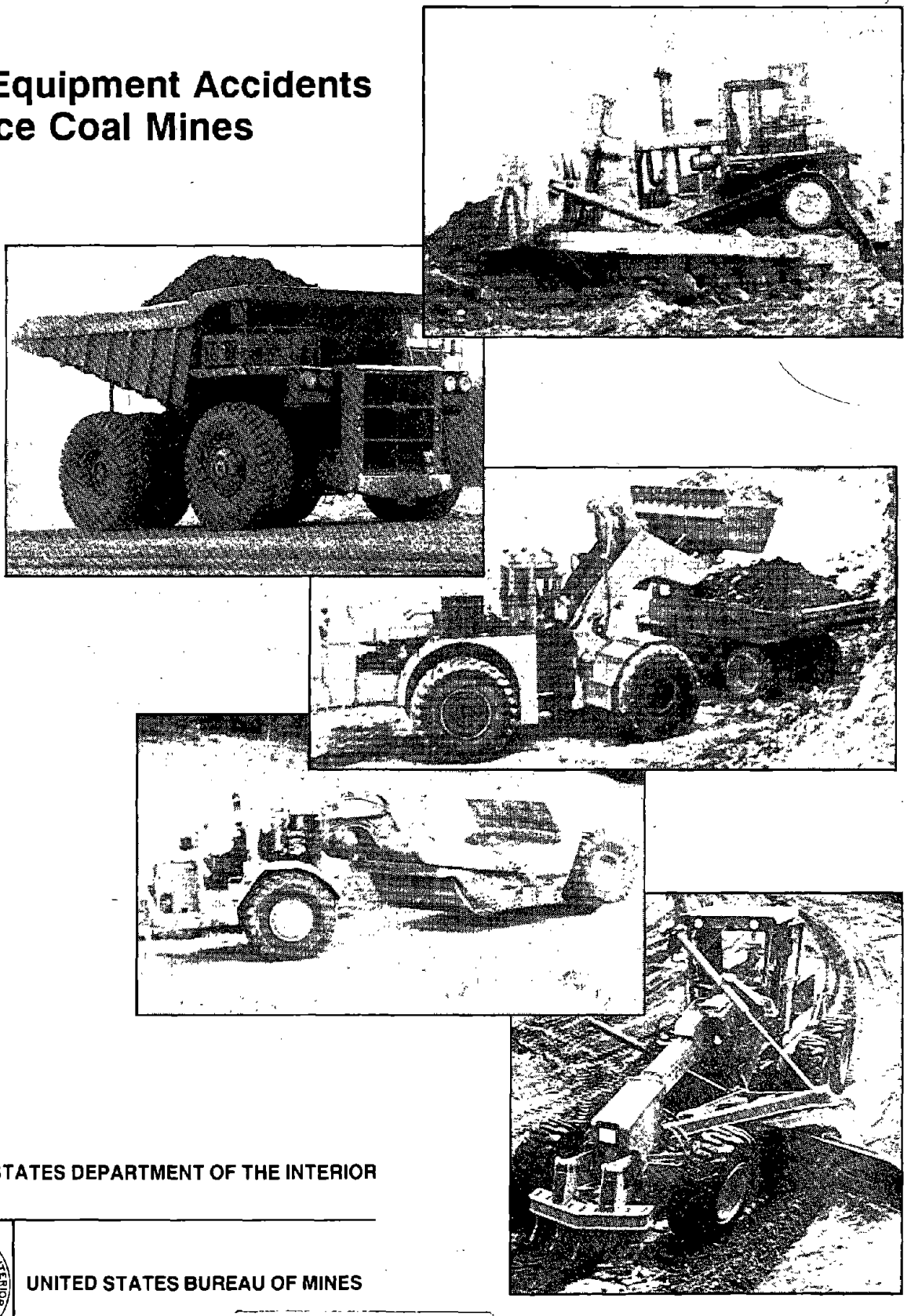
INFORMATION CIRCULAR/1995

Mobile Equipment Accidents in Surface Coal Mines



UNITED STATES DEPARTMENT OF THE INTERIOR

UNITED STATES BUREAU OF MINES

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Cover: Bulldozers, haulage trucks, front-end loaders, scrapers, and graders are the five types of surface mine mobile equipment covered by this report.

Information Circular 9428

Mobile Equipment Accidents in Surface Coal Mines

By Jeffrey A. Aldinger, Jean M. Kenney,
and Christopher M. Keran

UNITED STATES DEPARTMENT OF THE INTERIOR
Bruce Babbitt, Secretary

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

Metric Units

kW	kilowatt	Mt	million metric ton
m	meter	pct	percent
m^3	cubic meter	t	ton (metric)

U.S. Customary Units

ft	foot	st	ton, short
ft^3	cubic foot	yd^3	cubic yard
hp	horsepower		

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MOBILE EQUIPMENT ACCIDENTS IN SURFACE COAL MINES

By Jeffrey A. Aldinger,[1] Jean M. Kenney,[2] and Christopher M. Keran[3]

ABSTRACT

This U.S. Bureau of Mines report presents an analysis of surface coal mining accidents involving mobile equipment for the years 1989 through 1991. Mobile equipment is defined as haulage trucks, front-end loaders, bulldozers, scrapers, and road graders. These five pieces of mining equipment accounted for 20 pct of all surface coal mine accidents and 41 pct of the fatalities. The general discussion of these accidents covers the accident causes, the primary activity of the accident victims, and other contributing factors. A more detailed analysis of accidents associated with each piece of mobile equipment is also provided. This report will provide mine managers and mine safety personnel with a better understanding of the hazards associated with mobile mining equipment. It identifies where improvements in mobile equipment safety can be made and those areas requiring additional safety emphasis, such as safety training, work procedure changes, or engineering changes to the equipment or work environment. The analysis was performed by a team of researchers using accident data and narratives provided by the Mine Safety and Health Administration.

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INTRODUCTION

This U.S. Bureau of Mines (USBM) report provides detailed information on the accidents and injuries associated with the operation, maintenance and repair of surface coal mine mobile equipment. This report provides details of accidents associated with haulage trucks, front-end loaders, and scrapers, which are classified by the Mine Safety and Health Administration (MSHA) as powered haulage equipment, and also two pieces of equipment, bulldozers and road graders that are classified as machinery. These five pieces of equipment have historically accounted for a disproportionate share of the surface mining accidents and fatalities each year. Thus they must be a focal point for further reductions in surface mining accidents.

The USBM is dedicated to surface mining safety, and specifically surface mine mobile equipment. One goal of the USBM is to reduce accidents, injuries, and fatalities associated with surface mine mobile equipment in both coal and in metal and nonmetal (MNM) mining. The information obtained in this report will be used to focus future research to achieve this goal. This information should also help mine operators and safety personnel to better understand the dangers involved in surface mining and provide clues to the areas most in need of safety improvement. This may include new areas of emphasis for safety training for miners, work procedure changes, or engineering changes to equipment or the work environment. Figures included within the text are suitable for reproduction and presentation in support of safety and training meetings.

Past research in the area of surface coal mine mobile equipment accident analysis has been limited. A 1976 report (*1*)[4] found that many surface coal mining fatalities occurred during maintenance and repair and while operating haulage trucks, bulldozers, and front-end loaders. Grundy's (*2*) study of fatal and nonfatal coal mine injuries found that slip or fall accidents were the most frequent.

Most of the past research was for accidents in the MNM mining industry, but much of this is applicable to surface coal mining. In 1975, Miller (*3*) looked at MNM haulage truck accidents while Oitto and McLellan (*4*) looked at fatal accidents involving front-end loaders in MNM mining. Tierney (*5*) analyzed maintenance related injuries and found that haulage trucks, followed by conveyors, were the most hazardous equipment to maintain in MNM mining. An analysis of coal and MNM haulage truck maintenance and repair accidents in 1987 by Long (*6*) found that 34 pct of all surface mining lost time accidents were attributed to maintenance and repair activities. More recently, Kenney (*7*) found that MNM haulage truck accidents were more severe than nonhaulage truck accidents. May (*8*) looked at mobile equipment accidents in both coal and MNM mining which occurred at the dump-points of stockpiles and waste dumps.

Since many of the past accidents in surface mining were related to mobile equipment, an updated report was needed to provide a current snapshot of the accident distribution. The increasing size and complexity of today's machines is likely to have altered accident trends from those of the past. This is the first report that has brought together information for these five pieces of mobile equipment.

The accident data were obtained by searching the Accident Data Analysis (ADA) database, maintained by the USBM's Spokane Research Center (*9*), for any surface coal mine accident which involved one of the five pieces of mobile equipment in the years 1989-91. The database does not include contractor accidents, only accidents attributed to mine personnel. A total of 2,899 accidents associated with surface mine haul trucks, loaders, dozers, scrapers, and graders were examined by USBM researchers.

This report can be used as a reference guide to the types of accidents and injuries which are of interest to the reader. The report is organized into three main sections to help direct the reader to the area of interest. Section I provides a general discussion and overview of the accidents. It discusses the leading accident causes, the primary activities of the person at the time of the incident, and a brief overview of accidents related to specific types of equipment. Section II provides a significantly more detailed analysis by equipment type for those who want more specific information. Section III discusses miscellaneous accident factors that apply to all types of mobile equipment, and is followed by a list of recommendations for reducing mobile equipment accidents. The reader is encouraged to read the first section and reference following sections of particular interest. Appendix A, Perspective of Mining Safety, provides a broader perspective of the mobile equipment accidents in relation to other sectors of the mining industry. A review of the analysis procedures used in the development of this report can be found in appendix B. Appendix C gives definitions of many of the accident descriptions used in this report.

[4]Italic numbers in parentheses refer to items in the list of references preceding the appendixes at the end of this report.

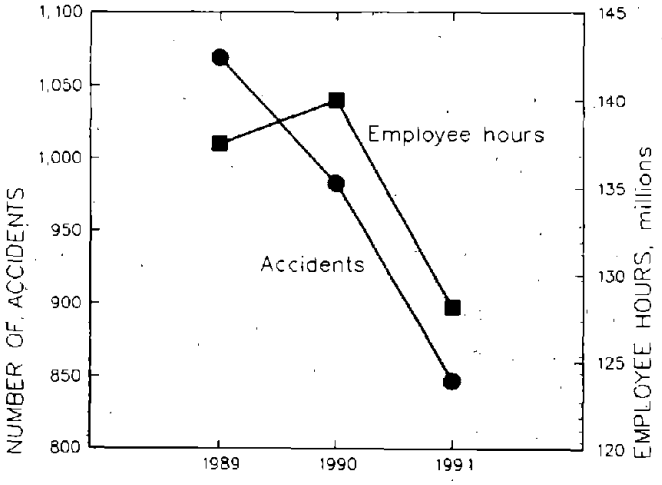
SECTION I: GENERAL DISCUSSION AND OVERVIEW

A total of 2,899 mobile equipment accidents were reported in surface coal mining for the years 1989-91. The number of accidents decreased each year through the 3-year period (figure 1). Downsizing of the mining industry might be expected to be the largest factor in this trend, but figure 1 shows that the trend was not strictly due to the number of employee hours worked. From 1989 to 1990, the number of accidents went down while employee hours actually increased slightly (*10*). Other reasons for the decrease in accidents may be increased safety, decreased reporting by mines, or increased use of contractors by mine operators.

Mobile equipment accidents were more severe than the average surface coal mine accident. Mobile equipment accidents accounted for 20 pct of surface mine accidents, but 24 pct of the lost workdays (LWD) and 41 pct of the fatalities. Fatalities occurred in 0.7 pct of the mobile equipment accidents, compared with 0.3 pct for all surface coal mining.

There are many reasons for mobile equipment accidents being so severe. The size of the equipment and the large blind areas around the equipment are possible reasons for many accidents. The frequency of pedestrian fatalities supports this. The high speeds at which some mobile equipment is operated increases the potential for serious accidents. The rugged or steep terrain common in surface mines is also likely to contribute to the accident severity. Other important factors are the dynamic environment of the mine and the amount of time spent operating in close proximity to other equipment. These are particularly evident at truck loading areas and dump points, such as stockpiles, spoil piles and waste dumps, and any other location where material is being moved. Perhaps the largest factor is the ability of the operator, which is particularly important in mobile equipment operation. The operator must be in control of the vehicle at all times and be able to react quickly when faced with road hazards, mechanical failures, severe weather conditions, etc. The size of the equipment makes operator reaction to hazards even more critical for safe operation.

Figure 1



Accident and employee hour distribution by year.

ACCIDENT CAUSES

The most frequent cause of accidents was a slip or fall. Over 60 pct of the accidents were the result of four causes: slip or fall, jarring, overexertion, and getting caught or smashed. The most frequent causes of coal mine mobile equipment accidents are shown in table 1. Refer to the appendix for the definitions of some of the accident causes. The "cause" of the accidents listed was not the underlying, root cause of the accidents, but the general action that caused the accident or injury to occur.

Table 1.—Number, percentage, and LWD of leading accident causes

Accident cause	Accidents		Mean LWD
	Number	Pct	
Slip or fall	736	25.4	27.2
Jarring	425	14.7	23.3
Overexertion	352	12.1	20.3
Getting caught or smashed	229	7.9	14.6
Loss of control	196	6.8	32.7
Being struck by flying object	194	6.7	11.7
Passive strain	107	3.7	27.5
Striking against equipment	105	3.6	12.5
Debris in eye	93	3.2	1.4
Fire or burn	90	3.1	11.8
Collision	78	2.7	21.8
Hand tool injury	53	1.8	4.1
All others	241	8.3	19.5
Total	2,899	100.0	21.1

LWD Lost workday.

Slip or Fall

Slips or falls were responsible for 736 accidents, or 25 pct of the total (table 1). They resulted in 20,011 LWD, averaging 27 LWD per accident. Thus, not only were they frequent, but they also tended to be serious accidents. Just over 70 pct of the slip or fall accidents occurred while mounting or dismounting the equipment and were prevalent in all of the equipment categories. Slips or falls were the leading cause of mobile equipment accidents during ingress-egress and maintenance activities and third most common for pedestrian accidents. The

most common injuries were a sprain or strain to the back, multiple body parts, or knees. Bruises and fractures were also frequent injuries. Seven disabling injuries resulted from a slip or fall.

Jarring

Next to slips or falls, the second most frequent accident cause was jarring, with 15 pct of the total (table 1). These 425 accidents averaged 23 LWD. All jarring accidents occurred to equipment operators, except one incident in which a passenger was jarred. Of the jarring accidents, 54 pct resulted from the equipment traveling over rough ground. The resulting jolt to the equipment was transmitted through the machine to the operator. The next most frequent type of jarring accident was to haulage truck operators while the truck was being loaded. These were most often caused by a boulder being dropped into the bed of the truck. The most common injuries from jarring accidents were sprains or strains to the back in particular, but also to the neck. Many of the jarring injuries occurred when the equipment operator was in an awkward position, such as twisted around while backing or bent over to pick up something or reaching for a control lever.

Overexertion

Overexertions were the third most common cause of accidents (table 1). Overexertions were most frequent in maintenance and ingress-egress accidents. Maintenance activities accounted for 47 pct of the overexertion accidents and ingress-egress 42 pct. In maintenance, overexertion injuries were usually caused by lifting, pulling, or pushing motions. Injuries were predominately sprains or strains to the back, but knee and shoulder sprains or strains were also common. Overexertions during mounting or dismounting the equipment were usually the result of stretching too far while climbing or placing the body in an awkward position. These injuries were also predominately sprains or strains, but were more evenly distributed among the back, knee, or ankle. The typical overexertion accident resulted in 20 LWD. Five overexertion accidents resulted in permanent disabilities.

Getting Caught or Smashed

The fourth most frequent cause of accidents was getting body parts caught or smashed between moving objects (table 1). Maintenance activities accounted for 56 pct of this type of accident. Getting caught or smashed injuries during maintenance activities usually resulted from parts slipping as they were being installed or removed from the machine. Getting caught in the machine's door while getting in or out of the cab was also common. Injuries to pedestrians were mostly from handling materials, such as getting fingers pinched while loading barrels into a loader bucket. These accidents usually resulted in cut or fracture injuries, especially to fingers and hands. Getting fingers caught in the heater fan was the most common way for equipment operators to get injured in this category. Compared with the other types of accidents, getting caught or smashed injuries were less severe, averaging 15 LWD. However, getting caught or smashed accidents were the leading cause of permanent disabilities, accounting for 8 of the 25 permanent disabilities. Amputated fingers were the most frequent disabling injury.

Other Causes

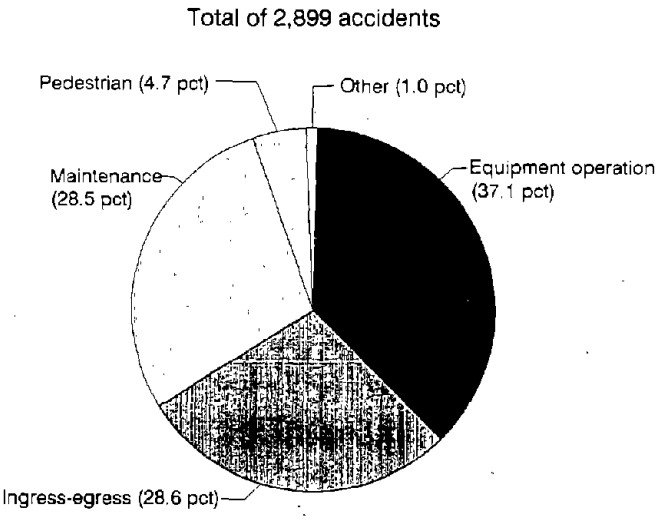
The remainder of the accident causes represent a smaller portion of the accidents. Refer to table 1 for a list of these causes and the severity of the injuries as measured by the LWD. Loss of control accidents were the fifth most frequent accident cause, but had the highest number of LWD (33 days). This was expected intuitively because of the violent nature of loss of control accidents, many of which involve vehicles falling down steep slopes and rolling over. The least severe accident cause was debris in eyes, having a mean of just 1 LWD. A brief doctor's visit typically results in removal of an object from the eye and only minor eye irritation, but no permanent or lasting damage.

PRIMARY ACTIVITY

Mobile equipment accidents were analyzed within this report by the primary activity of the accident victim at the time of the accident. These categories are in order of decreasing frequency, equipment operation, ingress-egress, maintenance, pedestrian, and other (figure 2).

The largest percentage of accidents (37 pct) occurred while operating the equipment. One might expect this to be the largest portion of accidents because of the many hours the equipment is operated and also the inherent danger of operating any vehicle. Ingress-egress activities were found to be the second most frequent primary activity, with 29 pct of the accidents. The frequency of accidents in this category was surprising considering the small amount of time spent getting on or off the machines. Maintenance workers and supervisors also were frequently involved in ingress-egress accidents. Maintenance activities were responsible for 29 pct of the accidents. This category includes maintenance workers and equipment operators or anyone else who was performing maintenance, repair, inspection, or refueling tasks with the machine. The smallest primary activity category of significance was pedestrians, with 5 pct of the accidents. The most severe injuries occurred during ingress-egress. These accidents

Figure 2



Primary activity of accident victims.

had a mean of 24 LWD (table 2). Maintenance injuries were the least severe in terms of LWD (14 days).

Equipment Operation

Equipment operation accidents were not only the most frequent primary activity, but were also among the more severe, averaging 24 LWD (table 2). The largest number of fatalities occurred during equipment operation (13 of 21). Some of the most violent and severe accidents, loss of control, were included in this category and account for many of the fatalities.

Jarring accidents were the largest class of accidents occurring during equipment operation. For haulage trucks and scrapers, jarring was the leading cause of accidents. Jarring while operating a haulage truck occurred most frequently when the truck contacted rough ground, often in the form of potholes, rocks, or bumps in the road. Other frequent causes of jarring to haulage truck operators were boulders being dropped into the bed of the truck, the loader or shovel bucket striking the truck body while loading, hydraulic lift cylinder failure, and the load shifting while dumping. Front-end loader jarring accidents happened most frequently from the bucket striking a large rock or boulder, or the bucket striking a hidden stationary object such as a rail or a bolt head protruding from a concrete pad. Jarring to loader operators also occurred from driving over rough ground. Jarring accidents occurring while operating a dozer resulted predominantly from rough ground, but also while ripping or dozing large boulders. Scraper jarring accidents occurred from rough ground or during tandem operation while loading. Road grader jarring accidents were largely from rough ground or striking objects with the blade.

The high incidence of jarring injuries being caused by rough ground points to the need for better haul road construction and maintenance. Many rough road problems and accidents could be eliminated through better haul road construction. Road base construction and drainage have a large affect on road surface quality. Attention to material spillage and road repair or maintenance is also important for reducing these accidents.

Rough ground accidents with bulldozers and scrapers present a different problem. Most of these accidents occur off the haulage roads. Reducing the incidence of these accidents hinges on the operators and the shock and vibration isolation qualities of the machine. Operators need to stay aware of the rough ground hazards around their machine. Equipment should have adequate isolation capability and operators should be properly restrained. An operator tightly coupled to the vehicle seat can safely take a larger jolt than the operator not wearing a seat belt.

The second most frequent accident occurring during equipment operation was loss of control of the vehicle. These were most prevalent with haulage trucks (12 pct of haulage truck accidents). Many different factors play a part in these accidents, but the biggest is operator reaction

Table 2.—Accident severity by primary activity

Primary activity	Accidents			Fatalities			Permanent disabilities		
	Number	Pct[1]	Mean LWD	Number	Pct[1]	Ratio[2]	Number	Pct[1]	Ratio[2]
Equipment operation	1,076	37.1	23.7	13	62	1.2	3	12	0.3
Ingress-egress	830	28.6	24.4	1	5	0.1	6	24	0.7
Maintenance	826	28.5	14.2	3	14	0.4	12	48	1.5
Pedestrian	137	4.7	22.1	3	14	2.2	4	16	2.9
Passenger	1	0.03	0	0	0	0	0	0	0
Unknown	29	1.0	25.7	1	5	3.4	0	0	0
Total	2,899	100.0	21.1	21	100	0.7	25	100	0.9

LWD Lost workday.
[1]Percent of column total.
[2]Percentage of number of accidents.

and judgement. Skilled and experienced operators can avoid many of these accidents. Many runaway accidents were found to be caused by operator errors and not strictly mechanical problems. Emergency situation training is of particular importance for haulage truck drivers who may be faced with a runaway vehicle. Quick, informed reactions in these situations may help to avoid many accidents or at least reduce their severity. Increased utilization, and training on the use of runaway vehicle stopping techniques, such as center safety berms and escape lanes would greatly improve the safety in this area. The use of seat belts or harnesses is also important in loss of control accidents, many of which involve a rollover.

The rollover protective structure (ROPS) is of little use if the operator is thrown out of the cab. The accident data showed that when the operator was thrown from the cab or jumped, the severity of injuries was higher than when restrained in the cab. Many operators have a fear of getting trapped in the vehicle during a rollover accident because of a fire. No such incidences were reported over the 3-year period. Another fear may be getting trapped in the cab from a rollover and subsequently drowning. Only one case like that was found in this study. In an emergency or accident situation, it is almost always better to keep the seat belt on, rather than trying to jump clear of the vehicle, which often results in the operator being run over by their own machine.

Equipment operators need to make sure their windows and mirrors are clean and the mirrors are adjusted properly. This is especially important for haulage truck drivers to prevent backing over the dump and because of the large blind areas around trucks. Good visibility is important when backing a truck to the dump to ensure that the truck is square with the edge.

Ingress-Egress

The high number of ingress-egress accidents was surprising (29 pct of all mobile equipment accidents). The largest causes of ingress-egress accidents were a slip or fall and overexertion. Slips or falls were the most severe in terms of LWD. Ingress-egress accidents averaged 24 LWD, compared with 21 LWD for all mobile equipment accidents. The fatality ratio (percent of accidents which were fatal) of 0.1 pct (table 2) was the lowest for any of the primary activities. One fatality occurred in 830 ingress-egress accidents.

Perhaps the most effective way to reduce injuries occurring during mounting or dismounting is through training. Mine personnel need to understand the potential dangers in this seemingly benign task. This is not a subject to be taken lightly. All mine personnel should be instructed to never climb down an access ladder facing out, away from the machine. Special precautions need to be taken whenever the access ladders are wet, icy, oily or greasy, covered with mud, or when carrying objects up or down the ladder. Mud, grease, or oil should be cleaned off steps, handrails, and walkways as soon as possible. The three points of contact rule when getting on or off needs to be instilled in mine personnel. Many ingress-egress accidents probably result from carelessness and inattention to this apparently simple maneuver. Engineering solutions to this problem are difficult without becoming too elaborate or costly. Front-end loaders were more susceptible to ingress-egress accidents. This may be due to the greater frequency that loader operators get in or out of their machine or poorer access to the machine. Maintenance personnel were as susceptible to these accidents as the equipment operators. Maintenance workers may be carrying tools or other items as they get on or off the machine, increasing their chance for a slip or fall.

Overexertions while mounting or dismounting generally occurred when trying to reach the first step when getting on or stepping down to the ground when getting off. Two primary contributing factors in these accidents were generally the distance from the ground to the first step and the condition of the bottom step (*11*). Many muscle strain injuries occurred when trying to stretch to the first step. This high step is often necessary to prevent damage to the step during equipment operation. On many machines the bottom step is not rigid, often attached by a cable or chains. This free-moving step also contributes to many strain injuries. A more rigid step would help to reduce the injury potential in many cases. Strains to the arms or shoulders often happened when the miner would try to catch themselves after losing their balance.

Maintenance

The percentage of all mobile equipment accidents related to maintenance was 29 pct (table 2). Long (*6*) found that 34 pct of haulage truck accidents in 1987 involved maintenance and repair activities compared with the 22 pct (haulage trucks only) found in this study. Long's higher percentage was probably the result of a broader definition of haulage trucks, which included accidents associated with service vehicles. Long's study also included both coal and MNM mining.

Bulldozers had the highest incidence of maintenance related accidents and also the most severe. The large number of accidents involving the repair of the bulldozer track and its components points to an increased danger in bulldozer maintenance. Bulldozer mechanics should be trained and reminded of the hazards associated with handling the track components. The types of accidents which occurred during track repair were most frequently overexertions from lifting track components and getting caught or smashed fingers or hands. Increased use of mechanical

lifting devices may help reduce the number of these injuries.

Maintenance activities had a mean of 14 LWD, less than all the other primary activities. Slips or falls and overexertions were the largest causes of maintenance accidents. Slips or falls during maintenance activities had the same severity as the slips or falls during ingress-egress, however overexertions were less severe for maintenance than they were for ingress-egress. All the remaining maintenance accidents were significantly less severe. Injuries from getting caught or smashed and being struck by flying objects tended to be less severe lacerations, commonly to fingers, hands, or the head. The fifth most frequent maintenance accident was debris in the eyes, which were some of the least severe accidents in any accident category. Maintenance injuries generally require less recovery time than the sprain, strain, or multiple injuries common to other accidents.

Pedestrian

Pedestrian accidents were the fourth most frequent primary activity, totaling 5 pct of all mobile equipment accidents (table 2). Front-end loaders were the piece of equipment with the largest percentage of pedestrian accidents (6 pct). This probably results from the use of loaders in many different tasks besides loading trucks. Many of these utility tasks require mine personnel to work around the loader to help guide it or to load or unload materials from the bucket. Loader operators frequently get out of the loader to do some of these tasks also. These situations naturally increase the odds of pedestrian accidents occurring. The most frequent pedestrian accidents were getting caught or smashed, being struck by flying object, slip or fall, and overexertion. Accidents involving a pedestrian averaged 22 LWD. A particular concern of these accidents was the number of fatalities. Fatalities occurred in 2 pct of pedestrian accidents, compared with 0.7 pct for all the accidents (table 2). Pedestrians working around any piece of equipment need to be aware at all times of their surroundings. They especially need to watch their location in relation to the mobile equipment so that they stay out of harms way and out of the driver's blind spots.

EQUIPMENT TYPE

Overview

A brief summary of the largest classes of accidents and injuries by type of equipment is illustrated in table 3. The table gives the number of accidents, mean number of

Table 3.—Accident frequency, severity, and most frequent accident types and injuries by type of equipment

Equipment	Accidents		Mean LWD	Fatalities			Most common accident types[2]	Most common types of injuries[2]	Most common body parts injured[2]
	Number	Pct		Number	Pct	Ratio[1]			
Bulldozers	1,009	34.8	21.1	3	14	0.3	IE-slip or fall, EO-jarring, M-slip or fall, M-overexertion.	Sprain or strain, laceration, bruise, fracture.	Back, multiple body parts, fingers, knee.
Haulage trucks	888	30.6	24.5	8	38	0.9	EO-jarring, IE-slip or fall, EO-loss of control, IE-overexertion.	Sprain or strain, multiple injury, fracture, laceration.	Back, multiple body parts, fingers, neck.
Front-end loaders	695	24.0	20.6	6	29	0.9	IE-slip or fall, EO-jarring, IE-overexertion, M-slip or fall.	Sprain or strain, laceration, bruise, fracture.	Back, multiple body parts, fingers, knee.
Scrapers	216	7.5	13.4	2	10	0.9	EO-jarring, IE-slip or fall, M-overexertion, M-slip or fall.	Sprain or strain, laceration, fracture, unclassified.	Back, multiple body parts, fingers, shoulder.
Road graders	91	3.1	11.4	2	10	2.2	IE-slip or fall, EO-jarring, M-getting caught or smashed, IE-overexertion.	Sprain or strain, laceration, multiple injury, fracture.	Back, multiple body parts, fingers, ankle.

EO Equipment operation primary activity.
IE Ingress-egress primary activity.
LWD Lost workday.
M Maintenance primary activity.
[1]Percentage of number of accidents.
[2]In order of decreasing frequency.

LWD, and fatalities for each type of equipment. The four most frequent accident types, types of injuries, and body parts injured are also listed. Notice that slip or fall accidents during ingress-egress or jarring accidents while operating the equipment were the first or second most frequent type of accident for each piece of equipment. The type of injury column shows that sprains or strains were the number one type of injury for all equipment. The majority of sprain or strain injuries occurred to the back, so it's not surprising that back injuries were the most frequent for each type of equipment. The increased incidence of multiple injuries for haulage trucks was most likely due to the higher percentage of loss of control accidents (frequently resulting in rollovers) with trucks.

The following sections give a brief synopsis of the accidents and injuries that were prevalent for each piece of equipment. More detail of these accidents are given in Section II of the report.

Bulldozers

Of the five pieces of mobile equipment, bulldozers were responsible for the most accidents. Nearly 35 pct of the accidents occurred with bulldozers (table 3). This was a total of 1,009 accidents having a mean of 21 LWD, the same as for all accidents combined. The fatality ratio of bulldozer accidents was the lowest, 0.3 pct. This may be due to the slower operating speeds and greater stability of bulldozers, particularly crawler bulldozers, which were the most common. Also, the lower percentages of bulldozer accidents in the pedestrian and equipment operation primary activity categories reduced the potential for fatalities. These two activities had the highest fatality ratios (table 2). As mentioned above, maintenance activities were the largest portion of the bulldozer accidents, and they tended to be lower in severity. This was the only piece of equipment with maintenance accidents being the most common.

Bulldozer ingress-egress accidents occurred at a rate similar to all equipment ingress-egress accidents and with nearly the same number of LWD. Accidents to the operator while operating a bulldozer were a smaller percentage of the bulldozer accidents than for the other equipment. Some types of accidents within this category occurred at a higher rate. Bulldozers had the highest percentage of passive strain injuries. This was most likely due to the rough terrain on which bulldozers typically operate. Also, bulldozer accident victims were slightly older on average than the other equipment accident victims, which could have made them more susceptible to these types of injuries. Bulldozer operators need to pay special attention to their surroundings and use care when operating on unusually rough ground. Better operator restraints and increased use of seat belts, along with better seat suspensions, would help to reduce the incidence of these accidents. Bulldozer operators were also most likely to be struck by a flying object. Most frequently the object was a tree limb. Care is needed when performing brush clearing or grubbing operations. Bulldozers were susceptible to highwall collapses or rocks falling from a highwall or material pile. Bulldozers frequently are used to move coal or waste from highwall areas. If these accidents or occurrences are a frequent problem at a mine, mine operators should take measures to increase highwall stability or modify procedures to keep bulldozers out of those areas.

Haulage Trucks

Haulage truck accidents were the second most frequent equipment type. These 888 accidents made up 31 pct of the total (table 3). Haulage truck accidents were the most severe, averaging 25 LWD. The severity of the haulage truck accidents was due largely to the high percentage and severity of the accidents occurring during equipment operation. The average of 30 LWD was the highest number of LWD for any of the equipment primary activities. Haulage trucks had a particularly high frequency of loss of control accidents compared with the other equipment. Trucks tend to be larger than other equipment and are often operated at higher speeds on steep grades. These factors increase the chance of severe injuries resulting from accidents while operating a haul truck. Haulage trucks also had the highest number of fatalities (eight, table 3).

Maintenance accidents occurred less frequently with haulage trucks compared with the other equipment. Pedestrian accidents associated with haulage trucks were most frequently to the operator who had got out of the cab to clear the tail gate or climbed onto the bed to check the load or fasten down the bed cover.

Front-End Loaders

Front-end loader accidents were the third most frequent (table 3, 24 pct). Loader accidents were unique in several different ways. Loader accidents occurred most frequently during ingress-egress, the only piece of equipment with that distinction. Pedestrian accidents were also a larger percentage of loader accidents than for any other equipment. The percentage of loader accidents occurring during equipment operation was lower than any other equipment. The reasons for this are varied. Front-end loaders typically operate at slower speeds and often work within smaller areas than most of the other equipment. This reduces their exposure to collision, loss of control, and rough ground hazards. Rough ground accidents were

particularly low. Most loaders, especially those loading trucks, operate on fairly smooth surfaces. If material spillage hazards exist, the loader operator can easily remove them.

Loaders were much more prone to have equipment fires. Twenty-three loader fires were reported over the 3-year period. Four of the 23 loader fires involved burn injuries, while six operators were hurt jumping from the loader, and the remainder resulted in equipment damage only and no injuries. Broken hydraulic or fuel lines and overheated brakes were most frequently mentioned as causing the fires. Some loaders were not equipped with fire suppression systems. Work cycle and thermal fatigue of the hydraulic components may account for the greater incidence of fires with front-end loaders. Greater attention to preventive maintenance should reduce these hazards.

Scrapers

Scrapers, accounting for 8 pct of the total accidents, had the highest percentage of their accidents occurring during equipment operation. This indicates that scrapers may be one of the more hazardous pieces of equipment to operate. They tend to be unstable on steep terrain. Although loss of control accidents were not numerous, over half of them involved a rollover. Scrapers had a high incidence of rough ground and passive strain injuries. They operate at high speeds when tramming and travel over rough ground when loading or dumping. Also the design of most scrapers tends to make them bouncy, accounting for many of the passive strain injuries. Push loading of scrapers adds more injuries which were not found with other equipment. Scraper and bulldozer operators need to carefully coordinate movement when push loading to reduce the incidence of unexpected bumps. Better operator seats, seat suspensions, and restraints would help eliminate some of these injuries, while reducing the severity of others. Scraper accidents were among the least severe, having a mean of 13 LWD (table 3). Thus, although scraper accidents were most frequent while operating the machine, injuries tended to be less severe than the other equipment, except graders.

Road Graders

Graders were involved in just 3 pct of the total mobile equipment accidents. Grader accidents fit the norm for all equipment accidents in most accident categories. One exception was collisions. Six road graders were involved in collisions, accounting for 7 pct of the grader accidents. This large percentage in comparison with the other equipment may be due to skewing of the data from the small sample of grader accidents. Just as likely, it could be because the relatively slow-moving graders frequently encounter haulage trucks on the roads, and a greater opportunity exists for a collision. Most grader collisions were with haulage trucks.

TYPE OF INJURIES

Injuries occurred in 99 pct of the accidents, and varied with the activity of the injured person and the type of equipment involved. Sprains or strains were far and away the largest portion of injuries, totaling 40 pct (table 4). Following sprains or strains were lacerations (13 pct), fractures (10 pct), bruises (10 pct), and multiple injuries (9 pct). These five types of injuries accounted for 82 pct of the accidents. The next most common types of injuries were unclassified, burns, dust in eyes, scratches, dislocations, and crushing.

Table 4.—Number, percentage, and LWD of injury types

Injury type	Accidents		Mean
	Number	Pct	LWD
Sprain or strain	1,165	40.2	24.8
Laceration	373	12.9	4.5
Fracture	290	10.0	35.6
Bruise	280	9.7	14.9
Multiple injuries	269	9.3	24.1
Unclassified	229	7.9	30.2
Burn	45	1.6	10.0
Dust in eye	39	1.3	0.8
Scratch	26	0.9	1.9
Dislocation	24	0.8	32.5
Crushing	23	0.8	12.7
Irritated tendon	18	0.6	25.8
All others	75	2.6	9.8
None	43	1.5	NAp
Total	2,899	100.0	21.1

LWD Lost workday.
NAp Not applicable.

The most frequent injury, sprain or strain, was more severe than the average accident. The mean number of LWD for sprain or strain injuries was 25 days (table 4). This compares with 21 days for all accidents. The majority of the sprain or strain injuries were to the back or neck, and represent nearly a quarter of all mobile equipment accidents. Back and neck sprain or strain injuries occurred across many different accident types, but they were particularly prevalent in slip or fall, jarring, overexertion, and passive strain accidents.

The most severe of the top one dozen injuries were fractures, having a mean of 36 LWD (table 4). This long recovery time was expected for fractures, especially with many fractures occurring to the lower extremities. Dislocations were next with a mean of 33 LWD. Dust in the eye injuries were the least severe, having just 0.8 LWD.

PART OF BODY INJURED

The part of the body injured was more evenly distributed than the types of injuries. Just five types of injuries madeup over 80 pct of the total injuries, while 13 different body parts were required to total over 80 pct (table 5). The most common body part injured was the back (26 pct), followed by multiple injuries (12 pct), fingers (8 pct) and knees (6 pct). Additional body part injuries are shown in table 5. Back injuries were common throughout different accident types and were often the most frequent. Multiple body part injuries occurred most frequently from slip or fall, loss of control, or collision accidents. Finger and hand injuries were more concentrated in the maintenance-getting caught or smashed accidents.

Shoulder injuries were the most severe, requiring a mean of 33 days for recovery (table 5). The most frequent body part injured, the back, averaged 28 LWD. Multiple body part injuries tended to be quite severe, averaging 32 LWD. All accidents combined had a mean of 21 LWD.

If the body parts are grouped together into body regions the injury trends are perhaps a little easier to grasp (figure 3). The largest number of injuries occurred to the back and neck (30 pct), followed by the lower extremities (17 pct) and the upper extremities (17 pct). Back and neck injuries were prevalent in nearly all accident categories, except hand tool injury, being struck by flying object, and getting caught or smashed accidents. Back and neck injuries were quite severe, having a mean of 27 LWD. Lower extremity injuries were prevalent in overexertion and slip or fall accidents. Upper extremity injuries happened most frequently in getting caught or smashed, striking against equipment, hand tool injury, and being struck by flying object accidents, all of which were most prevalent during maintenance activities. Multiple body part injuries, the fourth most frequently injured body region, occurred most often from loss of control, collision, jarring, or slip or fall accidents and were the most severe, averaging 32 LWD. Injuries to the trunk were most prevalent in loss of control and overexertion cases. Head injuries were particularly common in being struck by flying object and jarring cases.

Table 5.—Number, percentage, and LWD of injuries by part of body injured

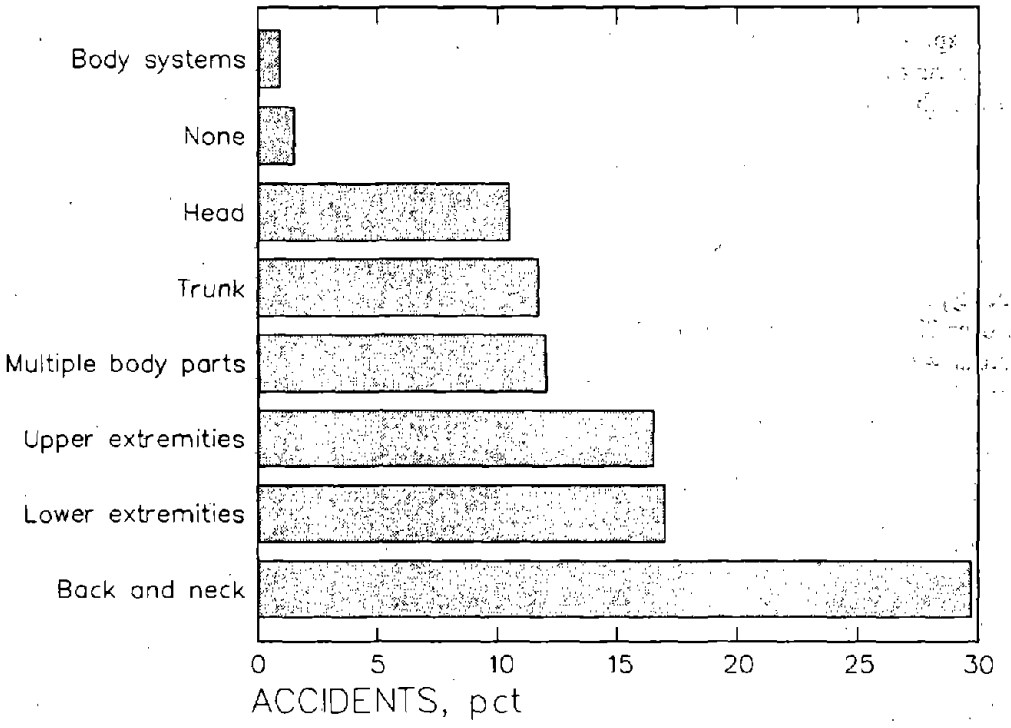
Part of body injured	Accidents		Mean
	Number	Pct	LWD
Back	746	25.7	28.1
Multiple body parts	349	12.0	31.5
Fingers	228	7.9	9.9
Knees	173	6.0	25.3
Eyes	119	4.1	2.0
Neck	116	4.0	23.5
Ankle	115	4.0	17.9
Shoulder	101	3.5	33.4
Head, NEC	95	3.3	5.1
Hand	89	3.1	7.5
Chest	85	2.9	15.3
Hips	71	2.4	21.1
Leg, NEC	71	2.4	27.3
Foot	52	1.8	25.4
All others	446	15.4	18.7
None	43	1.5	NAp
Total	2,899	100.0	21.1

LWD Lost workday.
NAp Not applicable.
NEC Not elsewhere classified.

SUMMARY OF ACCIDENT CLASSIFICATIONS

Table 6 summarizes the accidents and injuries which occurred in the 12 most frequent accident classifications. See appendix C for definitions of some of the accident classifications. For a given type of accident this table shows the frequency, severity, the types of equipment most prone to that accident, the types of injuries likely to occur, and body parts most commonly injured. For instance, loss of control of a vehicle occurs at the highest rate for haulage truck operators (row 3, table 6). These accidents were more severe than other accidents, having a mean of 33 LWD, and were most likely to result in multiple injuries. The three most frequent types of accidents were a slip or fall during ingress-egress, jarring during equipment operation, and loss of vehicle control during equipment operation.

Figure 3



Percentage of accidents by body region.

Table 6.—Accidents and injuries for top twelve accident classifications

Accident classification[1]	Number	Mean LWD	Most common equipment type[2]	Most common type of injury[3]	Most common body part injured[3]
Ingress-egress, slip or fall	522	27.2	Front-end loader, dozer, road grader.	Sprain or strain, bruise, fracture.	Back, multiple body parts, knee.
Equipment operation, jarring	424	23.3	Scraper, haul truck, road grader.	Sprain or strain, bruise, laceration.	Back, neck, multiple body parts.
Equipment operation, loss of control.	196	32.7	Haul truck, dozer, road grader.	Multiple injury, fracture, bruise.	Multiple body parts, head, back.
Maintenance, slip or fall	187	27.3	Dozer, front-end loader, road grader.	Sprain or strain, bruise, fracure.	Back, neck, multiple body parts.
Maintenance, overexertion	164	16.8	Dozer, scraper, front-end loader.	Sprain or strain.	Back, knee, shoulder.
Ingress-egress, overexertion	150	22.3	Front-end loader, road grader, haul truck.	Sprain or strain.	Back, knee, ankle.
Maintenance, getting caught or smashed.	130	14.0	Road grader, dozer, front-end loader.	Laceration, fracture.	Finger, hand.
Maintenance, being struck by flying object.	125	7.1	Dozer, scraper, front-end loader.	Laceration, fracture.	Hand, head, finger.
Equipment operation, passive strain.	107	27.5	Dozer, scraper, front-end loader.	Sprain or strain.	Back, neck.
Equipment operation, collision . .	63	24.2	Road grader, haul truck, scraper.	Sprain or strain, multiple injury, bruise.	Multiple body parts, back, neck.
Maintenance, debris in eye	60	1.8	Haul truck, dozer, front-end loader.	Laceration, dust in eyes, chemical burn.	Eye.
Maintenance, striking against equipment.	54	6.1	Haul truck, road grader, front-end loader.	Laceration, bruise, multiple injury.	Finger, back, head.

LWD Lost workday.
[1]See appendix for definitions of classifications.
[2]Based on percentage, in order of decreasing frequency.
[3]Based on number of occurrences, in order of decreasing frequency.

SECTION II: ANALYSIS BY EQUIPMENT TYPE

This section examines in detail the accidents associated with each type of mobile mining equipment. Within each equipment section, the accidents are grouped by the primary activity. Both the equipment and primary activity categories are listed in descending order of the frequency of accident occurrence.

GENERAL DISCUSSION

Accident Frequency and Severity

The accidents were broken down by the type of mobile equipment involved in the accident. Table 3 gives the number of accidents, mean LWD, and fatalities reported for each type of equipment. This shows that bulldozers, haulage trucks, and loaders accounted for 89 pct of the accidents while scrapers and graders accounted for only 11 pct. The degree of injury by type of equipment is shown in table 7.

Bulldozers were responsible for 35 pct of all the accidents or a total of 1,009 accidents (table 3). Bulldozer accident severity, as measured by the mean number of LWD, was equal to the mean for all equipment types (21 days). Three fatalities involving bulldozers were recorded for the 3-year period. The fatality ratio for bulldozers, 0.3 pct, was lower than the ratio for any of the other equipment (table 3).

Haulage trucks were second to bulldozers in the number of accidents (888 accidents reported), representing 31 pct of the total. The mean number of LWD for haulage trucks was 25 days, the highest of any of the equipment. The eight truck fatalities were 38 pct of the total fatal accidents, the largest portion of any of the equipment (table 3). The fatality ratio for haulage trucks was three times that of the bulldozer fatality ratio (0.9 versus 0.3), but the same as for loaders and scrapers.

Front-end loaders accounted for 24 pct of the accidents (table 3). Loader accidents averaged 21 LWD and had a fatality ratio of 0.9 pct (6 fatalities, table 3). Scrapers and road graders had significantly fewer accidents. Both had 10 pct of the fatal accidents, or two fatals each, and both had lower mean LWD than the other accidents. Road graders had the highest fatality ratio (2 pct), two fatalities in 91 accidents.

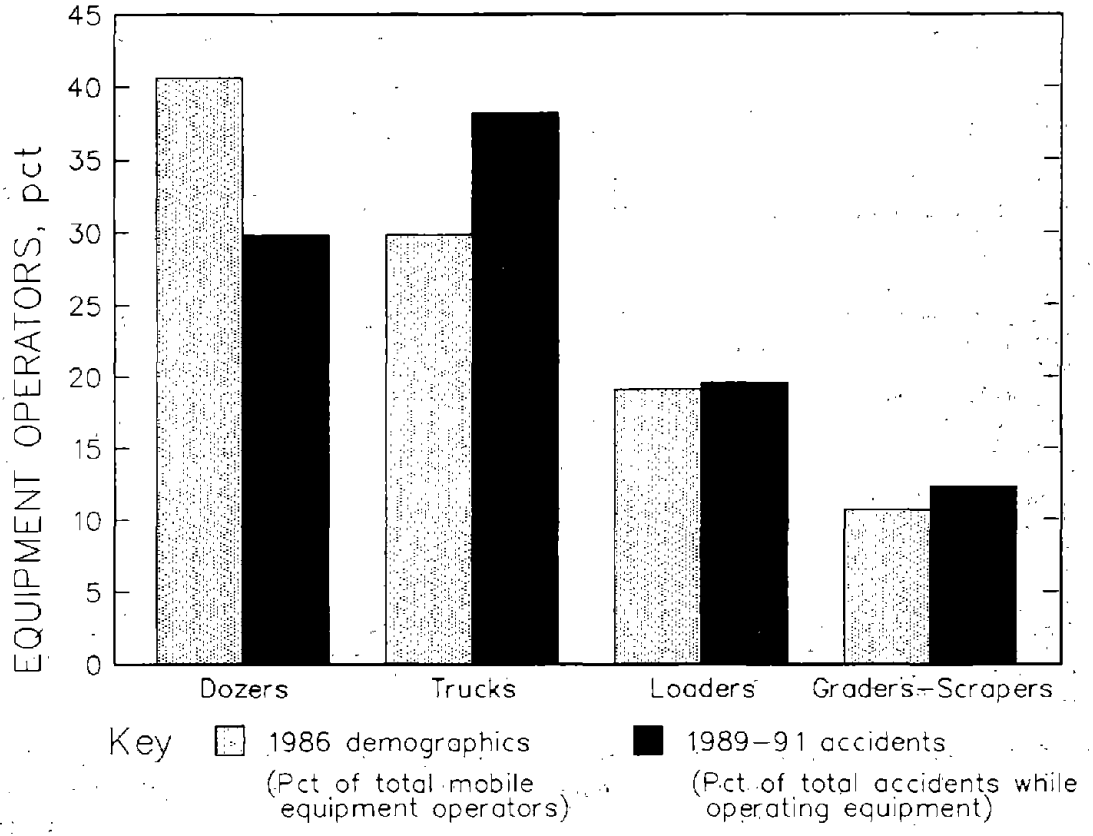
Information on the amount of time each type of equipment was used was not available, thus the accident data could not be normalized for equipment utilization or to calculate incidence rates. Because hours of equipment use were not available, numbers of equipment operators were used instead. The most recent estimate (1986) of the coal mine industry work force was reported by Butani and Bartholomew (*12*). Estimates of the number of employees working as mobile equipment operators in 1986 were plotted against the accident data from this study (figure 4). The left bar for each equipment type is Butani and Bartholomew's estimate of the percentage of all mobile equipment operators in the 1986 surface coal mining work force operating that piece of equipment. The right bars are based on the 1989-91 accident data from this study. The right bars are only the accidents which occurred during mobile equipment operation. They do not include accidents from the ingress-egress, maintenance, or pedestrian categories.

Figure 4 shows that the number of operators and the number of operator accidents were approximately the same for loaders and graders-scrapers. The number of bulldozer accidents was 27 pct less than expected from the number of bulldozer operators, while the number of haulage truck accidents were 28 pct more than expected. Bulldozer accidents occurred at a lower frequency than expected, suggesting they were relatively safer to operate than the other equipment. Conversely, the difference in the number of haulage truck accidents and operators suggests that trucks were relatively more hazardous to operate. One must be cautioned that these comparisons are made between 1989-91 accident data and 1986 demographics data. It is likely that the demographics have not changed much over that time span. This information helps to give a feel for the incidence rates of accidents occurring during equipment operation.

Table 7.—Accidents by degree of injury and equipment type

Degree of injury	Bulldozer		Haulage truck		Loader		Scraper		Grader	
	Number	Pct	Number	Pct	Number	Pct	Number	Pct	Number	Pct
Fatality	3	0.3	8	0.9	6	0.9	2	0.9	2	2.2
Permanent disability	12	1.2	7	0.8	6	0.9	0	0	0	0
Days off	693	68.7	614	69.1	490	70.5	126	58.1	51	55.4
Days off and restricted	9	0.9	11	1.2	6	0.9	6	2.8	2	2.2
Restricted	18	1.8	23	2.6	11	1.6	12	5.5	7	7.6
No lost time	252	25.0	205	23.1	153	22.0	64	29.5	26	28.3

Figure 4



Comparison of equipment operator distributions from 1986 demographics with 1989-91 accidents by equipment type.

Equipment Size

Mobile equipment size was determined for roughly 70 pct of the accidents, except haulage trucks (58 pct, table 8). The table also shows the mean size of the equipment involved in the accidents and its standard deviation, which indicates a large range of sizes for bulldozers, trucks, and loaders. A detailed distribution of sizes for each type of equipment is included in later sections on each piece of equipment.

Table 8.—Mobile equipment mean size

Equipment	Mean size	Standard deviation	Pct size determined
Bulldozers	336 kW	123 kW	70
Graders	181 kW	33 kW	73
Haulage trucks	73 t	41 t	58
Loaders	6.0 m^3	3.1 m^3	71
Scrapers	25 m^3	4 m^3	70

Primary Activity

The accidents associated with each piece of equipment were categorized by primary activity. The number and percentage of accidents and the mean number of LWD per accident by equipment type and primary activity are shown in table 9. The percentage of accidents occurring during equipment operation ranged from 30 pct for loaders to 48 pct for scrapers. Accidents occurring while operating a haulage truck had the highest number of mean LWD, 30 days, while grader operator accidents had a mean of 9 LWD. Scrapers had the lowest percentage of ingress-egress accidents (26 pct), while loaders had the highest (33 pct). The most severe ingress-egress accidents occurred to haulage trucks (28 LWD). About 35 pct of bulldozer accidents were attributed to maintenance activities, compared with 22 pct for haulage trucks. Bulldozer maintenance accidents also were more severe (17 LWD) than the other equipment maintenance activities. Pedestrian accidents were most frequent with loaders (6 pct) and most severe with bulldozers (28 LWD). Further details of each of these categories is available in the following sections.

Table 10 gives a detailed account of the number and percentage of accidents by equipment type for each of the major accident classifications. The accidents for each piece of equipment are arranged by the primary activity of

Table 9.—Number, percentage, and LWD of accidents by primary activity and equipment type

Primary activity	Bulldozers	Trucks	Loaders	Scrapers	Graders	Total
Equipment operation:						
Number of accidents	321	411	210	103	31	1,076
Percent of column total	31.8	46.3	30.2	47.7	34.1	37.1
Mean LWD	21.1	29.7	25.2	9.8	8.6	23.7
Ingress-egress:						
Number of accidents	286	229	231	55	29	830
Percent of column total	28.3	25.8	33.2	25.5	31.9	28.6
Mean LWD	24.7	27.6	22.0	24.0	16.5	24.4
Maintenance:						
Number of accidents	354	196	198	52	26	826
Percent of column total	35.1	22.1	28.5	24.1	28.6	28.5
Mean LWD	17.0	10.4	15.1	8.3	8.8	14.2
Pedestrian:						
Number of accidents	41	44	42	5	5	137
Percent of column total	4.1	5.0	6.0	2.3	5.5	4.7
Mean LWD	28.3	22.8	17.8	17.6	6.0	22.1
Other:						
Number of accidents	7	8	14	1	0	30
Percent of column total	0.7	0.9	2.0	0.5	0	1.0
Mean LWD	37.6	24.9	14.5	51.0	NAp	24.5
Total:						
Number of accidents	1,009	888	695	216	91	2,899
Mean LWD	21.1	24.5	20.6	13.4	11.4	21.1

LWD Lost workday.
NAp Not applicable.

the accident victim. Comparisons of the percentage of accidents in each classification can be made between equipment types because the percentages are given as a portion of the total for each equipment. Table 10 will be referred to frequently as the accidents for each machine are discussed in the following sections. Appendix C provides definitions of the accident classifications which may not be self-explanatory.

BULLDOZERS

Bulldozers were associated with 35 pct of the coal mine mobile equipment accidents (table 3), making it the largest equipment category. The high percentage of bulldozer accidents was most likely due to the frequent use of bulldozers in the surface coal mining industry. The geology and geography of surface coal mines are often amenable to using bulldozers for overburden removal, prestripping, ripping, and reclamation activities. Figure 4 showed that in 1986, bulldozer operators were the largest share of mobile equipment operators. However, bulldozer operating accidents occurred at a lower rate than expected from the number of bulldozer operators. The stability and typically low-operating speeds of a bulldozer may have contributed to the lower relative frequency of accidents during bulldozer operation.

Bulldozers are used extensively on material stock piles, surge piles, spoil piles, and waste dumps. Bulldozers are used to move material only short distances, such as for pushing material into feeders and for maintaining berms along roads and stockpiles. Other frequent uses of bulldozers are brush-clearing or grubbing operations, ripping or stripping overburden, and also push loading of scrapers.

The most common size bulldozer reported in coal mine accidents was in the range 301 to 350 kW (404 to 469 hp), representing about 42 pct of the accidents (figure 5). This was followed by 201 to 250 and 501 to 550 kW (270 to 335 and 672 to 738 hp) machines. On average, the bulldozers had an engine power of 336 kW (451 hp). Just 9 pct of the bulldozer accidents involved a dozer of less than 201 kW (270 hp). As with most other mobile equipment, the size of bulldozers has been increasing in recent years. The mean size of the bulldozers involved in accidents increased from 324 kW (434 hp) in 1989 to 356 kW (477 hp) in 1991. This equipment included both crawler and wheel dozers. Accidents associated with crawler dozers were much more common than wheel or rubber tired dozers.

A breakdown of the bulldozer accidents by primary activity shows that maintenance was the leading category, followed by equipment operation and ingress-egress (figure 6). Bulldozers were the only piece of equipment in which maintenance was the most frequent primary activity. This suggests that bulldozer maintenance was more hazardous than maintenance for the other equipment or that comparatively more time was spent repairing or maintaining bulldozers. The following sections discuss each primary activity in more detail.

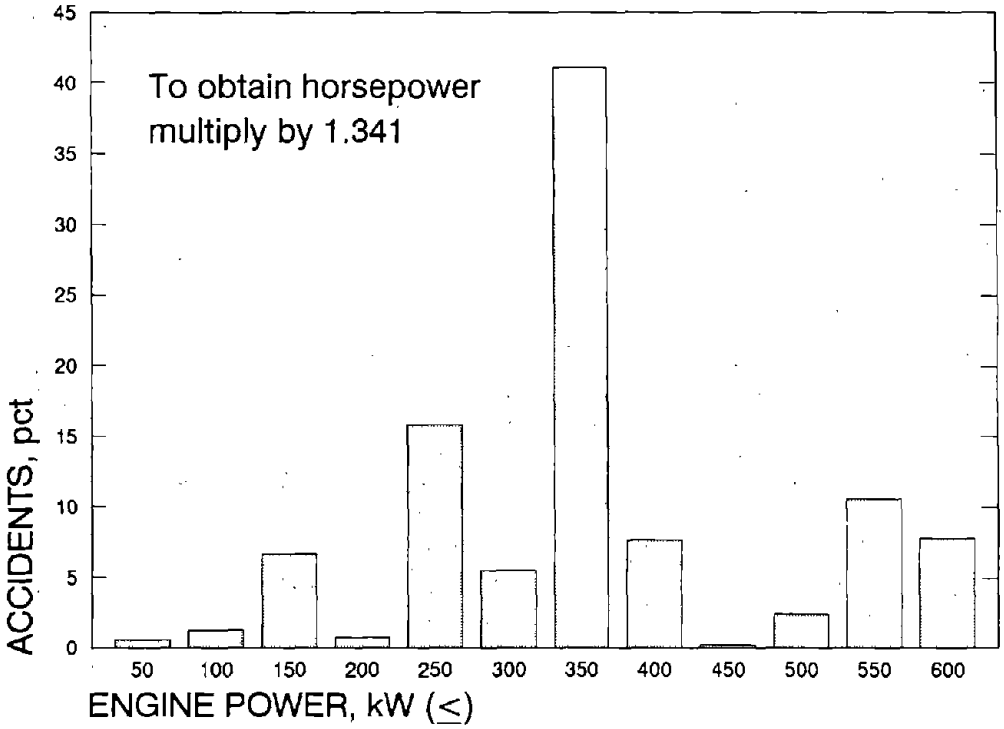
Table 10.—Accidents by equipment type and accident classification

Accident classification[1]	Bulldozers		Haulage trucks		Loaders		Scrapers		Road graders	
	Number	Pct	Number	Pct	Number	Pct	Number	Pct	Number	Pct
Equipment operation	321	31.8	411	46.3	210	30.2	103	47.7	31	34.1
Jarring	127	12.6	155	17.5	75	10.8	55	25.5	12	13.2
Rough ground	94	9.3	69	7.8	21	3.0	38	17.6	7	7.7
Loading shock	NAp	NAp	52	5.9	NAp	NAp	NAp	NAp	NAp	NAp
Cutting edge jarred	12	1.2	NAp	NAp	29	4.2	8	3.7	5	5.5
Unspecified	13	1.3	2	0.2	19	2.7	1	0.5	0	0
Dumping shock	NAp	NAp	24	2.7	NAp	NAp	NAp	NAp	NAp	NAp
All others	8	0.8	8	0.9	6	0.9	8	3.7	0	0
Loss of control	45	4.5	110	12.4	28	4.0	9	4.2	4	4.4
Too close to edge	30	3.0	40	4.5	6	0.9	1	0.5	0	0
Runaway	7	0.7	30	3.4	17	2.4	0	0	2	2.2
All others	8	0.8	40	4.5	5	0.7	8	3.7	2	2.2
Passive strain	48	4.8	25	2.8	22	3.2	10	4.6	2	2.2
Collision	9	0.9	35	3.9	7	1.0	6	2.8	6	6.6
Vehicle to vehicle	3	0.3	30	3.4	4	0.6	6	2.8	5	5.5
Stationary object	6	0.6	5	0.6	3	0.4	0	0	1	1.1
Being struck by flying object	18	1.8	6	0.7	12	1.7	1	0.5	0	0
Fire	6	0.6	8	0.9	17	2.4	3	1.4	0	0
Debris in eye	15	1.5	7	0.8	2	0.3	3	1.4	2	2.2
Getting caught or smashed	8	0.8	5	0.6	13	1.9	0	0	1	1.1
Highwall collapse	14	1.4	5	0.6	8	1.2	0	0	0	0
All others	31	3.1	55	6.2	26	3.7	16	7.4	4	4.4
Ingress-egress	286	28.3	229	25.8	231	33.2	55	25.5	29	31.9
Slip or fall	192	19.0	144	16.2	137	19.7	33	15.3	16	17.6
Overexertion	42	4.2	42	4.7	50	7.2	10	4.6	6	6.6
Uneven ground	17	1.7	12	1.4	16	2.3	3	1.4	2	2.2
Caught in door	16	1.6	7	0.8	6	0.9	2	0.9	3	3.3
All others	19	1.9	24	2.7	22	3.2	7	3.2	2	2.2
Maintenance	354	35.1	196	22.1	198	28.5	52	24.1	26	28.6
Slip or fall	85	8.4	35	3.9	50	7.2	11	5.1	6	6.6
Overexertion	74	7.3	31	3.5	39	5.6	15	6.9	5	5.5
Getting caught or smashed	62	6.1	24	2.7	32	4.6	4	1.9	8	8.8
Being struck by flying object	66	6.5	18	2.0	29	4.2	10	4.6	2	2.2
Debris in eye	20	2.0	26	2.9	10	1.4	3	1.4	1	1.1
Striking against equipment	12	1.2	23	2.6	14	2.0	3	1.4	2	2.2
All others	35	3.5	39	4.4	24	3.5	6	2.8	2	2.2
Pedestrian	41	4.1	44	5.0	42	6.0	5	2.3	5	5.5
Getting caught or smashed	9	0.9	12	1.4	8	1.2	1	0.5	2	2.2
Being struck by flying object	13	1.3	6	0.7	12	1.7	0	0	0	0
Slip or fall	6	0.6	14	1.6	3	0.4	3	1.4	1	1.1
Overexertion	9	0.9	7	0.8	6	0.9	1	0.5	0	0
All others	4	0.4	5	0.6	13	1.9	0	0	2	2.2
Passenger	0	0	0	0	1	0.1	0	0	0	0
Unknown	7	0.7	8	0.9	13	1.9	1	0.5	0	0

NAp Not applicable.

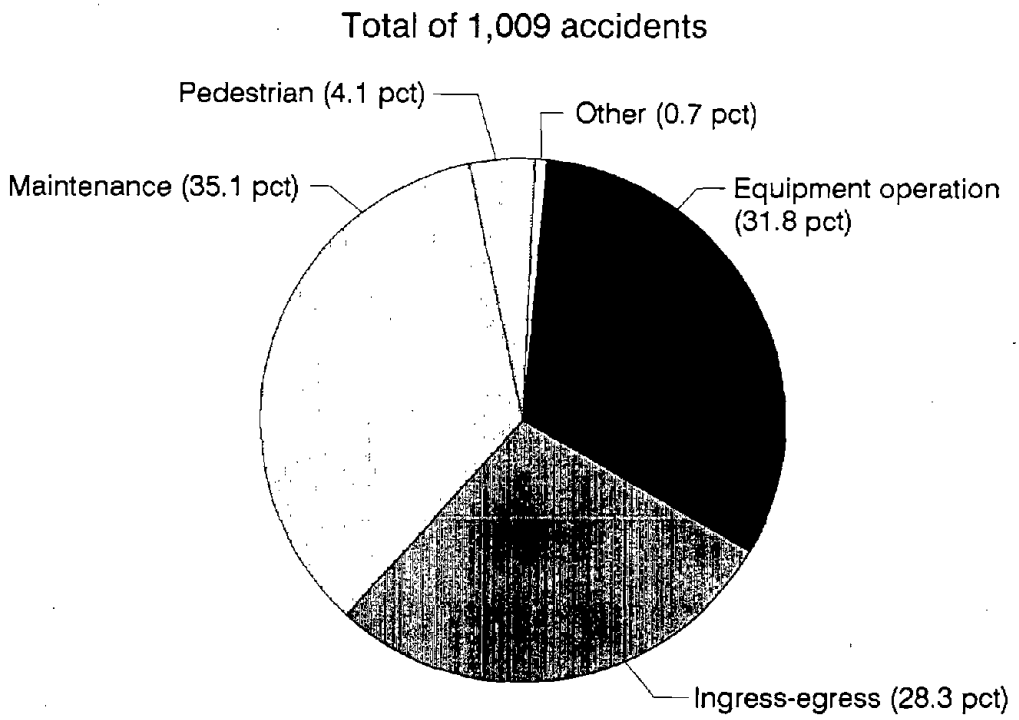
[1]See appendix for definitions of accident classifications.

Figure 5



Bulldozer size distribution.

Figure 6



Percentage of bulldozer accidents by primary activity.

Maintenance

Bulldozers had the highest incidence of maintenance related accidents of all the equipment types (35 pct), totaling 354 accidents. Four classifications cover 81 pct of these accidents. In decreasing order of frequency, they are slip or fall, overexertion, being struck by flying object, and getting caught or smashed (figure 7). Bulldozer maintenance accidents repeatedly involved the removal and replacement of the track or related parts. This suggests an extra hazard associated with the maintenance of these components. This was also revealed by the mean of 17 LWD for the bulldozer maintenance accidents (table 9). This was more severe than any of the other equipment and compares with a mean of 12 days for the other equipment maintenance accidents.

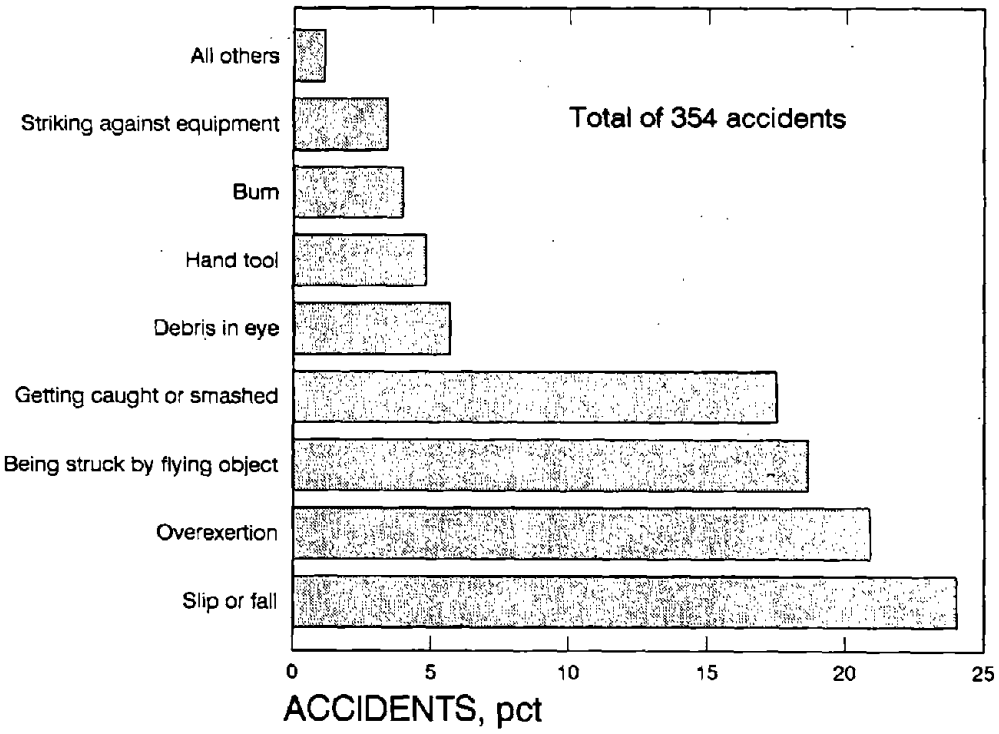
Slips or falls were the leading cause of bulldozer maintenance accidents, with 85 accidents or 8 pct of the total bulldozer accidents (table 10), and also the most severe maintenance accident, averaging 33 LWD. Injuries were most often sprains, strains, or bruises. These injuries occurred largely to the back, but also to various portions of the leg. Many slip or fall accidents occurred while performing routine maintenance tasks, such as checking, adding or changing fluids, or cleaning windows.

Overexertions were the next most frequent maintenance accident. These 74 accidents averaged 17 LWD. Nearly all of these injuries were a sprain or strain, but a few hernias were also recorded. Back injuries were most prevalent, but knees and hips were also frequently injured. The following narrative from the accident database is representative of overexertion accidents. "Employee was lifting a roller to a Cat dozer. He strained a muscle in his side." Three bulldozer mechanics were permanently disabled while lifting machine parts.

Being struck by a flying object was the third most common bulldozer maintenance accident (figure 7). The severity of these accidents was 8 LWD per accident. Most of the injuries were cuts and fractures, most often to hands or fingers, legs, or the back. The following narratives are typical of flying object injuries: "Driving pin with chisel, piece of chisel broke off and went into left hand." "Employee was removing track rollers from track frame on dozer with impact wrench. He had removed the bolts from the roller and was removing bolts from the next roller when the first roller fell on his lower leg, causing a simple fracture."

Getting caught or smashed maintenance accidents accounted for 6 pct of the total bulldozer accidents. Most of these accidents resulted in cuts or fractures. Amputation

Figure 7



Distribution of bulldozer maintenance accidents.

was more frequent in this accident classification than for any other. As one would expect, the vast majority of the injuries occurred to the fingers and hands. This was expected given the typical accident scenario; mechanics get fingers caught or smashed as they remove or replace parts from the bulldozer. These accidents often happened when handling the track or its components. An example of a typical narrative: "While trying to put a track on a bulldozer with an auto crane, the employees left fingers were caught between the gear sprocket and the track."

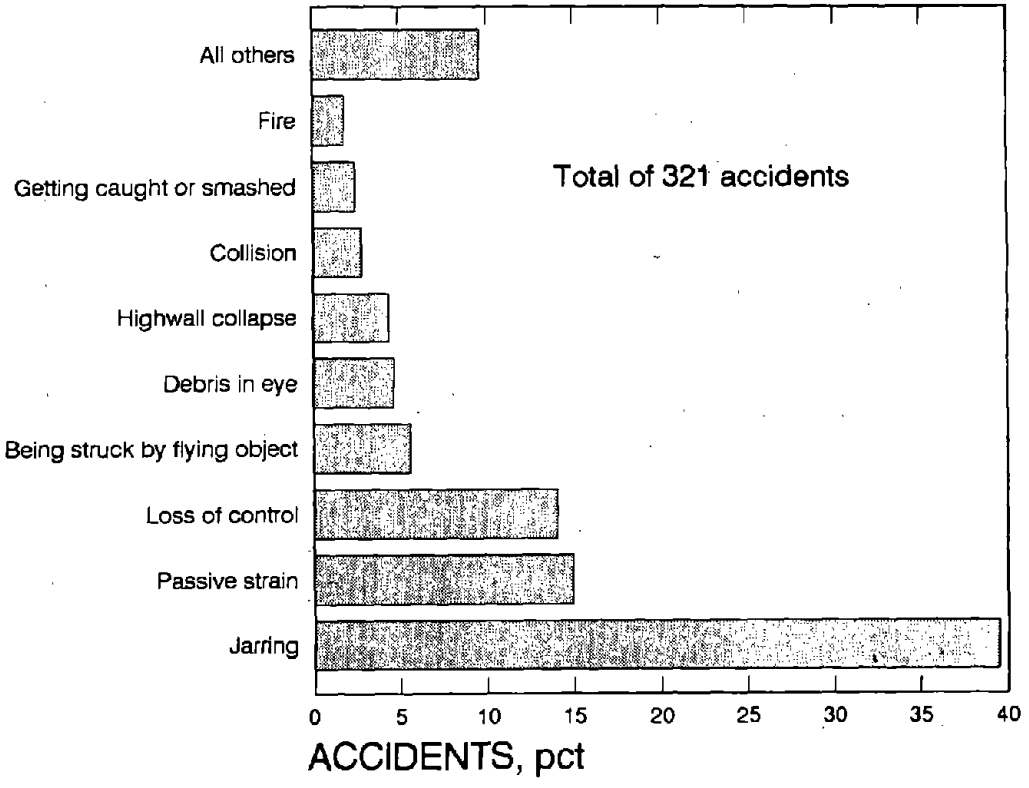
Equipment Operation

About 32 pct of the bulldozer accidents occurred to the operator while operating the machine (figure 6). This was a lower percentage than the average for all types of equipment (37 pct), possibly because of the higher incidence of maintenance accidents with bulldozers. The most frequent operator injuries occurred from jarring, passive strains, loss of control, and being struck by flying objects (figure 8).

Jarring accidents were the largest portion of the equipment operation category for bulldozers (figure 8). A large number (74 pct) of these were due to rough ground. Hitting a bump, rock, or windrow caused the most accidents and most of the accidents occurred as the bulldozer was backing up. Visibility is not as good when backing up and the operator twisting around is more susceptible to injury. Also when backing up, the bulldozers path is not smoothed out by the blade as it is when going forward. By far the most common injury was back strains. An average of 21 days was lost from work because of these accidents. The following is a typical accident narrative: "Employee was operating a bulldozer preparing drill bench. Working on top of loose material backing up when rear of machine dropped over rock. This caused pain in the lower back."

Another type of jarring accident, in which the jolt was transmitted through the bulldozer blade, accounted for 9 pct of the jarring accidents. Unlike the rough ground accidents in which vertical jarring forces were most common, these accidents typically involved longitudinal forces, i.e., forward and backward. These accidents occurred when the bulldozer blade either struck a solid, hidden object, or when slipping off an object such as a boulder. An example narrative of the former is "Employee was operating a rubber tired dozer at the coal hopper. While operating, the blade struck a piece of the runway and came to a sudden stop. Employee received several tests and a back brace." These jarring accidents most commonly resulted in a back sprain or strain, averaging 28 LWD.

Figure 8



Distribution of bulldozer equipment operation accidents.

Bulldozer operators were subjected to the highest rate of passive strains (5 pct) of any of the equipment operators (table 10). This may be due to the stiff suspension of a bulldozer. Also, bulldozers typically operate on some of the roughest terrain, except when tramming between jobs and when building or maintaining haulage roads. Most of these injuries were sprains or strains, to the back, however neck and shoulder injuries were also common. Passive strains averaged 18 LWD. The following narrative typifies passive strains: "He was operating a dozer and throughout the day he felt pain in his lower back. The pain increased around 3:30 p.m., so he went home to see the doctor." Because no specific incident was cited as causing the back pain, this accident was classified as a passive strain.

Loss of control of the bulldozer was the cause of 45 bulldozer accidents, or 5 pct of all bulldozer accidents (table 10). Two-thirds of these were the result of the bulldozer getting too close to the edge of a slope or drop off. The remaining accidents were runaways (mechanical problems), unknown causes or operating on too steep of a slope. Loss of control bulldozer accidents involved a rollover in 38 pct of the cases. Loss of control accidents averaged 33 LWD, significantly more severe than most bulldozer accidents. Injuries were frequently cuts, bruises, or multiple injuries occurring to multiple body parts or the head. The following is an example of a loss of control accident caused by getting too close to the edge of a slope: "Working large rock out of material on dump to be used for berming. When he approached existing berm, employee pushed material too far over the edge causing machine to break over and roll to bottom." This operator received multiple lacerations.

Bulldozer operators were subjected to a higher percentage of a number of accident types compared with the other equipment. One was passive strains as just discussed. Bulldozer operators also suffered a high frequency of the accidents being struck by flying object, debris in eye, and highwall collapse (table 10).

About 2 pct of all bulldozer accidents were the operators being struck and injured by a flying object. These injuries frequently were the result of a tree limb or branch striking the bulldozer operator while clearing brush or trees. Even with the protection of a ROPS or falling object protective structures (FOPS), bulldozer operators were being struck by tree limbs. These incidents usually result in cuts to the face or legs, averaging 6 LWD.

Bulldozer operators got dust or other objects in their eyes in 15 different cases, or 2 pct of the bulldozer accidents. Generally, these injuries were caused by wind blown particles of dust, dirt, or metal. These accidents averaged 0.3 LWD, one of the least severe types of injuries recorded. Often there was no injury once the particle had been removed from the eye, but in some cases the eye may have been scratched or cut.

Another small classification of accidents was highwall collapses or rock falls from highwalls (figure 8). Just 1 pct of all bulldozer accidents were of this type, but bulldozers were the equipment type most prone to these accidents (table 10). Front-end loaders also had 1 pct of their accidents in this classification. These two machines are most likely to be working near the highwall or working face. Some highwall collapse or rock fall cases involved property damage only and no injury. Injuries were either indirect from the bulldozer getting hit by the rock and thus jolting the operator or from the rock or window glass striking the operator directly. Injuries were frequently multiple in nature or bruises, with the head or multiple body parts receiving the injury.

Ingress-Egress

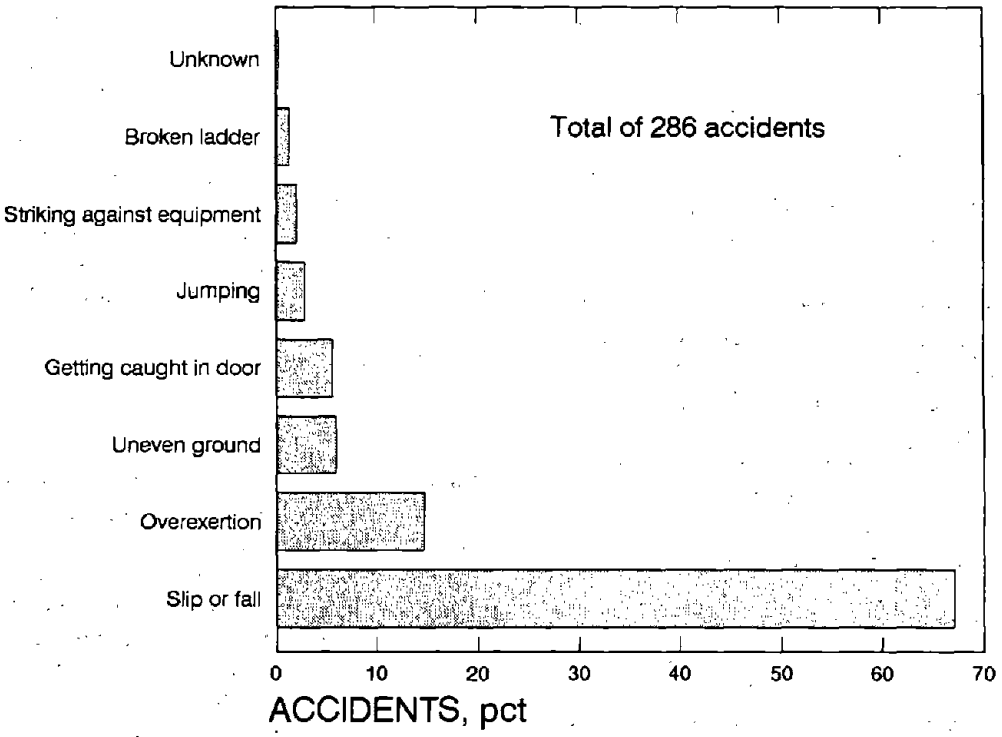
Bulldozers had the highest number of ingress-egress accidents of any equipment category, although the percentage (28 pct) was about average for the different equipment types (table 10). Bulldozer operators must be careful when getting on or off the equipment because they often must step on the track or the push arm. The track often creates a hazard because it is wet or muddy and typically presents uneven footing.

The 286 bulldozer ingress-egress accidents were predominately of two types: slips or falls or overexertions. Two-thirds of the ingress-egress accidents were a slip or fall (figure 9). Slips or falls tended to be more severe, averaging 28 LWD, compared to 22 LWD for overexertions. The most common injury for both types was a sprain or strain to the back or knee. Bruises and fractures also were frequent injuries in slip or fall accidents. The following is a narrative from a typical slip or fall accident: "Employee had finished fueling dozer and was dismounting dozer when he stepped down on push arm and he slipped and fell against the push arm injuring left arm and ribs." Less frequent ingress-egress accidents occurred from stepping down onto uneven ground, such as stepping on a rock and twisting an ankle, or from getting hands, fingers, or arms caught in the cab door (figure 9).

Pedestrian

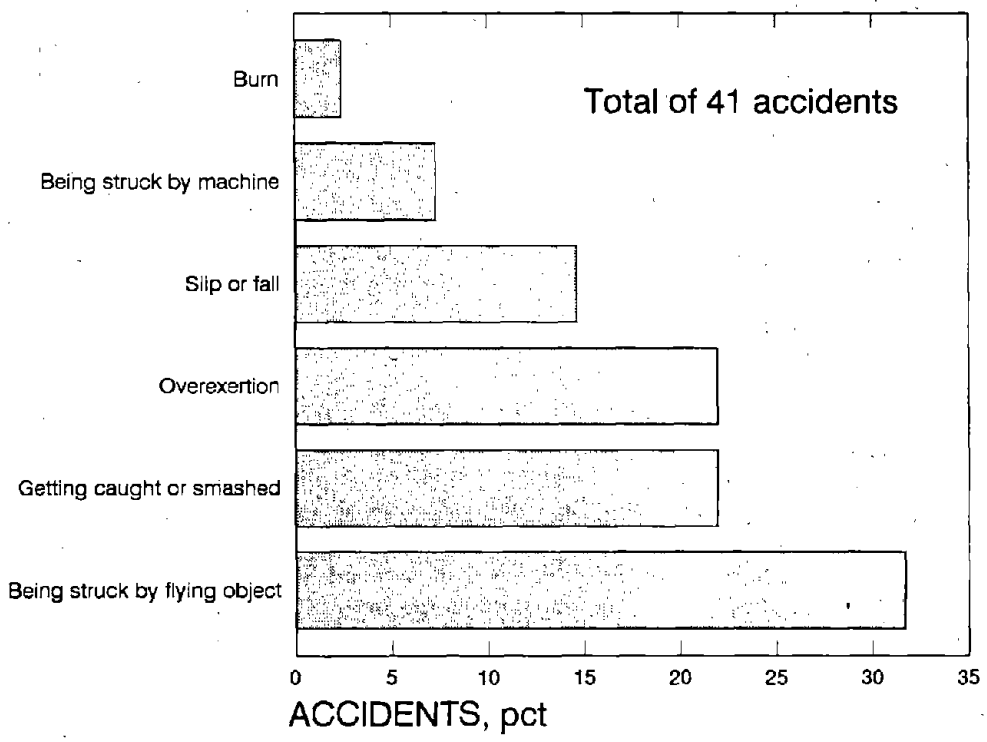
Pedestrian accidents associated with bulldozers were just 4 pct of the total, or 41 accidents. Most happened when a bulldozer was being used for utility purposes, not while blading material. A frequent scenario was using the bulldozer as a towing vehicle or for winching heavy objects. Many pedestrian injuries were inflicted by a towing or winch cable attached to a bulldozer. Another common activity was clearing brush or trees. The most frequent accident types were being struck by flying object, getting caught or smashed, or overexertion (table 10 and figure 10). As a group these accidents had a mean of

Figure 9



Distribution of bulldozer ingress-egress accidents.

Figure 10



Distribution of bulldozer pedestrian accidents.

28 LWD, making bulldozer pedestrian accidents the most severe of any equipment pedestrian accident and also the most severe bulldozer related primary activity.

The 13 being struck by flying object pedestrian accidents had a mean of 51 LWD. This was one of the most severe accident classes of any piece of equipment for classes of at least 10 accidents. These injuries were most frequently multiple in nature. Getting struck by tree limbs was common as illustrated by this narrative: "While removing a tree from the hood of the dozer, another tree broke, striking the one the employee was holding, pushing him into the dozer door and then he fell off the dozer."

Getting caught or smashed pedestrian accidents totaled nine incidences. The injuries from these accidents were much less severe, averaging 7 LWD. Injuries were mostly bruises or fractures, commonly to the fingers or hand. A typical example: "Employee pulling trees from slide area with dozer and winch. Employee removing winch cable from log of 18 inch diameter. Log rolled on top of right foot."

Pedestrian overexertion accidents occurred nine times. Many of these accidents involved pulling on winch cables or prying or pulling tree limbs loose which had jammed in the bulldozer. This is a typical accident narrative: "Employee was in a bulldozer hooked by cable to another bulldozer. They were clearing the hollowfill and getting ready to quit and he got out of the bulldozer to unhook the cable and could not get it loose, so he pulled on it to loosen it and pulled his right side - possible hernia." Overexertion injuries were predominately sprains or strains to the back, or to a lesser extent the knees and averaged 34 LWD.

HAULAGE TRUCKS

Haulage trucks are the principal means of coal and waste haulage in many surface mines. They were the second most common piece of mobile equipment involved in surface mine accidents (table 3). Most of the trucks used in the mining industry are off-road trucks, but smaller highway trucks were involved in some mining accidents. Smaller size highway trucks are used frequently in eastern coal mines to deliver coal to customers who are near the mine site. Highway truck drivers who are not mine employees may not be aware of the hazards associated with mines, because they don't have the training that miners do. Bottom dump or side dump tractor trailer units are common, although rear dump trucks still predominate.

Figure 11 shows that the capacity of the trucks involved in accidents was most frequently in the 80 t (85 st) range, followed by 50 (55 t) and 120 t (132 st) trucks. Trucks in the 80 t (85 st) range represented about 32 pct of the haulage truck accidents in which the truck size could be determined. Trucks of 20 t (22 st) or less were involved in only 7 pct of the accidents. Trucks over 160 t (176 st) were just 2 pct of the total. The overall mean truck size was 73 t (80 st), but size increased each year of the study, from 69 t (76 st) in 1989 to 77 t (85 st) in 1991.

Haulage truck accidents were more severe than other equipment accidents, with a mean of 25 LWD (table 9). This compares to 20 days for all the other equipment and a low of 11 days for graders. The equipment operation and ingress-egress activities had particularly severe accidents.

The primary activity of the injured person involved in haulage truck accidents is shown in figure 12. The figure shows that accidents during equipment operation were the largest portion (46 pct). Ingress-egress activities, maintenance, and pedestrian were the second through fourth categories, respectively.

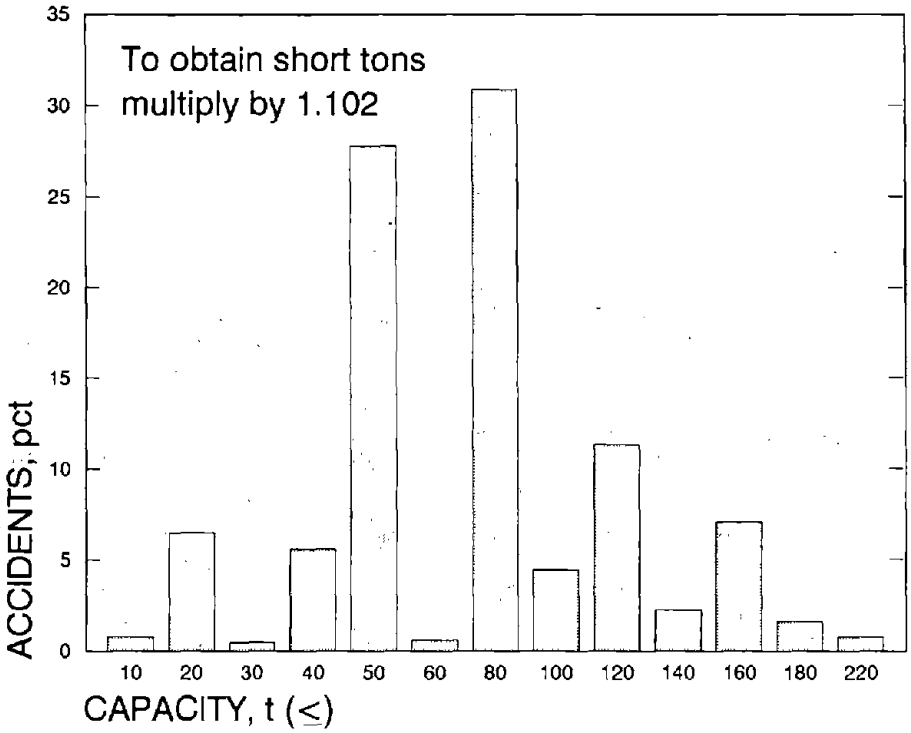
Equipment Operation

Accidents occurring while operating a haulage truck represented nearly half of the total truck accidents (figure 12). This large percentage, in relation to smaller portions for the other equipment, except scrapers, may indicate that haulage trucks were more hazardous to operate or that trucks spend a larger portion of their time in operation. Figure 4 indicated that more haulage truck accidents occurred during equipment operation from 1989 to 1991 than expected from the 1986 miner demographics. The size and speed of the trucks, along with the long steep grades encountered by trucks in surface mines present many potential dangers. The mean of 30 LWD for accidents while operating a haulage truck also points to the extra hazards. This was the highest LWD figure for any primary activity, for any type of equipment (table 9). The most frequent haulage truck operation accidents were jarring, loss of control, and collisions (figure 13).

Jarring injuries to the operator occurred principally from rough ground and loading shocks, but also dumping shocks. The source of the rough ground was nearly evenly split between bumps (which includes rocks) and holes or dips. These injuries, as with the other equipment, were largely back sprains or strains. The typical accident left the operator out of work for 25 days. The following narrative illustrates a typical scenario: "Employee stated that he was hauling slate to refuse area, he hit a rut and bounced into the top of the truck cab." The injury from that accident was a sprain or strain to the neck.

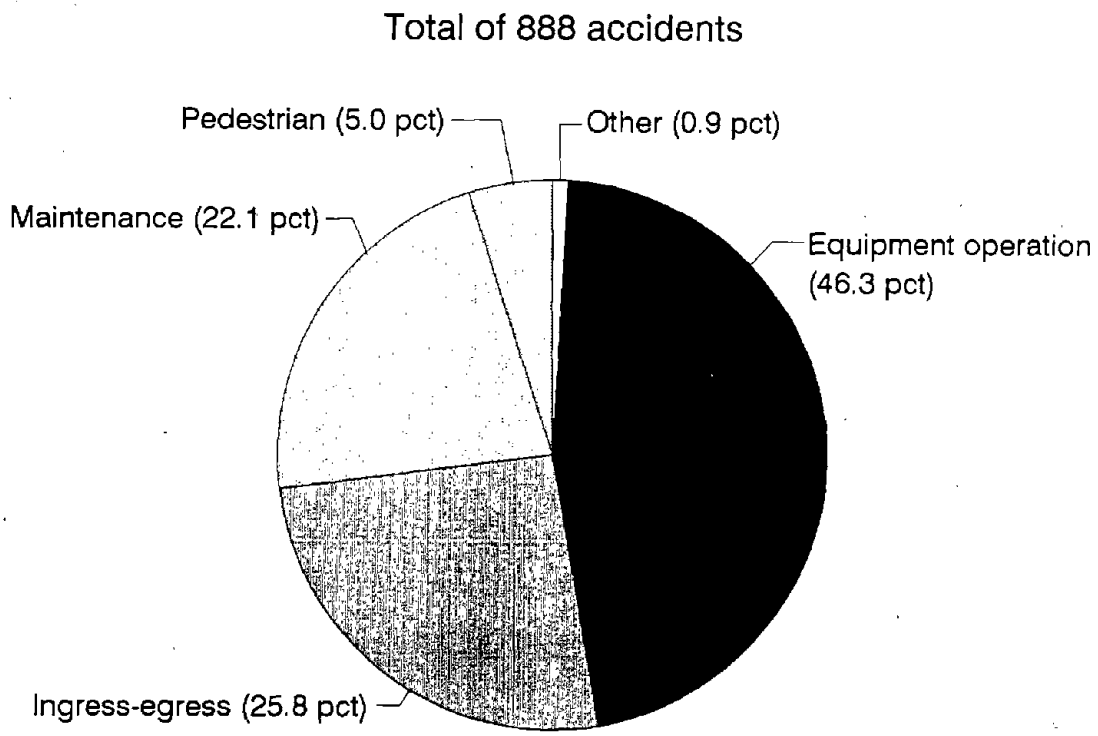
Loading and dumping shock accidents were unique to haulage trucks. Loading shocks occurred about twice as often as dumping shocks (34 versus 15 pct of jarring accidents). Loading shocks were most often the result of a large rock being dropped into the truck bed or the loader bucket striking the side of the truck body. Dumping shocks often happened when the dump bed fell unexpectedly, usually when a hoist cylinder failed. Loading shocks typically caused back sprain or strain injuries.

Figure 11



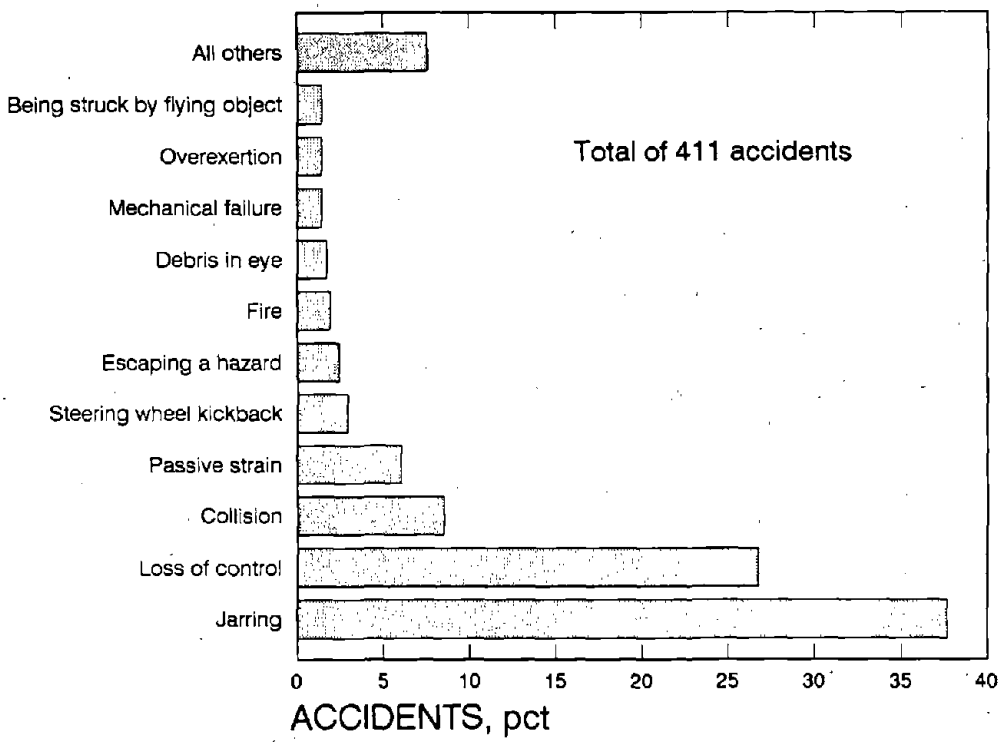
Haulage truck size distribution.

Figure 12



Percentage of haulage truck accidents by primary activity.

Figure 13



Distribution of haulage truck equipment operation accidents.

Dumping shocks most frequently caused neck or back sprain or strain injuries. Dumping shocks were more severe, resulting in 47 LWD, compared to 37 days for loading shocks. A typical loading shock accident narrative read as follows: "Injured was in the cab of truck being loaded by hydraulic shovel. A large boulder was being loaded into the truck, it struck the side of the truck bed and it jerked. The driver hit his head against the drivers side door and injured his back." Dumping shock cases were typical of the following: "While employee was dumping a load of material, box of 65 ton truck came down and jarred employee's neck."

Loss of control accidents for haulage trucks were 12 pct of all haulage truck accidents, a percentage nearly three times higher than for any other piece of equipment (table 10). These 110 accidents were severe in terms of LWD, averaging 36 days. Fifty-five percent (60 accidents) of the loss of control accidents resulted in a rollover. In another 19 accidents, the operator was either thrown or jumped from the cab. Rollover accidents averaged 36 LWD while accidents in which the operator was thrown or jumped resulted in 45 LWD.

About 62 pct of the loss of control accidents occurred while the truck was tramming. Another 32 pct occurred with the truck at the dump point or while dumping. Dumping accidents, although less frequent, were more severe than the tramming accidents. The types of injuries resulting from tramming or dumping accidents were similar; multiple injuries or fractures occurring to multiple body parts or the back.

Loss of control accidents while dumping were predominately caused by getting too close to the edge of the dump point. The following are typical examples of these accidents: "While operating 50 ton rock truck employee backed into dump area. While he was in process of dumping, ground collapsed which caused truck to slide backwards." "Was backing loaded rock truck up ramp to dump. Backed rear wheel over to side off roadway. Truck dropped down and flipped over throwing him out the door to the ground. Injuries included small cut to forehead and bruises, no broken bones." About 70 pct of the dump point loss of control accidents involved a rollover of the truck. Three fatalities occurred in this classification of accidents. They all appeared to result from the truck driver backing too close to the edge of a dump point.

Loss of control tramming accidents had more varied accident causes compared with dumping accidents. Tramming accidents were caused by runaways, getting too close to the roadway edge, road conditions or avoiding obstacles (listed in decreasing order). Typical narratives help to give a feeling for these accidents. "Truck engine died at top of

ramp into pit and brakes also failed. Operator jumped from truck when he thought safety berm wouldn't stop truck from entering sump hole." The resulting injury was a fractured lower leg that put the victim out of work for 56 days. "Employee stated he was driving gob truck when he got too close to the shoulder of the road and truck overturned on side causing him to hit knee on cab door."

Collisions were the third most frequent classification of accidents occurring during haulage truck operation (figure 13). Collisions were of two main types: vehicle to vehicle and vehicle to stationary object. Another type of collision, vehicle to pedestrian, was included in the primary activity "pedestrian." Vehicle to vehicle collisions were the most frequent, totaling 30 collisions, as shown in table 10. Half of the vehicle to vehicle collisions were unclear as to the orientation (i.e., head-on, rear-end, etc.) of the vehicles at the time of the crash. Of the remainder, the most frequent collision was a truck backing into another vehicle. This included trucks backing into the shovel at the loading point. A typical example of this situation is as follows: "Haul truck operator backed into shovel bucket while positioning to load, causing truck to stop abruptly. Operator suffered neck strain." Multiple injuries or bruises often resulted from vehicle to vehicle collisions. In comparison with all other equipment operation accidents, vehicle to vehicle collisions were not that severe, averaging 16 LWD. Two haul truck collisions did result in fatalities. One scraper operator was killed in a truck and scraper collision as follows: "While operating a loaded haul truck, loaded scraper apparently did not see the haul truck coming down the haul road and crossed in front of the haul truck. The haul truck operator veered to the left to avoid the scraper. Both pieces of equipment collided on the left shoulder of the road. As a result of the collision the scraper operator was killed." The haul truck operator dislocated his shoulder.

Vehicle to stationary object collisions totaled five cases as shown in table 10. The objects struck were a highwall, steel supports, power lines, and berms. The overhead power line was struck because the dump bed was not lowered. The narrative of that accident was as follows: "Driver failed to lower bed of truck after dumping at tipple. When driving from tipple, dump bed of truck caught on low voltage lines, causing truck to overturn. No electrical charges occurred to driver or truck." Injuries were typically bruises, cuts, or multiple injuries occurring to the back, eyes, shoulder, or multiple body parts. The severity was nearly the same as the vehicle to vehicle collisions (17 LWD).

Another accident occurring to haulage truck operators was steering wheel kickbacks (figure 13). These were a small portion of the haulage truck accidents (12 accidents, 1 pct), but an interesting type of accident occurring mostly to trucks. Steering wheel kickbacks usually result from the tires hitting a hole or soft spot in the road or while making a sharp turn. Injuries were normally sprains, strains or fractures to the fingers, wrist, or hand and averaged 9 LWD. This is a typical example: "Employee got right thumb caught in spokes of 150 ton haul truck steering wheel. The truck was attempting to back up and the tires stuck in some mud and steering wheel spun back to original position and hit the drivers right thumb." This particular accident resulted in a fracture.

Ingress-Egress

Approximately one-quarter of the haulage truck accidents occurred while mine personnel were getting on or off a truck (figure 12). Haulage truck accidents occurring during mounting or dismounting of the equipment were the most severe of any of the equipment types (table 9, 28 LWD). Ingress-egress accidents resulted principally from a slip or fall or from overexertion.

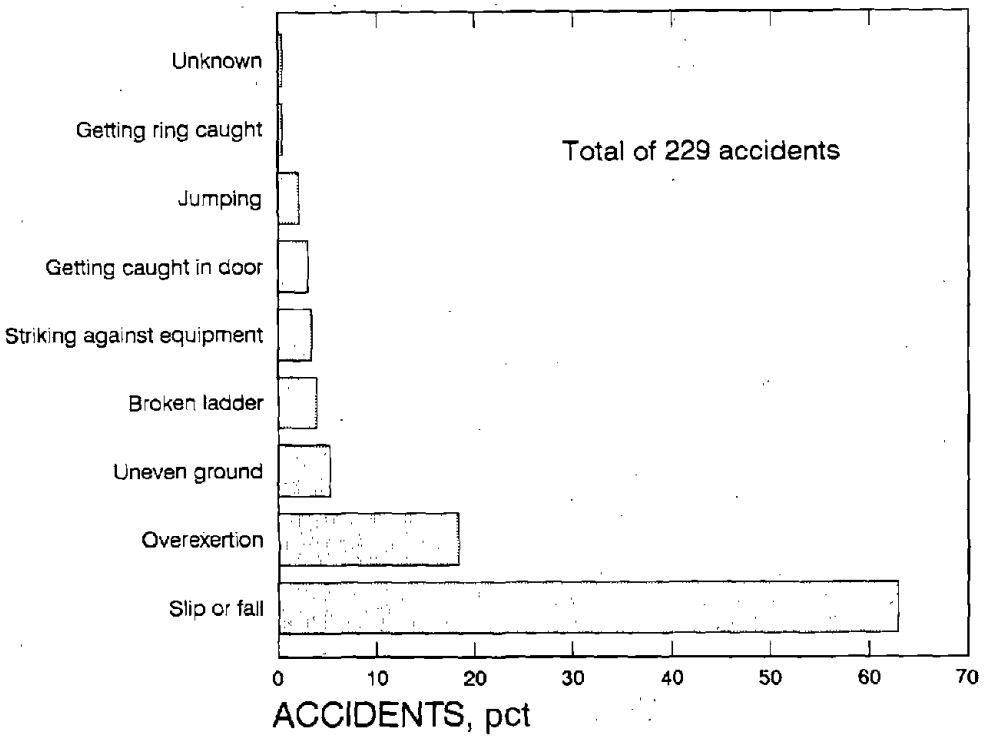
Nearly two-thirds of the ingress-egress accidents resulted from a slip or fall off the access stairs, ladders, or platforms (figure 14). This represents 16 pct of all the haulage truck accidents. More slip or fall accidents occurred when getting off the equipment than when getting on. Both equipment operators and maintenance personnel were prone to these types of accidents. Many resulted from people being in a hurry or trying to climb a ladder with objects in their hands. These typically severe accidents, averaging 30 LWD, most frequently caused sprain or strain injuries to the back. Knee and multiple injuries were also common, as were bruises and fractures.

Overexertions while getting on or off a haulage truck were 5 pct of the total truck accidents (table 10) or 18 pct of the ingress-egress accidents (figure 14). Overexertions were equally likely to have occurred when mounting or dismounting the truck. These accidents caused an average of 22 LWD, less severe than slips or falls, but still costly in terms of lost time. The most prevalent injuries were sprains or strains to the back, and to a lesser extent the knees and ankles. The following narrative is typical of overexertion accidents: "Employee stated he was dismounting from a truck when he felt a pain in his back. Employee worked until 2-12-90. He went to doctor and began missing at this point." The remaining ingress-egress accidents total less than 5 pct, with stepping onto uneven ground the largest portion (1 pct).

Maintenance

Haulage truck maintenance accidents were 22 pct of the total, the lowest percentage for any type of equipment (table 9). The reason for the low percentage of haulage truck maintenance accidents was not clear. The higher incidence of truck accidents while operating probably

Figure 14



Distribution of haulage truck ingress-egress accidents.

reduced the percentage of maintenance accidents. Haulage truck maintenance accidents were more evenly distributed among the 12 different maintenance classifications compared with the other equipment (table 10). No classification had more than 18 pct of the total maintenance accidents. The most frequent maintenance accidents were classified as slip or fall, overexertion, debris in eye, getting caught or smashed, and striking against equipment (figure 15).

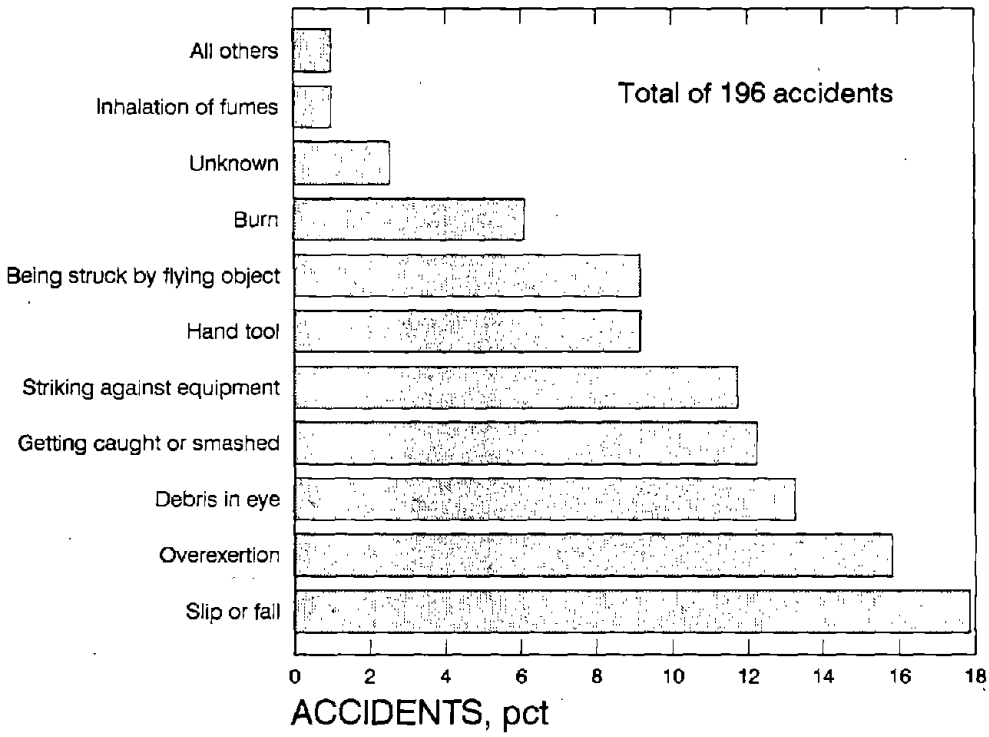
Maintenance slips or falls accounted for nearly 4 pct of all truck accidents or 18 pct of the maintenance accidents (figure 15). These accidents produced an average of 19 LWD. Fractures were the most common injury, followed by sprains or strains and multiple injuries. The body parts most frequently injured were the back or multiple body parts. Many of these accidents resulted from the poor access conditions maintenance workers must endure to get at the truck parts. A typical narrative follows: "While installing hoist cylinder on truck, slipped on frame and fell to the ground injuring lower back."

Overexertions during maintenance activities were responsible for 4 pct of all truck accidents (table 10). Many of these incidences resulted from lifting, pushing or pulling motions while doing repairs. Overexertions while lifting often happened when parts were being replaced or removed. Pushing or pulling overexertions often arose when torquing on wrenches or prying. The severity of these accidents was similar to the slip or fall accidents. The resulting injuries were repeatedly back sprains or strains and a smaller number of knee injuries. A common accident scenario is as follows: "Employee was tightening bolt under truck when he twisted his back." Working in awkward positions probably contributes to many of these injuries.

Accidents involving debris in the eye were the third most frequent haulage truck maintenance accident (figure 15). This type of incident was more common in haul truck maintenance than the other equipment. These injuries were some of the least severe, having just 0.6 LWD on average. Most of these incidences occurred when looking up while working underneath a truck or from dust kicked up by wind or compressed air.

Accidents involving a maintenance worker getting caught or smashed between machine parts was common in truck maintenance (3 pct of all truck accidents). These accidents usually happened when removing or replacing parts. Most of the injuries were lacerations to the fingers, hand, or wrist with an average of 2 LWD. Some more severe injuries did occur, namely fractures and amputations. Many of these accidents occurred similarly to the following narrative: "Tie rod end smashed and cut finger against steering jack of rock truck when making repairs."

Figure 15



Distribution of haulage truck maintenance accidents.

Other accident classes with more than 6 pct of the maintenance accidents were striking against equipment, hand tool injury, and being struck by flying object (figure 15). These accidents all had an average of less than 12 LWD. Striking against equipment accidents involved the worker bumping into a stationary object. A wrench slipping off a bolt often caused a finger, hand, or elbow to be struck against and cut by a part of the machine. Hand tool injury accidents typically resulted in cuts and bruises to fingers and hands. A common scenario was striking a finger with a hammer. Getting hit by a flying object often was due to metal chips flying from metal objects struck by a hammer or machine parts falling while being removed. Cuts to the head or arm were the most likely result.

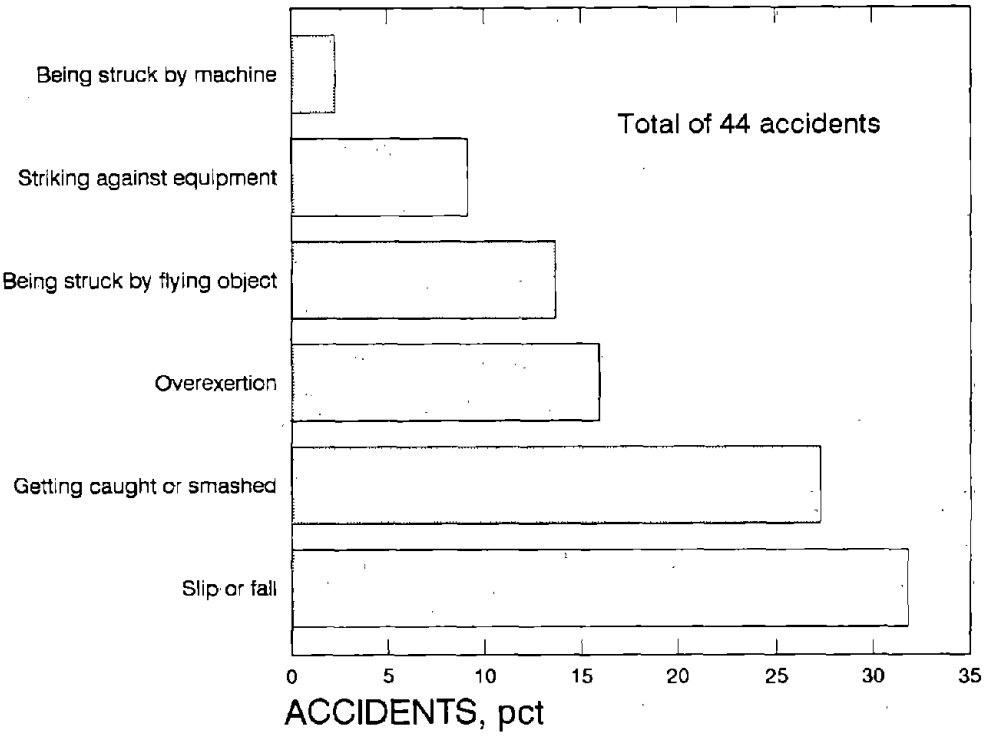
Pedestrian

Pedestrian accidents related to haulage trucks were 5 pct of the total (figure 12). These accidents usually involved the operator of the truck, after dismounting from the cab. The most frequent accidents were slip or fall, getting caught or smashed, overexertion, and being struck by flying object (figure 16 or table 10).

About one-third of the haulage truck pedestrian cases were a slip or fall. Recall from table 1 that slip or fall accidents were the most frequent cause for all mobile equipment accidents. Many pedestrian slip or fall accidents occurred as the truck driver climbed onto the bed of the truck to check the load or while securing the dump bed cover for on-road transport. The injuries from these slips or falls, averaging 38 LWD, were more severe than the other pedestrian accidents. Bruises, cuts or fractures were most frequent, often to the back, multiple body parts, or the head. The following narrative illustrates a typical scenario: "Employee was rolling tarp up from loaded coal truck. Foot slipped on wet step and fell from truck. Fractured left 3rd rib."

Just over a quarter of the haulage truck related pedestrian accidents were getting caught or smashed type of injuries. These also were generally the operator and usually happened while trying to free a stuck tail gate. Injuries were often cuts or fractures to the fingers or hand and averaged 14 LWD. The following example illustrates a typical incident: "Injured closing tailgate on dump truck. Grabbed tailgate and swung it up then slammed it shut. Failed to keep finger out of the way and it was smashed between truck bed and tailgate. Tip of small finger on right hand was severed."

Figure 16



Distribution of haulage truck pedestrian accidents.

FRONT-END LOADERS

The mobility of wheel loaders makes them a frequent choice for loading coal or waste into haulage trucks or for other duties around the mine site. The large front-end loaders on the market today are frequently being used to replace shovels for loading trucks. Loaders are versatile machines used for a variety of tasks besides loading trucks, such as cleaning up spillage, short range hauling to a crusher, stockpile or feeder, utility duty for hauling supplies, stripping overburden, grade work, as a tow vehicle, and even as a fork lift and personnel lift. Front-end loaders are more susceptible to rollovers because of their higher center of gravity. The center of gravity is even higher when a full bucket is in the raised position. Tramming the loader when empty is the most dangerous task because of the higher speeds involved, and because the empty loader will frequently bounce and weave at high speeds (*13*). The loaders involved in accidents included both wheel loaders and crawler mounted tractors, with wheel loaders more frequently involved in accidents than crawler loaders.

The most common size bucket for front-end loaders in the accident database was in the range 5.1 to 6 m^3 (6.7 to 7.8 ft^3). Figure 17 shows that the second most common size bucket was 10.1 to 12 m^3 (13.2 to 15.7 ft^3). The mean size of front-end loader buckets was the same as the mode, 6.0 m^3 (7.8 ft^3). These bucket capacities are the rated (heaped) capacities. Loader size stayed essentially the same over the 3-year period 1989-91.

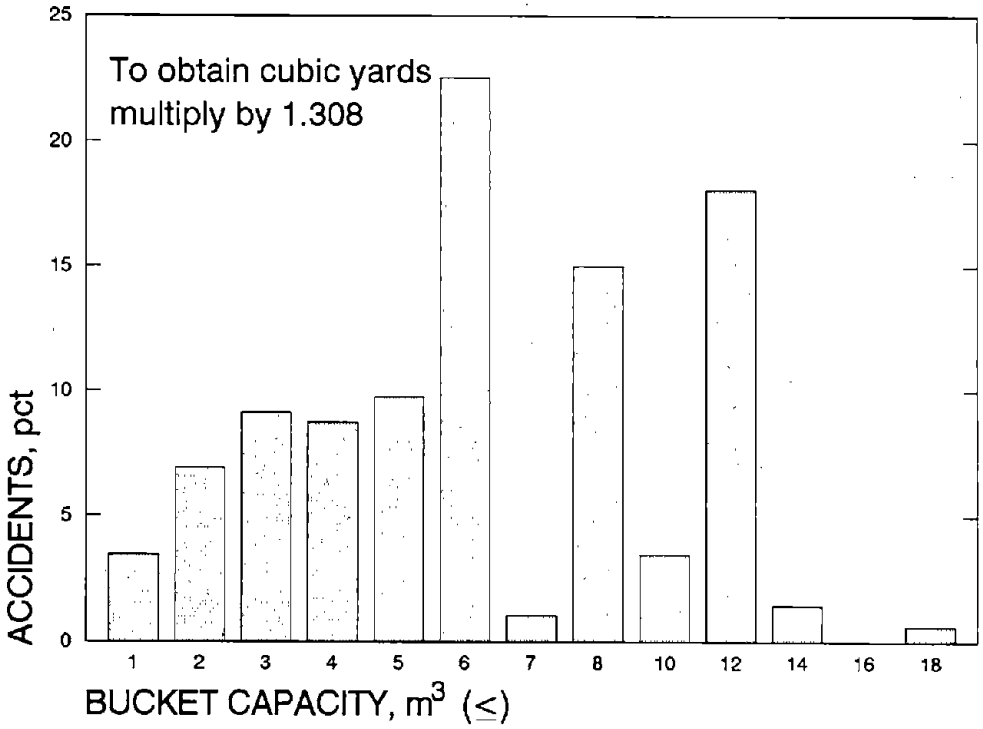
In the following sections, the front-end loader accidents are broken down by the primary activity of the accident victim. The percentage of accidents for each primary activity is shown in figure 18. Ingress-egress was the largest primary activity category for loaders. The second largest, equipment operation, was followed by maintenance and pedestrian activities. The 6 pct attributed to pedestrian accidents was higher than any other equipment.

Ingress-Egress

Accidents occurring while mounting or dismounting were the largest primary activity of front-end loader accidents, accounting for 33 pct of the total (figure 18). This was the largest percentage of ingress-egress accidents for any of the pieces of mobile equipment. Slips or falls were the leading classification of mounting and dismounting accidents for loaders, as it was for all the other equipment (table 10).

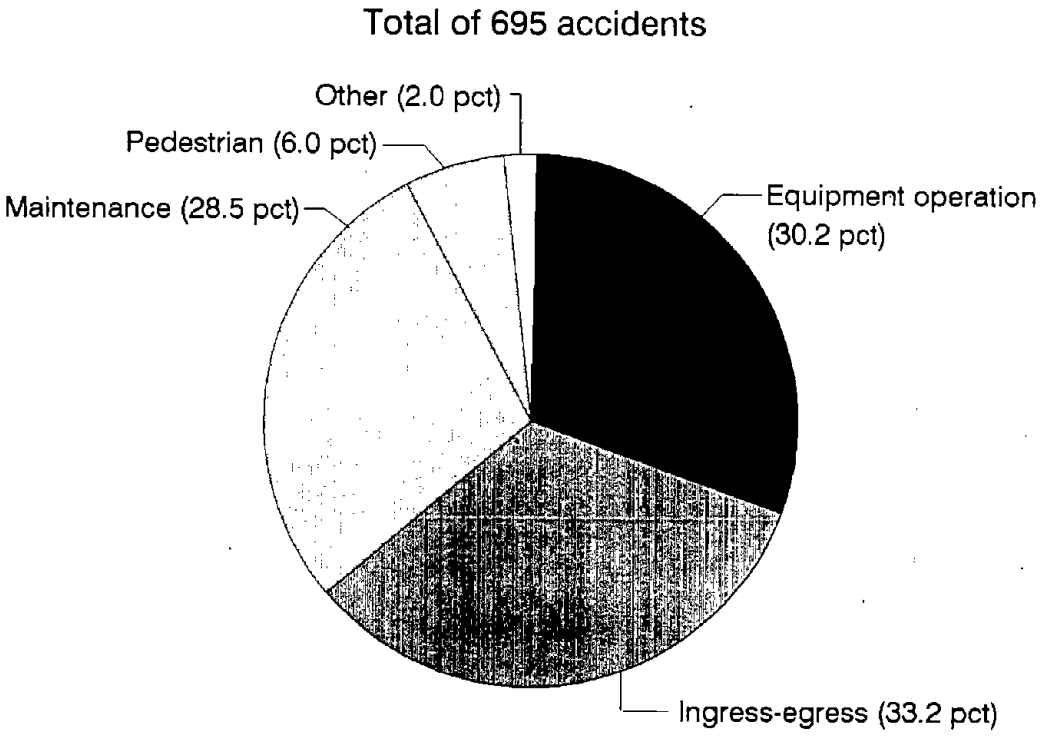
Nearly 60 pct of ingress-egress accidents resulted from a slip or fall from the access ladders on the equipment (figure 19) and averaged 25 LWD. This was higher than

Figure 17



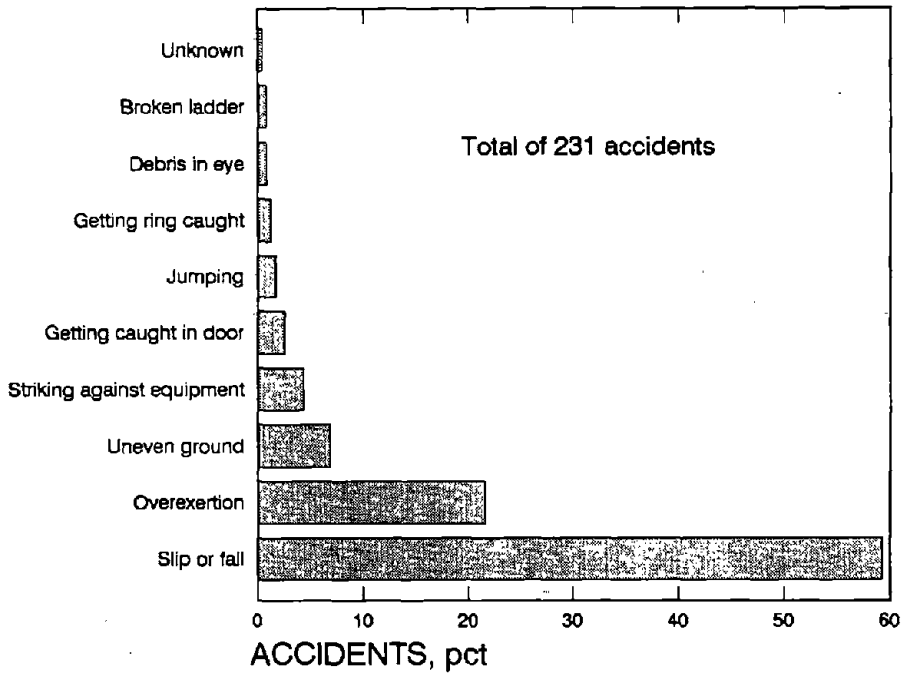
Front-end loader size distribution.

Figure 18



Percentage of front-end loader accidents by primary activity.

Figure 19



Distribution of loader ingress-egress accidents.

the average of 21 LWD for all loader accidents. The most common injury from these accidents was sprains or strains, then bruises and fractures. The back was the most frequently injured part of the body, followed by ankles, knees, and hips. A typical accident narrative reads as follows: "While dismounting loader, employee's foot slipped from the ladder steps causing him to fall to the ground."

Overexertions were the second most common ingress-egress accident. Table 10 shows that these 50 accidents accounted for 7 pct of the loader total. Injuries were nearly always a sprain or strain. The most common body part injured was evenly distributed among knees, backs, and ankles. An example of this type of accident is "Stepped off of ladder on left side of loader and pulled something in his back." These accidents averaged 19 LWD. About three-fourths of both the overexertion and slip or fall accidents occurred while dismounting the loader. Many of these injuries occurred from having to stretch to reach the first step when climbing on the machine or stepping to the ground when getting off. Many of the knee and ankle injuries were from simply landing wrong when getting off.

Another 2 pct of the loader accidents happened while stepping down off the loader onto uneven ground (table 10). These 16 incidences were about 7 pct of the ingress-egress accidents (figure 19) and averaged 19 LWD. Usually these cases involved the injured person stepping onto a rock, windrow, or rut. Some cases also resulted from stepping onto objects such as hoses on the shop floor. Injuries were mostly sprains or strains to ankles, but also occurred to knees or the back.

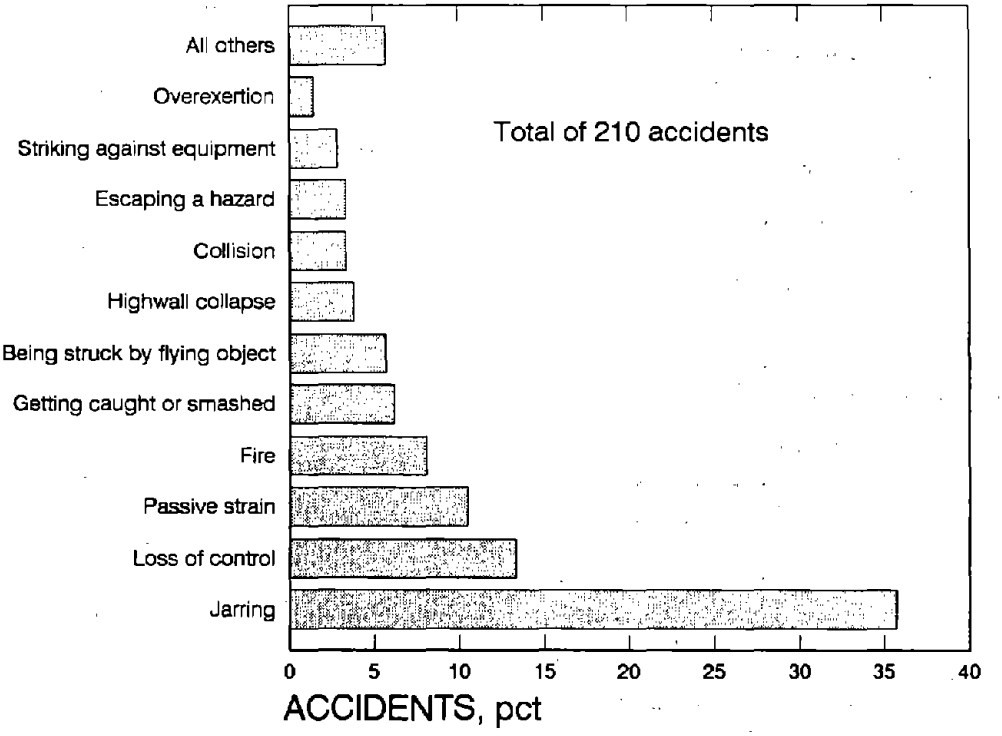
Equipment Operation

Accidents occurring to the driver while operating the equipment were 30 pct of the total loader accidents (figure 18). This was the lowest such percentage for the different pieces of mobile equipment. This could be due to several reasons. Loaders are typically operated at lower speeds than haulage trucks and scrapers and often don't tram long distances, but work within a limited area. This could lead to fewer accidents. The higher percentage of ingress-egress and pedestrian accidents would lower the number of accidents during loader operation. None the less, accidents during equipment operation were still the second largest category of loader accidents.

Injuries to the operator occurred most frequently from jarring, comprising 36 pct of the equipment operation accidents (figure 20) and averaging 24 LWD. These jarring accidents resulted from, in decreasing order, bucket cutting-edge slipping or striking an object, rough ground, and unspecified (table 10). Front-end loaders were the only piece of equipment in which rough ground was not the leading classification of jarring accidents.

Just over 4 pct of front-end loader accidents were jarrings or jolts to the operator transmitted through the loader bucket. These bucket-jarring accidents had a mean of 36 LWD, much more severe than most accidents. Most

Figure 20



Distribution of loader equipment operation accidents.

of these accidents occurred when the loader bucket cutting-edge slipped off a large rock while digging into a rock pile or a boulder slipped out of the bucket when backing away from the pile. An example from the accident narratives is as follows: "Employee was working end loader in some rock, he hung bucket of loader under rock and it slipped out, jerking his back when the loader came down." This accident was typical in the way the accident happened and also in the injury which occurred. Another frequent scenario was a loader bucket striking a solid object buried in a material pile, such as a large rock or a concrete apron surrounding a stockpile feeder. Injuries were typically sprains or strains to the back or neck.

Accidents due to rough ground were the second most common type of jarring accident, with 3 pct of the total loader accidents (table 10). This was less than half the percentage for any other piece of equipment. The slower operating speeds of loaders compared with other equipment probably accounted for the lower incidence of rough ground accidents. This may also explain the relatively low mean of 11 LWD. Running over a bump or rock, or hitting a pothole were the most likely to cause a rough ground accident. Most of these accidents resulted in back sprain or strain injuries. Neck and shoulder strains were also prevalent.

Loss of control was the second most frequent equipment operation accident after jarring (figure 20). Of the loader accidents, 4 pct involved a loss of control of the vehicle, resulting in an average of 35 LWD. The most frequent cause of the operator losing control was runaways resulting from mechanical failures. Examples include loss of brakes, loss of steering, and stalled engines. An example of a runaway: "Employee was performing reclamation work, moving spoil with front-end loader. Engine on loader stalled on a slope, employee stated that he lost control and jumped from the machine, causing a fracture to the right tibia." Besides runaways, the next most common loss of control accident resulted from operator error in getting too close to the edge of a slope. The types of injuries varied for loss of control accidents, but bruises, cuts, and scratches were the most frequent, occurring to various parts of the body.

Of the 28 loss of control accidents, 11 involved the operator jumping or being thrown from the loader. When the operator jumped from the vehicle, the injuries tended to be severe, averaging 66 LWD. Injuries were often a fracture of the leg or arm. Eight loss of control accidents resulted in a rollover of the loader. Rollover accidents averaged 11 LWD, six times less than when the operator jumped. Rollovers that occurred after the operator had jumped out of the vehicle were not included as a rollover accident.

The third most frequent accident occurring to loader operators was passive strains (figure 20). Twenty-two of these accidents were reported, representing just over 10 pct of the accidents during equipment operation. Injuries were mostly back sprains or strains and averaged 34 LWD. Many of these injuries result from the cumulative effect of the operator being bounced around in the cab over time.

Equipment fires occurred more often with loaders than with any other type of equipment. Table 10 shows that 17 fires occurred to loaders. Four of these involved burn injuries while the remainder resulted in equipment damage only and no injuries. These fires generally occurred in the engine compartment, often caused by broken hydraulic or fuel lines. Overheated brakes were also cited as a reason for fires. Six additional fire accidents occurred in which the loader operator was injured by jumping from a burning loader, but was not burned. These accidents were included in the "all others" classification in table 10. A large share of those injuries were a sprain or strain to the back or less frequently the foot or ankle and resulted in 14 LWD on average.

Front-end loader operators were also more likely to be struck by a flying object than other equipment operators, except bulldozer operators (table 10). Accidents of this type were 2 pct of the total loader accidents. These accidents most often were the result of a rock rolling out of the raised bucket and striking the operator either directly or by going through the windshield. The types of injuries and the body parts injured varied in these accidents. Cuts, scratches, bruises, and multiple injuries to shoulders, hands, knees, and arms were most common. These injuries were generally less severe than others, averaging 3 LWD per accident.

Maintenance

Maintenance was the primary activity at the time of the accident in 29 pct of all loader cases (figure 18), about average for all the different types of equipment. Of the maintenance accidents, 75 pct were concentrated in four different classifications, listed in decreasing order of frequency: slip or fall, overexertion, getting caught or smashed, and being struck by flying object (figure 21).

The largest classification of maintenance accidents, slip or fall, was 7 pct of the total loader accidents (table 10). Slip or fall accidents were the most severe loader maintenance accident in terms of LWD. Lost time averaged 29 days, compared to 15 LWD for all loader maintenance accidents. Most slips or falls during maintenance activities occurred during routine maintenance tasks such as cleaning windshields and mirrors, greasing, or checking fluid levels. The most common injuries were sprains or strains, bruises, or fractures to the back, ribs, or anywhere on the lower extremities. The following is a typical narrative from the accident database: "Employee was greasing machine. He slipped and fell against machine breaking two ribs."

Overexertions were the second most frequent maintenance accident (figure 21), but were much less severe than the slip or fall accidents. Overexertion injuries averaged 15 LWD. These injuries resulted mostly from lifting, pushing or pulling actions, often when the worker was in an awkward position. The following is a typical accident scenario: "Employee was repairing the front drive line on a loader. While lifting the universal and holding it in place to start the bolts he twisted and strained his back." Most of the injuries were back sprains or strains.

Getting caught or smashed maintenance accidents accounted for 5 pct of all loader accidents and averaged 19 LWD. These accidents generally occurred while mechanics were removing or replacing parts. Fingers and hands were often pinched or smashed when the parts slipped. Injuries were frequently cuts, crushing, and fractures. The following narrative illustrates a typical accident: "A mechanic was removing a brake assembly when it suddenly slipped, mashing his fingers between the assembly and a support bracket. He broke one finger and required stitches in the other." One fatality occurred in this accident classification when a loader mechanic was crushed by a hoist cylinder.

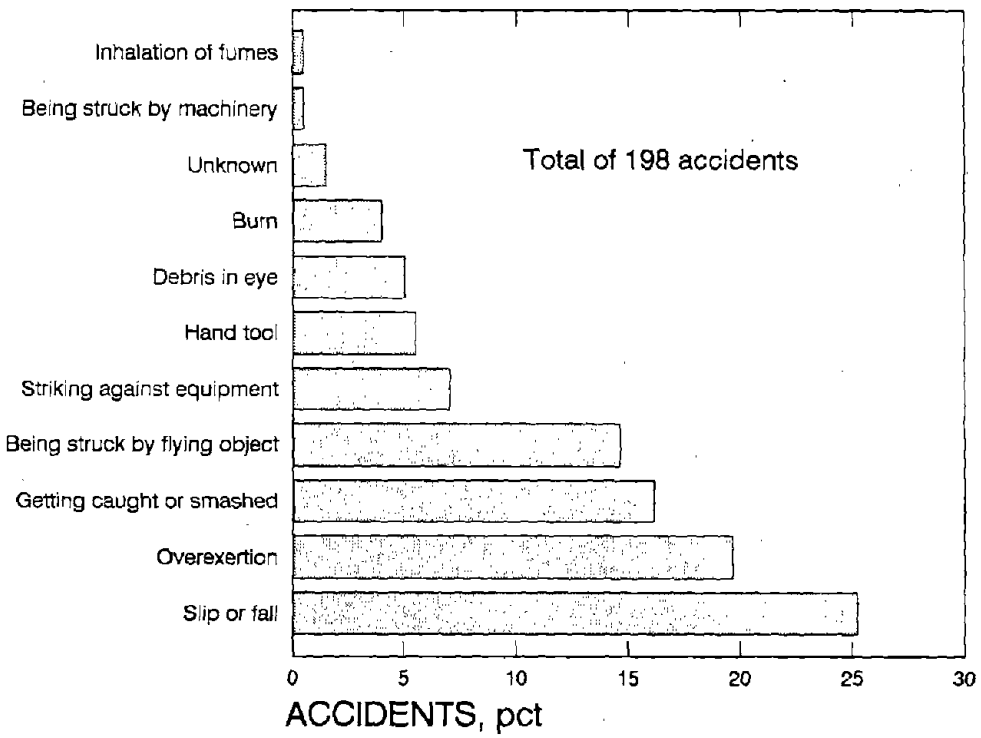
The fourth most frequent loader maintenance accident involved the injured being struck by a flying object (figure 21). Twenty-nine accidents or 4 pct of the total loader accidents were of this type (table 10). The severity of these accidents was quite low, 3 LWD. Half of these cases were from flying objects and half from falling objects. Falling objects included such items as tools, chains, and machine parts. Injuries were often cuts to the head, toes, or hands. Flying objects were largely pieces of metal from striking a metal object with a hammer. This accident scenario was observed repeatedly: "While changing the bucket teeth, the injured was using a sledge hammer to drive teeth on the bucket. A small piece of metal flew off either the hammer or the tooth and lodged in the upper left arm..."

Pedestrian

Front-end loaders had the highest percentage (6 pct) of pedestrian accidents of all the equipment (table 10). This was probably because of the diverse usage of loaders, which often involves pedestrians working closely with a loader operator to perform utility tasks. The most frequent accidents were categorized as follows: being struck by flying object, being struck by machine, getting caught or smashed, and overexertion (figure 22).

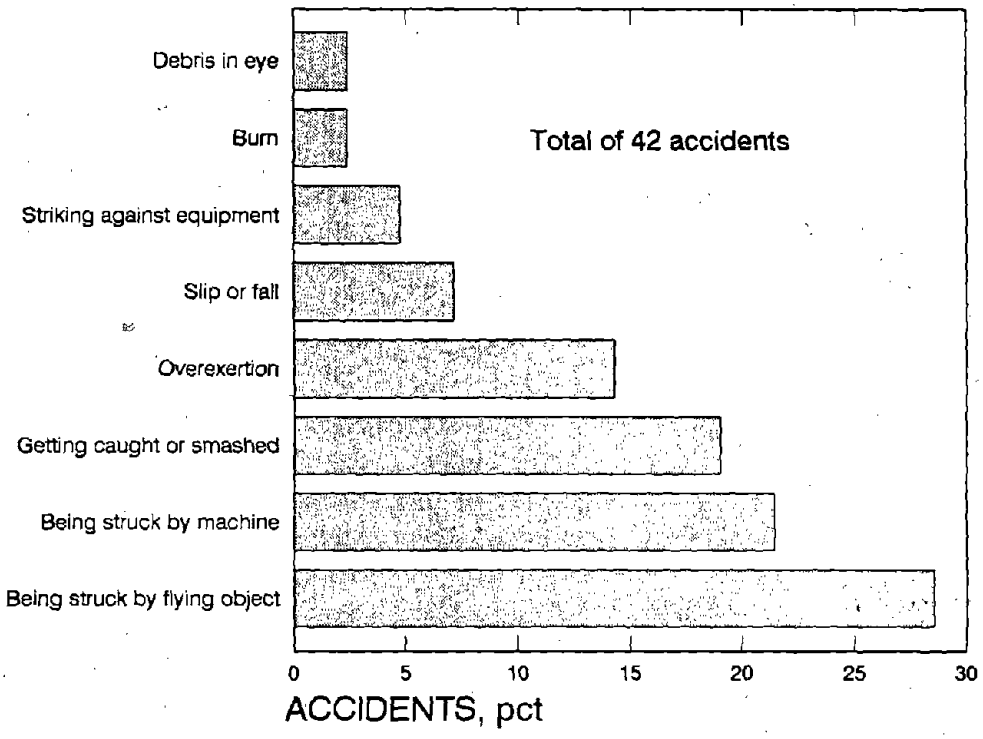
Pedestrians working with or near a front-end loader were most frequently injured by flying objects. Twelve of the 42 pedestrian accidents were of this type. The types of injuries that occurred varied greatly, as did the body parts

Figure 21



Distribution of loader maintenance accidents.

Figure 22



Distribution of loader pedestrian accidents.

injured. These accidents were quite severe, having a mean of 32 LWD. The most common accident was a person being struck by material or supplies that fell out of the loader bucket. The narrative "Tamping a drill hole and a frozen lump fell out of the loader and hit his right upper thigh" is a typical example.

Nine pedestrians were struck by front-end loaders, making this the second most common pedestrian accident. One fatality occurred in this manner. The following is the narrative of the fatality: "A coal truck driver experienced fatal injuries when he was crushed beneath an endloader in the stockpile area of the plant. Victim had dumped his coal load, parked his truck and got out to observe the frozen coal load in another truck attempting to dump when he was struck by the endloader. The endloader was backing out of the stockpile." More typically these cases involve a pedestrian working with the operator to guide and position the bucket into place. For example: "Moving light plant with chain, hooking chain to ring on plant. Bucket of loader drifted down catching his right arm against the light plant. Received deep cut on right forearm." The most frequent injuries were bruises or multiple injuries to the back, foot, or multiple body parts.

Pedestrians getting caught or smashed were another 1 pct of the loader accidents (table 10). These accidents most often resulted from loading or unloading equipment or supplies into the bucket. This is a typical example: "Employee loading scrap metal into loader bucket. Got left ring finger caught between two pieces of metal and cut it." Injuries were mostly bruises and cuts to the fingers and averaged 9 LWD.

Six pedestrians overexerted themselves while working with a front-end loader. Lifting or pushing objects into the loader bucket caused most of these injuries. The injuries were primarily back sprains or strains, averaging 35 LWD.

SCRAPERS

Scrapers are used for short to medium distance hauling, most commonly in loose material such as coal stock piles, topsoil, or overburden stripping, but also in dam construction, road construction, road maintenance, and contouring for reclamation. Scrapers are often used with draglines or bulldozers for stripping operations. For longer range hauling or moving blocky material, trucks are usually preferred. Elevating scrapers are self-loading, but are not as common in the mining industry as push or pull scrapers. Push loading of single engine scrapers is often done with bulldozers, while push or pull loading is done with two scrapers, one pushing and the other pulling.

Scrapers are designed for relatively level ground. Operators must use extreme caution when working on sidehills because scrapers are not stable in those situations. Operating the scraper with the bowl high shifts the center of gravity upwards, creating an unstable situation. Accidents resulting during push loading of scrapers were unique to scrapers and bulldozers, although most of these types of accidents occur to the scraper operator.

The mode size bowl capacity for scrapers involved in surface coal mine accidents was found to be 24 m^3 (31 yd^3), with about 50 pct of the total. The size distribution of the scrapers involved in accidents is shown in figure 23. The mean bowl size was 25 m^3 (33 yd^3). This number stayed the same through the 3-year period of this study.

Scrapers had the highest percentage of back injuries (32 pct) and also sprains or strains (49 pct). This was probably because of the high number of rough ground and passive strain injuries that occurred to scraper operators (discussed below). Injuries associated with scraper accidents averaged 13 LWD, lower than the other equipment, except road graders (table 9).

Accidents occurring during the operation of a scraper were 48 pct of the total (figure 24). This was the highest percentage for any of the equipment (table 9). Ingress-egress accidents were the second most frequent category, followed by maintenance and then pedestrians. Scrapers had the lowest percentage of ingress-egress or pedestrian accidents. This was expected given the high incidence of equipment operation accidents.

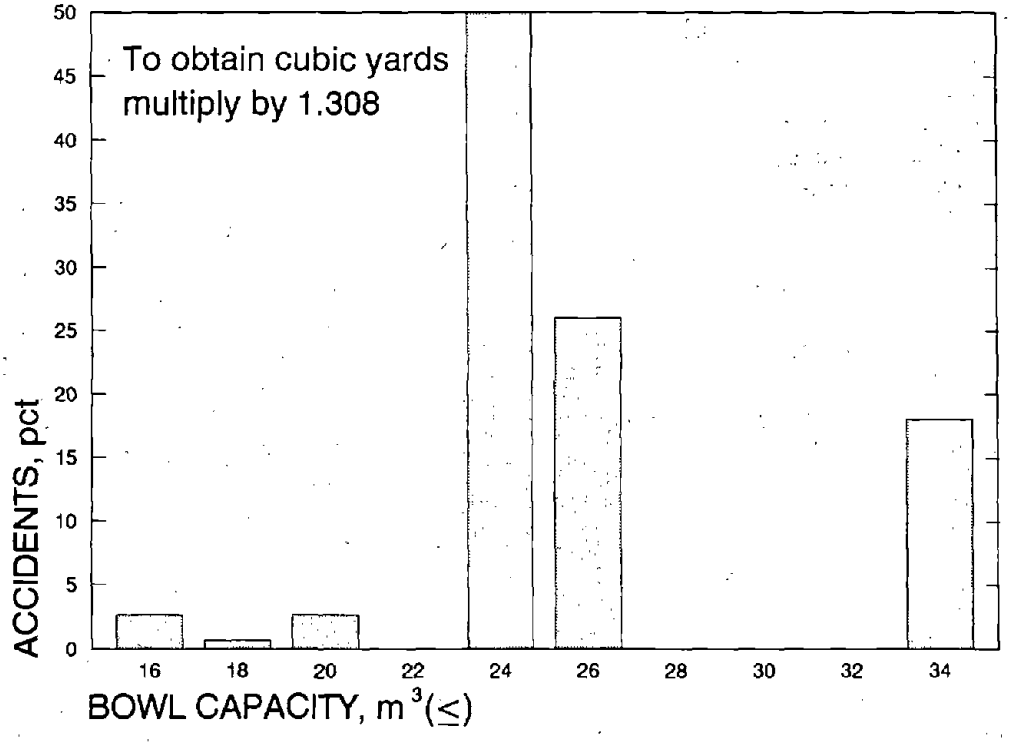
The total number of scraper accidents was 216, less than three times that of the previously discussed equipment. Scrapers accounted for just 8 pct of the total mobile equipment accidents (table 3). The lower number of scraper accidents was primarily a consequence of fewer scrapers being utilized in surface mining compared with bulldozers, haul trucks, or front-end loaders. Figure 4 showed there were substantially less operators of scrapers and graders in the 1986 surface coal mining work force than the other types of equipment. As a result of the smaller scraper data population, the data are less reliable. Thus, less detail will be given for the scraper accidents than for the previously discussed accidents.

Equipment Operation

The high rate of accidents while operating scrapers may indicate that this machine was inherently more hazardous to operate, or perhaps less of a maintenance or ingress-egress hazard. Scraper operation accidents were less severe than the other equipment. Their mean lost work time was 10 days, compared to 24 days for all equipment (table 9). Accidents occurring while operating a scraper were categorized as follows: jarring (26 pct), passive strain (5 pct), loss of control (4 pct), collision (3 pct), and striking against equipment (2 pct).

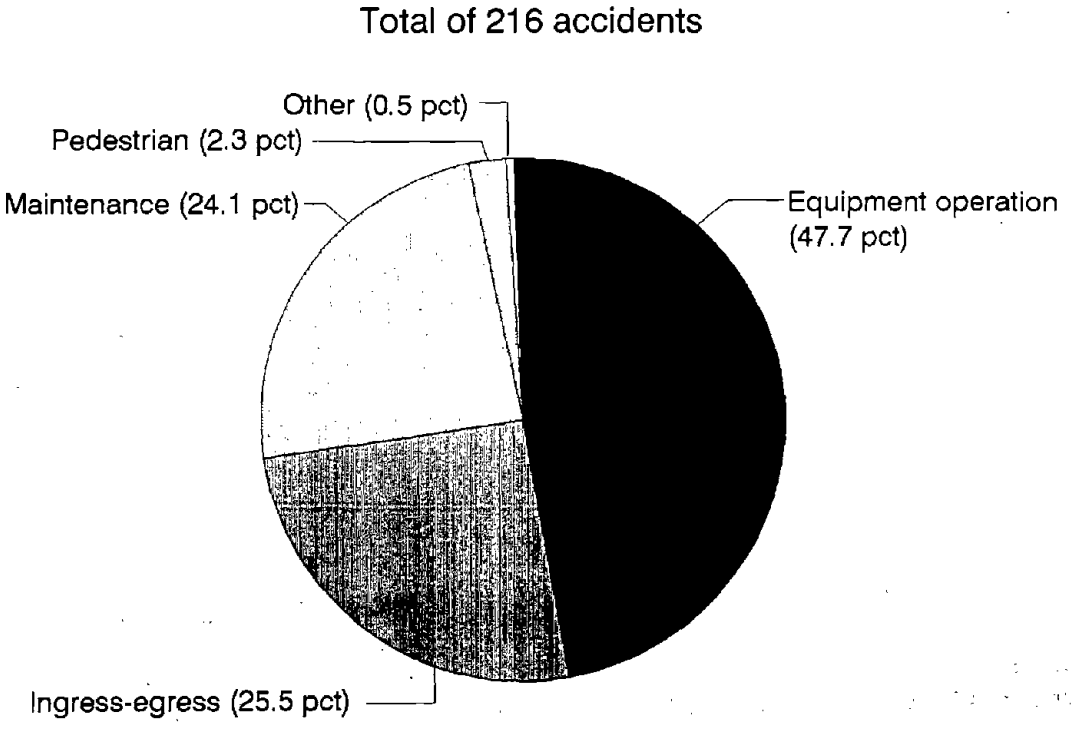
Jarring injuries to the scraper operator were over 50 pct of the equipment operation accidents (figure 25). This

Figure 23



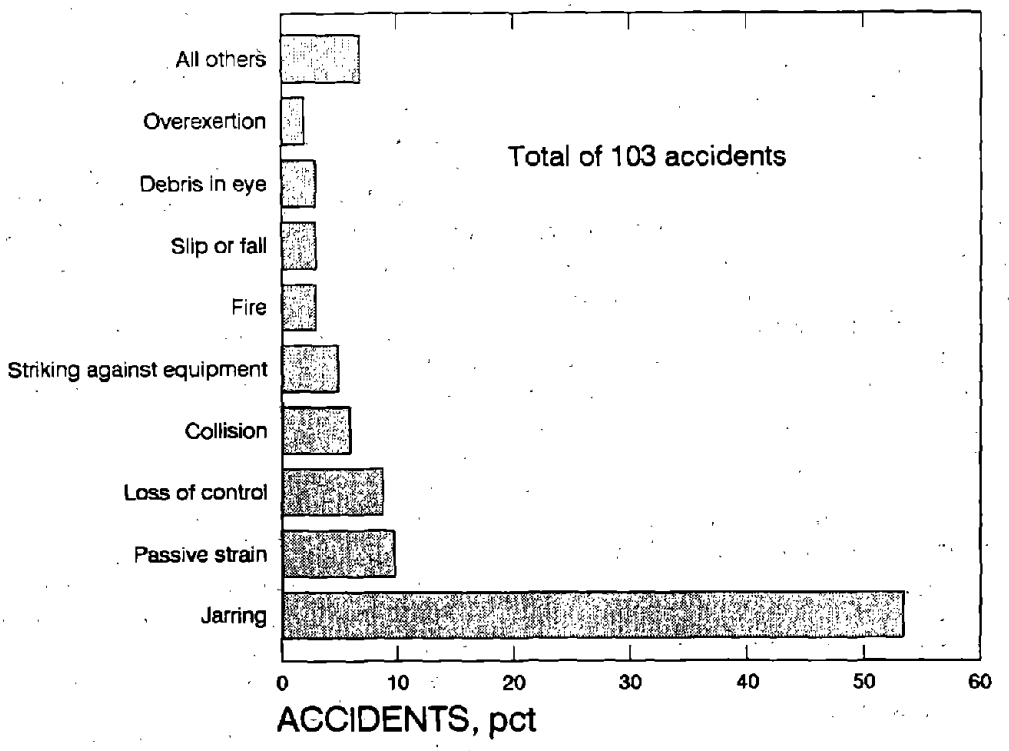
Scraper size distribution.

Figure 24



Percentage of scraper accidents by primary activity.

Figure 25



Distribution of scraper equipment operation accidents.

was the largest portion for any of the equipment. This was largely due to the high number of rough ground cases. Rough ground accidents were 18 pct of the total scraper accidents. These accidents were caused by the scraper hitting a bump or hole in their path. Hitting bumps accounted for more accidents than holes. The rugged terrain on which scrapers operate contributes to the high incidence of these accidents. Fortunately the resulting injuries, averaging 9 LWD, were less severe than the rough ground accidents for the other equipment. As with the other equipment, the injuries were mostly back sprains or strains. The following narrative typifies these accidents: "While operating a pan, the operator was turned to his right watching the back of the machine dump his load of material when the front wheel dropped into a hole, jarring and bouncing the employee and hurting his back."

Another type of jarring accident was due to the scraper's cutting edge striking a solid object. Most often this was a rock or boulder that was solid enough to jolt the operator. These accidents totaled 4 pct of the scraper accidents. These eight accidents averaged 11 LWD. Injuries were usually a sprain or strain to either the neck or back. The following is a typical accident narrative: "Employee was loading the pan through the cut and pan caught a large rock and came to a complete stop. Rock chipped off from pan's cutting edge moving on over some rocks that were ahead of it, jarring the operator and causing injuries to the back, neck and elbow. Saw a chiropractor."

Jarring accidents during push or pull loading were unique to scrapers and bulldozers. Most of these accidents injured the scraper operator, not the bulldozer operator. Six accidents of this type were recorded, about 3 pct of the scraper accidents. The injury usually occurred when one vehicle stopped or slowed suddenly, causing a collision which jolted the operator. Injuries were usually sprains or strains to the abdomen, back, shoulder, or neck.

The second major classification of accidents occurring to scraper operators were passive strains, with nearly 10 pct of the equipment operation accidents (figure 25). These occurred more frequently to scraper operators than for any other equipment, except bulldozers (table 10). Both of these machines operate off roadways on rough ground, which has a cumulative effect on the operator. The severity of these accidents was just 5 LWD, compared to values as high as 50 LWD for haulage trucks. The injuries sustained were nearly always back sprains or strains.

Loss of control was the third main classification of equipment operation accidents. The small number of accidents (9) prevents any detailed discussion. Generally, these occurred in similar fashion to the other equipment. Common causes were getting too close to an edge,

runaways, excessive speed, or poor road conditions. Injuries were mostly fractures and sprains or strains to either the torso (back, shoulders, chest) or the face (jaw, chin, mouth). The severity of these accidents was lower than corresponding accidents for other equipment.

Ingress-Egress

About one quarter of the scraper accidents occurred during mounting or dismounting of the machine (figure 24). This was the lowest percentage of ingress-egress accidents for any of the equipment. The accidents that occurred were similar to the ingress-egress accidents for all the other pieces of equipment. Slips or falls were the most common, followed by overexertions (figure 26 or table 10). The average number of days lost from work for all the scraper ingress-egress accidents was 24 days, about average for all the other types of equipment. The severity of scraper slip or fall accidents was lower than for the other equipment, while the severity of the overexertions was higher. Injuries were similar to those of the other equipment, with back sprains or strains the most frequent.

Maintenance

Maintenance accidents, totaling 52, were 24 pct of the total for scrapers (figure 24). The average was about 28 pct for all the equipment types. Scraper maintenance accidents had a mean of 8 LWD, compared to 15 days for all the other equipment. Scraper maintenance accidents were the least severe of the five pieces of mobile equipment. The largest classification of scraper maintenance accidents was overexertion (15), followed by slip or fall (11), and being struck by flying object (10). Figure 27 gives the percentage of the maintenance accidents in each of those classifications. Overexertion injuries, as with the other equipment, happened principally from lifting, pushing, or pulling motions and largely resulted in back sprains or strains. These were also the most frequent injuries for slip or fall accidents. Injuries to maintenance workers struck by flying objects were more varied. Cuts and fractures were the most common injury types and toes or the back were the most frequently injured body parts. One fatality occurred to a scraper maintenance worker trying to put out a fire. See previous equipment types for more detail on the nature of the accidents and injuries common to these maintenance classifications.

Pedestrian

Just five pedestrian accidents were associated with scrapers. This was only 2 pct of the scraper accidents, a smaller percentage than any other machine (table 10). Ground personnel typically don't work around scrapers and thus few pedestrian accidents occurred. Slips or falls accounted for three of the five accidents (table 10).

ROAD GRADERS

Road graders are an important road maintenance tool in surface mines. The frequency of rough ground accidents with all mobile equipment points to the importance of maintaining smooth haulage roads. Material spillage, road washouts, and pitted or rutted roads lead to many rough ground accidents. Only 91 road grader accidents were reported over the 3-year period of this study, making road graders the smallest category of mobile equipment accidents (3 pct). This was expected because of the low number of graders used in mines compared with other mobile equipment. The few grader accidents can easily skew the data. As a result, only broad trends for each primary activity will be discussed.

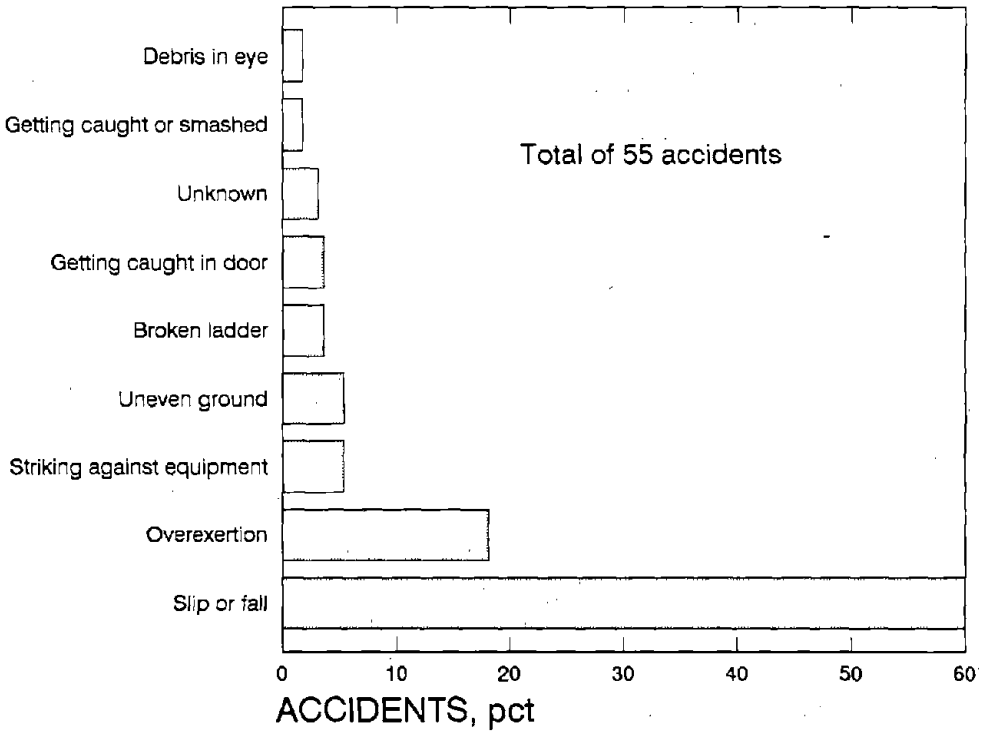
The size of road graders involved in coal mine accidents tended to be at the high end of the range of sizes. Larger road graders are generally more productive and thus are more frequently used. Figure 28 shows that the most common size, with nearly 60 pct of the total, were graders with 201 to 225 kW (270 to 302 hp) engines, while the average size was 181 kW (243 hp).

The primary activity for the road grader accident victims is shown in figure 29. The figure shows that the largest category was equipment operation (34 pct), followed by ingress-egress (32 pct), maintenance (29 pct), and pedestrian (6 pct). Just five pedestrian accidents were reported, thus they will not be discussed further. The overall mean severity of the grader accidents was lower than any of the other equipment, 11 LWD (table 9). This was nearly half the value for all the equipment types combined.

Equipment Operation

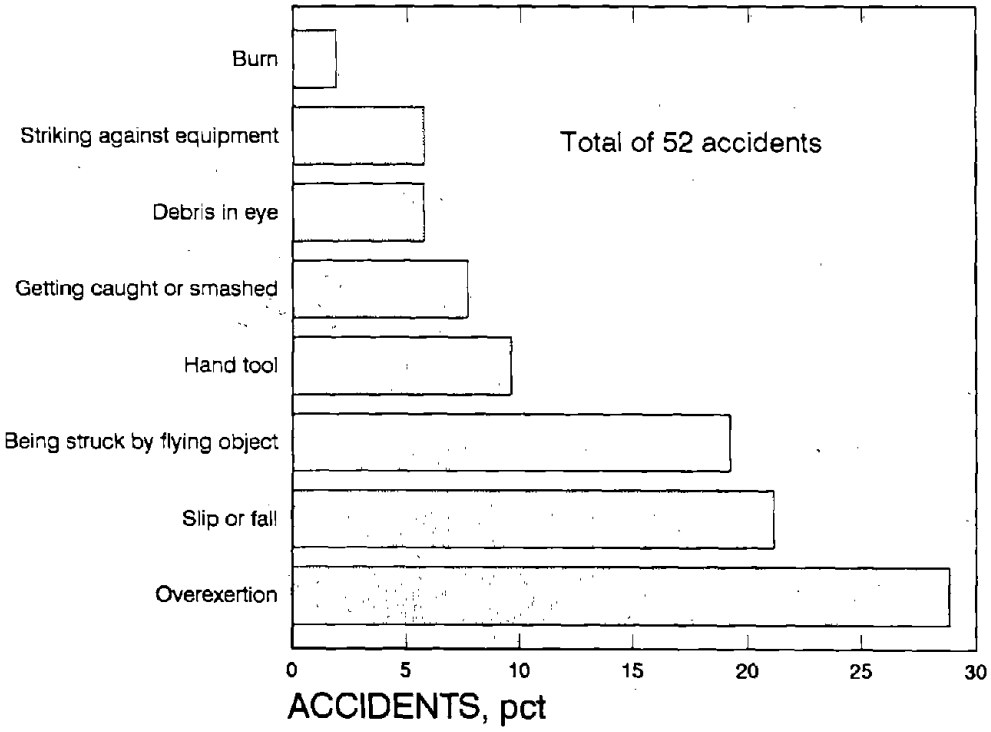
The percentage of accidents occurring while operating a grader were in line with the other equipment, but the severity was much less. The number of LWD was about three times less than the average for the other equipment types (9 versus 24 days). The most frequent types of accidents were jarrings, collisions, and loss of control as illustrated in figure 30. The jarring accidents were predominately due to rough ground or the blade striking a solid object such as a buried rock. Collisions, mainly vehicle to vehicle, occurred at a higher rate than any of the other equipment (table 10). This may be due to skewing of the data from the small sample size or because frequent users of haulage roads, namely trucks, don't expect graders to be on the road. Most grader collisions were with haulage trucks. The two fatalities, which occurred with graders, were loss of control accidents.

Figure 26



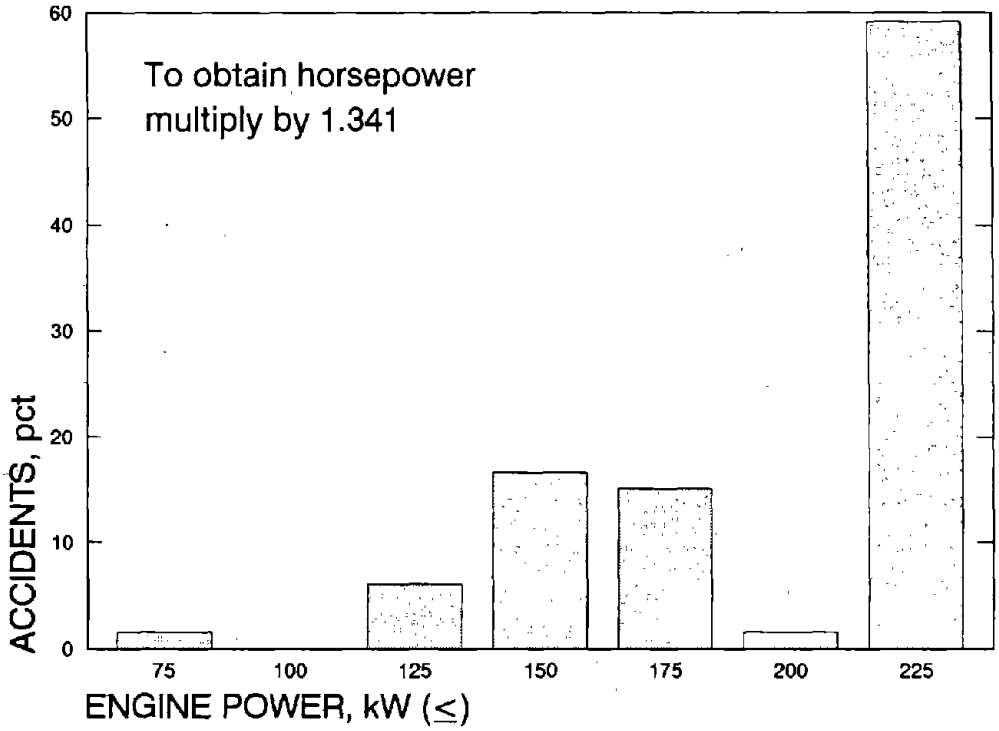
Distribution of scraper ingress-egress accidents.

Figure 27



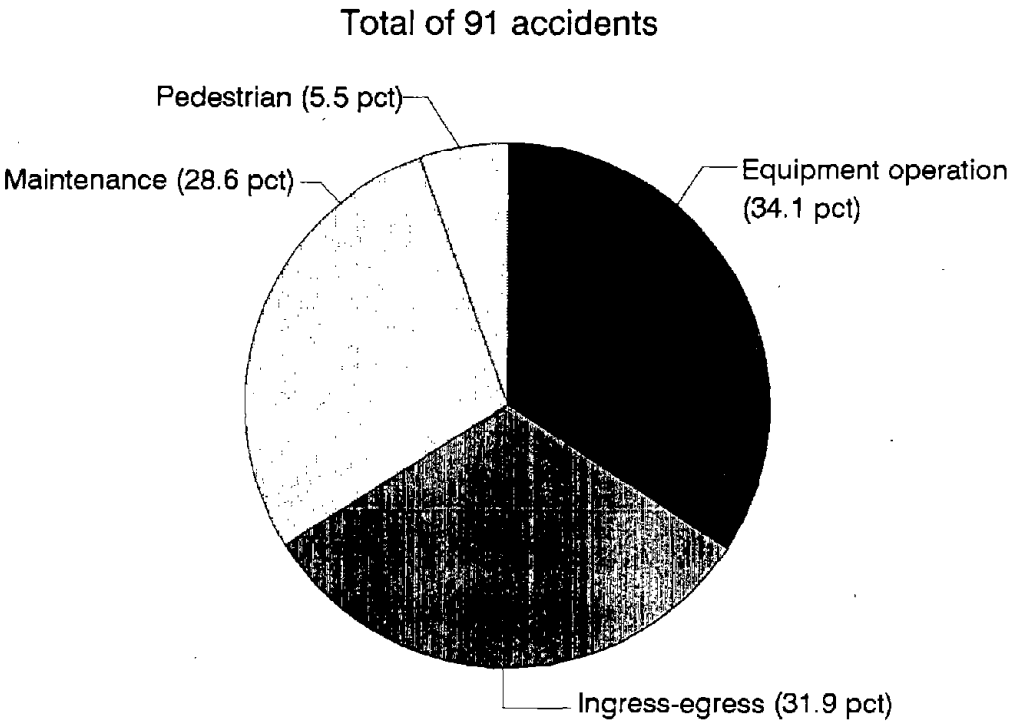
Distribution of scraper maintenance accidents.

Figure 28



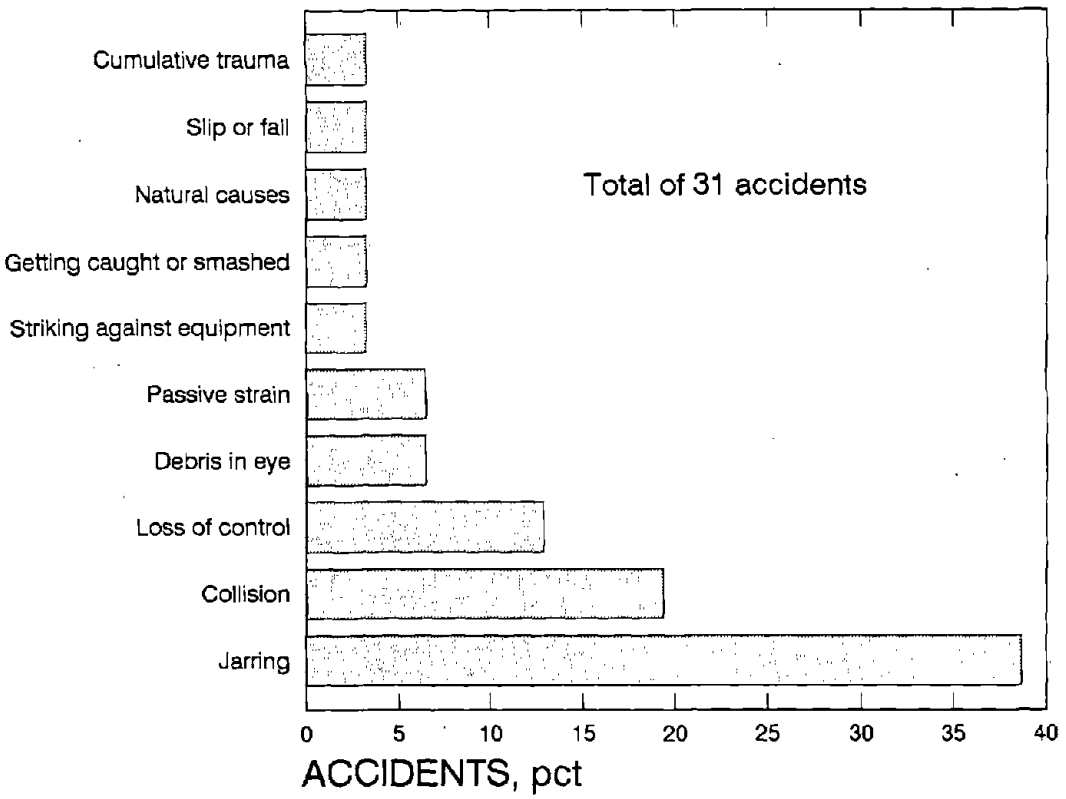
Road grader size distribution.

Figure 29



Percentage of road grader accidents by primary activity.

Figure 30



Distribution of grader equipment operation accidents.

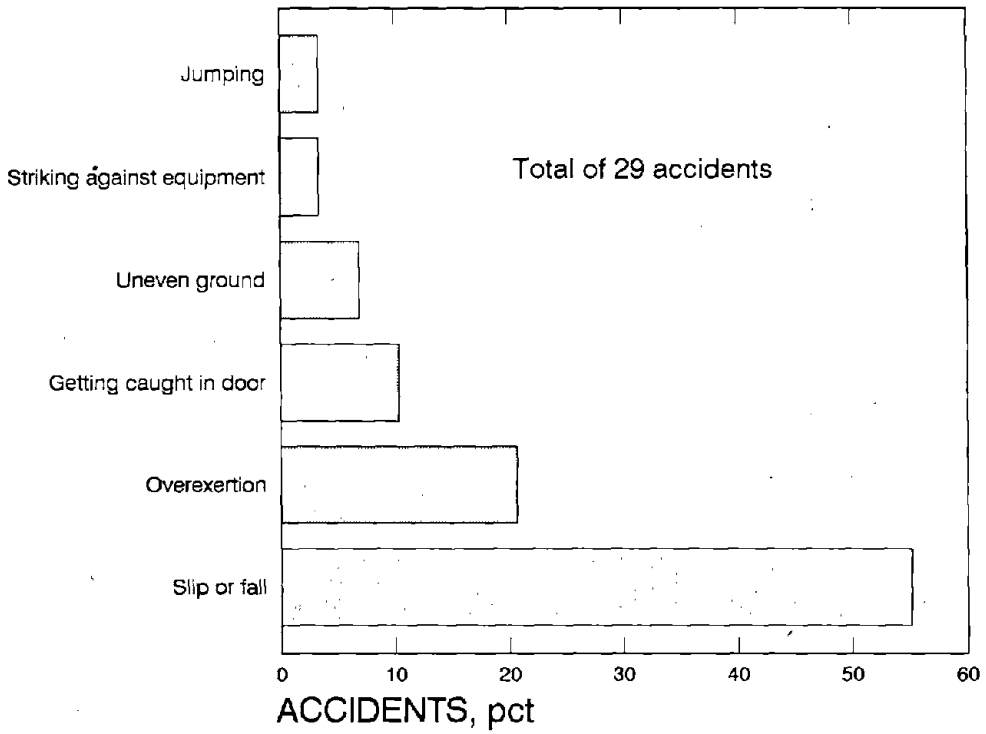
Ingress-Egress

Grader accidents, which happened during ingress-egress of the machine, were 32 pct of the total. The overall severity of these accidents (17 LWD) was lower than the other types of equipment (table 9), but ingress-egress accidents as a group still produced the most severe grader injuries. This agrees with the other equipment, because ingress-egress was the primary activity with the most severe injuries for all accidents combined. The most common ingress-egress accidents were slips or falls, followed by overexertions (figure 31). These occurred at rates similar to the other equipment and produced similar injuries, most frequently back sprains or strains.

Maintenance

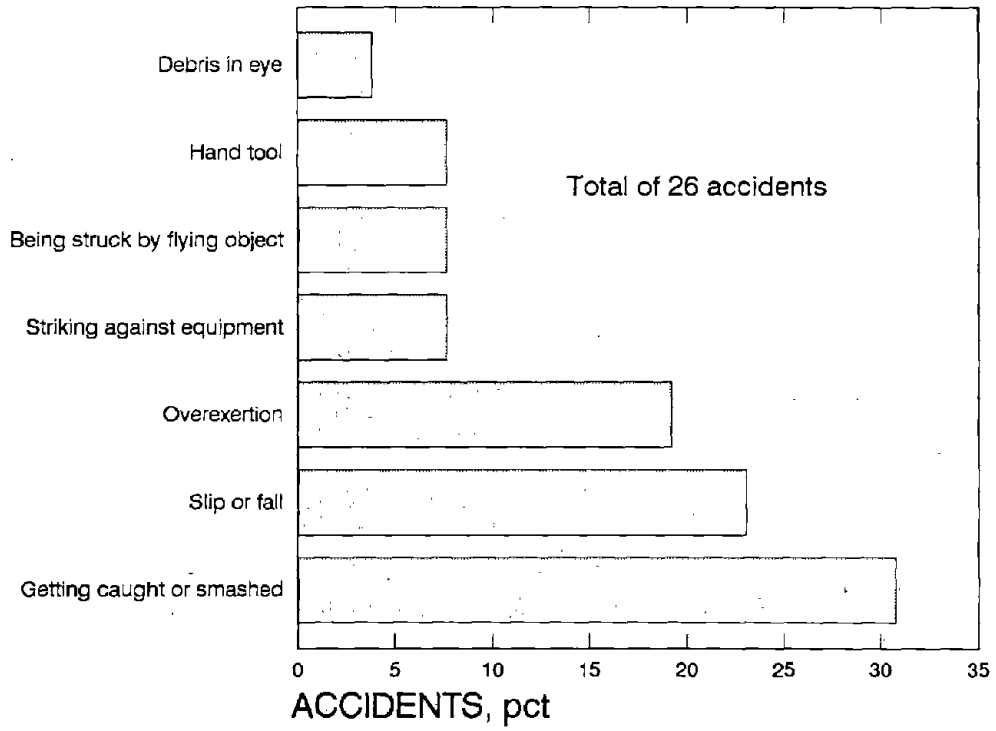
Road grader maintenance accidents occurred at a rate that was average for all the equipment types (about 29 pct), however, the severity of these 26 accidents was lower. Grader maintenance injuries had a mean of 9 LWD, compared to 14 LWD for all equipment. Road grader maintenance accidents were concentrated in three classifications; getting caught or smashed, slip or fall, or overexertion (figure 32). The nature of these accidents and their associated injuries was similar to those of the other equipment types.

Figure 31



Distribution of grader ingress-egress accidents.

Figure 32



Distribution of grader maintenance accidents.

SECTION III: MISCELLANEOUS ACCIDENT FACTORS

FATALITIES

A total of 21 fatalities occurred over the 3 years, six in 1989, eight in 1990, and seven in 1991. A large portion of the fatalities (62 pct) occurred to operators during operation of the equipment (table 2). The maintenance and pedestrian activities each had three fatalities, or 14 pct. One fatality occurred while getting on or off a loader and in one case the primary activity was unknown. The number of fatalities and fatality ratios for each primary activity were summarized in table 2.

The type of accident responsible for the largest number of fatalities was loss of control, accounting for 9 of the 13 equipment operator fatalities. Table 11 gives a short description of the fatal cases for each primary activity, along with the number of fatalities. The most common cause for losing control of the vehicle was getting too close to the edge of a slope (six of nine loss of control accidents). Seven of the nine loss of control fatalities involved a rollover of the vehicle and five involved the operator jumping or getting thrown from the vehicle. Loss of control accidents as a whole were particularly deadly when looking at the fatality ratio. Nine of the 196 loss of control accidents resulted in fatalities, giving a fatality ratio of 5 pct. This compares to a ratio of 0.7 pct for all accidents (table 2). Four of the nine loss of control fatalities occurred to equipment operators who were not wearing sealtbelts according to the accident reports. In the other five loss of control fatal accidents, seatbelt use could not be determined. Other fatalities during equipment operation were two fatalities resulting from vehicle to vehicle collisions, another was a heart attack, and the last was a flash fire from a ruptured propane tank.

Maintenance was the primary activity in three fatalities. One incident was a maintenance worker trying to extinguish a smoldering coal fire. The fire flashed back causing severe burns (table 11). Another fatality occurred when a mine employee was checking a loader for hydraulic oil leaks. He was asphyxiated when he became crushed between the hoist cylinder and the machine and could no longer breathe. The details of the third maintenance fatality were unknown.

Pedestrian activities accounted for another three fatalities (table 11). These three fatalities in 137 total pedestrian accidents produced the highest fatality ratio of 2 pct for any primary activity (table 2). In one case, a mine employee was supervising the placement of a pump into a dragline pit. The pump was being lowered on cables attached to a loader when the victim slipped and fell off the 49 m (160 ft) highwall. Another fatality occurred to a pedestrian who was struck by a tire and wheel assembly after it had rolled down a 137 m (450 ft) slope. The third pedestrian fatality was a haulage truck driver crushed beneath a front-end loader after getting out of the truck. The truck driver, while observing another truck attempting to dump a load of frozen coal, was backed over by a loader.

Table 11.—Description of fatalities by primary activity

Primary activity, accident description	Fatalities
Equipment operation:	
Loss of control:	
Too close to edge, fell down slope	6
Unknown	2
Parked truck started to roll, tried to mount and stop it	1
Collision, vehicle to vehicle	2
Natural causes, heart attack	1
Fire or burns, propane leak and fire	1
Total equipment operation	13
Maintenance:	
Fire or burns, extinguishing flash fire	1
Getting caught or smashed, hoist cylinder fell	1
Unknown	1
Total maintenance	3
Pedestrian:	
Slip or fall, fell off highwall	1
Being struck by flying object, runaway tire	1
Being struck by machine, run over by loader	1
Total pedestrian	3
Ingress-egress, slip or fall, fell off loader	1
Unknown	1

The lone ingress-egress fatality occurred to a loader operator. The miner apparently slipped and fell, striking the tire with the miner's chest. The details of this accident were unclear. The final fatality involved a fire and severe burns to the miner. The primary activity of the victim could not be determined from the accident report.

AGE AND WORK EXPERIENCE

Age

The mean age of the victims of coal mine mobile equipment accidents was 39 years. This age did not vary much over the five different pieces of equipment. The low was a mean age of 38.0 years for loader accident victims to a high of 39.2 years for bulldozer accidents. These numbers agree with the mean age of 39 years reported for the 1986 surface coal mine work force by Butani and Bartholomew (*12*). Butani and Bartholomew also showed bulldozer operators to be the oldest of these equipment types (mean age 40 years), while grader-scraper operators and truck drivers had the lowest mean age of 37 years.

The distribution of the ages of all the accident victims is shown in figure 33. The figure shows that the distribution was approximately normal with a slight blip in the number of victims less than 20 years old. These data indicate there was no relationship between age and the potential for mobile equipment accidents, assuming the 1989-91 mine work force age distribution was similar to the 1986 distribution.

Job and Mining Experience

The average years of mining experience for all the accident victims was 11.1 years. The range of average mine experience was from 9.8 years for haulage truck accident victims to 13.1 years for graders. Mining experience is total work experience at any job within the mining industry. Victim job experience ranged from 6.1 years for scrapers to 8.4 years for bulldozers. The average job experience for all types of equipment was 7.6 years.

The distribution of job experience of the accident victims is shown in figure 34. The graph shows that inexperienced workers accounted for many of the accidents. Miners with one year or less of job experience had 20 pct of the accidents and another 8 pct had just 1 to 2 years experience on the job. The percentage of accidents generally decreased with increasing experience. These accidents did not just occur to young miners new to the work force, but to miners of any age who were new to the job.

A comparison of the job experience of the accident victims in this study to the job experience reported in Butani's and Bartholomew's (*12*) demographics survey is shown in table 12. The demographics data were from 1986 while the data from this study were from 1989-91. Keep in mind that the demographics data were for the whole coal mining industry, both surface and underground, and all job and equipment types. The table shows the percent of the total population of data in seven different job experience ranges. For job experience less than or equal to one year, the percentages for the two data sets were about equal. For the four job experience ranges greater than 1 year on up to 10 years, the table shows that less mobile equipment accidents occurred in 1989-91 than would be expected from the 1986 industry wide figures. At the job experience ranges greater than 10 years, accidents occurred at a much higher rate than the coal mining population.

The comparisons shown in table 12 suggest that miners with less than 1 year of job experience were not more likely to be involved in mobile equipment surface mine accidents. The large number of inexperienced worker accidents, as shown in figure 34, was more a factor of worker demographics than it was of their inexperience. Miners with an intermediate amount of job experience, 1 to 10 years, were less likely to have had accidents, while those with more than 10 years experience were more likely to have had mobile equipment accidents.

Table 12.—Comparison of job experience from 1986 demographics with 1989-91 accidents

Job experience	1986 demographics[1]	1989-91 accidents
Years	Pct	Pct
>0 to ≤1	19.6	19.5
>1 to ≤2	15.8	8.0
>2 to ≤3	10.3	6.4
>3 to ≤5	16.5	9.4
>5 to ≤10	25.8	21.4
>10 to ≤20	10.7	29.2
>20	1.3	6.8

[1]Source: Butani and Bartholomew (*12*).

COMMODITY

Coal mine accidents are broken down by MSHA into two commodities, bituminous and anthracite. Bituminous coal mining accounted for 97 pct of the accidents (table 13). Although fewer accidents occurred in anthracite coal mining, the incidence rate (mobile equipment accidents per 200,000 employee-hours) was 2.18 for anthracite compared to a rate of 1.41 for bituminous mining.

Table 13.—Accident distribution and incidence rates by commodity mined

Commodity	Accidents		Employee hours[1]	Incidence rate[2]
	Number	Pct		
Bituminous coal	2,798	96.5	396,344,600	1.41
Anthracite coal	101	3.5	9,254,800	2.18
Total	2,899	100.0	405,599,400	1.43

[1]Total hours at surface mines and preparation plants for all activities (not just those related to mobile equipment) from 1989 to 1991, source: MSHA (*10*).

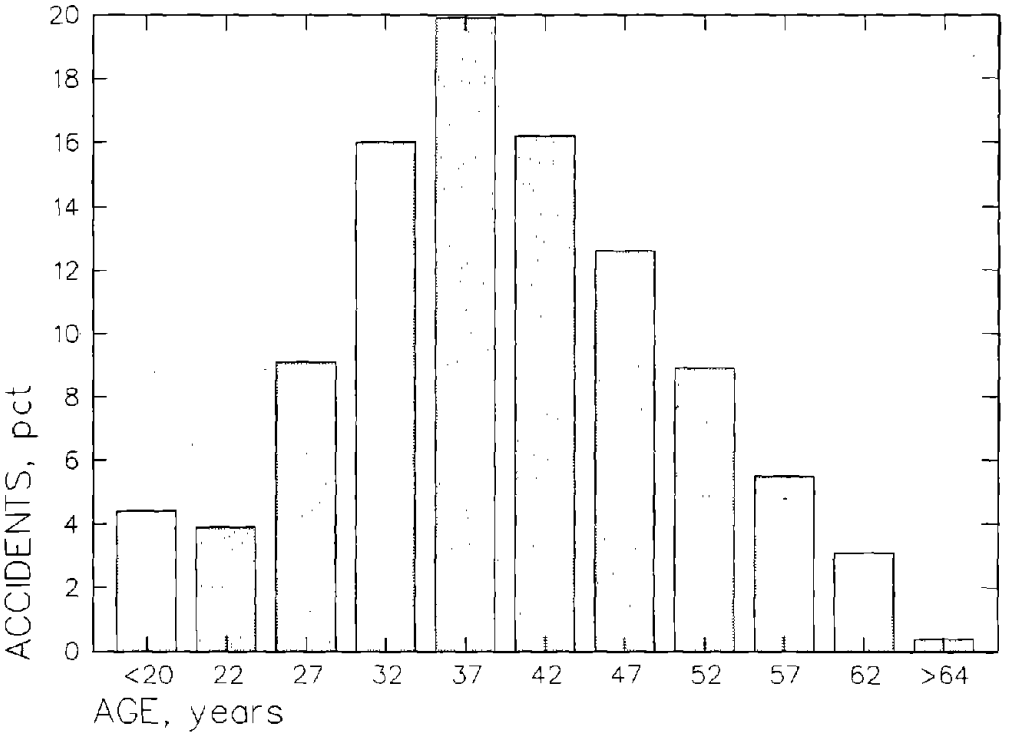
[2]Number of mobile equipment accidents per 200,000 employee hours.

LOCATION

The accidents analyzed in this study include all surface mining locations. Figure 35 shows that 81 pct of the accidents occurred in strip mining operations, 11 pct in prep plants and 6 pct at surface operations of underground mines. A small percentage of the accidents occurred in "other" locations as shown in the figure. These include independent shops and yards, culm banks and refuse, and surface auger operations.

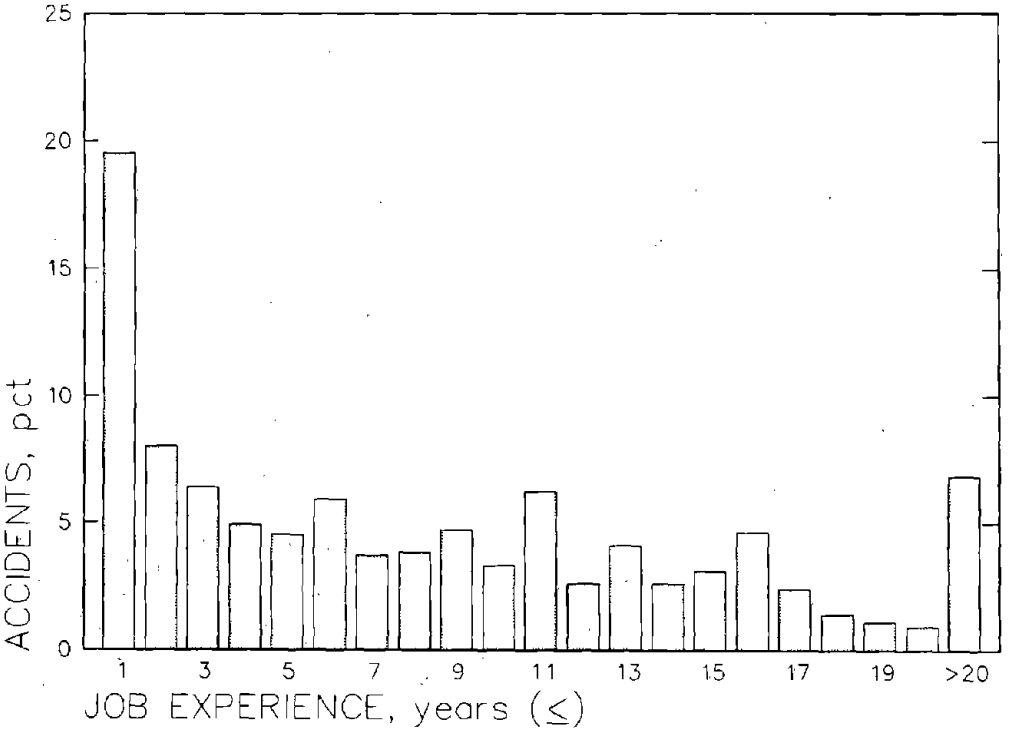
The states in which the most accidents occurred were Kentucky, West Virginia, and Pennsylvania (table 14). These three states accounted for 56 pct of the accidents.

Figure 33



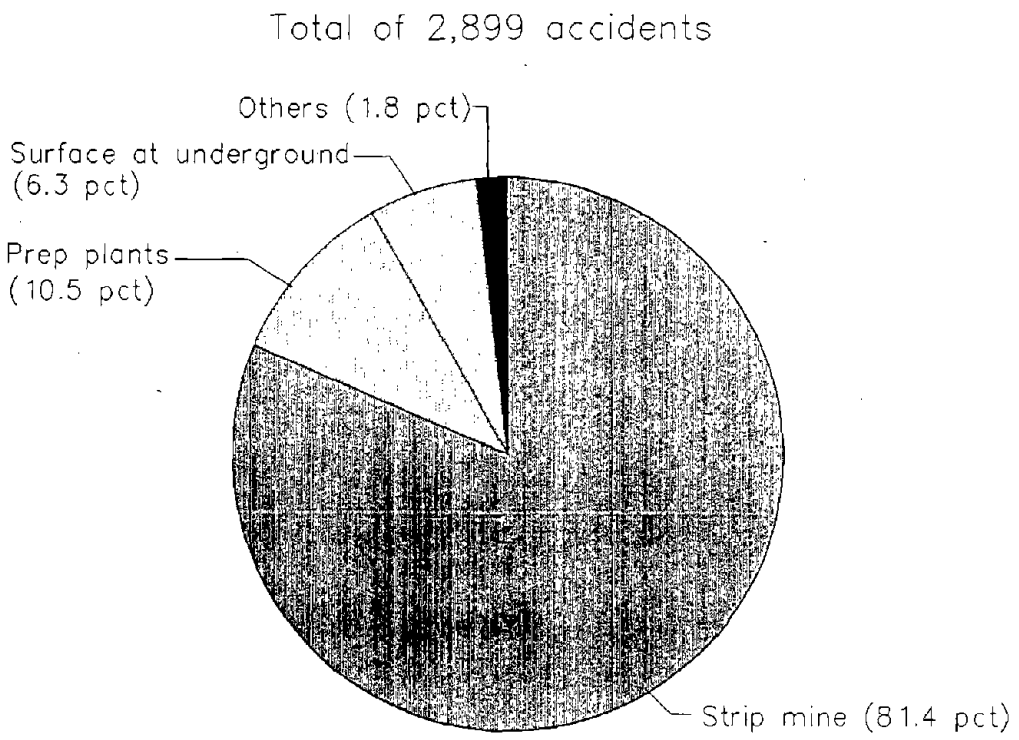
Accident victim age distribution.

Figure 34



Distribution of accident victim job experience.

Figure 35



Mobile equipment accidents by location.

Coal mine mobile equipment accidents were reported in 25 different states. Notice that the top three states are Appalachian states, while the next three are Mid-Western states. The category "all others" in table 14 includes the following states, in order of decreasing percentage: Missouri, Montana, Maryland, Arizona, Utah, Iowa, Louisiana, Kansas, and Alaska.

Table 14.—Accident distribution by State

State	Accidents	Pct
Kentucky	688	23.7
West Virginia	502	17.3
Pennsylvania	424	14.6
Ohio	209	7.2
Indiana	186	6.4
Illinois	148	5.1
Virginia	135	4.7
Texas	113	3.9
Alabama	92	3.2
Wyoming	75	2.6
North Dakota	39	1.3
Oklahoma	39	1.3
Washington	36	1.2
Colorado	33	1.1
New Mexico	32	1.1
Tennessee	29	1.0
All others	119	4.1

SUMMARY AND DISCUSSION

Slips or falls were the single largest cause of accidents. A total of 736 slip or fall accidents occurred, or 25 pct of all accidents. Most of these occurred while getting on or off the equipment, but also during maintenance tasks and to pedestrians. A slip or fall during ingress-egress was the number one accident classification for bulldozers, front-end loaders, and road graders. The mean of 27 LWD for slip or fall accidents was more severe than most accidents. This points to the importance of miners taking the hazard of slips or falls seriously. As much as possible, hazards should be removed that could cause a slip or fall. However, miners must watch where they are walking or climbing, and be especially careful while getting on or off equipment. Training needs to emphasize safe mounting and dismounting procedures from equipment, both for operators and maintenance personnel. Maintenance workers have additional slip or fall risks when working on the equipment. Maintenance is often done on less than ideal work platforms and may involve difficult access to the machine.

Sprain or strain injuries were far and away the largest portion of the injuries. They accounted for 40 pct of the total and averaged 25 LWD. National Safety Council data for 1991 show that sprains or strains were the number one

type of injury for all industries (*14*). Sprain or strain injuries were common to many different accidents, but were predominate in overexertions and passive strains. The next most frequent injury was lacerations with 13 pct, but averaged just 5 LWD. The most frequent body region injured was the back and neck, with 30 pct of the injuries. This agrees with National Safety Council data for 1991 which show that back injuries were the most common work related injury in all industries (*14*). Back and neck injuries were prevalent in many different accident types. They were particularly common in slip or fall, jarring, overexertion, and passive strain accidents. This was also one of the body regions requiring the most recovery time, 27 days away from work. These were followed by lower and upper extremity injuries.

Because the most frequent injuries were back sprains or strains, reducing on-the-job injuries requires targeting these injuries. Better seats, seat suspensions, and cab suspensions would help reduce the incidence of injuries to the operators. In particular, these devices need to reduce the magnitudes of the shock forces that are most likely to cause injuries. For maintenance tasks, or other jobs which require lifting of heavy objects, mechanical lifting devices can help to reduce back strains. All employees would benefit from strengthening their backs through exercise.

Accident victims with 2 years or less of job experience accounted for 28 pct of the accidents. The many accidents attributed to inexperienced workers appears to be due to the high number of inexperienced workers, not their inexperience per se. Demographic data of the 1986 mining work force indicated that many workers were inexperienced at their jobs. The higher population of inexperienced workers may have led to more accidents for those workers. Comparisons to the demographics data actually indicated that workers with more than 10 years experience had more accidents than expected. The increased age of experienced workers may have made them more susceptible to some injuries. It's possible experienced workers took their job and its safety for granted and were not as careful as they once were, or possibly there were more experienced workers in 1989-91 than in 1986. Unfortunately the latest demographic data on the mining work force was for 1986, and therefore may not be valid for the 1989-91 work force. One can argue that things had not changed that much between those years, and that many of the general trends should be similar.

Workers of all experience levels and in all job categories would benefit from additional training on the hazards of mobile equipment. The additional training should concentrate on reducing the most frequent and severe accidents outlined in this report for each type of equipment or job activity.

For most measures, there were a small number of conditions that account for most of the selected accidents. This is an advantage for future USBM and industry safety research, because efforts concentrated in a few areas can address the majority of the accidents.

RECOMMENDATIONS

1. Increase training emphasis on the hazards of slips and falls, especially during ingress-egress from machines, for both operators and maintenance workers. This was the single largest cause of mobile equipment accidents.

2. Improve access ladders or other means of getting on and off equipment. Design changes in access to equipment may prevent a lot of accidents. The height of the first step onto the equipment is especially a problem.

3. Mining companies would benefit from back-strengthening measures for employees, i.e., physical fitness. Companies in other industries have taken this approach in recent years.

4. Improve or use more mechanical-lifting devices, especially for mechanics and maintenance workers. This would help reduce the number of back injuries, the most common injury.

5. Improve haulroad construction and maintenance to reduce rough roads. Smoother roads reduce the number of jarring accidents to equipment operators. Poor road construction also leads to continuous maintenance problems for the roadway and vehicles.

6. Increase training for loader and shovel operators to minimize buckets striking trucks and boulders jarring truck drivers. Loader operators should load fine material into truck bed first if possible. This will help to cushion the loading of larger chunk material. Dump bucket slowly when loading large boulders. For really large boulders, the loader operator should signal the truck driver to leave the cab and stand a safe distance away.

7. Increase utilization of seat belts. The percentage of miners wearing seat belts is not known. Anecdotally, in conversation with mine safety personnel, numbers as low as 10 pct have been mentioned. Seat belt usage, however, may be on the rise because of the mandatory seat belt laws in many states and the increased acceptance of using seat belts in automobiles.

8. Improve restraints for equipment operators. Better restraints can reduce the incidence of jarring injuries and provide more protection in loss of control or collision accidents.

9. Improve vehicle, cab, and seat suspensions to reduce shock transmission. Suspensions on late model trucks have improved considerably, however there are still many older machines in use that have inadequate suspensions. Improved seat or cab isolation from shocks and vibrations would also reduce jarring injuries.

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APPENDIX A.—PERSPECTIVE OF MINING SAFETY

This section is provided to give the reader a perspective of the frequency and severity of the accidents occurring in the mining industry, in particular, the impact of mobile equipment accidents on the industry.

MINING INDUSTRY COMPARED TO OTHER INDUSTRIES

Injury and fatality rates in the mining industry have historically been high compared to many other industries, and this continues to be true today. According to 1991 National Safety Council (*14*)[1] and MSHA data (*10, 15-18*), the death rate (deaths per 100,000 workers) in the mining industry was 30, fourth highest behind the oil and gas extraction industries' 60, agriculture's 44, and construction's 31. The average death rate for all industries was nine. Disabling injury rate statistics show a different trend, with mining having the highest rates. The disabling injury rate (injuries per 100,000 workers) for mining was 5,100, compared to 4,400 for agriculture, 3,300 for oil and gas extraction, 3,100 for construction, and 1,500 for all industries (*10,14-18*). National Safety Council data include mining contractor accidents, which were not included in the mobile equipment accidents analyzed in this report.

TOTAL MINING INDUSTRY

From 1989 to 1991 there were a total of 99,654 accidents, resulting in 297 fatalities for the whole mining industry (table A-1). This includes both surface and underground, and coal and MNM mining. Fatalities were 0.3 pct of the total number of accidents. Of all accidents, 50 pct resulted in lost work time. The average number of LWD per accident was 14 days.

[1]Italic numbers in parentheses refer to items in the list of references preceding the appendixes.

COAL MINING

About 55 pct of all mining accidents (surface and underground) occurred in the coal mining industry, with the remainder in MNM mining. Surface and underground coal mine accidents were more severe than the MNM mine accidents. This is evidenced by the sixth row of data on table A-1, which shows that coal mining fatalities, LWD accidents, and LWD as a percentage of the total mining accidents were all greater than 55 pct, the percentage of coal mine accidents. Notice that coal mine accidents averaged 18 LWD per accident compared to 14 days for all mining sectors.

Surface coal mining accounted for 15 pct of all mining accidents. Table A-1 shows that the percentage of surface mining fatalities, LWD accidents and LWD as a percent of all mining were more than 15 pct, indicating that surface coal mine accidents were more severe than the average mining accident. Also, surface coal mining averaged 17 LWD versus the 14 days for all mining segments, however, comparing surface coal mining to all coal mining (surface plus underground), table A-1, row 11 shows that the two were not substantially different. Surface coal mining accidents were 27 pct of all coal mine accidents (i.e., underground mining was 73 pct), while fatalities were slightly higher (29 pct), LWD accidents the same (27 pct), and LWD lower (26 pct).

SURFACE COAL MINE MOBILE EQUIPMENT

The accidents associated with bulldozers, haulage trucks, front-end loaders, scrapers, and road graders in surface coal mining accounted for 20 pct of surface coal mine accidents (table A-1), but 41 pct of the surface mine fatalities. Mobile equipment accidents in surface coal mining also had a higher percentage of LWD accidents and average number of LWD per accident than broader sectors of the mining industry.

Table A-1.—Comparison of accident data for different mining industry sectors, 1989-91

	Total accidents	Fatalities	LWD accidents	LWD
All mining:				
Number reported	99,654	297	49,604	1,437,678
Percentage	100	0.3	50	NAp
Average[1]	NAp	NAp	NAp	14.4
Coal mining:				
Number reported	54,917	175	30,441	986,399
Percentage:				
Within catergory[2]	100	0.3	55	NAp
Of all mining	55	59	61	69
Average[1]	NAp	NAp	NAp	18.0
Surface coal:				
Number reported	14,705	51	8,367	251,869
Percentage:				
Within category[2]	100	0.3	57	NAp
Of all mining	15	17	17	18
Of all coal	27	29	27	26
Average[1]	NAp	NAp	NAp	17.1
Surface coal mobile equipment:				
Number reported	2,899	21	1,974	61,287
Percentage:				
Within category[2]	100	0.7	68	NAp
Of all mining	3	7	4	4
Of all coal	5	12	6	6
Of surface coal	20	41	24	24
Average[1]	NAp	NAp	NAp	21.1

LWD Lost workdays.
NAp Not applicable.
[1]Average number of LWD per accident.
[2]Percentage of total number reported.

APPENDIX B.—ANALYSIS PROCEDURES

The data used in these analyses were gathered from an accident database maintained by the USBM's Spokane Research Center (*9*).[1] The Accident Data Analysis (ADA) database uses data collected and managed by MSHA. ADA provides accident statistics and narrative descriptions of all noncontractor accidents reported to MSHA for the MNM and coal mining industries back to 1975. The accident narratives were those supplied by the mine at the time of the accident.

The Federal Mine Safety and Health Act of 1977 requires mine operators to submit a report to MSHA when any one of the following three incidents occur at a mine: an accident, an occupational injury, or an occupational illness (*19*). According to the Code of Federal Regulations (CFR), title 30, part 50, a reportable accident is defined to be any incident that causes death, an injury which has reasonable potential to cause death, entrapment of an individual for more than 30 min, the unplanned inundation of a mine by a liquid or gas, and other incidents as listed in the CFR. An occupational injury is defined as any injury requiring medical treatment, or results in death, loss of consciousness, lost work time, or the inability to perform normal job duties. An occupational illness is any illness or disease that may have resulted from work at a mine or for which an award of compensation is made.

The accidents analyzed were for the years 1989-91, the most recent 3-year period of complete accident data available at the time of this study. A 3-year period provided a large pool of data without becoming too large. Surface mining, for this report, includes all MSHA mine locations, except those classified as underground and offices.

The accident data were obtained by searching the ADA database for any surface mine accident that involved one of the five pieces of mobile equipment in the years 1989-91. A total of 2,899 accidents associated with surface mine haulage trucks, loaders, bulldozers, scrapers, and graders were examined. The data include not only accidents associated with equipment operation, but also equipment maintenance and inspection, getting on and off the equipment, pedestrians working with or near the equipment, etc.

A list of variables were saved for each accident retrieved from the database and stored on computer hard disk. The data were then brought into a spreadsheet for viewing and categorizing. A print out of each accident narrative was obtained. The narrative for each accident was read by a team of researchers familiar with mining accidents to make sure the data were correctly entered in the database, to delete any entries which didn't appear to fit the mobile equipment categories and also to determine a short description and classification for each accident. The description of each accident provides a simple means of describing the action of the injured and also how the injury occurred and at the same time categorize the data.

Statistical information for all the accident variables were obtained using the software program Statistical Package for the Social Sciences (SPSS). This program provided extensive statistical routines for analyzing the data in a number of different fashions.

One question the authors were curious about was whether equipment size had any effect on accident rates or the types of accidents associated with a given size class of equipment. An attempt at collecting information on the population distribution of equipment sizes was not successful because it was often considered proprietary data. As a result, equipment size information was obtained from the accident data. Although this data may not represent the actual equipment size distribution in the mining industry, it is thought to be representative of general trends. Equipment size was determined from the make and model number of the equipment. Haulage truck size was measured by body or bed capacity (payload), front-end loader size by bucket rated capacity, bulldozer and grader size by engine power, and scraper size by bowl capacity.

The data presented in this report are the number of accidents, not the number of injuries, unless otherwise noted. A slight difference exists between the two numbers. The number of accidents resulting in injuries was 99 pct of the total. Some accidents resulted in more than one person injured, while others resulted in property damage only and no personal injuries. Owing to rounding, not all the percentages provided in the tables and figures add up to 100 pct.

[1]Italic numbers in parentheses refer to items in the list of references preceding the appendixes.

APPENDIX C.--DEFINITIONS OF ACCIDENT DESCRIPTIONS

This list of definitions does not include all accident types, only those which may not be obvious to the reader.

Being struck by flying object—accidents in which the injured was hit by a flying or falling object, usually free and not connected to a larger unit.

Escaping a hazard—involve injuries in which the operator or individual was actively escaping a potential danger such as a vehicle fire.

Getting caught or smashed—accidents in which the injured becomes caught in or had an appendage smashed by an object usually attached to a larger unit. These accidents often involve cuts, bruises, or fractures.

Highwall collapse or rock fall—injuries to an equipment operator resulting from the collapse of a highwall, inundation from a stockpile or spoil pile, or a rock falling from a highwall or pile. Similar to "struck by flying object," but if falling object was specifically mentioned as coming from a highwall or material pile, then the accident was classified as a highwall collapse or rock fall.

Ingress-egress (IE)—injuries resulting from slipping, falling, bumping, straining, or becoming caught while in the process of getting on or off of a vehicle.

Uneven ground—injuries occurring while getting on or off a machine which specifically result from poor footing, i.e., stepping onto a rock or hose. Injuries may be similar to overexertions, but must be specifically related to poor footing.

Jarring—a general classification in which injury usually occurs from an acute incident of jarring while in routine operation of vehicle. Does not include unusual events such as collisions or loss of control of the vehicle.

Cutting edge jarred—injuries in which the operator was jarred during the operation of a bulldozer, loader, scraper, or grader as a result of the bucket or blade slipping or striking a hidden object.

Dumping shock—involves injuries from a haulage truck being jarred while in the process of dumping material whether from load shifting, bed of truck falling, or part of truck raising.

Loading shock—injuries to a haulage truck operator being jarred by heavy material or struck by loader bucket during the loading process.

Rough ground—injuries either acute or cumulative in nature in which the operator of the vehicle was jarred while traveling over potholes, ditches, rocks or boulders.

Loss of control—the state in which the operator was unable to effectively maneuver or control the vehicle because of mechanical failure, human error, road conditions, avoidance of an obstacle, etc.

Rollover—accidents in which the outcome involves the vehicle rolling or turning over whether on its side or multiple revolutions.

Runaway—accidents resulting from mechanical failure or human error in which the operator had little or no control of the vehicle. Examples include loss of brakes or steering and engine stalls.

Too close to edge—a precursor to an accident in which the vehicle was too close to the edge of road, embankment, berm, or ramp.

Lost workdays (LWD)—consist of actual days away from work.

Maintenance—activities involving repair or upkeep of equipment or machinery. Also includes tasks such as checking fluid levels, refueling, cleaning windows, etc.

Being struck by machinery—injuries resulting from an individual being hit by any portion of a powered machine or vehicle.

Hand tool injury—accidents that cause injury as a direct result of the use of a hand tool or powered hand tool.

Mechanical failure—involves accidents in which there was a malfunction in the vehicle such as a blown tire or broken axle.

Natural causes—involve injuries attributable to internal causes such as heart attack, stroke or uncontrollable forces of nature such as heat, cold, insects, etc.

Overexertion—involves injuries that were incurred while actively involved in an activity and result in a sprain, strain, or hernia.

Passive strain—injuries in which the operator receives a sprain or strain while passively operating the vehicle. These injuries were usually cumulative in nature and were not caused by direct overexertion or active manipulation of

machinery. A typical example is a driver complaining of a sore back after operating a haulage truck for a complete shift. These injuries were different than the jarring accidents because they were not identified as being acute events.

Pedestrian (Ped)—accidents which involve injury to a pedestrian or to an operator while off of the vehicle.

Being struck by vehicle—injuries that occurred from an individual being directly struck by a vehicle or by a part that was connected to, carried by, or pushed by the vehicle.

Striking against equipment—injury resulting from striking a part of the body against an object, piece of equipment, or machinery.

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