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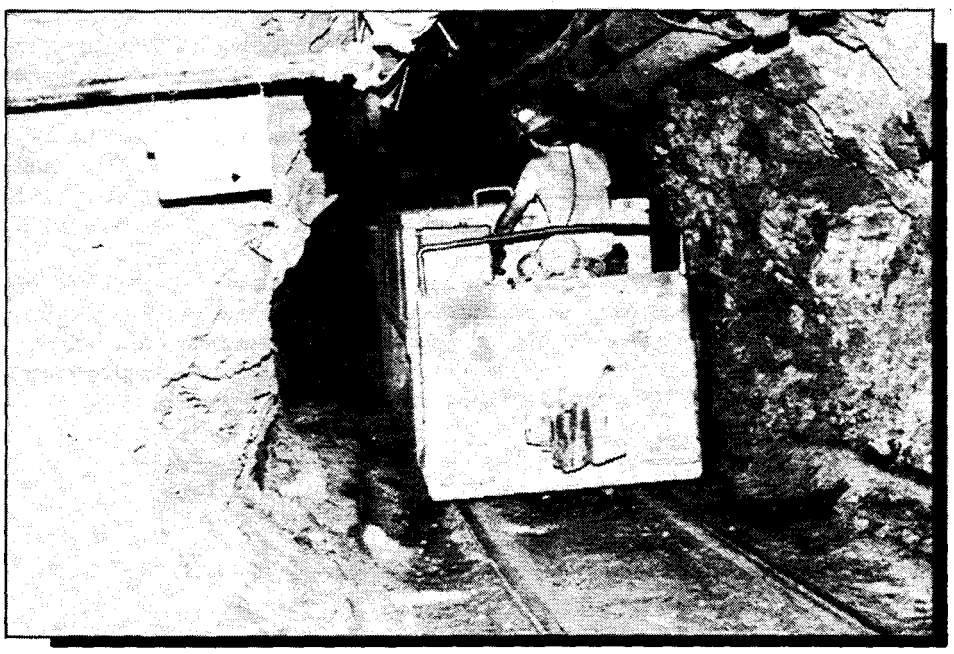
Analysis of Metal/Nonmetal Underground Mining Accidents Involving Mobile Mining Equipment

By P. A. Hendricks, E. E. Leagjeld, and M. G. Pojar



UNITED STATES DEPARTMENT OF THE INTERIOR

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Cover: Locomotive operating in an underground copper mine located in the southwest United States. Locomotives are often used for main haulage in underground metal mines. This picture depicts several of the hazards faced by mobile-equipment operators in underground mines. Note the pipes hanging from the back and the tight confines with respect to the stope walls.

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Paul A. Hendricks, Eric E. Leagjeld, and Michael G. Pojar

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Minneapolis, MN 55417

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ANALYSIS OF METAL/NONMETAL UNDERGROUND MINING ACCIDENTS INVOLVING MOBILE MINING EQUIPMENT

By P. A. Hendricks,[1] E. E. Leagjeld,[2] and M. G. Pojar[3]

ABSTRACT

This U.S. Bureau of Mines (USBM) report identifies and evaluates factors responsible for metal/nonmetal (M/NM) underground mining accidents involving mobile equipment. Information regarding the occurrence and severity of the accidents, the type of equipment involved, the primary and contributing causes, and preventive measures is included. The goal of this report is to provide information that will aid mine operators and safety managers in the recognition of hazards associated with operating mobile mining equipment in an underground mining environment.

[1]Electrical engineer.
[2]Civil engineering student.
[3]Mining engineer.
Twin Cities Research Center, U.S. Bureau of Mines, Minneapolis, MN.

INTRODUCTION

Mining continues to rank as the most dangerous industrial occupation in the United States, with an overall fatality rate of 0.043 (fatalities per 100 full-time employees). This compares with a fatal incident rate of 0.009 for all industries combined. Some sectors of the mining industry are more hazardous than others. During the 1990 through 1992 time period, the fatality rate for underground metal/nonmetal (M/NM) mining was almost 50% higher than the industry rate at 0.060. The sector with the worst rate was underground metal mining, with a rate of 0.074. The backbone of modern underground, M/NM mining methods are heavily dependent upon the use of mobile mining equipment. As such, 16.5% of all accidents and 37.9% of all fatalities occurring in underground M/NM mines are directly attributable to mobile mining equipment (*1-3*).[4]

The cost associated with each accidental death occurring in the workplace is estimated by the National Safety Council to be $730,000 (*4*). This cost includes estimates for lost wages, lost productivity, insurance costs, medical costs, and investigative costs, but excludes property damage costs except to motor vehicles. It also does not take into account the great social cost associated with a fatal accident. The cost of the average Mine Safety and Health Administration (MSHA) reportable accident involving mobile equipment is estimated at $10,632.[5]

As part of the mission of the U.S. Bureau of Mines (USBM) to assist mining companies in reducing the number of accidents and the costs associated with these accidents, this report provides a detailed analysis of accidents involving mobile mining equipment in underground M/NM mines. This report provides information that will aid mine operators and safety personnel in the recognition and abatement of hazards associated with mobile mining equipment in the underground mining environment. This information will alert mine operators and safety personnel where additional training or changes in procedures would help reduce the number of accidents and injuries associated with mobile mining equipment.

The body of this report is organized into three main sections. The first section gives an overview of all accidents involving mobile mining equipment that occurred in an underground M/NM mine. The second section provides a detailed examination of accidents by equipment type. The third section contributes an analysis of mobile-equipment accidents by accident classification.

RESEARCH METHOD

Accidents involving mobile mining equipment in M/NM underground mines were analyzed for the 1990 through 1992 time frame. A 3-year period was considered large enough to be a representative sample of accidents, while keeping the amount of data at a manageable level. The most recent 3-year period was chosen to provide the best representation of current mining practices.

All data utilized in the analysis were gathered from the Accident Data Analysis computerized database that is maintained by the USBM (*5*). It is based on accident and injury report data files gathered by the Safety and Health Technology Center in Denver, a branch of MSHA. These data files include all coal and M/NM accidents reported by mining operations since 1975.

A mine operator is required by Federal law to submit a report for each accident or occupational injury meeting the criteria set forth in title 30, part 50, of the Code of Federal Regulations (CFR) (*6*). In certain instances, accident severity may require the operator to notify MSHA immediately. MSHA officials will then make a determination if a more thorough investigation is required. By MSHA's definition of an accident and occupational injury, reporting is only required for those incidents that caused death or had a reasonable potential to cause death, resulted in lost work time, required medical attention, or restricted an individual from performing normal work duties. Only those accidents meeting MSHA reporting criteria and involving mobile mining equipment were analyzed in the preparation of this report.

Accidents relating to 17 distinct pieces of mobile equipment were analyzed. Certain pieces of equipment such as roofbolters, drill jumbos (jumbos), load-haul dumps (LHDs), and ore trucks are typical mobile equipment and are analyzed within this report. Additionally, accidents involving rail-mounted equipment such as locomotives, muckers, and mine cars were analyzed. Also included in this accident analysis are some less typical pieces of mobile mining equipment, i.e., forklifts (used in material handling), and manlifts (used in scaling operations).

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

[5]OFR 72-86. Accident Cost Indicator Model to Estimate Costs to Industry and Society From Work Related Injuries and Deaths in Coal Mining by D. G. DiCano, A. H. Nakata, D. Colvert, and E. G. LaVeque.

REGULATORY EFFORTS

MSHA has the responsibility for the development and enforcement of Federal regulations relating to health and safety within the mining industry. A review of the regulations pertaining to mobile equipment highlights the difficulties encountered in regulating the minerals industry. The difficulties arise because the industry is so very diverse in nature. Operations vary widely, depending on the commodity mined and the specific mining methods and equipment used.

The development and implementation of most safety regulations takes place over time in response to specific hazards occurring in the minerals industry. The regulations in effect today are the result of many years of effort by MSHA to reduce the frequency and severity of mining accidents. The regulations continue to evolve to reflect changes in technologies and mining practices. A review of those regulations that have been developed in response to the specific hazards associated with mobile equipment provides a more thorough understanding of those accidents. Regulations pertaining to mobile equipment usage in underground M/NM mines are included in CFR, Title 30-Mineral Resources, part 57 (*7-8*).

DEFINITIONS

Definitions of terms used in this report:

Incidence Rate: The number of injuries plus occupational illnesses multiplied by 200,000, and divided by the total hours worked by all employees during the period covered, where 200,000 employee hours is the base for 100 full-time equivalent employees (working 40 hours per week 50 weeks per year).

Lost-Workday Accident (LWA): Injury resulting in employee's inability to perform all job duties on any day after the injury.

Mobile Mining Equipment: Tracked or rubber-tired equipment that by its very nature is mobile. For the purpose of this report it applies to all equipment that is self propelled or that can be towed on its own wheels, tracks, or skids.

MSHA: Regulatory and enforcement branch of the U.S. Department of Labor responsible for maintenance of mine safety through the enforcement of Federal mine laws and technical and training assistance to mine operators.

No Days Lost Accident: Accidents that do not involve fatalities or lost work days but result in loss of consciousness or in medical treatment other than first aid.

Occupational Injury: Any injury such as a cut, bruise, strain, sprain, fracture, etc., that results from a work accident or from a single instantaneous exposure in the work environment.

Occupational Illness: Any abnormal condition or disorder, other than one resulting from an occupational injury, caused by exposure to environmental factors associated with employment. It includes acute and chronic illnesses or diseases that may be caused by inhalation, absorption, ingestion, or direct contact.

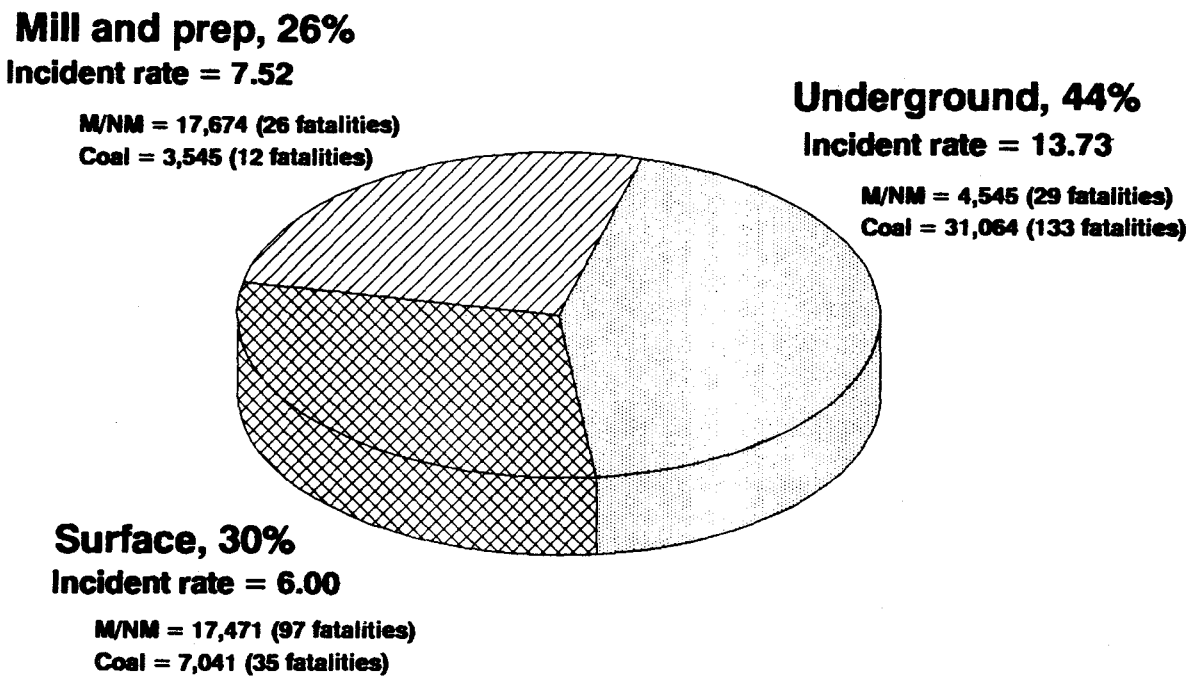
ACCIDENT DATA ANALYSIS FOR MOBILE-EQUIPMENT ACCIDENTS IN M/NM UNDERGROUND MINES

GENERAL OVERVIEW

The potential for an accident resulting in serious injury is greater for a mobile-equipment operator as compared with the average miner. This can be attributed to the size and complexity of the equipment and the ever-changing mine environment. The mine environment changes to reflect the progression of the mine's development. Safe operation of mobile equipment is extremely dependent on the capabilities of the operator. The ability of an equipment operator to identify and react quickly and correctly to a potential hazard is more critical than for most mining tasks.

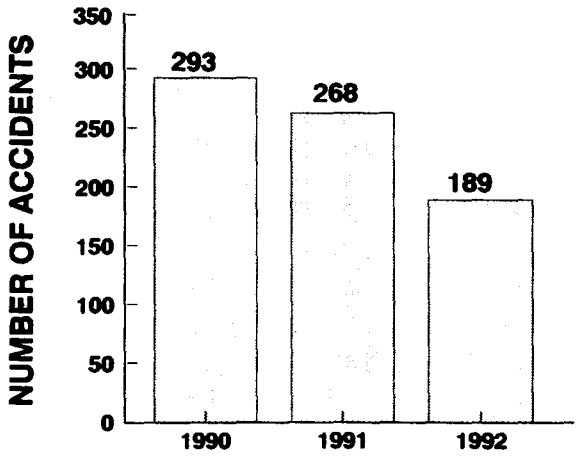
To be included as a mobile-equipment accident, the incident must have met two criteria: (1) be MSHA reportable, and (2) directly involve mobile equipment. The distribution of reportable accidents throughout the entire mining industry is shown in figure 1. The number of mobile-equipment accidents per year occurring in the underground M/NM mining industry is depicted in figure 2. The total number of accidents in the 3 years studied is 750. It is unclear why there is a downward trend in the

Figure 1



1990-92 reportable accident distribution for all mining. Total = 81,340.

Figure 2



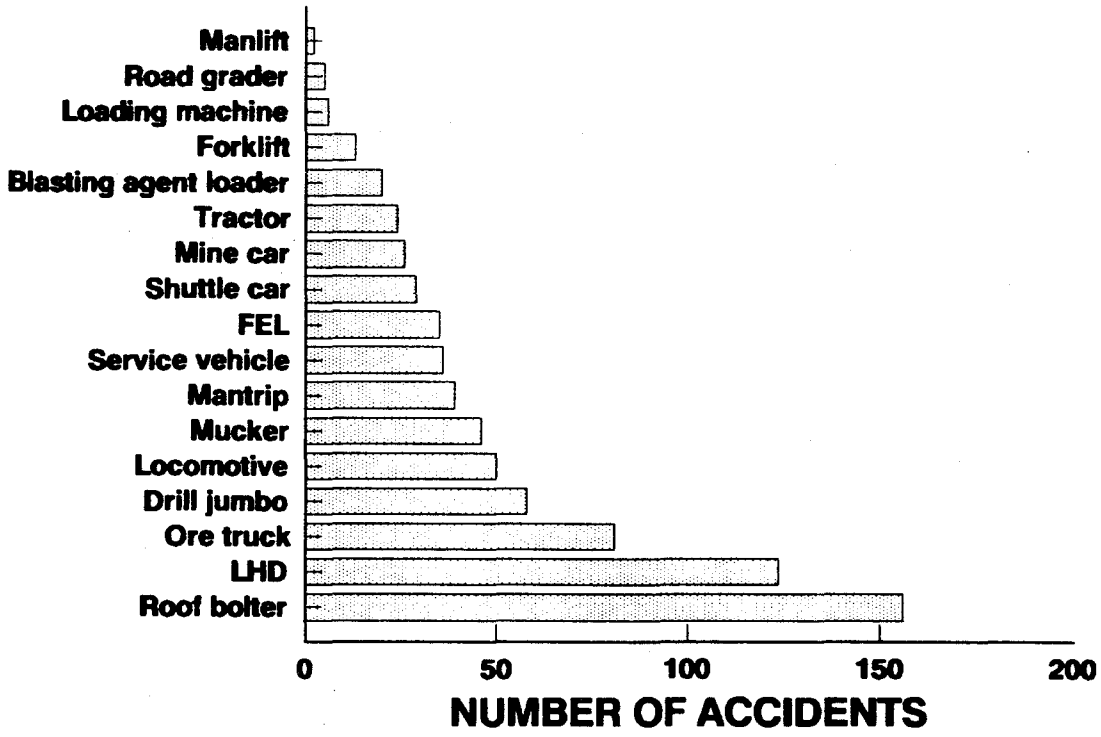
M/NM underground mobile-equipment accidents by year (MSHA reportable). Total = 750.

number of mobile-equipment incidents. There are several possible contributing factors: (1) the closure of mines that were generally unsafe (tight profit margins do not allow unsafe mines to remain open), (2) the M/NM underground workforce is shrinking (down 14% from 1990 to 1992), (3) the work force is safer, and (4) mining companies and/or contractors may not be complying fully with MSHA reporting requirements.

The vast majority of mobile-mining-equipment accidents can be placed in three broad categories: drilling, haulage, and rail specific. Drilling accidents are associated with roofbolters and jumbos and account for 28.5% of all mobile-equipment accidents. Haulage accidents are associated with LHDs, ore trucks, and front-end loaders (FELs). Haulage as a broad category accounts for about 32.0% of all mobile-equipment accidents and tend to be the most severe. Rail-mounted equipment, while often being used in ore haulage, has its own unique accidents such as derailment. Rail equipment is involved in 21.5% of all mobile-equipment accidents. Figure 3 graphically displays the number of accidents associated with each distinct piece of mobile equipment. Roofbolters followed by LHDs, ore trucks, jumbos, and locomotives are the most common pieces of equipment involved in accidents.

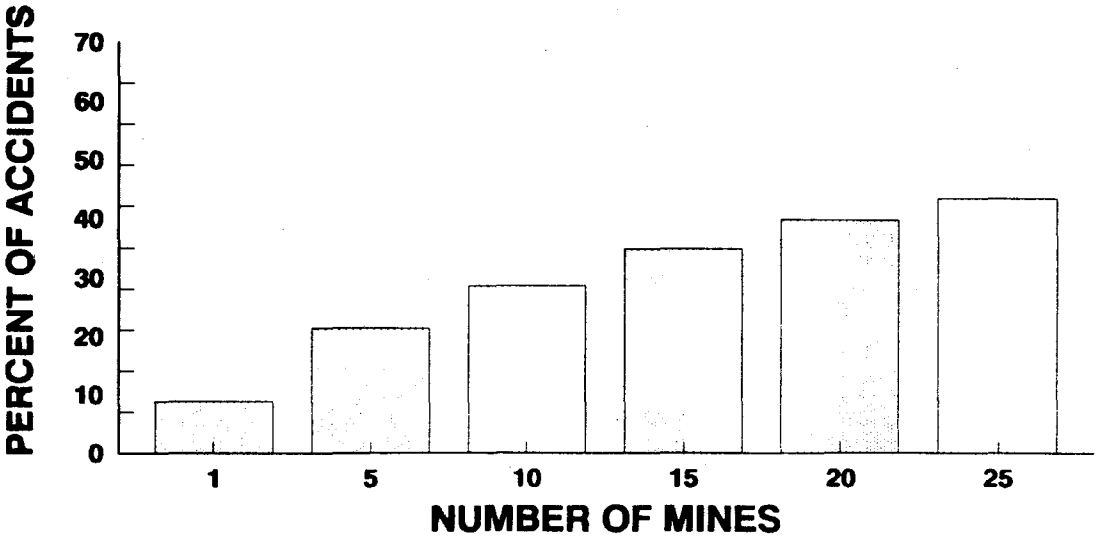
Figure 4 shows that one M/NM underground mine in the United States accounts for over 10% of all mobile-mining-equipment accidents. Of the 296 M/NM underground mines that reported to MSHA, just 15 mines are

Figure 3



Accidents by type of mobile equipment.

Figure 4



M/NM underground mobile-equipment accidents by mine.

responsible for over half of all mobile-equipment accidents. Of these 15 mines, 13 are metal mines, with the majority involved in drill and blast mining, and they would all be considered large mines with employment ranging from 67 to 1,500 employees.

Figure 5 further illustrates that certain commodities tend to have higher incident rates. For example, copper has only 6 different mines reporting accidents, but those 6 mines account for 124 accidents as compared with limestone where 35 mines account for only 78 accidents. This can be attributed to the differences in mining method (stope versus room and pillar), the different pieces of mobile equipment utilized, and mine size.

ACCIDENT CLASSIFICATION

Knowing the root cause of an accident is necessary in preventing reoccurrences of similar accidents. The accidents were classified as a first step in the process of determining root causes. These classifications are shown in figure 6. From figure 6 it becomes apparent that a few accident classifications account for the majority of all mobile-equipment accidents. Specifically, the accident classifications rockfall, collision, jarring, and ingress and egress account for 51.8% of the mobile-equipment accidents studied. The accident classification of rockfall would include fall of rock from both the roof and rib. Over three-quarters of all rockfall accidents occur during roof bolting, matting, or drilling operations. The majority of remaining rockfall accidents involve operating equipment under improperly supported or improperly scaled roof. Collisions account for the second largest group of accidents. Examples of collisions include collisions between equipment and rib, operator and rib, and pedestrians being hit by mobile equipment. Jarring injuries are the result of the body receiving a sudden shock loading such as hitting a rough spot in the road or a large piece of muck being dropped into the bed of an ore truck. Most often, jarring accidents result in an injury to the operator's back. Another major accident classification is ingress and egress. Ingress-and-egress accidents occur as the operator mounts or dismounts the equipment. Most injuries associated with ingress and egress are to the lower leg (i.e., knee and ankle).

RELATIVE SEVERITY

The average mobile-equipment LWA results in a loss of 33 actual workdays (figure 7) compared with the average mining LWA that results in the loss of 24 workdays. Mobile equipment was involved in 11 fatal accidents in M/NM mines from 1990 through 1992.

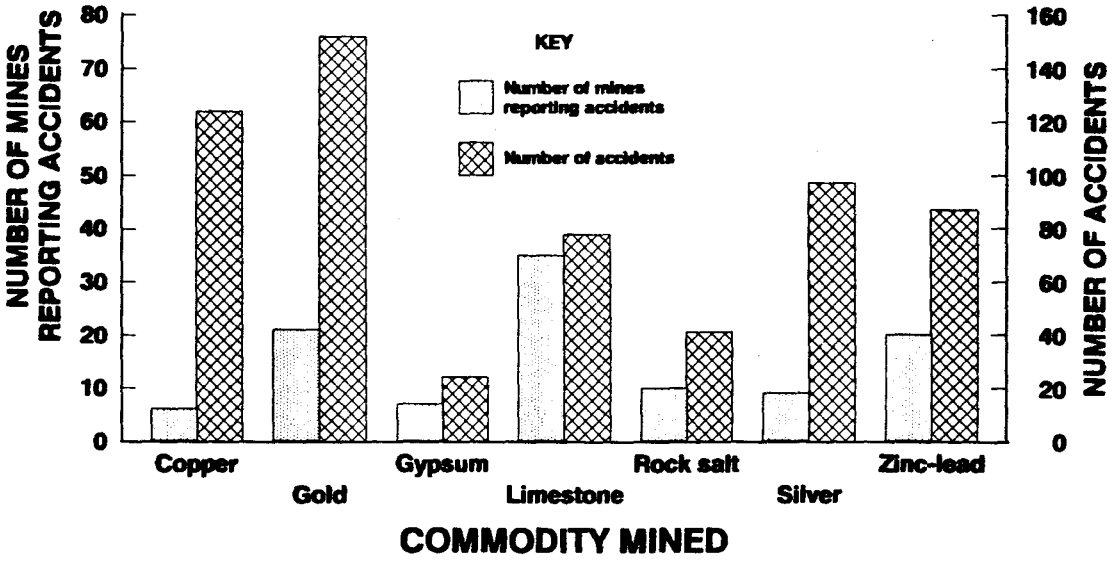
The accident category explosives-blasting, while being relatively few in number, are very severe. For example, in 1991 at a mine in Washington state, an ammonium nitrate-fuel oil truck suddenly exploded instantly killing two people and severely injuring a third. Most of the remaining unplanned detonations occurred when a drill operator inadvertently hits a misfire while drilling. Rail-specific accidents (i.e., coupling, derailing, and rerailing) also demonstrated a trend towards more severe accidents. Mechanical-failure-type accidents such as sudden loss of brakes or a hydraulic line bursting also tended to be more severe in nature. To summarize the most severe accident categories in order of severity are explosives-blasting, rail specific, mechanical failure, ingress and egress, jarring, and collisions. The accident category with the lowest relative severity is dust or particle in the eye.

Certain pieces of equipment also tend to be associated with a disproportionate share of severe accidents. Mantrips have the most severe accidents as a group. The average LWA involving a mantrip resulted in the loss of 76 workdays. Two distinct classifications of accidents, mechanical failure and jarring, contributed to the high severity of mantrip accidents. Shuttle cars have the next highest relative severity when considered as a group, typically the injury occurs because the operator was jarred while tramming the shuttle car. A typical example is, "Employee was operating a shuttle car and hit a bump causing the employee to hit his head on the canopy." Accidents like this are typical of haulage operations. Another piece of equipment just as prone to be involved in a relatively severe accident is the mine car. Typically, the accident occurs while coupling or decoupling the car from the locomotive. The car dropper inadvertently gets in a position between the cars and is injured when one of the mine cars unexpectedly moves. Also, mine cars, and hence locomotives, are involved in a large portion of collisions. Jumbos have the next highest relative severity. The accidents associated with jumbos vary greatly. Ingress and egress, pinching fingers in drill steel, rock falls, and falling objects all contributed about equally to the number and severity of jumbo-operator injuries.

NATURE OF INJURY

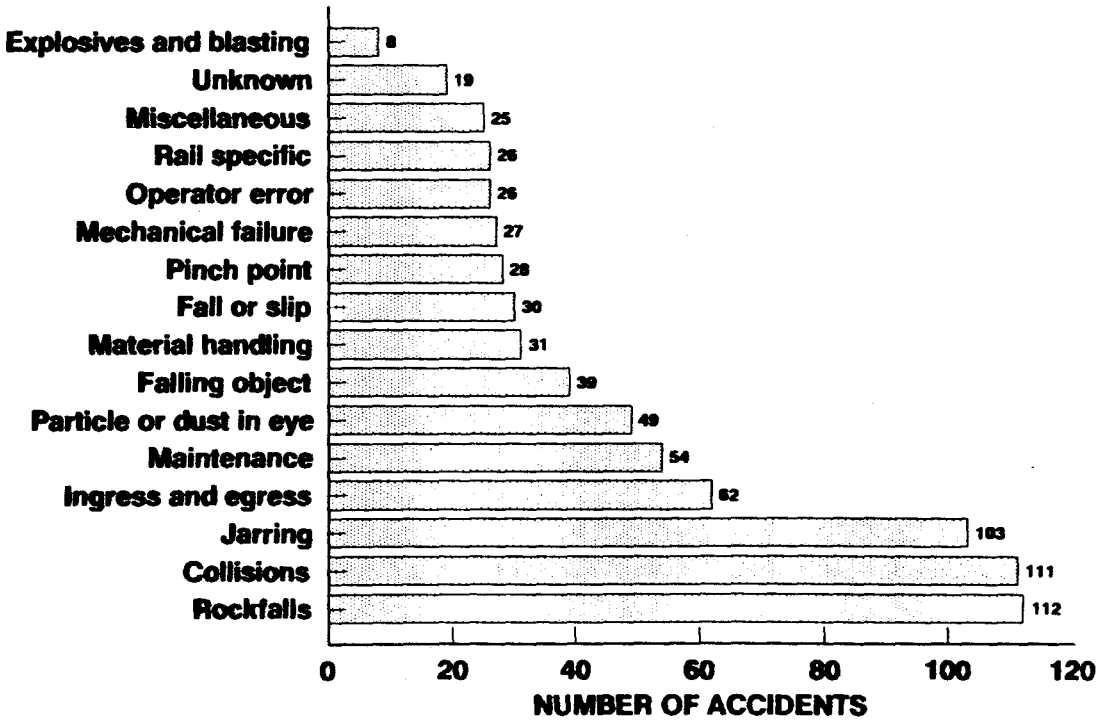
Figure 8, nature of injury, indicates that by far and away lacerations, fractures, multiple injuries, and sprains or strains account for the majority of injuries associated with mobile equipment. Sprains or strains can most closely be correlated with jarring accidents. Over three-quarters of jarring accidents result in sprain-or-strain-type injuries. Sprain-or-strain injuries are also common in ingress-and-egress and fall-or-slip accident categories. A similar relationship exists between rockfall accidents, roof bolters, and lacerations. About half of all rockfall accidents result in a laceration. Interestingly, injuries to mucker operators tend to involve broken bones. Of the 46 mucker accidents, 30% resulted in fractures (14) compared with just over 4% fracture injuries for mobile-equipment operators as a whole.

Figure 5



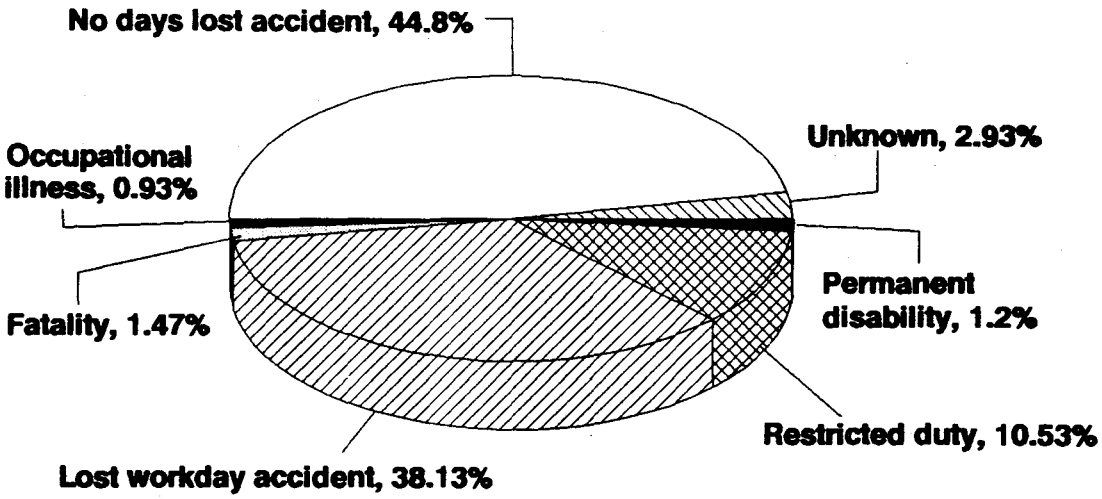
Accidents by commodity mined.

Figure 6



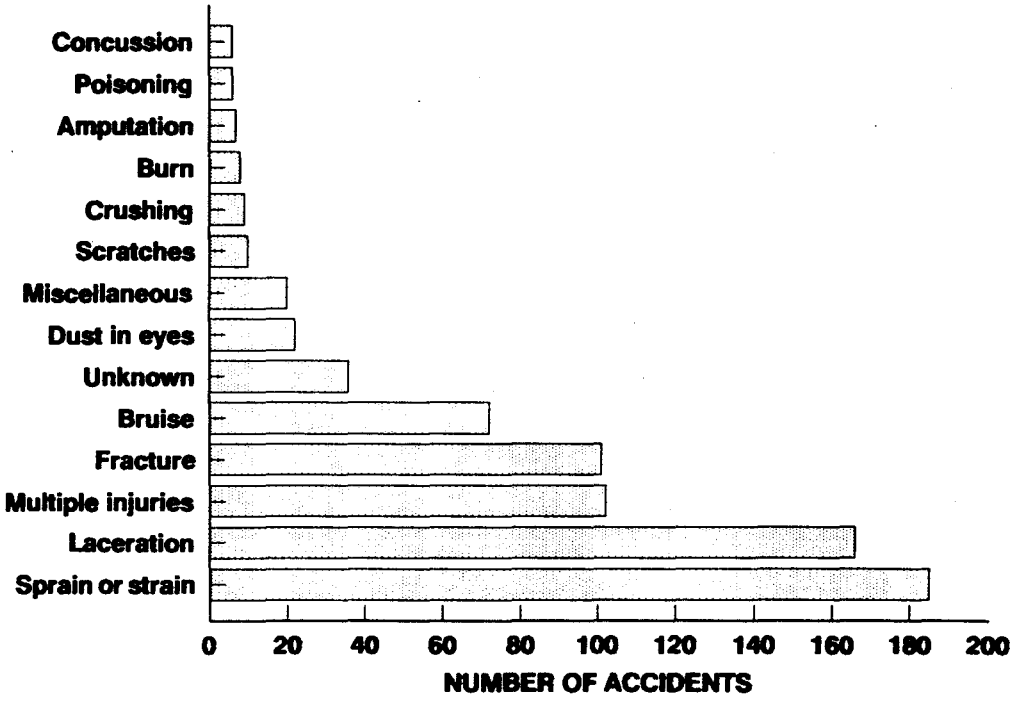
Accidents by classification.

Figure 7



Mobile-equipment accident severity.

Figure 8



Accidents by nature of injury.

PART OF BODY

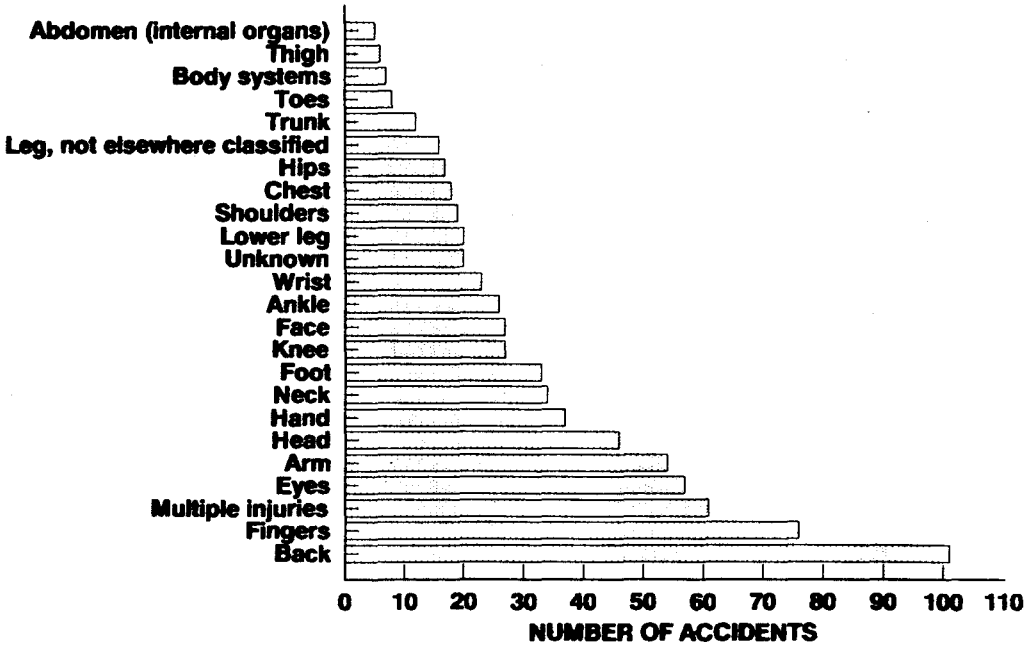
Figure 9 suggests that back, finger, and eye injuries are most common. Operators of equipment associated with trackless haulage (LHDs, ore trucks, shuttle cars, etc.) tend to experience back injuries. These injuries are associated with operating the equipment at relatively high speed on rough floors and narrow drifts, and are most often the result of a jarring-type accident. Roofbolter and jumbo operators have more hand and finger accidents. Most of these hand and finger injuries are the result of falling rock or getting fingers pinched in drill steel. Also accounting for numerous injuries to the hands are the accident categories maintenance, material handling, and falling object. The severity of these accidents can be reduced by wearing leather gloves whenever possible. Ingress-and-egress accidents result most often in injury to the ankle and knee. The most common causes of ingress-and-egress accidents include operators jumping off their equipment, slipping on the ladder, and stepping onto unlevel ground. Collisions between the operator and rib result in injury to the operator's foot the majority of the time. Clearly, this is due to the operator's body protruding beyond the protective zone of the operator's compartment.

JOB EXPERIENCE

The experience of the operator plays a significant role in an operator's ability to safely operate mobile equipment. The number of mobile-equipment accidents by years of operator experience is shown in figure 10. The average amount of job experience for an operator involved in an accident was 5.26 years. However, 30.8% of all mobile-equipment accidents occurred to an operator with less than 1 year of job experience, and almost 19% involved operators with less than 6 months of experience.

It is obvious that a lack of job experience is a significant contributing factor to the occurrence of a mobile-equipment accidents. This suggests that experienced operators have learned to identify and avoid potentially unsafe operating practices. It also suggests that human error (administrative and operator) is responsible for numerous accidents. Additionally, the possibility exists that new workers are often given the least desirable job, a job that often poses a significantly higher risk of an accident. Increased emphasis on hazards associated with mobile-equipment operation during mandatory miner training could have a significant impact on the reduction of mobile-equipment accidents.

Figure 9



Accidents by body part injured.

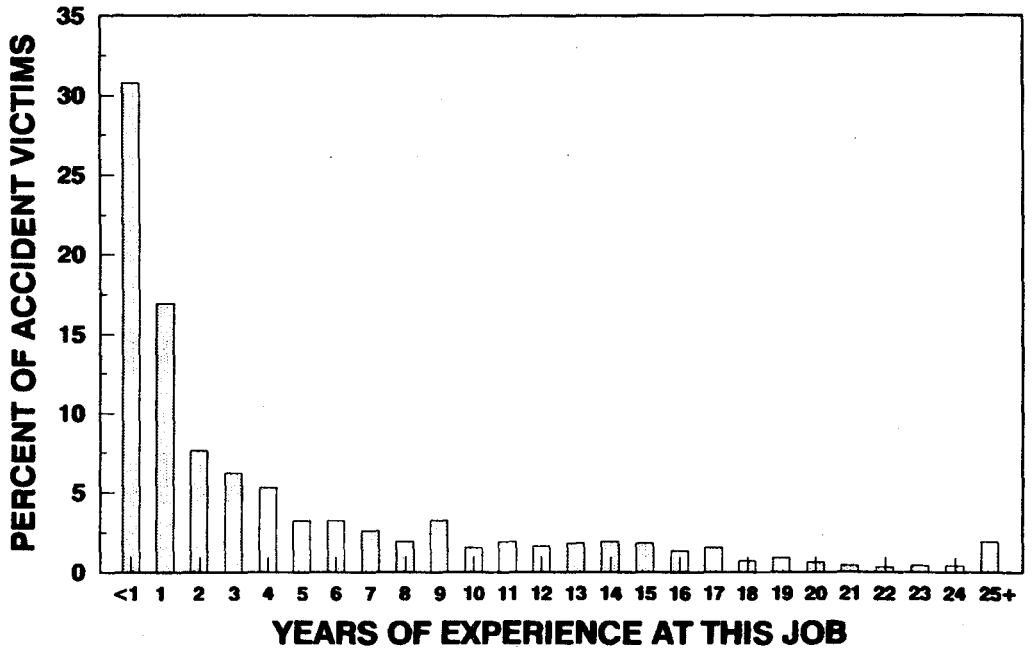
TOTAL MINING EXPERIENCE

The number of accidents per years of total mine experience is shown in figure 11. The average amount of total mine experience for an operator involved in a mobile-equipment accident is 8.9 years. This is higher than the 5.26 years of average job experience for mobile-equipment accident victims. This suggests that experience gained in mining activities other than operating a particular piece of mobile equipment had little impact on the operator's ability to safely operate that piece of mobile equipment. This could also imply the possibility of a supervisor's incorrect assumption that an experienced miner has the required training or experience to perform a new task (such as operate equipment) even when that person is not properly trained in the operation of the specific equipment.

OPERATOR AGE

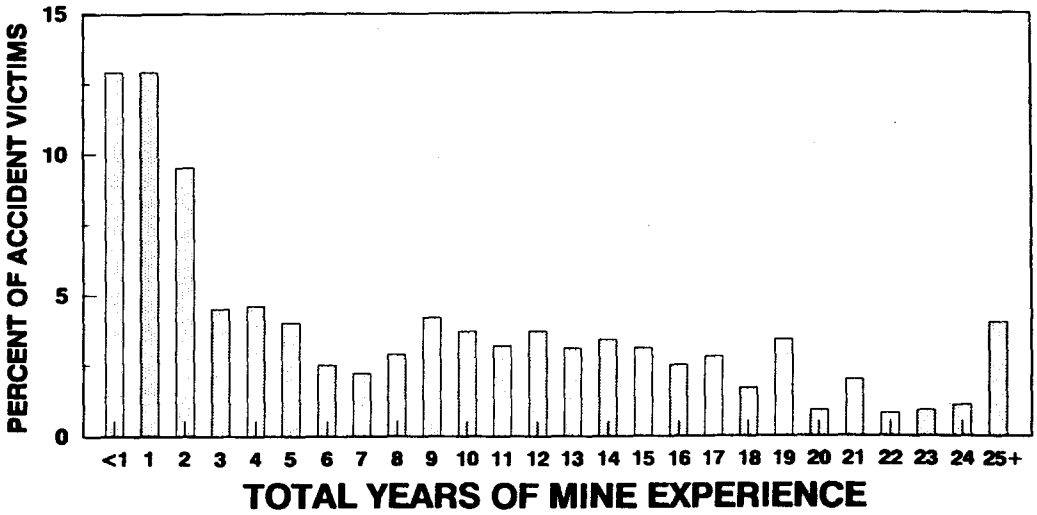
The age distribution of operators involved in mobile-equipment accidents closely matches the overall age distribution of underground miners (*9*). It therefore appears that there is no relationship between the age of an operator and the potential for involvement in a mobile-equipment accident.

Figure 10



Total mine experience.

Figure 11



Experience in this job.

ACCIDENT DATA ANALYSIS BY EQUIPMENT TYPE FOR MOBILE-EQUIPMENT ACCIDENTS IN M/NM UNDERGROUND MINES

The following section provides an analysis of mobile-equipment accidents classified by equipment type. Understanding what pieces of equipment face greater hazards and realizing what these hazards are will allow the proper training of operators to recognize specific safety hazards that exist in their workplace. Table 1 is a summary relating equipment type to accident type, nature of injury, and part of body injured.

LOAD-HAUL DUMPS

LHDs are one of the most common pieces of mobile equipment found in an underground M/NM mine and are associated with ore removal and haulage operations. LHD accidents tend to be more severe than the typical mobile-equipment accident. For example, LHD operators were the victims in 5 of the 11 mobile-equipment-related fatalities. Three of these deaths were due to massive rockfalls. When lost workdays were associated with an LHD accident, the miner on average missed 36 days of work, compared with an average of 33 lost work days for all mobile equipment.

Typical LHD accidents include jarring, collisions, rockfalls, and accidents relating to maintenance of the LHD. Jarring accidents account for roughly one-fourth of all LHD accidents, and most of these jarring accidents are due to rough floors. The high number of jarring type accidents indicates that mine operators should try to keep the floor as even as possible. Over 60% of back injuries to LHD operators can be directly attributed to jarring accidents. Collisions are another major accident type and account for 15% of all LHD accidents. The nature of these collisions varies from the LHD hitting spillage, striking the rib, or actually running over other workers in the area. Rockfalls were the next largest accident category for LHDs. These rockfall accidents occur when the LHD moves into an area to begin mucking operations immediately after blasting. Operators must be cautioned to inspect the roof and ribs before commencing operations. Maintenance activities also take their toll on the work force, accounting for 11.3% of LHD accidents. Of the 10 ingress-and-egress accidents, all resulted in either a sprain or fracture to the lower leg.

Two-thirds of all LHD accidents occur in underground metal mines, fully 30% occur in copper mines. As with most mobile equipment the part of body most often injured included the back, eyes, and fingers. Almost half (48.7%) of all LHD accidents involve operators with less than 2 years of experience at operating an LHD. This may indicate a lack of proper training or an enthusiasm to run the equipment harder under poor operating conditions. Experienced miners new to LHD operation also show a need for more adequate task-specific training.

Table 1.—Summary of accidents by equipment type

Equipment	Number of accidents	Average number of days per LWA	Accident type[1]	Nature of injury[2]	Part of body[3]
Roof bolter	156	23.2	Rockfall, particle or dust in eye, falling object, pinch point.	Laceration, fracture, sprain or strain, dust in eye.	Head (mouth, eyes, etc.), knee to toes, forearm to fingers.
LHD	124	36	Jarring, collision, maintenance, rockfall.	Sprain or strain, laceration, fracture.	Wrist, hand and fingers, back and neck, eyes.
Ore truck	81	39.2	Jarring, collision, maintenance, ingress and egress.	Sprain or strain, fracture, laceration.	Neck and back.
Jumbo	58	25	Rockfall, ingress and egress, falling object, operator error.	Laceration, sprain or strain	Hand and fingers, back.
Locomotive	50	24	Collision	Laceration, sprain or strain, fracture.	Hand and fingers, back.
Mucker	46	21.8	Collision, derail	Fracture, laceration, sprain or strain.	Wrist, hand and fingers, ankle, foot and toes, eyes.
Mantrip	39	75.9	Collision, jarring	Sprain or strain, fracture	Back and neck.
Service vehicle	36	33.5	Collision, ingress and egress, maintenance, jarring.	Sprain or strain	Back, wrist, hand and fingers.
FEL	35	18.4	Ingress and egress, jarring, maintenance, collision.	Sprain or strain, laceration, fracture.	Back, wrist, hand and fingers.
Shuttlecar	29	48.9	Jarring and collision	Sprain or strain	Back.
Mine car	26	39.8	Coupling, derail, and rerail	Fracture, sprain or strain, laceration.	Fingers, back, chest, lower leg.
Tractor	24	22.1	Jarring	Sprain or strain	Back, ankle, knee.

[1]Most common classification associated with corresponding equipment type listed in order of decreasing correlation.
[2]Most common type of injury associated with given type of equipment listed in order of decreasing correlation.
[3]Most commonly injured body part associated with corresponding equipment type listed in order of decreasing correlation.

ORE TRUCK

Ore-truck operators and LHD operators face comparable hazards; operating over rough roads at high speeds in tight confines. As a result, the injuries and accidents involving truck operators are similar to those happening to LHD operators. The most common injury to truck operators is a strained neck or back as the result of jarring from rough roadways. The number of jarring-type accidents indicates a need for better road maintenance. Collision accidents accounted for the next highest number of accidents. The most common type of collision was the operator or truck striking the rib. For example, the following accident occurred in a limestone mine located in Kentucky: "Employee states it was foggy in the mine and he did not see the pillar that he hit."

Mechanical-failure accidents involving ore trucks were rather severe and numerous with two-thirds of them resulting in lost workdays (in general 38% of mobile-equipment accidents result in lost days). Ore trucks accounted for over one-third of all mechanical-failure accidents. This is probably due to high travel speeds. Mechanical-failure accidents typically involved the brakes failing.

A lost-work-time accident involving an ore truck caused an average of 39.2 days lost. Fifty percent of all ore-truck accidents occur in metal mines (predominantly gold or zinc-lead mines) with the majority of the remaining accidents occurring in underground limestone mines. Inexperienced operators are again at the highest risk of injury.

FRONT-END LOADERS

FELs are usually associated with room and pillar mining, but interestingly, 50% of FEL accidents occur in metal mines. FEL operators are the victims in a disproportionate share of ingress-and-egress accidents. This could be due to the height of a FEL as compared with the typical piece of underground mining equipment. Ingress-and-egress accidents involving FELs tend to result in sprains or strains to the lower back resulting in time away from work. FEL-operator accidents as a whole tend to be less severe than LHD or ore-truck accidents. This may well be due to the lower average speed of a FEL as compared with a tramming LHD or ore truck. Jarring accidents also account for a large portion of FEL accidents (23%). The third most common type of accident involving FELs are accidents relating to maintenance. A typical example of

this type of accident is "Employee was driving a steel pin from a cylinder rod on a FEL when the pin came out and struck his forehead resulting in a laceration." Interestingly, 4 of the 17 pieces of equipment analyzed, FEL, LHD, ore truck, and service vehicle account for two-thirds of all maintenance-related accidents.

The body parts most likely to be injured in a FEL accident are the back or hands. The average victim involved in a FEL accident had just under 4 years of experience on the job.

ROOF BOLTERS

Roof bolters account for the largest number of mobile-equipment accidents; however, these accidents do not tend to be very severe. Nearly 60% of all roof-bolter accidents result in no lost work days. This is not to imply that prevention of these accidents is unimportant. Prevention of these accidents is an important concern. Many of these minor accidents arise from the same root causes that result in much more severe accidents.

The typical roof-bolter accident is a rockfall from the roof resulting in a laceration requiring sutures. Slightly under half of all roof-bolter accidents involve rockfalls. Rockfall accidents can happen at any time during the rock-bolting process. Several examples of roof-bolter accidents follow: "...just finished drilling, cleaning drill. Rock came out of back struck on left elbow. Required sutures."; "Employee was bolting hanging wall with a steel mat, when a small rock fell out and cut the employee's forehead."; "While drilling the back, a rock fell out lacerating right thigh." These examples show that the operator must constantly be aware of the dangers associated with rock falls.

Falling objects (typically drill steel) account for the next largest share of roof-bolter accidents. Also, closely related to falling-object accidents are pinch-point accidents. Operators are having their fingers pinched as they are handling drill steel. Roof-bolter operators are also prone to accidents involving particle or dust in the eyes. It is imperative that operators wear safety glasses. The most severe accidents involving roof bolters are collisions. Although they are relatively infrequent, over 60% of collision accidents involving roof bolters result in lost workdays. Roof-bolter accidents usually involve an injury to the face, eyes, fingers, or foot.

DRILL JUMBO

Jumbo accidents, not surprisingly, reflect the accident types and injuries associated with roofbolters; however, jumbo accidents are more severe than roofbolter accidents. In the 1990 through 1992 time period there were four fatalities involving jumbo operators. Two of these fatalities were from rockfalls, one from a collision, and the other from the explosion of an isolated pocket of methane gas. The most common jumbo accidents are associated with rockfalls, ingress and egress, falling objects, and operator error.

Rockfalls are the largest cause of accidents involving a jumbo, and similarly to roof bolters, most often result in a laceration to the hands. Half of these rockfall accidents result in no lost workdays. Ingress-and-egress accidents are the second most common type of accident and are typically more severe than a rockfall accident. Of all ingress-and-egress accidents, 89% resulted in lost workdays (averaging 25 lost work days). Most ingress-and-egress accidents involving a jumbo result in a sprain or strain to the ankle or foot. Falling objects also result in numerous injuries to jumbo operators.

Also of concern would be the number of accidents associated with operator error. Roof bolters and jumbos account for half of all operator-error-type accidents. This is most likely due to the complexity of operating these pieces of equipment. An example of an operator-error accident would include the following roof-bolter accident that occurred in a rock salt mine: "Employee was attempting to free auger which was stuck and had foot on top of toe guard protection plate. He hit the wrong handle and roof bolt transmission came down and struck his foot."

Notably, pinch-point accidents almost always involve an injury to the hands or fingers. Some of these accidents could have been avoided by wearing gloves.

Two-thirds of all jumbo accidents occur in metal mines, with gold, zinc-lead, and copper mines being the most dangerous. Nonmetal mines with a propensity towards jumbo accidents include limestone, and rock salt. The most common type of injuries are sprains or strains, and lacerations.

SERVICE-UTILITY VEHICLE

The service-utility vehicle class includes such vehicles as fuel trucks, maintenance vehicles, tractors, and forklifts. Four accident classes account for most of the accidents associated with this type of mobile equipment: collisions, jarring, ingress and egress, and material handling.

As with other types of equipment, collisions tend to be varied in nature. Ranging from tractors colliding with FELs to forklift operators being struck by ventlines as they drove underneath.

Of the 10 jarring accidents due to rough roads, all of them resulted in sprained or strained backs and 9 of them resulted in lost workdays. Ingress-and-egress accidents were the next most common accident. Service vehicles and tractors (not forklifts) were usually involved in ingress and egress accidents. Ingress and egress accounted for 60% of all ankle and foot injuries associated with service vehicles.

Tractor passengers were also involved in numerous slip and fall accidents. There simply is not a good place on most tractors for passengers to ride. Almost all of these

accidents involved passengers losing their grip on the rollbar or fender and tumbling off the moving tractor. In one severe case, this resulted in the passenger being run over by the rear wheels of the tractor, resulting in two broken legs.

MANTRIPS

A mantrip is loosely defined as any vehicle normally employed in the transportation of personnel within the mine. In addition to the more common notion, a mantrip may include jeeps, "cushmans," and golf carts. Mantrip accidents can be severe in that the potential exists for one accident to result in multiple injuries. The 17 mantrip LWA had a total of 1,291 lost days (an average of 76 lost work days per accident). One-third of mantrip injuries were sprain or strains and an additional one-quarter were lacerations.

Mantrips were involved in 13 collisions and 9 jarring accidents out of 39 total mantrip accidents. The 13 collisions varied in nature. The most common being the mantrip striking another vehicle. Also, mantrips had a number of collisions that were due to cargo (typically a shovel) sticking out beyond the mantrip sides. As the mantrip would closely pass another vehicle or an obstacle, the shovel would be hit causing it to swing around and strike the driver or a passenger.

Jarring due to rough roads also gave mantrip operators and passengers some problems. Of the nine jarring accidents, five resulted in injury to the back or neck. Jarring accidents can be very serious in nature. Two jarring injuries associated with mantrips resulted in the loss of 410 workdays. Also of considerable concern is the severity of the mechanical-failure accidents. The three mechanical-failure accidents associated with mantrips resulted in 502 lost workdays at an estimated cost of over $200,000.[6]

RAIL-MOUNTED EQUIPMENT

Locomotives, muckers, and mine cars provide their own unique safety concerns. Being rail mounted, the operator needs to be concerned with the dangers associated with derailment, rerailment, and coupling; however, the injuries associated with jarring are not present. In the 3 years studied over one-quarter of all rail accidents were collisions.

Locomotives

Locomotives are often used for main haulage. The most common accident involving locomotives are collisions, which account for 40% of all locomotive accidents. About half of these collisions result in lost work time. Locomotives account for nearly one-fifth of all collisions that occur in underground M/NM mines. Typical examples would include having two locomotives collide (about one-fourth of all collisions involving locomotives were of this type), a pedestrian in the area being struck, or as in the following example from a mine in the Coeur d'Alene district, "Employee had leg outside of motor, pinched leg between motor and car." This accident scenario is relatively common across all types of mobile equipment due to small operator compartments.

As with other types of mobile equipment, inexperienced operators are at greater risk of having an accident, 32% of all locomotive accidents involved operators with less than 1 year of experience. Metal mines accounted for 88% of all locomotive accidents with copper, gold, silver, and zinc-lead mines contributing about equally to the total.

Mucker

Almost 90% of all mucker accidents occur in underground metal mines with gold mines accounting for the most accidents. Most injuries involve the hand or foot of the mucker operator. The most common type of injury is a fracture followed by sprains or strains, and bruises.

Most mucker accidents could be classified either as a collision or a derailment. Collisions were the most common type of accident. A number of these collisions were due to the bucket striking an object attached to the roof (i.e., ventline or lagging). Derailments usually occurred as the result of the mucker bucket becoming hung up during the loading operations.

Mine Cars

Mine-car accidents can be related most closely to coupling and derailing, just as one would expect. Over one-fourth of all mine-car accidents involve coupling, another one-fourth involve derailing. Over half of these coupling and derailing accidents result in lost workdays.

Typically, coupling accidents occur when the persons attempting to couple the mine car place themselves in a position between the mine cars and one of the cars moves unexpectedly. For example, "While the employee was coupling a car, he stepped between the cars to hook up the safety chains. The cars rolled forward causing his ankle to be caught under the lip of the car."

There are two distinct types of derailment accidents. One type is when the accident and resulting injury occur during the actual derailment. The second, and equally likely accident and injury, results from the rerailment efforts following a derailment. These rerailment injuries are almost always back strains. Proper lifting precautions and good procedures must be followed to prevent this type of injury.

[6]Refer to footnote 5.

An average mine-car LWA results in a loss of 39.8 work days. Almost all mine-car accidents occur in metal mines (96%). Copper and silver mines each account for 35% of all mine-car accidents. In 46% of all mine-car accidents, the victim had less than 2 years of experience.

ACCIDENT ANALYSIS BY ACCIDENT CLASSIFICATION FOR MOBILE-MINING-EQUIPMENT ACCIDENTS IN M/NM UNDERGROUND MINES

As part of the accident analysis, the accidents were classified by root cause. By classifying the accidents it became obvious that a few classifications accounted for the majority of accidents. These accident classifications are depicted in figure 6. Table 2 provides a summary relating accident classification to equipment type, nature of injury, and part of body most commonly injured. The following sections thoroughly evaluate the leading accident categories and are listed in decreasing order of accident frequency.

ROCKFALLS

Rockfalls are the leading cause of accidents and fatalities in underground M/NM mines involving mobile-mining equipment. Between 1990 through 1992, rockfalls accounted for 112 accidents including 5 fatalities. Even though rockfalls accounted for the largest number of fatalities by classification, the nonfatal rockfall accidents tended to be less severe than the average mobile-equipment accident. Over half of all rockfall accidents (61 of 112) resulted in no lost days from work. However, this does not imply the accident did not cause lost time or lost production. The most common type of injury associated with rockfalls is a laceration, the next most common is a fracture. The operator's arms, hands, or fingers are the body part most often injured.

The pieces of equipment that could most closely be correlated to rockfall accidents are roof bolters, jumbos, and LHDs. Two-thirds of all rockfall accidents involve roof bolters.

The typical rockfall accident is a rockfall from the roof during rock bolting. Rockfall accidents can happen at any time during the rock bolting process. A few examples of typical rockfall accidents involving roof bolters follow: "Employee was roof bolting and a piece of rock fell from the roof and struck head, right shoulder, both arms and right leg;" "Rock fell through wire mesh while roof bolting;" and "Employee was roof bolting and was not standing under canopy when a piece of loose fell out of back." These examples show the operator must be constantly aware of the dangers associated with rockfalls. Every effort must be made to properly scale the roof and to keep the operator under a protective canopy.

Table 2.—Summary of accidents by classification

Accident classification	Number of accidents	Equipment type[1]	Nature of injury[2]	Part of body[3]
Rockfall	112	Roof bolter, LHD, jumbo	Laceration, fracture, sprain or strain.	All extremities.
Collision	111	Locomotive, LHD, mantrip, ore truck.	Laceration, fracture, sprain or strain.	Foot, head, lower leg.
Jarring	103	LHD, ore truck, shuttlecar, mantrip.	Sprain or strain	Back and neck.
Ingress and egress	62	LHD, jumbo, ore truck, FEL	Sprain or strain, fracture	Ankle, back, lower leg.
Maintenance	54	LHD, jumbo, ore truck, FEL, service vehicle.	Laceration, sprain or strain, burn, fracture.	Fingers, hand, back.
Particle or dust in eye	49	Roof bolter, LHD	Particle or dust in eyes	Eyes.
Falling object	39	Roof bolter, jumbo, mucker	Laceration, fracture	Hand and fingers, mouth, foot.
Fall-slip accidents	30	Varied	Sprain or strain, fracture	Varied.
Pinch point	28	Roof bolter, jumbo	Laceration, fracture	Hand and fingers.
Mechanical failure	27	Ore truck	Sprain or strain, laceration, fracture.	Varied.

[1]Most common type of equipment associated with corresponding classification listed in order of decreasing correlation.
[2]Most common type of injury associated with given type of classification listed in order of decreasing correlation.
[3]Most commonly injured body part associated with corresponding classification listed in order of decreasing correlation.

LHDs are also involved in numerous rockfall accidents. These rockfall accidents are occurring when the LHD begins mucking operations immediately after blasting. Operators must be taught to inspect the roof and ribs before mucking.

Rockfalls are the largest cause of accidents involving jumbos, and similarly to roof bolters, most often result in a laceration to the arms or hands.

COLLISIONS

There are several different types of collisions that can occur. These different subcategories are depicted in figure 12. Most commonly, the equipment operator lost control of the equipment and struck the rib or other object such as an air door. Of considerable concern is the number of pedestrians being struck by mobile equipment, as this particular type of collision tends to be rather severe.

Collisions tend to be associated with locomotives, LHDs, ore trucks, mantrips, tractors, and muckers. These six pieces of equipment account for 77% of all collisions in underground M/NM mines.

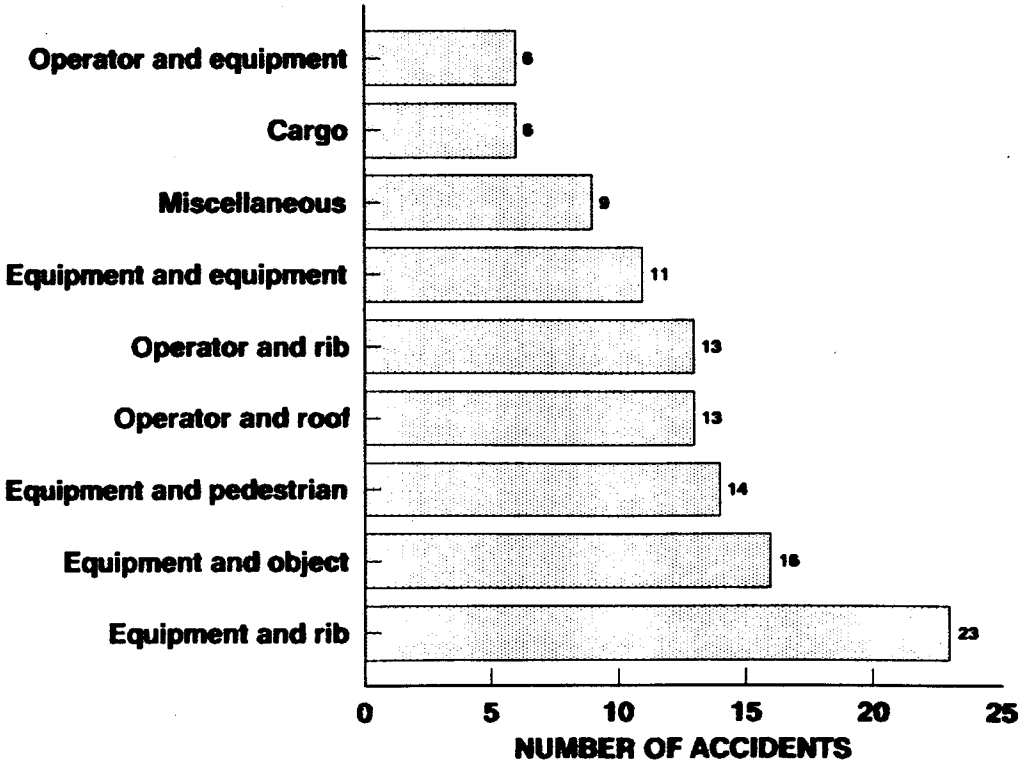
Collisions accounted for 20 of the 50 locomotive accidents. About half of these collisions result in lost work time. Typical examples would include having two locomotives collide (about one-fourth of all collisions involving locomotives were of this type) or a pedestrian in the area being struck by a moving train.

Collisions accounted for 15% of all LHD accidents. The nature of these collisions varies from the LHD colliding with spilled haulage, striking the rib, or the operator being pinched between the rib and the LHD. Usually, this type of a collision accident results in a foot injury. The most common type of collision involving an ore truck was the operator or truck striking the rib.

One-third of all mantrip accidents were collisions. The most common being the mantrip colliding with another vehicle. Also, mantrips had a number of collisions that were due to cargo extending beyond the mantrip sides.

Muckers also were involved in numerous collisions. A number of these collisions were due to the bucket striking an object attached to the roof (i.e., ventline or lagging).

Figure 12



Detailed accident classification: collisions.

JARRING

Jarring is the third most common type of accident in underground M/NM mines. Jarring could most closely be related to LHDs, shuttle cars, and ore trucks. These three pieces of equipment account for 64% of all jarring type accidents. Jarring accidents are also common in utility vehicles, mantrips, and FELs. The jarring accident category has several subcategories: jarring due to rough, uneven floors; cumulative jarring; and jarring due to loading operations.

Jarring due to rough or uneven floor accounted for the vast majority of jarring type accidents (70 of 103). This particular category is defined as an injury that occurred as the result of identifiable shock loading during tramming operations (i.e., hitting a large pothole and having the seat bottom out). Improved road maintenance and blasting techniques to produce even floors would greatly reduce the number of jarring accidents. Back injuries were the most common (39 of 70). The nature of the injures tended to be sprain and strains. Thirty-seven of the seventy (53%) accidents resulted in lost workdays compared with 38% of all mobile equipment accidents resulting in lost workdays.

The second largest category of jarring accidents was due to the cumulative jarring associated with continually operating equipment on rough, uneven roads. This subcategory accounted for 15 reportable injuries from 1990 through 1992. All but 4 of these 15 accidents resulted in lost days from work. Almost all of these injuries were strains or sprains of the back.

A third category of jarring accidents occurred due to the jarring the operator received during loading operations. There were two distinct types of loading jarring accidents; those involving ore trucks and those involving LHDs. When an ore truck was involved in a loading jarring accident, it was typically due to an oversize boulder being dropped into the box of the truck. The resulting impact of the boulder jarred the operator, inflicting the injury. Conversely, when an LHD was involved in a loading jarring accident, it was usually due to the LHD bucket working into the muck and striking either a large boulder or the floor.

INGRESS AND EGRESS

Ingress and egress accounted for 62 accidents in the 3-year period. Thirty-two of these accidents resulted in an injury to the lower leg. LHDs, ore trucks, jumbos, service vehicles, and FELs accounted for over three-quarters of all ingress-and-egress accidents. Thirty-three (53%) ingress-and-egress accidents resulted in lost workdays. There are four distinct types of ingress-and-egress accidents: (1) the operator dismounts the equipment and steps onto uneven ground (typically a small rock) and twists an ankle or knee; (2) the individual does not utilize the three point method of ingress and egress (as an example, "Injured was climbing into personnel carrier. Injured lost balance and fell to floor of carrier. Injured hands holding lunch bucket and thermos at time of accident."); (3) the employees foot slips off the ladder often due to grease, oil, or hydraulic fluid being spilled on the step; and (4) the employee simply jumps off the piece of machinery.

MAINTENANCE

Maintenance activities accounted for 54 accidents. Four pieces of equipment, FEL, LHD, ore truck, and service vehicles, account for about two-thirds of all maintenance-related accidents. Generally speaking, maintenance-related accidents resulted in no lost days from work (32 of 54). Also, most maintenance accidents resulted in a laceration to the hands or fingers.

There were several typical maintenance accident scenarios. The first and least severe involved a wrench slipping off or breaking as pressure was applied. This resulted in the maintenance workers hitting their hands causing a laceration.

The second and much more severe scenario is where the maintenance worker does not properly block up the equipment while working on the hydraulic system (typically the bucket or bed). For example consider the following accident from 1992 involving a FEL: "Two employees were changing out a hoist cylinder on a front-end loader when he crawled between the boom arms of the loader without supporting the boom and removed the hydraulic line allowing the bucket to fall pinning him between the bucket and shop floor, resulting in death."

A third type of maintenance-related accident involves workers slipping and falling off the equipment while performing maintenance. Usually this type of accident occurs simply because a person is trying to perform the maintenance without utilizing a ladder or platform.

SUMMARY

This report has identified and evaluated factors responsible for M/NM underground mining accidents involving mobile equipment. Information regarding the occurrence and severity of the accidents, the type of

equipment involved, the primary and contributing causes, and preventive measures have been included. Significant findings include:

- 16.5% of all accidents and 37.9% of all fatalities in underground M/NM mines are directly attributable to mobile equipment (1990-92).
- For the entire mining industry, the average LWA results in a loss of 24 workdays as compared with a mobile-equipment LWA occurring in an underground M/NM mine, which results in a loss of 33 workdays.
- The major accident categories are rockfall, collisions, jarring (i.e., due to rough roads), and ingress-egress. These four categories account for over 50% of all mobile-equipment accidents.
- Of all mobile-equipment accidents, 30.8% involve operators with less than 1 year of experience. This fact suggests that greater emphasis must be placed on proper task training. Only through proper training and employee awareness will the number of mobile-equipment accidents and fatalities be reduced.
- Haulage activities account for 46% of all mobile equipment accidents and typically involve LHDs, ore trucks, locomotives, or FELs.
- The cost associated with the average MSHA reportable, mobile-mining-equipment accident is estimated at $10,632.

Reasons for continued concern include the large number, severity, and costs (both human and economic) associated with mobile-mining-equipment accidents.

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