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U. S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot (feet)	hr	hour(s)
g	standard acceleration of gravity (1 g = 32 ft/sec^2)	Hz	hertz (1 hertz = 1 cycle/sec)

AN ANALYSIS OF SERIOUS INJURIES TO DOZER OPERATORS IN THE U.S. MINING INDUSTRY

By William J. Wiehagen,[1] Alan G. Mayton,[2] Jasinder S. Jaspal,[2] and Fred C. Turin[1]

ABSTRACT

This report describes serious injuries occurring to bulldozer operators working at U.S. coal, metal, and nonmetal mines. The period covered is 1988-97. The data were collected by the Mine Safety and Health Administration (MSHA). A total of 873 injury records are examined. These injuries resulted in 18 fatalities and 31,866 lost workdays. All of these injuries occurred to dozer operators while they were doing common production tasks.

An injury classification system was developed to code the narrative information that describes the circumstances surrounding the injuries. Injury records are categorized by activity (task being done), incident result (what apparently happened to the dozer), and operator impact (how the operator was injured). Where information is available, contributing factors are identified. This classification system supplemented the standard injury/illness data classification system compiled by MSHA.

The results of the study indicate that, from 1993 to 1997, the number of serious injuries to dozer operators declined by 30%. The reduction in serious injuries was accompanied by a decrease in days lost due to injury. Although the number of reported injuries has decreased, dozer operators being jolted and jarred accounts for the largest percentage (70% of the incidents) and severity (75% of the workdays lost) of serious injuries while operating the equipment. Vertical jars (while backing up the dozer) resulting in injury to the operator accounted for a sizable percentage of jolting and jarring injuries.

Working near an edge carries significant risk for fatal injuries. Of 116 incidents where the dozer fell over an edge, rolled over, or fell into a hidden void, 14 (12%) resulted in fatal injuries. In cases where the dozer operator either jumped or was thrown out of the cab in a fallover or rollover, 7 out of 26 were killed. Overall, 80% of the fatalities occurred while working near an edge or hidden void or on a steep slope.

Further reductions in injury risk will require more widespread use of seatbelts, field and laboratory research interventions to better assess the effect of alternative engineering (e.g., seat and seat suspension) designs to dampen or isolate the effects of shock and vibration, and continued focus on hazard awareness, recognition, and response.

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INTRODUCTION

From 1988 to 1997, surface mine workers sustained nearly 80,000 serious injuries, including 619 fatalities. Off-highway mobile equipment was involved in about 20% of these injuries and 42% of the fatalities [Turin et al. 2001]. Bulldozers are a common type of earthmoving equipment. Dozers are used extensively in surface mining to do a variety of tasks. These include clearing land, roadway construction, ripping unconsolidated earthen material, construction and maintenance of stockpiles, assisting other equipment via towing or pushing, building and maintaining waste dumps, and pushing material short distances to assist in overburden removal or reclamation work. The versatility of the dozer makes it an indispensable asset at nearly all surface mine operations. The nature of mining requires dozers to work in all types of weather and ground conditions. The variety of conditions and difficulty of many of the tasks adds both challenges and risk. Dozer operators work in conditions that are dynamic with hazards that vary and can be subtle and difficult to recognize. Many of the tasks require high levels of skill in blade control, machine positioning, judgment, and decision-making.

Dozer operators face some common hazards while doing a variety of work activities. These include working on steep slopes or near an edge, water, or hidden voids. There is also the everyday risk of vertical jars and jolts due to uneven terrain, lateral jolts and jars from working material, and being struck by objects (such as fall of ground or tree limbs) that can bump the dozer or enter the cab. These examples can be characterized as acute or traumatic, whereby a singular event is identified as responsible for the often unexpected energy release resulting in the incident.

Injury surveillance studies [Sparrell 1980; Stanevich 1986; May 1990; Cross and Walters 1994] sought to identify the types of injuries and risk while operating off-highway mobile equipment. Each of these studies examined injury data, in part involving off-highway mobile equipment similar to that found at surface mines. Their analyses were aggregated across equipment types. Although the context for each of these studies is different, their findings are somewhat common. They suggest that general approaches involving training, work practices, enhanced workstation design, and improved ingress and egress offer good opportunities for reducing injury risk to those who operate off-highway earth-moving equipment. None of these studies examined dozer operation in detail nor the unique kinds of injuries associated with common bulldozing tasks.

In addition to the risk of traumatic injury, there are other risk factors that involve long-term, cumulative exposures to health hazards. For dozer operators, relevant examples include the potential health impact from exposures to silica dust, noise, and whole-body vibration (WBV). The literature on the effects of WBV on comfort, performance degradation, and worker health is partially relevant to this study. There are two reasons for this. WBV is an environmental stressor. It detracts from safe, productive performance. Reviews of the literature suggest that WBV can distract, induce fatigue, reduce comfort, impede efficiency, lead to accidents, and may have bad health effects [Love et al. 1992]. Secondly, the International Organization for Standardization has established limits on WBV (ISO 2631/1) [ISO 1985].

This report touches on some of the research literature related to WBV. A few studies are referenced in later sections of this report. Generally, we presume that the traumatic effects of (short-duration) shock, along with the annoying and performance-limiting effects of vibration, are logically intertwined and difficult to separate. Thus, the injuries sustained by dozer operators are summarized without inferring or trying to distinguish those injuries that might have been aggravated by exposure to machine vibration versus those that are truly acute, i.e., due to a singular event.

No attempt is made to attribute error to these injuries. Much is written on the subject of human error in accident causation, and attempts have been made to understand and parcel errors to different entities. Errors will always be part of the workplace. Our purpose is to organize and summarize information that can help safety professionals understand risk and promote discussion and experimentation on what might be done to further reduce the chance of an injury.

PURPOSE AND SCOPE

The purpose of this work is to profile serious injuries sustained by bulldozer operators while performing common production tasks at mining sites. A set of 873 serious injuries is examined. These include 18 fatalities and 855 lost-time incidents that occurred during 1988-97. This study is based on an analysis of occupational fatality and lost-time injuries to those who operate dozers at surface mines or surface areas of underground mines. The data are reported by mine operators and independent contractors and are collected and compiled by the Mine Safety and Health Administration (MSHA). Both track and rubber-tired dozers are considered. From our analysis, implications of the data are discussed within the context of injury prevention strategies.

Table 1 provides the context for this study based on our initial analysis of the MSHA injury data. This table builds on the findings of Turin et al. [2001] and provides a general framework for the serious injuries examined in this report. Dozers were involved in 3.7% of all surface mining serious injuries and accounted for 4.3% of the lost workdays. Table 1 categorizes the "dozer-related" injuries based on the activity (MSHA code: "mine worker activity") being performed at the time of the accident. "Operating dozers" was the largest risk

Table 1.—Surface mining, mobile equipment, and injuries involving dozers, 1988-97

Category	Serious injuries	Fatalities	Lost-time injuries	Lost workdays	Average lost workdays
Surface mining	79,601	619	78,982	2,289,152	28.98
Mobile equipment	15,601	262	15,339	507,594	33.09
Percent of surface mining	20	42	19	22	114
Injuries involving dozers	2,962	23	2,939	98,476	33.5
Percent of surface mining	3.7	3.7	3.7	4.3	116
Mine worker activity:					
Getting on or off (dozer)	875	1	874	30,889	35.3
Maintenance and repair (dozer)	612	3	609	17,978	29.4
Operating dozer	921	17	904	33,793	37.4
All others (involving dozers)	554	2	552	15,816	28.7

category. It accounted for 17 fatalities (74% of the dozer-related fatalities) and, overall, about one-third (921) of the serious injuries and lost workdays (33,793). Of note, "getting on and off the [dozer] equipment" accounted for the next highest category of serious injury, about 30% (875) of both the incidents and days lost (30,889) involving dozers.

A classification system was developed to help organize and summarize the fatality and lost-time injury data for those injuries sustained while dozers are being used to perform common production tasks. The classification system is specific to dozers and how this equipment is commonly used within mine sites. Injury narratives were coded and categorized by (1) activity (task being done), (2) incident results (what apparently happened to the dozer) and (3) operator impact (how the operator was injured). Where information is available, contributing factors are identified without attempting to rank their relative importance.

The following sections provide the methods, results, and analysis (discussion). Appendices are provided to offer more detail with regard to the methods used to select, classify, and code the injury records; supplementary findings from the review of the 18 dozer operator fatality reports; and additional data on the 855 lost-time injuries.

METHOD

Two data sets were used in this analysis:

1. *Fatality reports*.–MSHA personnel conduct investigations of every mine fatality. These reports were obtained from MSHA and used to conduct a more in-depth review and compile a summary of bulldozer operator fatalities over the 10-year period.
2. *The injury/illness data set*.–MSHA regulations at 30 CFR 50.20 require mine operators and contractors to file a Mine Accident, Injury and Illness Report (MSHA Form 7000-1) for each accident, occupational injury, or occupational illness that occurs at a mine site. Instructions for completing this form can be found on the MSHA Web site at www.msha.gov/FORMS/70001prv.HTM. Mine operators completing this form and MSHA personnel constructing the database provided the input data for this study. This comprehensive data set was sorted and reviewed to select records, i.e., identify the subset of injuries sustained by dozer operators while doing common production tasks.

INJURY RECORD SELECTION

Records were chosen from the MSHA injury and fatality database that met three criteria:

1. Each of the injury records resulted in death, permanent disability, or lost work time. We excluded records that *only* included days of restricted work time.
2. Each of the incidents involved operating a dozer on mine property (by mining company employees or contractors) to perform a common production task.
3. The period covered was January 1, 1988, to December 31, 1997.

Researchers selected injury records from the MSHA database based on the decision rules shown in table A-1 in appendix A. This strategy yielded a set of 960 records. Each injury narrative[3] was reviewed to select the final set of records (873). The set included 18 fatalities and 855 injuries involving lost workdays.

CODING OF THE RECORDS

A qualitative analysis was performed based on the review of the injury narratives to code the records. A classification system was developed to code information contained in the

[3]The narratives are short summaries prepared by the individual (at the mine site) completing the MSHA Form 7000-1.

narrative. The new variables and descriptors are identified in table A-2 in appendix A. These include:

Activity.—This variable was defined to code the specific task being performed by the dozer operator at the time of injury. It is a more specific clarification of the MSHA code "mine worker activity." For this study, each injury record was assigned one of seven different activities. These relate to the primary tasks of bulldozer operation. A default activity—blade/groundwork—was assigned if the narrative omitted specific task information, but it was clear that the dozer was used to perform a common production task.

Incident result (dozer impact).—This variable describes what happened to the dozer. The categories for this field are described in table A-2. If it was apparent that the injury occurred and there was no apparent impact on the dozer, then these records were coded as "normal operations." Examples include injuries due to twisting and turning in the seat, control usage, or eye injuries due to dust blowing into the cab.

Operator impact.—This field describes the type of injury sustained. Coding of this field was based on the injury narrative with supplemental information obtained from other fields in the MSHA database (e.g., part of body, nature of injury). Examples include the operator being jolted or jarred, the operator was jolted and struck against an object inside the cab, or the operator landed outside of the cab. Other categories include the operator was struck by an object, came in contact with a hot object, and musculoskeletal injuries (injuries due to twisting and turning, reaching, control usage, etc.). This latter category is often tied directly to normal dozer operations where there was no apparent impact to the dozer.

Contributing factors to the event.—This variable was coded for those injury records where the narratives offered information that may have contributed to the occurrence. The options for this variable were not derived a priori, but were developed based on the review of the narratives and common categories identified.

Contributing factors to the severity.—This field was used in those cases where the injury narratives offered information that may have contributed (either to enhance or decrease) to the severity of the injury. Examples include the use of seatbelts.

Team members reviewed and coded each of the 18 fatality records and the 855 lost-time injury records. Several discussions were held to identify discrepancies and ambiguities in the interpretation of the injury narratives. Where ambiguity was found, these records were discussed and changes were made to simplify or clarify the coding scheme or definitions of categories within the new variables. Checks of other, but related fields in the MSHA database were made to help with the coding. Appendix A provides more detail on how the records were selected and coded.

For the fatality reports, variables were added to the data set in addition to those identified in table A-2. Because the quality and quantity of the information is much greater for the MSHA fatality investigative reports, a more in-depth level of analysis could be done.

SERIOUS INJURIES TO DOZER OPERATORS WHILE PERFORMING COMMON PRODUCTION TASKS

GENERAL CHARACTERISTICS OF THE SERIOUS INJURIES

There were 873 serious injuries that fit the parameters of this study: (1) the injuries occurred while the worker was operating a dozer and (2) the worker was injured to the degree where work time was lost. Table 2 summarizes these serious injuries by year. There were no dozer fatalities in 1996-97. Lost-time incidents averaged 102 annual incidents in 1988-92 and averaged 69 incidents in 1993-97. The data are not normalized by hours of exposure. However, if one assumes that the number of employee hours spent on the dozer has been fairly constant, then the reported injury data suggest a 30% reduction in injury risk. This assumption seems reasonable since surface mine employment has remained fairly constant (about 250,000 employees) over the 10-year time period [Turin et al. 2001].

Overall, the 855 lost-time incidents resulted in a total of 31,886 days of lost work. This total does not include statutory days charged in cases of permanent disability. Over the 10-year period, five injuries were classified as permanent disability.[4]

Table 2.—While operating a dozer: fatalities and lost-time injuries by year

Year	Fatalities	Lost-time injuries	Lost workdays	Average lost days
1988	1	91	3,149	34.6
1989	2	105	2,328	22.2
1990	1	114	4,655	40.8
1991	1	107	3,933	36.8
1992	2	94	4,848	51.6
1993	5	79	3,166	40.1
1994	3	67	2,793	41.7
1995	3	76	3,069	40.4
1996	0	58	2,063	35.6
1997	0	64	1,882	29.4
Total . . .	18	855	31,886	37.3

[4] We include "days lost" for these injuries as reported by the mine operator or contractor, but do not include the statutory days charged.

Table 3 describes these injuries and fatalities by mining sector. Figure 1 illustrates the 10-year trend of lost-time injuries by mining sector. Overall, bituminous coal had the largest share (62%) of the serious injuries and 65% of the lost workdays. It was also the sector with the largest improvement in lost-time injuries over the 10-year period. Other sectors (sand and gravel, metal, and stone) also experienced some improvement, although the relative gain was small. The annual tally of dozer injuries at anthracite and nonmetal mines was low compared to the other sectors. Ninety-five percent of the injuries (822) were reported by mine operators; the rest (51) was reported by independent contractors.

Four States accounted for 53% of the total dozer injuries and about the same percentage of the total days lost (figure 2). Two States (Kentucky and West Virginia) account for the largest individual and combined share of the lost-time injuries (38% of the total incidents) and days lost (43% of the days lost). Supplemental tables summarizing the incident data by State are found in appendix C.

Tables 4 and 5 summarize the demographics of the injury victims by age and mining experience. The injury victims were, on average, 42 years old. Almost all (99.8%) were male. Median days lost was the largest for the age group 40-49. The large majority had a significant amount of total mining experience (>5 years), although 21% of the lost-time injury victims had 1 year or less of experience at the particular mine site where the injury occurred.

For the 18 fatalities, figure 3 illustrates the amount of experience on the dozer. This information was obtained from the fatality investigation reports. Experience in the task (operating a dozer) ranged from only a few days to over 40 years. Five of the victims had less than 2 months of experience on the

Table 3.—While operating a dozer: serious injuries by mining sector

Product class	Serious injuries		Fatalities	Lost-time injuries	Lost workdays		Average lost workdays
	No.	% of total			No.	% of total	
Bituminous coal . . .	543	62	10	533	20,691	65	38.8
Stone	99	11	2	97	2,755	9	28.4
Metal	96	11	2	94	3,610	11	38.4
Sand and gravel . . .	76	9	4	72	2,435	8	33.8
Nonmetal	36	4	0	36	1,418	4	39.4
Anthracite coal	23	3	0	23	977	3	42.5
Total	873	100	18	855	31,886	100	37.3

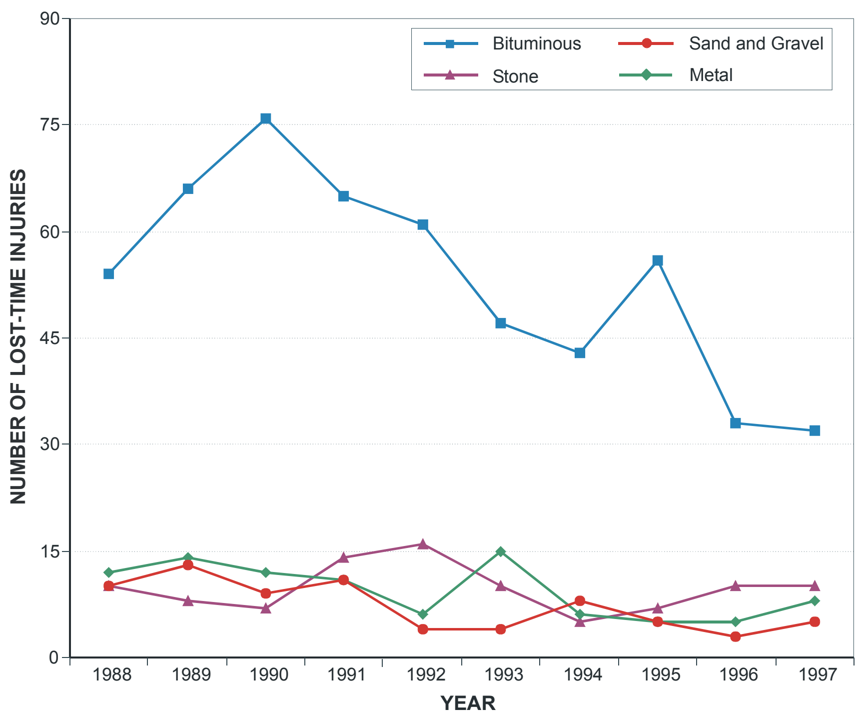

Figure 1.—While operating a dozer: lost-time injuries by year and mining sector.

Table 4.—While operating a dozer: serious injuries by age of victim

(fatalities in parentheses)

Age range (years)	Serious injuries	Percent	Median days lost[1]
Less than 29	77 (2)	9	5
30 to 39	291 (5)	33	14
40 to 49	283 (4)	33	25
50 to 59	160 (4)	18	19
60 or greater	33 (3)	4	22.5
Unknown	29 (0)	3	—
Total	873 (18)	100	N/A

[1]Median days lost for the 855 lost-time injuries.

Table 5.—While operating a dozer: lost-time injuries by mining experience

Experience (years)	Total mining	Percent	At this mine	Percent
Less than 1	34	4	182	21
1 to 2	31	4	86	10
2-3	31	4	66	8
3-5	52	6	78	9
More than 5	595	69	379	44
Unknown	112	13	64	8
Total	855	100	855	100

dozer. Three of these five were on the job for less than a week. Another two had 1-2 years of experience; the rest (11) had 2-40 years of experience.

Table 6 summarizes the lost-time injury data by job title and experience in that job title. Overall, 701 injuries were sustained by miners with the job title reported as "dozer/tractor operator"; 154 had other job titles (see table C-3). For the dozer/tractor operators, 616 records included information on the level of experience in the job title. About 14% of the lost-time injuries were incurred by miners with less than 1 year of job experience; 60% of the victims had more than 5 years of experience. The number and percentage of workers injured with less than 1 year of experience in the job are about twice the number and percentage as those with 1-2, 2-3, 3-4, and 4-5 years of experience.

DOZER ACTIVITY, RESULT, OPERATOR IMPACT, AND CONTRIBUTING FACTORS

Tables 7-9 summarize the incidents by *activity* (task being performed), *incident results* (what apparently happened to the dozer) and *operator impact* (how the operator was injured). These tables were based on the coding of the injury narratives by the authors.

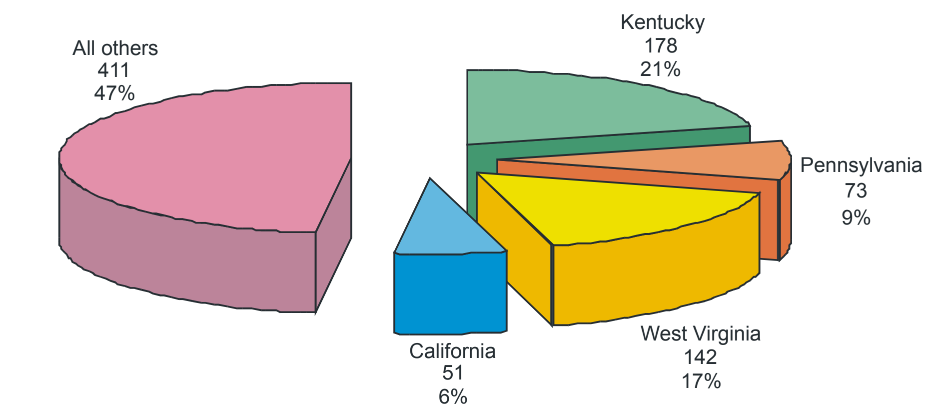

Figure 2.—While operating a dozer: lost-time injuries and percent by State.

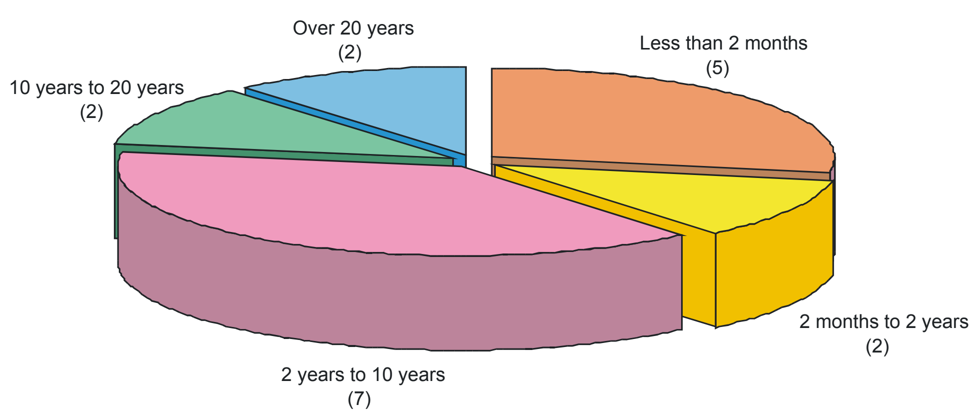

Figure 3.—While operating a dozer: number of fatalities by job experience.

Table 6.—While operating a dozer: lost-time injuries by job title and job experience

Job experience (years)	All job titles	Job title: dozer operator	% of 616	Job titles: other	% of 146
1 or less	111	85	14	26	18
1 to 2	51	37	6	14	10
2-3	69	55	9	14	9
3-4	38	34	5	4	3
4-5	57	39	6	18	12
More than 5	436	366	60	70	48
Subtotal	762	616	100	146	100
Unknown/missing	93	85	—	8	—
Total	855	701	—	154	—

Table 7.—While operating a dozer: serious injuries by dozer activity (fatalities in parentheses)

Dozer activity	Serious injuries	Percent
Blade/ground work	500 (9)	57
Tramming backward	266 (5)	30
Tramming forward	51 (3)	6
Land clearing	23 (1)	3
Ripping	18	2
Towing equipment	8	1
Pushing equipment	7	1
Other/unknown	0	0
Total	873 (18)	100

Table 8.—While operating a dozer: serious injuries by incident result (fatalities in parentheses)

Incident result	Serious injuries	Percent
Vertical jar	354	41
Normal operations (no apparent impact to the dozer)	212	24
Fall over edge/roll over/hidden void	116 (14)	12
Lateral jar/collision	69 (1)	8
Dozer struck by an object	56	6
Lateral jar/dozer lurched forward or backward	28	3
Equipment failure	29	3
Fire (external)	2	<1
Other	3 [1](3)	<1
Unknown	4	<1
Total	873 (18)	100

[1]Incidents involved a dozer operator run over by the machine he was using.

Table 9.—While operating a dozer: serious injuries and lost workdays by operator impact (fatalities in parentheses)

Operator impact	Serious injuries	Percent	Days lost	Average days lost[1]
Jolted/jarred	436	50	17,630	40.4
Jolted/jarred - struck against	142	16	5,388	37.9
Jolted/jarred - landed outside cab	26 (7)	3	906	47.7
Musculoskeletal injury (MSI)	155	18	5,656	36.5
Struck by object	78	9	1,733	22.2
Burned/contact with a hot object	10 (1)	1	324	36
Asphyxiated	4 (4)	<1	—	—
Drowned	3 (3)	<1	—	—
Crushed/run over by dozer	3 (3)	<1	—	—
Other	16	2	249	15.6
Total	873 (18)	100	31,886	—

[1]For the 855 lost-time injuries.

For activity (table 7), blade/groundwork was the most common. This activity was unique to the other choices as it was also the default value. Many narratives only indicated that the employee was injured *while operating the dozer*. Thus, we coded these injuries as blade/groundwork. Other narratives were more specific. Thus, for dozer activities other than "blade/groundwork", one can surmise that in *at least* 266 cases, the dozer was backing up, or in *at least* 23 incidents, land was being cleared, etc.

Table 8 summarizes the results of the incidents. For 24% of the incidents, we coded those incidents as "normal operations" with *no* apparent impact to the dozer. For the rest (76%) of the incidents, there was some impact to the dozer that resulted in a lost-time injury to the operator. This could be through vertical or lateral jarring (52% of the cases), falling off an edge or rollover (13%), the dozer being struck by an object (6%), or equipment failure (3%). Of note, in 12% of the cases (14 out of 116 incidents) where the dozer rolled or fell off an edge or into a hidden void, the victim died.

Table 9 summarizes the categories chosen for describing the impact to the dozer operator. These choices reflect functional categories chosen by the authors. Categories related to jolts and jars account for 69% of the serious injuries. Of note, where an operator was jolted or jarred and landed outside of the cab (either by jumping or being thrown out), 7 of 26 (27%) sustained fatal injuries. In 142 cases (16%), the operator was jolted to a degree that he or she struck something (inside the cab).

Figure 4 presents the trend for the lost-time injury data by operator impact. It groups the data into two broad categories: (1) musculoskeletal injuries (MSI) and (2) injuries due to jolting and jarring. The jolting and jarring injuries included (a) fallover/rollover, (b) jolted/jarred, and (c) jolted/jarred - struck against. For the lost-time injuries, there was a fairly consistent reduction from 1993 to 1997 in the annual tally of incidents resulting from jolts and jars. The remaining categories of operator impact (struck by, burns, and others) were too few to show a trend.

Table 10 presents a cross tabulation of *activity* and *incident results*. In total, vertical jars accounted for 354 injuries, about 40% of the injury set. In over one-half (185) of the injuries resulting from a vertical jar, the dozer operator was backing up. (*Italicized* sentences that follow in this section are examples of actual narratives from the MSHA Form 7000-1.)

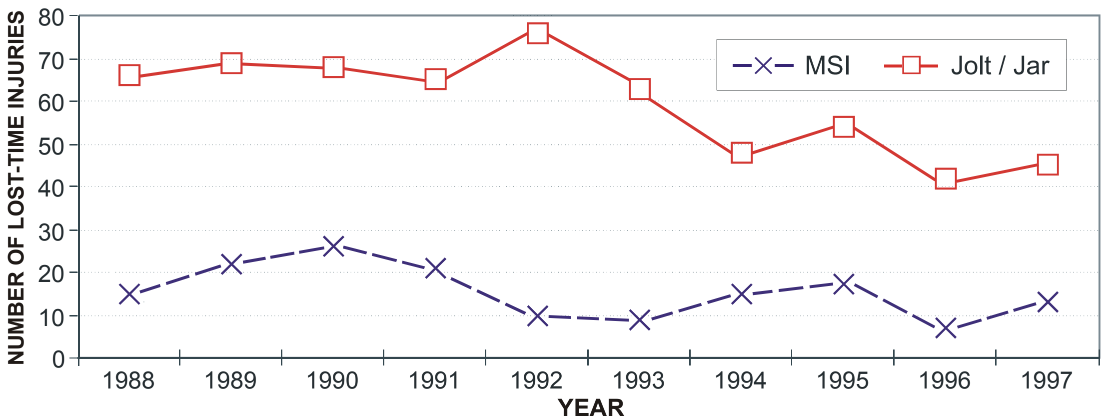

Figure 4.—While operating a dozer: jolting/jarring and musculoskeletal lost-time injuries by year.

Table 10.—Serious incident results by dozer activity (fatalities in parentheses)

Incident result	Dozer activity						
	Blade/ground-work	Tramming forward	Tramming backward	Land clearing	Ripping	Towing/ pushing	Total
Fallover/rollover/fall into void	66 (7)	13 (3)	30 (3)	4 (1)	1	2	116 (14)
Vertical jar	127	27	185	1	11	3	354
Lateral jar (collision)	37 (1)	3	27	1	1	0	69 (1)
Lateral jar (lurch forward/ backward)	16	4	3	1	0	4	28
Fire (external source)	2	0	0	0	0	0	2
Normal operations (no apparent impact to the dozer)	185	4	14	1	5	3	212
Dozer struck by an object	37	0	2	14	0	3	56
Equipment failure	26	0	3	0	0	0	29
Unknown/other	4 (1)	0	2 (2)	1	0	0	7 (3)
Total	500 (9)	51 (3)	266 (5)	23 (1)	18	15	873 (18)

Operator was backing a bulldozer over rough terrain and was severely jolted, causing muscle spasms in the lower back.

Victim was backing up dozer when it dropped off into hole, causing jar.

When a dozer fell over or rolled over an edge, backing up was involved in 25% of the cases. Backing up was also involved in about 40% of the cases involving a collision.

In 102 cases, the dozer operator survived a rollover or falling off/rolling off an edge. About 4,800 days of lost-time resulted from these incidents.

Employee was operating a dozer cleaning a bench. He backed dozer too close to edge. Dozer rolled off bench and dropped 20 ft and landed on its top.

Injured was blading a road on the highwall bench. He was pushing dirt out to the edge in order to build a berm. He apparently ran his tracks too far off the edge. The dozer tumbled off the edge and free fell approximately 30 ft.

Tramming dozer, dozer slid on frozen ground. Went over highwall, dozer fell about 30 ft, and then rolled over. Rollover structure and seatbelt held; however, the employee apparently struck his face and fractured left cheekbone.

Of these 102 incidents, a seatbelt was mentioned in 11 of the narratives. Nine involved operators wearing a seatbelt. Six of these workers lost 7 days or less because of the incident. The other three lost a sizable amount of time, from 84 to 238 days. In two cases involving a dozer falling over or rolling over, the narrative mentioned that the seatbelt was *not* worn. These incidents resulted in lost time of 20 and 25 days, respectively. In one incident, the dozer fell off of a 5- to 6-ft lift; the other incident was a rollover.

Lateral jars of the dozer were identified in 97 of the incidents. A sudden stop (collision) occurred in 69 cases, and the dozer pitched forward or backward in 28 cases.

Employee was operating dozer. He was pushing overburden to high lift. The dozer slid from right to left, then stopped suddenly. When the dozer slid right to left, and then stopped suddenly, it caused a jerk to employee's neck.

Employee stated that when he was backing up on the dozer, he struck a large rock. The jolt caused the transmission to shift to the next higher gear, causing him to strain his neck when the dozer accelerated.

He was operating a dozer when the dozer slid on a rock, causing him to be jarred.

An object such as a rockslide struck the dozer in 56 incidents.

Cutting drill bench and cleaning wall, wall fell on dozer. Employee jumped to the other side of dozer and bruised shin.

Employee was dozing out a ramp on a bench with a dozer he got in close to a previous cut, and a large rock came out of the bank onto the track, causing the dozer to rock back and forth, jerking and straining his neck.

Table 11 summarizes the injury records by "incident result" and "operator impact." The table shows that the dozer operator was jolted or jarred in a large majority of cases. These are cases where (1) the operator landed outside of the cab (26 cases), (2) the operator was jolted or jarred and struck against an object inside the cab (142 cases), or (3) the incidents were classified as a "jolt/jar" (436 cases). Together they account for almost 70% of the serious injuries and about 75% of the lost workdays.

In 78 cases, the operator was *struck by* something that resulted in the injury. In 33 cases, something (e.g., rockslide,

Table 11.—Serious incident results by operator impact (fatalities in parentheses)

Incident result	Operator impact								
	Jolted/ jarred	Landed outside of cab	Struck against an object inside cab	Struck by an object	MSI	Burned/ contact with hot object	Asphyxi- ation or drowning	Other/ unknown	Total
Fall over/roll over/fall into void	31	17 (7)	61	—	—	—	7 (7)	—	116 (14)
Vertical jar	306	3	45	—	—	—	—	—	354
Lateral jar (collision)	54	—	14	—	—	1 (1)	—	—	69 (1)
Lateral jar (lurch forward/ backward)	22	—	6	—	—	—	—	—	28
Fire (external source)	—	—	—	—	—	2	—	—	2
Normal operations	—	—	4	39	155	—	—	14	212
Dozer struck by an object	12	—	10	33	—	1	—	—	56
Equipment failure	9	4	2	6	—	6	—	2	29
Unknown/other	2	2	—	—	—	—	—	3 (3)	7 (3)
Total	436	26 (7)	142	78	155	10 (1)	7 (7)	19 (3)	873 (18)

tree limbs) struck the dozer and the object impacted the operator. In 39 of the struck-by cases, the "incident result" was coded as "normal operation." Many of these were instances where dust blew into the operator's eye. A few cases involved fumes entering the cab or the dozer running over a bee's nest.

An MSI was identified for 155 of the incidents. In all cases, there was no apparent impact to the dozer. These were incidents where the operator was injured during the course of the shift, but no specific information was offered (such as backing over a rock). In fact, for many of the incidents, the narrative specifically implied that it was not a singular event. Some of these incidents related to the operator twisting or turning in the seat, control usage, or general situations where the narrative implied a back injury due to dozer usage.

Too much strain on back from turning in seat to back up. Too many hours on dozer.

Injured claimed he was operating a dozer, ripping 2 ft of overburden from off of the Dorchester Seam. While ripping with the dozer, which caused a jerking motion and the operator turning in the seat to watch his ripper, he stated he strained his back.

The employee was operating a bulldozer performing backfilling operation. During normal operator procedures, employee was turning and twisting while operating dozer. Employee started to experience back pains and swelling of muscles in the lower back.

Equipment failure was identified in 29 cases. Hydraulic hoses and seats breaking were predominant in this small set of incidents. In a few cases, a fire erupted with the rupturing of the hydraulic lines near the exhaust manifold or engine. In the few cases involving a fire, the operator jumped from the cab.

Employee states he was digging a large rock out of the cast area with the left corner bit of the dozer. While doing this, the right tilt cylinder end broke on the blade ram. The dozer suddenly dropped down, shaking the employee up, causing pain in his lower back.

The hydraulic line blew off fitting, resulting in an oil vapor that hit the turbo charger that flashed, causing a flash burn to operator's forearm.

Table 12 summarizes seatbelt usage for all cases involving jolts and jars. There was seatbelt information on 25 lost-time cases and all 7 of the fatalities where the operator landed outside of the cab. For the fatalities, there were three instances that involved dozers manufactured before the date requiring rollover protection systems (ROPS) and seatbelts, three where the seatbelt was not worn, and one where it seemed to the investigators that the seatbelt may have torn in the accident. For the lost-time cases, there were 604 cases of jolting and jarring.

Table 13 summarizes the contributing factors that we were able to identify from the lost-time injury narratives. Appendix B provides a more detailed analysis of possible contributing factors to the fatalities. Table 13 shows that contributing factors could not be identified for 84% (733) of the cases. This is not unusual or unexpected; injury narratives are rather short descriptors. In cases where the dozer fell over an edge, edge failure was mentioned 14 times and the dozer sliding was mentioned in 13 cases. The dozer sliding was also mentioned in several cases involving lateral and vertical jolts and jars. In cases where the dozer was struck by an object, a rockslide was mentioned in 21 of the incidents. Mechanical/hydraulic failure was mentioned in 39 instances. Over 50% of these cases involved the operator being jolted/jarred or struck by.

Table 14 summarizes information relative to operator impact, part of the body injured, and workdays lost. This table shows that injuries to the back, neck, and the classification of "multiple body parts" were identified most often as the body part injured in the MSHA database. Together, these three groups accounted for 83% (25,960 days) of the days lost. This is not surprising due to the nature of the injuries within this data set (jolts/jars, struck against, struck by, and MSIs).

Table 12.—Jolting and jarring injuries and seatbelt usage (fatalities in parentheses)

Operator impact	Serious injuries	Percent	Seatbelt		No information
			Worn	Not worn	
Jolted/jarred	436	50	12	3	421
Jolted/jarred - struck against	142	16	8	2	132
Jolted/jarred - landed outside cab	26 [1](7)	3	[2](1)	(3)	19
Total - jolting and jarring	604 (7)	69	—	—	—
All other injuries	269 (11)	31	—	—	—
Total	873 (18)	100	21	8	572

[1]Three fatalities involved dozers manufactured prior to the requirement for ROPS.
[2]Investigative report suggested that the belt may have torn in the accident.

Table 13.—Lost-time incident results by contributing factors

Contributing factors	Fall over/ rollover	Vertical and lateral jar	Dozer struck by an object	Other/ unknown	Total
Edge failure	14	0	0	0	14
Mechanical/hydraulic failure	3	10	0	26	39
Hidden void	4	1	0	0	5
Dozer slid	13	23	1	1	38
Rock slide	1	0	21	0	22
Other	2	—	2	0	4
Total	37	34	24	27	122
Unknown	65	416	32	220	733

Table 14.—Lost-time injuries by operator impact and part of body injured

Body part injured	Operator impact							
	Jolted/ jarred	Landed outside of cab	Struck against an object	Struck by an object	MSI	Burned/ contact with hot object	Other/ unknown	Total
Head	2	1	22	11	—	—	—	36
Eyes	—	—	—	30	—	1	2	33
Back	272	—	21	3	99	—	1	396
Neck	71	—	6	—	13	—	—	90
Multiple parts	56	11	44	12	11	4	1	139
Trunk, shoulders, upper extremities, chest, hips, abdomen	27	3	27	4	17	1	5	84
All other	8	4	22	18	15	3	7	77
Total	436	19	142	78	155	9	16	855

DISCUSSION

From 1993 to 1997, there was a notable reduction (30%) in the number of serious injuries to dozer operators while performing common production tasks compared to those in the baseline period (1988-92). Specifically, there are fewer injuries and workdays lost due to lateral and vertical jolts, MSIs, struck by, struck against, and falling off an edge. It is difficult to name the specific reasons for this improvement. It is likely a combination of factors involving *technology* (e.g., better seating and seat suspension systems), *people* (e.g., more frequent use of restraint systems, *higher skill levels* in recognizing and responding to difficult dozing conditions), and the *work environment* (e.g., better ways to organize the work, better training and awareness, more consistent work procedures and practices tailored to the job conditions). The work (e.g., roadway, ramp and berm construction) accomplished by dozer operators is essential in that it helps to enhance efficiency *and* reduce injury risk for other parts of the mining plan.

It is noteworthy that, although this study only examined serious injuries to dozer operators while performing common production tasks, injuries sustained while mounting and dismounting the dozer (table 1) *are almost equal in number and severity* to the injury set examined in this report.

INJURIES RELATED TO JOLTS AND JARS

Vertical and lateral jolting and jarring (including those where the operator strikes an object inside the cab) are the most common sources of injury to dozer operators while they are operating the equipment. Although the incidents have declined over the period examined, this area is still the most opportune to achieve further reductions in injury risk. A total of 597 injuries resulting in 23,924 lost workdays were due to jolts and jars. These were all acute incidents where the operator was impacted in any one of three ways: the operator (1) was jolted/jarred and remained in the seat, (2) was thrown against an object inside the cab, or (3) landed outside of the cab. This accounts for nearly 70% of the lost-time injuries and 75% of the workdays lost.

These findings are similar to another recent study that identified jolts and jars as a significant concern to equipment operators. Cross and Walters [1994] examined vibration and jarring as a source of back pain in the mining industry in New South Wales, Australia. Their study involved the review of 28,306 compensation claims over a 4-year period (July 1986 to March 1990) and covered both surface and underground environments. They identified 8,961 claims relating to the head, back, and neck, of which 11% (986) were due to vehicular jarring. Underground transporters and shuttle cars accounted for 53% of all vehicular jarring injuries. Surface loaders, dozers, and dump trucks accounted for another 29% of the vehicular jarring injuries.

Regardless of the source, all jolts and jars seem to come as a complete surprise to the operator. The rough and variable conditions present significant challenges to research and engineering personnel to develop and test methods to protect the operator.

Backing up the dozer was associated with many of the jolting and jarring injuries. For 185 of the 357 vertical jarring incidents (table 10) the dozer was backing up. Backing up is an activity that most would like to minimize, both in terms of distance and time. Dozer operators may tend to maximize their output (material moved) by minimizing their necessary, but unproductive time in backing. Higher tram speeds (generally about 5 miles per hour maximum for track dozers) in backing up may introduce risk by exacerbating the effects of small rises or rocks and provide a low margin of error in perception, judgment, and corrective action (slowing down). If operators recognized the hazard, the response might be direct and more reliable—slow down and maneuver the dozer through or around the obstacle.

Body posture also plays a role. Griffin [1990] and Bottoms and Barber [1978] suggest that poor body posture partially contributes to disorders among agricultural tractor operators. Twisting and turning in the seat (to look behind) is likely to contribute to the frequency and severity of these incidents as it increases the risk of a back injury due to the uneven distribution of the vibrating and shock forces on the spine. Bottoms and Barber [1978], in their study of agricultural tractor injuries, suggest that a swivel seat might be appropriate to minimize the awkward postures that can increase the impact of vibration and shock to the back.

High-energy, short-duration jolts and jars may also prematurely wear certain components of the dozer. Undercarriage, track maintenance, wear items, and repair costs are estimated at about $27 per hour [Hays 1990]. High-speed backing also accelerates wear.

Strategies to reduce the effect of vehicular jarring include seating (methods to dampen the shock or isolate the operator from the shock) and use of operator restraint devices. For the 855 lost-time injuries, only 25 of the injury narratives provided information on whether or not the seatbelt was in use at the time of the incident. Of those cases, 20 indicated that the seatbelt was worn.

It is difficult to conclude much from these data except that seatbelt usage was only *mentioned* in a small percentage of the cases. Table 11 shows that there were many cases where the operator was jolted and struck against an object (inside the cab) and a few cases where the operator landed outside of the cab. We did *not* infer that the seatbelt was not being used. Where the operators landed outside of the cab, they either jumped or were thrown. Operators who were jolted and struck an object inside the cab may have been within the zone of protection, even with a seatbelt on. In many cases, one might reasonably surmise from the narratives that the seatbelt was not worn. However, we only noted seatbelt usage when specifically mentioned in the narrative. At the same time, table 14 suggests that the substantial injuries to various parts of the body might have been reduced by more consistent use of restraint devices.

For off-highway equipment used in mining, the need to protect the operator via operator restraint devices and protection from rollover has been established for some time [Oitto and McLellan 1975]. Although seatbelts have been required by regulation for some time, there seems to be much variability in their use among dozer operators. The reasons for this variability might be further investigated.

Carlson and Hoffman [1981] conducted a series of field studies of improved seatbelt restraint systems involving retractable sheath designs and automatic and manual locking features. The purpose was to design a restraint system that would enhance comfort, fit, and convenience. Their previous investigations found that the designs of conventional restraint systems contributed to limited use among equipment operators. A vehicle-sensitive retractor design was chosen, similar to the automotive mechanisms. The off-highway equipment systems were set to operate at 0.75 g, which is higher than what was common with automotive designs. Their new seatbelt design was a combination of commercially available retracting systems, inertial-type locking mechanisms, and webbing material. The new designs were field tested at mining sites. Results showed better acceptance by equipment operators compared to the conventional restraint system design.

The importance of integrating a restraint system with appropriate seat and seat suspension designs was suggested by Appel et al. [1984]. They report on the laboratory testing of seatbelts, stating that early applications of seat restraints to off-road equipment were similar in design to those used for highway applications (and frontal crashes). Their work proved the designs to be less than effective for lateral impact forces (such as those involved in a rollover). They also found that the harness belt gave lateral protection, but was cumbersome and restricted the operator. Appel et al. thought that a lap belt with lateral shoulder supports would offer a good balance in protection and usability that would go well beyond the conventional lap belts. They also noted that the lack of a shock-absorbing seat was the weakest link in the restraint system.

Seat designs for surface off-highway equipment have improved greatly with features such as mechanical and pneumatic suspension systems, lumbar spine support, and viscoelastic foam padding. Assessing their usability and performance under different shock and vibration test conditions might offer useful information on ways to better secure the worker since many jolts and jars are not predictable. Some researchers [Gouw et al. 1990] have developed computer simulation models to help designers select seat suspension parameters. This research area seems to have some potential in testing certain seating (performance) characteristics before field application.

There has been much study of the potential health effects of WBV among groups of workers operating off-highway equipment such as agricultural tractors and surface mining/construction equipment [Griffin 1990; Remington et al. 1983]. Although much of the literature is indirectly relevant, one study is pertinent.

Robinson et al. [1997] gathered WBV data on 11 mining vehicles, 3 of which included dozers. They profiled vehicles and made recommendations that could help with a planned reintegration of workers who experienced a back injury into jobs at the mine site. Their goal was to reduce the likelihood of reinjury (due to the cumulative effects of vibration and repeated shocks) by not placing these workers into a vibration- or shock-prone environment. Results showed that vibration levels varied considerably across the vehicles tested. Newer equipment tended to fare better. However, a severe mechanical shock level (measured by the maximum crest factor) was recorded for *all* production vehicles[5] monitored. This suggests that severe mechanical shock can occur in any mine vehicle, and ground conditions have a significant role. Vehicle speed was not reported in this study.

Gagliardi and Utt [1993] collaborated with a mining firm to assess the characteristics for mechanical and air suspension seats, as well as various seat cushions. All tests were performed in a laboratory. Information obtained offered guidance with respect to the use (e.g., setting adjustments) of both types of suspension systems and the performance of a variety of seat density cushions. The tests applied mostly to vibration damping versus damping the effects of high-energy shocks. Thus, the results are more in line with parameters to counter fatigue-decreased proficiency (ISO 2631) as opposed to acute, high-impact jolts.

It is not certain how many dozer operators who were injured by jolts and jars are able to return to the dozer to do the same tasks once they return to work. One could reasonably surmise from the injury data that those operators sustaining injuries that require them to be off work for extended weeks may not perform at the same level once they return to the worksite. On average, 37 days were lost for all dozer operator injuries reported to MSHA and examined in this set. The median was 19 days. On one end of the distribution, 25% of the incidents resulted in 4 days or less of lost work time. On the other end, 25% of the incidents resulted in a loss of 45 to 485 days.

MUSCULOSKELETAL INJURIES

MSIs accounted for the next largest category that appeared in the database. Overall, they accounted for 155 incidents (table 11). All of these injuries were in situations where nothing external to the dozer contributed to the incident. Many of these did not seem to result from a single source. Many related to awkward postures, tiring work, and difficult dozing conditions. These injuries are often reported as having occurred during the shift, but there was not a lot of detail surrounding these incidents. Most involved back pain.

Zimmermann et al. [1997] reviewed the literature on work-related musculoskeletal disorders (MSDs) and WBV among off-highway equipment operators. One study referenced by Zimmermann et al. (Miyashita et al. [1992]) examined work-related disorders for dozer operators. Common ailments among the 127 dozer operator participants included reports of low back pain (36.2%), general fatigue (44.1%), and stiff shoulders (54.3%). Zimmerman et al. note that the frequency range in which WBV is most problematic is 4 to 8 Hz. They concluded that the high risk of MSD among equipment operators might be caused by a combination of the sustained and awkward sitting postures and the vibrating environments in which off-highway equipment operators work. Based on their literature review, they gave general suggestions regarding cab and control designs, minimizing vibration exposures, and regular work breaks among off-highway equipment operators.

The risk of injury due to twisting and turning in the seat is a problem. If one accepts that jolts are unexpected, then one solution is for the dozer operators to recognize terrain conditions that are likely to produce high levels of shock. Once identified, the path is to slow down or carefully maneuver to avoid the dip, rock, or other uneven ground. Backing up is a common and necessary task. If operators are twisting to look behind as they back up, then it could expose them to injury due to the effect of lower level vibrations and shock. By twisting and looking behind, their purpose is to avoid the larger hazards (jolts). If they do not look behind (in order to maintain a good body posture), then they become more susceptible to the risk of larger shocks (jolts and jars) due to unseen undulations or obstacles.

TRAINING

Hazard recognition and response skills seem to be an integral part of safe and efficient dozer operation. Figure 3 shows that five of the dozer operator fatalities had 2 months or less of experience on the dozer. For lost-time injuries (tables 6 and C-6), dozer operators with less than 1 year of experience are involved in a sizable number of lost workday incidents. Almost 15% of the lost-time injuries were incurred by operators who worked less than 1 year in the job classification. For fallover and rollover incidents, job experience data were available for 93 incidents. Fourteen of these incidents occurred to those with less than 1 year of experience. By contrast, injury victims with 1-5 years of experience in their job classification were involved in 16 out of 93 fallover, rollover lost-time incidents.

Of 116 incidents where the dozer fell over an edge, rolled over, or fell into a hidden void, 14 (12%) resulted in fatal injuries. Overall, 80% of the fatalities and 12% of the lost-time injuries occurred while working near an edge or hidden void or on a steep slope. Thus, the hazards of working near an edge or on a steep slope is especially evident from the analysis of the lost-time and fatality data. Part of the training task is to teach hazard recognition and response skills, especially in areas that can likely result in serious injury or economic loss.

It makes good economic sense to invest in training when an employee is assigned to a job that involves sizable risk, capital, and significant hourly costs in fuel, repair, and maintenance. For dozers, this investment can total well over $100 per hour. The operator's wages are a small percentage of the total hourly

[5]For three dozers in the sample, crest factors (max-along the z, or vertical axis) of 12.4, 14.8, and 24 were measured.

investment. This offers an obvious opportunity to invest in skills, as many recognize that dozer operator performance can have a sizable impact on the return on the technology investment. Provisions to formally teach and evaluate (integrating safety with efficiency) skills are common within many organizations. Many use experienced dozer operators who have been taught how to teach and evaluate skills.

Skill in operating a dozer does not come quickly or easily. Blade control takes time. The more sophisticated the dozer control systems, the greater the need to ensure that there is a good and reasonable fit between the operator and the technology. Judgment and decision-making are always important in day-to-day operation of off-highway equipment. It would seem to be of even greater importance as the value of the investment increases. Training can serve to enhance the fit between the technology and how it is used at the job site. *Hazard recognition and response skills* seem to be an indispensable component of safe and efficient dozer operation. Many of the incidents affected both the dozer and the operator. Hazards can be subtle and hidden. Each of the serious injuries in the data set resulted in a significant social and economic cost.

RELEVANT NIOSH RESEARCH

NIOSH is currently conducting collaborative work to help reduce the effects of shock and vibration. This work is framed within a series of research experiments [Biggs and Miller 1999] to characterize jolting and jarring on surface mine haulage trucks. Biggs and Miller describe the use of a global positioning system in conjunction with truck-mounted accelerometers as a tool for profiling mine site locations that are associated with jolts in excess of 2 g. The experimental system could be useful to map locations *where* workers are most likely to be exposed to jolting and jarring hazards. The mapping and acceleration measurements are monitored in real time.

CONCLUSIONS

Risk is part and parcel of everyday worklife. The purpose of this study is to examine injury experience to dozer operators while performing common production tasks. Our goal is to organize information to help understand risk and what might be done to further reduce the risk of serious injury. We suggest that the factors that reduce risk are also the ones that increase risk. They involve technology, people, and the work environment.

Although this study suggests a sizable reduction in injury risk from 1993 to 1997, one should keep in mind that the odds of a fatal injury are quite high if a dozer is involved in a rollover or falling over an edge. In 12% (14 out of 116 incidents) of the incidents involving a rollover or a dozer falling over an edge, the operator died. Not wearing seatbelts (or older equipment without a ROPS or seatbelt) contributed to six of the fatalities. In cases where the dozer operator either jumped or was thrown out of the cab, 7 of 26 were killed.

Vertical and lateral jolting and jarring is the most common source of injury to dozer operators while they are operating the equipment. Although the incidents have declined over the period examined, this still seems to be the most opportune area for further decreases in injury risk. MSIs are also an area where further progress could be made with regard to reducing the frequency and severity of incidents resulting from everyday usage of dozers.

Seating, seat suspension systems, and operator restraint devices are critical tools that can enhance safety and efficiency. The effects of shock and vibration are complex, and there are no simple ways to measure, lessen, or neutralize their effects. The very unique and often uncertain conditions that dozers work can make interfacing the technology with the operator difficult.

Incremental improvements in designing and field testing innovative seating, seat suspension, and operator restraint technologies offer good opportunities to further reduce the risk of serious injury. For some dozer tasks, isolating the operator via remote operation might also be a promising option [Singh 1997]. Lastly, continued emphasis on hazard recognition of edge, hidden voids, and difficult ground conditions could reduce the number of surprises and allow for corrective action. All potential solutions have components of technology, people, and the work environment. The relative merits of any solution should be accurately described in field tests.

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APPENDIX A.—INJURY RECORD SELECTION AND CODING

RECORD SELECTION

MSHA injury data for 1988-97 were analyzed based on the decision rules listed in table A-1. Selecting on "mining machine ' bulldozer" yielded 2,962 records. The mine worker activity criteria were used to select those records that *primarily* involved "operating the dozer." Other selection criteria (e.g., escaping a hazard) were used to capture relevant records that may have been coded differently, but still involved an injury to a miner while performing common production tasks with the dozer.

The set of 960 injury records included 17 fatalities. We reviewed the narratives of all 23 fatals involving dozers for 1988-97. This review yielded one additional record that is included in the data set. Upon reviewing the set of 960 records, the authors selected 873 that met these criteria: (1) the injuries occurred while the worker was operating a dozer and (2) the worker was injured to the degree where work time was lost.

Table A-1.—Criteria for the selection of injury records

Target data	MSHA data field	Selection criteria	No. of records
Surface Mining Serious Injuries	Subunit	Surface OR Underground OR Strip OR Auger OR Culm Bank OR Dredge OR Other Surface OR Preparation Plant	79,601
	Degree of Injury	Death OR Permanent Disability OR Days away from Work Only OR Days Away and Restricted Activity	
Surface Mining Injuries Involving Bulldozers	Mining Machine	Bulldozer	2,962
Surface Mining Dozer Serious Injuries	Mine Worker Activity	Escaping a Hazard OR Bulldozer OR Front-end Loader OR Haulage Truck OR Surface Equipment NEC (not elsewhere classified)	960
Surface Mining Dozer Serious Injuries	Narrative	Author Selection	873

CODING OF THE RECORDS

Table A-2 specifies the variables and categories used to code the injury narratives.

Table A-2.—Author-defined variables and categories added to the injury set

Variable	Description of categories
Activity	Blade/groundwork (default value if narrative vague)
	Tramming forward
	Tramming backward
	Ripping
	Land clearing
	Towing
	Pushing equipment
	Other
Incident result (dozer impact)	Fallover/rollover/fall into void
	Lateral jar (collision)
	Lateral jar (lurch forward/backward)
	Dozer struck by an object
	Vertical jar
	Equipment failure
	Fire - external source
	Normal operations (no apparent impact to the dozer)
	Other
	Unknown
Operator impact	Jolted/jarred
	Jolted/jarred (landed outside of cab)
	Jolted/jarred (struck against an object inside cab)
	Struck by an object
	Burned/contact with a hot object
	Asphyxiation
	Drowned
	Musculoskeletal injury (MSI) - operator hurt while twisting and turning, reaching too far, pulling or pushing on something, (often cannot be tied to a singular source/event)
	Other
	Unknown
Contributing factors to the event	Edge failure
	Hidden void
	Equipment failure
	Dozer slid
	Rock slide
	Other
	Unknown
Contributing factors to the severity	Operator jumped out of cab
	Operator thrown out of cab
	Operator either jumped from or thrown out of cab
	Seatbelt worn
	Seatbelt not worn
	Other
	Unknown

APPENDIX B.—ANALYSIS OF FATALITY REPORTS (1988-97)

This analysis of the 18 dozer fatalities during 1988-97 is obtained from the review of MSHA investigative reports supplemented by information from the MSHA Form 7000-1 filed by the mine operator or independent contractor. Included in this analysis are variables/fields added to the fatality database that are in addition to those variables referred to in table A-1. The depth of information contained in the fatality reports allowed for supplemental analysis.

The mines where these fatalities occurred ranged in size from 2 to 1,400 employees. Seven of the fatalities were at mines employing 25 or fewer miners. Of note, 5 of these occurred in a single year—1993. Six fatalities occurred at mines employing more than 100 workers. The rest (5) occurred at mines ranging in size from 26 to 100 employees. For 11 of the 18 fatalities, MSHA noted the "last quarter" frequency rate at the mine site compared to an average rate for similar mines. In 8 of the 11 cases, the mines where the fatalities occurred had an injury rate (for the past quarter) that was *below* the industry average.

Although most of the lost-time injuries were concentrated within 4 States (see figure 2), the fatalities were spread across 13 States. However, by industry sector, bituminous coal mines had the highest number (10) of dozer fatalities, followed by sand and gravel (4); stone and metal mines each had 2.

Witnesses to the accidents were present in one-half of the 18 cases. The other half were discovered anywhere from within a few minutes to several hours after the incident.

AGE AND EXPERIENCE

All victims were male between the ages of 21 and 70. The median age was 43. Experience in the task ranged from only a few days to over 40 years. Five of the victims had less than 2 months of experience on the dozer. Three of these five were on the job for less than a week. Another two had 1-2 years of experience. The rest (11) had from 3 to 40 years of experience. Of the seven victims that had less than 2 years of experience, five fell over an edge or into a void. The other two were run over by the dozer they were operating. Four victims had more than 10 years of experience. In all of these cases, the dozer fell over an edge; three of the victims landed outside of the compartment, and one victim drowned. No witnesses were present at these four incidents.

INCIDENT RESULT

Falling over an edge.—In 11 cases, the dozer fell over an edge. In seven of these cases, the operators were found outside of the cab; they either had jumped or were thrown out. In one of these seven cases, the fatality report indicated that the operator tried to jump clear of the machine as it was falling. In three cases, the cause of death was drowning. In one case, the dozer fell over an edge and loosened material covered the machine.

A seatbelt was not available in the dozer in three of these incidents (the machine had been manufactured before the requirements for ROPS and seatbelts[1]). In three other cases, it was noted that the seatbelts were not worn. In one of these cases, the investigators indicated that the operator had removed his belt. In another case, it seemed to the investigators that the belt was being worn, but had torn due to the nature of the incident.

Edge failure was a factor in four incidents. Working near bodies of water was implicated in two other cases (one case was at dusk, the other involved pushing material at the edge of a frozen pond). In two cases, the investigators noted that the operators lost control of the dozer as they were working near an embankment or elevated road.

Falling into a hidden void.—There were three incidents where the dozer fell over an edge into a hidden void. In all cases, the void was hidden (bridged). In one other case (noted above), the dozer fell (backed) over the edge of an open draw hole and the loosened material engulfed the machine. In all cases, suffocation was noted as the cause of death. In each case, the stockpile was the work area, and these operators were working in an active area. Rescue attempts were made right away (once the incident was discovered) by mine personnel to dig the operators out of the material. In two cases, the feeders were turned on to see if the dozer could be more quickly uncovered versus the time-consuming process of digging out the equipment from the outside edges or crest of the stockpile/ loosened material. Both of these cases failed, and digging operations continued from the periphery. Rescue operations took from 2 to over 10 hr. The fatality investigation found that in all of four cases, the windows of the equipment were pushed in or broken by the material that engulfed the dozer cab. One entrapped operator was in voice contact with rescuers for about 8 hr. In two cases, the operators had 2 months or less of task experience.

Unmanned dozer.—Three dozer operators were run over by their own dozer. No witnesses were present at any of these incidents. Investigators concluded that these operators had attempted to exit or enter their machine either while the dozers were in gear, or the dozers jumped into gear, or the controls

[1]ROPS and seatbelts are not required on dozers manufactured before July 1, 1969. See 30 CFR 56.14130 and 30 CFR 77.403(a), “Roll-over protective structures (ROPS) and seat belts.”

were accidentally activated. Failure to take the machine out of gear and set the parking brake was mentioned in two of the reports. One of these operators had 2 days of experience; the other two had 1.5 and 9.9 years of dozer experience, respectively.

Collision.—In one case, the dozer hit a (buried) natural gas line, and the operator was killed by the ensuing fire.

Time of the incidents and time into work shift.—With regard to when these incidents occurred, we summarized both the "time" and "time into shift." Twelve incidents occurred between 8:00 a.m. and 4:00 p.m. Four were between 4:00 p.m. and 7:30 p.m. The remaining two were between midnight and 8:00 a.m. The large majority of incidents (15) occurred within 8 hr of beginning work. One incident was slightly over 10 hr into the shift, and one case was estimated at 5-10 hr into the shift. For the remaining case, there was no information in the investigation report that allowed us to calculate a value for the "time into shift."

Dozer year of manufacture.—In eight of the incidents, the age of the equipment was mentioned in the fatality reports. The year of manufacture ranged from 1936 to 1991. Three were manufactured before the requirement (July 1, 1969) for ROPS and seatbelts. In these three incidents, the dozer fell over an edge and the operator landed outside of the cab. Seatbelts were not available to the operator in these cases. The age of the dozer was not directly available in the investigative report for 10 of the incidents.

30 CFR violations/citations issued.—Based on the results of four of the investigations, no violations were found by MSHA. However, for the other 14 investigations, violations of the following regulations were identified: 30 CFR 48.27, 50.10, 56.14100, 56.14101, 56.14130, 56.16002, 56.3401, 59.9101, 56.9303, 77.1000, 77.1606, 77.1607, 77.1710, 77.1713, and 77.410. The general areas noted include seatbelt usage, machine defects (e.g., brakes), aspects related to mine design (e.g., ramps, bins, and hoppers), training, failure to notify MSHA, workplace inspections, and maintaining control of mobile equipment.

APPENDIX C.—SUPPLEMENTAL INJURY TABLES

Table C-1.—Lost-time injuries by subunit

Subunit	Lost-time injuries	Percent	Days lost	Percent
Surface or underground	25	3	1,243	4
Strip	728	85	26,833	84
Auger	2	<1	43	<1
Culm banks	11	1	461	1
Preparation plants	77	9	2,841	9
Dredges	11	1	458	1
Other surface	1	<1	7	<1
Total	855	100	31,886	100

Table C-2.—Dozer serious injuries by mine worker activity (fatalities in parentheses)

Mine worker activity	Serious injuries
Haulage truck	2
Escaping a hazard	7
Surface equipment NEC	6
Get on or off equipment	1 (1)
Bulldozer	855 (17)
Front-end loader	2
Total	873 (18)

Table C-3.—Lost-time injuries by job title

Job title	Lost-time injuries	Percent
Bulldozer/tractor operator	701	82
Crane operator/dragline	32	4
Laborer/utilityman	32	4
Truck driver	16	2
Highlift operator/end loader . . .	14	1
Other (20 other job titles)	50	6
Unknown	10	1
Total	855	100

Table C-4.—Serious injuries by State and year (fatalities in parentheses)

State or territory	Year										Total
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	
Alabama	2	5	3	2	1	1 (1)	2	1	3	—	20 (1)
Alaska	—	1	—	—	—	—	—	—	3	—	4
Arizona	2	2	1	2	2	1	1	1	—	—	12
Arkansas	1	—	1	—	1	—	—	—	—	—	3
California	6	7	10	8	6	3	3	5 (1)	2	2	52 (1)
Colorado	1	—	—	1	—	—	1	1	—	1	5
Florida	1	1	1	1	3	2	—	1	3	3	16
Georgia	1	1	2	—	—	—	—	—	—	—	4
Hawaii	—	—	3	—	2	2	1	—	—	1	9
Idaho	2	—	1	1	—	—	1	1	1	1	8
Illinois	6	5	6	7	5	1	—	3	—	1	34
Indiana	1	2	4 (1)	6	—	2	2	2	1	3	23 (1)
Iowa	—	—	—	2	—	2	—	1	—	—	5
Kansas	—	—	—	—	—	—	—	1	1	—	2
Kentucky	14	20	26	19	25	15	22 (1)	20 (1)	10	9	180 (1)
Louisiana	1	1	1	—	—	—	—	—	—	—	3
Maine	1	—	—	—	—	—	—	—	—	—	1
Maryland	—	—	—	—	—	—	—	—	—	1	1
Massachusetts	(1)	—	—	—	—	—	—	—	1	—	1 (1)
Michigan	3	5	3	2	1	7 (1)	—	2	—	5	26 (1)
Minnesota	—	5 (2)	2	2	—	5	1	1	1	1	18 (2)
Mississippi	1	—	—	—	1	—	1	—	—	—	3
Missouri	1	—	—	—	3	—	—	1	1	1	7
Montana	1	1	—	1	1	2	1	—	1	—	8
Nevada	6	4	4	6	3	1	2	2	1	5	34
New Jersey	—	—	—	1	—	2	—	—	—	1	4
New Mexico	2	3	1	2	2 (1)	2 (1)	—	2	1	—	15 (2)
New York	3	—	1	2	1	—	—	1 (1)	1	—	9 (1)
North Carolina	—	2	—	—	—	—	—	—	1	—	3
North Dakota	—	2	—	2	—	—	—	—	1	—	5
Ohio	4	3	5	2	7	2	3 (1)	1	1	—	28 (1)
Oklahoma	—	—	—	1	—	—	—	—	—	2	3
Oregon	—	—	—	—	1	2	—	—	1	—	4
Pennsylvania	9	6	11	10	8 (1)	8 (1)	7	8	4	4	75 (2)
Puerto Rico	—	1	1	—	—	—	—	—	1	1	4
South Carolina	—	1	—	—	—	—	—	—	—	—	1
South Dakota	1	—	1	—	—	1	1	1	—	—	5
Tennessee	2	2	2	3	1	—	—	—	—	—	10
Texas	4	3	1	2	2	1	2 (1)	2	1	2	20 (1)
Utah	—	1	—	—	—	—	2	—	—	1	4
Virginia	7	5	5	3	4	1	5	5	2	2	39
Washington	—	2	2	1	1	—	—	—	—	1	7
West Virginia	7	14	16	17 (1)	15	19 (1)	12	15	15	14	144 (2)
Wyoming	1	2	1	2	—	2	—	1	—	2	11
Total	92 (1)	107 (2)	115 (1)	108 (1)	96 (2)	84 (5)	70 (3)	79 (3)	58 (0)	64 (0)	873 (18)

Table C-5.—Lost-time injuries by State, industry sector, and lost workdays

State or territory	Industry sector: Anthracite coal	Bituminous coal	Sand and gravel	Stone	Nonmetal	Metal	Total incidents	Total days lost
Alabama	—	14	1	4	—	—	19	573
Alaska	—	1	—	—	—	3	4	42
Arizona	—	4	—	1	1	6	12	669
Arkansas	—	—	—	2	—	1	3	251
California	—	—	30	9	4	8	51	1,074
Colorado	—	2	2	1	—	—	5	44
Florida	—	—	1	7	8	—	16	744
Georgia	—	—	—	1	3	—	4	84
Hawaii	—	—	—	9	—	—	9	179
Idaho	—	—	1	—	6	1	8	242
Illinois	—	30	—	4	—	—	34	1,816
Indiana	—	21	1	—	—	—	22	949
Iowa	—	—	—	5	—	—	5	111
Kansas	—	—	—	2	—	—	2	8
Kentucky	—	174	—	4	—	—	178	7,541
Louisiana	—	1	2	—	—	—	3	14
Maine	—	—	1	—	—	—	1	124
Maryland	—	—	—	1	—	—	1	62
Massachusetts	—	—	—	1	—	—	1	45
Michigan	—	—	2	6	—	19	27	1,135
Minnesota	—	—	1	—	—	15	16	347
Mississippi	—	—	2	—	1	—	3	42
Missouri	—	5	—	2	—	—	7	149
Montana	—	3	2	—	—	3	8	258
Nevada	—	—	3	—	3	28	34	1,561
New Jersey	—	—	2	2	—	—	4	40
New Mexico	—	9	—	—	—	4	13	191
New York	—	—	1	6	1	—	8	300
North Carolina	—	—	2	1	—	—	3	51
North Dakota	—	5	—	—	—	—	5	27
Ohio	—	22	1	2	2	—	27	476
Oklahoma	—	2	—	1	—	—	3	28
Oregon	—	—	2	1	—	1	4	179
Pennsylvania	23	43	—	7	—	—	73	2,660
Puerto Rico	—	—	1	3	—	—	4	66
South Carolina	—	—	—	—	—	1	1	32
South Dakota	—	—	2	—	—	3	5	98
Tennessee	—	2	2	3	3	—	10	286
Texas	—	9	2	5	3	—	19	1,372
Utah	—	1	2	—	—	1	4	136
Virginia	—	32	2	5	—	—	39	1,374
Washington	—	5	2	—	—	—	7	141
West Virginia	—	141	—	1	—	—	142	6,087
Wyoming	—	7	2	1	1	—	11	278
Total	23	533	72	97	36	94	855	31,886

Table C-6.—Lost-time injuries by job experience and incident result

Job experience (years)	Incident result								
	Fall over/ rollover/ fall into void	Vertical jar	Lateral jar (collision)	Lateral jar (lurch forward/ backward)	Dozer struck by an object	Normal operations	Equip-ment failure	Other/ unknown	Total
<1	14	43	10	3	12	28	1	—	111
1-2	4	19	6	2	3	16	1	—	51
2-3	4	33	3	6	4	16	3	—	69
3-4	3	18	3	—	2	11	1	—	38
4-5	5	29	5	—	2	13	2	1	57
>5	63	172	40	14	29	97	17	4	436
Subtotal	93	314	67	25	52	181	25	5	762
Unknown	9	40	1	3	4	31	4	1	93
Total	102	354	68	28	56	212	29	6	855

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