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Effects of Mining Height on Injury Rates in U.S. Underground Nonlongwall Bituminous Coal Mines

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

ft	foot (feet)	in	inch(es)
hr	hour(s)	%	percent

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EFFECTS OF MINING HEIGHT ON INJURY RATES IN U.S. UNDERGROUND NONLONGWALL BITUMINOUS COAL MINES

By Barbara Fotta[1] and Launa G. Mallett, Ph.D.[2]

ABSTRACT

This report examines the effects of mining height on injury rates in U.S. underground nonlongwall bituminous coal mines, controlling for both the employment size of the mine and the mining methods. Using the mine-level employment and injury data reported to the Mine Safety and Health Administration, mines were stratified by average coal seam height (<43 in, 43-60 in, and >60 in) and by the average number of employees working at the mine (<20 employees, 20-49 employees, 50-99 employees, and >99 employees). To reduce the confounding effects of mining method on injury rates, mines using longwall mining methods were identified and excluded from analysis. The employment data show that as the mine size increases, the proportion of hours worked in low seams decreases substantially. Additionally, miners injured in small, low-seam mines are, on average, younger and less experienced than those injured in large high-seam mines. Nonfatal disabling and fatal injury rates were computed within each category of employment size and seam height for the major types of accidents (ground falls, powered haulage equipment, machinery, handling materials, slips and falls, and hand tools). Our findings suggest that, regardless of the employment size, as mining height increases, miners are at increasingly higher risk of injury from accidents due to slips or falls and accidents involving shuttle cars and falls of ground. As mining height decreases, miners are at higher risk of injury from accidents involving roof bolting machines, load-haul-dump types of powered haulage equipment, personnel carriers, and powered haulage conveyors. On the other hand, regardless of the height of the coal seam, miners working in large underground mines had higher rates of injuries resulting from accidents involving handling materials and nonpowered hand tools, but lower rates of injury from accidents involving continuous mining machines and lower rates of fatal injuries from falls of supported and unsupported mine roof. Finally, miners working at small mines in low or medium seams are at higher risk of being fatally injured by a fall of unsupported mine roof. These findings suggest the importance of considering the working height of the mine, as well as the employment size of the mining operation, when developing intervention strategies to reduce injury risk to underground coal miners. Results also identify the need to further explore how mining height contributes to the frequency and severity of injuries.

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INTRODUCTION

This report examines the relationships between injury rates and mining height in the U.S. underground nonlongwall bituminous coal industry. Mining height is usually equal to the height of the coal seam and can vary from as low as 20 in to a height of 12 ft or more. Mining height affects not only mining method and equipment choices, but also the posture, mobility, and vision of the worker. The relationship between mining height and the frequency and severity of injuries is confounded by the effects of both mine size and mining method. Mines operating in thinner seams of coal (less than 42 in high) tend to have fewer employees and are more likely to use conventional or continuous mining versus longwall mining methods. Two previous studies [Hudson c.1977; National Academy of Sciences 1983] that examined injury rates at different seam heights were plagued by inadequate reporting of seam heights to the Mine Safety and Health Administration (MSHA), particularly by small mines. Although Hudson's study identified trends in injury rates across seam height for certain types of accidents, the results were confounded by lack of control for mine size and mining method. Although the National Academy of Sciences study controlled for mine size, it only examined overall fatality rates. In the present study, an attempt is made to control for both mine size and mining method. Incident rates for fatal and nonfatal disabling injuries are examined separately by type of accident (using MSHA's accident classifications) and, when relevant, by the type of equipment involved. Determining the extent to which seam height, as opposed to other factors, affects fatal and nonfatal injury rates at underground bituminous coal mines will increase our understanding of how the underground mining environment affects the risk of injury to miners.

METHODS AND DEFINITIONS

Data used in the present study are a subset of the data collected annually by MSHA and recorded in its employment and accident/injury databases for the U.S. coal industry. Underground bituminous coal mines were identified and categorized annually by their average seam height (reported in inches) and their size (average annual number of employees). Three categories of seam height were defined based on previous definitions and the distribution of underground employee hours. Low-seam heights are less than 43 in, medium-seam heights range from 43 to 60 in, and high-seam heights exceed 60 in. Mines with missing or unrealistic seam heights (e.g., seam height of 1 in) were individually examined and corrections were made based on valid seam heights for the mine from previous and/or subsequent years. When such corrections could not be made, the mines were excluded from all analyses. The excluded mines accounted for less than 1% of underground exposure hours.

Mine size is defined as the average annual number of employees working at the underground mine (excluding office and preparation plant workers). Four categories of mine size were defined: <20 employees, 20-49 employees, 50-99 employees, and >99 employees. These distinctions were based on previous definitions and the distribution of underground exposure hours.

In the present study, nonfatal disabling injuries are defined as those that resulted in a permanent disability and/or in days away from work or days of restricted work activity. Nonfatal disabling injury rates were computed for the 5-year period from 1990 to 1994. Fatal accident investigation reports were used to obtain the actual mining height at the scene of the accident. These mining heights, as opposed to the average coal seam height of the mine, were used to categorize fatalities by seam height. Given the low frequency of such events, fatal injury rates were computed for the 7-year period from 1989 to 1995.[3]

To control for the effects of mining method on injury rates, mines using the longwall mining method were identified and excluded from analysis. Because only one longwall mine could be identified as operating in low-seam heights, analyses across seam height were not conducted separately for these mines. Annually, about 70 to 75 mines utilize longwall technology, accounting for about one-third of the employee hours worked in underground coal. Although many of these mines may also use continuous mining methods in separate sections of the mine, exposure hours for the different mining methods are not available.

[3]Although MSHA data for 1995 are preliminary and nonfatal injuries and employee hours may be underestimated, records of fatal injuries were complete.

MINE POPULATION DESCRIPTION

For the 7-year period from 1989 to 1995, 2,699 U.S. underground nonlongwall bituminous coal mines with valid seam heights were identified in the employment database. For the 5-year period from 1990 to 1994, 2,288 mines were identified. From 1989 to 1995, 51% of the mines included in the analysis reported underground employee hours for at least 3 of the 7 years. For the 5-year period from 1990 to 1995, 56% of the mines reported hours for at least 3 years. Eleven percent and 22% of the mines reported hours annually throughout the 7- and 5-year periods, respectively. The distributions of underground employee hours by mine size and seam height are presented in figures 1 and 2 for the years 1989-95 and 1990-94, respectively. Included in these figures are the percentage of hours worked in low, medium, and high coal within each category of mine size. Both figures illustrate that as mine size increases, the proportion of hours worked in low coal decreases substantially. Additionally, these proportions remained relatively constant across the two time periods.

From 1989 to 1994, the number of active nonlongwall bituminous underground coal mines decreased by 32%, with a corresponding 27% decrease in underground employee hours and an 11% increase in coal production. The proportion of mines operating in low, medium, or high coal seam heights has remained relatively constant over the past 10 years. The distribution of these mines in 1994 (the most recent year for which MSHA data are complete) by seam height and mine size is presented in figure 3. Both the number and percentage of mines operating in low-coal seams decrease substantially as the size of the mine increases. Virtually all low-coal mines are located in the Appalachian coal basin, principally in Kentucky, West Virginia, Virginia, and Pennsylvania (see figure 4).

Although continuous mining is the most prevalent method used in underground coal, some smaller mining operations may use conventional mining methods. The employment and injury databases do not provide enough information to identify all of the mines employing conventional mining methods or all of the exposure hours and injuries associated with this method of mining. However, included in the injury database is a field identifying the underground mining method being employed at the time of injury. For the 22,607 nonfatal disabling injuries included in the present study for the period 1990-94, the underground mining method was coded as continuous for 72.9%, conventional for 4.6%, unknown for 21.5%, and other for 1% of the injuries. For each category of seam height and mine size, the percentage of nonfatal disabling injuries within that category for which the underground mining method was coded as conventional mining is presented in figure 5. The two highest percentages of conventional mining-related injuries are reflected in mines with fewer than 50 employees operating in low-coal seams. Additionally, nearly 10% of the nonfatal disabling injuries that occurred in mines with more than 99 employees operating in medium seams were associated with conventional mining methods. These implied differences in exposure to conventional versus continuous mining methods must be considered when examining differences in injury rates, particularly for those injuries involving continuous mining machines.

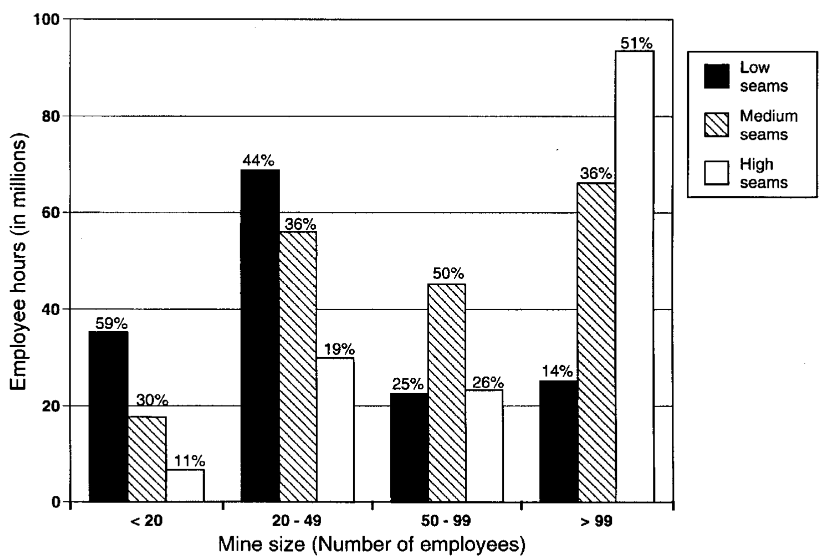

Figure 1.—Number and percent (within mine size) of underground emplyee hours by mine size and seam height for nonlongwall bituminous coal mines, 1989-95.

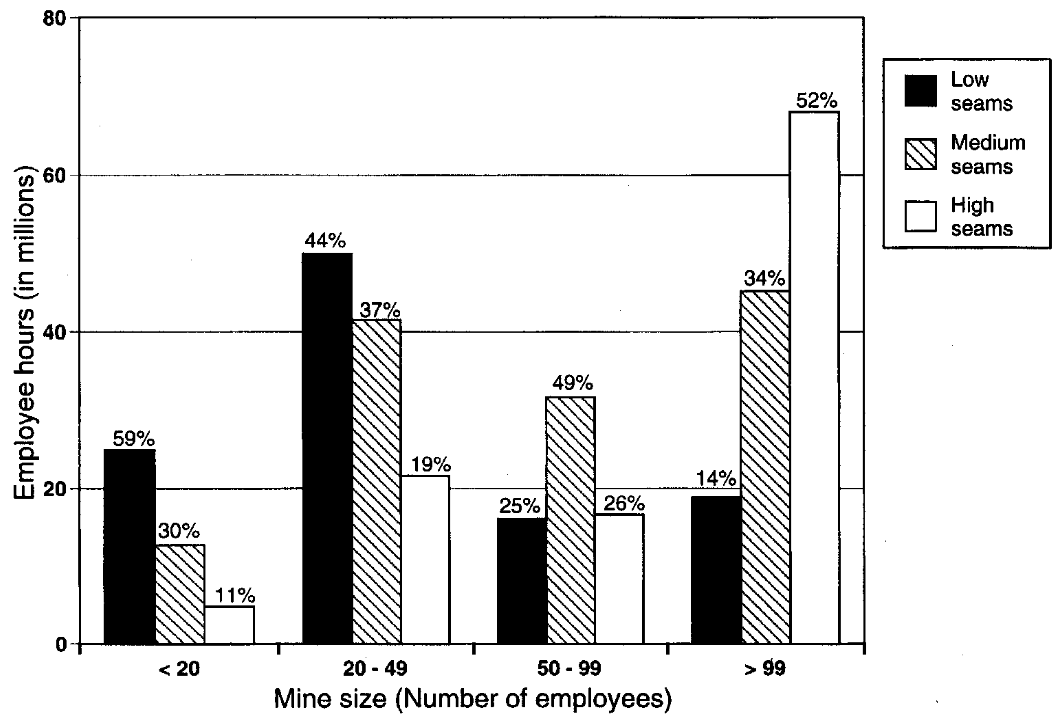

Figure 2.—Number and percent (within mine size) of underground employee hours by mine size and seam height for nonlongwall bituminous coal mines, 1990-94.

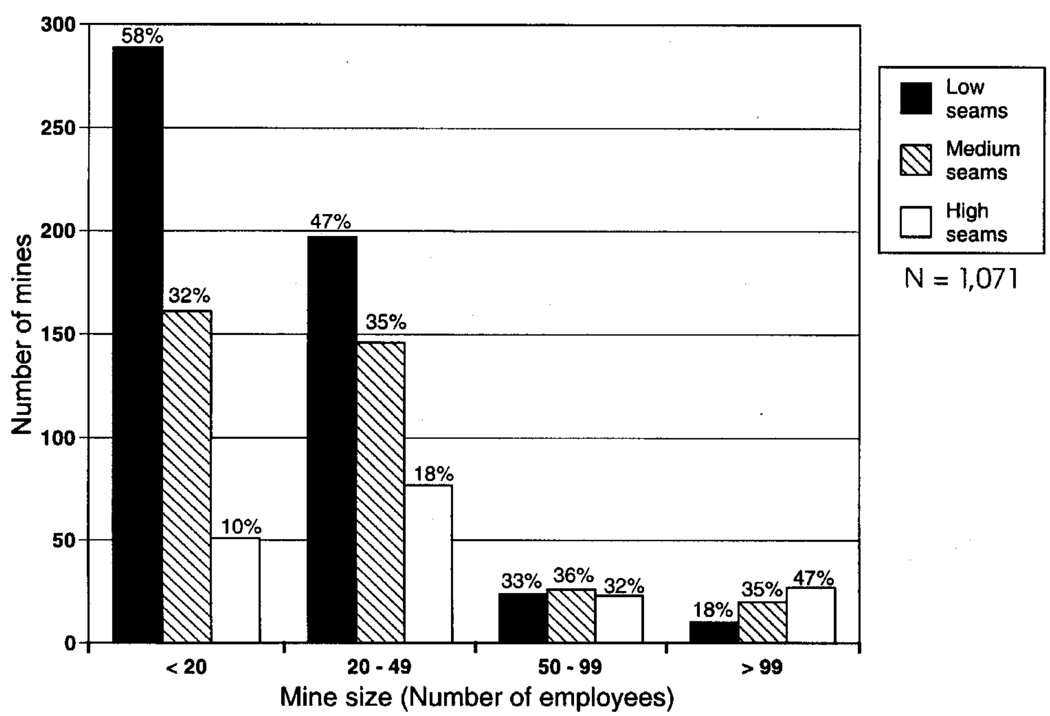

Figure 3.—Number of underground nonlongwall bituminous coal mines by mine size and seam height, 1994.

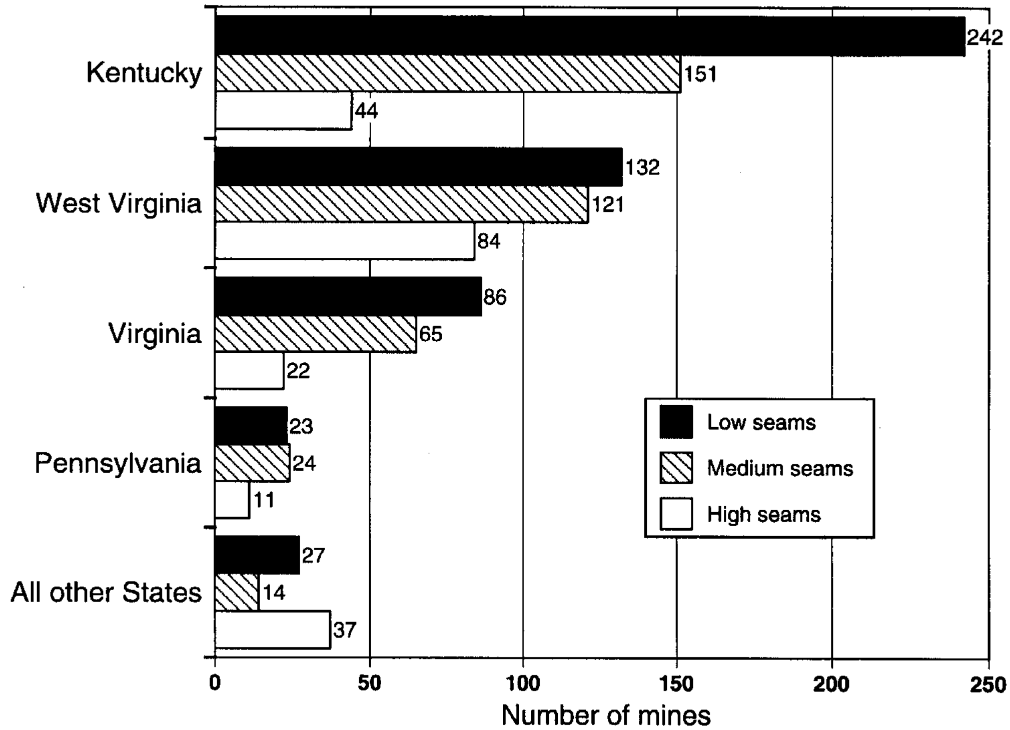

Figure 4.—Number of underground nonlongwall bituminous coal mines by seam height and State, 1994.

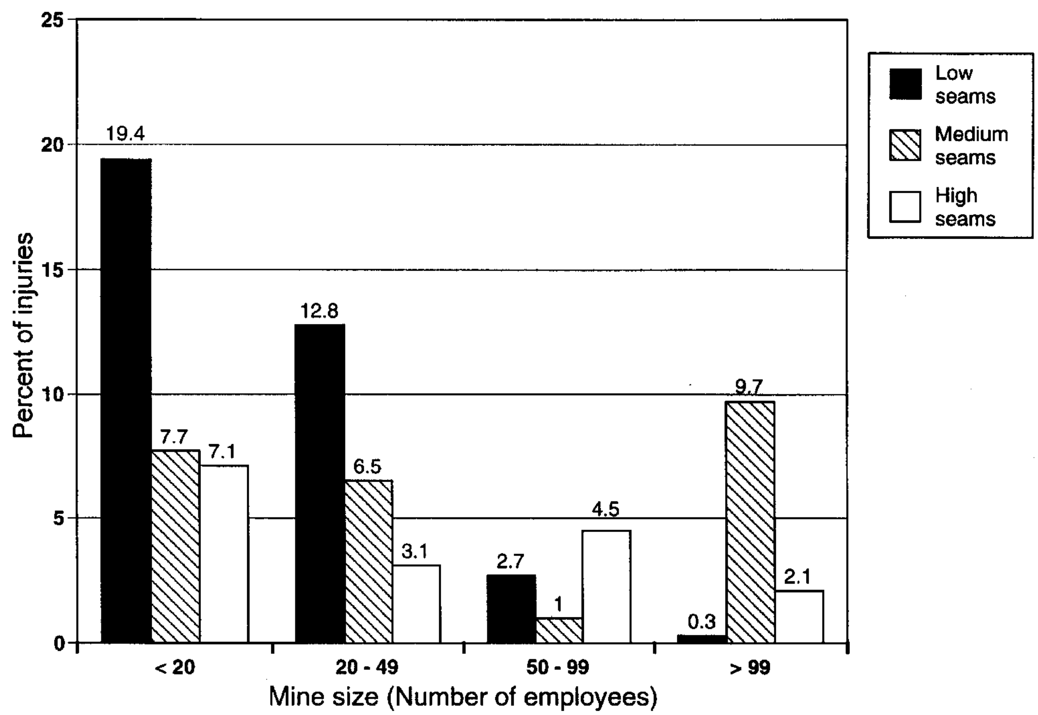

Figure 5.—Percentage of conventional mining-related injuries within each combination of seam height and mine size, 1990-94.

DEMOGRAPHICS OF INJURED MINERS

Previous studies have suggested that miners working in large underground mines (>50 employees) are older and more experienced than those working in smaller mines [Peters and Fotta 1994b]. Although the age and experience of injured miners may not be representative of the mining population as a whole, differences among groups of injured miners may reflect differences in the population as well. The MSHA injury/accident database contains fields for recording the age, years of total mining experience, years of experience at current mining operation, and years of experience in current job classification of the injured miner. The distributions of the median number of years by seam height and mine size for miners injured in 1994 are presented for each of these four variables in figures 6 through 9, respectively. Note that within each category of mine size, the lowest median number of years for both age and total mining experience occurs in low seams. Note also that the largest mines display the overall highest medians for age, years of total mining experience, and years of experience at current mine. The substantially higher medians observed at the largest mines for the years of experience at current mine reflect, in part, the longevity of larger underground mines. The distribution of the median years of experience in current job classification shows no consistent relation to either mine size or seam height.

In general, these statistics suggest that miners working in small, low- seam mines are younger and have less overall mining experience and less experience working in the mine where they are currently employed than those working in large, high-seam mines.

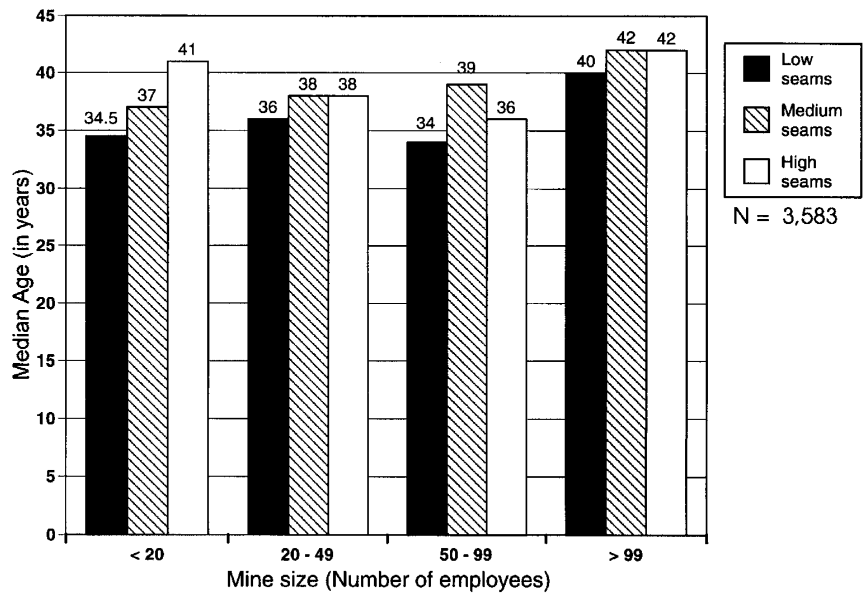

Figure 6.—Distribution by mine size and seam height of the median age of miners injured in 1994.

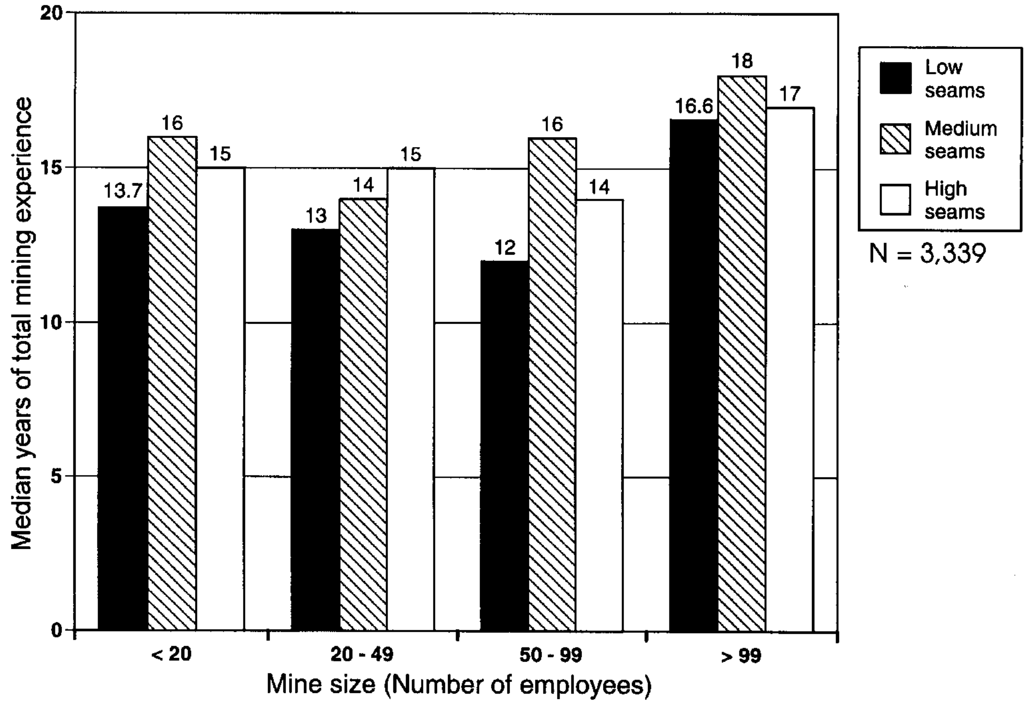

Figure 7.—Distribution by mine size and seam height of the median years of total mining experience for miners injured in 1994.

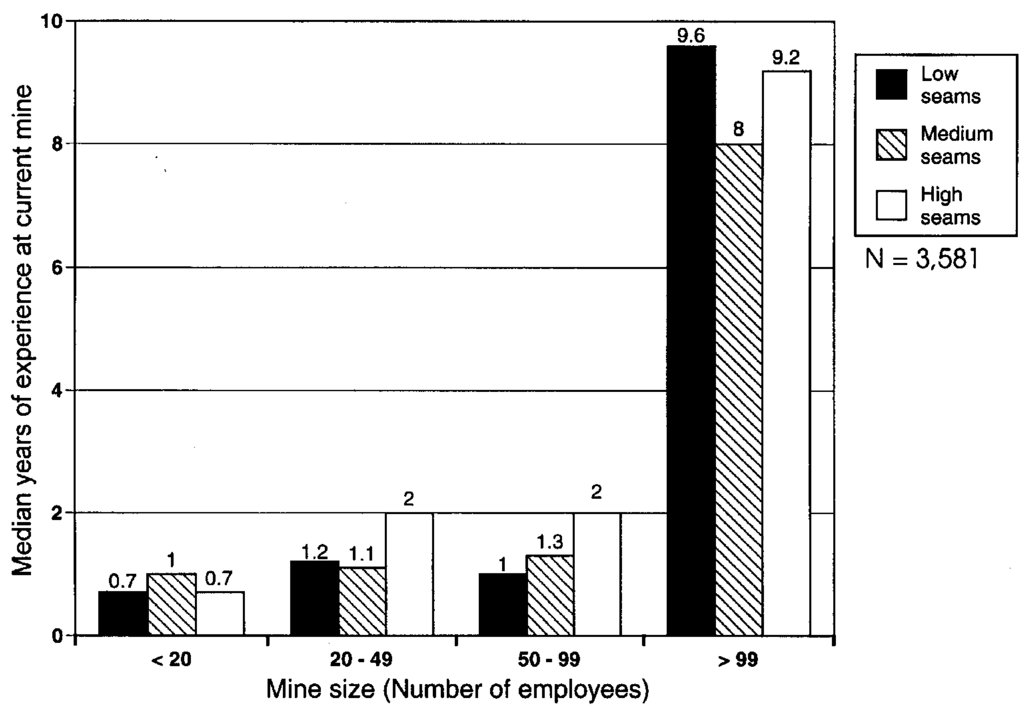

Figure 8.—Distribution by mine size and seam height of the median years of experience at current mine for miners injured in 1994.

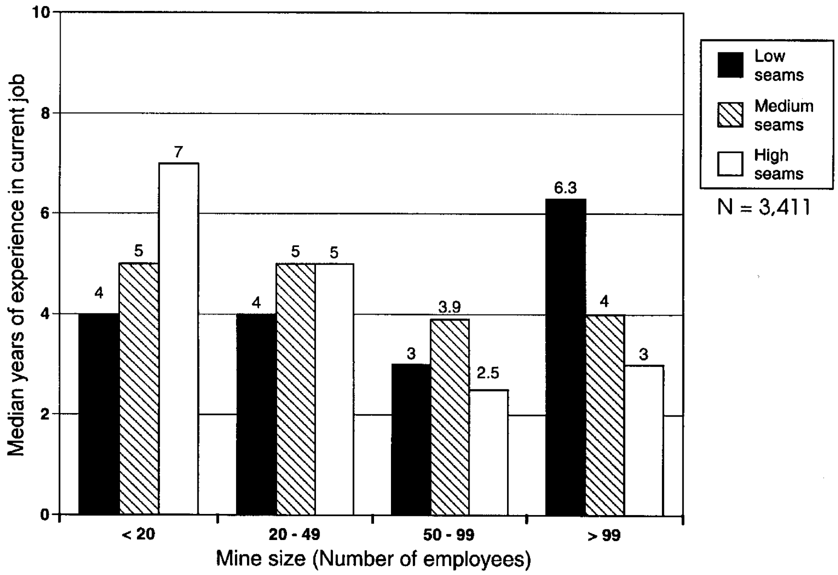

Figure 9.—Distribution by mine size and seam height of the median years of experience in current job classification for miners injured in 1994.

RELIABILITY OF SEAM HEIGHT DATA

To determine the relationship between mining height and the types and rates of injuries in underground mines, obtaining the actual working height of the mine at the scene of the injury would be ideal. This information, however, is not usually available unless a fatality occurs. Actual mining height at the scene of the accident is documented for most underground fatalities as part of the information detailed in the investigation report. Although MSHA's database for underground coal mine operators contains a field listing the average height of the coal seam currently being mined, the difference between this height and the actual mining height may vary considerably between, as well as within, sections of a mine.

Preliminary analyses were conducted to determine whether the average seam heights recorded in the database were accurate enough to identify trends in injury rates related to mining height differences. These analyses involved the selection of a subset of the nonfatal disabling injuries for which the miner's activity at the time of injury was coded as walking/running or crawling/kneeling. The expectation was that the rate of injury to miners whose activity was classified as walking or running at the time of injury would increase as seam heights increase. Conversely, the rate of injury to miners whose activity was classified as crawling or kneeling at the time of injury should decrease as seam heights increase. Additionally, these trends should be evident regardless of the size of the mining operation. The results of these analyses are summarized in tables 1 and 2 and graphically displayed in figures 10 and 11. As expected, the rate of injury to miners walking or running when injured increases as seam height increases. Similarly, the rate of injury to miners crawling or kneeling at the time of injury decreases as seam height increases. Both of these trends are evident across, as well as within, categories of mine size.

Table 1.—Number and rate (per 200,000 hr) of nonfatal disabling injuries for miners walking/running at time of injury by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	24	.19	84	.34	33	.41	100	1.06	241	.44
Medium	34	.53	116	.56	122	.77	283	1.25	555	.85
High	18	.75	108	1.00	81	.97	600	1.76	807	1.45
Overall	76	.36	308	.55	236	.73	983	1.49		

Table 2.—Number and rate (per 200,000 hr) of nonfatal disabling injuries for miners crawling/kneeling at time of injury by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	49	.39	118	.47	24	.30	25	.27	216	.39
Medium	5	.08	27	.13	26	.16	16	.07	74	.11
High	0	.00	6	.06	5	.06	18	.05	29	.05
Overall	54	.26	151	.27	55	.17	59	.09		

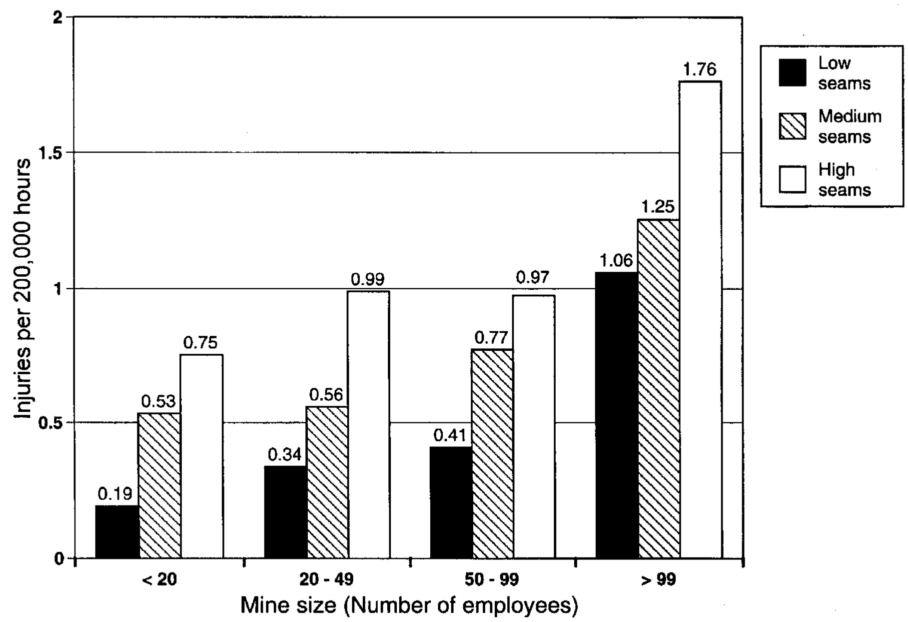

Figure 10.—Rate (per 200,000 hr) of nonfatal disabling injuries for miners walking/running at time of injury by mine size and seam height, 1990-94.

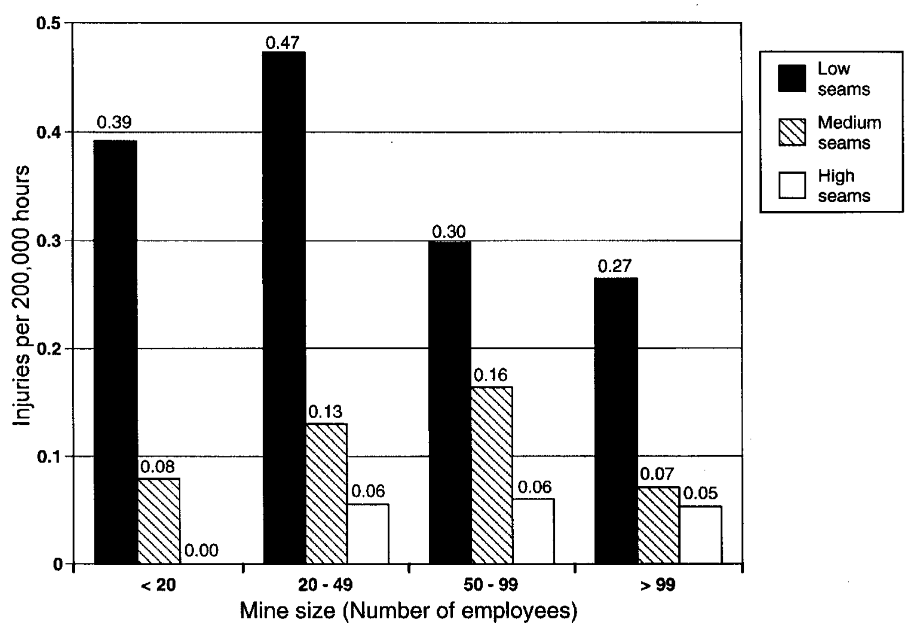

Figure 11.—Rate (per 200,000 hr) of nonfatal disabling injuries for miners crawling/kneeling at time of injury by mine size and seam height, 1990-94.

Although the expected trends were evident within each mine size category, the strength of the trends for both walking/running and crawling/kneeling appears to weaken as mine size increases. For example, within the smallest mine size, the rate of injury to miners injured while walking/running in high seams (.75) is almost four times the rate of injury observed in low seams (.19). As mine size increases, this factor decreases such that for the largest mines, the rate of injury to miners injured while walking/running in high seams (1.76) is less than twice the rate observed in low seams (1.06). A similar observation can be made for the trends in injuries to miners whose activity was classified as crawling/kneeling. These decreases in the variability of injury rates for larger mining operations suggest that the method of using average coal seam heights to approximate actual working mining heights throughout a mine may decrease in reliability as the size of the mining operation increases. This is expected given that larger mining operations are more extensive and therefore more likely to encounter variations in coal seam thickness. Larger mines are also more likely to be mining in multiple sections of the mine and, as noted previously, the thickness of the coal seam can vary within, as well as between, different sections of a mine.

Despite these variations, it appears that using three categories of average coal seam heights to approximate actual mining heights is a useful method for relating variations in mining height to variations in the rate of injury to underground miners.

DISTRIBUTION OF INJURIES BY ACCIDENT CLASSIFICATION

The analyses conducted for this report covered two separate time periods. Nonfatal disabling injuries that occurred during the 5-year period from 1990 to 1994 were the primary focus. Findings from those analyses were then supplemented by a review of fatal injuries during the 7-year period 1989 to 1995. The additional years of data were required for the analyses involving fatalities because of the small number of such events in any one category. Regardless of how low the actual number of fatalities is, however, the importance of the death of even one worker cannot be overlooked. Additionally, the detailed information obtained from fatal accident investigation reports is rarely available for nonfatal injuries. Therefore, although special care must be taken in the interpretation of such relatively low-frequency events, such analyses may provide additional insight.

NONFATAL DISABLING INJURIES

During the 5-year study period, 22,684 underground nonfatal injuries resulting in lost time or days of restricted activity were reported to MSHA by nonlongwall underground bituminous coal mines. More than 99% of these injuries (22,607) had corresponding seam height information reported by the mine and were used in the analyses. Six major classifications of accidents accounted for 91.6% of these injuries: (1) handling materials, (2) machinery, (3) powered haulage, (4) slip or fall of person, (5) fall of roof, and (6) nonpowered hand tools (see figure 12).

FATAL INJURIES

During the 7-year period used for computing fatality rates, 180 miners were killed at U.S. underground nonlongwall bituminous operations. The corresponding fatality rate was .073 deaths per 200,000 underground employee hours. Three types of accidents accounted for 78% of the deaths: (1) roof falls, (2) powered haulage, and (3) machinery. Understanding where these types of accidents are most likely to occur would allow a more focused effort in reducing fatality rates (see figure 13).

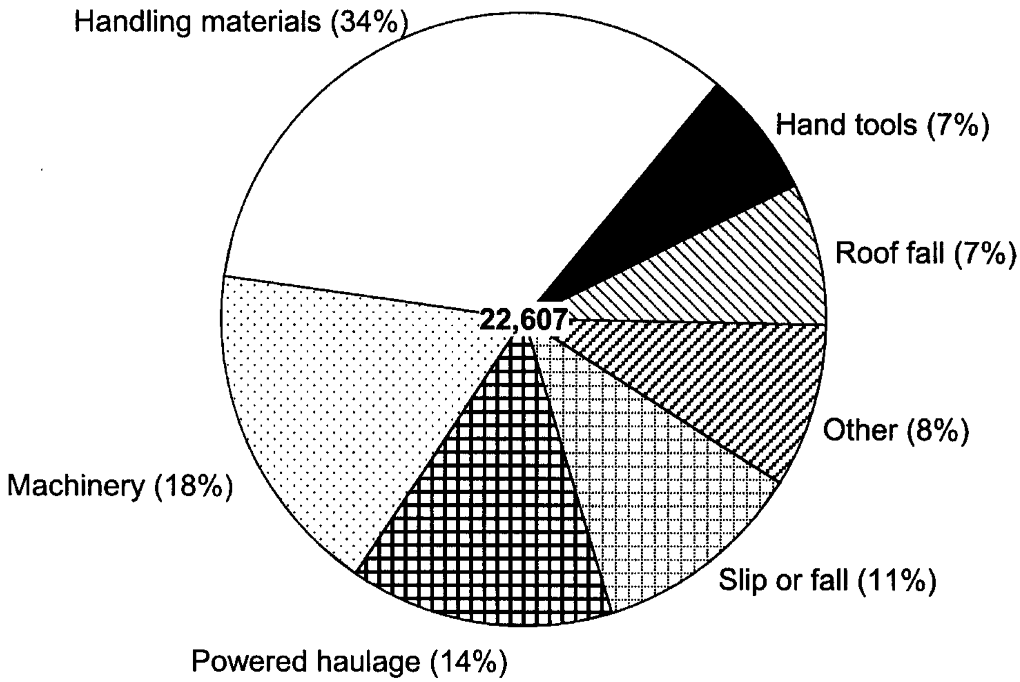

Figure 12.—Nonfatal disabling injuries by MSHA accident classification, 1990-94.

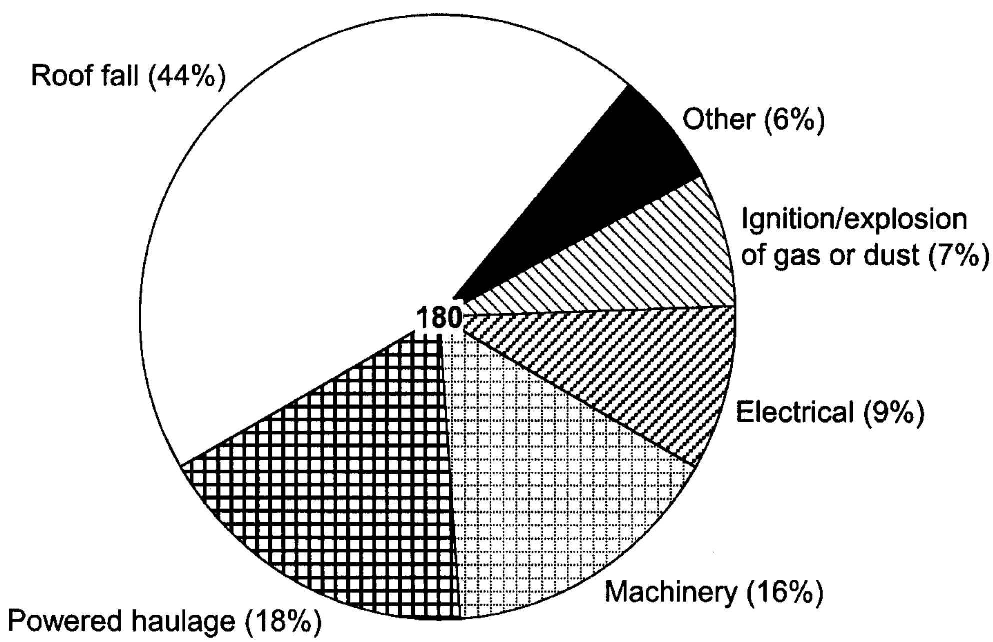

Figure 13.—Fatal injuries by MSHA accident classification, 1989-95.

RESULTS

In the following sections of this report, the distributions of nonfatal disabling injury rates in the United States across both mine size and seam height are presented for the six major accident classifications. The sections are ordered from the most frequently occurring class of accidents (handling materials) to the least frequently occurring accident type (hand tools). The distributions of fatal injury rates are reported for accidents classified as ground falls, machinery, or powered haulage. Both figures and tables are used to identify and describe variations and trends in the rates of injuries with regard to both seam height and mine size. The tables contain the actual numbers of injuries and the corresponding rates (injuries per 200,000 employee hr). A summary of the findings follows the presentation of data.

HANDLING MATERIALS ACCIDENTS

Handling materials injury rates increase slightly overall as seam height increases (see table 3). Within levels of mine size, this trend is observed only for the smallest mines (see figure 14). The variations in these rates appear to be more strongly related to mine size, increasing as mine size increases. A more focused analysis was obtained by examining the subset of the data for which the part of the body injured was reported to be the back (see table 4 and figure 15). Back injuries accounted for 55% of the injuries sustained while handling materials during the 5-year period. Similar to the trend observed for all handling material injuries, the rates of back injuries increase as mine size increases and show no obvious relation to variations in seam height.

MACHINERY ACCIDENTS

A closer examination of the injury records within the accident classification of machinery revealed that the actual source of the disabling injury for 37% of the accidents was coded as "caving rock" that had fallen from either the mine roof or rib. The miner involved was either operating or assisting in

Table 3.—Number and rate (per 200,000 hr) of nonfatal disabling injuries from handling materials accidents by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	368	2.95	901	3.61	365	4.53	542	5.75	2,176	3.96
Medium	222	3.49	840	4.05	742	4.69	1,089	4.83	2,893	4.42
High	90	3.75	413	3.82	313	3.76	1,790	5.26	2,606	4.69
Overall	680	3.20	2,154	3.81	1,420	4.41	3,421	5.18		

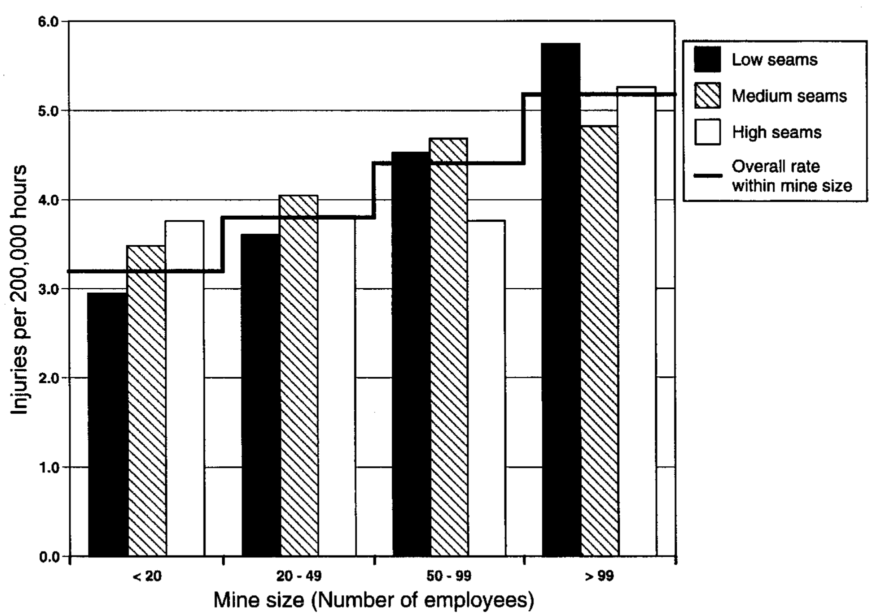

Figure 14.—Rate of nonfatal disabling injuries from handling materials accidents by mine size and seam height, 1990-94.

Table 4.—Number and rate (per 200,000 hr) of nonfatal disabling back injuries from handling materials accidents by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	210	1.68	485	1.94	226	2.80	297	3.15	1,218	2.22
Medium	144	2.26	498	2.40	450	2.84	596	2.64	1,688	2.58
High	49	2.05	230	2.13	169	2.03	881	2.59	1,329	2.39
Overall	403	1.90	1,213	2.15	845	2.62	1,774	2.69		

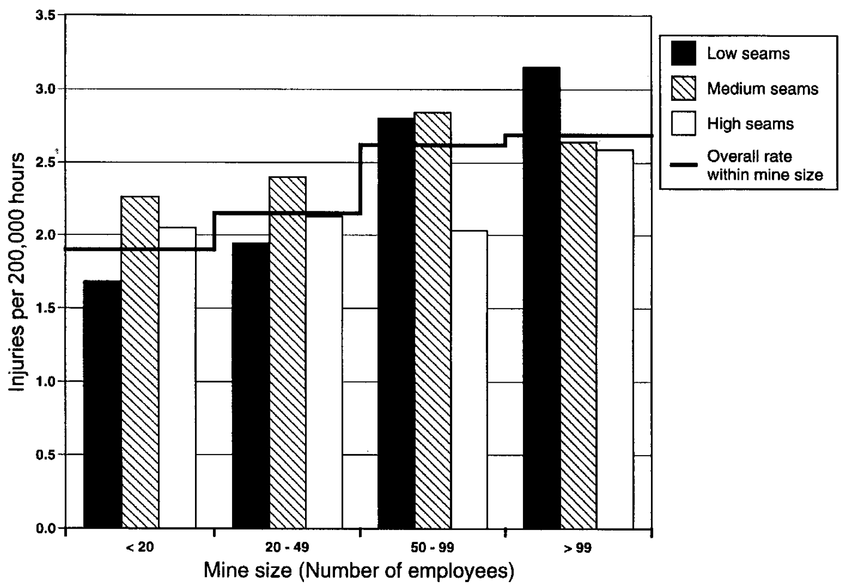

Figure 15.—Rate of nonfatal disabling back injuries from handling materials accidents by mine size and seam height, 1990-94.

the operation of some type of machinery, usually a roof bolting machine (for 88% of these injuries) or a continuous miner (8% of the injuries). However, when these types of incidents result in a fatal injury, the accident is classified as a ground fall accident, not a machinery accident. For consistency, nonfatal disabling injuries resulting from these types of machinery-related ground fall accidents will be excluded from the machinery analysis and analyzed separately under accidents involving falls of the mine roof or rib.

Of the remaining machinery-related incidents, 69% involved roof bolting machines, 15% involved continuous miners, and 16% involved some other type of machinery, any one of which provided too few numbers for meaningful analysis. The nonfatal disabling and fatal injuries resulting from machinery accidents involving roof bolting machines and continuous miners are examined separately below.

Roof Bolting Machinery Accidents

Nonfatal disabling injury rates related to roof bolting machines decrease overall as seam height increases (see table 5 and figure 16). For all except the largest mine size, injury rates in low and medium seams are substantially higher than those observed in high seams. Rates for the largest mines are the lowest overall (.81) and show less variability across seam height than rates for the smaller mine sizes. Consistent with the distribution observed for nonfatal disabling injury rates, fatal injury rates are substantially lower overall in high seams than in low- or medium-seam heights (see table 6 and figure 17). Of the 11 fatal injuries involving roof bolting machines, 10 occurred in low or medium mining heights. Mines operating at those heights accounted for 91% of the fatalities, but only 69% of the employee hours.

Table 5.—Number and rate (per 200,000 hr) of nonfatal disabling injuries from roof bolting machinery accidents by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	136	1.09	303	1.21	103	1.28	68	.72	610	1.11
Medium	72	1.13	224	1.08	201	1.27	173	.77	670	1.02
High	16	.67	90	.83	65	.78	296	.87	467	.84
Overall	224	1.05	617	1.09	369	1.15	537	.81		

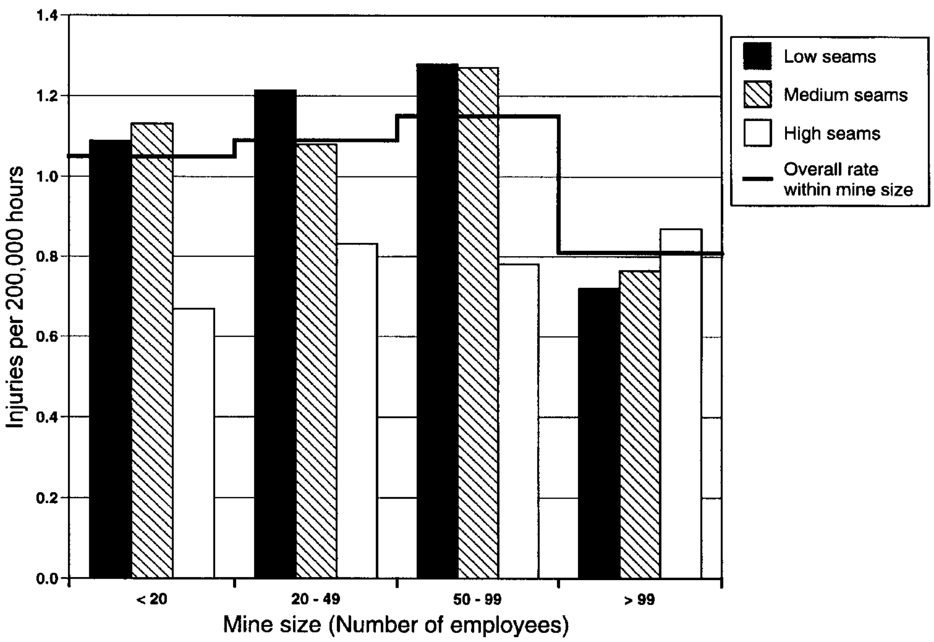

Figure 16.—Rate of nonfatal disabling injuries from roof bolting machinery accidents by mine size and seam height, 1990-94.

Table 6.—Number and rate (per 200,000 hr) of nonfatal injuries from roof-bolting machinery accidents by mine size and seam height, 1989-95

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	1	.006	3	.009	0	–	0	–	4	.005
Medium	1	.011	1	.004	2	.009	2	.006	6	.006
High	0	–	0	–	0	–	1	.002	1	.001
Overall	2	.007	4	.005	2	.004	3	.003		

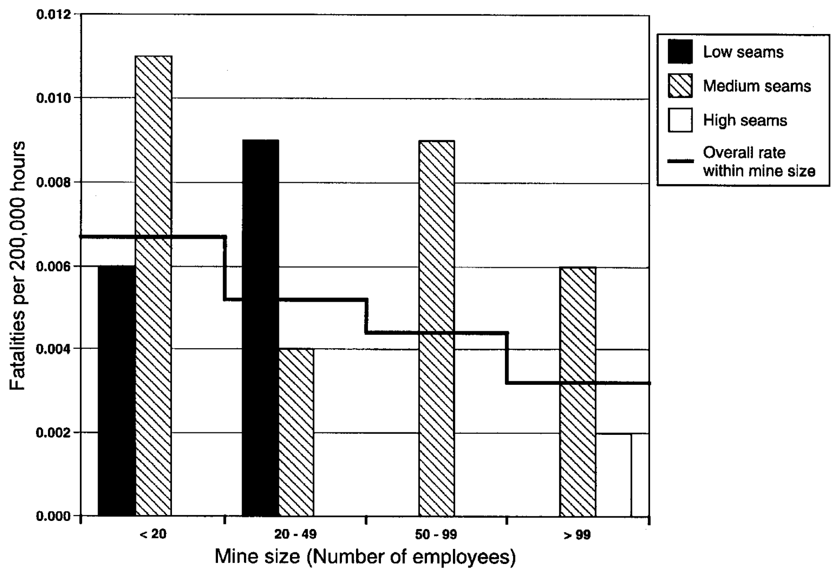

Figure 17.—Rate of fatal injuries from roof bolting machinery accidents by mine size and seam height, 1989-95.

Continuous Miner Machinery Accidents

Although injuries related to the operation of continuous mining machines account for only 15% of the nonfatal disabling machinery-related injuries, they account for 54% of the fatal machinery-related injuries. It is important to bear in mind that variations in injury rates for accidents involving continuous mining machines will reflect, in part, variations in exposure to continuous versus conventional mining methods because the latter do not employ these machines. Because apparent exposure to continuous mining machines increases both as seam height and mine size increases (refer to figure 5), injury rates may be expected to increase as well. Contrary to expectations, nonfatal disabling injury rates decrease slightly overall as seam height increases and more substantially as mine size increases see table 7 and figure 18). Additionally, the single highest nonfatal disabling injury rate (.36) is observed for the smallest mines working in the lowest seams. Mines in this category had the highest percentage of injuries related to conventional mining methods (19%). Similar to the trend observed for nonfatal disabling injury rates, fatal injury rates related to continuous miners decrease overall as mine size increases (see table 8 and figure 19). However, as seam height increases, fatal injury rates also show an overall increase. Although the numbers are small, this trend is relatively persistent for all but the smallest mines.

Table 7.—Number and rate (per 200,000 hr) of nonfatal disabling injuries from continuous miner machinery accidents by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	45	.36	63	.25	17	.21	17	.18	142	.26
Medium	12	.19	54	.26	48	.30	36	.16	150	.23
High	7	.29	27	.25	11	.13	54	.16	99	.18
Overall	64	.30	144	.25	76	.24	107	.16		

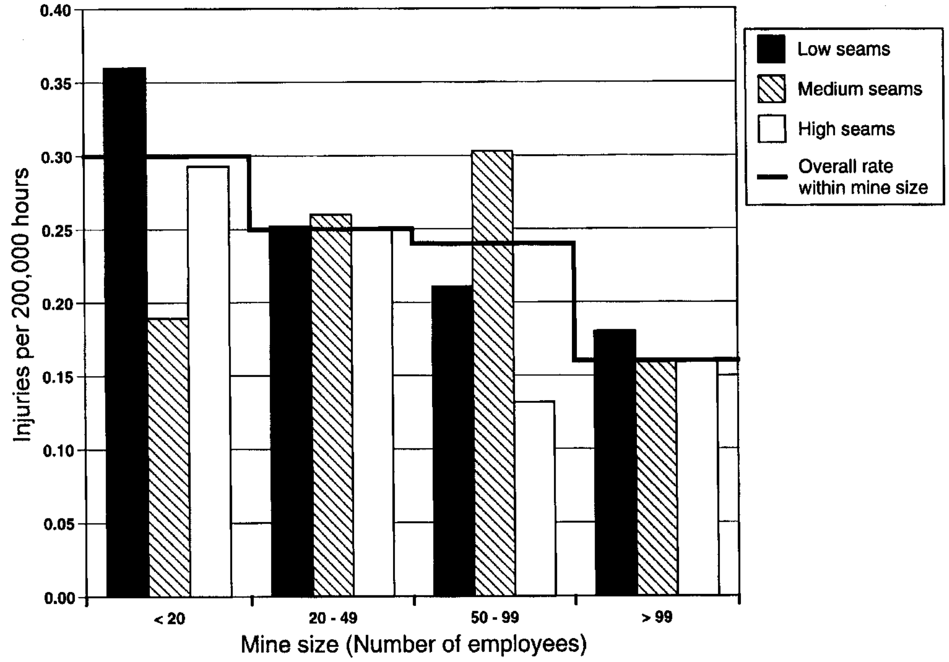

Figure 18.—Rate of nonfatal disabling injuries from continuous miner machinery accidents by mine size and seam height, 1990-94.

Table 8.—Number and rate (per 200,000 hr) of fatal injuries from continuous miner machinery accidents by mine size and seam height, 1989-95

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	2	.011	1	.003	0	–	0	–	3	.004
Medium	1	.011	2	.007	2	.009	1	.003	6	.006
High	0	–	3	.020	1	.009	2	. 004	6	.008
Overall	3	.010	6	.008	3	.007	3	.003		

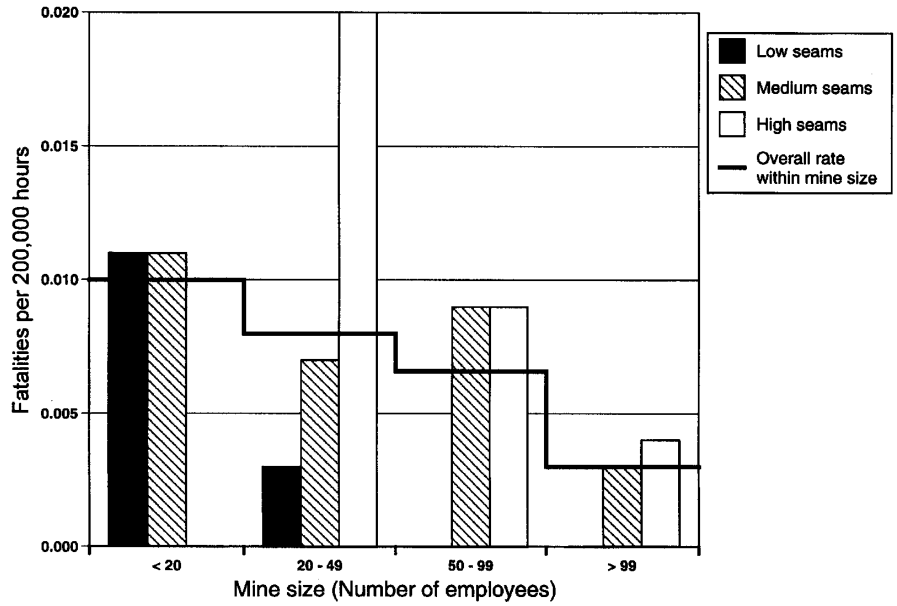

Figure 19.—Rate of fatal injuries from continuous miner machinery accidents by mine size and seam height, 1989-95.

POWERED HAULAGE ACCIDENTS

Most of the nonfatal disabling injuries (93%) and all except one of the fatal injuries resulting from powered haulage accidents involved one of five types of powered haulage equipment: (1) shuttle cars, (2) load-haul-dumps, scoops, trams, etc., (3) personnel carriers, such as man cars, man trips, etc., (4) conveyors of all types, stationary or mobile, or (5) locomotives (see figure 20). Nonfatal disabling and fatal injury rates for each of these five types of equipment are examined separately below.

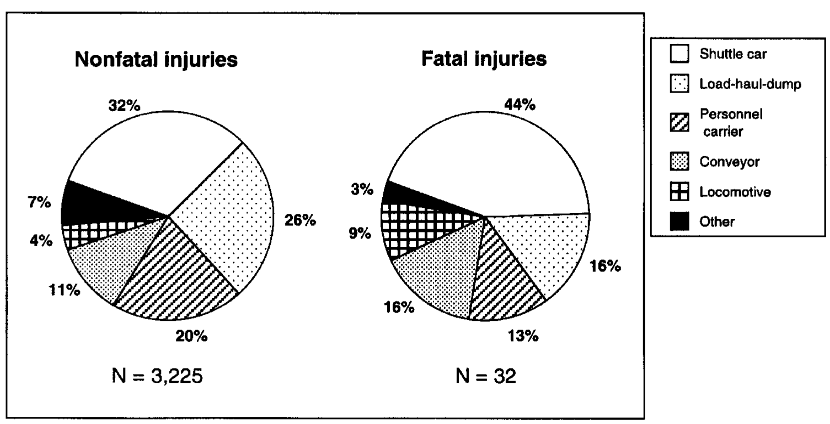

Figure 20.—Nonfatal disabling injuries (1990-94) and fatal injuries (1989-95) by type of equipment involved in powered haulage accidents.

Shuttle Cars

Nonfatal disabling injury rates related to the use of shuttle cars are lowest in low seams both overall as well as within each category of mine size (see table 9 and figure 21). Additionally, a trend of increasing injury rates with increasing seam height is particularly evident for the smallest mine size. A similar, but weaker trend appears for the largest mine size as well. Fatal injury rates, however, show an overall decrease with increasing seam height (see table 10 and figure 22). Although small mines operating in low coal had the lowest nonfatal disabling injury rates (.29), they had the highest fatality rate (.017). Of the 14 fatalities involving shuttle cars, 12 (86%) occurred in low or medium mining heights. As noted previously, these mines accounted for 69% of the underground employee hours.

Table 9.—Number and rate (per 200,000 hr) of nonfatal disabling injuries from shuttle car haulage accidents by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	36	.29	110	.44	43	.53	49	.52	238	.43
Medium	37	.58	143	.69	113	.71	133	.59	426	.65
High	17	.71	72	.67	45	.54	234	.69	368	.66
Overall	90	.42	325	.57	201	.62	416	.63		

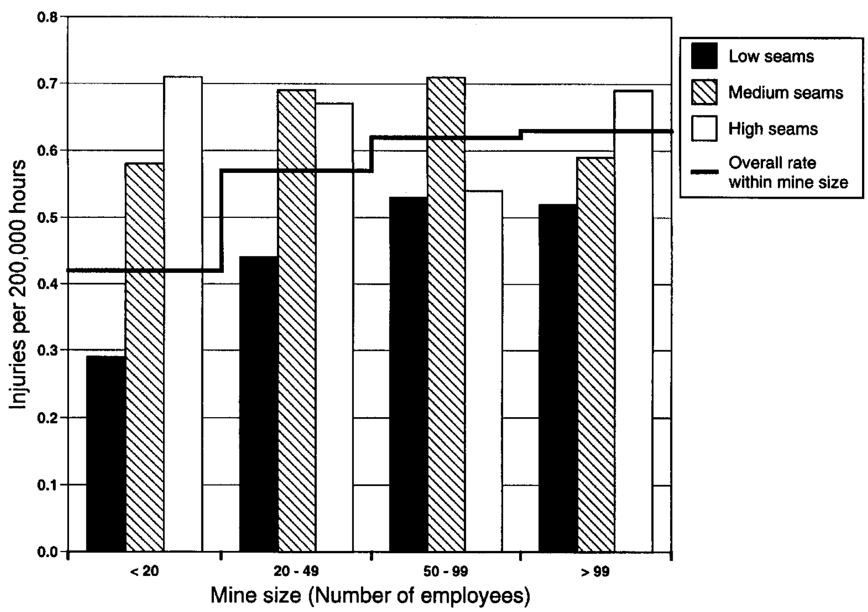

Figure 21.—Rate of nonfatal disabling injuries from shuttle car haulage accidents by mine size and seam height, 1990-94.

Table 10.—Number and rate (per 200,000 hr) of fatal injuries from shuttle car haulage accidents by mine size and seam height, 1989-95

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	3	.017	1	.003	1	.009	1	.008	6	.008
Medium	1	.011	2	.007	1	.004	2	.006	6	.006
High	0	–	0	.020	1	.009	1	.002	2	.003
Overall	4	.013	3	.008	3	.007	4	.004		

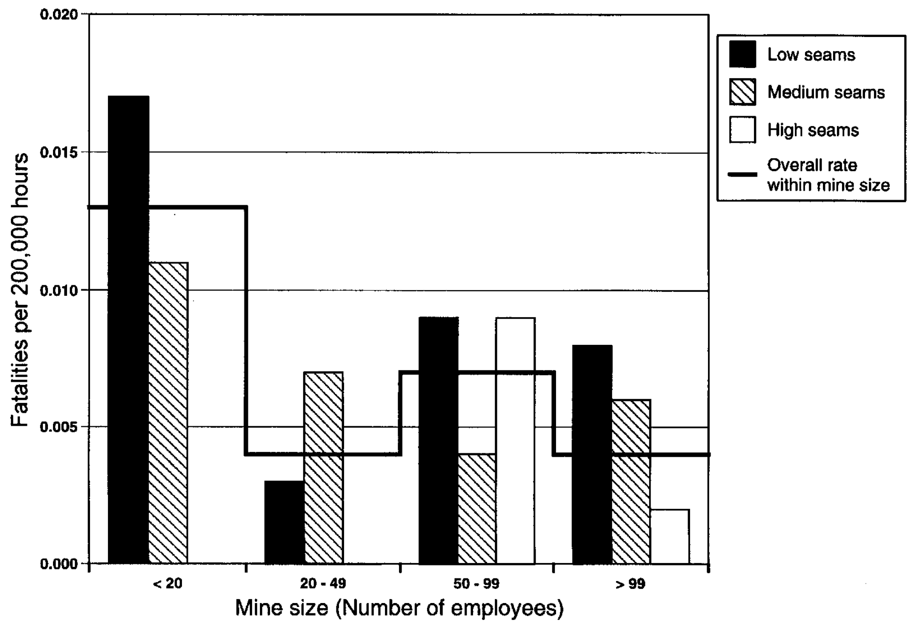

Figure 22.—Rate of fatal injuries from shuttle car haulage accidents by mine size and seam height, 1989-95.

Load-Haul-Dump Equipment

Nonfatal disabling injury rates related to the use of load-haul-dump types of powered haulage equipment decrease as seam height increases both overall as well as within each mine size category (see table 11 and figure 23). The five fatal injuries associated with load-haul-dump types of powered haulage are too few in number and widely scattered for meaningful analysis (see table 12).

Personnel Carriers

Nonfatal disabling injury rates involving personnel carriers decrease overall as seam height increases (see table 13 and figure 24). This trend is particularly evident within the two smaller mine sizes. The four fatal injuries involving personnel carriers are too few in number and widely scattered for meaningful analysis (see table 14).

Table 11.—Number and rate (per 200,000 hr) of nonfatal disabling injuries from load-haul-dump haulage accidents by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	129	1.03	216	.87	39	.48	32	.34	416	.76
Medium	35	.55	90	.43	63	.40	65	.29	253	.39
High	6	.25	32	.30	26	.31	96	. 28	160	.29
Overall	170	.80	338	.60	128	.40	193	.29		

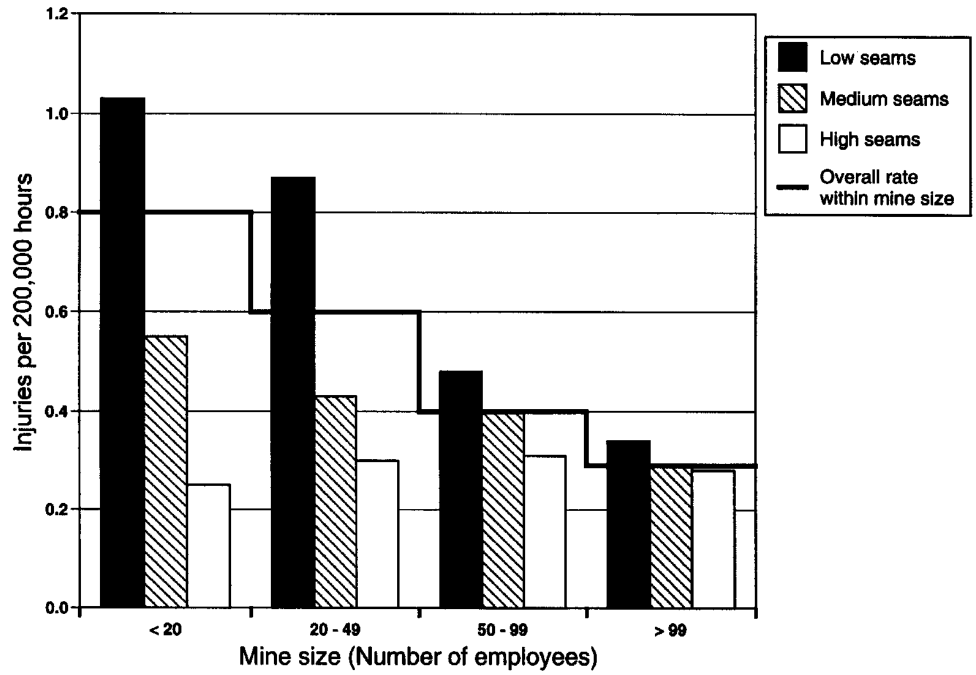

Figure 23.—Rate of nonfatal disabling injuries from load-haul-dump haulage accidents by mine size and seam height, 1990-94.

Table 12.—Number and rate (per 200,000 hr) of fatal injuries from load-haul-dump haulage accidents by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	0	–	1	.003	0	–	0	–	1	.001
Medium	1	.004	1	.004	0	–	0	–	2	.002
High	0	–	0	–	1	.009	1	.002	2	.003
Overall	1	.003	2	.003	1	.002	1	.001		

Table 13.—Number and rate (per 200,000 hr) of nonfatal disabling injuries from personnel carrier haulage accidents by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	46	.37	132	.53	38	.47	30	.32	246	.45
Medium	19	.30	67	.32	54	.34	88	.39	228	.35
High	3	.13	17	.16	31	.37	134	.39	185	.33
Overall	68	.32	216	.38	123	.38	252	.38		

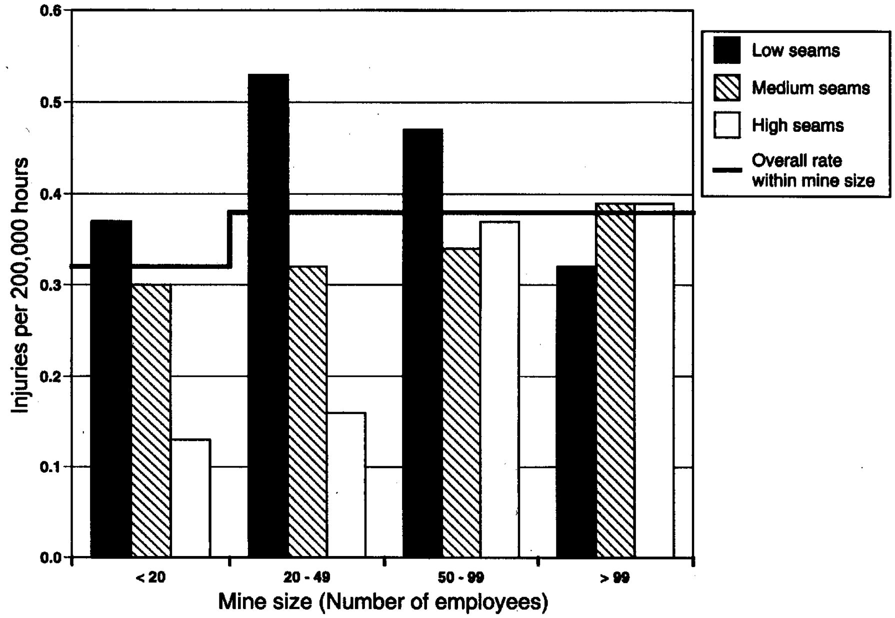

Figure 24.—Rate of nonfatal disabling injuries from personnel carrier haulage accidents by mine size and seam height, 1990-94.

Table 14.—Number and rate (per 200,000 hr) of fatal injuries from personnel carrier haulage accidents by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	0	–	0	–	0	–	1	.008	1	.001
Medium	0	–	1	.004	1	.004	0	–	2	.002
High	0	–	0	–	1	.009	0	–	1	.001
Overall	0	–	1	.001	2	.004	1	.001		

Conveyors

Overall, nonfatal disabling injury rates involving powered haulage conveyors decrease with increasing seam height (see table 15 and figure 25.) Although this trend persists for only the smallest and largest mine sizes, the highest rates are consistently observed in low seams for every mine size. Although few in number, it is worth noting that of the five fatal injuries involving powered haulage conveyors, none occurred in low seams. However, 4 of the 5 (80%) occurred in mines with fewer than 50 employees, which account for only 44% of the employee hours (see table 16).

Table 15.—Number and rate (per 200,000 hr) of nonfatal disabling injuries from powered haulage conveyor accidents by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	446	.35	96	.38	38	.47	17	.18	195	.35
Medium	19	.30	33	.16	19	.12	25	.11	96	.15
High	43	.17	17	.16	19	.23	21	.06	61	.11
Overall	67	.32	146	.26	76	.24	63	.10		

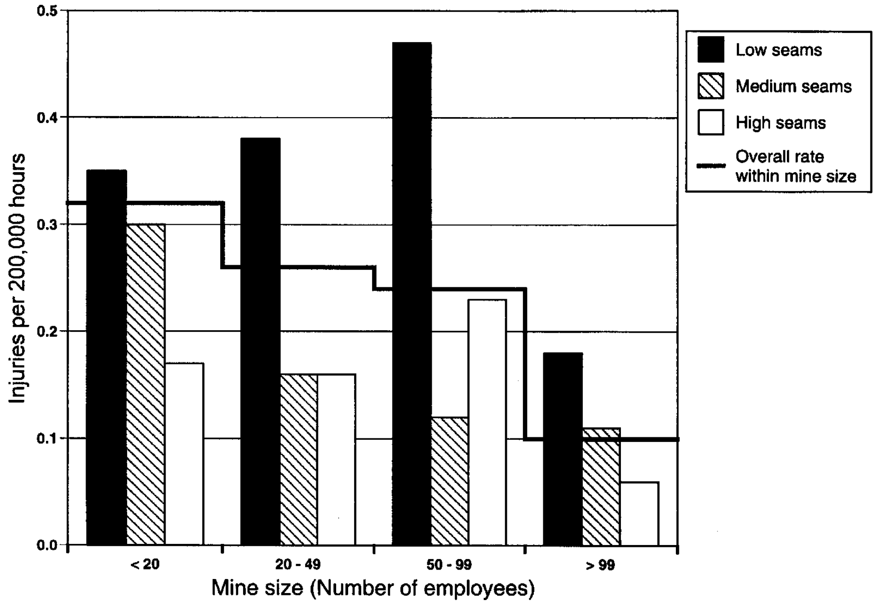

Figure 25.—Rate of nonfatal disabling injuries from powered haulage conveyor accidents by mine size and seam height, 1990-94.

Table 16.—Number and rate (per 200,000 hr) of fatal injuries from powered haulage conveyor accidents by mine size and seam height, 1989-95

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	0	–	0	–	0	–	0	–	0	–
Medium	1	.001	1	.004	0	–	0	–	2	.002
High	0	–	2	.013	0	–	1	.002	3	.004
Overall	1	.003	3	.004	0	–	1	.001		

Locomotives

Although the types of powered haulage accidents classified by machine type as locomotive, rail-mounted, or lorry car accounted for only 4% of the nonfatal disabling powered haulage injuries, they accounted for 9% (3 out of 32) of the fatal injuries. Most of the nonfatal disabling injuries (84%) occurred in mines with 50 or more employees (see table 17 and figure 26) and all 3 fatalities occurred in mines with more than 99 employees, 1 in each seam height category. These differences related to mine size reflect the fact that larger mines are most likely to employ this type of powered haulage. Although overall nonfatal disabling injury rates increase with increasing seam height (see table 16), this trend is not evident within any mine size category. However, all nonfatal disabling injury rates for mines with 50 or more employees are higher than any of the rates for the smaller mines. Both fatal and nonfatal injury trends reflect that these types of powered haulage are predominantly used by larger mining operations.

Table 17.—Number and rate (per 200,000 hr) of nonfatal disabling injuries from locomotive accidents by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	6	.05	3	.01	11	.14	11	.12	31	.06
Medium	3	.05	7	.03	15	.09	24	.11	49	.08
High	0	.00	2	.02	5	.06	41	.12	48	.09
Overall	9	.04	12	.02	31	.10	76	.12		

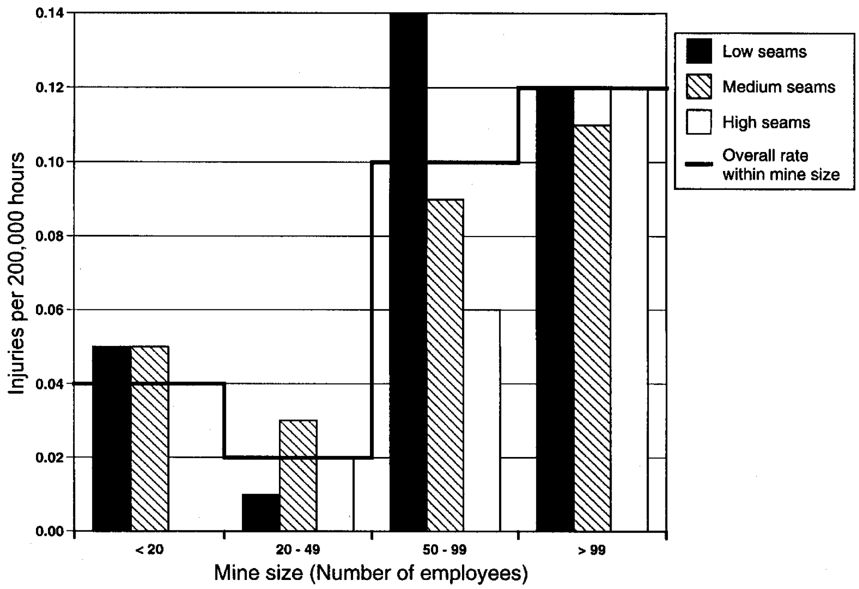

Figure 26.—Rate of nonfatal disabling injuries from locomotive accidents by mine size and seam height, 1990-94.

SLIPS AND FALLS

Injuries obtained when a miner either slips or falls are expected to increase as seam height increases. Except for the largest mines, nonfatal disabling injury rates related to the slip or fall of a miner increases with increasing seam height both overall as well as within each mine size category (see table 18 and figure 27). Note that the strength of this increasing trend diminishes as mine size increases. A similar observation was made in the preliminary analysis of nonfatal disabling injury rates for miners injured while walking or running (refer to figure 10).

FALLS OF GROUND

Ground fall accidents are classified separately as due primarily to a fall of rock from either the mine roof or the mine rib. When incidents classified as machinery-related ground fall accidents are included with accidents classified directly as ground falls, they total 3,521 and account for 15.6% of all nonfatal disabling underground injuries. Machinery-related ground fall accidents, discussed previously, account for 42.3% of all ground fall accidents and include both falls of roof and rib. Accidents attributed directly to falls of roof account for another 47.9%; the remaining 9.8% are attributed directly to falls of the mine rib. Fatal injuries classified as ground falls accounted for 83 (46.1%) of the 180 fatal underground injuries examined. Of these 83 fatalities, 80 were directly attributed to falls of roof and 3 to falls of rib. Nonfatal disabling injury rates will be examined separately for each of the three types of ground fall accidents, and fatal injury rates will be examined for falls of roof.

Table 18.—Number and rate (per 200,000 hr) of nonfatal disabling injuries from slips or falls by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	61	.49	148	.59	76	.94	176	1.87	461	.84
Medium	51	.80	200	.96	187	1.18	423	1.87	861	1.31
High	42	1.76	177	1.64	128	1.54	893	2.63	1,240	2.23
Overall	154	.72	525	.93	391	1.21	1,492	2.26		

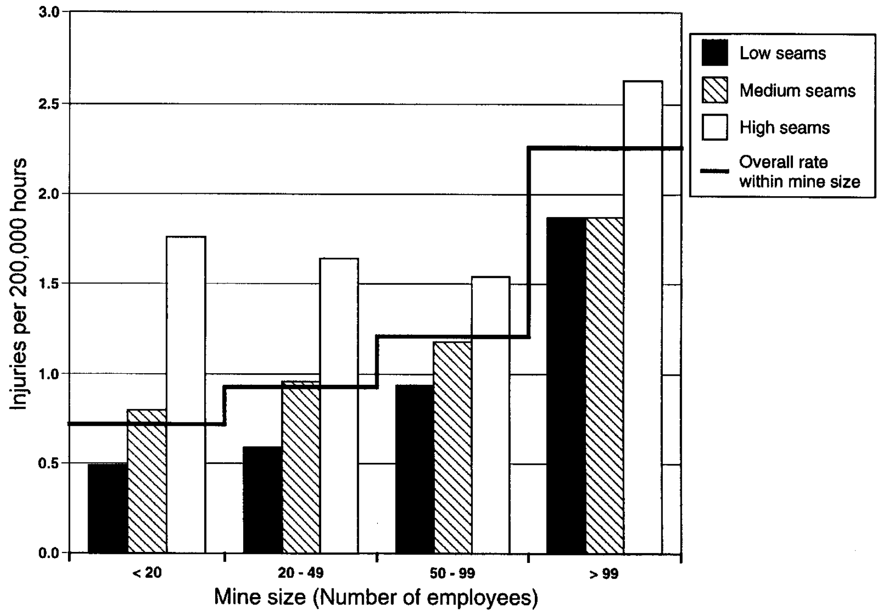

Figure 27.—Rate of nonfatal disabling injuries from slips or falls by mine size and seam height, 1990-94.

Nonfatal Disabling Injuries Resulting From Falls of Roof

Overall nonfatal disabling injury rates due to falls of roof increase as seam height increases, with a noticeably larger increase from medium to high seams (see table 19 and figure 28). Although this increasing trend is observed for only the smallest and largest mines, injury rates in low seams are consistently lower than rates in high seams within all mine sizes.

Table 19.—Number and rate (per 200,000 hr) of nonfatal disabling injuries from falls of roof by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	107	.86	243	.97	71	.88	52	.55	473	.86
Medium	69	1.08	189	.91	150	.95	170	.75	578	.88
High	28	1.17	133	1.23	75	.90	399	1.17	635	1.14
Overall	204	.96	656	1.00	296	.92	621	.94		

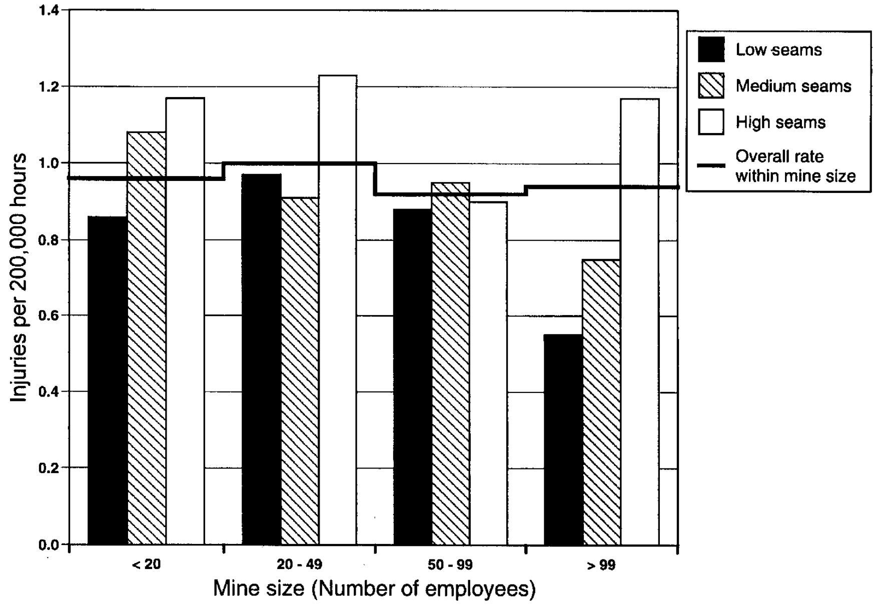

Figure 28.—Rate of nonfatal disabling injuries from falls of roof by mine size and seam height, 1990-94.

Fatal Injuries Resulting From Falls of Roof

In contrast to the trends observed for nonfatal disabling injury rates, the rates of fatalities due to falls of the mine roof show more variation across mine size than across seam height (see table 20 and figure 29). As mine size increases, the overall fatality rate sharply decreases. Although these rates decline overall as seam height increases, this trend, which is the reverse of that observed for nonfatal disabling roof fall injuries, persists only within the smallest mine size. Conversely, within the two largest mine size categories, fatality rates increase with increasing seam height, which is consistent with trends observed for nonfatal disabling injuries.

Roof fall fatalities can be further differentiated as to whether the victim was standing under supported or unsupported roof at the time. A previous study reported higher fatality rates in low seams than in high seams for falls of roof in which the victim was positioned inby permanent roof supports [Peters and Fotta 1994a]. Using fatality investigation reports, a determination was made as to whether the victim was positioned under supported roof or unsupported roof. Of the 80 roof fall fatalities, 50 were due to falls of supported roof; the remaining 30 were due to falls of unsupported roof. The distribution across seam height and mine size of the numbers and rates of these fatalities is presented in tables 21 and 22, respectively.

The rate of fatalities due to falls of supported roof declines overall as mine size increases (see figure 30). The overall rate for the smallest mines is about seven times that for the largest mines. Variations in these rates show no obvious relation to variations in seam height.

Fatality rates associated with falls of unsupported roof decline overall as seam height increases (see table 22 and figure 31). However, this decreasing trend is observed only for the two smaller mine sizes. The decline related to mine size is a particularly strong trend, with rates decreasing by at least one-half with each subsequent increase in mine size. The two highest rates are observed for the smallest mines operating in the low and medium seam heights. In fact, these mines accounted for 43% (13 out of 30) of unsupported roof fall fatalities, but only 11% of underground employee hours.

Table 20.—Number and rate (per 200,000 hr) of fatal injuries from falls of roof by mine size and seam height, 1989-95

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	17	.097	12	.035	0	–	1	.008	30	.35
Medium	7	.079	16	.057	7	.031	3	.009	33	.15
High	2	.059	4	.027	6	.051	5	.011	17	.11
Overall	26	.087	32	.041	13	.029	9	.010		

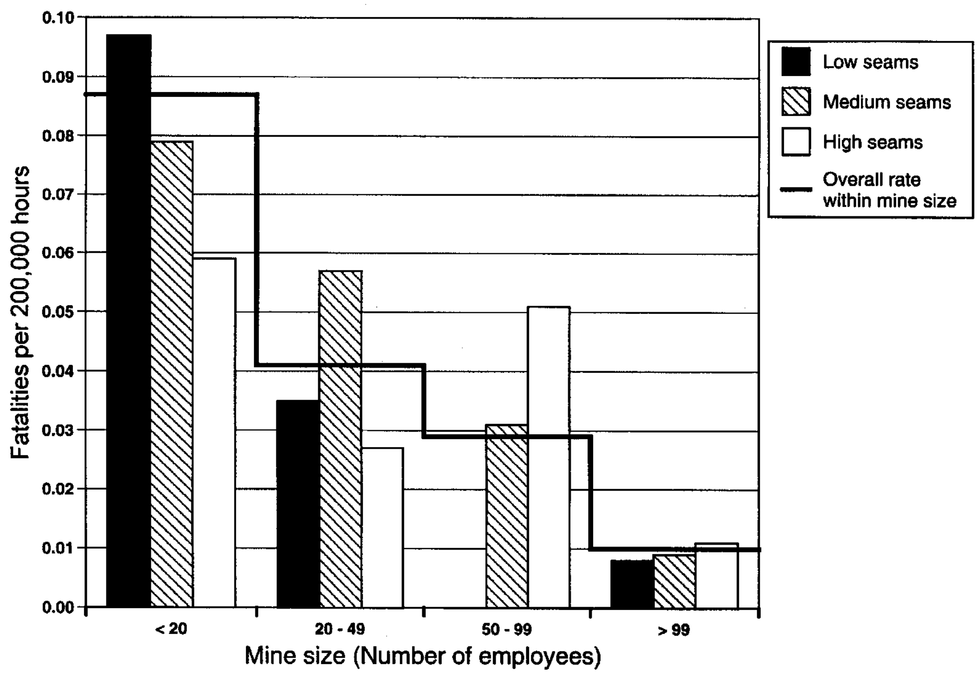

Figure 29.—Rate of fatal injuries from falls of roof by mine size and seam height, 1989-95.

Table 21.—Number and rate (per 200,000 hr) of fatal injuries from falls of supported roof by mine size and seam height, 1989-95

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	8	.045	5	.015	0	–	1	.008	14	.018
Medium	3	.034	13	.046	7	.031	2	.006	25	.027
High	2	.059	3	.020	3	.026	3	.006	11	.014
Overall	13	.044	21	.027	10	.022	6	.006		

Table 22.—Number and rate (per 200,000 hr) of fatal injuries from falls of unsupported roof by mine size and seam height, 1989-95

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	9	.051	7	.020	0	–	0	–	16	.021
Medium	4	.045	3	.011	07	–	1	.003	8	.009
High	0	–	1	.007	3	.026	2	.004	6	.008
Overall	13	.044	11	.014	3	.007	3	.003		

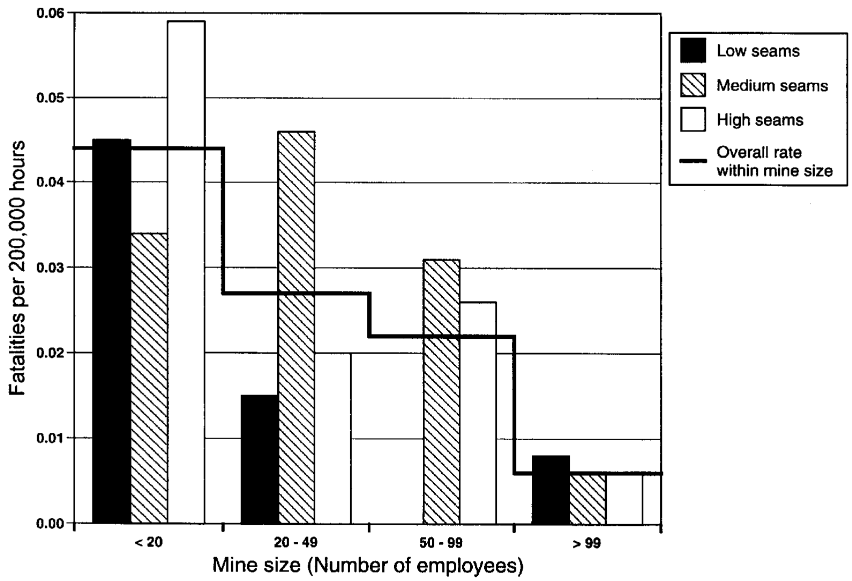

Figure 30.—Rate of fatal injuries from falls of supported roof by mine size and seam height, 1989-95.

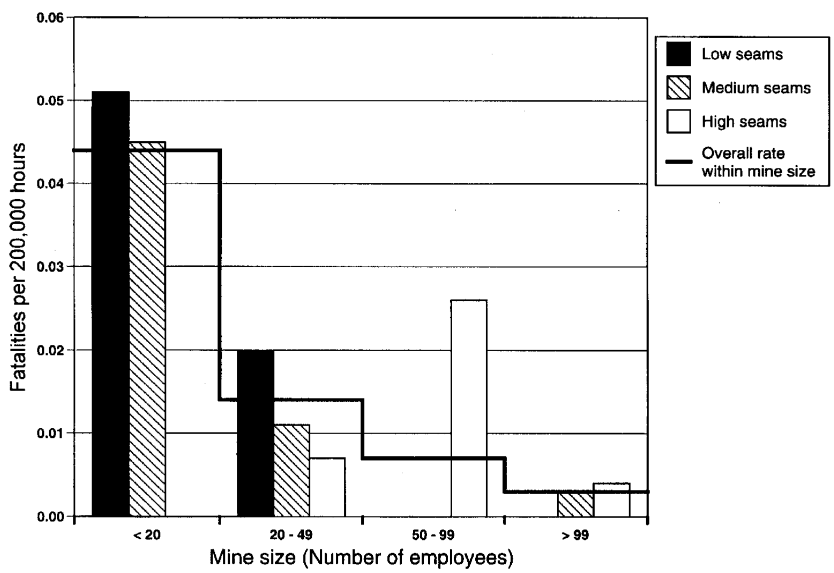

Figure 31.—Rate of fatal injuries from falls of unsupported roof by mine size and seam height, 1989-95.

Falls of Rib

Because the amount of exposed rib increases as mining height increases, the expectation is that injury rates for falls of rib will increase as seam height increases. Despite the relatively low frequencies of injuries related to rib falls, this increasing trend is evident overall as well as within two of the four mine size categories (see table 23 and figure 32). Although injury rates in low and medium seams within the smallest mine size are the same, the highest rate occurs within high seams.

Table 23.—Number and rate (per 200,000 hr) of nonfatal disabling injuries from falls of rib by mine size and seam height, 1990-94

Seam height	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	11	.09	33	.13	13	.16	22	.23	79	.14
Medium	6	.09	40	.19	36	.23	34	.15	116	.18
High	7	.29	39	.36	29	.35	75	.22	150	.27
Overall	24	.11	112	.20	78	.24	131	.20		

Mine size (No. of employees) spans the <20, 20-49, 50-99 and >99 columns.

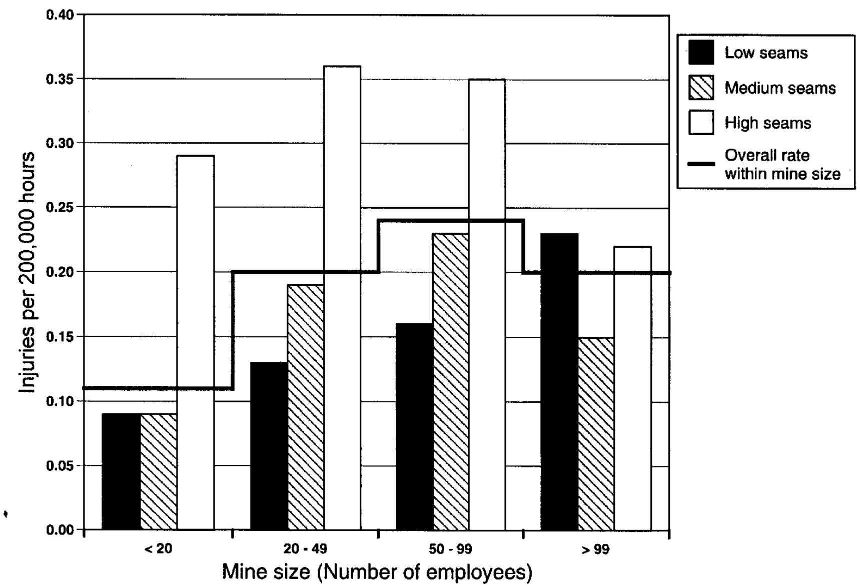

Figure 32.—Rate of nonfatal disabling injuries from falls of rib by mine size and seam height, 1990-94.

Conversely, within the largest mine size, the highest rate is observed in low seams. All three of the fatal injuries due to falls of rib occurred in high seams for mines with 20-49 employees.

Machinery-Related Falls of Ground

As previously noted, machinery-related ground fall accidents include both falls of the mine roof as well as falls of rib. Although nonfatal disabling injury rates associated with these accidents increase slightly overall as seam height increases, this increasing trend persists only for the largest mines and mines with 20-49 employees (see table 24 and figure 33).

USE OF NONPOWERED HAND TOOLS

Nonfatal disabling injury rates for accidents involving the use of hand tools show no obvious trends related to seam height (see table 25 and figure 34). Mines with fewer than 20 employees have the lowest rates of injury within every level of seam height; the largest mines have the highest rates overall.

Table 24.—Number and rate (per 200,000 hr) of nonfatal disabling injuries from machinery-related falls of ground by mine size and seam height, 1989-95

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	112	.90	205	.82	64	.79	62	.66	443	.81
Medium	49	.77	199	.96	130	.82	159	.70	537	.82
High	19	.79	107	.99	66	.79	318	.93	510	.92
Overall	180	.85	511	.90	260	.81	539	.82		

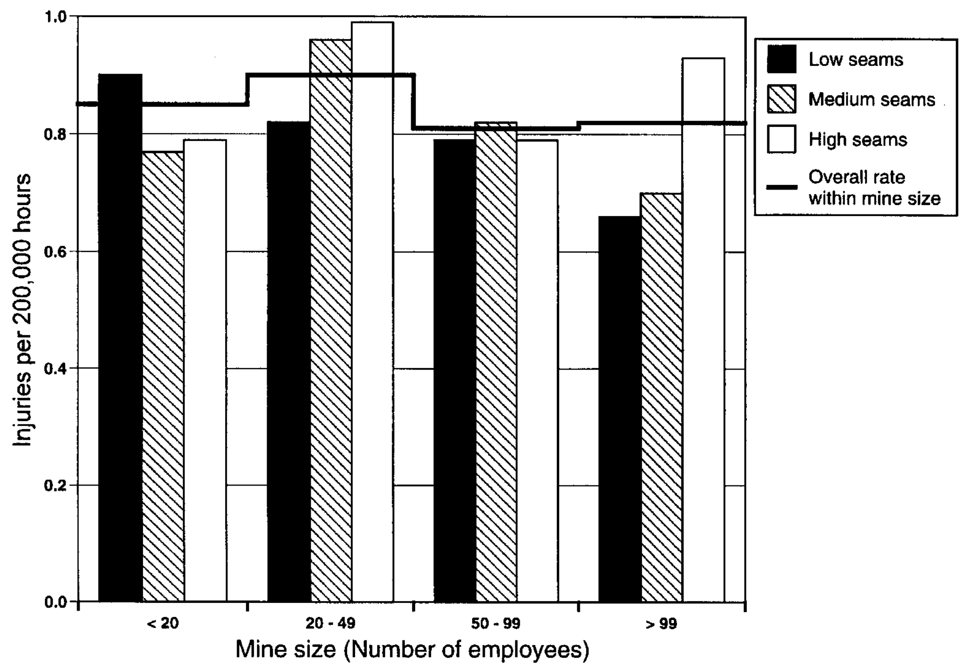

Figure 33.—Rate of nonfatal disabling injuries from machinery-related falls of ground by mine size and seam height, 1990-94.

Table 25.—Number and rate (per 200,000 hr) of nonfatal disabling injuries from the use of nonpowered hand tools by mine size and seam height, 1990-94

Seam height	Mine size (No. of employees)									
	<20		20-49		50-99		>99		Overall	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Low	90	.72	222	.89	74	.92	96	1.02	482	.88
Medium	41	.64	167	.80	135	.85	189	.84	532	.81
High	16	.67	101	.93	59	.71	337	.99	513	.92
Overall	147	.69	490	.87	268	.83	131	.94		

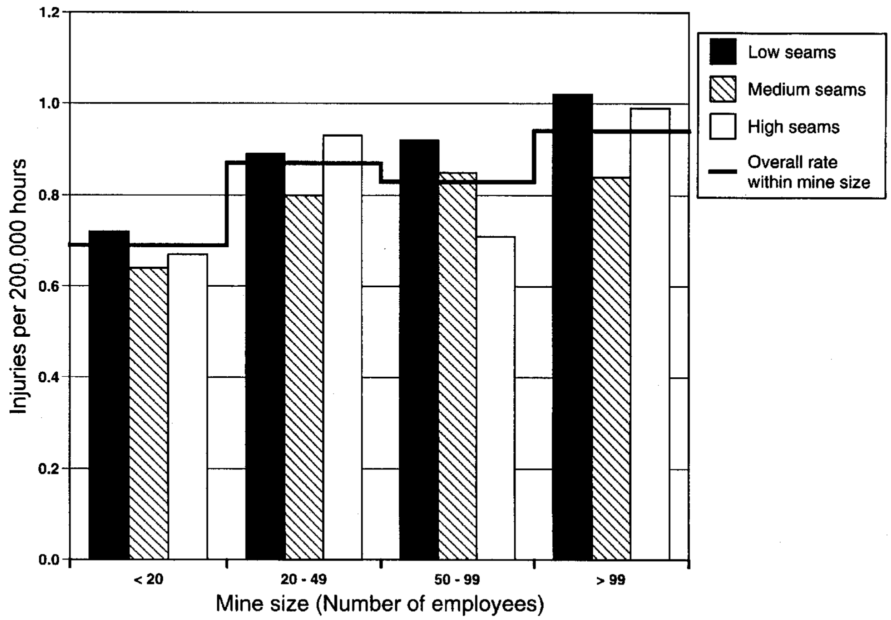

Figure 34.—Rate of nonfatal disabling injuries from the use of nonpowered hand tools by mine size and seam height, 1990-94.

SUMMARY

Few of the trends in injury rates across seam height described in this report were as strong as those observed in the preliminary analysis of injuries related to the activities of walking/running and crawling/kneeling. The most consistent trend in injury rates associated with differences in seam height was observed for nonfatal disabling injury rates for accidents involving load-haul-dump types of powered haulage equipment (refer to figure 23). For these types of accidents, injury rates declined as seam height increased within every category of mine size. However, the strength of the trend also decreased as the size of the mining operation increased. As discussed previously, using mine-level average coal seam heights to approximate actual mining height at the scene of an accident may become less reliable as the size of a mining operation increases. This may explain why injury rates for accidents involving slips/falls and rib falls did not show the expected increases within the largest mine size category (refer to figures 27 and 32, respectively). Despite these aberrations, the trends in injury rates for several categories of accidents suggest a relationship, whether direct or indirect, to mining height.

In several cases, although a steadily increasing or decreasing trend was not observed within each mine size category, the highest or lowest injury rates were consistently observed within one level of seam height across all mine sizes. For example, the lowest rates of injuries involving shuttle cars and the highest rates of injuries involving powered haulage conveyors were observed in low seams across all mine sizes (refer to figures 22 and 25, respectively). Similar, but less consistent observations were made for several other types of accidents. Both fatal and nonfatal injury rates for machinery accidents involving roof bolters were lowest in high seams, except for the largest mines (refer to figures 16 and 17, respectively). Additionally, nonfatal injury rates increased with increasing seam height for mines with 20-49 and 50-99 employees. The highest rates of injuries involving powered haulage personnel carriers were also observed in low seams, again except for the largest mines (refer to figure 24). The highest rates of nonfatal injuries resulting from falls of roof were observed in the highest seams, except for mines with 50-99 employees (refer to figure 28). Additionally, these rates increased with increasing seam height for both the smallest and largest category of mines.

The distributions of fatal injury rates for accidents involving falls of the mine roof varied considerably depending on whether the victim was positioned under supported or unsupported roof. Rates of fatal injuries resulting from falls of supported roof showed no consistent trend relating to changes in seam height, but showed a marked relationship to changes in the employment size of the mine (refer to figure 30). Although fatal injury rates associated with falls of unsupported roof showed a similar relationship to mine size, for mines with fewer than 50 employees the trends appeared to be related to changes in seam height (refer to figure 31). Previous researchers have suggested various reasons why miners working in low seams may be more likely to venture under unsupported roof [Peters and Fotta 1994a]. One contributing factor may be the absence of protective canopies on equipment. Mines operating in heights of less than 42 in may apply for exemption from the requirement for canopies. Of the 80 roof fall fatalities, 9 involved miners operating equipment without a canopy. Seven of the nine fatalities occurred in low seams; two, in medium seams.

Although there appeared to be little relation to seam height for accidents involving handling materials, continuous mining machines, and powered haulage locomotives, variations related to mine size were observed in the injury rates for these accidents. Nonfatal disabling injury rates for material handling accidents showed substantial increases with increasing mine size within every level of seam height (refer to figure 14). For accidents involving continuous mining machines, both fatal and nonfatal injury rates decreased as mine size increased (refer to figure 19). This is particularly significant given that exposure hours to this type of equipment are probably inflated for smaller mines, which are more likely to employ both conventional and continuous mining methods. The injury rates for accidents involving powered haulage locomotives were substantially higher for mines with 50 or more employees than for those with fewer than 50 employees. This latter difference is not unexpected given that this type of powered haulage is more prevalent in larger mining operations.

In summary, nonfatal disabling injury rates for accidents involving slips/falls, shuttle cars, and ground falls increased as seam height increased. On the other hand, nonfatal disabling injury rates for accidents involving load-haul-dumps, personnel arriers, powered haulage conveyors, and roof bolting machines decreased as seam height increased. For mines with fewer than 50 employees, fatal injury rates for accidents involving falls of unsupported mine roof decreased as seam heights increased. Finally, a disproportionate number of fatalities from accidents involving shuttle cars and roof bolting machines occurred in low- and medium-seam heights.

DISCUSSION

The working height of an underground bituminous coal mine can directly affect safety in a number of ways. As the working height decreases to the extent that miners must stoop, duck, or crawl, the miners' vision, posture, and mobility become increasingly restricted. The increased physical demands placed on the miner working in low-seam heights may be reflected in the younger ages observed for miners injured in low-seam mines. Additionally, as mining height decreases, the mine roof increasingly becomes an additional source of injury to the miner. Although equipment is sized proportionally for thinner coal seams, the height restriction puts limitations on placements of operator compartments and affects what and how much an operator can see while in the cab. Lower mining heights can also make tasks more difficult to perform, such as requiring a roof bolter operator to bend and unbend long roof bolts in order to insert them into the mine roof. A safety concern at medium-seam operations is posture. Miners working at these heights cannot lift by using the traditionally advocated safe lifting procedures. Laboratory studies of the effects of lifting materials using different postures (e.g., kneeling, stooping, etc.) suggest that working heights in the medium range (about 48 to 72 in) are more stressful on the back than those that require a person to remain kneeling or that allow a person to stand [Gallagher et al. 1995]. Reduced mobility is another concern in lower seam heights. Miners who must duck walk or crawl from place to place within their work area may be moving more slowly and with greater expenditure of energy than those who are free to walk upright or even run if the situation requires. On the other hand, this increased mobility can also create problems, as shown by the increased rate of slip and fall injuries in higher seam heights. Visibility, limits to mobility, and posture restrictions can all affect miners' safety and health. To appropriately focus prevention efforts for the underground bituminous coal industry, statistical analyses of injury data can provide direction for more detailed research. On the basis of this preliminary analysis, the effects of mining height warrant further investigation involving a more detailed examination of the injury records, as well as task analyses of mining activities such as roof bolting in various mining heights. Additionally, more information regarding the amount of exposure to different types and makes of equipment is required to determine whether differences in the rates of injuries for machinery and powered haulage accidents are directly or indirectly related to differences in mining height or mine size, or both.

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