Injuries and illnesses among bituminous and lignite coal miners

Data indicate that surface mining is safer than underground mining; the preponderant injury categories are sprain, contusion, cut, and fracture; the preponderant illness category is 'dust diseases of the lungs'

Jack Reardon

Coal is one of the most important sources of energy in the United States, accounting for 33 percent of total domestic energy production.[1] But the future of coal as a leading source of energy is in doubt because of its high sulfur content and contribution to acid rain.[2] Nevertheless, for now and at least for the next generation, coal is likely to be an important source of energy production in the United States.[3]

As debate continues over the use of coal, policymakers would benefit from detailed information on the frequency and nature of injuries and illnesses incurred by workers mining coal. This article describes mining processes associated with the coal industry and, more specifically, the factors associated with injury and illness in the bituminous and lignite coal industry.[4] Bituminous coal is a mineral coal that burns with a smoky, yellow flame, and lignite is a low-grade, brownish-black coal. This article briefly describes the history and work processes in coal mining, provides information about injuries and illnesses among coal miners, and offers some concluding observations and comments.

The industry at a glance

Coal has been mined commercially in the United States since colonial times, but it was not until the mid-19th century that the demand for coal began to escalate, increasing at a rate of nearly 11 percent annually.[5] Industrialization, particularly the development of the railroads, provided the impetus for demand, while at the same time woodlands on the Atlantic coast were being depleted.[6] By 1890, coal had emerged as one of the most important sources of domestic energy consumption and remained as such until the late 1940's, when competition from cheap oil in the Middle East diminished coal's relative importance.[7]

Electric utilities have emerged as the most important consumer of coal during the last 40 years. During the 1940's, utilities consumed an average of about 16 percent of domestic coal production and, by 1990, that proportion increased sharply to 86 percent.[8] In the next 20 years at least, utilities are expected to continue as the Nation's major consumer of coal.[9]

Several factors account for the emergence of utilities as the most important customer of coal. First, utilities, with their own supply of coal, used that supply to obtain bargaining leverage in negotiations with other coal suppliers.[10] Second, the expectation that oil prices would continue to rise during the 1970's prompted many utilities to secure their own long-term coal supplies.[11] Third, utilities purchased coal companies as a defensive strategy against what was perceived as a growing monopolization of the coal industry by the oil conglomerates.[12]

The increasing consumption of coal by utilities is one factor contributing to the dramatic decline in

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the number of mines that produce fewer than 50,000 tons of coal per year. In 1970, 4,006 such mines accounted for 72 percent of the total mines in the United States and 10 percent of total U.S. production; by 1988, 1,112 such mines accounted for 39 percent of total mines and 3 percent of total U.S. production.[13] One explanation for this decline is that utilities require a supply commitment of several years that many of the smaller mines cannot guarantee.[14]

Therefore, at least for the immediate future, the fortunes of the U.S. coal industry will depend largely on which fuel utilities primarily choose.[15] The mandates of the 1990 Clean Air Act, which substantially curbs the emissions of sulfur dioxide, and concerns related to global warming and the role that the carbon content of coal plays in that concern, will influence this choice.

The sulfur content of coal varies widely among geographic regions.[16] As a general rule, however, western coal is lower in sulfur content than Appalachian or midwestern coal. The West contains 86 percent of U.S. low-sulfur coal reserves, while Appalachia contains 13 percent, and the Midwest contains 1 percent, indicating that the West will continue to grow in relative importance as a coal-producing region.[17]

Coal is mined from the surface or underground. In 1990, coal from surface mines accounted for 59 percent of total U.S. coal production.[18] During the last 40 years, a greater percentage of U.S. coal has been mined from the surface. Three reasons account for this development. One, the machinery used in surface mining has more alternative uses, primarily in excavation and road construction, than machinery used in underground mining, which reduces the cost of exit for operators.[19] Two, the coal best suited for use by utilities is steam coal, which is found close to the surface.[20] Three, average surface productivity (measured in short tons per miner per shift) is approximately double that of underground productivity. And regional differences are even more pronounced: for example, surface coal productivity in the West is about five times that in Appalachia. Surface mining tends to be more productive because the coal is closer to the surface and is easier to mine (especially evident in the West) and because surface mines employ fewer workers—about 25 percent—than underground mines due to technological requirements.

Mining processes

Underground and surface mining use different methods to process coal and thus have different hazards facing the miner. Following is a discussion of the processing methods and attendant hazards.

Underground mining. The two methods of mining coal underground are the *room and pillar*, which accounts for 70 percent of the total coal mined underground in the United States, and the *long wall*, which accounts for 29 percent.[21]

In the *room and pillar* method, a series of underground rooms is constructed, and as the coal is extracted from the room the miners leave pillars to support the roof. The two major techniques of this method are the conventional approach, which accounted for 7 percent of the total coal mined underground in 1990, and the continuous approach, which accounted for 63 percent.[22]

In conventional mining, a machine undercuts the coal face and then a second machine drills holes into the face. Explosives are placed in the holes and the loose coal will fall based on the undercuts made. A mechanical device scoops up the loose coal and transports it outside the mine. Finally, the roof is supported, allowing the procedure to begin again.[23]

Continuous mining, by far the most frequently used room and pillar method, consolidates the first four steps of conventional mining into one operation. A continuous mining machine scoops out the coal from the face. A loading machine transfers

Table 1. **Occupational injury and illness rates for the bituminous coal industry and all private industry, United States, 1989–90**

Industry and year	Incidence rates per 100 full-time workers[1]		
	Total injury and illness cases	Lost workday cases	Lost workdays[2]
Private industry:			
1989	8.6	4.0	78.7
1990	8.8	4.1	84.0
Bituminous coal mining:			
1989	11.6	8.3	253.0
1990	10.8	8.2	140.9

[1] For method of calculation, see footnote 38 to text.

[2] Lost workdays consist of days away from work and days of restricted acitivity. Unlike Mine Safety and Health Administration measures, the Bureau of Labor Statistics does not include "time charges" to estimate lost worktime for fatalities and permanent injuries. Thus, BLS estimates primarily relate to days lost or restricted in the year of the incident.

NOTE: The lost workdays rates for bituminous coal mining differ slightly from those published for all coal mining (including bituminous and anthracite coal) in 1989 (254.8) and in 1990 (141.7). The case rates for bituminous coal and all coal mining are identical for those years.

SOURCE: *Occupational Injuries and Illnesses in the United States, by Industy, 1990*, Bulletin 2399 (Bureau of Labor Statistics, 1992).

the coal to a conveyor belt that transports the coal outside. Finally, the roof is secured, enabling the continuous mining machine to advance.

The *longwall* method of underground mining uses a longwall machine to shear off long slices of coal from the face. The coal falls into a conveyer belt that transports it outside. As the longwall machine advances, the roof behind it is allowed to collapse. This decreases the geological stress in areas still to be mined, thus reducing the chances of a roof collapse later.[24] The longwall machine has built-in roof supports to protect the miner as it advances.

Several hazards confront miners who use either the room and pillar or the longwall method. The ever-present danger of an inadvertent roof collapse is one hazard. As coal is mined, the overlying rock strata is exposed and must be supported before mining continues. The task of supporting the roof (by a roof bolter) is one of the more dangerous jobs in underground mines; but even after the roof is supported, the danger of a roof fall remains.

Another hazard of underground mining is the noise generated by the machinery. The conventional and continuous methods generate noise levels of more than 105 decibels, which can create hearing impairment if the worker is exposed over time.[25] Such noise also is a safety hazard because it prevents the miner from hearing shifts of the roof—often a harbinger of a roof fall.[26]

A third hazard is methane gas, which is colorless, odorless, and can be ignited in concentrations of 5 percent to 15 percent of the mine atmosphere.[27]

A fourth hazard is the dust generated by machinery. Dust levels in underground mines increased substantially with the introduction of continuous mining machines during the 1950's. Dust is a safety hazard because it impairs visibility, and a health hazard because it is responsible for pneumoconiosis, or black lung disease.[28] Although not conclusive, evidence indicates that dust generated by the longwall method is greater than dust generated by either the conventional or continuous room and pillar method.[29]

Other hazards associated with underground mining include the dangers of electrocution from wires and cables used to power equipment, being hit by mining machines and equipment that have little room to maneuver, and inhalation of diesel fumes.[30]

Surface mining. Four methods are used in surface mining: area, open pit, contour, and auger.[31] The area and open pit methods, used primarily in the Midwest and the West where land usually is flat, develop a series of long open pits on surfaces. The difference between the two methods is one of scale: area mining uses much larger tracts of land than does open pit mining.

Table 2. **Distribution of total injuries in bituminous coal mining operations by type of operation and nature of injury, United States, 1990**

Physical condition	Underground		Surface	
	Total injuries	Percent of total	Total injuries	Percent of total
Total	11,363	100	2,428	100
Amputation	50	(1)	9	(1)
Burn/scald	78	1	61	3
Chemical burn	45	(1)	27	1
Contusion/bruise	1,731	15	214	9
Fracture	1,152	10	239	10
Scratch/abrasion	81	1	35	1
Sprain/strain	4,783	42	888	37
Multiple injuries	781	7	203	8
Cut/puncture	1,699	15	481	20
All other	963	8	271	11

[1] Less than 0.5 percent.

NOTE: Columns may not add to 100 percent due to rounding.

SOURCE: *Injury Experience in Coal Mining, 1990*, Information Report 1205 (Denver, CO, Mine Safety and Health Administration, 1991), pp. 126 and 128.

Table 3. **Distribution of injuries in bituminous coal mining operations by type of operation and event or exposure, United States, 1990**

Accident classification	Underground		Surface	
	Total injuries	Percent of total	Total injuries	Percent of total
Total	11,363	100	2,428	100
Electrical	134	1	20	1
Handling material	3,957	35	715	29
Hand tool	1,144	10	309	13
Powered haulage[1]	1,365	12	218	9
Machinery	1,738	15	369	15
Roof fall	723	6		
Slip or fall (person)	1,431	13	601	25
Stepping or kneeling on object	243	2	53	2
Striking or bumping	184	2	7	(2)
Fall of face, rib, side or highwall	174	2	23	1
All other	270	2	113	5

[1] Accident related to the motion of powered haulage equipment such as forklift, trucks, and conveyors.

[2] Less than 0.5 percent

NOTE: Columns may not add to 100 percent due to rounding.

SOURCE: *Injury Experience in Coal Mining, 1990*, Information Report 1205 (Denver, CO, Mine Safety and Health Administration, 1991), pp. 250 and 252.

The other two mining methods, contour and augur, are used primarily in Appalachia, where deposits of coal are found in hills and mountains. Both methods involve drilling into the coal seam. The contour method extracts coal by vertical drilling. The augur method is used if the terrain is too steep to allow vertical drilling: the coal is extracted by drilling horizontally into the coal seam. Contour and auger mining occur on a much smaller scale than do area and open pit mining.

Area, open-pit, and contour mining involve the following steps:[32] top soil is removed from the

surface to be mined; overburden—rock or shale—is removed, primarily by blasting; the coal is fractured, primarily by blasting; coal is loaded, using coal shovels, front-end loaders, and trucks; the overburden is back-filled; top soil is returned and the area is revegetated.

Surface miners also are exposed to dust and noise, particularly operators of trucks and earth moving equipment, although on a smaller scale than underground miners.[33] Surface miners also face the hazard of falling support materials and props, rock falls, and mishaps with machinery.

Injury and illness experience

Of the 131,000 bituminous coal miners employed in 1990, 83,840 worked in underground mines and 47,160 worked on surface mines.[34]

Several measures used by the Mine Safety and Health Administration indicate that surface mining is safer than underground mining. The fatality incidence rate for underground mines in 1990 was 6 per 10,000 full-time workers, compared with 2 per 10,000 workers for surface mines.[35] And the nonfatal disabling injury rate for underground mines, at 12.4 per 100 full-time workers, was much higher than that of surface mines, 3.6 per 100 workers. These data indicate that underground miners have a higher probability of incurring an injury, measured in terms of exposure, than do surface miners.[36] Also, the severity measure for bituminous coal mining (including all fatal and nonfatal disabling injuries) in 1990 was 979 workdays lost per 100 full-time workers for underground miners, compared with 270 days lost for surface mining.[37]

The Bureau of Labor Statistics also reports the incidence of occupational injuries and illnesses for workers in bituminous coal mining as a whole. The BLS incidence rate, calculated in terms of 100 full-time workers, is a proxy for the level of risk for injury and illness.[38] The rate of 10.8 total injuries and illnesses per 100 full-time workers for bituminous miners is two points higher than the corresponding rate for all private industry in 1990. (See table 1.) The lost workday case rate measures the number of injuries and illnesses per 100 full-time workers that result in days away from work or restricted work duties, or both. The lost workday case rate for the bituminous coal industry is double that of the private sector. Another measure of the severity of an injury is the total lost workdays per 100 full-time workers: the rate of lost workdays for bituminous coal in 1990 was nearly double that of all private industry.

Occupational injury and illness rates provide useful information at the industry level, but do not provide detailed data on the characteristics of the injury and illness. This information is available from the Mine Safety and Health Administration.[39]

The distribution of total injuries by physical condition show that the preponderant injury category is sprain/strain, accounting for 42 percent of the cases reported in underground mines, and 37 percent of the cases reported for surface mines. (See table 2.) The three categories of contusion/bruise, cut/puncture, and fracture combined account for 40 percent of injuries reported in underground mines and 38 percent for surface mines.

Of the 45 fatal injuries in underground mines, 22 were the results of a contusion/bruise, 11 resulted from multiple injuries, and 6 from an electrical shock. Of the 9 fatalities for surface mining, 4 resulted from multiple injuries.

Event or exposure. The distribution of occupational injuries by event or exposure shows that the category "handling material" led all others, accounting for 35 percent of the underground mining total and 29 percent of all surface mining injuries in 1990. (See table 3.) When "handling material" was cited, the most common injury was a sprain or strain, primarily to the back.

In underground mining, four other event/exposure categories—machinery accidents, persons slipping or falling, accidents involving powered haulage equipment, and events/exposures involving nonpowered hand tools—accounted for be-

Table 4. **Distribution of injuries in bituminous coal mining operations by type of operation and occupation, United States, 1990**

Operation type and occupation	Total injuries	Percent of total
Underground:		
Total	11,363	100
Mining machine operator	1,063	9
Laborer	2,257	20
Haul dump	1,268	11
Electrician	569	5
Mechanic/maintenance	1,187	10
Rock, roof bolter	1,812	16
Supervisor/foreman	945	8
All other	2,262	20
Surface:		
Total	2,428	100
Bulldozer, mobile equipment operator	315	13
Laborer	207	9
Mechanic/maintenance	770	32
Front end loader	143	6
Supervisor/foreman	81	3
Truck driver	232	10
Welder/machinist	211	9
Drill operator	103	4
All other	366	15

NOTE: Columns may not add to 100 percent due to rounding.

SOURCE: *Injury Experience in Coal Mining, 1990*, Information Report 1205 (Denver, CO, Mine Safety and Health Administration, 1991), pp. 231–32.

tween 10 percent and 15 percent each of the injury total. In surface mining, persons slipping or falling was cited nearly as frequently (25 percent) as handling materials. The steepness of the grade partially explains why slipping and falling occurs more often in surface mining than in underground mining.

In both types of mining, slips and falls resulted typically in a sprain or strain injury, commonly to the back or the knees.

Of the 45 fatalities in underground mining, nearly half (21) resulted from roof falls.[40] Of the 21 fatal roof falls, 12 resulted in a contusion/bruise and 5 in multiple injuries. Machinery accidents accounted for eight fatalities in underground mining, and electrical incidents or powered haulage equipment were involved in six fatalities each.

Of the nine fatalities in surface mining, powered haulage equipment was involved in deaths of three workers, and machinery and persons slipping and falling in two deaths each.

Occupation. The distribution of bituminous coal mining injuries by occupation indicates that two occupational categories led all others in underground mining injuries—laborer and rock/roof bolter each accounted for between 15 percent and 20 percent of the total injuries reported in those operations in 1990. (See table 4.) Four other occupational activities each accounted for about 10 percent of the underground mining total—mining machine operator, haul/dump, mechanic/maintenance, and supervisor/foreman.

In surface mining, mechanic/maintenance was by far the major occupation/activity of the injured, accounting for 32 percent of the total injuries in those operations. Next in frequency were bulldozer/mobile equipment operator and truck driver, each with between 10 percent and 15 percent of the total.

Of the 45 fatalities in underground mining, the leading occupational categories were mining machine operator (nine deaths) supervisor/foreman (eight) and electrician (six). In surface mining, bulldozer/mobile equipment operator was cited in three of the nine fatalities and laborer or truckdriver in two other deaths each.

The risk of fatal injury for supervisors and foremen is much higher in underground mining, which exposes them to roof falls at the mine face, than in surface mining, where they work at dispersed sites.

For both sectors, the preponderant major body part affected by an injury is the trunk, accounting for roughly a third of each injury total. (See table 5.) Nearly three-fourths of the trunk injuries affected the back; most of the remaining trunk injuries are divided about evenly among the chest, pelvic region, and shoulders. Upper extremity injuries are about one-fourth of the total in each mining sector. In underground mines, 1,536 of the 2,719 upper extremities injuries affected the fingers and 485 affected the hand. In surface mines, 292 of the 555 upper extremities injuries affected the fingers and 102 affected the hand.

Lower extremity injuries are approximately one-fifth of the total in each mining sector. In surface mines, of the 463 injuries to lower extremities, 144 affected the knee and 113 affected the ankle. In underground mines, 949 of the 2,348 lower extremities injuries affected the knee, 479 affected the foot, and 353 affected the ankle. Head and neck injuries accounted for one-eighth of the underground mining total and nearly one-fifth of the surface mining total. As a percent of total injuries to the head and neck, eye injuries are more common for surface miners (44 percent of total injured) than for underground mining (29 percent of total injured). In contrast, neck injuries occur more frequently in underground mining (29 percent of head and neck total) than in surface mining (11 percent of total).

According to the Mine Safety and Health Administration, 471 of the 516 reported occupational

Table 5. **Distribution of injuries in bituminous coal mining operations by type of operation and major part of body affected, United States, 1990**

Physical condition	Underground		Surface	
	Total injuries	Percent of total	Total injuries	Percent of total
Total	11,363	100	2,428	100
Head and neck	1,450	13	430	18
Upper extremities	2,719	24	555	23
Trunk	4,088	36	763	31
Lower extremities	2,348	21	463	19
Multiple body parts	714	6	200	8
All other	44	(1)	17	1

[1] Less than 0.5 percent.

NOTE: Columns may not add to 100 percent due to rounding.

SOURCE: *Injury Experience in Coal Mining, 1990*, Information Report 1205, (Denver, CO, Mine Safety and Health Administration, pp. 105 and 108.

Table 6. **Occurrences reported to the Mine Safety and Health Administration as occupational illnesses in bituminous coal mining operations, by type of operation and illness category, United States, 1990**

Physical condition	Underground		Surface	
	Total illnesses	Percent of total	Total illnesses	Percent of total
Reported illness total	471	100	45	100
Dust diseases of the lungs	316	67	17	38
Disorders associated with repeated trauma	131	28	26	58
All other illnesses	24	5	2	4

SOURCE: *Injury Experience in Coal Mining, 1990*, Information Report 1205 (Denver, CO, Mine Safety and Health Administration, 1991), pp. 304–05.

illnesses in bituminous coal mining in 1990 occurred in underground mines, and 45 occurred in surface mines. (See table 6.)

Of the occupational illnesses in underground mines, 67 percent were "dust diseases of the lungs" and 28 percent were "disorders associated with repeated trauma," such as tendonitis and carpal tunnel syndrome. In surface mines, 58 percent of the occupational illnesses were "disorders associated with repeated trauma," while 38 percent were "dust diseases of the lungs."

These illness data indicate that in addition to dust diseases of the lungs, which have long been known as a major occupational illness in the coal industry, "disorders associated with repeated trauma" is an emerging problem in underground and surface mines and requires further investigation.

IN SUMMARY, material handling in bituminous coal mining, as in the private sector, is a major cause of injury that merits special attention. The data also suggest that efforts should focus on preventing conditions that lead to injuries caused by roof collapses in underground mines, particularly at reducing the vulnerability of supervisors to fatalities resulting from roof falls. Researchers and policymakers also should focus on reducing occupational illnesses to miners due to "disorders associated with repeated trauma." □

Footnotes

ACKNOWLEDGMENT: The author thanks Martin E. Personick of the Office of Safety, Health and Working Conditions, Bureau of Labor Statistics for helpful comments on an earlier draft of this article.

[1] See *Monthly Energy Review* (U.S. Department of Energy, March 1992), p. 7. Dry natural gas accounts for 27 percent of total domestic energy production; crude oil, 23 percent; nuclear electric power, 9 percent; hydroelectric power, 4 percent; other sources, 4 percent. However, petroleum accounts for 40 percent of the total U.S. energy consumption, which is the largest source of energy consumption. Coal and natural gas combined account for approximately 23 percent of total domestic energy consumption.

[2] When high sulfur coal is burned, it combines with oxygen to form sulfur dioxide, which can damage human health, forests, and vegetation. For a discussion of the origins of sulfur in coal, its distribution across the United States, and a discussion of the molecular content of coal, see Robert Noyes, ed., *Coal Resources, Characteristics and Ownership in the U.S.A.* (Park Ridge, NJ, Noyes Data Corp., 1978), pp. 45–49.

[3] For an argument that coal and other fossil fuels should be replaced by renewable sources of energy, see Christopher Flavin, "Building a Bridge to Sustainable Energy," in Lester Brown, ed., *State of the World* (New York, W. W. Norton, 1992), pp. 27–45.

[4] Lignite is the lowest rank of coal in heat content moisture. In 1990, lignite accounted for approximately 10 percent of the total coal mined in the United States. Excluded from this analysis is anthracite coal, which accounted for less than 1 percent of coal mined in 1990, and coal mining services for others on a contract or fee basis. See *Coal Data: A Reference*, (U.S. Department of Energy, 1991), p. 39.

[5] See Alexander M. Thompson III, *Technology, Labor and Industrial Structure of the U.S. Coal Industry* (New York, Garland Publishing, 1979), p. 19.

[6] See Thompson, *Technology, Labor*, p. 21; Curtis Seltzer, *Fire in the Hole* (Lexington, University of Kentucky Press, 1985), p. 5.

[7] See Thompson, *Technology, Labor*, p. 22.

[8] See *Monthly Energy Review*, March 1992, p. 84. For an expanded discussion, see Robert Johnson and Caleb Solomon, "Coal Quietly Regains a Dominant Chunk of Generating Market," *The Wall Street Journal*, Aug. 20, 1992, pp. A1 and A4.

[9] "NCA: U.S. Coal Production to Top 1 Billion Tons by 2000," *Coal*, May 1989, p. 9.

[10] Office of Technology Assessment, *The Direct Use of Coal*, (U.S. Government Printing Office, 1979), p. 112.

[11] Energy Information Administration, *The Changing Structure of the U.S. Coal Industry 1976–1986*. (U.S. Government Printing Office, 1988), p. 1.

[12] Thompson, *Technology, Labor*. p. 326. For a discussion of the "growing monopolization of the coal industry by the oil conglomerates;" see Jack Reardon, "Restructuring of the Oil Industry: A Comment," *Journal of Economic Issues*, September 1993.

[13] The 1970 figures are from Richard Hannah and Garth Mangum, *The Coal Industry and Its Industrial Relations* (Salt Lake City, UT, Olympus Publishing, 1985), p. 34. The 1988 figures are from Energy Information Administration, *Coal Production, 1988* (U.S. Government Printing Office, 1988), p. 30.

[14] The emergence of utilities is not the only causal factor in the reduction of the number of small mines. An argument has been made that the requirements of the Coal Mine Health and Safety Act put many small companies out of business, Garth and Mangum, *The Coal Industry*, p. 87; and Charles R. Perry, *Collective Bargaining and the Decline of the United Mine Workers* (Philadelphia, University of Pennsylvania, the Wharton School, Industrial Research Unit, 1984), p. 17. Increasing technological economies of scale have forced the smallest mines to close, *Coal Production 1988*, p. 11.

[15] See Perry, *Collective Bargaining*, p. 10; and Johnson and Solomon, "Coal Quietly Regains," p. A1.

[16] The three distinct coal mining regions in the United States are Appalachia, the Midwest, and the West. In 1990, the three regions accounted for 48, 20, and 33 percent of total U.S. coal production, *Coal Data*, p. 40. Partly reflecting the growth of strip mining, the West is the fastest growing region. In 1965 the West accounted for less than 5 percent of total U.S. coal production. By 2000, the National Coal Association predicts that the West will account for 50 percent of total coal production. "NCA: U.S. Coal," p. 9.

[17] *Coal Data*, p. 33.

[18] *Ibid.*, p. 44. In 1990, the West accounted for 50 percent of coal production from surface mines, and the Midwest and Appalachian regions accounted for 22 percent and 28 percent.

[19] Morton S. Baratz, *The Union and the Coal Industry* (Port Washington, NY, Kennikat Press, 1955), p. 13.

[20] Perry, *Collective Bargaining*, pp. 17–18.

[21] *Coal Data*, p. 10. The shortwall method is similar to the

longwall, except it utilizes a smaller working area. In 1990, the shortwall method accounted for 1 percent of total production.

[22] *Ibid.*, p. 10.

[23] The hand-cut technique of the room and pillar method is similar to the conventional, except hand labor is used instead of machinery. In 1990, the hand cut technique accounted for less than 1 percent of the coal mined underground. *Ibid.*, p. 10.

[24] Leslie I. Boden, "Underground Coal Mining Accidents and Government Enforcement of Safety Regulations," (Ph.D diss., Massachusetts Institute of Technology, 1977), p. 46.

[25] Michael Yarrow, "The Labor Process in Coal Mining: The Struggle for Control," in Andrew Zimbalist, ed., *Studies on the Labor Process* (New York, Monthly Review Press, 1979), p. 179. Sustained exposure to noise levels greater than 90 decibels during an 8-hour shift can cause hearing impairment.

[26] John P. David, "Earnings, Health, Safety and Welfare of the Bituminous Coal Miners Since the Encouragement of Mechanization by the United Mine Workers of America," (Ph.D diss., University of West Virginia, 1972), p. 153.

[27] Methane gas is an amalgam of gases of which methane is the largest constituent component, accounting for 80 percent to 99 percent of the total content. Other components include ethane, butane, propane, pentane, helium, hydrogen, and nitrogen. Maurice Duel and Ann G. Kim, *Methane Control Research: Summary of Results*, Bulletin 687 (U.S. Bureau of Mines, 1986), p. 15.

[28] Black lung disease represents a broad definition of occupational respiratory disabilities in coal miners, of which coal miner's pneumoconiosis is one major component. *The Direct Use of Coal*, p. 203. For a discussion of black lung disease see pp. 259–69.

[29] "Weeks Cites Dust and Noise as Major Hazard in Mines, *Coal Age*, May 1986, p. 17. "Dust Control Isn't Working," *United Mine Workers Journal*, February 1984, pp. 3–9. Also, *The Direct Use of Coal*, p. 269.

[30] Underground diesel equipment gained widespread use in the 1970's, and by 1989 approximately 15 percent of underground miners were exposed to diesel fumes. "Limit for Diesel Emissions Studied," *United Mine Workers Journal*, February 1992, p. 16. Diesel soot is small enough to travel through the respiratory system and carries with it cancer causing agents that contribute to contracting black lung disease. "Mine Workers Tell Congress: Diesel Standards Needed Immediately," *United Mine Workers Journal*, October 1989, p. 17. The Mine Safety and Health Administration announced in January 1992 that it will develop a permissible exposure level to govern the amount of diesel exhaust particulate in underground mines.

[31] This discussion is based on *The Direct Use of Coal*, pp. 64-66.

[32] *Ibid.*, pp. 65–66.

[33] *Ibid.*, p. 265.

[34] *Coal Data*, p. 39.

[35] Division of Mining Information, *Injury Experience in Coal Mining, 1990* (Denver, co, Mine Safety and Health Administration, Safety and Technology Center, 1989), p. 18. See footnote 38 for a description of the calculation of the incidence rate.

[36] *Injury Experience in Coal Mining*, p. 18.

[37] *Ibid.*, p. 18. The severity measure is calculated in the following manner:

Severity measure = (L X 200,000) /E

where

L = number of lost workdays

E = number of employee-hours

Lost workdays (L) include days away from work, days of restricted work activity, and statutory days charged for fatalities and permanent total and partial disabilities.

[38] Specifically, the rate is calculated as:

(N/EH) X 200,000

where

N = number of injuries/illnesses, or number of lost workdays

EH = total hours worked by all employees of the industry during the calender year.

200,000 = base for 100 full time equivalent workers (working 40 hours per week 50 weeks per year).

For further discussion of the calculation of the occupational injury and illness incidence rate, see *Handbook of Methods*, Bulletin 2414 (U.S. Bureau of Labor Statistics, 1992), pp. 111–15.

[39] Data on underground mines include surface at underground but excludes coal processing plants. Data on independent contractors are excluded, as are data for office workers.

[40] Data from 1969–89 indicate that roof and rib falls accounted for 46 percent of total underground fatalities. Arthur P. Sanda, "MSHA Undertakes Appalachian Offensive," *Coal*, August 1990, p. 58.