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Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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Analyses of Mobile Equipment Fires for All U.S. Surface and Underground Coal and Metal/Nonmetal Mining Categories, 1990-1999

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

hr	hour	st	short tons
min	minute	°F	degrees Fahrenheit

ANALYSES OF MOBILE EQUIPMENT FIRES FOR ALL U.S. SURFACE AND UNDERGROUND COAL AND METAL/NONMETAL MINING CATEGORIES, 1990-1999

By Maria I. De Rosa[1]

ABSTRACT

This report analyzes mobile equipment fires for all U.S. surface and underground coal and metal/nonmetal mining categories by state and 2 year time periods during 1990-1999. Risk rate values are derived, and ignition source, methods of fire detection and suppression, and other variables are examined. The data were derived from MSHA mine fire accident publications and verbal communications with mine personnel. The analyses will provide the National Institute for Occupational Safety and Health (NIOSH), the Mine Safety and Health Administration (MSHA), and the mining industry with a better understanding of the hazards associated with mobile equipment fires and will create a basis for future fire research programs.

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INTRODUCTION

Mobile equipment fires are extremely hazardous to the safety of miners and their livelihood, especially when they occur in the confined space of underground mines. Enactment of safety laws [30 CFR[2] 75], which require machine fire suppression systems on all underground coal mine diesel equipment and electrical powered mine face equipment using non-fire-resistant hydraulic fluids, has greatly improved the safety of miners. However, equipment fires still occur with disastrous consequences. Fire-resistant hydraulic fluid for use in equipment is not required at all metal/nonmetal mining operations.

This report analyzes mobile equipment fires for all surface and underground coal and metal/nonmetal[3] mining categories during 1990-1999. Fires involving semimobile equipment such as shearers, hoists, and continuous miners have also been included. The mining categories include surface coal mines, surface of underground coal mines, coal preparation plants, and underground coal mines; surface metal/nonmetal mines, surface sand and gravel and stone mines, metal/nonmetal and stone mills, and underground metal/nonmetal and stone mines. No equipment fires were reported for surface of underground metal/nonmetal and stone mines.

For each category, the injury risk rates for a 10-year time period and for five successive 2-year time periods within the 10-year period are derived. The fire risk rates were derived for surface and underground coal only.[4] Also, risk rate values for individual states for a 10-year time period are derived. Other variables such as ignition source, methods of detection/suppression, and other variables are explored. Included are mobile equipment fire data for working contractors.

The data were derived from "Injury Experience in Mining" [MSHA 1990b,c,d,e,f; 1991a,b,c,d,e; 1992a,b,c,d,e; 1993a,b,c,d,e; 1994a,b,c,d,e; 1995a,b,c,d,e; 1996a,b,c,d,e; 1997a,b,c,d,e; 1998a,b,c,d,e; 1999b,c,d,e,f], "Fire Accident Reports" [MSHA 1990a,g; 1991f; 1992f,g,h; 1993f; 1994f,g,h,i; 1995f,g,h; 1996f,g; 1997f,g; 1998f; 1999a], MSHA "Fire Accident Abstracts" internal publications, and verbal communications with mine personnel. Mining companies are required by 30 CFR 50 to report to MSHA all fires that result in injuries and those that cannot be extinguished within 30min from their discovery. A small number of courtesy reports (regarding fires without injuries lasting <30 min) reported in the "Abstracts" were included in the analyses.

The analyses, which are done by state (10-year time period) and five 2-year time periods, include the number of equipment fires, fire injuries, risk rates,[4] employees' working hours, and production[3] according to the equipment involved. Also, by time period, the analyses include other variables such as activity, ignition source, and methods of detection and suppression according to the equipment involved. Furthermore, the analyses include the number of fire injuries and fatalities per number of equipment fires causing injuries and total fires by year, ignition source, equipment involved, and location. For comparison purposes, major fire and fire injury findings are reported for 1990-1999.

The current analyses will provide the National Institute for Occupational Safety and Health, MSHA, and the mining industry with a better understanding of the causes and hazards associated with equipment fires and fire injuries and will create a basis for present and future research programs.

Previous analyses/studies by the former U.S. Bureau of Mines (USBM) included: mobile equipment accidents at surface coal mines during 1989-1991 [Aldinger et al. 1995]; underground coal mine fires during 1950-1977 [McDonald and Pomroy 1980] and 1978-1992 [Pomroy and Carigiet 1995]; underground and surface metal/nonmetal mine fires during 1950-1984 [Butani and Pomroy 1987]; and equipment fire detection and suppression systems [Johnson and Forshey 1975; Pomroy and Bickel 1980].

METHODOLOGIES

In this report, the methodologies used to analyze the data deal with actual numbers and calculated values.

1. For each mining category, actual numbers include the total numbers of equipment fires, injuries, employees' working hours, and production for a 10-year time period (1990-1999) and for five successive 2-year time periods within the 10-year period according to the equipment involved and activity. Actual numbers of fires, injuries, employees' working hours, and production[4] were also reported by state for the 10-year time period. Also, for the five 2-year time periods, the actual number of fires were reported by ignition source and methods of detection and suppression according to the equipment involved. Furthermore, actual numbers of fire injuries per number of equipment fires causing injuries and total fires were reported by year, ignition source, equipment involved, and location for 1990-1999.

2. For each mining category, the calculated values include the fire and injury risk rates during the 10-year time period and the five 2-year time periods. The fire risk rate (Frr) values were calcuated according to the USBM formula [Pomroy and Carigiet 1995]. The injury risk rate (Irr) values were calculated

[2]Code of Federal Regulations. See CFR in references.

[3]"Metal/nonmetal" includes stone and sand and gravel.

[3]Coal production values used to calculate the fire risk rates have been reported for these two mining categories only.

according to the MSHA formula (incidence rate (IR) = number of injuries multiplied by 200,000 working hours divided by the number of working hours) [MSHA 1990b,c,d,e,f; 1991a,b,c,d,e; 1992a,b,c,d,e; 1993a,b,c,d,e; 1994a,b,c,d,e; 1995a,b,c,d,e; 1996a,b,c,d,e; 1997a,b,c,d,e; 1998a,b,c,d,e; 1999b,c,d,e,f]. Also, fire and injury risk rate values for individual states during the 10-year time period were calculated according to the abovementioned formulas.

Of note is that only the risk rate values for the 10-year and five 2-year time periods and risk rate values for individual states with the highest number of fires and fire injuries have been considered for comparison purposes. The fatality risk rate values were not calculated because of the extremely small number of fatalities occurring during the 10-year period.

Calculations of risk rate values and other values were done as follows:

a. Fire risk rate values (Frr): Number of fires per million tons of coal produced [Pomroy and Carigiet 1995] (calculated for surface and underground coal mines only).
b. Injury risk rate values (Irr): Number of injuries multiplied by 200,000 working hours per total employees' working hours [MSHA 1990b,c,d,e,f; 1991a,b,c,d,e; 1992a,b,c,d,e; 1993a,b,c,d,e; 1994a,b,c,d,e;1995a,b,c,d,e; 1996a,b,c,d,e; 1997a,b,c,d,e; 1998a,b,c,d,e; 1999b,c,d,e,f]. The Irr value is the average risk rate value for the number of injuries per 200,000 working hours for a given time period.
c. Total employees' working hours (Ewhr) value during 1990-1999: Sum of 10 yearly Ewhr values for all the states involved in equipment fires. This value also includes the Ewhr value reported for all of the other states not involved in equipment fires. The Ewhr value for each state (10-year time period) is the sum of 10 yearly Ewhr values for that state.
d. Total employees' working hours for five 2-year time periods: Sum of two yearly Ewhr values for all of the states, with and without equipment fires, within that 2-year time period.
e. The coal production (CP) values in short tons were calculated similarly.
f. Calculations of Ewhr values for the states within mining categories with more than one subcategory (e.g., metal/nonmetal and stone mills) were made according to that subcategory.
g. All flame cutting/welding fires and injuries occurring on mobile equipment, which include fires involving welders' clothing, oxyfuels, and/or grease embedded in the equipment's mechanical components, have been reported here.

MOBILE EQUIPMENT DATA ANALYSIS FOR ALL COAL MINING CATEGORIES

MOBILE EQUIPMENT FIRES AT SURFACE COAL MINES

At surface coal mines, there were a total of 140 equipment fires during 1990-1999; 56 of those fires caused 56 injuries (table 1 and figure 1). Eleven fires with six injuries involved contractors. In all, five pieces of equipment (3.6%) involved in the fires had machine fire suppression systems.

The highest number of equipment fires occurred in Kentucky (39 fires and 18 injuries), followed by West Virginia (19 fires and 9 injuries), Pennsylvania (16 fires and 6 injuries), and Indiana (15 fires and 5 injuries). Pennsylvania had the highest fire risk rate (Frr = 0.07); Kentucky had the highest injury risk rate (Irr = 0.027). For surface coal mines, the total Ewhr value was 729×10^6 hr (Irr = 0.015); the total CP value was 6,355 $\times 10^6$ st (Frr = 0.022).

The equipment involved, mostly during working activities, included haulage/utility trucks (46 fires and 24 injuries), dozers (25 fires and 8 injuries), shovels (22 fires and 10 injuries), loaders (22 fires and 5 injuries), and drills (12 fires and 4 injuries) (table 2 and figure 2).

A large number of equipment fires (77 fires or 55%) were caused by pressurized hydraulic fluid/fuel sprayed onto equipment hot surfaces due to ruptured lines and failed fittings and gaskets (table 3 and figure 2). Of note is that the wear and tear of lines, fittings, and gaskets may occur more readily beyond 5,000 operating hours, which was acknowledged by mine personnel during field visits.

Most of the hydraulic fluid/fuel fires, although detected by the operators when they started as flames/flash fires, a popping sound, or power loss, often raged out of control (requiring at least 15 fire-fighting interventions) because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure, lack of an emergency line drainage system (whose flow is not affected by the engine shutoff system), difficulty in reaching available emergency systems at ground level due to flames engulfing the area, or lack of effective and rapid local fire-fighting response capabilities. On at least five occasions the cab was suddenly engulfed in flames, forcing the operator to exit the cab under difficult conditions, most likely due to the ignition of flammable vapors and mists that formed and penetrated the cab during the spraying of hydraulic fluid/fuel onto equipment hot surfaces. Dual activation (three activations) of machine fire suppression/engine shutoff systems succeeded in abating the flames temporarily. However, the flames reignited, fueled by the flow of pressurized hydraulic fluid/fuel entrapped in the lines. Four fires were detected late (which made fire-fighting efforts ineffective), and 10 were undetected and burned themselves out (table 4 and figure 2).

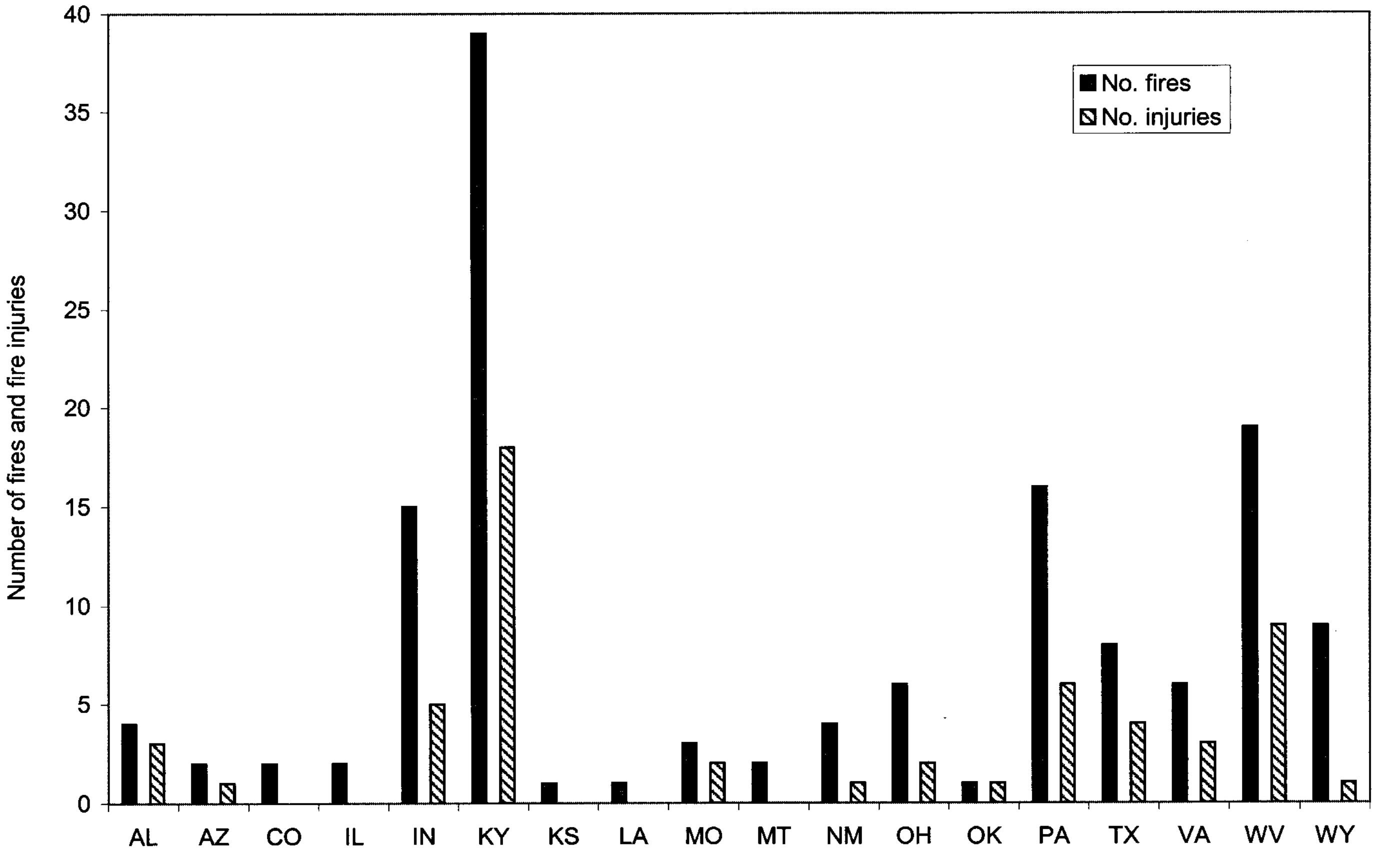

Figure 1.—Mobile equipment fires and injuries for surface coal mines by state, 1990-1999.

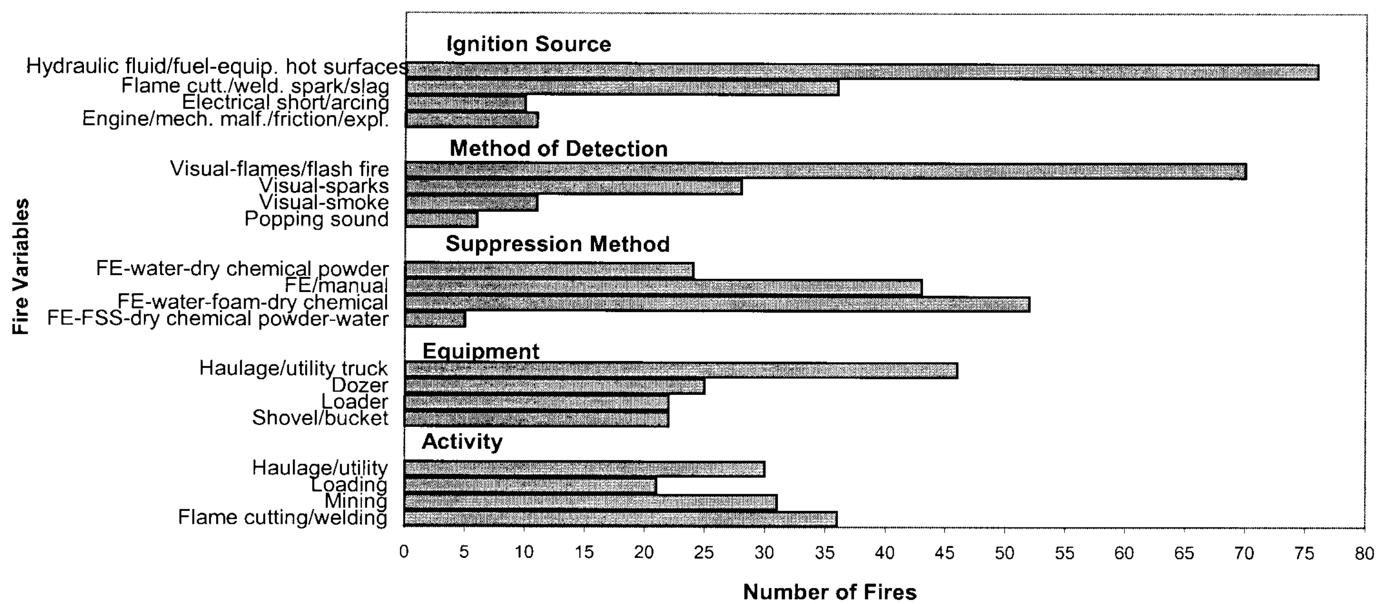

Figure 2.—Major variables for mobile equipment fires at surface coal mines, 1990-1999. (FE = portable fire extinguisher; FSS = machine fire suppression system.)

Table 1.—Number of mobile equipment fires, injuries, and risk rates for surface coal mines by state, equipment involved, coal production, and employees' working hours, 1990-1999

State[1]	Equipment[1]	No. fires[1]	No. Injuries	Ewhr,[2] 10^6 hr	Cp,[2] 10^6 st	Irr[3]	Frr[3]
AL	Truck	1	1				
	Drill	1	1				
	Loader	1	1				
	Shovel	1	—	25.5	80.3	0.024	0.05
AZ	Truck	1	—				
	Shovel	1	1	16.3	120	0.012	0.017
CO	Truck	1	—				
	Dozer	1	—	11.8	90	—	0.022
IL	Truck	1	—				
	Shovel	1	—	24.2	93.6	—	0.021
IN	Loader	1	—				
	Drill	1	—				
	Truck	5	2				
	Dozer	1	—				
	Shovel	5	2				
	Excavator	2	1	53.5	290.3	0.02	0.052
KS	Dozer	1	—	1.5	3.7	—	0.27
KY	Loader	5	1				
	Truck	15	7				
	Dozer	4	2				
	Backhoe	3	2				
	Drill	5	3				
	Shovel/bucket	5	2				
	Auger/miner	2	1	133.2	602	0.027	0.06
LA	Dozer	1	—	2.5	27.2	—	0.037
MO	Truck	1	1				
	Dozer	1	1				
	Drill	1	—	4.8	11.8	0.08	0.25
	Loader	1	—				
	Shovel	1	—	16.2	394	—	0.005
NM	Truck	1	1				
	Loader	1	—				
	Dozer	2	—	30	245.6	0.007	0.016
OH	Loader	2	1				
	Truck	1	—				
	Dozer	3	1	40	167.3	0.01	0.04
OK	Scraper	1	1	6	16	0.03	0.063
PA	Loader	4	1				
	Truck	3	2				
	Dozer	2	—				
	Drill	2	—				
	Shovel	5	3	72.6	228.1	0.017	0.07
TX	Truck	3	2				
	Shovel	2	1				
	Drill	1	—				
	Miner	1	—				
	Dozer	1	1	60.1	535.2	0.013	0.015
VA	Loader	3	—				
	Dozer	3	3	22.5	88.5	0.027	0.07
WV	Loader	2	1				
	Truck	11	7				
	Dozer	4	—				
	Drill	1	—				
	Shovel	1	1	94.5	455.8	0.02	0.042
WY	Loader	3	—				
	Truck	2	1				
	Dozer	1	—				
	Excavator	1	—				
	Auger/miner	2	—	76	2,454.4	0.003	0.004
All other states		—	—	38	551.2	—	—
Total		140	56	729	6,355	[3]0.015	[3]0.022

[1]Derived from MSHA "Fire Accident Abstract" and "Fire Accident Report" publications.
[2]Derived from MSHA "Injury Experience in Coal Mining" publications.
[3]Calculated according to MSHA and USBM formulas reported in the "Methodologies" section.

Table 2.–Number of mobile equipment fires, injuries, and risk rates for surface coal mines by time period, equipment involved, activity, and employees' working hours, 1990-1999

Equipment	Activity	Time period											
		90-91		92-93		94-95		96-97		98-99		90-99	
		No. fires	No. injuries	No. fires	No. injuries	No. fires	No. injuries	No. fires	No. injuries	No. fires	No. injuries	No. fires	No. injuries
Loader	Loading	8	2	1	1	5	–	5	1	2	–	21	4
	Flame cutting/welding	–	–	1	1	–	–	–	–	–	–	1	1
Dozer	Mining	6	1	3	–	3	3	1	–	4	1	17	5
	Flame cutting/welding	1	1	–	–	1	1	–	–	2	1	4	3
	Maintenance/idle	1	–	1	–	–	–	2	–	–	–	4	–
Shovel/bucket	Mining	3	1	5	2	–	–	–	–	1	–	9	3
	Flame cutting/welding	4	2	2	1	1	–	1	1	2	1	10	5
	Maintenance/idle	1	–	–	–	–	–	2	2	–	–	3	2
Scraper	Flame cutting/welding	–	–	1	1	–	–	–	–	–	–	1	1
Drill	Drilling	3	1	2	1	1	–	–	–	–	–	6	2
	Flame cutting/welding	1	1	2	1	1	–	–	–	–	–	4	2
	Maintenance/idle	1	–	1	–	–	–	–	–	–	–	2	–
Haulage/utility truck	Haulage/utility	9	4	4	2	7	3	8	3	2	1	30	13
	Flame cutting/welding	1	1	2	2	4	4	1	1	1	1	9	9
	Maintenance/idle	2	1	3	1	1	–	1	–	–	–	7	2
Excavator	Mining	–	–	1	–	–	–	–	–	1	–	2	–
	Flame cutting/welding	–	–	–	–	1	–	1	1	–	–	2	1
Auger/miner	Mining	–	–	1	–	1	–	1	–	–	–	3	–
	Flame cutting/welding	–	–	–	–	2	1	–	–	–	–	2	1
Backhoe	Flame cutting/welding	2	2	1	–	–	–	–	–	–	–	3	2
Total		43	17	31	13	28	12	23	9	15	5	140	56
Ewhr,[1] 10^6 hr		177		154		143		131		124		729	
Irr[2]		0.019		0.017		0.017		0.014		0.008		[2]0.015	
CP[1], 10^6 st		1,182		1,176		1,267		1,325		1,405		6,355	
Frr[2]		0.036		0.026		0.022		0.017		0.011		[2]0.022	

[1]Derived from MSHA "Injury Experience in Mining" publications.
[2]Calculated according to MSHA and USBM formulas reported in the "Methodologies" section.

Table 3.–Number of mobile equipment fires for surface coal mines by ignition source, equipment involved, and time period, 1990-1999

Equipment	Ignition source	Time period					
		90-91	92-93	94-95	96-97	98-99	90-99
		No. fires	No. fires	No. fires	No. fires	No. fires	No. fires
Loader	Hydraulic fluid/fuel on equipment hot surfaces	8	1	5	5	2	21
	Flame cutting/welding spark/slag	–	1	–	–	–	1
Dozer	Hydraulic fluid/fuel on equipment hot surfaces	5	2	3	1	2	13
	Electrical short/arcing	–	2	–	2	1	5
	Engine/mechanical malfunctions	1	–	–	–	–	1
	Flame cutting/welding spark/slag	1	–	1	–	2	4
	Natural gas explosion	1	–	–	–	1	2
Shovel/bucket	Flammable liquid on hot surfaces	1	–	–	2	–	3
	Flame cutting/welding spark/slag	4	2	1	1	2	10
	Engine/mechanical friction	1	1	–	–	–	2
	Hydraulic fluid/fuel on equipment hot surfaces	2	3	–	–	1	6
	Electrical short/arcing	–	1	–	–	–	1
Scraper	Flame cutting/welding spark/slag	–	1	–	–	–	1
Drill	Flame cutting/welding spark/slag	1	2	1	–	–	4
	Hydraulic fluid/fuel on equipment hot surfaces	2	3	1	–	–	6
	Flammable liquid on hot surfaces	1	–	–	–	–	1
	Mechanical friction/explosion	1	–	–	–	–	1
Haulage/utility truck	Hydraulic fluid/fuel on equipment hot surfaces	8	4	8	6	1	27
	Mechanical malfunction	1	3	–	2	1	7
	Flame cutting/welding spark/slag	1	2	4	1	1	9
	Electrical short/arcing	2	–	–	1	–	3
Excavator	Flame cutting/welding spark/slag	–	–	1	1	–	2
	Hydraulic fluid on equipment hot surfaces	–	1	–	–	1	2
Auger/miner	Hydraulic fluid on equipment hot surfaces	–	1	1	–	–	2
	Flame cutting/welding spark/slag	–	–	2	–	–	2
	Electrical short/arcing	–	–	–	1	–	1
Backhoe	Flame cutting/welding spark/spark	2	1	–	–	–	3
Total		43	31	28	23	15	140

Table 4.–Number of mobile equipment fires for surface coal mines by method of detection, equipment involved, and time period, 1990-1999

Equipment	Method of detection	Time period					
		90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Loader	Visual-flames/flash fire	7	1	3	3	2	16
	Popping sound	–	–	2	1	–	3
	Visual–smoke	1	–	–	1	–	2
	Visual-sparks	–	1	–	–	–	1
Dozer	Undetected	1	–	–	1	1	3
	Visual-smoke	1	2	–	1	1	5
	Late detection–smoke	–	–	–	1	–	1
	Visual-sparks	1	–	1	–	1	3
	Explosion	1	–	–	–	1	2
	Visual-flames/flash fire	4	1	2	–	1	8
	Power loss	–	–	–	–	1	1
	Smell	–	1	–	–	–	1
	Popping sound	–	–	1	–	–	1
Shovel/bucket	Visual-flames/flash fire	3	2	–	2	1	8
	Visual-sparks	3	–	1	1	2	7
	Popping sound	1	–	–	–	–	1
	Undetected	1	1	–	–	–	2
	Visual-smoke	–	3	–	–	–	3
	Power loss	–	1	–	–	–	1
Scraper	Visual-sparks	–	1	–	–	–	1
Drill	Visual-sparks	1	1	1	–	–	3
	Undetected	1	1	–	–	–	2
	Explosion	1	–	–	–	–	1
	Popping sound	1	–	–	–	–	1
	Visual-flames/flash fire	1	3	1	–	–	5
Haulage/utility truck	Visual-flames/flash fire	9	3	7	8	2	29
	Visual-sparks	1	2	3	1	1	8
	Late detection-smoke	–	1	–	1	–	2
	Visual-smoke	2	–	–	–	–	2
	Popping sound	–	1	–	–	–	1
	Power loss	–	2	–	–	–	2
	Undetected	–	–	1	–	–	1
	Explosion	–	–	1	–	–	1
Excavator	Visual-sparks	–	–	–	1	–	1
	Visual-flames/flash fire	–	1	–	–	1	2
	Undetected	–	–	1	–	–	1
Auger/miner	Late detection-smoke	–	–	1	–	–	1
	Visual-flames/flash fire	–	1	1	–	–	2
	Visual-sparks	–	–	1	1	–	2
Backhoe	Visual-sparks	2	1	–	–	–	3
Total		43	31	28	23	15	140

Fire brigades and fire departments, handicapped by travel distances, fought the hydraulic/fuel fires with foam (mostly used by fire brigades), dry chemical powder (mostly used by fire departments), and water. Ten pieces of equipment were destroyed or heavily damaged because of failed fire suppression and fire-fighting methods, late fire detection, undetected fires, or fire size (table 5 and figure 2).

Other ignition sources included flame cutting/welding spark/slag (this source usually caused fires involving welders' clothing, oxyfuel, or grease embedded in the equipment's mechanical components), electrical short/arcing of wires and cables, engine/mechanical malfunctions/friction/explosion, and flammable liquids on hot surfaces (table 3 and figure 2). The flame cutting/welding fires, detected mostly as sparks, were suppressed by manual methods (welders' method to extinguish clothing fires) or with portable fire extinguishers (welders' method to extinguish oxyfuel and/or grease fires). The electrical, engine malfunction/friction/explosion, and flammable liquid fires, detected as smoke or flames, were also extinguished with portable fire extinguishers (table 5 and figure 2).

The five hydraulic fluid/fuel fires involving equipment with fire suppression systems behaved as follows. In three instances, the flames, which abated temporarily upon dual activation of the fire suppression/engine shutoff systems, reignited, fueled by the fluids entrapped in the lines. In the other two instances, the fires raged out of control because of engine shutoff failure upon activation of the machine fire suppression system.

Data during the five time periods, including the number of fires, injuries, risk rates, employees' working hours, and coal production according to the equipment involved and activity are shown in table 2 and partly illustrated in figure 3. Other variables such as ignition source and methods of detection and suppression are shown in tables 3-5.

Equipment fires and injuries decreased sharply throughout the five time periods (the decline in haulage truck fires was evident only during the last period (table 3)), accompanied by a

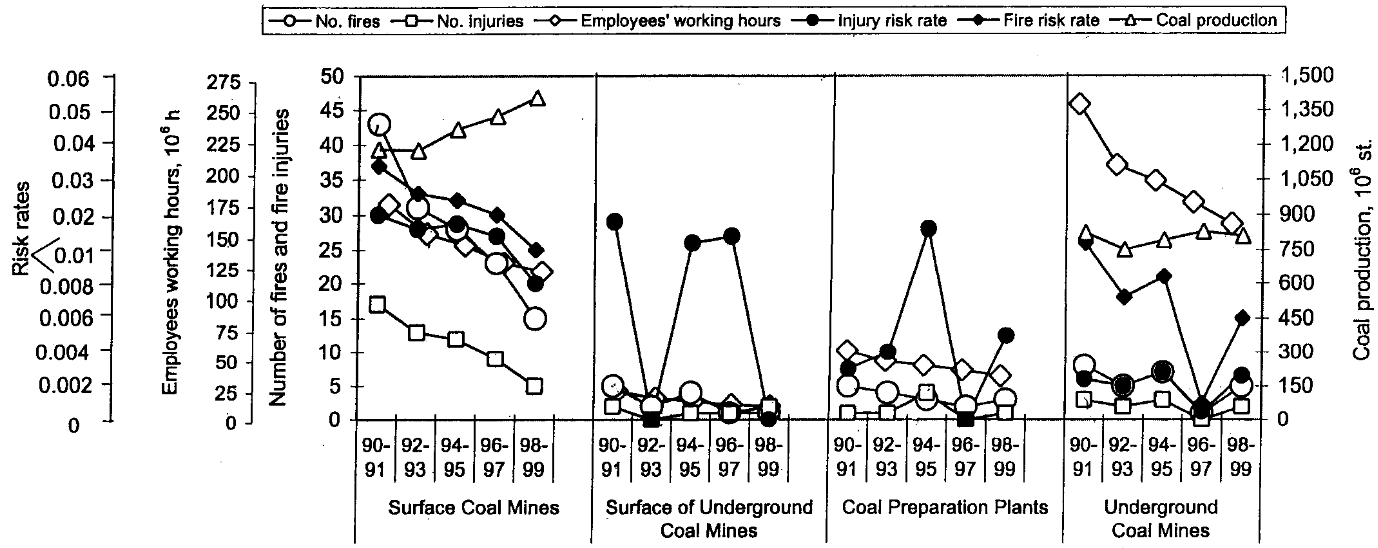

Figure 3.—Mobile equipment fires, injuries, risk rates, employees' working hours, and coal production (coal production for surface and underground coal mines only) by time period for each coal mining category, 1900-1999.

Table 5.–Number of mobile equipment fires for surface coal mines by suppression method, equipment involved and time period, 1990-1999

Equipment	Suppression method	Time period 90-91	92-93	94-95	96-97	98-99	90-99
		No. fires	No. fires	No. fires	No. fires	No. fires	No. fires
Loader	FE-water-foam-dry chemical powder[1]	5	–	5	4	2	16
	FE/manual[2]	1	1	–	–	–	2
	FE-FSS-water-dry chemical powder[3]	1	–	–	1	–	2
	Water-dry chemical powder[4]	1	1	–	–	–	2
Dozer	FE-dry chemical powder[4]	5	2	3	1	1	12
	Portable fire extinguisher	1	2	–	2	1	6
	FE/manual[2]	1	–	1	–	2	4
	FE-FSS-dry chemical powder[3]	–	–	–	–	1	1
	Destroyed/heavily damaged[5]	1	–	–	–	1	2
Shovel/bucket	FE-water-foam-dry chemical powder[1]	2	3	–	–	1	6
	FE/manual[2]	4	3	1	3	2	13
	Destroyed/heavily damaged[5]	1	–	–	–	–	1
	Water-dry chemical powder[4]	1	1	–	–	–	2
Scraper	FE/manual[2]	–	1	–	–	–	1
Drill	FE-water-foam-dry chemical powder[1]	2	2	1	–	–	5
	FE/manual[2]	1	1	1	–	–	3
	Water-dry chemical powder[4]	–	1	–	–	–	1
	Destroyed/heavily damaged[5]	2	1	–	–	–	3
Haulage/utility truck	FE-water-foam-dry chemical powder[1]	7	3	4	5	1	20
	FE/manual[2]	4	4	4	3	1	16
	Water-dry chemical powder[4]	1	2	2	1	–	6
	FE-FSS-dry chemical powder[3]	–	–	–	1	1	2
	Destroyed/heavily damaged[5]	–	–	2	–	–	2
Excavator	FE-water-foam-dry chemical powder[1]	–	1	–	–	1	2
	FE/manual[2]	–	–	–	1	–	1
	Destroyed/heavily damaged[5]	–	–	1	–	–	1
Auger/miner	FE-water-foam-dry chemical powder[1]	–	–	2	–	–	2
	FE/manual[2]	–	–	1	–	–	1
	Water-dry chemical powder[4]	–	1	–	–	–	1
	Destroyed/heavily damaged[5]	–	–	–	1	–	1
Backhoe	FE-water-foam-dry chemical powder[1]	–	1	–	–	–	1
	FE/manual[2]	2	–	–	–	–	2
Total		43	31	28	23	15	140

FE Portable fire extinguisher.
FSS Machine fire suppression system.
[1]Methods used by fire brigades (mostly foam) and fire departments (mostly dry chemical powder).
[2]Methods used by welders to extinguish clothing or oxyfuel/grease fires (grease embedded in the equipment's mechanical components).
[3]Methods used by fire departments following available FSS discharge by operator.
[4]Method used by fire departments.
[5]Usually due to failed fire suppression and fire-fighting methods, late fire detection, undetected fires, or fire size.

decline in employees' working hours and a small increase in coal production.

During 1990-1991, there were 43 fires (Frr = 0.036) and 17 fire injuries (Irr = 0.019). The equipment involved included haulage/utility trucks (12 fires and 6 injuries), shovels (8 fires and 3 injuries), loaders (8 fires and 2 injuries), dozers (8 fires and 2 injuries), and drills (5 fires and 2 injuries) mostly during haulage, loading, mining, and drilling activities. The Ewhr value was 177 $\times 10^6$ hr; the CP value was 1,182 $\times 10^6$ st. The most common ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces and flame cutting/welding spark/ slag, followed by engine/mechanical malfunctions/ friction explosion and electrical short/arcing. The most frequent methods of detection were operators who saw flames/flash fires, followed by operators/ miners/welders who saw smoke or sparks. The most commonly used fire suppression methods were foam, dry chemical powder, and water, followed by manual methods and portable fire extinguishers (four equipment fires were not extinguished). A machine fire suppression system was discharged once.

During 1992-1993, there were 31 fires (Frr = 0.026) and 13 fire injuries (Irr = 0.017). The equipment involved included haulage/utility trucks (nine fires and five injuries), drills (five fires and two injuries), shovels (seven fires and three injuries), and dozers (four fires and no injuries) mostly during haulage/utility, drilling, and mining activities. The Ewhr was 154 $\times 10^6$ hr; the CP value was 1,176 $\times 10^6$ st. The most common ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by flame cutting/welding spark/slag and electrical short/arcing. The most frequent methods of detection were operators who saw flames/flash fires and welders/operators/miners who saw sparks or smoke (one fire was detected late). The most commonly used suppression methods were foam, dry chemical powder, water, and portable fire extinguishers (one equipment fire was not extinguished).

During 1994-1995, there were 28 fires (Frr = 0.022) and 12 fire injuries (Irr = 0.017). The equipment involved included haulage/utility trucks (12 fires and 7 injuries), loaders (5 fires and no injuries), dozers (4 fires and 4 injuries), and augers (3 fires and 1 injury) mostly during haulage, loading, and mining activities. The Ewhr value was 143 $\times 10^6$ hr; the CP value was 1,267 $\times 10^6$ st. The most common ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by flame cutting/welding spark/slag. The most frequent methods of detection were operators who saw flames/flash fires and welders who saw sparks (two fires were undetected). The most commonly used suppression methods were foam, dry chemical powder, water, and portable fire extinguishers (three equipment fires were not extinguished).

During 1996-1997, there were 23 fires (Frr = 0.017) and 9 fire injuries (Irr = 0.014). The equipment involved included haulage/utility trucks (10 fires and 4 injuries), dozers (3 fires and no injuries), loaders (5 fires and 1 injury), and shovels (3 fires and 3 injuries) mostly during haulage, loading, and mining activities. The Ewhr value was 131 $\times 10^6$ hr; the CP value was 1,325 $\times 10^6$ st. The most common ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by electrical short/arcing and flame cutting/welding spark/slag. The most frequent methods of detection were operators who saw flames/flash fires and miners/welders who saw smoke, flames, or sparks. The most commonly used suppression methods were foam, dry chemical powder, and water, followed by manual methods and portable fire extinguishers (one equipment fire was not extinguished). The machine fire suppression systems were discharged twice.

During 1998-1999, there were 15 equipment fires (Frr = 0.011) and 5 fire injuries (Irr = 0.008). The equipment involved included dozers (six fires and two injuries), haulage/utility trucks (three fires and two injuries), shovels (three fires and one injury), and loaders (two fires and no injuries) mostly during mining, haulage, and loading activities. The Ewhr value was 124 $\times 10^6$ hr; the CP value was 1,405 $\times 10^6$ st. The most common ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by flame cutting/welding spark/slag and electrical short/arcing. The most frequent methods of detection were operators who saw flames/flash fires, welders who saw sparks, and operators/miners who saw smoke. The most commonly used suppression methods were foam, dry chemical powder, water, and portable fire extinguishers (one equipment fire was not extinguished). The machine fire suppression systems were discharged twice.

Table 6 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location. The highest number of fire injuries was recorded in 1990 (10 fire injuries caused by 10 equipment fires). These involved haulage/utility trucks, drills, shovels, backhoes, and dozers during hydraulic fluid/fuel, flammable liquids, mechanical friction/explosion, and flame cutting/welding fires.

MOBILE EQUIPMENT FIRES AT SURFACE OF UNDERGROUND COAL MINES

At surface of underground coal mines, there were 14 equipment fires with 4 injuries (caused by 4 equipment fires) during 1990-1999 (table 7 and figure 4). No contractor fires were reported for this mining category. In all, two pieces of equipment (14%) involved in the fires had machine fire suppression systems.

The highest number of equipment fires occurred in Pennsylvania (four fires and two injuries), followed by West Virginia and Alabama (three fires and no injuries for each state) and Kentucky (two fires and one injury). Pennsylvania had the highest injury risk rate (Irr = 0.038). For surface of underground coal mines, the total Ewhr value was 97 $\times 10^6$ hr (Irr = 0.008) (table 7).

The equipment involved, mostly during working activities, included loaders (three fires and one injury), scrapers (three fires and no injuries), and dozers and hoists (two fires and no injuries for each) (table 8 and figure 5).

Most of the fires were caused by pressurized hydraulic fluid/fuel (10 fires or 71%) sprayed onto equipment hot surfaces. At least twice the cab was suddenly engulfed in flames, forcing the operator to exit under difficult conditions

Table 6.–Number of fire injuries per number of mobile equipment fires causing injuries and total fires at surface coal mines by year, ignition source, equipment involved, and location, 1990-1999

Year	No. total fires	No. fires causing injuries	No. fire injuries	Ignition source	Equipment	Location
1990 . . .	25	3	3	Hydraulic fluid/fuel on equipment hot surfaces	Truck	Haulage area.
		1	1	Mechanical friction/explosion	Drill	Drilling area.
	–	2	2	Flammable liquid on hot surfaces	Shovel-truck	Maintenance area.
	–	4	4	Flame cutting/welding spark/slag	Truck-bucket/ dozer-backhoe.	Flame cutting/welding areas.[1]
1991 . . .	18	5	5	Hydraulic fluid/fuel on equipment hot surfaces	Loader-truck-dozer	Loading/haulage/mining areas.
	–	2	2	Flame cutting/welding spark/slag	Back hoe-shovel- drill.	Flame cutting/welding areas.[1]
1992 . . .	16	3	3	Hydraulic fluid/fuel on equipment hot surfaces	Drill-shovel	Drilling/mining areas.
	–	3	3	Flame cutting/welding spark/slag	Loader-shovel	Flame cutting/welding areas.[1]
	–	1	1	Flammable liquid on hot surfaces	Truck	Maintenance area.
1993 . . .	15	2	2	Hydraulic fluid/fuel on equipment hot surfaces	Truck-loader	Haulage/loading areas.
	–	3	3	Flame cutting/welding spark/slag	Shovel-drill-truck . .	Flame cutting/welding areas.[1]
		1	1	Engine malfunction	Truck	Haulage area.
1994 . . .	15	2	2	Hydraulic fluid/fuel on equipment hot surfaces	Dozer	Mining area.
	–	2	2	Flame cutting/welding spark/slag	Dozer-truck	Flame cutting/welding areas.[1]
1995 . . .	13	4	4	Hydraulic fluid/fuel on equipment hot surfaces	Truck-dozer	Haulage/mining areas.
	–	4	4	Flame cutting/welding spark/slag	Auger-truck	Flame cutting/welding/haulage areas.[1]
1996 . . .	12	3	3	Hydraulic fluid/fuel on equipment hot surfaces	Truck-loader	Haulage/loading areas.
	–	1	1	Flame cutting/welding spark/slag	Truck	Flame cutting/welding areas.[1]
	–	1	1	Engine malfunction	Truck	Haulage area.
1997 . . .	11	2	2	Flame cutting/welding spark/slag	Shovel-excavator	Flame cutting/welding areas.[1]
	–	2	2	Flammable liquid on hot surfaces	Shovel	Maintenance area.
1998 . . .	8	1	1	Hydraulic fluid/fuel on equipment hot surfaces	Truck	Haulage area.
	–	2	2	Flame cutting/welding spark/slag	Dozer-truck	Flame cutting/welding areas.[1]
	–	1	1	Natural gas explosion	Dozer	Pipeline area.
1999 . . .	7	1	1	Flame cutting/welding spark/slag	Shovel	Flame cutting/welding areas.[1]
Total . . .	140	56	56			

[1]Includes working, mining, and maintenance areas.

Table 7.–Number of mobile equipment fires, injuries, and risk rates for surface of underground coal mines by state, equipment involved, and employees' working hours, 1990-1999

State[1]	Equipment[1]	No. fires[1]	No. injuries[1]	Ewhr,[2] 10^6 hr	Irr[3]
AL	Dozer	1	–		
	Scraper	2	–	5.8	–
CO	Excavator	1	–	3.6	–
KY	Loader	2	1	23.1	0.01
PA	Hoist	2	–		
	Highlift	1	1		
	Tractor	1	1	10.5	0.038
UT	Truck	1	1	3.7	0.05
WV	Loader	1	–		
	Scraper	1	–		
	Dozer	1	–	19.5	–
All other states		–	–	30.35	–
Total		14	4	97	[3]0.008

[1]Derived from MSHA "Fire Accident Abstract" and "Fire Accident Report" publications.
[2]Derived from MSHA "Injury Experience in Mining" publications.
[3]Calculated according to MSHA formula reported in the "Methodologies" section.

most likely due to the ignition of flammable vapors and mists that formed and penetrated the cab. Other ignition sources were flame cutting/welding spark/slag (this source caused at least one hydraulic fluid fire), electrical short/arcing, and overheated oil on hot surfaces due to compressor malfunction (table 9 and figure 5). Operators/ miners/ welders detected most of the fires when they started as flames/flash fires, smoke, sparks, or as a battery explosion. Two fires were detected late (which made fire-fighting efforts ineffective) (table 10 and figure 5). Most of the hydraulic fluid/ fuel fires grew out of control (requiring at least once fire-fighting intervention) because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure, lack of an emergency line drainage system, difficulty in reaching available emergency systems at ground level, or lack of effective and rapid local fire-fighting response capabilities.

Table 8.–Number of mobile equipment fires, injuries, and risk rates for surface of underground coal mines by time period, equipment involved, activity, and employees' working hours, 1990-1999

Equipment	Activity	Time period 90-91 No. fires	90-91 No. injuries	92-93 No. fires	92-93 No. injuries	94-95 No. fires	94-95 No. injuries	96-97 No. fires	96-97 No. injuries	98-99 No. fires	98-99 No. injuries	90-99 No. fires	90-99 No. injuries
Highlift	Mining	1	1	–	–	–	–	–	–	–	–	1	1
Hoist	Hoisting	2	–	–	–	–	–	–	–	–	–	2	–
Loader	Loading	2	1	–	–	–	–	–	–	1	–	3	1
Haulage truck . . .	Flame cutting/welding	–	–	–	–	–	–	1	1	–	–	1	1
Scraper	Mining	–	–	–	–	1	–	–	–	1	–	2	–
	Idle	–	–	–	–	1	–	–	–	–	–	1	–
Dozer	Mining	–	–	1	–	1	–	–	–	–	–	2	–
Tractor	Flame cutting/welding	–	–	–	–	1	1	–	–	–	–	1	1
Excavator	Mining	–	–	1	–	–	–	–	–	–	–	1	–
Total		5	2	2	–	4	1	1	1	2	–	14	4
Ewhr,[1] 10^6 hr		27		21		18		16		15		97	
Irr[2]		0.015		–		0.011		0.013		–		[2]0.008	

[1]Derived from MSHA "Injury Experience in Mining" publications.
[2]Calculated according to MSHA formula reported in the "Methodologies" section.

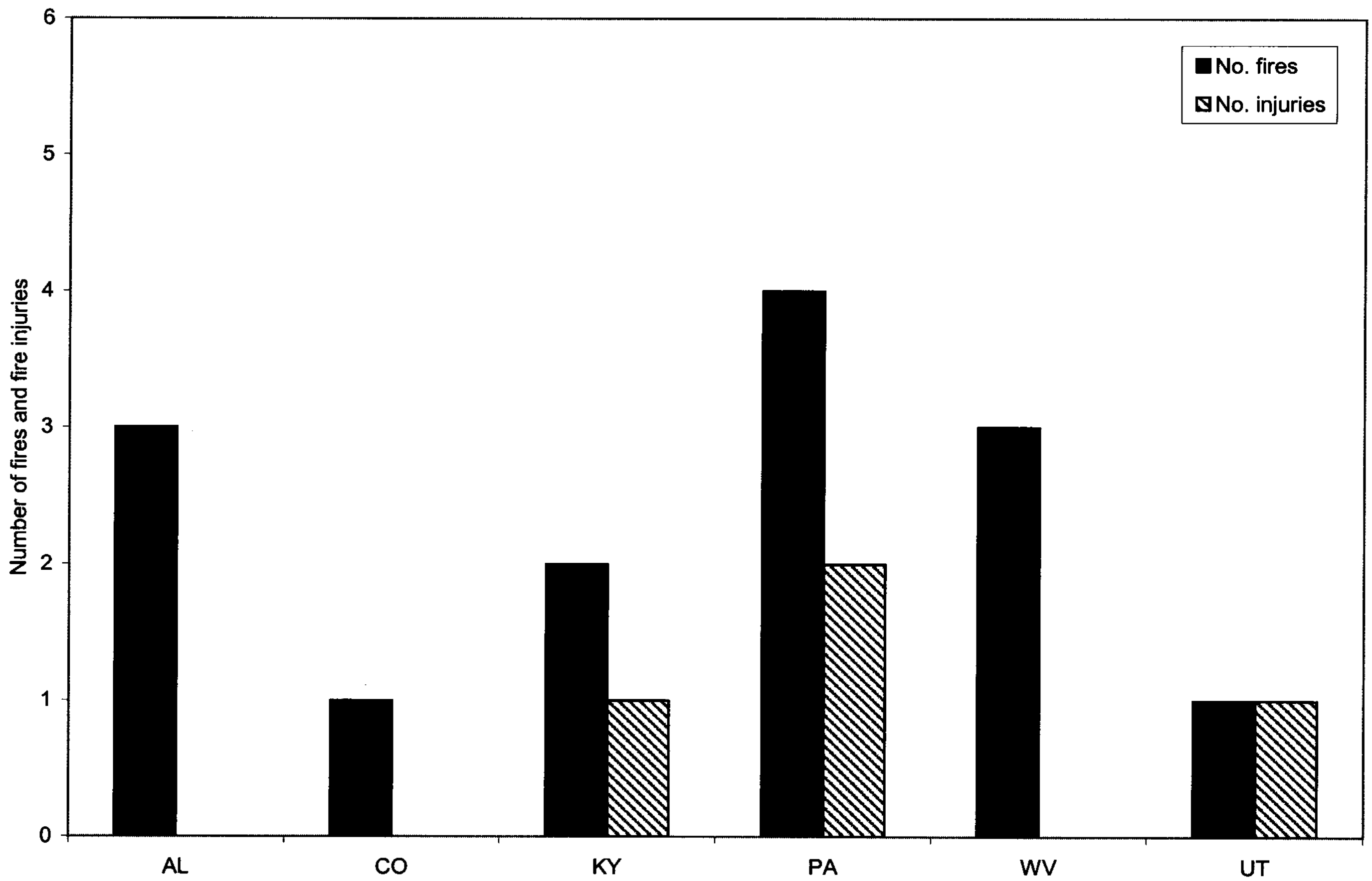

Figure 4.—Mobile equipment fires and injuries for surface of underground coal mines by state, 1990-1999.

Fire brigades and fire departments fought the hydraulic fluid/fuel fires with foam, dry chemical powder, and water. Two pieces of equipment were destroyed or heavily damaged because of failed fire suppression methods (table 11 and figure 5).

The two fires involving equipment with fire suppression systems behaved as follows. In one instance, a fuel fire involving a scraper burned out of control, although the operator had performed dual activation of machine fire suppression and engine shutoff systems. Evidently, the flow of fuel entrapped in the lines continued to fuel the fire. In the second instance, a hydraulic fluid/fuel fire involving an excavator burned out of control because the operator had first tried to fight the fire with portable fire extinguishers instead of activating the machine fire suppression system.

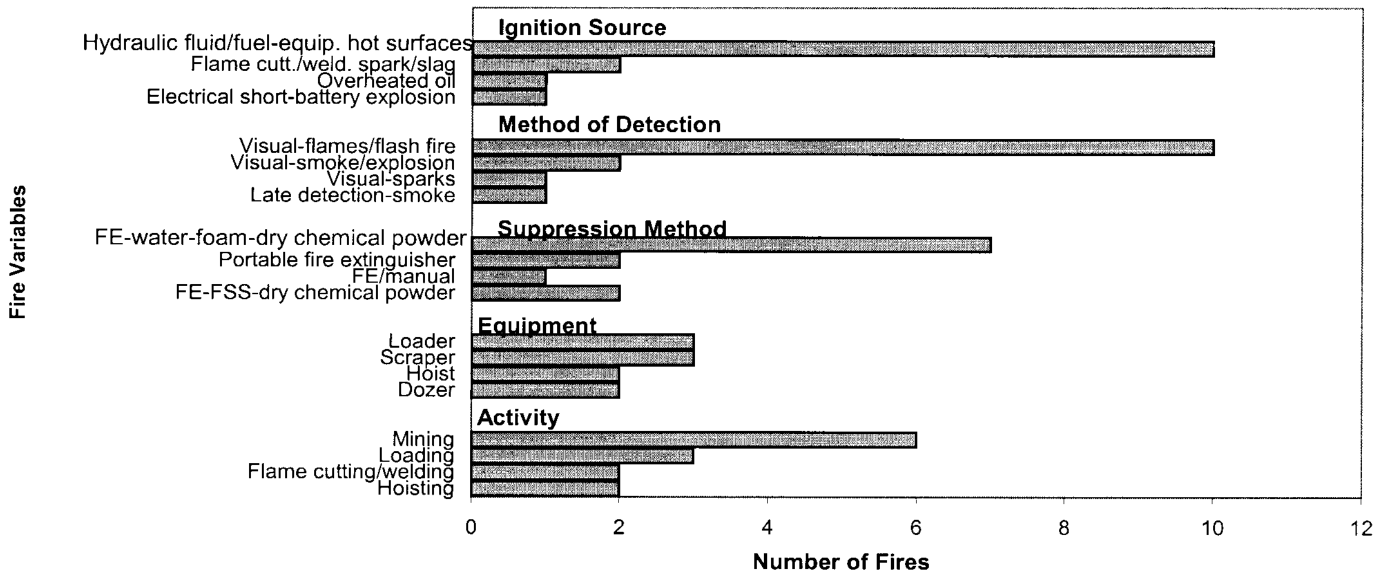

Figure 5.—Major variables for mobile equipment fires at surface of underground coal mines, 1990-1999. (FE = portable fire extinguisher; FSS = machine fire suppression system.)

Table 9.–Number of mobile equipment fires for surface of underground coal mines by ignition source, equipment involved, and time period, 1990-1999

Equipment	Ignition source	Time period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Highlift	Electrical short-battery explosion	1	–	–	–	–	1
Hoist	Hydraulic fluid on equipment hot surfaces	1	–	–	–	–	1
	Overheated oil [1]	1	–	–	–	–	1
Loader	Hydraulic fluid/fuel on equipment hot surfaces	2	–	–	–	1	3
Haulage truck	Flame cutting/welding spark/slag [2]	–	–	–	1	–	1
Scraper	Hydraulic fluid/fuel on equipment hot surfaces	–	–	2	–	1	3
Dozer	Hydraulic fluid/fuel on equipment hot surfaces	–	1	1	–	–	2
Tractor	Flame cutting/welding spark/slag	–	–	1	–	–	1
Excavator	Hydraulic fluid/fuel on equipment hot surfaces	–	1	–	–	–	1
Total		5	2	4	1	2	14

[1]Due to compressor malfunction.
[2]This source caused a hydraulic fluid fire.

Table 10.–Number of mobile equipment fires for surface of underground coal mines by method of detection, equipment involved, and time period, 1990-1999

Equipment	Method of detection	Time period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Highlift	Visual-smoke/explosion	1	–	–	–	–	1
Hoist	Visual-smoke	1	–	–	–	–	1
	Visual-flames/flash fire	1	–	–	–	–	1
Loader	Visual-flames/flash fire	2	–	–	–	1	3
Haulage truck	Visual-flames/flash fire	–	–	–	1	–	1
Scraper	Visual-flames/flash fire	–	–	1	–	1	2
	Late detection-smoke	–	–	1	–	–	1
Dozer	Visual-flames/flash fire	–	1	1	–	–	2
Tractor	Visual-sparks	–	–	1	–	–	1
Excavator	Visual-flames/flash fire	–	1	–	–	–	1
Total		5	2	4	1	2	14

Table 11.–Number of mobile equipment fires for surface of underground coal mines by suppression method, equipment involved, and time period, 1990-1999

Equipment	Suppression method	Time period 90-91	92-93	94-95	96-97	98-99	90-99
		No. fires	No. fires	No. fires	No. fires	No. fires	No. fires
Highlift	Portable fire extinguisher	1	–	–	–	–	1
Hoist	Water-foam-dry chemical powder-water[1]	1	–	–	–	–	1
	Portable fire extinguisher	1	–	–	–	–	1
Loader	Water-foam-dry chemical powder[1]	2	–	–	–	1	3
Haulage truck	FE-foam-dry chemical powder-water[1]	–	–	–	1	–	1
Scraper	FSS-water-foam/dry chemical powder/HD[2]	–	–	1	–	–	1
	FE-dry chemical powder-water	–	–	1	–	1	2
Dozer	FE-water-foam/dry chemical powder[1]	–	1	1	–	–	2
Tractor	FE/manual[3]	–	–	1	–	–	1
Excavator	FE-FSS-HD	–	1	–	–	–	1
Total		5	2	4	1	2	14

FSS Machine fire suppression system.
FE Portable fire extinguisher.
HD Heavily damaged.
[1]Methods used by fire brigades (mostly foam) and fire departments (mostly dry chemical powder).
[2]Methods used by fire department and fire brigades following available FSS discharge by operator.
[3]Methods used by welders to extinguish clothing or oxyfuel/grease fires (grease embedded in the equipment's mechanical components).
[4]Usually due to failed fire suppression methods.

Data during the five time periods, including the number of fires and fire injuries, risk rates, and employees' working hours according to the equipment involved and activity, are shown in table 8 and partly illustrated in figure 3. Other variables such as ignition source and methods of detection and suppression are shown in tables 9-11.

Fires and injuries decreased slightly during most of the five time periods; employees' working hours also declined (figure 3).

During 1990-1991, there were five fires and two injuries. The equipment involved included loaders (two fires and one injury), hoists (two fires and no injuries), and a highlift (one fire and one injury) mostly during loading, hoisting, and lifting activities. The Ewhr value was 27 × 10^6 hr (Irr = 0.015). The ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by overheated oil and electric short/arcing. The most frequent methods of detection were operators who saw flames/flash fires and operators/miners who saw smoke. The most commonly used suppression methods were foam, dry chemical powder, water, and portable fire extinguishers.

During 1992-1993, there were two fires and no injuries. The equipment involved included a dozer and an excavator (one fire and no injuries for each) during mining activities. The Ewhr value was 21 × 10^6 hr. The ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces. The fires, detected by the operators as flames/flash fires, were extinguished with foam, dry chemical powder, and water (one equipment fire was not extinguished). A machine fire suppression system was discharged once.

During 1994-1995, there were four fires and one injury. The equipment involved included scrapers (two fires and no injuries), a tractor (one fire and one injury), and a dozer (one fire and no injuries) mostly during mining and flame cutting/welding activities. The Ewhr value was 18 × 10^6 hr (Irr = 0.011). The ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces and flame cutting/welding spark/slag. The fires detected by the operator/welder as flames/flash fires or sparks were extinguished with foam, dry chemical powder, and water and by manual techniques (one equipment fire was not extinguished). A machine fire suppression system was discharged once.

During 1996-1997, there was only one fire and one injury. The equipment involved was a haulage truck during flame cutting/welding activities. During these activities, undetected hot slag caused a hydraulic fluid fire. The Ewhr value was 16 × 10^6 hr (Irr = 0.013).

During 1998-1999, there were two fires and no injuries. The equipment involved included a loader and a scraper (one fire and no injuries for each) during loading and mining activities. The Ewhr value was 15 × 10^6 hr. The ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces. The fires, detected by the operators as flames/flash fires, were extinguished with foam, dry chemical, and water.

Table 12 shows the number of fire injuries per number of equipment fires causing injuries and total fires by year, ignition source, equipment involved, and location. In 1990, 1991, 1994, and 1997, there were four fire injuries (one injury per year caused by one fire per year). These involved highlifts, loaders, tractors, and trucks during battery explosion, hydraulic fluid/fuel, and flame cutting/welding fires.

MOBILE EQUIPMENT FIRES AT COAL PREPARATION PLANTS

At coal prep plants, there were a total of 17 equipment fires during 1990-1999; 7 injuries were caused by 6 of those fires (table 13 and figure 6). One fire with one injury involved a contractor. None of the equipment involved in the fires had machine fire suppression systems.

Table 12.–Number of fire injuries per number of mobile equipment fires causing injuries and total fires at surface of underground coal mines by year, ignition source, equipment involved, and location, 1990-1999

Year	No. fires causing injuries	No. total fires	No. fire injuries	Ignition source	Equipment	Location
1990	1	3	1	Battery explosion	Highlift . . .	Charging station.
1991	1	2	1	Hydraulic fluid/fuel on equipment hot surfaces . .	Loader . . .	Loading area.
1992	–	1	–	–	–	–
1993	–	1	–	–	–	–
1994	1	2	1	Flame cutting/welding spark/slag	Tractor . . .	Flame cutting/welding areas.[1]
1995	–	2	–	–	–	–
1996	–	–	–	–	–	–
1997	1	1	1	Flame cutting/welding spark/slag	Truck	Flame cutting/ welding areas.[1]
1998	–	1	–	–	–	–
1999	–	1	–	–	–	–
Total	4	14	4			

[1]Includes working and maintenance areas.

Table 13.–Number of mobile equipment fires, injuries, and risk rates for coal preparation plants by state, equipment involved, and employees' working hours, 1990-1999

State	Equipment[1]	No. fires[1]	No. injuries[1]	Ewhr,[2] 10^6 hr	Irr[3]
IN	Loader	1	–	8.3	–
KY	Loader	2	2		
	Truck	2	1	56.1	0.011
PA	Loader	1	–		
	Truck	1	–	34.6	–
VA	Loader	1	2		
	Truck	2	–		
	Dozer	1	–	24	0.0167
WV	Loader	2	1		
	Dozer	2	–		
	Truck	2	1	60.6	0.0066
All other states		–	–	57.2	–
Total		17	7	241	[3]0.006

[1]Derived from MSHA "Fire Accident Abstract" and "Fire Accident Report" publications.
[2]Derived from MSHA "Injury Experience in Mining" publications.
[3]Calculated according to MSHA formula reported in the "Methodologies" section.

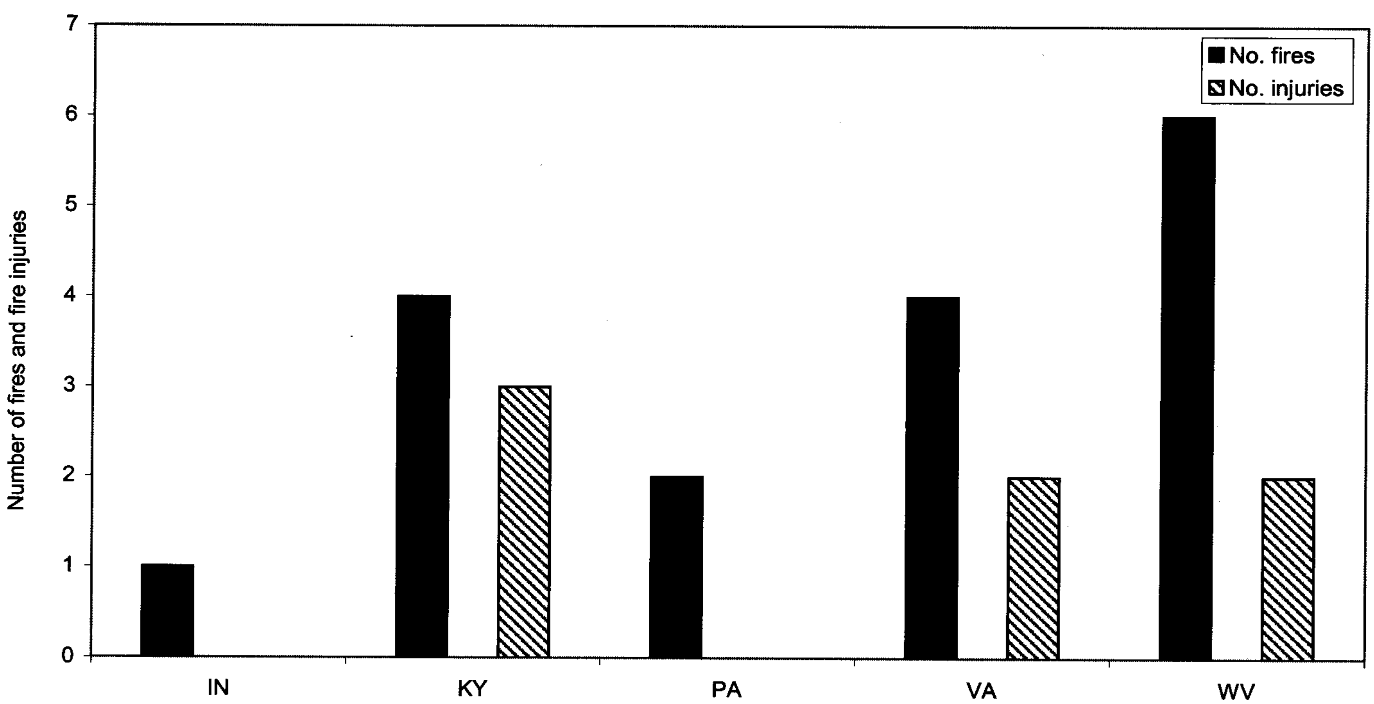

Figure 6.—Mobile equipment fires and injuries for coal preparation plants by state, 1990-1999.

The highest number of fires occurred in West Virginia (six fires and two injuries), followed by Kentucky (four fires and three injuries) and Virginia (four fires and two injuries). Virginia had the highest injury risk rate (Irr = 0.0167). For coal prep plants, the total Ewhr value was 241 × 10^6 hr (Irr = 0.006) (table 13).

The equipment involved, mostly during working activities, included loaders (seven fires and five injuries), haulage/utility trucks (seven fires and two injuries), and dozers (three fires and no injuries) (table 14 and figure 7).

The ignition sources that caused most of the fires were pressurized hydraulic fluid/fuel (7 fires or 41%) sprayed onto equipment hot surfaces, followed by engine/mechanical malfunctions, flammable liquid/ oil on hot surfaces, and electrical short/arcing. Other sources were flame cutting/welding spark/slag and heat sources (mostly heaters) (table 15 and figure 7).

Operators/miners/welders detected most of the fires when they started as flames/flash fires, dim lights, smoke, or sparks (table 16 and figure 7). One fire was detected late (which made fire-fighting efforts ineffective), and two fires were undetected and burned themselves out. Most of the hydraulic fluid/fuel fires, although detected by the operators when they started, grew out of control (requiring fire-fighting interventions at least once) because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure, lack of an emergency line drainage system, difficulty in reaching available emergency systems at ground level, or lack of effective and rapid local fire-fighting response capabilities. At least twice the cab was suddenly engulfed in flames, forcing the operator to exit under difficult conditions most likely due to the ignition of flammable vapors and mists that formed and penetrated the cab.

Fire departments fought the hydraulic fluid/fuel fires with dry chemical powder and water. Three pieces of equipment were destroyed or heavily damaged because of late fire detection, undetected fire, or fire size (table 17 and figure 7).

Data during the five time periods, including the number of fires, injuries, risk rates, and employees' working hours according to the equipment involved and activity, are shown in table 14 and partly illustrated in figure 3. Other variables such as ignition source and methods of detection and suppression are shown in tables 15-17.

The number of equipment fires shows small decreases during most of the periods, accompanied by a decline in employees' working hours. Injuries increased slightly during 1994-1995.

During 1990-1991, there were five fires and one injury. The equipment involved included loaders (three fires and one injury) and a haulage truck and dozer (one fire and no injuries for each) during loading, haulage, and grading activities. The Ewhr value was 60 × 10^6 hr (Irr = 0.003). The ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, flammable liquid/oil on hot surfaces, and heat sources. The most frequent methods of detection were operators/miners who saw flames/flash fires or smoke. (One fire was detected late, and one was undetected). The most commonly used suppression methods were portable fire extinguishers, dry chemical powder, and water.

During 1992-1993, there were four fires and one injury. The equipment involved included loaders (two fires and one injury) and a haulage truck and dozer (one fire and no injuries for each) during loading and haulage activities. The Ewhr value was 51 × 10^6 hr (Irr = 0.004). The ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, electrical short/arcing, flammable liquid/ oil on hot surfaces, and engine mechanical malfunctions. The most frequent methods of detection were operators who saw flames/flash fires and operators/miners who saw smoke (one fire was undetected). The most commonly used suppression methods were water, dry chemical powder, and portable fire extinguishers.

During 1994-1995, there were three fires and four injuries. The equipment involved included haulage/utility trucks (two fires and two injuries) and a loader (one fire and two injuries) during haulage and loading activities. The Ewhr value was 48 × 10^6 hr (Irr = 0.017). The most common ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by engine/mechanical malfunctions. The most frequent methods of detection were operators/miners who saw flames/flash fires or smoke. The most commonly used suppression methods were water, dry chemical powder, and portable fire extinguishers.

Table 14.–Number of mobile equipment fires, injuries, and risk rates for coal preparation plants by time period, equipment involved, activity, and employees' working hours, 1990-1999

Equipment	Activity	90-91 No. fires	90-91 No. Injuries	92-93 No. fires	92-93 No. Injuries	94-95 No. fires	94-95 No. injuries	96-97 No. fires	96-97 No. injuries	98-99 No. fires	98-99 No. injuries	90-99 No. fires	90-99 No. injuries
Loader	Loading	2	1	2	1	1	2	–	–	1	1	6	5
	Idle	1	–	–	–	–	–	–	–	–	–	1	–
Dozer	Grading	–	–	–	–	–	–	1	–	–	–	1	–
	Idle	1	–	1	–	–	–	–	–	–	–	2	–
Haulage/utility truck	Flame cutting/ welding.	1	–	–	–	–	–	–	–	–	–	1	–
	Haulage/utility	–	–	1	–	2	2	1	–	2	–	6	2
Total		5	1	4	1	3	4	2	–	3	1	17	7
Ewhr,[1] 10^6 hr		60		51		48		44		39		241	
Irr[2]		0.003		0.004		0.017		–		0.005		[2]0.006	

[1]Derived from MSHA "Injury Experience in Mining" publications.
[2]Calculated according to MSHA formula reported in the "Methodologies" section.

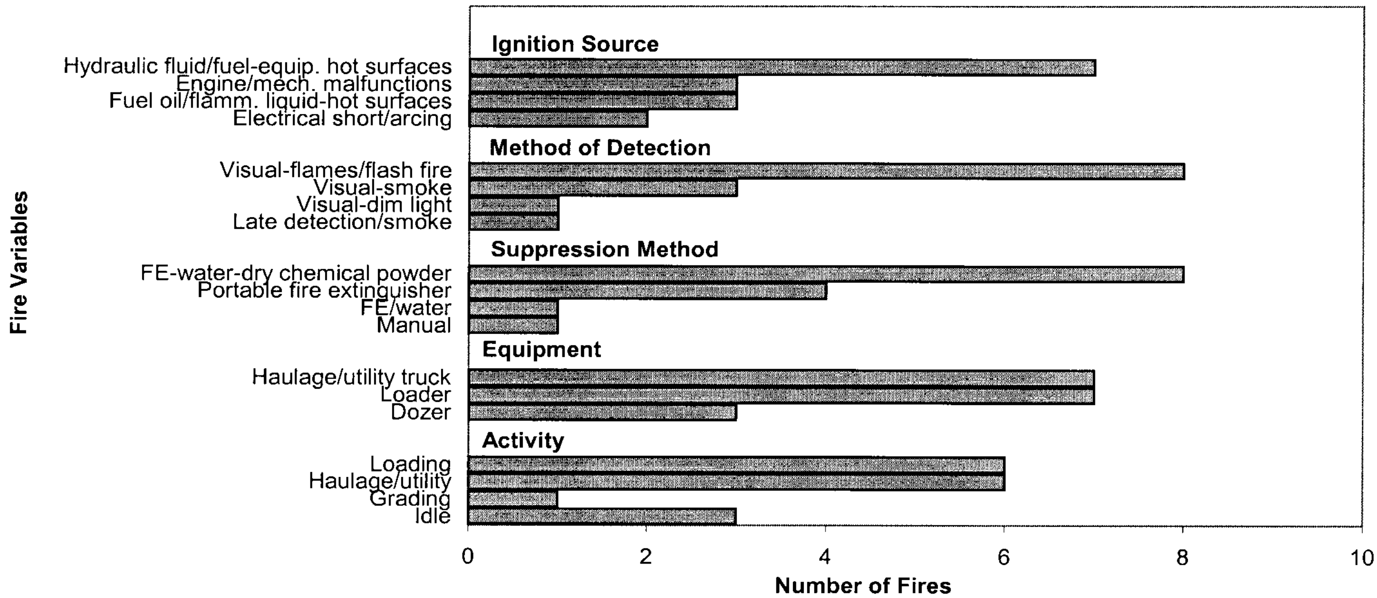

Figure 7.—Major variables for mobile equipment fires at coal preparation plants, 1990-1999. (FE = portable fire extinguisher.)

Table 15.–Number of mobile equipment fires for coal preparation plants by ignition source, equipment involved, and time period, 1990-1999

Equipment	Ignition source	Time period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Loader	Hydraulic fluid/fuel on equipment hot surfaces	2	1	1	–	1	5
	Heat source	1	–	–	–	–	1
	Electrical short/arcing	–	1	–	–	–	1
Dozer	Flammable liquid/fuel oil on hot surfaces	1	1	–	1	–	3
Haulage/utility truck	Hydraulic fluid/fuel on equipment hot surfaces	–	–	1	–	1	2
	Electrical short/arcing	–	–	–	–	1	1
	Flame cutting/welding spark/slag	1	–	–	–	–	1
	Engine/mechanical malfunctions	–	1	1	1	–	3
Total		5	4	3	2	3	17

Table 16.–Number of mobile equipment fires for coal preparation plants by method of detection, equipment involved, and time period, 1990-1999

Equipment	Method of detection	Time period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Loader	Visual-flames/flash fire	2	1	1	–	1	5
	Visual-smoke	–	1	–	–	–	1
	Late detection-smoke	1	–	–	–	–	1
Dozer	Visual-flames/flash fire	–	–	–	1	–	1
	Undetected	1	1	–	–	–	2
Haulage/utility truck	Visual-flames/flash fire	–	–	1	–	1	2
	Visual-sparks	1	–	–	–	–	1
	Touch-hot surface	–	–	1	–	–	1
	Visual-smoke	–	1	–	1	–	2
	Visual-dim lights	–	–	–	–	1	1
Total		5	4	3	2	3	17

During 1996-1997, there were two fires and no injuries. The equipment involved included a haulage truck and a dozer during haulage and grading activities. The Ewhr value was 44 × 10^6 hr. The ignition sources were flammable liquid/oil on hot surfaces and engine/mechanical malfunctions. The methods of detection were miners/operators who saw flames or smoke. The suppression methods used were portable fire extinguishers.

During 1998-1999, there were three fires and one injury. The equipment involved included haulage/utility trucks (two fires and no injuries) and a loader (one fire and one injury) during haulage and loading activities. The Ewhr value was 39 × 10^6 hr (Irr = 0.005). The ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces and electrical short/arcing. The fires, which were detected by the operators/miners as flames/flash fires, dim lights, or sparks, were extinguished with water, dry chemical powder, and portable fire extinguishers.

Table 18 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location. The highest number of injuries was recorded in 1995 (four fire injuries caused by three equipment fires). These involved loaders and trucks during hydraulic fluid/fuel and mechanical malfunction fires.

MOBILE EQUIPMENT FIRES IN UNDERGROUND COAL MINES

In underground coal mines, there were a total of 26 equipment fires during 1990-1999; 10 of those fires caused 10 injuries (table 19 and figure 8). One fire with one injury involved a contractor. In all, three pieces of equipment (12%) had machine fire suppression systems. These are required by law on all underground diesel equipment and electrically powered mine face equipment using non-fire-resistant hydraulic fluids.

The highest number of fires occurred in Kentucky (six fires and two injuries), followed by Alabama (five fires and two injuries), Virginia and Pennsylvania (four fires and one injury for each state), and West Virginia (three fires and two injuries). Alabama had the highest fire and injury risk rates (Frr = 0.03; Irr = 0.006). For underground coal mines, the total Ewhr value was 1,003 × 10^6 hr (Irr = 0.002); the CP value was 4,008 × 10^6 st (Frr = 0.007) (table 19).

The equipment involved, mostly during working activities, included scoops (six fires and three injuries), shuttle cars (five fires and three injuries), roof bolters (five fires and two injuries), and continuous miners (three fires and no injuries) (table 20 and figure 9).

The ignition sources that caused most of the underground equipment fires were electrical short/arcing (13 fires or 50%). At least once, an electrical fire spread to the hydraulic lines, (most underground equipment is electrically powered). Other ignition sources were flame cutting/welding spark/slag, refueling fuel on hot surfaces, mechanical malfunction/friction, heat source, hydraulic fluid sprayed onto equipment hot surfaces, and overheated oil (table 21 and figure 9). Operators/miners/ welders detected most of the fires when they started as flames, smoke, or sparks. One fire was detected by a conveyor belt entry carbon monoxide (CO) sensor alarm after the fire had started, and three were detected late (which made fire-fighting methods ineffective) (table 22 and figure 9). Upon mine/section evacuation, mine rescue teams (required five times), which were often severely hindered by intense smoke in trying to reach the fire location, fought three electrical fires, one hydraulic fluid fire, and one heat source fire with rock dust, dry chemical powder, and water. Four pieces of equipment were destroyed or heavily damaged because of failed fire suppression methods and late fire detection (table 23 and figure 9).

The three fires involving equipment with fire suppression systems behaved as follows. In two instances, a hydraulic fluid fire and an electrical fire involving two bolters were temporarily contained upon dual activation of the fire suppression/motor deenergization systems; portable fire extinguishers and water were used to complete the extinguishment. In the third instance, an electrical fire involving a scoop, detected by a conveyor belt entry CO sensor alarm long after the fire had started, raged out of control and spread to the hydraulic lines because of machine fire suppression system failure (clogged hoses).

Table 17.–Number of mobile equipment fires for coal preparation plants by suppression method, equipment involved, and time period, 1990-1999

Equipment	Suppression method	Time Period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Loader	FE-water-dry chemical powder[1]	2	1	1	–	1	5
	Destroyed/heavily damaged[2]	1	–	–	–	–	1
	Portable fire extinguisher	–	1	–	–	–	1
Dozer	Water-dry chemical powder[1]	–	–	–	1	–	1
	Destroyed/heavily damaged[2]	1	1	–	–	–	2
Haulage/utility truck	FE-water-dry chemical powder[1]	–	–	1	–	1	2
	FE-water	–	–	1	–	–	1
	Portable fire extinguisher	–	1	–	1	1	3
	Manual[3]	1	–	–	–	–	1
Total		5	4	3	2	3	17

FE Portable fire extinguisher.
[1]Methods mostly used by fire departments.
[2]Usually due to late fire detection, undetected fires or fire size.
[3]Methods used by welders to extinguish clothing fires.

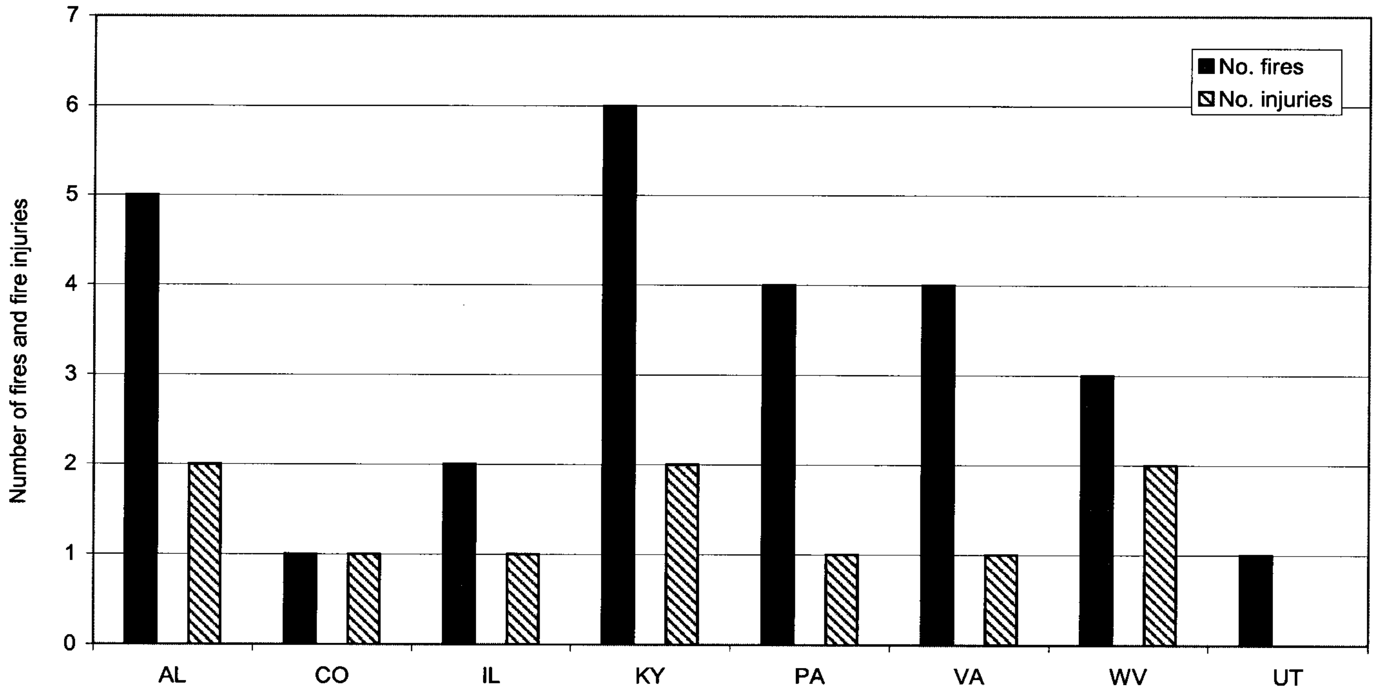

Figure 8.—Mobile equipment fires and injuries for underground coal mines by state, 1990-1999.

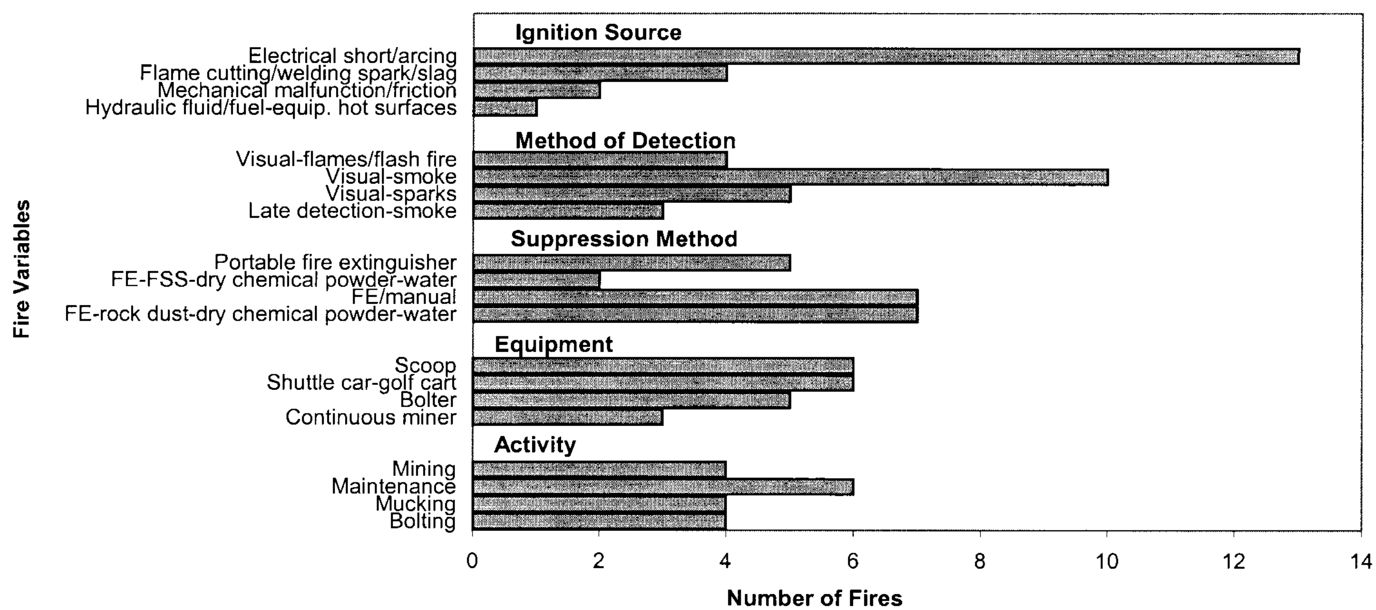

Figure 9.—Major variables for mobile equipment fires in underground coal mines, 1990-1999. (FE = portable fire extinguisher; FSS = machine fire suppression system.)

Table 18.–Number of fire injuries per number of mobile equipment fires causing injuries and total fires at coal preparation plants by year, ignition source, equipment involved, and location, 1990-1999

Year	No. fires causing injuries	No. total fires	No. fire injuries	Ignition source	Equipment	Location
1990	–	4	–	–	–	–
1991	1	1	1	Hydraulic fluid/fuel on equipment hot surfaces.	Loader	Loading area.
1992	–	1	–	–	–	–
1993	1	3	1	Hydraulic fluid/fuel on equipment hot surfaces.	Loader	Loading area.
1994	–	–	–	–	–	–
1995	2	3	3	Hydraulic fluid/fuel on equipment hot surfaces.	Loader–truck	Loading/haulage areas.
	1	–	1	Mechanical malfunction	Truck	Maintenance area.
1996	–	–	–	–	–	–
1997	–	2	–	–	–	–
1998	–	–	–	–	–	–
1999	1	3	1	Hydraulic fluid/fuel on equipment hot surfaces.	Loader	Loading area.
Total	6	17	7			

Table 19.–Number of mobile equipment fires, injuries, and risk rates for underground coal mines by state, equipment involved, coal production, and employees' working hours, 1990-1999

State[1]	Equipment[1]	No. fires[1]	No. injuries[1]	Ewhr,[2] 10^6 hr	CP,[2] 10^6 st	Irr[3]	Frr[3]
AL	Bolter	1	1				
	Scoop	1	1				
	Shuttle car	1	–				
	Continuous miner . . .	1	–				
	Shearer	1	–	67.1	165.1	0.006	0.03
CO	Scoop	1	1	20.1	148.2	0.01	0.007
IL	Scoop	1	–				
	Shuttle car	1	1	96.6	404.5	0.002	0.005
KY	Scoop	2	1				
	Continuous miner . . .	1	–				
	Bolter	1	–				
	Golf cart	1	–				
	Railrunner	1	1	245.6	949.5	0.0016	0.0063
PA	Scoop	1	–				
	Truck	1	–				
	3-wheeler	1	–				
	Jeep	1	1	124.5	455.4	0.0016	0.009
UT	Continuous miner . . .	1	–	34.3	241	–	0.0042
VA	Shearer	1	–				
	Shuttle car	2	1				
	Bolter	1	–	96	291.4	0.002	0.014
WV	Bolter	2	1				
	Shuttle car	1	1	281.5	1,156.2	0.0014	0.0026
All other states . .	–	–	–	37.6	196.7		
Total		26	10	1,003	4,008	[3]0.002	[3]0.007

[1]Derived from MSHA "Fire Accident Abstract" and "Fire Accident Report" publications.
[2]Derived from MSHA "Injury Experience in Mining" publications.
[3]Calculated according to MSHA and USBM formulas reported in the "Methodologies" section.

Table 20.–Number of mobile equipment fires, injuries, and risk rates for underground coal mines by time period, equipment involved, activity, and employees' working hours, 1990-1999

Equipment	Activity	Time period 90-91 No. fires	90-91 No. injuries	92-93 No. fires	92-93 No. injuries	94-95 No. fires	94-95 No. injuries	96-97 No. fires	96-97 No. injuries	98-99 No. fires	98-99 No. injuries	90-99 No. fires	90-99 No. injuries
Scoop	Mucking	–	–	–	–	3	1	–	–	1	–	4	1
	Flame cutting/welding	1	1	–	–	–	–	–	–	1	1	2	2
Continuous miner	Mining	2	–	–	–	–	–	–	–	–	–	2	–
	Flame cutting/welding	1	–	–	–	–	–	–	–	–	–	1	–
Shearer	Mining	2	–	–	–	–	–	–	–	–	–	2	–
Bolter	Bolting	–	–	2	1	–	–	–	–	2	–	4	1
	Flame cutting/welding	1	1	–	–	–	–	–	–	–	–	1	1
Shuttle car	Maintenance	1	1	1	–	2	1	–	–	1	1	5	3
Railrunner	Transportation	–	–	1	1	–	–	–	–	–	–	1	1
Golf cart	Maintenance	–	–	–	–	1	–	–	–	–	–	1	–
Haulage truck	Haulage	–	–	1	–	–	–	–	–	–	–	1	–
3–Wheeler	Idle	–	–	–	–	–	–	1	–	–	–	1	–
Jeep	Idle	–	–	–	–	1	1	–	–	–	–	1	1
Total		8	3	5	2	7	3	1	–	5	2	26	10
Ewhr,[1] 10^6 hr		257		209		196		179		162		1,003	
Irr[2]		0.0023		0.002		0.0031		–		0.0025		[2]0.002	
CP,[1] 10^6 st		824		752		792		830		810		4,008	
Frr[2]		0.01		0.007		0.009		0.001		0.006		[3]0.007	

[1]Derived from MSHA "Injury Experience in Mining" publications.
[2]Calculated according to MSHA and USBM formula reported in the "Methodologies" section.

Table 21.–Number of mobile equipment fires for underground coal mines by ignition source, equipment involved, and time period, 1990-1999

Equipment	Ignition source	Time period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Scoop	Electrical short/arcing[1]	–	–	1	–	–	1
	Flame cutting/welding spark/slag	1	–	–	–	1	2
	Electrical short/arcing	–	–	2	–	1	3
Continuous miner	Mechanical friction	1	–	–	–	–	1
	Flame cutting/welding spark/slag	1	–	–	–	–	1
	Fuel oil on hot surfaces	1	–	–	–	–	1
Shearer	Mechanical malfunction	1	–	–	–	–	1
	Overheated oil[2]	1	–	–	–	–	1
Bolter	Hydraulic fluid on equipment hot surfaces	–	1	–	–	–	1
	Flame cutting/welding spark/slag	1	–	–	–	–	1
	Electrical short/arcing	–	1	–	–	2	3
Shuttle car	Refueling fuel on hot surfaces	1	1	–	–	–	2
	Electrical short/arcing	–	–	2	–	–	2
	Heat source	–	–	–	–	1	1
Golf cart	Electrical short/arcing	–	–	1	–	–	1
Haulage truck	Electrical short/arcing	–	1	–	–	–	1
3–wheeler	Electrical short/arcing	–	–	–	1	–	1
Jeep	Heat source	–	–	1	–	–	1
Railrunner	Electrical short/arcing	–	1	–	–	–	1
Total		8	5	7	1	5	2

[1]This source caused a hydraulic fluid fire.
[2]Due to compressor malfunction.

Data during the five time periods, including the number of fires, fire injuries, risk rates, employees' working hours, and coal production according to the equipment involved and activity, are shown in table 20 and partly illustrated in figure 3. Other variables such as ignition source and methods of detection and suppression are shown in tables 21-23.

Equipment fires and fire injuries decreased during 1996-1997, then increased during 1998-1999, accompanied by a sharp decline in employees' working hours and small changes in coal production.

During 1990-1991, there were eight fires and three injuries. The equipment involved included continuous miners (three fires and no injuries), shearers (two fires and no injuries), and a bolter and shuttle car (one fire and injury for each) during mining, maintenance, and flame cutting/welding activities. The Ewhr value was 257×10^6 hr (Irr = 0.002); the CP value was 824 $\times 10^6$ st (Frr = 0.01). The most common ignition sources were flame cutting/welding spark/slag, followed by mechanical friction/malfunction and refueling fuel/fuel oil on hot surfaces. The

Table 22.–Number of mobile equipment fires for underground coal mines by method of detection, equipment involved, and time period, 1990-1999

Equipment	Method of detection	Time period 90-91	92-93	94-95	96-97	98-99	90-99
		No. fires	No. fires	No. fires	No. fires	No. fires	No. fires
Scoop	Visual-flames/flash fire	–	–	1	–	–	1
	Visual-sparks	1	–	–	–	1	2
	Late detection-CO alarm	–	–	1	–	–	1
	Visual-smoke	–	–	1	–	1	2
Continuous miner	Visual-smoke	2	–	–	–	–	2
	Visual-sparks	1	–	–	–	–	1
Shearer	Visual-flames/flash fire	1	–	–	–	–	1
	Visual-smoke	1	–	–	–	–	1
Bolter	Visual-sparks	1	–	–	–	–	1
	Visual-smoke	–	1	–	–	–	1
	Undetected	–	–	–	–	1	1
	Power loss	–	–	–	–	1	1
	Late detection–smoke	–	1	–	–	–	1
Shuttle car	Visual-flames/flash fire	1	1	–	–	–	2
	Late detection-smoke	–	–	1	–	–	1
	Visual-smoke	–	–	1	–	–	1
	Touch-hot spot	–	–	–	–	1	1
Golf cart	Visual-smoke	–	–	1	–	–	1
Haulage truck	Visual-smoke	–	1	–	–	–	1
3-wheeler	Late detection-smoke	–	–	–	1	–	1
Jeep	Late detection-smoke	–	–	1	–	–	1
Railrunner	Visual-sparks	–	1	–	–	–	1
Total		8	5	7	1	5	26

Table 23.–Number of mobile equipment fires for underground coal mines by suppression method, equipment involved, and time period, 1990-1999

Equipment	Suppression method	Time period 90-91	92-93	94-95	96-97	98-99	90-99
		No. fires	No. fires	No. fires	No. fires	No. fires	No. fires
Scoop	FE/manual[1]	1	–	–	–	1	2
	FE-rockdust-dry chemical powder-water[2]	–	–	2	–	1	3
	Destroyed/heavily damaged[3]	–	–	1	–	–	1
Continuous miner	FE-WSS[2]	2	–	–	–	–	2
	Portable fire extinguisher	1	–	–	–	–	1
Shearer	FE-WSS[2]	1	–	–	–	–	1
	Portable fire extinguisher	1	–	–	–	–	1
Bolter	FE-water-dry chemical powder[2]	–	–	–	–	1	1
	FE/manual[1]	1	1	–	–	–	2
	FE-FSS-water-dry chemical powder[4]	–	1	–	–	1	2
Shuttle car	FE-rockdust-dry chemical powder-water[2]	–	1	–	–	–	1
	Destroyed/heavily damaged[3]	–	–	1	–	–	1
	FE/manual[1]	1	–	1	–	1	3
Golf cart	Portable fire extinguisher	–	–	1	–	–	1
Haulage/utility truck	Portable fire extinguisher	–	1	–	–	–	1
3-wheeler	Portable fire extinguisher	–	–	–	1	–	1
Jeep	FE-dry chemical powder-water[2]	–	–	1	–	–	1
Railrunner	FE-dry chemical powder-water[2]	–	1	–	–	–	1
Total		8	5	7	1	5	26

FE Portable fire extinguisher.
FSS Machine fire suppression system.
WSS Machine water spray.
[1]Methods used by welders to extinguish clothing or oxyfuel/grease fires (grease embedded in the equipment's mechanical components).
[2]Method used by mine rescue teams following, at times, machine water spray discharge by operator.
[3]Usually due to failed fire suppression methods (one FSS failure) or late detection.
[4]Methods used by mine rescue teams following available FSS discharge by operator.

methods of detection were welders/operators who saw sparks, smoke, or flames. The suppression methods were manual methods, portable fire extinguishers, and machine water sprays.

During 1992-1993, there were five fires and two injuries. The equipment involved included bolters (two fires and one injury), a railrunner (one fire and one injury), and a truck and a shuttle car (one fire and no injuries for each) during bolting, transportation, and haulage activities. The Ewhr value was 209 × 10^6 hr (Irr = 0.002); the CP value was 752 × 10^6 st (Frr = 0.007). The ignition sources were electrical short/arcing, followed by hydraulic fluid sprayed onto equipment hot surfaces and refueling fuel on hot surfaces. The methods of detection were operators who saw smoke or flames/flash fires (one fire was detected late). The suppression methods used were portable fire extinguishers, rock dust, and dry chemical powder. A machine fire suppression system was discharged once.

During 1994-1995, there were seven fires and three injuries. The equipment involved included scoops (three fires and one injury), shuttle cars (two fires and one injury), a jeep (one fire and one injury), and a golf cart (one fire and no injuries) mostly during mucking and maintenance activities. The Ewhr value was 196 × 10^6 hr (Irr = 0.003); the CP value was 792 × 10^6 st (Frr = 0.009). The ignition sources were electrical/short/arcing, followed by heat sources. The most frequent methods of detection were operators who saw smoke or flames/flash fires three fires were detected late; (one of these fires was detected late by a conveyor belt entry CO sensor alarm). The most commonly used suppression methods were portable fire extinguishers, dry chemical powder, rock dust, and water. A machine fire suppression system failed to discharge because of clogged hoses.

During 1996-1997, there was one fire and no injuries involving a three-wheeler. The electrical fire was detected late as smoke; it was extinguished with dry chemical powder. The Ewhr value was 179 × 10^6 hr; the CP value was 830 × 10^6 st (Frr = 0.001).

During 1998-1999, there were five fires and two injuries. The equipment involved included scoops (two fires and one injury), bolters (two fires and no injuries), and a shuttle car (one fire and one injury) during mucking, bolting, flame cutting/welding, and maintenance activities. The Ewhr value was 162 × 10^6 hr (Irr = 0.003); the CP value was 810 × 10^6 st (Frr = 0.006). The ignition sources were electrical short/arcing, followed by heat sources and flame cutting/welding spark/slag. The most frequent methods of detection were operators/miners who saw smoke or flames or experienced power loss and welders who saw sparks (one fire was undetected). The most commonly used suppression methods were portable fire extinguishers, dry chemical powder, rock dust, and water. A machine fire suppression system was discharged once.

Table 24 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location. The highest number of fire injuries was recorded in 1994 (two fire injuries caused by two equipment fires) during electrical fires involving a scoop and a shuttle car.

Table 24.–Number of fire injuries per number of mobile equipment fires causing injuries and total fires in underground coal mines by year, ignition source, equipment involved, and location, 1990-1999

Year	No. fires causing injuries	No. total fires	No. fire injuries	Ignition source	Equipment	Location
1990 . . .	1	6	1	Flame cutting/welding spark/slag	Scoop	Flame cutting/welding areas.[1]
1991 . . .	1	2	1	Refueling fuel on hot surfaces	Shuttle car	Transport area.
	1	–	1	Flame cutting/welding spark/ slag . . .	Bolter	Flame cutting/welding areas.[1]
1992 . . .	1	3	1	Electrical short/arcing	Railrunner	Rail track area.
1993 . . .	1	2	1	Electrical short/arcing	Bolter	Bolting area.
1994 . . .	2	2	2	Electrical short/arcing	Scoop/shuttle car . . .	Mining face/charging station.
1995 . . .	1	5	1	Heat source	Jeep	Crosscut section.
1996 . . .	–	–	–	–	–	–
1997 . . .	–	1	–	–	–	–
1998 . . .	–	–	–	–	–	–
1999 . . .	1	5	1	Flame cutting/welding spark/ slag . . .	Scoop	Flame cutting/welding areas.[1]
	1	-	1	Heat source	Shuttle car	Maintenance area.
Total . . .	10	26	10			

[1]Includes headgate, bolting, and mining areas.

MOBILE EQUIPMENT DATA ANALYSIS FOR ALL METAL/NONMETAL MINING CATEGORIES

MOBILE EQUIPMENT FIRES AT SURFACE METAL/NONMETAL MINES

At surface metal/nonmetal mines, there were a total of 49 equipment fires during 1990-1999; 24 of those fires caused 24 injuries and 1 fatality (table 25 and figure 10). Six equipment fires with five injuries occurred at metal mines. Forty-three fires with nineteen injuries and one fatality occurred at nonmetal mines. Seven fires with five injuries involved contractors. In all, five pieces of equipment (10%) had machine fire suppression systems. The highest number of equipment fires occurred in Nevada (15 fires, 7 injuries, and 1 fatality), followed by Arizona (14 fires and 8 injuries), Minnesota (8 fires and 3 injuries), and California (3 fires and no injuries). Minnesota had the highest injury risk rate (Irr = 0.014). For surface metal/nonmetal mines, the total Ewhr value was 467 × 10^6 hr (Irr = 0.01) (table 25).

The equipment involved, mostly during working activities, included haulage/utility trucks (23 fires, 15 injuries, and 1 fatality), shovels (14 fires and 2 injuries), drills (5 fires and no injuries) and loaders (4 fires and 5 injuries) (table 26 and figure 11).

Table 25.–Number of mobile equipment fires, injuries, and risk rates for surface metal/nonmetal mines by state, equipment involved, and employees' working hours, 1990-1999

State[1]	Equipment[1]	No. fires[1]	No. injuries[1]	Ewhr,[2] 10^6 hr	Irr[3]
AK	Shovel	2	–	9.2	–
AL	Scraper	1	1	1.5	0.13
AZ	Truck	8	6		
	Shovel	5	1		
	Loader	1	1	80	0.015
CA	Shovel	1	–		
	Truck	1	–		
	Excavator	1	–	13	–
FL	Loader	1	1		
	Truck	1	1	33.4	0.012
GA	Truck	1	1	14.5	0.014
ID	Shovel	1	–	7.5	–
MN	Truck	3	2		
	Loader	1	1		
	Shovel	1	–		
	Drill	3	–	42.5	0.014
MO	Shovel	1	1	0.7	0.3
NV[4]	Truck	8	4		
	Drill	2	–		
	Shovel	3	–		
	Dozer	1	1		
	Loader	1	2	11.4	0.123
SC	Truck	1	1	0.7	0.3
All other states		–	–	252.2	–
Total		49	24	467	[3]0.01

[1]Derived from MSHA "Fire Accident Abstract" and "Fire Accident Report" publications.
[2]Derived from MSHA "Injury Experience in Mining" publications.
[3]Calculated according to MSHA formula reported in the "Methodologies" section.
[4]Nevada had one fire fatality.

Table 26.–Number of mobile equipment fires, injuries, fatalities, and risk rates for surface metal/nonmetal mines by time period, equipment involved, activity, and employees' working hours, 1990-1999

Equipment	Activity	Time period 90-91 No. fires	90-91 No. injuries	92-93 No. fires	92-93 No. injuries	94-95 No. fires	94-95 No. injuries	96-97 No. fires	96-97 No. injuries	98-99 No. fires	98-99 No. Injuries	90-99 No. fires	90-99 No. Injuries
Haulage/utility truck[1]	Haulage/utility	4	3	3	2	6	3	7	4	-	–	20	12
	Maintenance	–	–	1	1	–	–	–	–	1	1	2	2
	Flame cutting/welding	–	–	–	–	–	–	–	–	1	1	1	1
Scraper	Mining	–	–	1	1	–	–	–	–	–	–	1	1
Excavator	Mining	–	–	1	–	–	–	–	–	–	–	1	–
Shovel	Mining	1	–	4	–	1	–	2	–	–	–	8	–
	Flame cutting/welding	–	–	2	1	1	1	–	–	–	–	3	2
	Idle	1	–	2	–	–	–	–	–	–	–	3	–
Loader	Loading	2	3	2	2	–	–	–	–	–	–	4	5
Drill	Idle	–	–	–	–	1	–	–	–	–	–	1	–
	Drilling	–	–	1	–	2	–	1	–	–	–	4	–
Dozer	Mining	1	1	–	–	–	–	–	–	–	–	1	1
Total		9	7	17	7	11	4	10	4	2	2	49	24
No. fatalities		–		–		1		–		–		1	
Ewhr,[2] 10^6 hr		97		93		95		98		84		467	
Irr[3]		0.014		0.015		0.008		0.008		0.005		[3]0.01	

[1]This equipment caused one fire fatality.
[2]Derived from MSHA "Injury Experience in Mining" publications.
[3]Calculated according to MSHA formula reported in the "Methodologies" section.

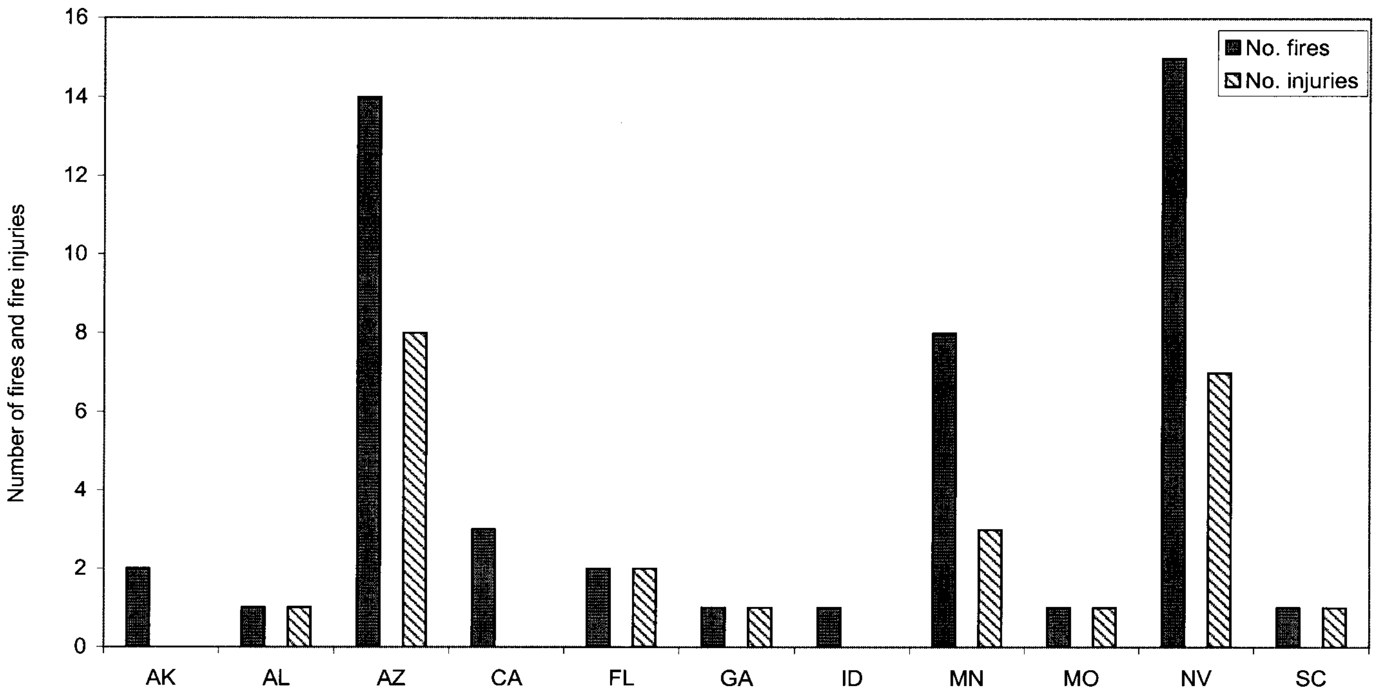

Figure 10.—Mobile equipment fires and injuries for surface metal/nonmetal mines by state, 1990-1999.

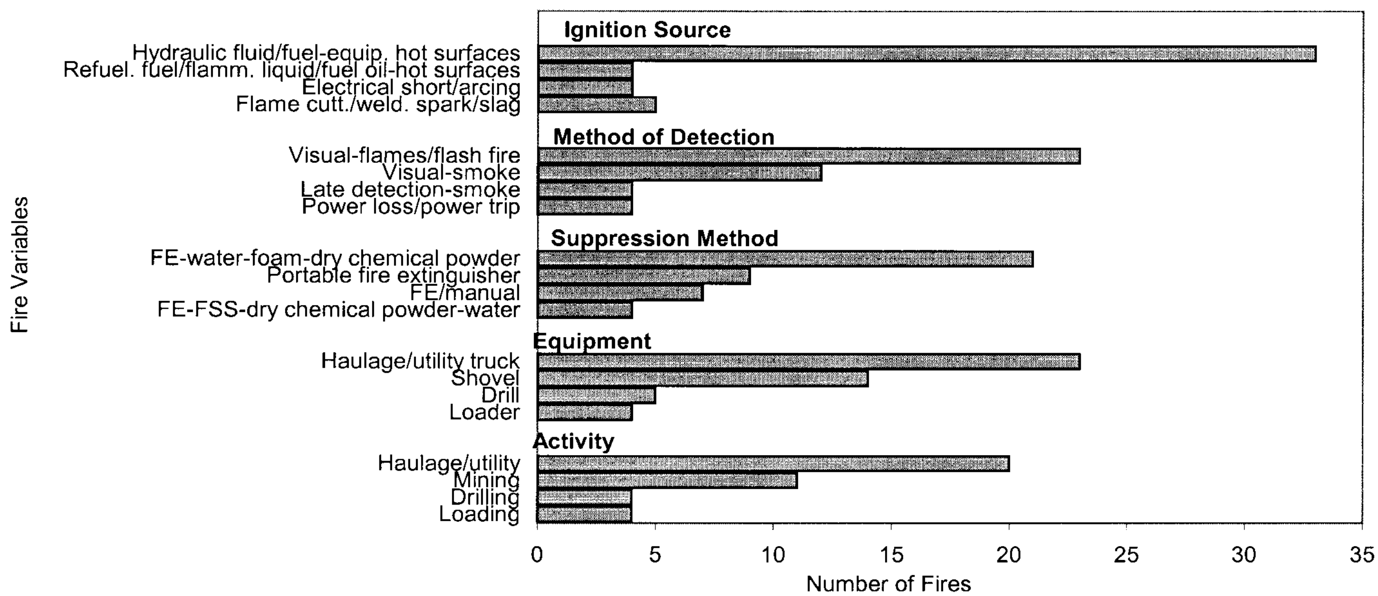

Figure 11.—Major variables for mobile equipment fires at surface metal/nonmetal mines, 1990-1999. (FE = portable fire extinguisher; FSS = machine fire suppression system.)

Most of the fires were caused by pressurized hydraulic fluid/fuel (33 fires or 67%) sprayed onto equipment hot surfaces, followed by flame cutting/welding spark/slag, flammable liquid/refueling fuel/oil on hot surfaces, flame cutting/welding spark/slag, and electrical short/arcing. Other sources were heat sources and overheated oil (table 27 and figure 11). Operators/miners/welders detected most of the fires when they started as flames/flash fires, smoke, power loss, or sparks. Most of the hydraulic fluid/fuel fires, although detected by the operators when they started, grew out of control (requiring at least one firefighter intervention) because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure, lack of an emergency line drainage system, difficulty in reaching available emergency systems at ground level due to flames engulfing the area, or lack of effective and rapid local fire-fighting response capabilities. Four fires were detected late (which made fire-fighting methods ineffective), and one was undetected and burned itself out (table 28 and figure 11). At least twice the cab was suddenly engulfed in flames, forcing the operator to exit the cab under difficult conditions (one fatality) most likely due to the ignition of flammable vapors and mists that formed and penetrated the cab during the spraying of hydraulic fluid/fuel onto equipment hot surfaces.

Fire brigades and fire departments, handicapped by travel distances, fought the hydraulic fluid/fuel fires with foam (mostly used by fire brigades), dry chemical powder (mostly used by fire departments), and water. Seven pieces of equipment were destroyed or heavily damaged because of failed fire suppression and fire-fighting methods, late fire detection, undetected fires, or fire size, (table 29 and figure 11).

The five hydraulic fluid fires that involved equipment with fire suppression systems behaved as follows. In the first instance, which involved a loader, the fire abated temporarily upon ground-level dual activation of the fire suppression and engine shutoff systems. In the second and third instances, the fires, which involved a shovel and haulage truck, raged out of control because, upon activation of machine fire suppression systems, the operators failed to shut off the engine because of advancing flames. In the fourth instance, which involved an idle shovel, the fire raged out of control because of late detection and failure to activate the machine fire suppression system due to fire size. In the fifth instance, which involved a haulage truck wheel motor, the hydraulic fluid fire raged out of control because the operator (one fatality), unaware of the automatic fire suppression system self-activation (which occurred at a preset temperature of 356 °F) due to unclear cab signals, continued to operate the rig until the flames suddenly engulfed the cab.

Data during the five time periods, including the number of fires, fire injuries and fire fatality, risk rates, and employees' working hours according to the equipment involved and activity, are shown in table 26 and partly illustrated in figure 12. Other variables such as ignition source and methods of detection and suppression are shown in tables 27-29.

Equipment fires increased sharply during 1992-1993 (the number of fire injuries stayed steady during this period), then decreased during subsequent periods, accompanied by a small decline in employees' working hours.

During 1990-1991, there were nine fires and seven injuries. The equipment involved included haulage/utility trucks (four fires and three injuries), loaders (two fires and three injuries), and shovels (two fires and no injuries) mostly during haulage, loading, and mining activities. The Ewhr value was 97×10^6 hr (Irr = 0.014). The ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by electrical short/arcing and flammable liquid/refueling fuel/oil on hot surfaces. The methods of detection were operators who saw flames/flash fires and operators/miners who saw smoke (one fire was detected late). The suppression methods used were portable fire extinguishers, foam, dry chemical powder, and water (one equipment fire was not extinguished). A machine fire suppression system was discharged once; in another instance, the system was not activated.

During 1992-1993, there were 17 fires and 7 injuries. The equipment involved included shovels (eight fires and one injury), haulage/utility trucks (four fires and three injuries), and loaders (two fires and two injuries) mostly during mining, haulage, and loading activities. The Ewhr value was 93×10^6 hr (Irr = 0.015). The most common ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by flame cutting/welding spark/slag, electrical short/arcing, and flammable liquid/refueling fuel/oil on hot surfaces (one fire was detected late and one fire was undetected). The most frequent methods of detection were operators who saw flames/flash fires, followed by miners/welders who saw smoke or sparks. The most commonly used suppression methods were portable fire extinguisher, foam, dry chemical powder, and water (three equipment fires were not extinguished). A machine fire suppression system was discharged once.

During 1994-1995, there were 11 fires, 4 injuries, and 1 fatality. The equipment involved included haulage/utility trucks (six fires, three injuries, and one fatality), drills (three fires and no injuries), and shovels (two fires and one injury) mostly during haulage, drilling, and mining activities. The Ewhr value was 95×10^6 hr (Irr = 0.008). The most common ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by electrical short/arcing, heat sources, and flame cutting/welding spark/slag. The most frequent methods of detection were operators who saw flames/flash fires or experienced power loss and operators/miners/welders who saw smoke or sparks. The most commonly used suppression methods were portable fire extinguishers, foam, and dry chemical powder (two equipment fires were not extinguished). The machine fire suppression systems were discharged twice.

During 1996-1997, there were 10 fires and 4 injuries. The equipment involved included haulage/utility trucks (seven fires and four injuries), shovels (two fires and no injuries), and drills (one fire and no injuries) mostly during haulage, mining, and drilling activities. The Ewhr value was 98×10^6 hr (Irr = 0.008). The ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by electrical short/arcing, heat sources, and flammable liquid/refueling fuel/oil on hot surfaces. The methods of detection were operators who saw flames/flash fires and operators/miners who saw smoke. The most commonly used suppression methods were portable fire extinguishers, foam, dry chemical powder, and water (one equipment fire was not extinguished).

During 1998-1999, there were two fires and two injuries. The equipment involved included haulage/utility trucks (two fires and two injuries) during maintenance and flame cutting/welding activities. The Ewhr value was 84×10^6 hr (Irr = 0.005). The ignition sources were flammable liquids on hot surfaces and flame cutting/welding spark/slag. The methods of detection were operators/miners who saw flames/flash fires and welders who saw sparks. The suppression methods used were portable fire extinguishers.

Table 30 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location. The highest number of fire injuries was recorded in 1995 (two fire injuries and one fire fatality caused by three equipment fires); these involved trucks during hydraulic fluid/fuel and flammable liquid fires. The fire fatality, which occurred in Nevada during a hydraulic fluid fire involving a haulage truck wheel motor, was caused by flames engulfing the cab. The operator, who was unaware of the automatic fire suppression system activation due to unclear signals, had continued to operate the rig [MSHA 1995f].

MOBILE EQUIPMENT FIRES AT SURFACE SAND AND GRAVEL AND STONE MINES

At surface sand and gravel and stone mines, there were a total of 46 equipment fires during 1990-1999; 35 injuries and 1 fatality were caused by 36 of those fires (table 31 and figure 13). Nineteen fires with fifteen injuries occurred at sand and gravel mines. Twenty-seven fires with twenty injuries and one fatality occurred at stone mines. Three fires with three injuries involved contractors. None of the equipment involved in the fires had machine fire suppression systems.

The highest number of equipment fires and fire injuries occurred in Pennsylvania (six fires and five injuries), followed by California (six fires and four injuries) and Michigan (five fires and two injuries). Pennsylvania had the highest injury risk rate (Irr = 0.017). For surface sand and gravel and stone mines, the total Ewhr value was $1{,}101 \times 10^6$ hr (Irr = 0.006) (table 31).

The equipment involved, mostly during working activities, included haulage/utility trucks (18 fires, 14 injuries, and 1 fatality), loaders (14 fires and 11 injuries), dozers (4 fires and 4 injuries), and dredges (3 fires and 3 injuries) (table 32 and figure 14).

Table 27.–Number of mobile equipment fires for surface metal/nonmetal mines by ignition source, equipment involved, and time period, 1990-1999

Equipment	Ignition source	Time period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Haulage/utility truck	Hydraulic fluid/fuel on equipment hot surfaces	3	1	6	5	–	15
	Heat source	–	–	–	1	–	1
	Flame cutting/welding spark/slag	–	1	–	–	1	2
	Flammable liquid/refueling fuel/fuel oil on hot surfaces	1	1	–	1	1	4
	Electrical short/arcing	–	1	–	–	–	1
Scraper	Hydraulic fluid/fuel on equipment hot surfaces	–	1	–	–	–	1
Excavator	Hydraulic fluid/fuel on equipment hot surfaces	–	1	–	–	–	1
Shovel	Electrical short/arcing	1	–	1	1	–	3
	Hydraulic fluid/fuel on equipment hot surfaces	1	5	–	1	–	7
	Overheated oil[1]	–	1	–	–	–	1
	Flame cutting/weldingark/slag	–	2	1	–	–	3
Loader	Hydraulic fluid/fuel on equipment hot surfaces	2	2	–	–	–	4
Drill	Hydraulic fluid/fuel on equipment hot surfaces	–	1	2	1	–	4
	Heat source	–	–	1	–	–	1
Dozer	Hydraulic fluid/fuel on equipment hot surfaces	1	–	–	–	–	1
Total		9	17	11	10	2	49

[1]Due to compressor malfunction.

Table 28.–Number of mobile equipment fires for surface metal/nonmetal mines by method of detection, equipment involved, and time period, 1990-1999

Equipment	Method of detection	Time period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Haulage/utility truck	Visual-smoke	3	1	1	2	–	7
	Visual-sparks	–	1	–	–	1	2
	Visual-flames/flash fire	1	1	3	5	1	11
	Power loss	–	1	2	–	–	3
Scraper	Visual-flames/flash fire	–	1	–	–	–	1
Excavator	Visual-flames/flash fire	–	1	–	–	–	1
Shovel	Visual-smoke	1	1	–	1	–	3
	Late detection-smoke	1	2	–	–	–	3
	Visual-sparks	–	2	1	–	–	3
	Visual-flames/flash fire	–	2	–	1	–	3
	Power trip	–	–	1	–	–	1
	Undetected	–	1	–	–	–	1
Loader	Visual-flames/flash fire	2	2	–	–	–	4
Drill	Late detection-smoke	–	–	1	–	–	1
	Visual-smoke	–	–	1	1	–	2
	Visual-flames/flash fire	–	1	1	–	–	2
Dozer	Visual-flames/flash fire	1	–	–	–	–	1
Total		9	17	11	10	2	49

Table 29.–Number of mobile equipment fires for surface metal/nonmetal mines by suppression method, equipment involved, and time period, 1990-1999

Equipment	Suppression method	Time period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Haulage/utility truck . . .	FE-FSS-water-dry chemical powder[1] .	–	–	1	–	–	1
	FE-water-foam-dry chemical powder[2]	1	1	–	1	–	3
	FE/manual[3]	–	1	1	1	1	4
	Portable fire extinguisher	3	2	–	–	1	6
	FE-water-foam-dry chemical powder[2]	–	–	3	3	–	6
	Water	–	–	–	1	–	1
	Destroyed/heavily damaged[4]	–	–	–	1	–	1
	FE-FSS-HD[5]	–	–	1	–	–	1
Scraper	FE-water-foam-dry chemical powder[2]	–	1	–	–	–	1
Excavator	FE-dry chemical powder[1]	–	1	–	–	–	1
Shovel	FE-FSS-dry chemical powder[1]	–	1	–	–	–	1
	Destroyed/heavily damaged[4]	1	3	–	–	–	4
	FE/manual[3]	–	1	1	1	–	3
	Portable fire extinguisher	–	–	1	–	–	1
	FE–water-foam-dry chemical powder[2]	1	1	–	1	–	3
	Portable fire extinguisher	–	2	–	–	–	2
Loader	FE-FSS-foam-dry chemical powder[1] .	1	–	–	–	–	1
	FE-water-foam-dry chemical powder[2]	1	2	–	–	–	3
Drill	FE-water-foam-dry chemical powder[2]	–	1	2	1	–	4
	Destroyed/heavily damaged[4]	–	–	1	–	–	1
Dozer	FE-water-foam-dry chemical powder[2]	1	–	–	–	–	1
Total		9	17	11	10	2	49

HD Heavily damaged.
FE Portable fire extinguisher.
FSS Machine fire suppression system.
[1]Method used by fire departments following, at times, available FSS discharge by operator.
[2]Methods used by fire brigades (mostly foam) and fire departments (mostly dry chemical powder) following available FSS discharge by operator.
[3]Methods used by welders to extinguish clothing or oxyfuel fires.
[4]Usually due to failed fire-fighting methods, late fire detection, undetected fires, or fire size (one FSS activation failure).
[5]Usually due to failed fire suppression methods.

Table 30.–Number of fire injuries per number of mobile equipment fires causing injuries and total fires at surface metal/nonmetal mines by year, ignition source, equipment involved, and location, 1990-1999

Year	No. fires causing injuries	No. total fires	No. fire injuries	Ignition source	Equipment	Location
1990 . .	1	2	1	Fuel oil on hot surfaces	Truck	Haulage area.
	1		1	Hydraulic fluid/fuel on equipment hot surfaces	Truck	Haulage area.
1991 . .	3	7	4	Hydraulic fluid/fuel on equipment hot surfaces	Loader-dozer . . .	Loading/mining areas.
	1		1	Hydraulic fluid/fuel on equipment hot surfaces	Truck	Haulage area.
1992 . .	1	8	1	Hydraulic fluid/fuel on equipment hot surfaces	Loader	Loading area.
	1		1	Flame cutting/welding spark/slag	Shovel	Flame cutting/welding areas.[1]
1993 . .	1	9	1	Flame cutting/welding spark/slag	Truck	Flame cutting/welding areas.[1]
	2		2	Hydraulic fluid/fuel on equipment hot surfaces	Scraper-loader . .	Mining/loading areas.
	1		1	Electrical short/arcing	Truck	Haulage area.
	1		1	Refueling fuel on hot surfaces	Truck	Maintenance area.
1994 . .	1	8	1	Flame cutting/welding spark/slag	Shovel	Flame cutting/welding areas.[1]
	1		1	Hydraulic fluid/fuel on equipment hot surfaces	Truck	Haulageway.
1995[2] .	1	3	1	Hydraulic fluid/fuel on equipment hot surfaces	Truck	Haulage area.
	1	–	1	Fuel oil on collision	Truck	Maintenance area.
1996 . .	2	6	2	Hydraulic fluid/fuel on equipment hot surfaces	Truck	Haulage area.
	2		2	Refueling fuel on hot surfaces	Truck	Haulage area.
1997 . .	–	4	–	–	–	–
1998 . .	–		–	–	–	–
1999 . .	1	2	1	Flame cutting/welding spark/slag	Truck	Flame cutting/welding areas.[1]
	1		1	Flammable liquid on hot surfaces	Truck	Maintenance area.
Total . .	24	49	24			

[1]Includes working and maintenance areas.
[2]During 1995, there was one fire fatality.

Table 31.–Number of mobile equipment fires, injuries, and risk rates for surface sand and gravel and stone mines by state, equipment involved, and employees' working hours, 1990-1999

State[1]	Equipment[1]	No. fires[1]	No. injuries	Ewhr,[2] 10^6 hr	Irr[3]
AZ	Truck	3	3	3.6	0.165
CA	Truck	4	3		
	Loader	1	1		
	Drill	1	–	95.7	0.0084
FL	Loader	1	1	35.5	0.0056
GA	Loader	2	2	21.2	0.019
IL	Dozer	1	1		
	Scraper	1	1		
	Loader	1	1	42	0.014
IN	Tanker	1	–		
	Truck	1	1		
	Dredge	1	1	34.1	0.012
KY	Dozer	1	1	15.5	0.013
LA	Dredge	1	1	14.2	0.014
MI	Truck	3	2		
	Loader	1	–		
	Shovel	1	–	40	0.005
MS	Dredge	1	1	15	0.013
NC	Crane	1	1	24	0.008
NE	Truck	1	1	1.5	0.13
NH	Loader	2	2	6.4	0.03
NJ	Truck	1	1	9.2	0.022
NY	Loader	1	–		
	Backhoe-forklift-truck	1	–	41	–
OK	Loader	1	1	17.5	0.011
OR	Dozer	1	1	13	0.015
PA	Loader	3	3		
	Truck	2	1		
	Bucket	1	1	58.3	0.017
PR	Dozer	1	1	11.4	0.013
SC	Loader	1	–		
	Truck	1	1	13	0.015
TN[4]	Truck	1	–	18	–
WV	Truck	1	1	5.2	0.04
All other states		–	–	565.81	–
Total		46	35	1,101	[3]0.006

[1]Derived from MSHA "Fire Accident Abstract" and "Fire Accident Report" publications.
[2]Derived from MSHA "Injury Experience in Mining" publications.
[3]Calculated according to MSHA formula reported in the "Methodologies" section.
[4]Tennessee had one fire fatality.

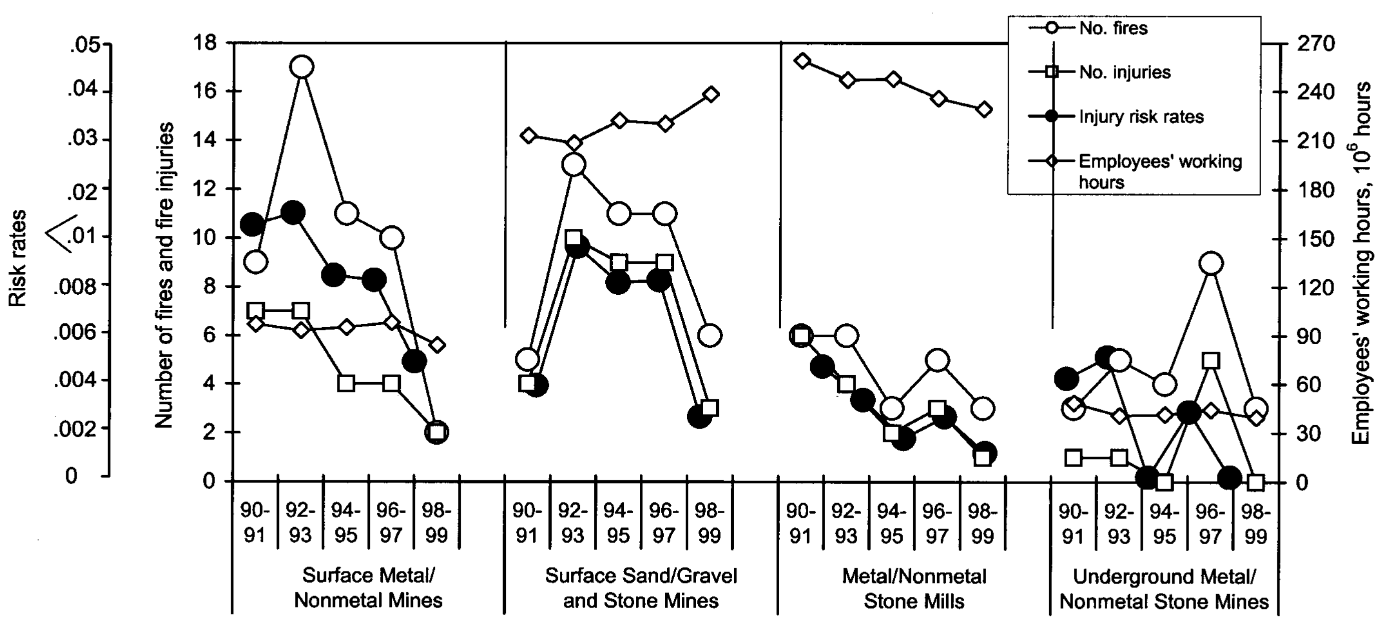

Figure 12.—Mobile equipment fires, injuries, risk rates, and employees' working hours by time period for each metal/nonmetal mining category, 1990-1999.

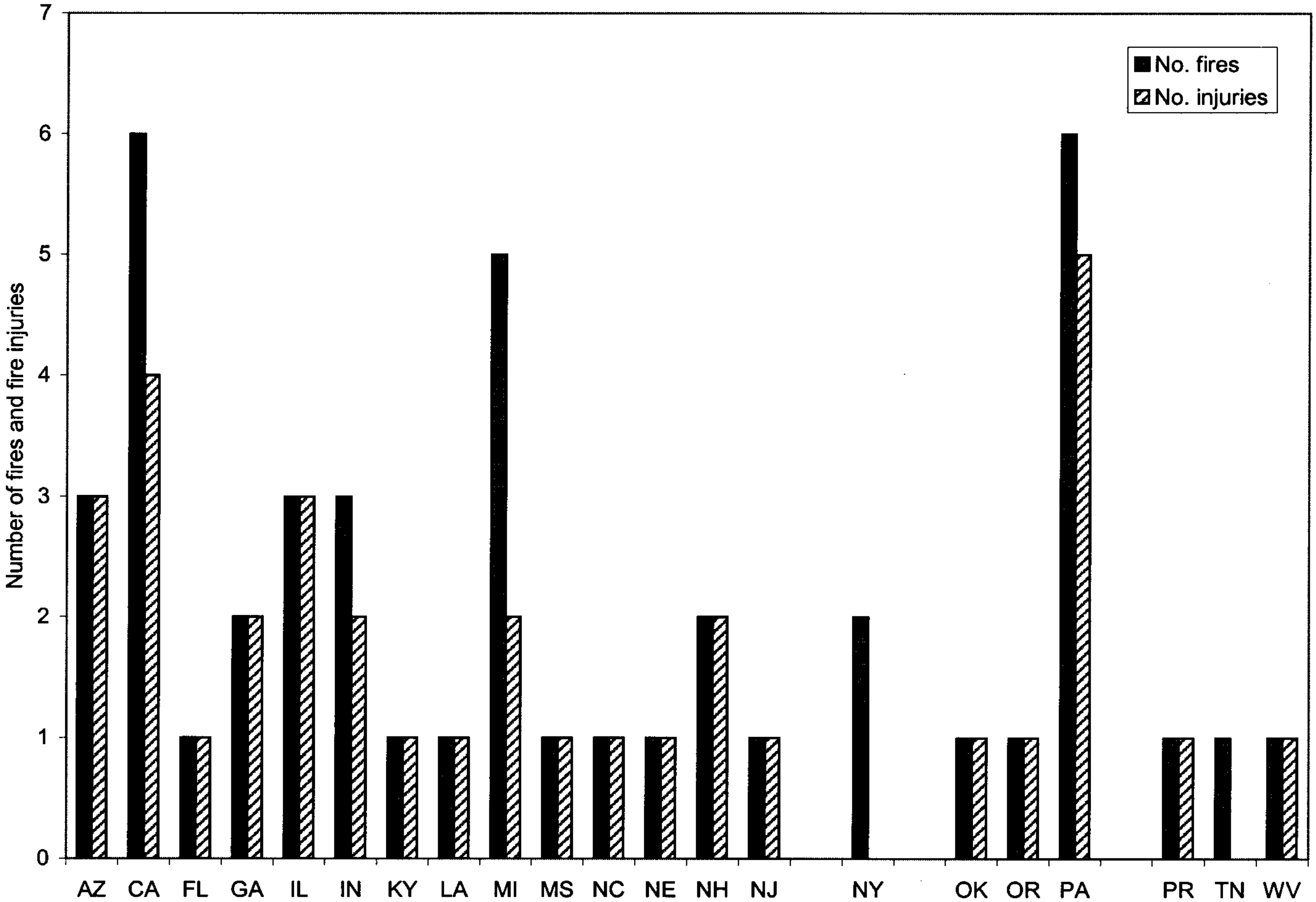

Figure 13.—Mobile equipment fires and injuries for surface sand and gravel and stone mines by state, 1990-1999.

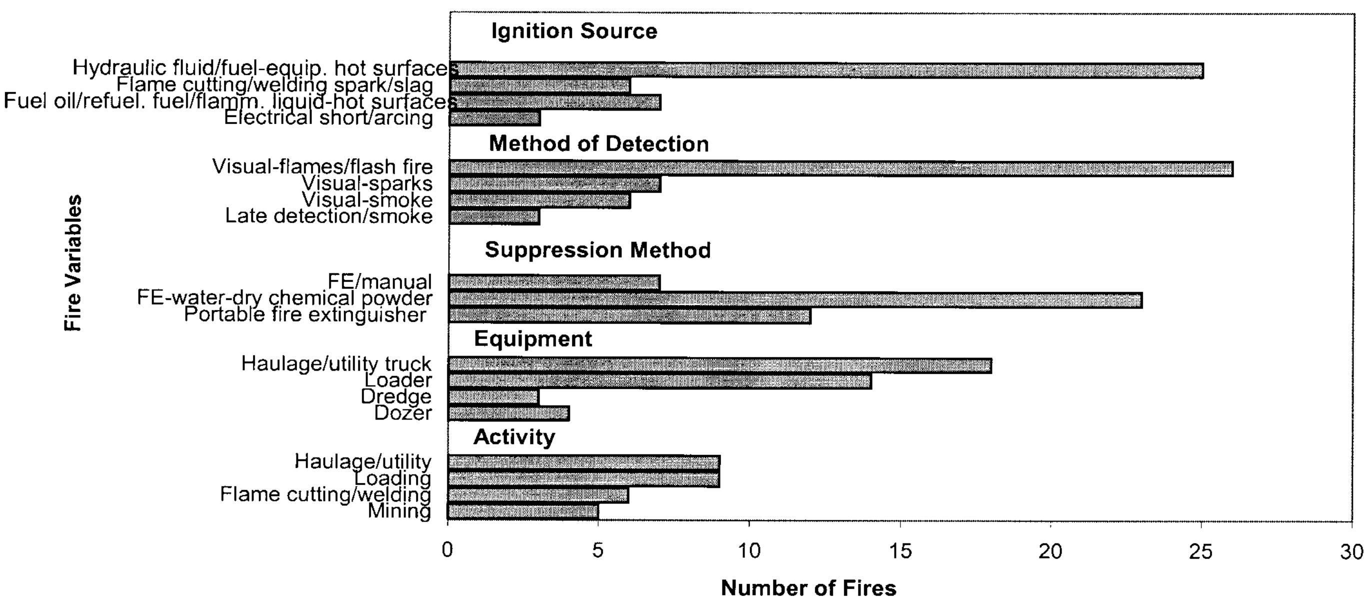

Figure 14.—Major variables for mobile equipment fires at surface sand and gravel and stone mines, 1990-1999. (FE = portable fire extinguisher.)

Table 32.–Number of mobile equipment fires, injuries, fatalities, and risk rates for surface sand and gravel and stone mines by time period, equipment involved, activity, and employees' working hours, 1990-1999

Equipment	Activity	Time period 90-91 No. fires	90-91 No. injuries	92-93 No. fires	92-93 No. injuries	94-95 No. fires	94-95 No. injuries	96-97 No. fires	96-97 No. injuries	98-99 No. fires	98-99 No. injuries	90-99 No. fires	90-99 No. injuries
Loader	Loading	2	1	2	2	2	2	2	2	1	1	9	8
	Flame cutting/welding	–	–	–	–	1	1	–	–	–	–	1	1
	Maintenance/idle	–	–	–	–	2	1	1	1	1	–	4	2
Haulage/utilitytruck[1]	Maintenance/idle	2	2	3	3	1	1	1	–	1	1	8	7
	Haulage/utility	–	–	3	1	1	–	4	4	1	1	9	6
	Flame cutting/welding	1	1	–	–	–	–	–	–	–	–	1	1
Drill	Drilling	–	–	1	–	–	–	–	–	–	–	1	–
Dozer	Mining	–	–	2	2	1	1	1	1	–	–	4	4
Dredge	Dredging	–	–	1	1	1	1	–	–	–	–	2	2
	Flame cutting/welding	–	–	–	–	1	1	–	–	–	–	1	1
Scraper	Mining	–	–	–	–	1	1	–	–	–	–	1	1
Backhoe/forklift/truck	Idle	–	–	–	–	–	–	1	–	–	–	1	–
Shovel/bucket	Flame cutting/welding	–	–	–	–	–	–	1	1	1	–	2	1
Tanker	Transportation	–	–	–	–	–	–	–	–	1	–	1	–
Crane	Flame cutting/welding	–	–	1	1	–	–	–	–	–	–	1	1
Total		5	4	13	10	11	9	11	9	6	3	46	35
No. fatalities		–		1		–		–		–		1	
Ewhr,[2] 10^6 hr		213		208		222		220		238		1,101	
Irr[3]		0.004		0.01		0.008		0.008		0.003		0.006	

[1]This equipment caused one fire fatality.
[2]Derived from MSHA "Injury Experience in Mining" publications.
[3]Calculated according to MSHA formula reported in this text "Methodologies" section.

Most of the fires were caused by pressurized hydraulic fluid/fuel (25 fires or 54%) sprayed onto equipment hot surfaces, followed by flammable liquid/refueling fuel/oil on hot surfaces, flame cutting/welding spark/slag, electrical short/arcing, mechanical friction/collision, and overheated oil (table 33 and figure 14). Operators/miners/welders detected most of the fires when they started as flames/flash fires or pressure and power loss, smoke, sparks, or by hearing an explosion. Most of the hydraulic fluid/fuel fires, although detected when they started, grew out of control (requiring fire-fighting interventions at least four times) because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure, lack of an emergency line drainage system, difficulty in reaching available emergency systems at ground level, or lack of effective and rapid local fire-fighting response capabilities. Three fires were detected late (which made fire-fighting efforts ineffective), and one was undetected and burned itself out (table 34 and figure 14). At least twice the cab was suddenly engulfed in flames, forcing the operator to exit the cab under difficult conditions most likely due to the ignition of flammable vapors and mists that formed and penetrated the cab during the spraying of hydraulic fluids onto equipment hot surfaces.

Fire departments fought the hydraulic fluid/fuel fires with dry chemicals and water. Four pieces of equipment were destroyed or heavily damaged (table 35 and figure 14).

Data during the five time periods, including the number of fires, fire injuries and fire fatalities, risk rates, and employees' working hours according to the equipment involved and activity, are shown in table 32 and partly illustrated in figure 12. Other variables such as ignition source and methods of detection and suppression are shown in tables 33-35.

Equipment fires and fire injuries increased sharply during 1992-1993, then decreased during subsequent periods, especially 1998-1999, accompanied by a small increase in employees' working hours.

During 1990-1991, there were five fires and four injuries. The equipment involved included haulage/utility trucks (three fires and three injuries) and loaders (two fires and one injury) mostly during maintenance and loading activities. The Ewhr value was 213×10^6 hr (Irr = 0.004). The most common ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces and flammable liquid/refueling fuel/oil on hot surfaces. The most frequent methods of detection were operators who saw flames/flash fires and miners who saw flames. The most commonly used suppression methods were portable fire extinguishers, water, and dry chemical powder.

During 1992-1993, there were 13 fires, 10 injuries, and 1 fatality. The equipment involved included haulage/utility trucks (six fires, four injuries, and one fatality), dozers, and loaders (two fires and two injuries for each), and dredges (one fire and one injury) mostly during haulage, mining, loading, and dredging activities. The Ewhr value was 208×10^6 hr (Irr = 0.01). The ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by flame cutting/welding spark/slag, flammable liquid/refueling fuel/oil on hot surfaces, and overheated oil. The most frequent methods of detection were operators who saw flames/flash fires or experienced power or pressure loss and operators/miners/welders who saw smoke or sparks. The most commonly used suppression methods were water, dry chemical powder, and portable fire extinguishers.

During 1994-1995, there were 11 fires and 9 injuries. The equipment involved included loaders (five fires and four injuries), dredges (two fires and two injuries), haulage/utility trucks (two fires and one injury), and scrapers and dozers (one fire and injury for each) mostly during loading, haulage, dredging, and mining activities. The Ewhr value was 222×10^6 hr (Irr = 0.008). The ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by flame cutting/welding spark/slag, flammable liquid/refueling fuel/oil on hot surfaces, and electrical short/arcing. The most frequent methods of detection were operators who saw flames/flash fires, miners who saw smoke, and welders who saw sparks (one fire was undetected). The most commonly used suppression methods were water, dry chemical powder, and portable fire extinguishers (one equipment fire was not extinguished).

During 1996-1997, there were 11 fires and 9 injuries. The equipment involved included haulage/utility trucks (five fires and four injuries), loaders (three fires and three injuries), a dozer and shovel (one fire and injury for each), and a backhoe, forklift, and truck (one fire and no injuries) mostly during haulage, loading, mining, and maintenance activities. The Ewhr was 220×10^6 hr (Irr = 0.008). The most common ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by flammable liquid/refueling fuel/oil on hot surfaces, electrical short/arcing, and flame cutting/welding spark/slag. The most frequent methods of detection were operators who saw flames/flash fires and miners/welders who saw smoke or sparks (two fires were detected late). The most commonly used suppression methods were water, dry chemical powder, and portable fire extinguishers (two equipment fires involving four pieces of equipment were not extinguished).

During 1998-1999, there were six fires and three injuries. The equipment involved included haulage/utility trucks (two fires and two injuries), loaders (two fires and one injury), and a shovel and tanker (one fire and no injuries for each) mostly during haulage, loading, mining, and transport activities. The Ewhr was 238×10^6 hr (Irr = 0.003). The most common ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by flammable liquid/refueling fuel/oil on hot surfaces, hazardous material explosion, and mechanical friction/collision. The most frequent methods of detection were operators/miners who saw flames/flash fires and miners who heard an explosion. The most commonly used suppression methods were water, dry chemical powder, and portable fire extinguishers (one equipment fire was not extinguished).

Table 36 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location. The highest number of fire injuries occurred in 1993 (six fire injuries and one fire fatality caused by seven equipment fires). These involved loaders, dozers, trucks, dredges, and a crane during hydraulic fluid/fuel, refueling fuel, and flame cutting/welding fires. The fatality, which occurred in Tennessee during a hydraulic fluid/fuel fire involving a haulage truck, was caused by flames that suddenly engulfed the cab [MSHA 1993f].

MOBILE EQUIPMENT FIRES AT METAL/NONMETAL AND STONE MILLS

At metal/nonmetal and stone mills, there were a total of 23 equipment fires during 1990-1999; 16 of those fires caused 16 injuries (table 37 and figure 15). Two fires with one injury occurred at a metal mill, 5 fires with 3 injuries occurred at nonmetal mills, and 16 fires with 12 injuries occurred at stone mills. Two fires with two injuries involved contractors. In all, one piece of equipment (4%) involved in a fire had a machine fire suppression system.

Table 33.–Number of mobile equipment fires for surface sand and gravel and stone mines by ignition source, equipment involved, and time period, 1990-1999

Equipment	Ignition source	Time period 90-91	92-93	94-95	96-97	98-99	90-99
		No. fires	No. fires	No. fires	No. fires	No. fires	No. fires
Loader	Electrical short/arcing	–	–	–	1	–	1
	Hydraulic fluid/fuel on equipment hot surfaces	2	2	3	1	1	9
	Flame cutting/welding spark/slag	–	–	1	–	–	1
	Flammable liquid on hot surfaces	–	–	1	–	–	1
	Mechanical friction/collision	–	–	–	1	1	2
Haulage/utility truck	Flammable liquid/refueling fuel/fuel oil on hot surfaces	2	1	1	1	1	6
	Hydraulic fluid/fuel on equipment hot surfaces	–	4	1	3	1	9
	Flame cutting/welding spark/slag	1	1	–	–	–	2
	Electrical short/arcing	–	–	–	1	–	1
Drill	Overheated oil[1]	–	1	–	–	–	1
Dozer	Hydraulic fluid/fuel on equipment hot surfaces	–	2	–	1	–	3
	Electrical short/arcing	–	–	1	–	–	1
Dredge	Flame cutting/welding spark/slag	–	–	1	–	–	1
	Hydraulic fluid/fuel on equipment hot surfaces	–	1	1	–	–	2
Scraper	Hydraulic fluid/fuel on equipment hot surfaces	–	–	1	–	–	1
Backhoe/forklift/truck	Hydraulic fluid/fuel on equipment hot surfaces	–	–	–	1	–	1
Shovel/bucket	Flame cutting/welding spark/slag	–	–	–	1	1	2
Tanker	Hazardous material-explosion	–	–	–	–	1	1
Crane	Flame cutting/welding spark/slag	–	1	–	–	–	1
Total		5	13	11	11	6	46

[1]Due to compressor malfunction.

Table 34.–Number of mobile equipment fires for surface sand and gravel and stone mines by method of detection, equipment involved, and time period, 1990-1999

Equipment	Method of detection	Time period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Loader	Visual-flames/flash fire	2	2	3	1	2	10
	Visual-sparks	–	–	1	–	–	1
	Visual-smoke	–	–	–	2	–	2
	Undetected	–	–	1	–	–	1
Haulage/utility truck	Visual-flames/flash fire	2	2	2	2	2	10
	Power loss	–	1	–	–	–	1
	Visual-smoke	–	1	–	2	–	3
	Visual-sparks	1	1	–	–	–	2
	Late detection-smoke	–	1	–	1	–	2
Drill	Pressure loss	–	1	–	–	–	1
Dozer	Visual-flames/flash fire	–	2	–	1	–	3
	Visual-smoke	–	–	1	–	–	1
Dredge	Visual-flames/flash fire	–	1	1	–	–	2
	Visual-sparks	–	–	1	–	–	1
Scraper	Visual-flames/flash fire	–	–	1	–	–	1
Backhoe-forklift-truck	Late detection-smoke	–	–	–	1	–	1
Shovel-bucket	Visual-sparks	–	–	–	1	1	2
Tanker	Explosion	–	–	–	–	1	1
Crane	Visual-sparks	–	1	–	–	–	1
Total		5	13	11	11	6	46

Table 35.–Number of mobile equipment fires for surface sand and gravel and stone mines by suppression method, equipment involved, and time period, 1990-1999

Equipment	Suppression method	Time period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Loader	Portable fire extinguisher	1	–	–	2	–	3
	FE-water-dry chemical powder[1]	1	2	2	1	2	8
	FE/manual[2]	–	–	2	–	–	2
	Destroyed/heavily damaged[3]	–	–	1	–	–	1
Haulage/utility truck	Dry chemical powder-water[1]	–	3	–	2	1	6
	Portable fire extinguisher	2	2	–	2	1	7
	FE/manual[2]	1	–	1	–	–	2
	Water-dry chemical powder[1]	–	1	1	–	–	2
	Destroyed/heavily damaged[3]	–	–	–	1	–	1
Drill	FE-dry chemical powder-water[1]	–	1	–	–	–	1
Dozer	Dry chemical powder-water[1]	–	2	–	1	–	3
	Portable fire extinguisher	–	–	1	–	–	1
Dredge	FE-dry chemical powder-water[1]	–	1	1	–	–	2
	FE/manual[2]	–	–	1	–	–	1
Scraper	FE-dry chemical powder/water[1]	–	–	1	–	–	1
Backhoe/forklift/truck[4]	Destroyed/heavily damaged[3]	–	–	–	1	–	1
Shovel/bucket	FE/manual[2]	–	–	–	1	1	2
Tanker	Destroyed/heavily damaged[3]	–	–	–	–	1	1
Crane	Portable fire extinguisher	–	1	–	–	–	1
Total		5	13	11	11	6	46

FE Portable fire extinguisher.
[1]Methods used by fire departments.
[2]Methods used by welders to extinguish clothing or oxyfuel fires.
[3]Usually due to undetected fires or fire size.
[4]Three pieces of equipment were destroyed during one fire.

The highest number of equipment fires and fire injuries occurred in Missouri (seven fires and four injuries), followed by Pennsylvania and Michigan (two fires and two injuries for each state). Michigan had the highest injury risk rate (Irr = 0.024). For metal/nonmetal and stone mills, the total Ewhr value was $1{,}219 \times 10^6$ hr (Irr = 0.003) (table 37).

The equipment involved, mostly during working and maintenance activities, included loaders (eight fires and six injuries), haulage/utility trucks (seven fires and five injuries), shovels (three fires and one injury), and dozers (two fires and one injury) (table 38 and figure 16).

Most of the fires were caused by pressurized hydraulic fluid/fuel (seven fires or 30%) sprayed onto equipment hot surfaces, followed by flame cutting/welding spark/slag and flammable liquids on hot surfaces/collision. Other sources were overheated oil and transmission oil on hot surfaces, electrical short/arcing, and hot material (table 39 and figure 16).

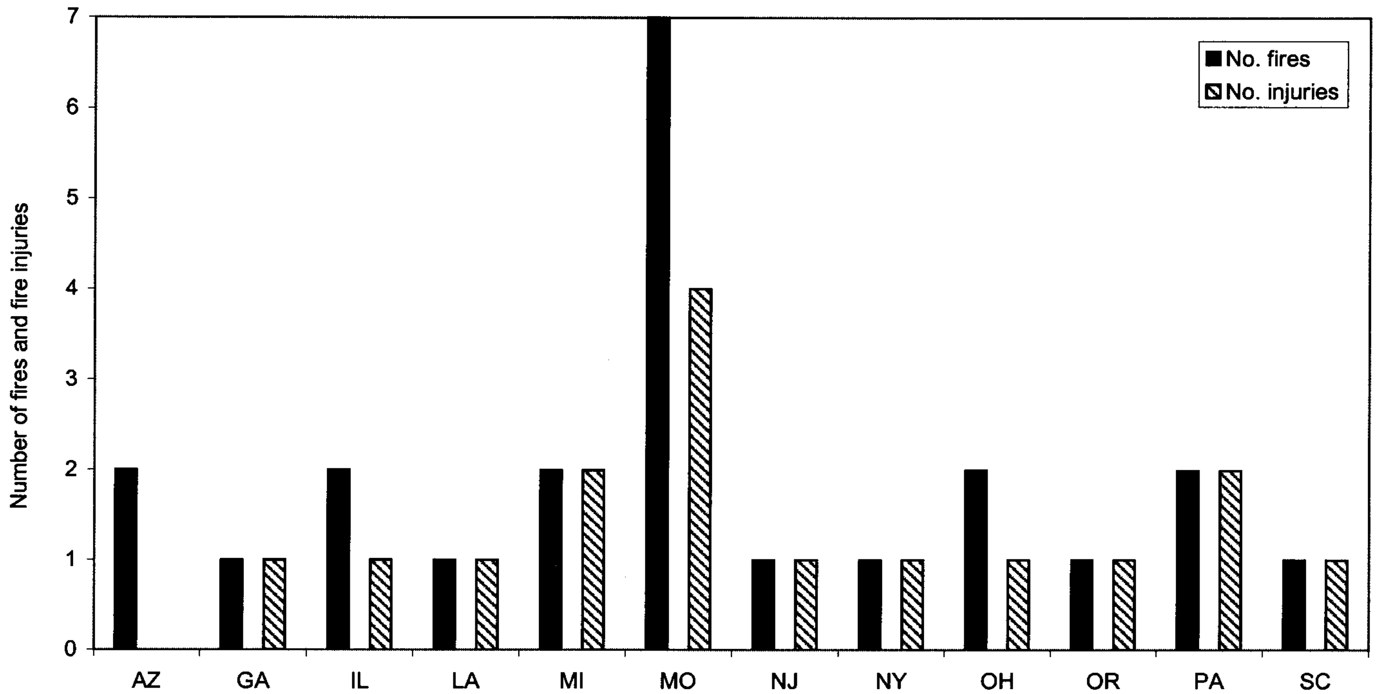

Figure 15.—Mobile equipment fires and injuries for metal/nonmetal and stone mills by state, 1990-1999.

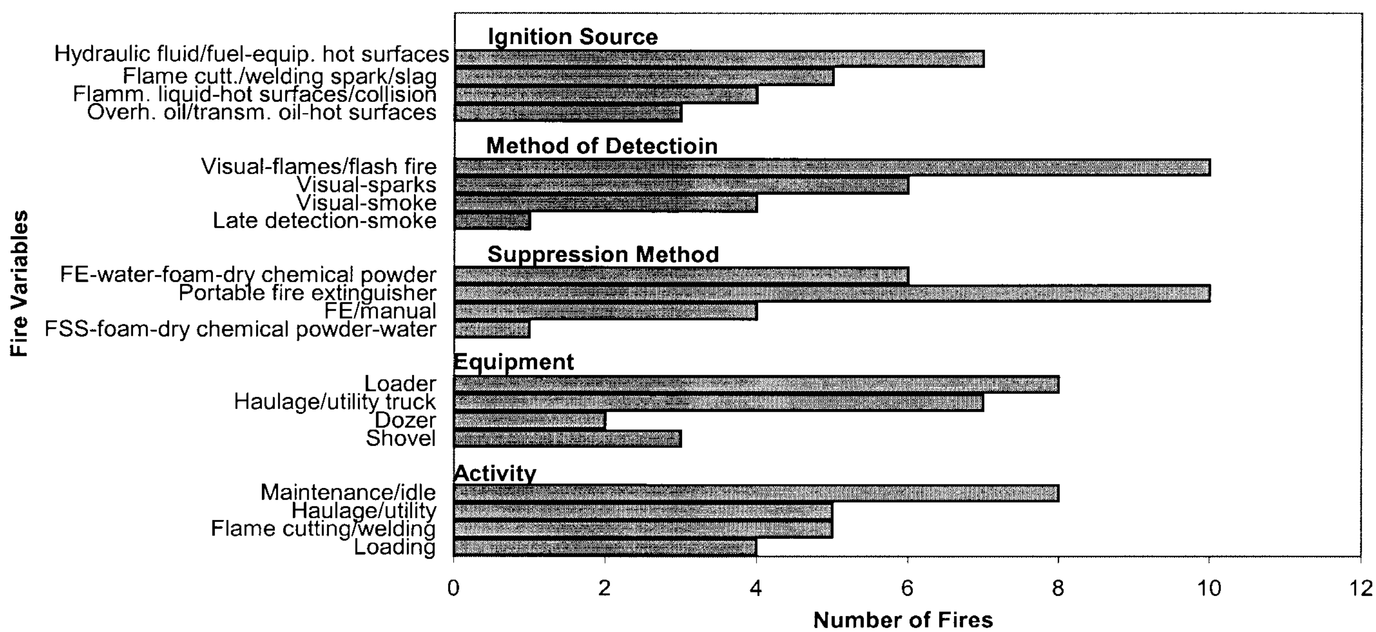

Figure 16.—Major variables for mobile equipment fires at metal/nonmetal and stone mills, 1990-1999. (FE = portable fire extinguisher; FSS = machine fire suppression system.)

Table 36.–Number of fire injuries per number of mobile equipment fires causing injuries and total fires at surface sand and gravel and stone mines by year, ignition source, equipment involved, and location, 1990-1999

Year	No. fires causing injuries	No. total fires	No. fire injuries	Ignition source	Equipment	Location
1990	2	4	2	Refueling fuel on hot surfaces	Truck	Maintenance areas.
	1	–	1	Flame cutting/welding spark/slag	Truck	Flame cutting/welding areas.[1]
1991	1	1	1	Hydraulic fluid on equipment hot surfaces	Loader	Loading area.
1992	3	6	3	Hydraulic fluid/fuel on equipment hot surfaces	Truck-dozer	Haulage/maintenance areas.
	1	–	1	Flame cutting/welding spark/slag	Truck	Flame cutting/welding areas.[1]
1993[2]	5	7	4	Hydraulic fluid/fuel on equipment hot surfaces	Loader-dredge-dozer-truck.	Haulage/mining areas.
	1	–	1	Refueling fuel on hot surfaces	Truck	Haulage area.
	1	–	1	Flame cutting/welding spark/slag	Crane	Flame cutting/welding areas.[1]
1994	2	4	2	Hydraulic fluid/fuel on equipment hot surfaces	Loader-dredge	Loading/dredging areas.
	1	–	1	Flame cutting/welding spark/slag	Loader	Flame cutting/welding areas.[1]
1995	2	7	2	Hydraulic fluid/fuel on equipment hot surfaces	Loader-scraper	Loading/mining areas.
	2	–	2	Flammable liquid/refueling fuel on hot surfaces	Loader-truck	Loading/haulage areas.
	1	–	1	Flame cutting/welding spark/slag	Dredge	Dredging area.
	1	–	1	Electrical short/arcing	Dozer	Mining area.
1996	4	9	4	Hydraulic fluid/fuel on equipment hot surfaces	Loader-truck-dozer	Loading/mining/haulage areas.
	2	–	2	Electrical short/arcing	Truck-loader	Haulage/loading areas.
	1	–	1	Fuel oil on hot surfaces	Truck	Haulage area.
1997	1	2	1	Mechanical friction	Loader	Loading area.
	1	–	1	Flame cutting/welding spark/slag	Bucket	Flame cutting/welding areas.[1]
1998	2	4	2	Hydraulic fluid/fuel on equipment hot surfaces	Truck-loader	Haulage-loading areas.
	1	–	1	Flammable liquid on hot surfaces	Truck	Haulage area.
1999	–	2	–	–	–	–
Total	36	46	35			

[1]Includes working and maintenance areas.
[2]During 1993, there was one fire fatality.

Table 37.–Number of mobile equipment fires, injuries, and risk rates for metal/nonmetal and stone mills by state, equipment involved, and employees' working hours, 1990-1999

State[1]	Equipment[1]	No. fires[1]	No. injuries[1]	Ewhr,[2] 10^6 hr	Irr[3]
AZ	Shovel	2	–	66.5	–
GA	Forklift	1	1	85.2	0.0024
IL	Loader	1	–	30	–
	Locomotive	1	1	–	0.0067
LA	Loader	1	1	1	0.2
MI	Drill	1	1		
	Truck	1	1	17	0.024
MO	Dozer	1	–		
	Loader	3	2		
	Truck	3	2	41.3	0.02
NJ	Shovel	1	1	0.6	0.33
NY	Loader	1	1	1.1	0.2
OH	Truck	1	–		
	Loader	1	1	29	0.007
OR	Dozer	1	1	0.24	0.83
PA	Truck	2	2	53.1	0.0075
SC	Loader	1	1	12	0.017
All other states		–	–	882	–
Total		23	16	1,219	[3]0.003

[1]Derived from MSHA "Fire Accident Abstract" and "Fire Accident Report" publications.
[2]Derived from MSHA "Injury Experience in Mining" publications.
[3]Calculated according to MSHA formula reported in the "Methodologies" section.

Table 38.–Number of mobile equipment fires, injuries, and risk rates for metal/nonmetal and stone mills by time period, equipment involved, activity, and employees' working hours, 1990-1999

Equipment	Activity	90-91 No. fires	90-91 No. injuries	92-93 No. fires	92-93 No. injuries	94-95 No. fires	94-95 No. injuries	96-97 No. fires	96-97 No. injuries	98-99 No. fires	98-99 No. injuries	90-99 No. fires	90-99 No. injuries
Loader	Loading	2	2	–	–	1	1	1	1	–	–	4	3
	Flame cutting/welding	–	–	1	1	–	–	–	–	1	1	2	2
	Maintenance/idle	–	–	–	–	–	–	2	–	–	–	2	1
Haulage/utility truck	Haulage/utility	2	2	1	–	1	1	1	1	–	–	5	4
	Maintenance	–	–	1	1	1	–	–	–	–	–	2	1
Dozer	Maintenance/idle	–	–	1	1	–	–	–	–	1	–	2	1
Shovel	Flame cutting/welding	–	–	–	–	–	–	1	1	1	–	2	1
	Maintenance/idle	–	–	1	–	–	–	–	–	–	–	1	–
Locomotive	Transportation	1	1	–	–	–	–	–	–	–	–	1	1
Drill	Flame cutting/welding	1	1	–	–	–	–	–	–	–	–	1	1
Forklift	Maintenance	–	–	1	1	–	–	–	–	–	–	1	1
Total		6	6	6	4	3	2	5	3	3	1	23	16
Ewhr,[1] 10^6 hr		259		247		248		236		229		1,219	
Irr[1]		0.005		0.003		0.002		0.003		0.001		[2]0.003	

[1]Derived from MSHA "Injury Experience in Mining" publications.
[2]Calculated according to MSHA formula reported in the "Methodologies" section.

Table 39.–Number of mobile equipment fires for metal/nonmetal and stone mills by ignition source, equipment involved, and time period, 1990-1999

Equipment	Ignition source	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Loader	Hydraulic fluid/fuel on equipment hot surfaces	1	–	–	1	–	2
	Flame cutting/welding spark/slag	–	1	–	–	1	2
	Hot material/fuel	–	–	1	1	–	2
	Overheated oil[1]	–	–	–	1	–	1
	Flammable liquid on collision	1	–	–	–	–	1
Haulage/utility truck	Hydraulic fluid/fuel on equipment hot surfaces	2	1	1	1	–	5
	Flammable liquid on hot surfaces	–	1	–	–	–	1
	Overheated oil[1]	–	–	1	–	–	1
Dozer	Electrical short/arcing	–	–	–	–	1	1
	Transmission oil-hot surfaces	–	1	–	–	–	1
Shovel	Flame cutting/welding spark/slag	–	–	–	1	1	2
	Flammable liquid on hot surfaces	–	1	–	–	–	1
Drill	Flame cutting/welding spark/slag	1	–	–	–	–	1
Locomotive	Electrical short/arcing	1	–	–	–	–	1
Forklift	Flammable liquid on hot surfaces	–	1	–	–	–	1
Total		6	6	3	5	3	23

[1]Due to compressor malfunction.

One fuel fire involving a truck with a machine fire suppression system continued to burn until it was extinguished by firefighters because of engine shutoff failure upon activation of the fire suppression system.

Operators/miners/welders detected most of the fires when they started as flames/flash fires, smoke, or sparks. One fire was detected late (which made fire-fighting efforts ineffective), and two fires were undetected (burned themselves out) (table 40 and figure 16). Most of the hydraulic fluid/fuel fires, although detected by the operators when they started, grew out of control (requiring fire-fighting interventions at least twice) because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure, lack of an emergency line drainage system, difficulty in reaching available emergency systems at ground level, or lack of effective and rapid local fire-fighting response capabilities. On at least one occasion the cab was suddenly engulfed in flames, forcing the operator to exit under difficult conditions most likely due to the ignition of flammable vapors and mists that formed and penetrated the cab during the spraying of hydraulic fluids onto equipment hot surfaces.

Fire brigades and fire departments fought the hydraulic fluid/fuel fires with foam, dry chemical powder, and water (table 41 and figure 16).

Data during the five time periods, including the number of fires and injuries, risk rates, and employees' working hours according to the equipment involved and activity, are shown in table 38 and partly illustrated in figure 12. Other variables such as ignition source and methods of detection and suppression are shown in tables 39-41.

Equipment fires decreased sharply during 1994-1995, followed by small increases and decreases during subsequent periods. This was accompanied by a small decline in employees' working hours. Fire injuries decreased steadily during most of the periods.

During 1990-1991, there were six fires and six injuries. The equipment involved included haulage/utility trucks and loaders (two fires and two injuries for each) and a drill and locomotive (one fire and one injury for each) during haulage, loading, transportation, and flame cutting/welding activities. The Ewhr value was 259 × 10^6 hr (Irr = 0.005). The ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by electrical short/arcing, flammable liquids on hot surfaces, and flame cutting/welding spark/slag. The most frequent methods of detection were operators who saw flames/flash fires or sparks. The most commonly used suppression methods were foam, dry chemical powder, water, and portable fire extinguishers. A machine fire suppression system was discharged once.

During 1992-1993, there were six fires and four injuries. The equipment involved included haulage/utility trucks (two fires and one injury) and a loader, dozer, and forklift (one fire and one injury for each) mostly during mining and maintenance activities. The Ewhr value was 247 × 10^6 hr (Irr = 0.003). The most common ignition sources were flammable liquids on hot surfaces followed by hydraulic fluid/fuel sprayed onto equipment hot surfaces. The most frequent methods of detection were operators/miners who saw flames or smoke. The most commonly used suppression methods were portable fire extinguishers, foam, dry chemical powder, and water.

During 1994-1995, there were three fires and two injuries. The equipment involved included haulage/utility trucks (two fires and one injury) and a loader (one fire and one injury) during haulage, loading, and maintenance activities. The Ewhr value was 248 × 10^6 hr (Irr = 0.002). The ignition sources were hot material/fuel, overheated oil, and hydraulic fluid/fuel sprayed onto equipment hot surfaces. The methods of detection were miners who saw smoke and operators who saw flames/flash fires (one fire was undetected). The suppression methods used were foam, dry chemical powder, and portable fire extinguishers and water alone.

During 1996-1997, there were five fires and three injuries. The equipment involved included loaders (three fires and one injury) and a haulage truck and shovel (one fire and one injury for each) mostly during loading, haulage, and maintenance activities. The Ewhr value was 236 × 10^6 hr (Irr = 0.003). The ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces, flame cutting/welding spark/slag, overheated oil, and hot material/fuel. The most frequent methods of detection were operators who saw flames/flash fires and operators/miners who saw smoke (one fire was detected late). The most commonly used suppression methods were foam, dry chemical powder, water, and portable fire extinguishers.

During 1998-1999, there were three fires and one injury. The equipment involved included a loader (one fire and one injury) and a dozer and shovel (one fire and no injuries for each) mostly during flame cutting/welding and maintenance activities. The Ewhr value was 229 × 10^6 hr (Irr = 0.001). The ignition sources were flame cutting/welding spark/slag followed by electrical short/arcing. The methods of detection were welders/miners who saw sparks (one fire was undetected). The suppression methods used were manual methods and portable fire extinguishers (one equipment fire was not extinguished).

Table 42 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location. The highest number of fire injuries was recorded in 1990 (four fire injuries caused by four equipment fires). These involved trucks, loaders, and drills during hydraulic fluid/fuel, flammable liquid, and flame cutting/welding fires.

MOBILE EQUIPMENT FIRES IN UNDERGROUND METAL/NONMETAL AND STONE MINES

At underground metal/nonmetal and stone mines, there were a total of 24 equipment fires during 1990-1999; 7 injuries were caused by 4 of those fires (table 43 and figure 17). Ten fires with one injury occurred at metal mines; nine fires with six injuries occurred at nonmetal mines; and five fires with no injuries occurred at stone mines. One fire with no injuries involved a contractor. In all, four pieces of equipment (17%) involved in the fires had machine fire suppression systems.

The highest number of fires occurred in New York and Idaho (four fires and no injuries for each state), followed by Louisiana (three fires and two injuries) and Michigan (two fires and five injuries). Michigan had the highest injury risk rate (Irr = 0.122). For underground metal/nonmetal and stone mines, the total Ewhr value was 214 × 10^6 hr (Irr = 0.007) (table 43).

The equipment involved, mostly during working activities, included scoops (five fires and five injuries), locomotives (three fires and no injuries), haulage/utility trucks (five fires and no injuries), loaders (three fires and no injuries), and power scalers (two fires and no injury) (table 44 and figure 18).

Most of the fires were caused by pressurized hydraulic fluid (12 fires or 50%) sprayed onto equipment hot surfaces followed by electrical short/arcing and flammable liquid/motor/fuel oil on hot surfaces. Other sources were flame cutting/welding spark/slag and overheated oil on hot surfaces (table 45 and figure 18).

Operators/miners detected most of the fires when they started as flames/flash fires, smoke, or power loss; one was undetected and burned itself out (table 46 and figure 18). Most of the hydraulic fluid fires grew out of control (requiring at least 10 mine rescue interventions) because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure, lack of an emergency line drainage system, or lack of effective and rapid local fire-fighting response capabilities. At least twice the cab was suddenly engulfed in flames, forcing the operator to exit the cab under difficult conditions most likely due to the ignition of flammable vapors and mists that formed and penetrated the cab. Upon mine/section evacuation, mine rescue teams fought the electrical and hydraulic fluid fires with dry chemical powder, rock dust, and water. Four pieces of equipment were destroyed or heavily damaged because of failed fire suppression methods, late machine fire suppression system discharge, or undetected fires (table 47 and figure 18).

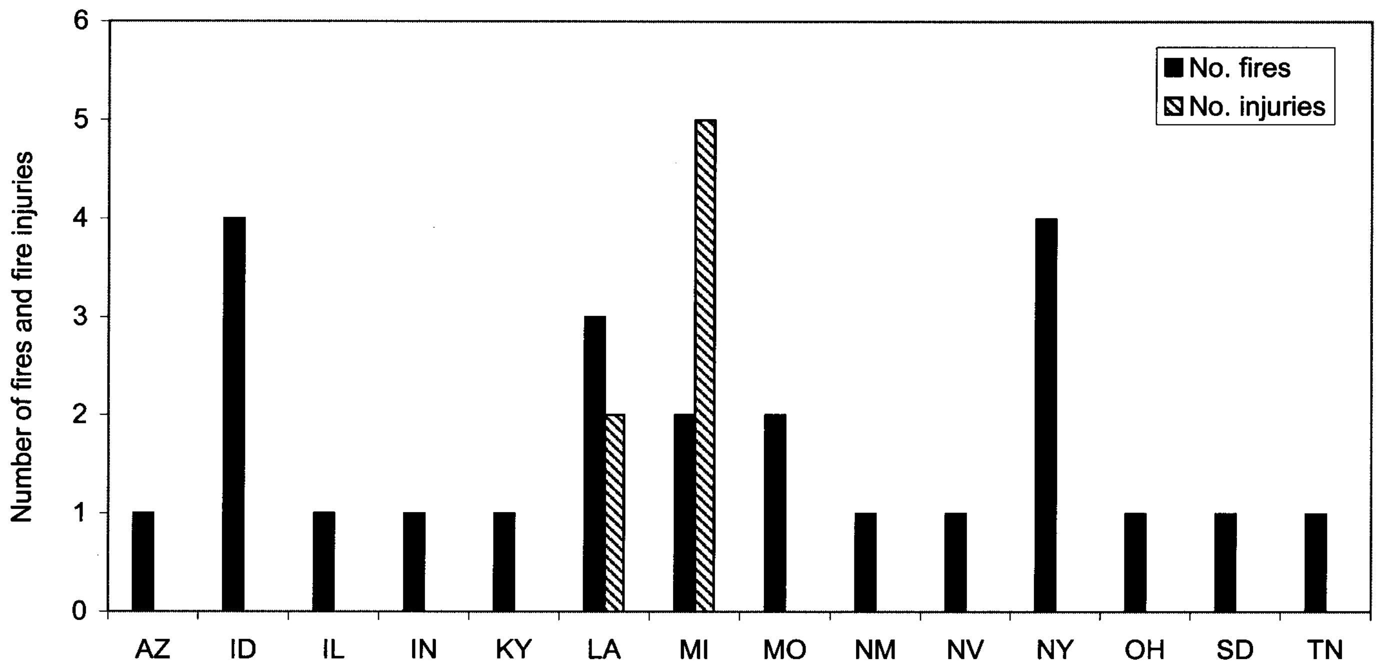

Figure 17.—Mobile equipment fires and injuries for underground metal/nonmetal and stone mines by state, 1990-1999.

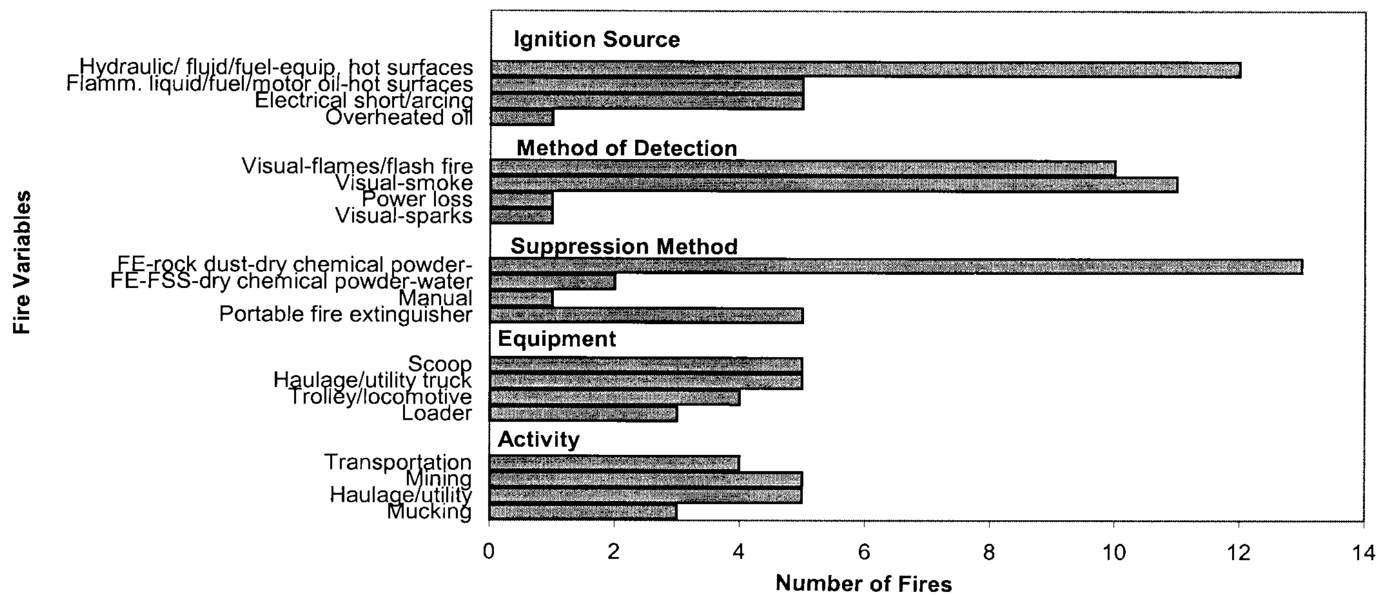

Figure 18.—Major variables for mobile equipment fires in underground metal/nonmetal and stone mines, 1990-1999. (FE = portable fire extinguisher; FSS = machine fire suppression system.)

The four hydraulic fluid fires involving equipment with machine fire suppression systems behaved as follows. In the first instance, the fire, which involved a scoop, burned out of control because the system failed to activate promptly. In the second and third instances, the fires, which involved a scoop and power scaler, raged out of control because the operators failed to activate the fire suppression systems. In the last case, the fire, which involved a loader, was contained by cab dual activation of the fire suppression and engine shutoff systems.

Data during the five time periods, including the number of fires and fire injuries, risk rates, and employees' working hours according to the equipment involved and activity, are shown in table 44 and partly illustrated in figure 12. Other variables such as ignition source and methods of detection and suppression are shown in tables 45-47.

Equipment fires and fire injuries increased sharply during 1996-1997, then decreased sharply during 1998-1999, accompanied by small changes in employees' working hours.

Table 40.–Number of mobile equipment fires for metal/nonmetal and stone mills by method of detection, equipment involved, and time period, 1990-1999

Equipment	Method of detection	Time period 90-91	92-93	94-95	96-97	98-99	90-99
		No. fires	No. fires	No. fires	No. fires	No. fires	No. fires
Loader	Visual-flames/flash fire	2	–	–	1	–	3
	Visual-sparks	–	1	–	–	1	2
	Visual-smoke	–	–	1	1	–	2
	Late detection-smoke	–	–	–	1	–	1
Haulage/utility truck	Visual-flames/flash fire	2	1	1	1	–	5
	Visual-smoke	–	1	–	–	–	1
	Undetected	–	–	1	–	–	1
Dozer	Visual-smoke	–	1	–	–	–	1
	Undetected	–	–	–	–	1	1
Shovel	Visual-sparks	–	–	–	1	1	2
	Visual-flash fire/flash fire	–	1	–	–	–	1
Drill	Visual-sparks	1	–	–	–	–	1
Locomotive	Visual-sparks	1	–	–	–	–	1
Forklift	Visual-flames/flash fire	–	1	–	–	–	1
Total		6	6	3	5	3	23

Table 41.–Number of mobile equipment fires for metal/nonmetal and stone mills by suppression method, equipment involved, and time period, 1990-1999

Equipment	Suppression method	Time period 90-91	92-93	94-95	96-97	98-99	90-99
		No. fires	No. fires	No. fires	No. fires	No. fires	No. fires
Loader	Portable fire extinguisher	1	–	–	1	1	3
	FE-water-foam-dry chemical powder[1]	1	–	–	2	–	3
	FE/manual[2]	–	1	–	–	–	1
	Water	–	–	1	–	–	1
Haulage/utility truck	Portable fire extinguisher	1	1	1	–	–	3
	FE-water-foam-dry chemical powder[1]	–	1	1	1	–	3
	FSS-water-foam-dry chemical powder[3]	1	–	–	–	–	1
Dozer	Portable fire extinguisher	–	1	–	–	–	1
	Destroyed/heavily damaged[4]	–	–	–	–	1	1
Shovel	FE/manual[2]	–	–	–	1	1	2
	Portable fire extinguisher	–	1	–	–	–	1
Drill	FE/manual[2]	1	–	–	–	–	1
Locomotive	Portable fire extinguisher	1	–	–	–	–	1
Forklift	Portable fire extinguisher	–	1	–	–	–	1
Total		6	6	3	5	3	23

FSS Machine fire suppression system.
FE Portable fire extinguisher.
[1]Methods used by fire brigades (mostly foam) and fire departments (mostly dry chemical powder).
[2]Methods used by welders to extinguish clothing or oxyfuel fires.
[3]Methods used by fire brigades and fire departments following available FSS discharge by operator.
[4]Usually due to undetected fires.

Table 42.–Number of fire injuries per number of mobile equipment fires causing injuries and total fires at metal/nonmetal and stone mills by year, ignition source, equipment involved, and location, 1990-1999

Year	No. total fires	No. fires causing injuries	No. fire injuries	Ignition source	Equipment	Location
1990	4	2	2	Hydraulic fluid/fuel on equipment hot surfaces	Truck	Haulage area.
	–	1	1	Flammable liquid-collision	Loader	Gas pump area.
	–	1	1	Flame cutting/welding spark/slag	Drill	Flame cutting/ welding areas.[1]
1991	2	1	1	Hydraulic fluid/fuel on equipment hot surfaces	Loader	Loading area.
	–	1	1	Electrical short/arcing	Locomotive	Transport area.
1992	4	1	1	Transmission oil on hot surfaces	Dozer	Mining area.
	–	1	1	Flame cutting/welding spark/slag	Loader	Flame cutting/welding areas.[1]
1993	2	2	2	Flammable liquid on hot surfaces	Forklift-truck	Maintenance area.
1994	1	1	1	Hydraulic fluid/fuel on equipment hot surfaces	Truck	Haulage area.
1995	2	1	1	Hot material	Loader	Kiln area.
1996	2	2	2	Hydraulic fluid/fuel on equipment hot surfaces	Loader/truck	Loading/haulage areas.
1997	3	1	1	Flame cutting/welding spark/slag	Shovel	Flame cutting/welding areas.[1]
1998	–	–	–	–	–	–
1999	3	1	1	Flame cutting/welding spark/slag	Loader	Loading area.
Total	23	16	16			

[1]Includes working and maintenance areas.

Table 43.–Number of mobile equipment fires, injuries, and risk rates for underground metal/nonmetal and stone mines by state, equipment involved, and employees' working hours, 1990-1999

State[1]	Equipment[1]	No. fires[1]	No. injuries[1]	Ewhr,[2] 10^6 hr	Irr[3]
AZ	Trolley	1	–	28.1	–
ID	Locomotive . . .	3	–		
	Loader	1	–	9.2	–
IL	Truck	1	–	2	–
IN	Scaler	1	–	1.4	–
KY	Crane	1	–	8.1	–
LA	Drill	1	1		
	Scoop	1	1		
	Loader	1	–	7	0.057
MI	Scoop	1	4		
	Ore cart	1	1	8.2	0.122
MO	Truck	2	–	4.6	–
NM	Shuttle car . . .	1	–	17.2	–
NV	Scoop	1	–	12	–
NY	Scoop	2	–		
	Scaler	1	–	7.5	–
	Bucket	1	–		
OH	Truck	1	–	5.3	–
SD	Truck	1	–	13	–
TN	Loader	1	–	13	–
All other states		–	–	77.4	–
Total		24	7	214	[3]0.007

[1]Derived from MSHA "Fire Accident Abstract" and "Fire Accident Report" publications.
[2]Derived from MSHA "Injury Experience in Mining" publications.
[3]Calculated according to MSHA formula reported in the "Methodologies" section.

Table 44.–Number of mobile equipment fires, injuries, and risk rates for underground metal/nonmetal and stone mines by time period, equipment involved, activity, and employees' working hours, 1990-1999

Equipment	Activity	Time period 90-91		92-93		94-95		96-97		98-99		90-99	
		No. fires	No. injuries	No. fires	No. injuries	No. fires	No. injuries	No. fires	No. injuries	No. fires	No. injuries	No. fires	No. injuries
Power scaler	Idle	–	–	–	–	–	–	–	–	1	–	1	–
	Mining	–	–	–	–	1	–	–	–	–	–	1	–
Loader	Mucking	–	–	–	–	1	–	1	–	–	–	2	–
	Loading	–	–	–	–	–	–	1	–	–	–	1	–
Scoop	Mining	–	–	1	1	–	–	3	4	–	–	4	5
	Mucking	–	–	–	–	–	–	–	–	1	–	1	–
Drill	Drilling	–	–	–	–	–	–	1	1	–	–	1	1
Haulage/utility truck . . .	Haulage	–	–	1	–	–	–	1	–	–	–	2	–
	Utility	–	–	2	–	–	–	1	–	–	–	3	–
Shuttle car	Transportation	–	–	1	–	–	–	–	–	–	–	1	–
Ore cart	Transportation	1	1	–	–	–	–	–	–	–	–	1	1
Locomotive	Transportation	–	–	–	–	–	–	1	–	–	–	1	–
	Maintenance	1	–	–	–	–	–	–	–	–	–	1	–
	Idle	–	–	–	–	–	–	–	–	1	–	1	–
Trolley	Transportation	–	–	–	–	1	–	–	–	–	–	1	–
Crane	Idle	1	–	–	–	–	–	–	–	–	–	1	–
Slusher bucket	Flame cutting/welding	–	–	–	–	1	–	–	–	–	–	1	–
Total		3	1	5	1	4	–	9	5	3	–	24	7
Ewhr,[1] 10^6 hr		48		41		41		44		40		214	
Irr[2]		0.004		0.005		–		0.027		–		[2]0.007	

[1]Derived from MSHA "Injury Experience in Mining" publications.
[2]Calculated according to MSHA formula reported in the "Methodologies" section.

Data during the five time periods show large increases in the number of equipment fires during 1992-1993 and 1996-1997 and an increase in injuries during 1996-1997 only, accompanied by a small decline in working hours throughout all of the periods.

During 1990-1991, there were three fires and one injury. The equipment involved included an ore cart (one fire and one injury) and a locomotive and crane (one fire and no injuries for each) during transportation and maintenance activities. The Ewhr value was 48 × 10^6 hr (Irr = 0.004). The ignition sources were hydraulic fluid sprayed onto equipment hot surfaces, followed by electrical short/arcing. The methods of detection were operators who saw flames/flash fires and miners who saw smoke (one fire was undetected). The suppression methods were rock dust, water, and portable fire extinguishers (one equipment fire was not extinguished).

During 1992-1993, there were five fires and one injury. The equipment involved included haulage/utility trucks (three fires and no injuries), a scoop (one fire and one injury), and a shuttle car (one fire and no injuries) during haulage/utility, mining, and transport activities. The Ewhr value was 41×10^6 hr (Irr = 0.005). The ignition sources were hydraulic fluid sprayed onto equipment hot surfaces, followed by electrical short/arcing and motor oil on hot surfaces. The most frequent methods of detection were operators who saw flames/flash fires or experienced power loss and miners who saw smoke. The most commonly used suppression methods were dry chemical powder, rock dust, and water (one equipment fire was not extinguished). A machine fire suppression system was not activated.

During 1994-1995, there were four fires and no injuries. The equipment involved included a loader, power scaler, slusher/bucket, and trolley (one fire and no injuries for each) during mining, mucking, transportation, and flame cutting/welding activities. The Ewhr value was 41×10^6 hr. The most common ignition sources were hydraulic fluid sprayed onto equipment hot surfaces, followed by electrical short/arcing and flame cutting/welding spark/slag. The methods of detection were operators who saw flames/flash fires and operators/miners/welders who saw smoke or sparks. The most commonly used suppression methods were dry chemical powder, rock dust, and portable fire extinguishers (one equipment fire was not extinguished). A machine fire suppression system was discharged once; in another instance, the system was not activated.

During 1996-1997, there were nine fires and five injuries. The equipment involved included scoops (three fires and four injuries), loaders, and haulage/utility trucks (two fires and no injuries for each), a drill (one fire and one injury), and a locomotive (one fire and no injuries) during mucking, loading, haulage/utility, mining, drilling, and transportation activities. The Ewhr was 44×10^6 hr (Irr = 0.027). The most common ignition sources were hydraulic fluid sprayed onto equipment hot surfaces followed by flammable liquid/fuel/motor oil on hot surfaces and electrical short/arcing. The most frequent methods of detection were operators who saw flames/flash fires and operators/miners who saw smoke. The most commonly used suppression methods were dry chemical powder, rock dust, water, and portable fire extinguishers. A machine fire suppression system was discharged once; however, the discharge occurred late because of system late response.

During 1998-1999, there were three fires and no injuries. The equipment involved included a power scaler, scoop, and locomotive (one fire and no injuries for each) during mining and idle activities. The Ewhr value was 40×10^6 hr. The ignition sources were hydraulic fluid sprayed onto equipment hot surfaces followed by electrical short/arcing. The methods of detection were operators who saw flames/flash fires and miners who saw smoke. The suppression methods used were dry chemical powder, rock dust, water, and portable fire extinguishers.

Table 48 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location. The highest number of fire injuries was recorded in 1997 (four fire injuries caused by one equipment fire). These involved scoops during hydraulic fluid fires.

Table 45.–Number of mobile equipment fires for underground metal/nonmetal and stone mines by ignition source, equipment involved, and time period, 1990-1999

Equipment	Ignition source	Time period					
		90-91	92-93	94-95	96-97	98-99	90-99
		No. fires	No. fires	No. fires	No. fires	No. fires	No. fires
Power scaler	Hydraulic fluid/fuel on equipment hot surfaces	–	–	1	–	1	2
Loader	Flammable liquid/fuel oil on hot surfaces	–	–	–	2	–	2
	Hydraulic fluid/fuel on equipment hot surfaces	–	–	1	–	–	1
Scoop	Motor oil on hot surfaces	–	1	–	1	–	2
	Hydraulic fluid/fuel on equipment hot surfaces	–	–	–	2	1	3
Drill	Overheated oil[1]	–	–	–	1	–	1
Haulage/utility truck	Hydraulic fluid/fuel on equipment hot surfaces	–	3	–	1	–	4
	Fuel oil on hot surfaces	–	–	–	1	–	1
Shuttle car	Electrical short/arcing	–	1	–	–	–	1
Ore cart	Hydraulic fluid on equipment hot surfaces	1	–	–	–	–	1
Locomotive	Electrical short/arcing	1	–	–	1	1	3
Trolley	Electrical short/arcing	–	–	1	–	–	1
Crane	Hydraulic fluid/fuel on equipment hot surfaces	1	–	–	–	–	1
Slusher bucket	Flame cutting/welding spark/slag	–	–	1	–	–	1
Total		3	5	4	9	3	24

[1]Due to compressor malfunction.

Table 46.–Number of mobile equipment fires for underground metal/nonmetal and stone mines by method of detection, equipment involved, and time period, 1990-1999

Equipment	Method of detection	Time period 90-91	92-93	94-95	96-97	98-99	90-99
		No. fires	No. fires	No. fires	No. fires	No. fires	No. fires
Power scaler	Visual-flames/flash fire	–	–	1	–	1	2
Loader	Visual-flames/flash fire	–	–	1	–	–	1
	Visual-smoke	–	–	–	2	–	2
Scoop	Visual-flames/flash fire	–	–	–	2	–	2
	Visual-smoke	–	1	–	1	1	3
Drill	Visual-smoke	–	–	–	1	–	1
Haulage/utility/truck	Visual-flames/flash fire	–	3	–	1	–	4
	Visual-smoke	–	–	–	1	–	1
Shuttle car	Power loss	–	1	–	–	–	1
Ore cart	Visual-flames/flash fire	1	–	–	–	–	1
Locomotive	Visual-smoke	1	–	–	1	1	3
Trolley	Visual-smoke	–	–	1	–	–	1
Crane	Undetected	1	–	–	–	-	1
Slusherbucket	Visual-sparks	–	–	1	–	–	1
Total		3	5	4	9	3	24

Table 47.–Number of mobile equipment fires for underground metal/nonmetal and stone mines by suppression method, equipment involved, and time period, 1990-1999

Equipment	Suppression method	Time period 90-91	92-93	94-95	96-97	98-99	90-99
		No. fires	No. fires	No. fires	No. fires	No. fires	No. fires
Power scaler	Destroyed/heavily damaged[1]	–	–	1	–	–	1
	FE-dry chemical powder-rock dust[2]	–	–	–	–	1	1
Loader	FE-FSS-dry chemical powder-rock dust[3]	–	–	1	–	–	1
	FE-dry chemical powder-rock dust-water[2]	–	–	–	2	–	2
Scoop	FE-FSS-HD[4]	–	–	–	1	–	1
	Destroyed/heavily damaged[1]	–	1	–	–	–	1
	FE-rock dust-dry chemical powder[2]	–	–	–	2	1	3
Drill	Portable fire extinguisher	–	–	–	1	–	1
Haulage/utility truck	FE-rock dust-dry chemical powder-water[2]	–	2	–	1	–	3
	Portable fire extinguisher	–	–	–	1	–	1
	FE-rock dust-water	–	1	–	–	–	1
Shuttle car	FE–dry chemical powder-water[2]	–	1	–	–	–	1
Ore cart	FE-rock dust-water	1	–	–	–	–	1
Locomotive	Dry chemical powder-water[2]	–	–	–	–	1	1
	Portable fire extinguisher	1	–	–	1	–	2
Trolley	Portable fire extinguisher	–	–	1	–	–	1
Crane	Destroyed-heavily damaged[1]	1	–	–	–	–	1
Slusher bucket	Manual-FE[5]	–	–	1	–	–	1
Total		3	5	4	9	3	24

FE Portable fire extinguisher.
FSS Machine fire suppression system.
HD Heavily damaged.
[1]Usually due to failed fire suppression methods or undetected fires (two FSS activation failures).
[2]Methods used by mine rescue teams.
[3]Methods used by mine rescue teams following available FSS discharge by operator.
[4]Due to failed fire suppression methods.
[5]Methods used by welders to extinguish clothing fires.

Table 48.–Number of fire injuries per number of mobile equipment fires causing injuries and total fires in underground metal/nonmetal and stone mines by year, ignition source, equipment involved, and location, 1990-1999

Year	No. fires causing injuries	No. total fires	No. fire injuries	Ignition source	Equipment	Location
1990	1	1	1	Hydraulic fluid/fuel on equipment hot surfaces	Ore cart	Transportation area.
1991	–	2	–			
1992	1	2	1	Motor fuel on hot surfaces	Scoop	Mining area.
1993	–	3	–	–	–	–
1994	–	3	–	–	–	–
1995	–	1	–	–	–	–
1996	1	5	1	Overheated oil	Drill	Drilling area.
1997	1	4	4	Hydraulic fluid/fuel on equipment hot surfaces	Scoop	Mining area.
1998	–	1	–	–	–	–
1999	–	2	–	–	–	–
Total	4	24	7			

SUMMARY OF MAJOR MOBILE EQUIPMENT FIRE AND FIRE INJURY FINDINGS FOR ALL COAL MINING CATEGORIES

Major mobile equipment fire and fire injury findings for all coal mining categories during 1990-1999 are reported in tables 49-50. Data during the five 2-year time periods (figure 19) are discussed below.

For these categories, there was a grand total of 197 equipment fires during 1990-1999; 77 injuries were caused by 76 of those fires. The Ewhr value was 2,070 × 10^6 hr (Irr = 0.007); the CP value (surface and underground coal mines only) was 10,363 × 10^6 st (Frr = 0.019). In all, 10 pieces of equipment (5%) involved in the fires had machine fire suppression systems. Nineteen equipment fires (9%) were not extinguished due to the failure of fire-fighting methods, late fire detection, undetected fires, or fire size, and the equipment involved was destroyed or heavily damaged. The greatest number of fires and injuries occurred at surface mines; the highest risk rates were also calculated for these operations.

For all surface coal mining categories, the largest number of equipment fires was caused by hydraulic fluid/fuel (94 fires or 48%, with 30 injuries) sprayed onto equipment hot surfaces. Most of these fires, although detected by the operators when they started, grew out of control because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure, lack of an emergency line drainage system, difficulty in reaching emergency systems at ground level due to flames engulfing the area, or lack of effective and rapid local fire-fighting response capabilities. At least nine times the cab was suddenly engulfed in flames, most likely due to the ignition of flammable vapors and mists that formed and penetrated the cab, and forced the operator to exit under difficult conditions. In four instances, upon machine fire suppression activation, the flames continued to be fueled by the flow of fluids from pumps and tanks because of engine shutoff failure or lack of an emergency line drainage system. Dual activation (nine activations) of machine fire suppression and engine shutoff systems succeeded in temporarily abating the flames, which reignited, fueled by the continuous flow of pressurized fluids entrapped in the lines (not affected by the engine shutoff operation). Other ignition sources were flame cutting/welding spark/slag (43 or 22%; at least once, this source caused a hydraulic fluid fire), electrical short/arcing (25 fires or 13%; at least once, this source caused a hydraulic fluid fire), flammable liquid/refueling fuel/fuel oil on hot surfaces (10 fires or 5%), and engine/mechanical/malfunctions/friction/explosion (9 fires or 5%). Other fires and injuries were caused by heat sources, overheated oil on hot surfaces due to compressor malfunction, and battery explosions.

In underground coal mines, the largest number of fires was caused by electrical short/arcing (13 fires or 7%) and 1 hydraulic fuel fire.

Fire brigades and fire departments at surface mines, handicapped by travel distances, fought the hydraulic fluid/fuel fires with foam, dry chemical powder, and water. Mine rescue teams in underground mines, which were often severely hindered by smoke, fought the electrical and hydraulic fluid fires with foam, dry chemical powder, rock dust, and water. Seventeen equipment fires (9%) were not extinguished and burned themselves out because of failed fire suppression and fire-fighting methods, late fire detection, undetected fires, or fire size, and the equipment involved was destroyed or heavily damaged.

For all coal mining categories, data during the five time periods show a decrease in the number of equipment fires and injuries, accompanied by a decline in employees' working hours and a small increase in coal production (this increase refers to surface and underground coal mines only). However, some observations common to all categories are reported below.

1. At surface coal mines, there were 140 fires; 56 of those fires caused 56 injuries. The Ewhr value was 729 × 10^6 hr (Irr = 0.015); the CP value was 6,355 × 10^6 st (Frr = 0.022). The ignition sources that caused most of the equipment fires were hydraulic fluid/fuel (77 fires or 55%) sprayed onto equipment hot surfaces due to ruptured lines and failed fittings and gaskets. Other ignition sources were flame cutting/welding spark/slag, electrical short/arcing, engine/mechanical malfunctions/friction/explosion, and flammable liquids on hot surfaces. The fires were easily extinguished with portable fire extinguishers. Five pieces of equipment (3.6%) involved in these fires had machine fire suppression systems. Dual activation (three activations) of machine fire suppression and engine shutoff systems succeeded in abating the flames temporarily. However, the flames re-ignited, fueled by the flow of fluids entrapped in the lines. In two other instances, the flames continued to be fueled by the flow of fluids from the pump because of engine shutoff failure. Most of the hydraulic fluid/fuel fires, although detected by the operators when they started, grew out of control (requiring 15 fire-fighting interventions) because of the continuous flow of hydraulic fluids from the pump and tanks due to engine shutoff failure, lack of an emergency line drainage system, difficulty in reaching emergency systems at ground level, or lack of effective and rapid local fire-fighting response capabilities. At least three times, flammable vapors and mists penetrated the cab and ignites. Fire brigades and fire departments, often handicapped by travel distances, fought the hydraulic fluid/fuel fires with foam, dry chemical powder, and water. Ten equipment fires were not extinguished because of failed fire-fighting methods, late fire detection, undetected fires, or fire size. The equipment involved in the fires included haulage/utility trucks, dozers, loaders, shovels, and drills mostly during working activities. The ignition sources that caused most of the injuries were hydraulic fluid/fuel sprayed onto equipment hot surfaces, flame cutting/welding spark/slag, flammable liquids on hot surfaces, and engine/mechanical malfunctions. The equipment involved in injuries included trucks, shovels, dozers, and loaders at haulage, mining, loading, flame cutting/welding, and maintenance areas.

Equipment fires and injuries decreased sharply throughout the five time periods, accompanied by a decline in employees' working hours and a small increase in coal production.

2. At surface of underground coal mines, there were 14 fires; 4 of those fires caused 4 injuries. The Ewhr value was 97×10^6 hr (Irr = 0.008). The ignition sources that caused most of the equipment fires were hydraulic fluid/fuel (10 fires or 71%) sprayed onto equipment hot surfaces, followed by flame cutting/welding spark/slag (at least once this source caused a hydraulic fluid fire), electrical short/arcing, and overheated oil. Two pieces of equipment (14%) involved in the fires had machine fire suppression systems. Dual activation (one activation) of machine fire suppression and engine shutoff systems failed to suppress the fires due to the flow of fluids entrapped in the lines. Most of the hydraulic fluid/fuel fires, although detected by the operators when they started, grew out of control (requiring at least one fire-fighting intervention) because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure, lack of an emergency line drainage system, difficulty in reaching available emergency systems at ground level, or lack of effective and rapid local fire-fighting response capabilities. At least twice, flammable vapors and mists penetrated the cab and ignited. Fire brigades and fire department fought the hydraulic fluid/fuel fires with foam, dry chemical powder, and water. Two equipment fires were not extinguished because of failed fire suppression and fire-fighting methods. The equipment involved included scrapers, loaders, dozers, and hoists mostly during working activities.

The ignition sources that caused the injuries were flame cutting/welding spark/slag, hydraulic fluid/fuel sprayed onto equipment hot surfaces, and battery explosion. The equipment involved in injuries included a haulage truck, highlift, tractor, and loader at flame cutting/welding and loading areas and at charging stations.

Equipment fires and injuries decreased slightly during most of the five time periods, accompanied by a small decline in employees' working hours.

3. At coal prep plants, there were 17 fires; 6 of those fires caused 7 injuries. The Ewhr value was 241×10^6 hr (Irr = 0.006). The ignition sources that caused most of the equipment fires were hydraulic fluid/fuel (7 fires or 41%) sprayed onto equipment hot surfaces, followed by engine/mechanical malfunctions, flammable liquid/fuel oil on hot surfaces, and electrical short/arcing. Most of the hydraulic fluid/fuel fires grew out of control (requiring at least one fire-fighting intervention) because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure, lack of an emergency line drainage system, difficulty in reaching available emergency systems at ground level, or lack of effective and rapid local fire-fighting response capabilities. At least twice, flammable vapors and mists penetrated the cab and ignited. None of the equipment involved in the fires had machine fire suppression systems. Fire departments fought the hydraulic fluid/fuel fires with dry chemical powder and water. Three equipment fires were not extinguished because of late detection, undetected fires, or fire size. The equipment involved included loaders, trucks, and dozers mostly during working activities.

The ignition sources that caused most of the injuries were hydraulic fluid/fuel sprayed onto equipment hot surfaces and mechanical malfunction. The equipment involved in fire injuries included loaders and trucks at loading, haulage, and maintenance areas.

Equipment fires decreased slightly throughout the five time periods, accompanied by a decline in employees' working hours. Fire injuries increased slightly during 1994-1995.

4. In underground coal mines, there were 26 fires; 10 of those fires caused 10 injuries. The Ewhr value was $1,003 \times 10^6$ hr (Irr = 0.002); the CP value was $4,008 \times 10^6$ st (Frr = 0.007). The ignition source that caused most of the equipment fires was electrical short/arcing of wires and cables (13 fires or 50%; at least once, this source caused a hydraulic fluid fire). Most of the underground equipment is electrically powered. Other ignition sources were flame cutting/welding spark/slag, refueling fuel/fuel oil on hot surfaces, mechanical malfunction/friction, heat source, hydraulic fluid sprayed onto equipment hot surfaces, and overheated oil. Three pieces of equipment (12%) involved in the fires had machine fire suppression systems. Dual activation (two activations) of machine fire suppression/motor deenergization systems succeeded in temporarily containing the fires. In another instance, the machine suppression system failed to activate because of clogged lines. Upon mine/section evacuation, mine rescue teams (required at least five times), which were often severely hindered by dense smoke in trying to reach the fire location, fought the electrical (three fires), hydraulic fluid (one fire), and heat source fires (one fire) with dry chemical powder, rock dust, and water. Two equipment fires were not extinguished because of failed fire suppression methods and late fire detection.

The equipment involved included scoops, bolters, shuttle cars, and continuous miners during mining, bolting, transportation, maintenance, and flame cutting/welding activities.

The ignition sources that caused most of the fire injuries were electrical short/arcing, flame cutting/welding spark/slag, heat sources, and flammable liquids on hot surfaces. The equipment involved in fire injuries included scoops, shuttle cars, bolters, and railrunners at mining faces, crosscuts, charging stations, rail track areas, and flame cutting/welding areas.

Equipment fires and injuries decreased during 1996-1997, then increased during 1998-1999, accompanied by a sharp decline in employees' working hours and small changes in coal production.

Table 49.–Major mobile equipment fire findings for all coal mining categories, 1990-1999

Variables	Surface coal mines	Surface of underground coal mines	Coal preparation plants	Underground coal mines
GT: No. fires: 197	No. fires: 140	No. fires: 14	No. fires: 17	No. fires: 26
CP 10^6 st: 10,363	CP 10^6 st 6,355			CP 10^6 st.: 4,008
Frr: 0.019	Frr: 0.022			Frr: 0.007
No. fires causing injuries: 76	No. fires causing injuries: 56	No. fires causing injuries: 4	No. fires causing injuries: 6	No. fires causing injuries: 10
Ignition source	Hydraulic fluid/fuel on equipment hot surfaces. Flame cutting/welding spark/slag Electrical short/arcing Engine/mechanical malfunction/ friction/explosion.	Hydraulic fluid/fuel on equipment hot surfaces. Flame cutting/welding spark/slag Electrical short/arcing Overheated oil	Hydraulic fluid/fuel on equipment hot surfaces. Engine/mechanical malfunctions. Flammable liquid/fuel oil on hot surfaces.	Electrical short/arcing Flame cutting/welding spark/slag Mechanical friction/malfunction Hydraulic fluid/fuel on equipment hot surfaces.
Method of detection	Visual-flames/flash fire Visual-sparks Visual-smoke Popping sound	Visual-flames/flash fire Visual-sparks Visual-smoke Late detection-smoke	Visual-flames/flash fire Visual-smoke Late detection-smoke Visual-dim lights	Visual-smoke Visual-sparks Visual-flames/flash fire Late detection-smoke
Suppression method	FE-foam-DCP-water Manual/FE FE-DCP-water FE-FSS-DCP-water	FE-foam-water-DCP FE-FSS-foam-HD Portable fire extinguisher Manual/FE	FE-DCP/water Portable fire extinguisher Manual FE/water	FE-DCP-rock dust-water FE/manual Portable fire extinguisher FE-FSS-DCP-water
Equipment	Trucks Dozers Loaders Shovels/bucket	Scrapers Loaders Dozers Hoists	Loaders Trucks Dozers	Scoops Shuttle cars Bolters Continuous miners
Location	Equipment working areas[1] Flame cutting/welding areas[2] Maintenance areas	Equipment working areas[1] Flame cutting/welding areas[2]	Equipment working areas[1] Flame cutting/welding areas[2]	Equipment working areas[1] Maintenance areas Flame cutting/welding areas[2]

DCP Dry chemical powder.
FE Portable fire extinguisher.
FSS Machine fire suppression system.
GT Grand total.
HD Heavily damaged.
[1]Includes haulage/utility, mining, loading, hoisting, bolting, drilling, mucking, and transport areas.
[2]Includes working, mining, and maintenance areas.
NOTE.–Variables are listed in descending order of occurrence.

Table 50.–Major mobile equipment fire injury findings for all coal mining categories, 1990-1999.

Variables	Surface coal mines	Surface of underground coal mines	Coal preparation plants	Underground coal mines
GT: No. fire injuries: 77 Ewhr, 10^6 hr: 2,070 Irr: 0.007	No. fire injuries: 56 Ewhr, 10^6 hr: 729 Irr: 0.015	No. fire injuries: 4 Ewhr, 10^6 hr: 97 Irr: 0.008	No. fire injuries: 7 Ewh, 10^6 hr: 241 Irr: 0.006	No. fire injuries: 10 Ewh, 10^6 hr: 1,003 Irr: 0.002
Ignition source	Hydraulic fluid/fuel on equipment hot surfaces. Flame cutting/welding spark/slag Flammable liquid on hot surfaces Engine/mechanical malfunctions	Flame cutting/welding spark/slag Hydraulic fluid/fuel on equipment hot surfaces. Battery explosion	Hydraulic fluid/fuel on equipment hot surfaces. Mechanical malfunction	Electrical short/arcing Flame cutting/weldingspark/slag Flammable liquid on hot surfaces Heat source
Method of detection	Visual-flames/flash fire Visual-sparks Visual-flames/explosion Visual/smoke	Visual-sparks Visual-flames/flash fires Visual-smoke	Visual-flames/flash fire Visual-smoke	Visual-smoke Visual-sparks Visual-flames/flash fire
Suppression method	FE-foam-DCP-water Manual/FE Portable fire extinguisher FE-DCP-water	Manual/FE FE-FSS-HD FE-foam-DCP-water Portable fire extinguisher	FE-DCP-water Portable fire extinguisher	FE-DCP-rock dust-water Manual/FE Portable fire extinguisher
Equipment	Trucks Shovels Dozers Loaders	Trucks Highlifts Tractors Loaders	Loaders Trucks	Scoops Shuttle cars Bolters Railrunners
Location	Flame cutting/welding areas[1] Equipment working areas[2] Maintenance areas	Flame cutting/welding areas[1] Charging station Equipment working areas[2]	Equipment working areas[2] Maintenance areas	Flame cutting/welding areas[1] Equipment working areas[2] Rail track/transportation areas

DCP Dry chemical powder.
FE Portable fire extinguisher.
FSS Machine fire suppression system.
GT Grand total.
HD Heavily damaged.
[1]Includes working, mining, and maintenance areas.
[2]Includes haulage, mining, and loading areas.
NOTE.–Variables are listed in descending order of occurrence.

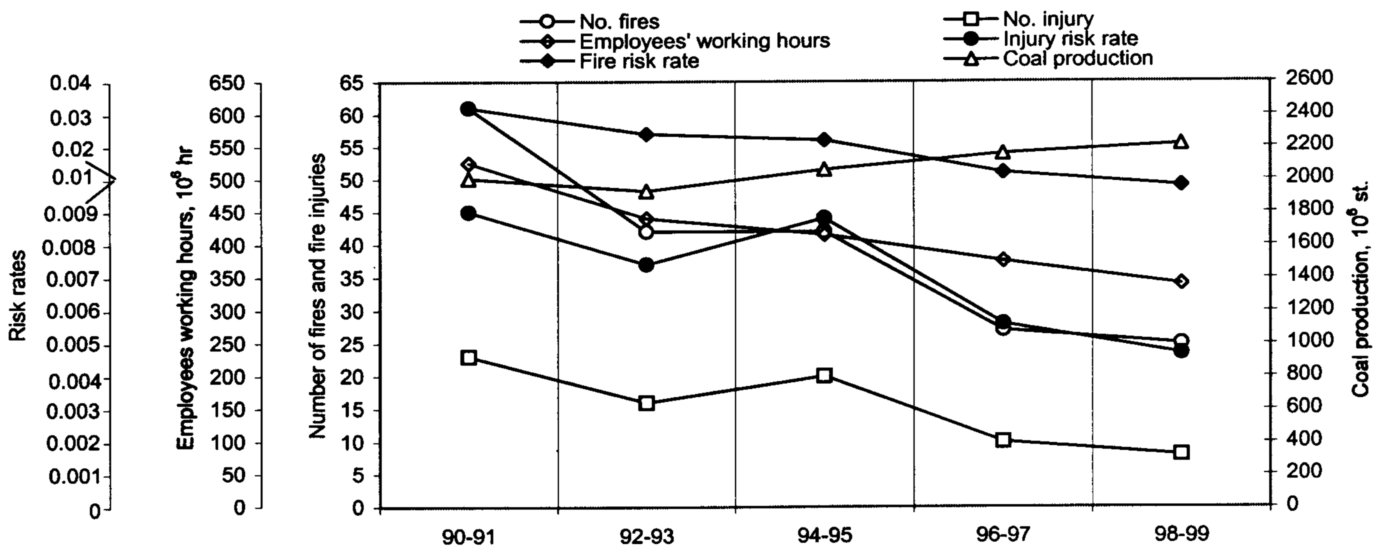

Figure 19.–Mobile equipment fires, injuries, risk rates, employees' working hours, and coal production (coal production for surface and underground coal mines only) for all coal mining categories by time period, 1990-1999.

SUMMARY OF MAJOR MOBILE EQUIPMENT FIRE AND FIRE INJURY FINDINGS FOR ALL METAL/NONMETAL MINING CATEGORIES

Major mobile equipment fire and fire injury findings for all metal/nonmetal mining categories during 1990-1999 are reported in tables 51-52. Data during the five 2-year time periods (figure 20) are discussed below.

For these categories, there was a grand total of 142 equipment fires during 1990-1999; 82 injuries and 2 fatalities were caused by 80 of those fires (Ewhr = 3,001 × 10^6 hr; Irr = 0.006). In all, 10 pieces of equipment (7%) involved in the fires had machine fire suppression systems.

The greatest number of fires and injuries occurred at surface mines; the highest risk rates were also calculated for these operations.

For all metal/nonmetal mining categories, the greatest number of equipment fires and fire injuries was caused by hydraulic fluid/fuel (77 fires or 54%, with 42 injuries) sprayed onto equipment hot surfaces. Fire-resistant hydraulic fluid is not required for equipment use at all metal/nonmetal operations. Most of the hydraulic fluid/fuel fires, although detected by the operators when they started, grew out of control (requiring at least 7 fire-fighting interventions at surface operations and 10 mine rescue interventions in underground mines) because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure, lack of an emergency line drainage system, difficulty in reaching available emergency systems at ground level due to flames engulfing the area, or lack of effective and rapid local fire-fighting response capabilities. On at least seven occasions the cab was suddenly engulfed in flames most likely due to the ignition of flammable vapors and mists that formed and penetrated the cab during the spraying of hydraulic fluid/fuel sprayed onto equipment hot surfaces. Dual activation (two activations) of the machine fire suppression and engine shutoff systems succeeded in abating the fires temporarily. However, the flames reignited, fueled by the flow of fluids entrapped in the lines.

In five other instances, the flames continued to be fueled by the flow of fluids from the pump because of engine shutoff failure (one fatality); in three other instances, the systems were not activated. Once, the system discharged automatically, undetected by the operator (one fatality), who continued to operate the rig until the flames suddenly engulfed the cab. Other ignition sources were flame cutting/welding spark/slag (17 fires or 12%), flammable liquid/refueling fuel/fuel/motor oil on hot surfaces/collision (21 fires or 15%), electrical short/arcing (14 fires or 10%), and overheated oil due to compressor malfunction (6 fires or 4%). Fire brigades and fire department at surface mines, handicapped by travel distances, fought the hydraulic fluid/fuel fires with foam, dry chemical powder, and water. Mine rescue teams in underground mines, which were often hindered by heavy smoke, fought the hydraulic fluid/fuel fires with dry chemical powder, rock dust, and water. Fourteen equipment fires (10%) were not extinguished because of failure of fire suppression and fire-fighting methods, late fire detection, undetected fires, or fire size.

For all metal/nonmetal mining categories, data during the five time periods show sharp increases followed by sharp decreases in the number of equipment fires and fire injuries throughout the periods, accompanied by small changes in employees' working hours. However, some observations common to all mining categories are reported below.

1. At surface metal/nonmetal mines, there were 49 fires; 24 of those fires caused 24 injuries and 1 fatality. The Ewhr value was 467×10^6 hr (Irr=0.01). The ignition sources that caused most of the equipment fires were hydraulic fluid/fuel (33 fires or 67%) sprayed onto equipment hot surfaces due to ruptured lines and failed fittings and gaskets. This was followed by flame cutting/welding spark/slag, flammable liquid/refueling fuel/fuel oil on hot surfaces, and electrical short/arcing. Most of the hydraulic fluid/fuel fires, although detected by the operators when they started, grew out of control (requiring at least one fire-fighting intervention) because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure, lack of an emergency line drainage system, difficulty in activating available emergency systems, or lack of effective and rapid local fire-fighting response capabilities. At least twice, flammable vapors and mists penetrated the cab and ignited. Five pieces of equipment (10%) involved in the fires had machine fire suppression systems. Dual activation (one activation) of machine fire suppression and engine shutoff systems succeeded in abating temporarily the flames. However, the flames reignited, fueled by the fluids entrapped in the lines. In one instance, the flames continued to be fueled by the flow of fluids from the pump because of engine shutoff failure. In another instance, the machine fire suppression system discharged automatically, undetected by the operator (one fatality), who continued to operate the rig until the flames suddenly engulfed the cab. Fire brigades and fire departments, handicapped by travel distances, fought the hydraulic fluid/fuel fires with foam, dry chemical powder, and water. Seven equipment fires were not extinguished because of failed fire suppression and fire-fighting methods, late fire detection, undetected fires, or fire size. The equipment involved included haulage/utility trucks, shovels, loaders, and drills mostly during working activities.

The ignition sources that caused most of the injuries were hydraulic fluid/fuel sprayed onto equipment hot surfaces, electrical short/arcing, flame cutting/welding spark/slag, and refueling fuel/flammable liquid on hot surfaces. The equipment involved in injuries included trucks, loaders, shovels, and dozers mostly at haulage, loading, mining, maintenance, and flame cutting/welding areas.

Equipment fires increased sharply during 1992-1993 (the number of fire injuries stayed steady during this period), then decreased during subsequent periods, accompanied by a small decline in employees' working hours.

2. At surface sand and gravel and stone mines, there were 46 fires; 36 of those fires caused 35 injuries and 1 fatality. The Ewhr value was $1{,}101 \times 10^6$ hr (Irr = 0.006). The ignition sources that caused most of the equipment fires were hydraulic fluid/fuel (25 fires or 54%) sprayed onto equipment hot surfaces, followed by flammable liquid/refueling fuel/oil on hot surfaces, flame cutting/welding spark/slag, electrical short/arcing, and mechanical malfunction/friction/collision. None of the equipment involved in the fires had machine fire suppression systems. Most of the hydraulic fluid/fuel fires grew out of control (requiring at least four fire-fighting interventions) because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure, lack of an emergency line drainage system, difficulty in reaching available emergency systems at ground level, or lack of effective and rapid local fire-fighting response capabilities. At least twice flammable vapors and mists penetrated the cab and ignited. Fire departments fought the hydraulic fluid/fuel fires with dry chemical powder and water. Four equipment fires involving six pieces of equipment were not extinguished because of undetected fires or fire size. The equipment included trucks, loaders, dozers, and dredges during haulage, loading, mining, dredging, flame cutting/welding, and maintenance activities.

The ignition sources that caused most of the fire injuries were hydraulic fluid/fuel sprayed onto equipment hot surfaces, followed by flame cutting/welding/spark/slag, refueling fuel/flammable liquid on hot surfaces, and electrical short/arcing. The equipment involved in fire injuries included trucks, loaders, dozers, and dredges at haulage, loading, mining, dredging, flame cutting/welding, and maintenance areas.

Equipment fires and fire injuries increased sharply during 1992-1993, then decreased throughout subsequent periods (especially 1998-1999), accompanied by a small increase in employees' working hours.

3. At metal/nonmetal and stone mills, there were 23 fires; 16 of those fires caused 16 injuries. The Ewhr value was $1{,}219 \times 10^6$ hr (Irr = 0.003). The ignition sources that caused most of the equipment fires were hydraulic fluid/fuel (seven fires or 30%) sprayed onto equipment hot surfaces, followed by flame cutting/welding spark/slag, flammable liquid on hot surfaces, electrical short/arcing, overheated oil and transmission oil on hot surfaces and hot material. Most of the hydraulic fluid/fuel fires, although detected by the operators when they started, grew out of control (requiring at least twice fire-fighting interventions) because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure, lack of an emergency line drainage system, difficulty in reaching available emergency systems at ground level, or lack of effective and rapid local fire-fighting response capabilities. On at least one occasion, flammable vapors and mists penetrated the cab and ignited. One piece of equipment (4%) involved in the fires had a machine fire suppression system. However, activation of the machine fire suppression system was ineffective in suppressing the hydraulic fluid/fuel fire because of engine shutoff failure. Fire brigades and fire departments fought the hydraulic fluid/fuel fires with foam, dry chemical powder, and water. One equipment fire was not extinguished because the fire was undetected, and the equipment involved was destroyed. The equipment included loaders, haulage/utility trucks, shovels, and dozers during working and maintenance activities.

The ignition sources that caused most of the injuries were hydraulic fluid/fuel sprayed onto equipment hot surfaces, flame cutting/welding spark/slag, flammable liquid on hot surfaces, and electrical short/arcing. The equipment involved in injuries included loaders, trucks, dozers, and drills at loading, haulage, drilling, flame cutting/welding, and maintenance areas.

Equipment fires decreased sharply during 1994-1995, followed by small increases and decreases during subsequent periods. However, fire injuries decreased steadily during most of the periods, accompanied by a small decline in employees' working hours.

4. In underground metal/nonmetal and stone mines, there were 24 fires; 4 of those fires caused 7 injuries. The Ewhr value was 214×10^6 hr (Irr = 0.007). The ignition sources that caused most of the equipment fires were hydraulic fluid (12 fires or 50%) sprayed onto equipment hot surfaces, followed by electrical short/arcing of wires and cables, flammable liquid/fuel/motor oil, overheated oil, and flame cutting/welding spark/slag. Most of the hydraulic fluid fires, although detected by the operators when they started, grew out of control (requiring at least 10 fire-fighting interventions) because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure, lack of emergency line drainage systems, or lack of effective and rapid local fire-fighting response capabilities. At least twice, flammable vapors and mists penetrated the cab and ignited. Four pieces of equipment (17%) involved in the fires had machine fire suppression systems. Dual activation (one activation) of machine fire suppression system and engine shutoff systems succeeded in containing the fire. In another instance, the flames continued to be fueled by the flow of fluids from the pump because of engine shutoff failure. Once the machine fire suppression system failed to activate promptly. Upon mine/section evacuation, mine rescue teams (required 20 times), which were often severely hindered by dense smoke in trying to reach the fire location, fought the hydraulic fluid and electrical fires with dry chemical powder, rock dust, and water. Four equipment fires were not extinguished because of failed fire suppression methods and undetected fires. The equipment included scoops, trucks, locomotives, and loaders during mining, mucking, haulage, and loading activities.

The ignition sources that caused most of the injuries were hydraulic fluid sprayed onto equipment hot surfaces, overheated oil, and motor oil on hot surfaces. The equipment involved in injuries included scoops, ore carts, and drills at mining, drilling, and transportation areas.

Equipment fires and fire injuries increased sharply during 1996-1997, then decreased sharply during 1998-1999, accompanied by small changes in employees' working hours.

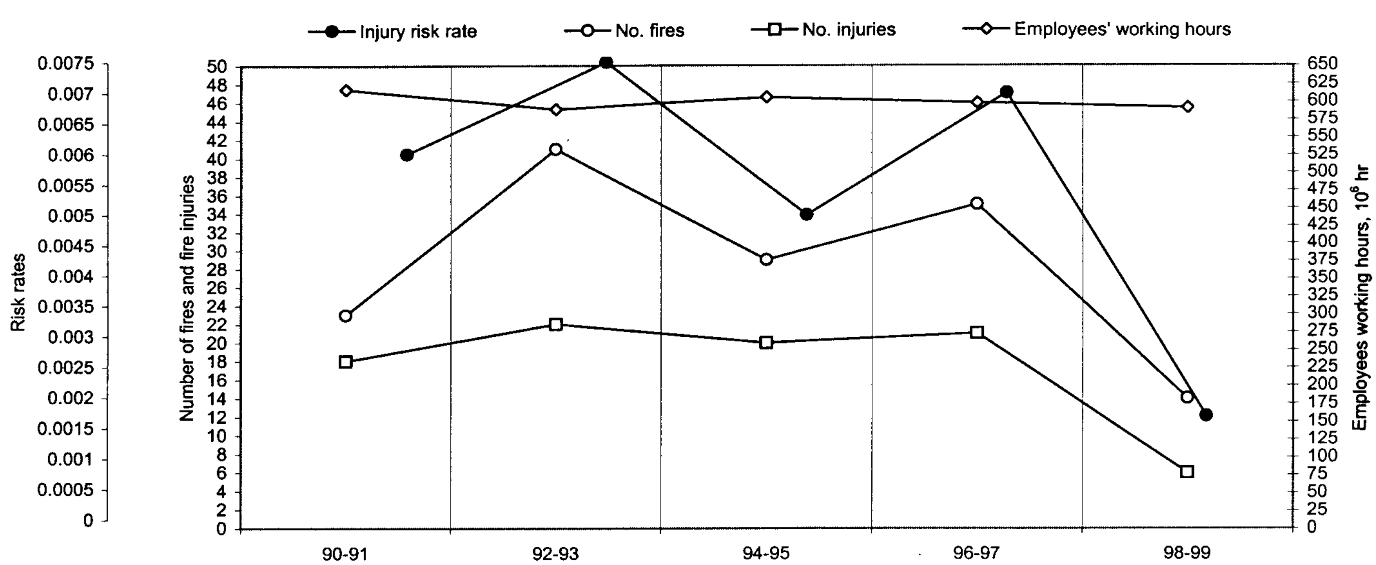

Figure 20.—Mobile equipment fires, injuries, risk rates, and employees' working hours for all metal/nonmetal mining categories by time period, 1990-1999.

Table 51.–Major mobile equipment fire findings for all metal/nonmetal mining categories, 1990-1999

Variables	Surface metal/nonmetal mines	Surface sand/gravel and stone mines	Metal/nonmetal and stone mills	Underground metal/nonmetal and stone mines
GT: No. fires: 142 No fires causing injuries: 80	No. fires: 49 No. fires causing injuries: 24	No. fires: 46 No. fires causing injuries: 36	No. fires: 23 No. fires causing injuries: 16	No. fires: 24 No. fires causing injuries: 4
Ignition source	Hydraulic fluid/fuel on equipment hot surfaces. Flame cutting/welding spark/slag Refueling fuel/flammable liquid/ fuel oil on hot surfaces. Electrical short/arcing	Hydraulic fluid/fuel on equipment hot surfaces. Refueling fuel/flammable liquid/fuel oil on hot surfaces. Flame cutting/welding spark/slag Electrical short/arcing	Hydraulic fluid/fuel on equipment hot surfaces. Flame cutting/welding spark/slag Flammable liquid/fuel oil on hot surfaces/ collision. Overheated oil/transmission oil on hot surfaces.	Hydraulic fluid/fuel on equipment hot surfaces. Electrical short/arcing Flammable liquid/fuel/motor oil on hot surfaces. Overheated oil
Method of detection	Visual-flames/flash fire Visual-smoke Visual-sparks Power loss/power trip	Visual-flames/flash fire Visual-sparks Visual-smoke Late detection-smoke	Visual-flames/flash fire Visual-sparks Visual-smoke Late det./smoke	Visual-smoke Visual-flames/flash fire Power loss Visual-sparks
Suppression method	FE-foam-DCP-water Portable fire extinguisher Manual/FE FE-FSS-DCP-water	FE-water-DCP Portable fire extinguisher Manual/FE	Portable fire extinguisher FE-foam-DCP-water Manual/FE FE-FSS-DCP-water	FE-water-rock dust-DCP Portable fire extinguisher FE-FSS-DCP-rock dust-water Manual
Equipment	Trucks Shovels Drills Loaders	Trucks Loaders Dozers Dredges	Loaders Trucks Shovels Dozers	Scoops Trucks Trolley/locomotives Loaders
Location	Equipment working areas[1] Flame cutting/welding areas[2] Maintenance areas	Equipment working areas[1] Maintenance areas Flame cutting/welding areas[2]	Equipment working areas[1] Flame cutting/welding areas[2] Maintenance areas	Equipment working areas[1] Transportation areas Flame cutting/welding areas[2] Maintenance areas

DCP Dry chemical powder.
FE Portable fire extinguisher.
FSS Machine fire suppression system.
GT Grand total.
[1]Includes haulage, mining, drilling, loading, mucking, and transport areas.
[2]Includes working, mining, and maintenance areas.
NOTE.–Variables are listed in descending order of occurrence.

Table 52.–Major mobile equipment fire injury findings for all metal/nonmetal mining categories, 1990-1999

Variables	Surface metal/nonmetal mines	Surface sand/gravel and stone mines	Metal/nonmetal and stone mills	Underground metal/nonmetal and stone mines
GT: No. fire injuries: 82 No. fire fatalities: 2 Ewhr, 10^6 hr: 3,001 Irr: 0.006	No. fire injuries: 24 No. fire fatalities: 1 Ewhr, 10^6 hr: 467 Irr: 0.01	No. fire injuries: 35 No. fire fatalities: 1 Ewhr, 10^6 hr: 1,101 Irr: 0.006	No. fire injuries: 16 Ewhr, 10^6 hr: 1,219 Irr: 0.003	No. fire injuries: 7 Ewhr, 10^6 hr: 214 Irr: 0.007
Ignition source	Hydraulic fluid/fuel on equipment hot surfaces. Electrical short/arcing Flame cutting/welding/spark/slag Refueling fuel/flammable liquid on hot surfaces.	Hydraulic fluid/fuel on equipment hot surfaces. Flame cutting/welding/spark/slag Flammable liquid/refueling fuel on hot surfaces. Electrical short/arcing	Hydraulic fluid/fuel on equipment hot surfaces. Flame cutting/welding spark/slag Flammable liquid on hot surfaces Electrical short/arcing	Hydraulic fluid on equipment hot surfaces. Overheated oil Motor oil on hot surfaces
Method of detection	Visual-flames/flash fire Visual-sparks Visual-smoke	Visual-flames/flash fire Visual-sparks Visual-smoke	Visual-flames/flash fire Visual-sparks Visual-smoke	Visual-flames/flash fire Visual-smoke Late detection-smoke
Suppression method	FE-foam-DCP-water Portable fire extinguisher FE-FSS-DCP Manual/FE	FE-DCP-water Portable fire extinguisher Manual/FE	FE-foam-DCP-water FE-FSS-DCP Manual/FE Portable fire extinguisher	FE-DCP-rock dust-water Portable fire extinguisher FE-FSS-DCP-rock dust
Equipment	Trucks Loaders Shovels Dozers	Trucks Loaders Dozers Dredges	Loaders Trucks Dozers Drills	Scoops Ore carts Drills
Location	Equipment working areas[1] Flame cutting/welding areas[2] Maintenance areas	Equipment working areas[1] Flame cutting/welding areas[2] Maintenance areas	Equipment working areas[1] Flame cutting/welding areas[2] Maintenance areas	Equipment working areas[1] Flame cutting/welding areas[2] Maintenance areas

DCP Dy chemical powder.
FE Portable fire extinguisher.
FSS Machine fire suppression system.
GT Grand total.
[1]Includes haulage, loading, mining, dredging, drilling, and transport areas.
[2]Includes working, mining, and maintenance areas.
NOTE.–Variables are listed in descending order of occurrence.

CONCLUSIONS

Findings show that the greatest number of equipment fires and injuries during 1990-1999 occurred at surface mines; the highest injury risk rate values were also calculated for these operations. For all mining categories, there was a total of 339 fires; 159 injuries and 2 fatalities were caused by 156 of those fires. In the future, these equipment fires and injuries may be prevented/reduced or suppressed at their earliest stage by improving techniques and strategies, developing new technologies, and improving safety training programs. Several suggestions follow.

1. *Schedule more frequent and more thorough inspections of hydraulic, fuel, and electrical systems.* A large number of equipment fires were due to ruptured hydraulic/fuel lines and failed fittings/gaskets and electrical short/arcing in power cable systems. By scheduling more frequent and thorough inspections, potential system failures may be detected beforehand.

2. *Develop new technologies for emergency engine shutoff system and line drainage system.* A large number of hydraulic fluid/fuel fires grew out of control because of the continuous flow of fluids from pumps and tanks due to engine shutoff failure. Furthermore, a large number of fires, upon successful dual activation of machine fire suppression and engine shutoff systems, continued to be fueled by the fluids entrapped in the lines. By developing emergency engine shutoff systems and line drainage systems, equipment fires may be contained more readily and the effectiveness of machine fire suppression systems could be enhanced.

3. *Develop cab fire detection and fire prevention/suppression systems.* None of the cabs involved in the fires had fire detection and suppression systems. During the hydraulic fluid/fuel fires, flammable vapors and mists often penetrated the cab. These ignited violently while the operator was performing emergency tasks, forcing the operator to exit the cab among intense flames. By equipping the cab with fire detection and fire prevention/suppression systems, vapor/mist concentrations could be detected and their ignition prevented.

4. *Develop effective and rapid local fire-fighting response capabilities.* Findings show that local mine personnel have inadequate fire-fighting capabilities to combat hydraulic fluid/fuel and electrical equipment fires. Fire brigades, fire departments, and mine rescue teams, handicapped by travel distances, were often called to fight these fires. By training local miners to fight equipment fires when they are detected with adequate fire-fighting capabilities, such as large quantities of dry chemical powder on vehicles for ease of deployment to the fire site, these fires could be better contained.

5. *Schedule more frequent fire emergency preparedness training for equipment operators.* During equipment hydraulic fluid/fuel fires, operators often failed to perform emergency tasks such as activating the machine fire suppression and engine shutoff systems. This was due mostly to lack of time and stressful conditions. By scheduling more frequent fire emergency preparedness training sessions, operators would be able to perform these tasks more quickly under fire conditions.

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