This was followed by hydraulic fluid/fuel and by flammable liquids, gas, and refueling fuel. Other burning materials included refuse and rubber tires, electrical control, wires and cables, belt material and crusher, and facilities and their contents. During all of the periods, the largest number of fires involved oxyfuel/ clothing/grease and other materials.

Fire Injuries

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 during 1990–2001. Overall, there were 60 injuries caused by 59 fires. The greatest number of fire injuries occurred in 1998 (10 injuries caused by 9 fires). The ignition sources that caused most of the fire injuries were flame cutting/welding spark/slag/flame, heat source, and hydraulic fluid/fuel sprayed onto equipment hot surfaces. Other ignition sources were flammable liquid/refueling fuel on hot surfaces and electrical short/arcing. The equipment most often involved in fire injuries included oxyfuel torches, heaters, and mobile equipment, followed by maintenance equipment, electrical systems, pumps, and generators. The locations where the fire injuries occurred were flame cutting/welding areas, maintenance areas, mobile equipment working areas, and pump and generator housing.

SURFACE STONE MINE FIRES

Table 37 and figure 13 show the number of fires and fire injuries for surface stone mines by state during 1990–2001. Table 37 also shows the injury risk rates, employees' working hours, and lost workdays. In all, 96 fires occurred in 31 states and 1 fire occurred in Puerto Rico. Sixty-eight of the fires caused 67 injuries and 1 fatality (including 6 fires and 5 injuries involving contractors). The yearly average was eight fires and 5.6 injuries. The Ewhr value was 689×10^6 hr (Irr = 0.02), and the LWD value was 7,399.

Indiana had the most fires (eight fires and four injuries), followed by Georgia (seven fires and seven injuries) and Pennsylvania (seven fires and five injuries). Of these states, Georgia had the highest injury risk rate value (Irr = 0.058).

Table 38, partly illustrated in figure 14, shows the number of fires, fire injuries, fire fatalities, risk rates, employees' working hours, and lost workdays by time period. The number of fires and fire injuries show an increase during the second period followed by a decrease during most of the remaining periods. Employees' working hours increased during most of the periods. The Irr values follow patterns similar to those shown by the injury values.

Tables 39–44 show the number of fires by ignition source, method of detection and suppression, equipment involved, location, and burning material by time period. Figure 15 shows the major variables related to fires for 1990–2001. Table 45shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location.

Ignition Source

Table 39 shows the number of fires and fire injuries by ignition source for each time period. The leading sources were flame cutting/welding spark/slag/flame (25 fires or 26%), heat source/explosion-flammable liquid (24 fires or 25%), and hydraulic fluid/fuel sprayed onto equipment hot surfaces (16 fires or 17%). At least 10 of the 16 mobile equipment hydraulic fluid/fuel fires became large fires because of the continuous flow of fluids from the pumps due to engine shutoff failure, difficulty in activating available emergency systems at the ground level, lack of an emergency line drainage system, or lack of effective and rapid local firefighting response capabilities. On two occasions, the cab was suddenly engulfed in flames, probably due to the ignition of flammable vapors and mists that penetrated the cab. Of note is that the hydraulic fluid fires subsequently involved the fuel system. Other ignition sources were electrical short/arcing, refueling fuel/flammable liquid on hot surfaces, explosion/ignition of hazardous material, chemical and explosives, hot material, engine malfunction/mechanical friction, and overheated oil. Nine ignition sources were unknown.

During the first, third, fourth, and fifth periods, the largest number of fires were caused by heat source/explosion-flammable liquid/gas. During the second period, the largest number of fires were caused by flame cutting/welding spark/slag/flame. During the sixth period, the largest number of fires were caused by hydraulic fluid/fuel sprayed onto equipment hot surfaces.

Method of Detection

Table 40 shows the number of fires by method of detection for each time period. The most frequent methods were operators who saw the fires when they started as flames/flash fires, welders who saw sparks, and miners who saw smoke shortly after the fires had started. Other methods of detection were miners who heard an explosion or touched a hot spot, miners who saw smoke long after the fires had started, and operators who saw a white mist. Eight fires were undetected.

During the first period, the largest number of fires were detected by welders as sparks and by miners who heard an explosion. During the second period, the largest number of fires were detected by welders as sparks. During the third period, the largest number of fires were detected by operators as flames/flash fires and by welders as sparks. During the fourth and fifth periods, the largest number of fires were detected by miners as smoke. During the sixth period, the largest number of fires were detected by operators as flames/flash fires.

Suppression Method

Table 41 shows the number of fires by suppression method for each time period. The most common methods were manual techniques with or without portable fire extinguishers or water alone, portable fire extinguishers with dry chemical powder, and foam and water. None of the equipment involved in fires had machine fire suppression systems. On at least six occasions, including one mobile equipment fire, fire brigades and fire departments fought the fires with portable fire extinguishers, foam, dry chemical powder, and water. However, 12 fires destroyed or heavily damaged equipment (including four pieces of mobile equipment) because of failure of firefighting methods, late fire detection, undetected fires, or fire size.

During the first and fifth periods, the largest number of fires were suppressed with water alone. During the second period, the largest

number of fires were suppressed manually with or without portable fire extinguishers. During the third period, the largest number of fires were suppressed with portable fire extinguishers or water alone and manually with or without portable fire extinguishers. During the fourth period, the largest number of fires were extinguished with portable fire extinguishers alone or together with dry chemical powder, foam, and water. During the sixth period, the largest number of fires were extinguished with portable fire extinguishers, dry chemical powder, foam, and water.

Equipment Involved

Table 42 shows the number of fires by equipment involved for each time period. The equipment most often involved was mobile equipment (dozers, loaders, trucks, tankers, drills, and shovels), oxyfuel torches (at times electrical arc welding equipment was used), heaters and burners, and maintenance equipment. Other equipment included facilities (considered equipment in this report), chemical/flammable liquid/gas tanks, beltlines, electrical control systems, a hopper, a crusher, a preheat system, a generator, a product treatment pot, and an explosive device. During the first, third, and fifth periods, the largest number of fires involved heaters, burners, and maintenance equipment. During the second period, the largest number of fires involved oxyfuel torches. During the fourth and sixth periods, the largest number of fires involved mobile equipment.

Location

Table 43 shows the number of fires by location for each time period. The most common locations were flame cutting/welding areas, maintenance and refuse areas, and mobile equipment working areas (haulage, loading, mining, drilling, transportation, and crusher areas). Other fire locations included facility and garage areas, raw mills, preheat and storage silo areas, product treatment areas, beltline and hopper areas, and waste dump, pit, crusher, screen, and deck areas. Electrical control and power house areas, chemical and flammable liquid storage areas, and generator housing were also affected by the fires. During the first, third, and fifth periods, the largest number of fires occurred at maintenance and refuse areas. During the second period, the largest number of fires occurred at flame cutting/welding areas. During the fourth and sixth periods, the largest number of fires occurred at mobile equipment working areas.

Burning Materials

Table 44 shows the number of fires by burning material for each time period. The materials most often involved were oxyfuel/

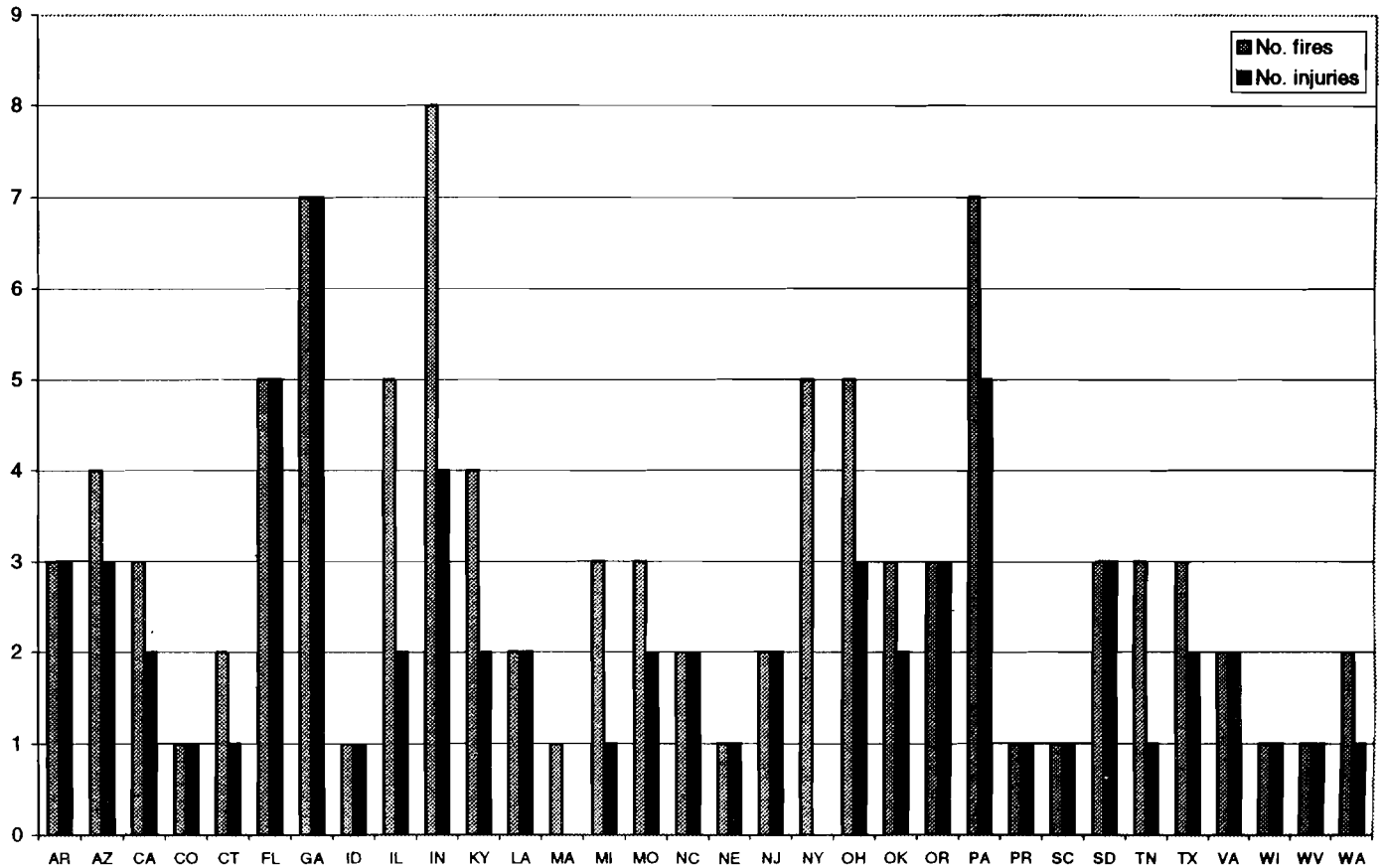

Figure 13.—Number of fires and fire injuries for surface stone mines by state, 1990–2001.

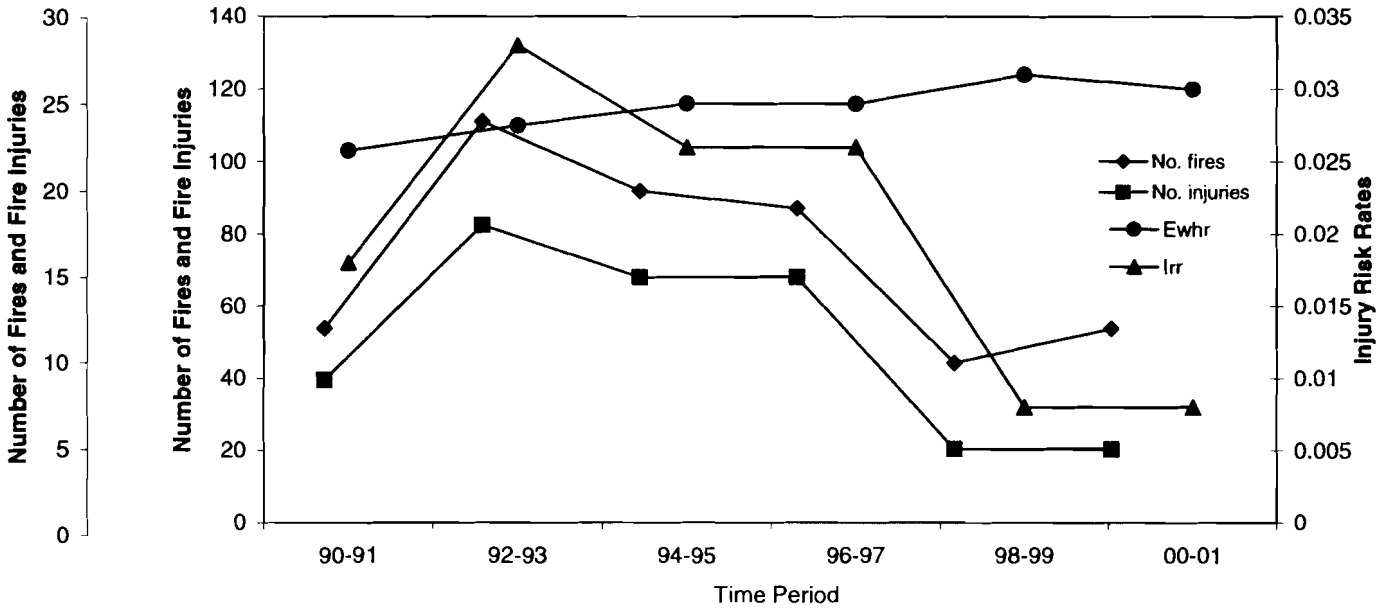

Figure 14.—Number of fires, fire injuries, risk rates, and employees' working hours for surface stone mines by time period, 1990–2001.

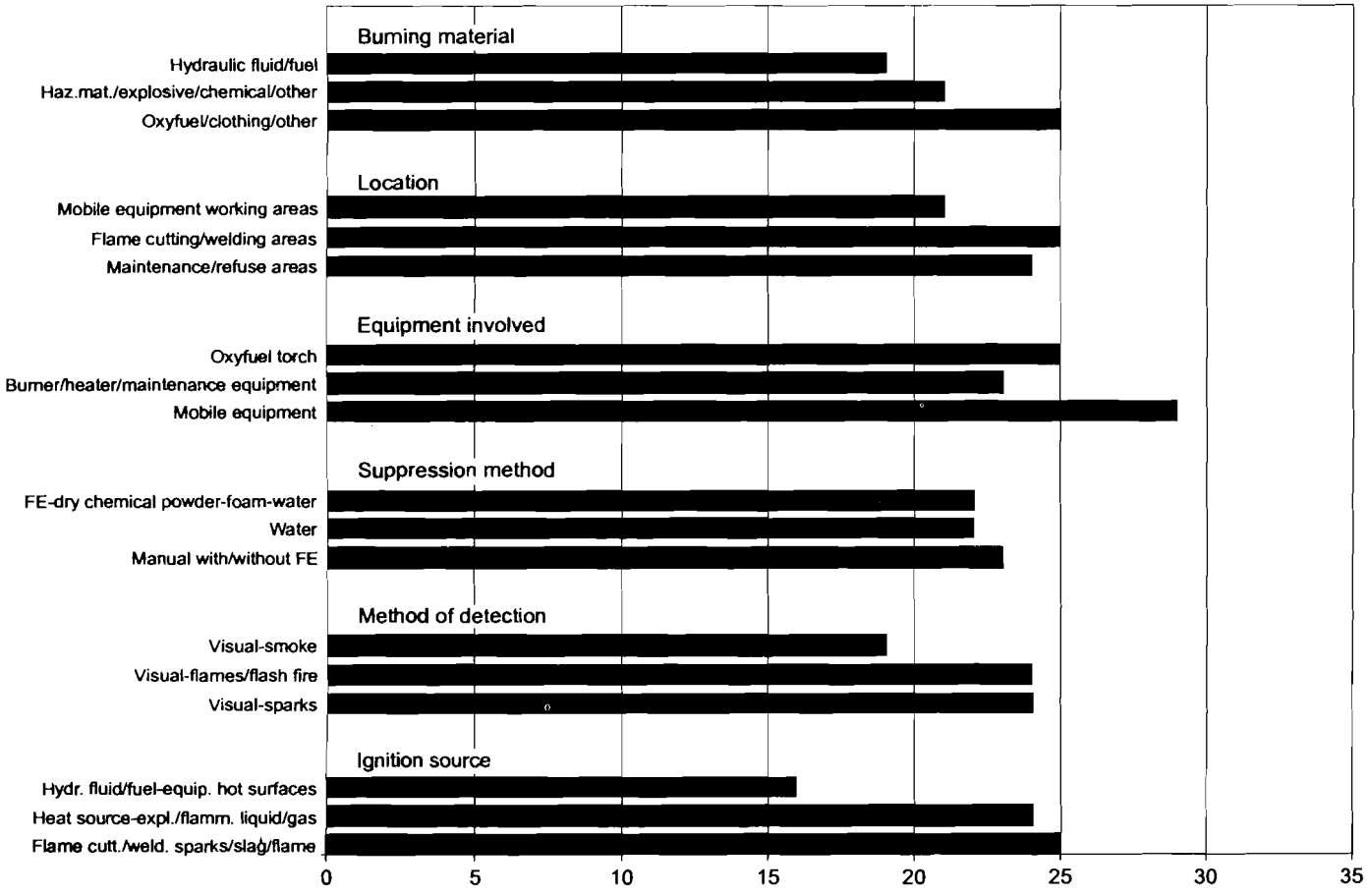

Figure 15.—Major variables for surface stone mine fires, 1990–2001. (FE = portable fire extinguisher)

Table 37.—Number of fires, fire injuries, and risk rates for surface stone mines by state,[1] employees' working hours, and lost workdays, 1990–2001

State[2]	No. fires[2]	No. fire injuries[2]	LWD[3]	Ewhr,[3] 10[6] hr	Irr[4]
Arizona	4	3	26	5.8	0.014
Arkansas	3	3	52	14	0.043
California	3	2	20	21.6	0.019
Colorado	1	1	12	8.2	0.024
Connecticut	2	1	—	5.3	0.038
Florida	5	5	50	39.5	0.025
Georgia	7	7	115	24	0.058
Idaho	1	1	—	3.5	0.057
Illinois	5	2	247	24.6	0.016
Indiana	8	4	64	17.6	0.046
Kentucky	4	2	6	16.4	0.024
Louisiana	2	2	2	4.2	0.095
Massachusetts	1	—	—	8.2	—
Michigan	3	1	43	11.3	0.018
Missouri	3	2	18	28	0.014
Nebraska	1	1	—	2	0.1
New Jersey	2	2	150	10	0.04
New York	5	—	7	17	—
North Carolina	2	2	24	27	0.015
Ohio	5	3	49	22	0.027
Oklahoma	3	2	32	19.2	0.021
Oregon	3	3	38	14.7	0.041
Pennsylvania	7	5	177	46	0.022
Puerto Rico	1	1	30	11.4	0.018
South Carolina	1	1	24	7.5	0.027
South Dakota	3	3	15	5.4	0.111
Tennessee[5]	3	1	6,152	18	0.011
Texas	3	2	37	49	0.008
Virginia	2	2	—	21.7	0.018
Washington	2	1	—	5.2	0.039
West Virginia	1	1	—	6	0.033
Wisconsin	1	1	9	18	0.011
All other states	—	—	—	157	—
Total	97	67	7,399	689	[4]0.02

[1]Includes Puerto Rico.
[2]Derived from MSHA "Fire Accident Abstract" internal publications.
[3]Derived from MSHA "Injury Experience in Mining" publications.
[4]Calculated according to MSHA formula reported in the "Methodologies" section.
[5]Tennessee had 1 fire fatality caused by a hydraulic fluid/fuel fire involving a truck.

clothing/grease and other materials (including screen shaft, crusher, hopper, stampler breaker materials, rubber hoses, gear boxes, bin feeder, hydraulic fluid, and chute liner), hazardous materials, chemicals, oil, refuse, detonated explosives, and hydraulic fluid/fuel. Other burning materials included flammable liquids and gas, facilities and their contents, electrical wires and cables, belts and hot materials, equipment mechanical components, and deck liner.

During the first and fifth periods, the largest number of fires involved hazardous material, chemicals, refuse, oil, and detonated explosives. During the second period, the largest number of fires involved oxyfuel/clothing/grease and other materials. During the third period, the largest number of fires involved oxyfuel and hazardous materials. During the fourth and sixth periods, the largest number of fires involved hydraulic fluid/fuel.

Fire Injuries

Table 45 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location for 1990–2001. Overall, there were 67 injuries and 1 fatality caused by 68 fires. The greatest number of fire injuries occurred in 1993 (11 injuries and 1 fatality caused by 12 fires). The ignition sources that caused the greatest number of fire injuries were flame cutting/welding spark/slag/flame, heat source, and hydraulic fluid/fuel sprayed onto equipment hot surfaces. Other ignition sources were flammable liquid/refueling fuel on hot surfaces, electrical short/arcing, overheated oil, hot material, and mechanical friction. The equipment involved in fire injuries included oxyfuel torches, heaters, mobile equipment, maintenance equipment, electrical systems, air compressors, beltline, and kiln. The locations where most of the fire injuries occurred were flame cutting/welding areas, maintenance and refuse areas, and mobile equipment working areas. Other fire locations were generator housing, beltlines, and kiln areas.

A fatality occurred in Tennessee [MSHA 1993e], which was caused by a hydraulic fluid fire involving a truck. The victim was severely burned in the cab, probably due to the sudden ignition of flammable vapors and mists that penetrated the cab.

Table 38.—Number of fires, fire injuries, fire fatalities, and risk rates for surface stone mines by time period, employees' working hours, and lost workdays, 1990–2001

	Time period						
	90-91	92-93	94-95	96-97	98-99	00-01	1990-2001
Number of fires[1]	12	24	20	19	10	12	97
Number of fire injuries[1]	9	18	15	15	5	5	67
Number of fire fatalities[1]	—	1	—	—	—	—	1
LWD[2]	191	6,133	784	155	57	79	7,399
Ewhr,[2] 10^6 hr	103	110	116	116	124	120	689
Irr[3]	0.018	0.033	0.026	0.026	0.008	0.008	[3]0.02

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

Table 39.—Number of fires for surface stone mines by ignition source and time period, 1990–2001

Ignition source	Time period						
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	00-01 No. fires	1990-2001 No. fires
Flame cutting/welding spark/slag/flame	3	10	5	3	2	2	25
Heat source/explosion-flammable liquid/gas	5	4	6	4	4	1	24
Hydraulic fluid/fuel on equipment hot surfaces	2	4	2	3	—	5	16
Electrical short/arcing	—	—	2	4	—	1	7
Refueling fuel/flammable liquid on hot surfaces	—	1	2	—	2	—	5
Explosion/ignition-hazardous material/chemical/ explosives/flammable gas	—	1	1	1	1	—	4
Hot material	—	—	1	1	1	—	3
Overheated oil	—	1	—	1	—	—	2
Engine malfunction/mechanical friction	—	—	—	1	—	1	2
Unknown	2	3	1	1	—	2	9
Total	12	24	20	19	10	12	97

Table 40.—Number of fires for surface stone mines by method of detection and time period, 1990–2001

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	00-01 No. fires	1990-2001 No. fires
Visual:							
Flames/flash fires	2	5	5	3	3	6	24
Sparks	3	10	5	3	2	1	24
Smoke	—	3	4	6	4	2	19
Late smoke detection	—	2	—	2	—	—	4
White mist	—	—	—	—	—	1	1
Heard an explosion	3	1	2	2	1	—	9
Touched a hot spot	2	1	3	2	—	—	8
Undetected	2	2	1	1	—	2	8
Total	12	24	20	19	10	12	97

Table 41.—Number of fires for surface stone mines by suppression method and time period, 1990–2001

Suppression method	Time period						
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	00-01 No. fires	1990-2001 No. fires
Manual with or without FE[1]	3	10	5	3	2	—	23
Water	4	4	5	4	4	1	22
FE-DCP-foam-water	2	5	4	5	2	4	22
FE	1	2	5	5	2	3	18
Destroyed/HD[2]	2	3	1	2	—	4	12
Total	12	24	20	19	10	12	97

DCP Dry chemical powder.
FE Portable fire extinguisher.
HD Heavily damaged.
[1]Method used by welders to extinguish clothing and oxyfuel/grease fires.
[2]Usually due to failure of firefighting methods, late fire detection, undetected fires, or fire size.

Table 42.—Number of fires for surface stone mines by equipment involved and time period, 1990–2001

Equipment	Time period						
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	00-01 No. fires	1990-2001 No. fires
Mobile equipment[1]	2	5	5	7	3	7	29
Oxyfuel torch[2]	3	10	5	3	2	2	25
Heater/maintenance equipment/burner	4	4	6	4	4	1	23
Facilities[3]	2	3	1	1	—	—	7
Chemical/flammable liquid/gas tanks	—	—	1	1	1	—	3
Hopper/crusher/preheat system	—	—	—	2	1	—	3
Generator/product treatment pot	1	—	—	1	—	—	2
Beltlines	—	1	—	—	1	1	2
Electrical control system	—	—	1	—	—	1	2
Explosive device	—	1	—	—	—	—	1
Other	—	—	1	—	—	—	1
Total	12	24	20	19	10	12	97

[1]Includes dozers, loaders, trucks, drills, shovels, and tankers.
[2]At times, electrical arc welding equipment was used.
[3]Considered equipment in this report.

Table 43.—Number of fires for surface stone mines by location and time period, 1990–2001

Location	Time period						
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	00-01 No. fires	1990-2001 No. fires
Flame cutting/welding areas[1]	3	10	5	3	2	2	25
Maintenance/refuse areas	4	4	7	4	5	—	24
Mobile equipment working areas[2]	2	4	3	6	1	5	21
Facility/garage areas	2	3	1	—	—	3	9
Raw mill/preheat/silo/product treatment areas	1	—	2	1	1	—	5
Waste dump/pit/crusher/screen deck areas	—	2	—	1	—	1	4
Beltline/hopper areas	—	1	1	1	—	1	4
Chemical/flammable liquid storage areas	—	—	—	1	1	—	2
Electrical control/power house areas	—	—	1	1	—	—	2
Generator housing	—	—	—	1	—	—	1
Total	12	24	20	19	10	12	97

[1]Includes generator housing, chute, deck, bin feeder, crusher, hopper, shop, stampler breaker and screen shaft areas, and maintenance areas.
[2]Includes haulage, loading, mining, drilling, transportation, and crusher areas.

Table 44.—Number of fires for surface stone mines by burning material and time period, 1990–2001

Burning material	Time period						
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	00-01 No. fires	1990-2001 No. fires
Oxyfuel/clothing/grease/other[1]	3	10	5	3	2	2	25
Hazardous material/chemical/refuse/oil/ detonated explosive	4	5	5	3	4	—	21
Hydraulic fluid/fuel/oil	2	4	2	6	—	5	19
Flammable liquid/gas	1	1	4	1	3	—	10
Facility/content	2	3	1	—	—	1	7
Electrical wires/cables	—	—	2	4	—	1	7
Belt/hot material	—	1	1	1	1	1	5
Equipment mechanical components	—	—	—	1	—	1	2
Deck liner	—	—	—	—	—	1	1
Total	12	24	20	19	10	12	97

[1]Includes screen shaft, crusher and hopper, stampler breaker, chute liner, hydraulic fluid, rubber hoses, gear boxes, and bin feeder.

Table 45.—Number of fire injuries per number of fires causing injuries and total fires for surface stone mines by year, ignition source, equipment involved, and location, 1990–2001

Year	No. total fires	No. fires causing injuries	No. fire injuries	Ignition source	Equipment	Location
1990	6	4	2	Heat source	Heater	Refuse pile area.
			2	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
1991	6	5	2	Heat source	Heater	Maintenance area.
			1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
			1	Flammable gas explosion	Product treatment pot	Product treatment areas.
			1	Hydraulic fluid/fuel on equipment hot surfaces	Loader	Loading area.
1992	10	7	5	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
			1	Heat source	Heater	Maintenance area.
			1	Overheated oil	Air compressor	Drilling area.
1993[2]	14	12	5	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
			3	Heat source	Heater	Beltline/refuse pile areas.
			2	Hydraulic fluid/fuel on equipment hot surfaces	Truck/dozer	Crusher/mining areas.
			1	Refueling fuel on hot surfaces	Truck	Maintenance area.
1994	9	6	3	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
			2	Heat source	Heater	Maintenance area.
			1	Hydraulic fluid/fuel on equipment hot surfaces	Loader	Loading area.
1995	11	9	4	Heat source	Heater	Hopper belt/maintenance areas.
			2	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
			2	Flammable liquid on hot surfaces	Truck/loader	Maintenance area.
			1	Electrical short/arcing	Dozer cab	Mining area.
1996	12	9	2	Heat source	Heater	Maintenance area.
			2	Electrical short/arcing	Generator/truck	Generator housing/haulage area.
			1	Flame cutting/welding spark/slag	Oxyfuel torch	Flame cutting/welding areas.[1]
			3	Hydraulic fluid/fuel on equipment hot surfaces	Dozer/truck	Mining/haulage areas.
			1	Oil on hot surfaces	Truck	—
1997	7	6	1	Mechanical friction	Loader	Loading area.
			2	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
			2	Heat source	Heater	Maintenance/working areas.
			1	Hot material	Hopper belt	Hopper area.
1998	4	4	1	Heat source	Heater	Maintenance area.
			1	Flammable liquid on hot surfaces	Truck	Preheat tower.
			1	Hot material	Kiln	Kiln area.
			1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
1999	6	1	1	Fuel on hot surfaces	—	Storage shed.
2000	4	3	1	Hydraulic fluid/fuel on equipment hot surfaces	Truck	Haulage area.
			1	Flame cutting/welding spark/slag/flame	Shovel	Flame cutting/welding areas.[1]
			1	Electrical short/arcing	Loader	Loading area.
2001	8	2	1	Flame cutting/welding spark/slag/flame	Oxyfuel/torch	Flame cutting/welding areas.[1]
			1	Heat source	Gas heater	Screen deck.
Total	97	68	67			

[1]Includes crusher, ball chain, bin feeder, screen shaft, stamper breaker and beltline areas, and mobile equipment maintenance areas.
[2]In 1993, there was 1 fire fatality, which was caused by a hydraulic fluid/fuel fire involving a truck.

METAL/NONMETAL MILL FIRES

Table 46 and figure 16 show the number of fires and fire injuries for metal/nonmetal mills by state during 1990–2001. Table 46 also shows the injury risk rates, employees' working hours, and lost workdays. In all, 77 fires occurred in 26 states. Thirty-seven of the fires caused 41 injuries and 1 fatality (including 5 fires and 3 injuries involving contractors). The yearly average was 6.4 fires and 3.4 injuries. Fifty-four fires with 26 injuries and 1 fatality occurred at metal mills; 23 fires with 15 injuries occurred at nonmetal mills. The Ewhr value was 845×10^6 hr (Irr = 0.01), and the LWD value was 6,681.

Minnesota had the most fires (16 fires and 5 injuries), followed by Arizona (9 fires and 3 injuries), Wyoming (8 fires and 3 injuries), Nevada (7 fires, 4 injuries, and 1 fatality), and Texas (4 fires and 7 injuries). Of these states, Texas had the highest injury risk rate value (Irr = 0.033).

Table 47, partly illustrated in figure 17, shows the number of fires, fire injuries, fire fatalities, risk rates, employees' working hours, and lost workdays by time period. The number of fires increased slightly during the second period, then decreased during the remaining periods. The number of fire injuries show a decrease during most of the periods (an increase is seen during the third period), accompanied by a decline in employees' working hours during most of the periods. The Irr values follow patterns similar to those shown by the injury values.

Tables 48–53 show the number of fires by ignition source, method of detection and suppression, equipment involved, location, and burning material by time period. Figure 18 shows the major variables related to fires for 1990–2001. Table 54 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location.