flame cutting/welding areas, maintenance and fire training areas, and generator housing.

Nevada and Minnesota each had a fire fatality [MSHA 1995e, 2000e]. These were caused by hydraulic fluid/fuel fires involving a truck and a dozer, respectively. The victims were severely burned while exiting the cab.

SURFACE SAND AND GRAVEL MINE FIRES

Table 28 and figure 10 show the number of fires and fire injuries for surface sand and gravel mines by state during 1990–2001. Table 28 also shows the injury risk rates, employees' working hours, and lost workdays. At surface sand and gravel mines, a total of 70 fires with 60 injuries occurred in 29 states during 1990–2001. Fifty-nine of the fires caused 60 injuries (none of the fires involved contractors). The yearly average was 5.8 fires and five injuries. The Ewhr value was 741 × 10^6 hr (Irr = 0.016), and the LWD value was 6,921. California had the most fires (nine fires and five injuries), followed by Michigan (six fires and six injuries) and Pennsylvania (five fires and five injuries). Of these states, Pennsylvania had the highest injury risk rate value (Irr = 0.052).

Table 29, partly illustrated in figure 11, shows the number of fires, fire injuries, 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 the fourth period followed by a small increase during the fifth period and a sharp decrease during the last period. Employees' working hours increased during most of the periods. The Irr values follow patterns similar to those shown by the injury values.

Tables 30–35 show the number of fires by ignition source, method of detection and suppression, equipment involved, location, and burning material by time period. Figure 12 shows the major variables related to fires for 1990–2001. Table 36 shows the fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location.

Ignition Source

Table 30 shows the number of fires by ignition source for each time period. The leading source was flame cutting/welding spark/slag/flame (29 fires or 41%), followed by heat source/explosion (15 fires or 21%) involving pressurized cans and flammable liquids and by hydraulic fluid/fuel sprayed onto equipment hot surfaces (14 fires or 20%). Other ignition sources were flammable liquid/gas/refueling fuel on hot surfaces/collision (in one instance, the fuel ignited upon equipment collision) and electrical short/arcing/explosion (involving a pump). Two ignition sources were unknown. At least 5 of the 14 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 ground level, lack of an emergency 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. During all of the periods, the largest number of fires were caused by flame cutting/welding spark/slag/flame.

Table 29.—Number of fires, fire injuries, and risk rates for surface sand and gravel 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]	8	16	16	11	13	6	70
Number of fire injuries[1]	7	13	15	8	11	6	60
LWD[2]	73	193	218	6,089	234	114	6,921
Ewhr,[2] 10^6 hr	115	112	118	122	134	140	741
Irr[3]	0.012	0.023	0.025	0.013	0.016	0.009	[3]0.016

[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 30.—Number of fires for surface sand and gravel 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	4	6	6	5	5	3	29
Heat source/explosion[1]	2	3	5	2	1	2	15
Hydraulic fluid/fuel on equipment hot surfaces	—	5	4	2	2	1	14
Flammable liquid/gas/refueling fuel on hot surfaces/ equipment collision	2	2	—	1	1	—	6
Electrical short/arcing/explosion[2]	—	—	1	1	2	—	4
Unknown	—	—	—	—	2	—	2
Total	8	16	16	11	13	6	70

[1]Involving pressurized cans and flammable liquid.
[2]Involving a pump.

Table 31.—Number of fires for surface sand and gravel 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	3	3	4	4	21
Sparks	4	5	6	1	4	1	21
Smoke	—	3	4	3	—	1	11
Late smoke detection	1	2	—	3	2	—	8
Heard an explosion	1	—	2	—	1	—	4
Power loss	—	1	—	—	—	—	1
Undetected	—	—	1	1	2	—	4
Total	8	16	16	11	13	6	70

Table 32.—Number of fires for surface sand and gravel 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]	4	5	6	2	4	3	24
FE-DCP-foam-water	1	6	4	4	4	1	20
Water	1	4	5	3	1	2	16
FE	2	1	—	1	2	—	6
Destroyed/HD[2]	—	—	1	1	2	—	4
Total	8	16	16	11	13	6	70

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 33.—Number of fires for surface sand and gravel 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
Oxyfuel torch[1]	4	6	6	5	5	3	29
Mobile equipment[2]	2	5	5	2	3	1	18
Heater/burner	2	3	5	2	1	2	15
Generator/pump	—	—	—.	1	2	—	3
Maintenance equipment	—	2	—	1	—	—	3
Facility[3]	—	—	—	—	2	—	2
Total	8	16	16	11	13	6	70

[1]At times, electrical arc welding equipment was used.
[2]Includes trucks, loaders, scrapers, dredges, backhoes, and buckets.
[3]Considered equipment in this report.

Table 34.—Number of fires for surface sand and gravel mines by location and time period, 1990–2001

Location	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]	4	6	6	5	5	3	29
Maintenance areas	3	4	5	3	1	1	17
Mobile equipment working areas[2]	—	5	4	3	3	1	16
Generator/pump/electrical control areas	—	—	1	—	2	—	3
Facility area	—	—	—	—	2	—	2
Crusher/refuse areas	1	—	—	—	—	1	2
Beltline area	—	1	—	—	—	—	1
Total	8	16	16	11	13	6	70

[1]Includes beltline, water pipelines, chute, crusher, hopper and compactor areas, washer plants, and maintenance areas.
[2]Includes haulage, loading, mining, and dredging areas.

Table 35.—Number of fires for surface sand and gravel mines by burning material and time period, 1990–2001

Burning material	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]	4	6	6	5	5	3	29
Hydraulic fluid/fuel	—	5	4	2	2	1	14
Refuse/rubber tires	1	2	4	1	—	1	9
Flammable liquid/gas/refueling fuel	2	2	1	2	1	1	9
Electrical control wires/cables	—	—	1	1	2	—	4
Belt material/crusher	1	1	—	—	1	—	3
Facility/content	—	—	—	—	2	—	2
Total	8	16	16	11	13	6	70

[1]Includes chute liner, washer plant, flammable liquids, shaker deck, belt material, crusher and hopper, and equipment mechanical components.

Table 36.—Number of fire injuries per number of fires causing injuries and total fires for surface sand and gravel 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	4	3	1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.
			2	Refueling fuel on hot surfaces	Truck	Maintenance area.
1991	4	4	3	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.
			1	Heat source	Heater	Refuse area.
1992	9	6	2	Flammable liquid on hot surfaces	Maintenance equipment	Maintenance area.
			1	Heat source	Heater	Maintenance area.
			1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.
			2	Hydraulic fluid/fuel on equipment hot surfaces	Truck	Haulage area.
1993	7	7	4	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.
			1	Heat source	Heater	Beltline areas.
			2	Hydraulic fluid/fuel on equipment hot surfaces	Dredge-loader	Dredging/loading areas.
1994	8	7	3	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.
			3	Heat source-flammable liquid	Heater	Maintenance area.
			1	Electrical short/arcing	Electrical system	Electrical control area.
1995	8	8	3	Heat source	Heater	Maintenance area.
			3	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.
			2	Hydraulic fluid/fuel on equipment hot surfaces	Loader/scraper	Loading/mining areas.
1996	7	6	1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.
			2	Heat source	Heater	Maintenance area.
			1	Flammable liquid on hot surfaces	Maintenance equipment	Maintenance area.
			1	Hydraulic fluid/fuel on equipment hot surfaces	Loader	Loading area.
			1	Electrical short/arcing	Loader cab	Loading area.
1997	4	2	2	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.
1998	10	9	4	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.
			3	Electrical short/arcing	Pump/generator	Pump/generator housing.
			1	Heat source	Heater	Maintenance area.
			2	Hydraulic fluid/fuel on equipment hot surfaces	Truck/loader	Haulage/loading areas.
1999	3	1	1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.
2000	3	3	2	Heat source	Heater	Maintenance/refuse areas.
			1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.
2001	3	3	2	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.
			1	Hydraulic fluid/fuel	Loader	Loading area.
Total	70	59	60			

Method of Detection

Table 31 shows the number of fires by method of detection for each time period. The most frequent methods were welders who saw sparks and operators who saw the fires when they started as flames/flash fires. Other methods of detection were miners who heard an explosion and operators who experienced an equipment power loss. Four fires were undetected.

During the first period, the largest number of fires were detected by welders as sparks. During the second and fifth periods, the largest number of fires were detected by operators and welders as flames/flash fires and sparks. During the third period, the largest number of fires were detected by welders as sparks. During the fourth period, the largest number of fires were detected by operators as flames/flash fires and by miners as smoke shortly or long after the fires had started. During the sixth period, the largest number of fires were detected by operators as flames/flash fires.

Suppression Method

Table 32 shows the number of fires by suppression method for each time period. The most frequent methods were manual techniques with or without portable fire extinguishers, portable

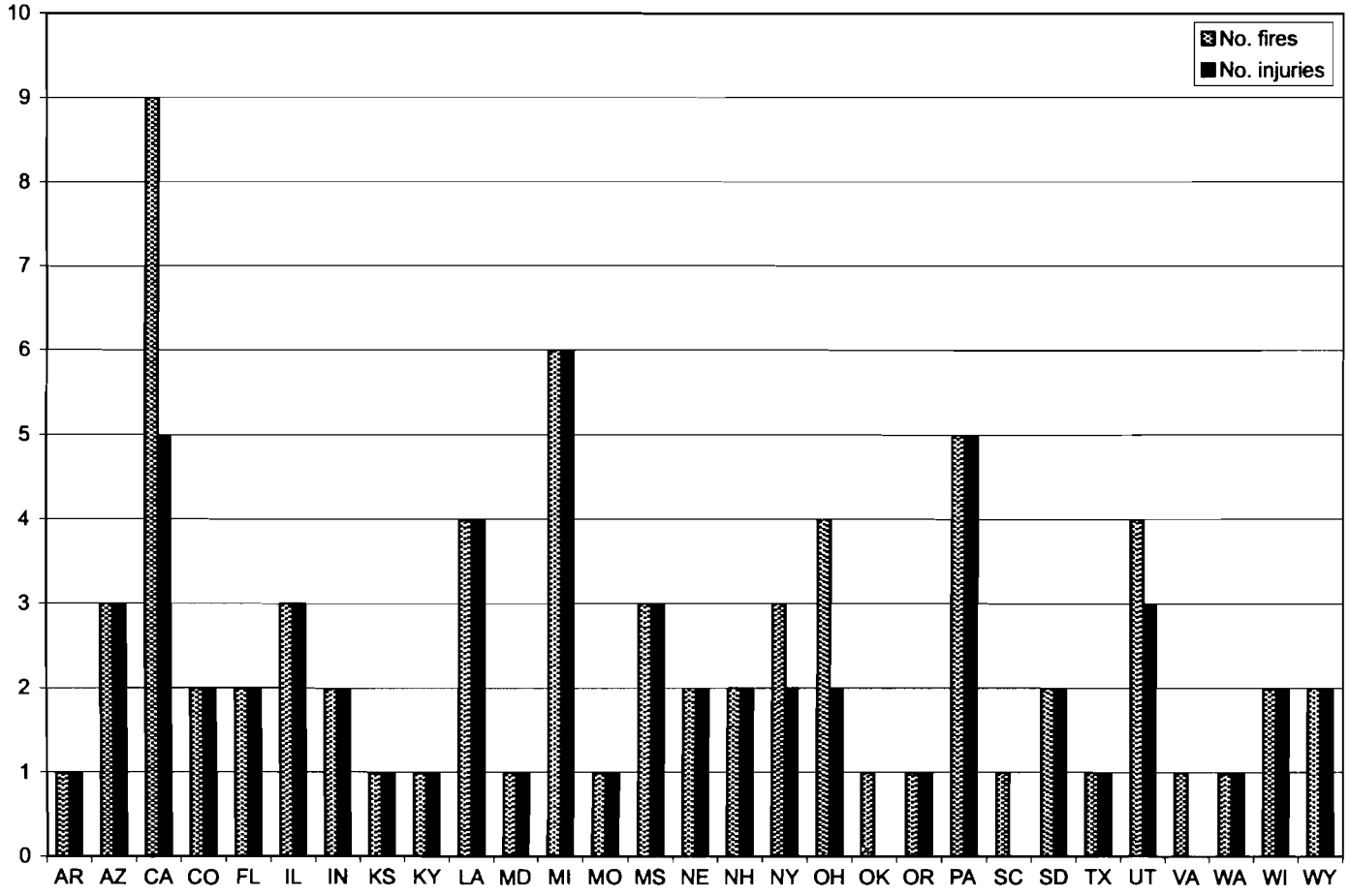

Figure 10.—Number of fires and fire injuries for surface sand and gravel mines by state, 1990–2001.

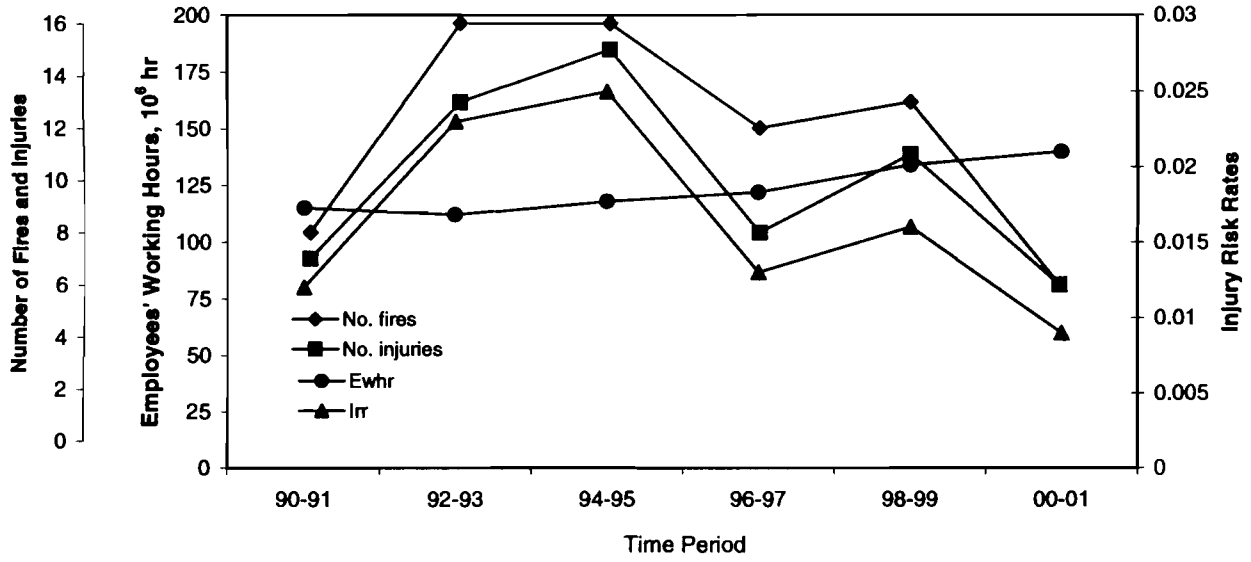

Figure 11.—Number of fires, fire injuries, risk rates, and employees' working hours for surface sand and gravel mines by time period, 1990–2001.

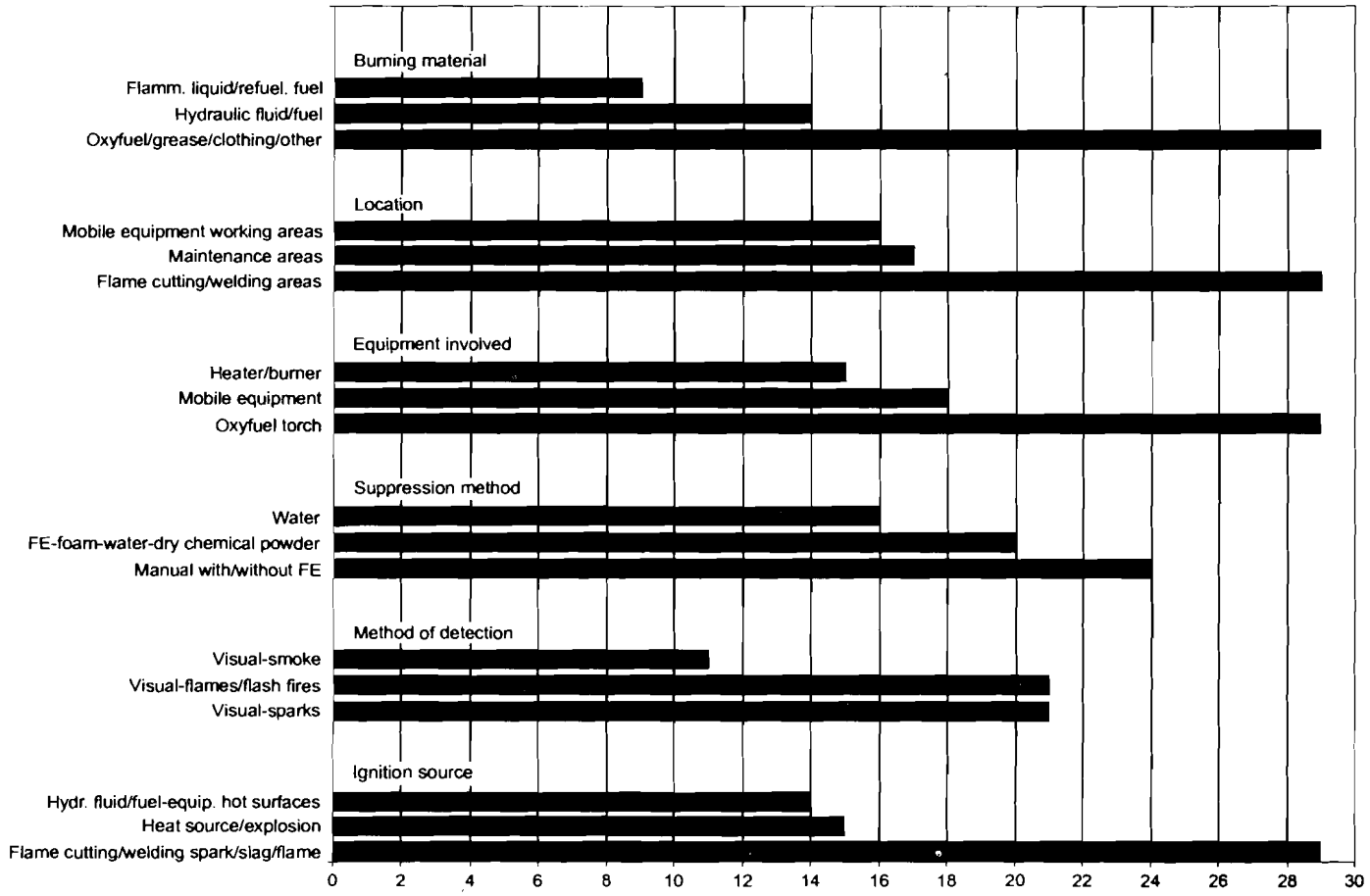

Figure 12.—Major variables for surface sand and gravel mine fires, 1990–2001. (FE = portable fire extinguisher)

fire extinguishers with dry chemical powder, foam and water, and water alone. Portable fire extinguishers alone were also used to suppress the fires. None of the equipment involved in fires had machine fire suppression systems. On at least three occasions, including one mobile equipment fire, fire brigades and fire departments fought the fires with foam, dry chemical powder, and water. However, in four instances the fires destroyed or heavily damaged equipment (including two pieces of mobile equipment) because of failure of other firefighting methods, late fire detection, undetected fires, or fire size.

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

Equipment Involved

Table 33 shows the number of fires by equipment involved for each time period. The equipment most often involved was oxyfuel torches (at times electrical arc welding equipment was used), followed by mobile equipment (loaders, trucks, scrapers, dredges, backhoes, and buckets) and heaters/burners. Other equipment included maintenance equipment, generators and pumps, and facilities (considered equipment in this report). During all of the periods, the largest number of fires involved oxyfuel torches.

Location

Table 34 shows the number of fires by location for each time period. The most common locations were flame cutting/welding areas (at beltline, pipeline, chute, crusher, hopper, and compactor areas, washer plants, and maintenance areas), followed by maintenance areas and mobile equipment working areas (loading, haulage, mining, and dredging areas). Other fire locations included generator and pump housing, electrical control areas, facility areas, crusher and refuse areas, and beltline areas. During all of the periods, the largest number of fires occurred at flame cutting/welding areas.

Burning Materials

Table 35 shows the number of fires by burning material for each time period. The materials most often involved were oxyfuel/clothing/grease and other materials (including chute liner, washer plant, flammable liquids, equipment mechanical components, shaker deck, crusher and hopper, and belt material).

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