water, compaction, and removal (method used to extinguish spontaneous combustion/hot coal fires). Other fire suppression methods were portable fire extinguishers alone and foam and water.

Two pieces of mobile equipment involved in fires had machine fire suppression systems. Dual activation (one activation) of machine fire suppression and engine shutoff systems failed to temporarily abate the flames because of the flow of pressurized fluids entrapped in the lines (not affected by the engine shutoff operation). Most of the hydraulic fluid/fuel fires became large fires. In at least three instances these fires required fire department interventions because of the continuous flow of fluid/fuel from the pumps due to engine shutoff failure, lack of an emergency hydraulic line drainage system, difficulty in activating available emergency systems at ground level, or lack of effective and rapid local firefighting response capabilities. (Fire-resistant hydraulic fluid is not required for equipment use at surface coal operations.)

Fire brigades and fire departments (required in six instances) fought three mobile equipment fires and other large fires with foam, dry chemical powder, and water. However, 20 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.

The largest number of fires were suppressed with portable fire extinguishers, foam, dry chemical powder, and water throughout the periods (table 14).

Equipment Involved

Table 15 shows the number of fires by equipment involved and time period. The equipment most often involved included mobile equipment (hoists, dozers, loaders, scrapers, trucks, highlifts, excavators, and tractors) and oxyfuel torches. Other equipment included heaters and maintenance equipment, beltlines, drives and pulleys, maintenance equipment, electrical systems, power units, and pumps.

During the first period, the largest number of fires involved mobile equipment. During subsequent periods, the largest number of fires involved facilities (see table 15).

Location

Table 16 shows the number of fires by location and time period. The most common locations were facilities and mobile equipment working areas (e.g., loading, hoisting, and haulage areas). These were followed by flame cutting/welding areas (at beltline areas, storage silos, and mobile equipment maintenance areas) and maintenance areas. Other fire locations were coal silos, stock and refuse pile areas, beltline and drawoff tunnel areas, and power and charging stations.

During the first period, the largest number of fires occurred at mobile equipment working areas. During subsequent periods, the largest number of fires occurred at facility areas (see table 16).

Burning Materials

Table 17 shows the number of fires by burning material and time period. The materials most often involved were pump housing and facilities/content, followed by hydraulic fluid/fuel, coal and methane, and belts, drives, and pulleys. Other burning materials were flammable liquids, electrical systems, wires and batteries, wood ties, refuse piles, electrical insulation, and oxyfuel/grease/clothing. During the first period, the largest number of fires involved hydraulic fluid/fuel and facility/content materials. During subsequent periods, the largest number of fires involved facility/content materials (see table 17).

Fire Injuries

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 during 1990–1999. Overall, 13 fires caused 12 injuries and 1 fatality.

The greatest number of fire injuries occurred in 1995 (three injuries caused by three fires). The sources that caused most of the fire injuries were flame cutting/welding spark/slag/flames, heat sources and pressurized can explosions, and hydraulic fluid/fuel sprayed onto equipment hot surfaces. Other ignition sources were an electrical short/arcing/battery explosion and a source used to light a training fire. The equipment most often involved included oxyfuel torches, heaters, mobile equipment, batteries, and turnout gear. The locations where most of the fire injuries occurred were flame cutting/welding, maintenance, and mobile equipment working areas. Other fire locations were charging stations and fire training areas.

The fire fatality in West Virginia in 1991 may actually have been caused by cardiac failure, although the victim's body was found among the burnt office rubble [MSHA 1991c].

SURFACE COAL MINE FIRES

Table 19 and figure 7 show the number of fires and fire injuries for surface coal mines by state during 1990–1999. Table 19 also shows by state the risk rates, employees' working hours, lost workdays, and coal production.

For surface coal mines, 215 fires occurred in 21 states during 1990–1999. Ninety-four of those fires caused 93 injuries and 1 fatality (the yearly average was 21.5 fires and 9.3 fire injuries). Fourteen fires and seven injuries involved contractors. The Ewhr value was 729×10^6 hr (Irr = 0.026), the CP value was $6{,}355 \times 10^6$ st (Frr = 0.034), and the LWD value was 8,141.

Kentucky had the most fires and fire injuries (45 fires and 23 injuries), followed by Pennsylvania (33 fires and 14 injuries), West Virginia (25 fires and 14 injuries), and Indiana (20 fires and 8 injuries). Among these states, Pennsylvania had the highest fire risk rate value (Frr = 0.145), while Kentucky had the highest injury risk rate value (Irr = 0.041).

Table 20, partly illustrated in figure 8, shows by time period the number of fires, fire injuries, fire fatalities, risk rates, employees' working hours, lost workdays, and coal production. There was a decrease in fires and fire injuries during most of the periods (an increase is seen only during 1994–1995), accompanied by a decline in employees' working hours throughout the periods and an increase in coal production during most of the periods. The Irr and Frr values follow patterns similar to those shown by the injury and fire values (see table 20 and figure 8).

Tables 21–26 show the number of fires by ignition source, method of detection and suppression, equipment involved, location, and burning material by time period. Figure 9 shows the major variables during 1990–1999. Table 27 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location.

Table 19.—Number of fires, fire injuries, and risk rates for surface coal mines by state, employees' working hours, lost workdays, and coal production, 1990–1999

State[1]	No. fires[1]	No. injuries[1]	LWD[2]	Ewhr,[2] 10^6 hr	CP,[2] 10^6 st	Frr[3]	Irr[3]
Alabama	5	4	176	24.8	80	0.063	0.032
Arizona	3	1	17	16.1	120.7	0.025	0.012
Colorado	2	—	—	11.6	91	0.022	—
Illinois	6	4	44	24.2	94	0.064	0.033
Indiana	20	8	430	53.7	280	0.071	0.03
Kansas	1	—	—	1.3	3.5	0.286	—
Kentucky	45	23	527	112.1	602.5	0.075	0.041
Louisiana	3	2	—	2.5	31.8	0.094	0.16
Missouri	3	2	41	4.8	11.4	0.263	0.083
Montana[4]	4	—	6,000	16	392.8	0.01	—
New Mexico	6	1	37	30	246.5	0.034	0.007
Ohio	11	6	8	40.3	168.1	0.065	0.03
Oklahoma	1	1	11	6.2	15.6	0.064	0.032
Pennsylvania	33	14	501	72.5	228.3	0.145	0.039
Tennessee	1	1	17	4.6	15	0.067	0.044
Texas	13	6	17	60.1	529.6	0.025	0.02
Utah	1	—	—	0.2	2.6	0.39	—
Virginia	6	3	79	22.7	88.4	0.068	0.026
Washington	1	—	—	10.4	47	0.021	—
West Virginia	25	14	182	92.7	536.6	0.047	0.03
Wyoming	25	3	54	62.7	2,454.1	0.01	0.01
Other states	—	—	—	60	394.5	—	—
Total	215	93	8,141	729	6,355	[3]0.034	[3]0.026

[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 USBM and MSHA formulas reported in the "Methodologies" section.
[4]Montana had one fire fatality.

Table 20.—Number of fires, fire injuries, fire fatalities, and risk rates for surface coal mines by time period, employees' working hours, lost workdays, and coal production, 1990–1999

	Time period					
	90-91	92-93	94-95	96-97	98-99	90-99
Number of fires[1]	67	37	47	40	24	215
Number of fire injuries[1]	32	17	19	16	9	93
Number of fire fatalities	1	—	—	—	—	1
LWD[2]	6,610	646	284	327	274	8,141
Ewhr,[2] 10^6 hr	177	154	143	131	124	729
CP,[2] 10^6 st	1,180	1,176	1,267	1,325	1,408	6,355
Frr[3]	0.057	0.032	0.037	0.03	0.017	[3]0.034
Irr[3]	0.036	0.022	0.026	0.024	0.015	[3]0.026

[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 USBM and MSHA formulas reported in the "Methodologies" section.

Table 21.—Number of fires for surface coal mines by ignition source and time period, 1990–1999

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
Heat source	5	—	2	1	2	10
Flammable liquid/refueling fuel on hot surfaces	5	3	2	6	2	18
Flame cutting/welding spark/slag/flame[1]	20	12	14	7	6	59
Spontaneous combustion/hot coal	4	1	7	6	3	21
Conveyor belt friction	—	—	2	1	—	3
Hydraulic fluid/fuel on equipment hot surfaces	24	15	18	13	6	76
Engine/mechanical malfunction/friction/explosion.	5	4	—	1	1	11
Overheated oil	1	—	1	1	1	4
Electrical short/arcing	1	2	—	3	2	8
Natural gas explosion	1	—	—	—	1	2
Unknown	1	—	1	1	—	3
Total	67	37	47	40	24	215

[1]This source caused fires usually involving welders' clothing or oxyfuel/grease. However, on four occasions undetected hot slag caused coal and belt fires. In another instance, undetected hot slag caused a coal chute smoldering fire, which, upon water application, produced a flashback accompanied by a gas explosion, resulting in one fatality.

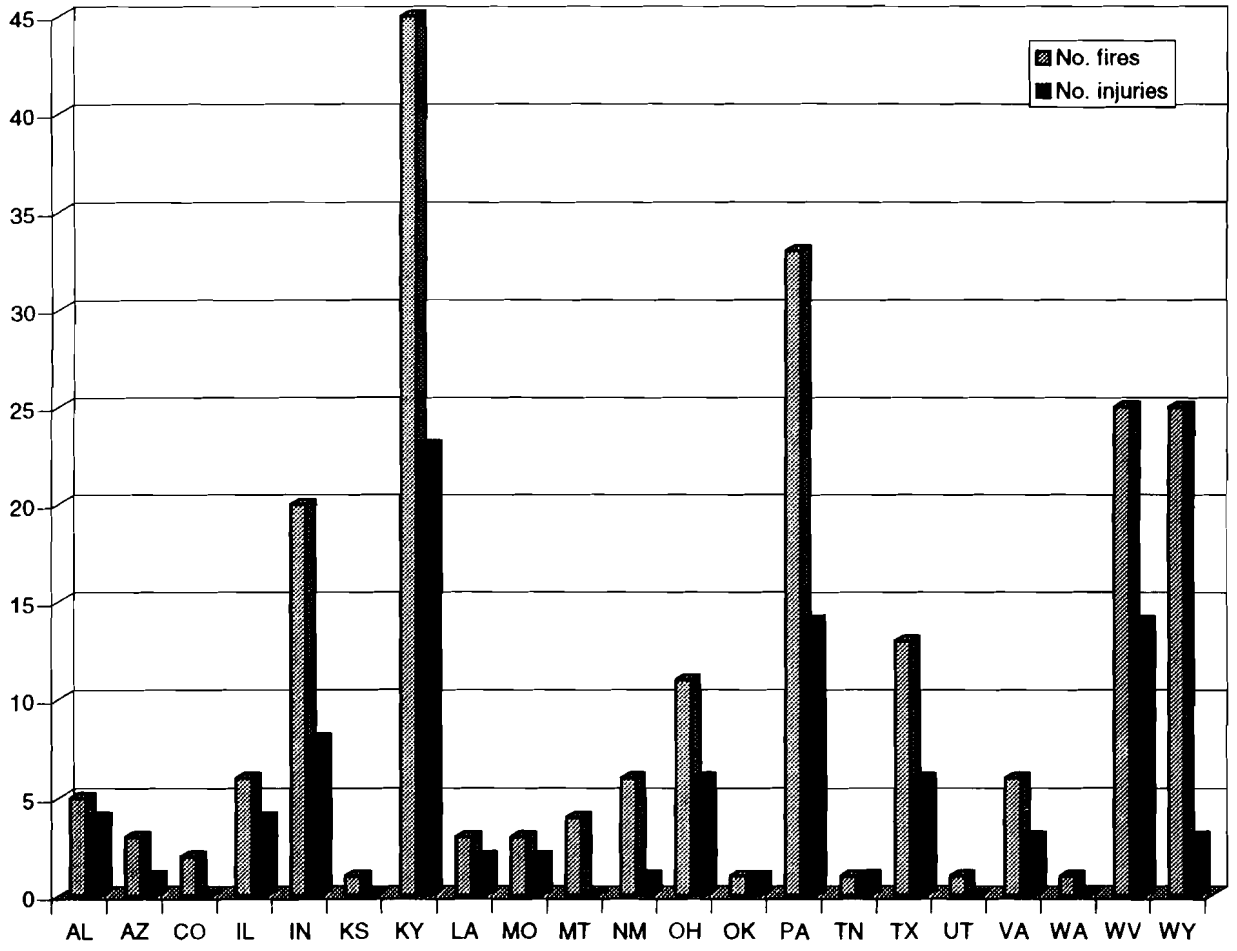

Figure 7.—Number of fires and fire injuries for surface coal mines by state, 1990–1999.

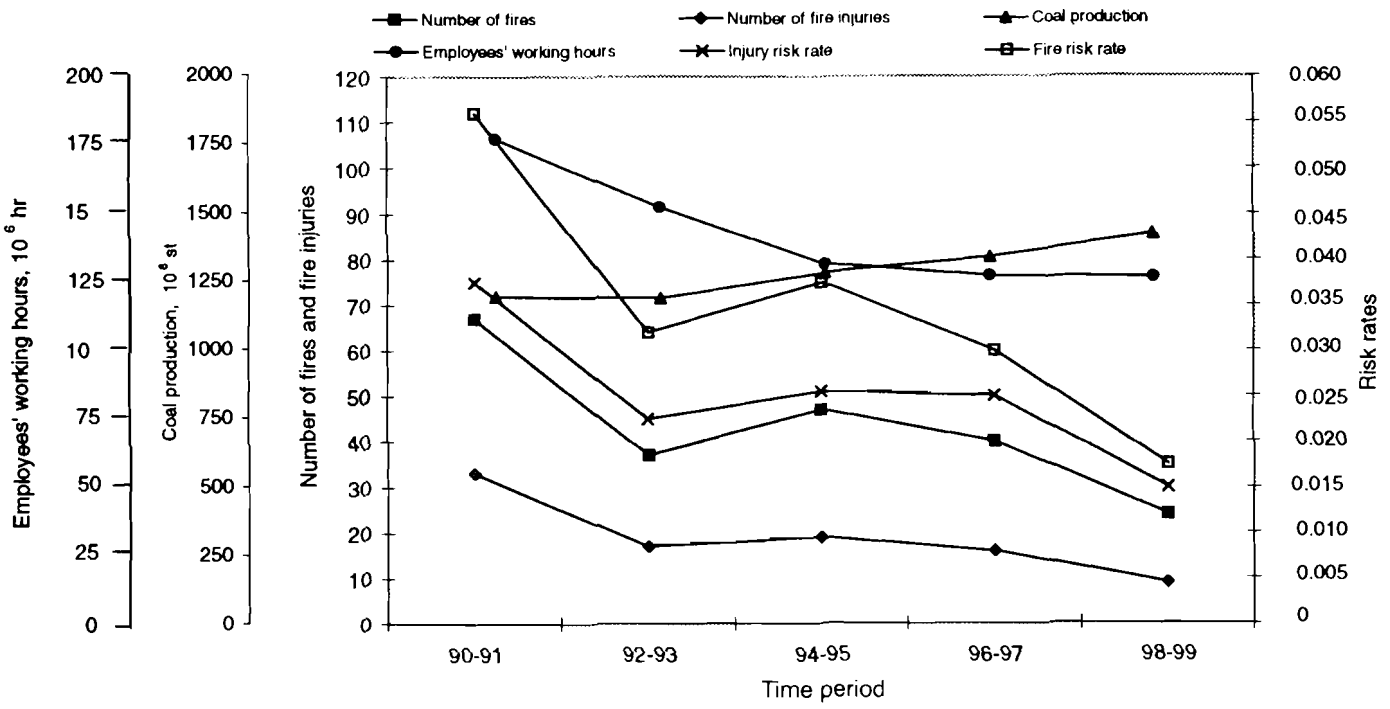

Figure 8.—Number of fires, fire injuries, risk rates, and coal production for surface coal mines by time period and employees' working hours, 1990–1999.

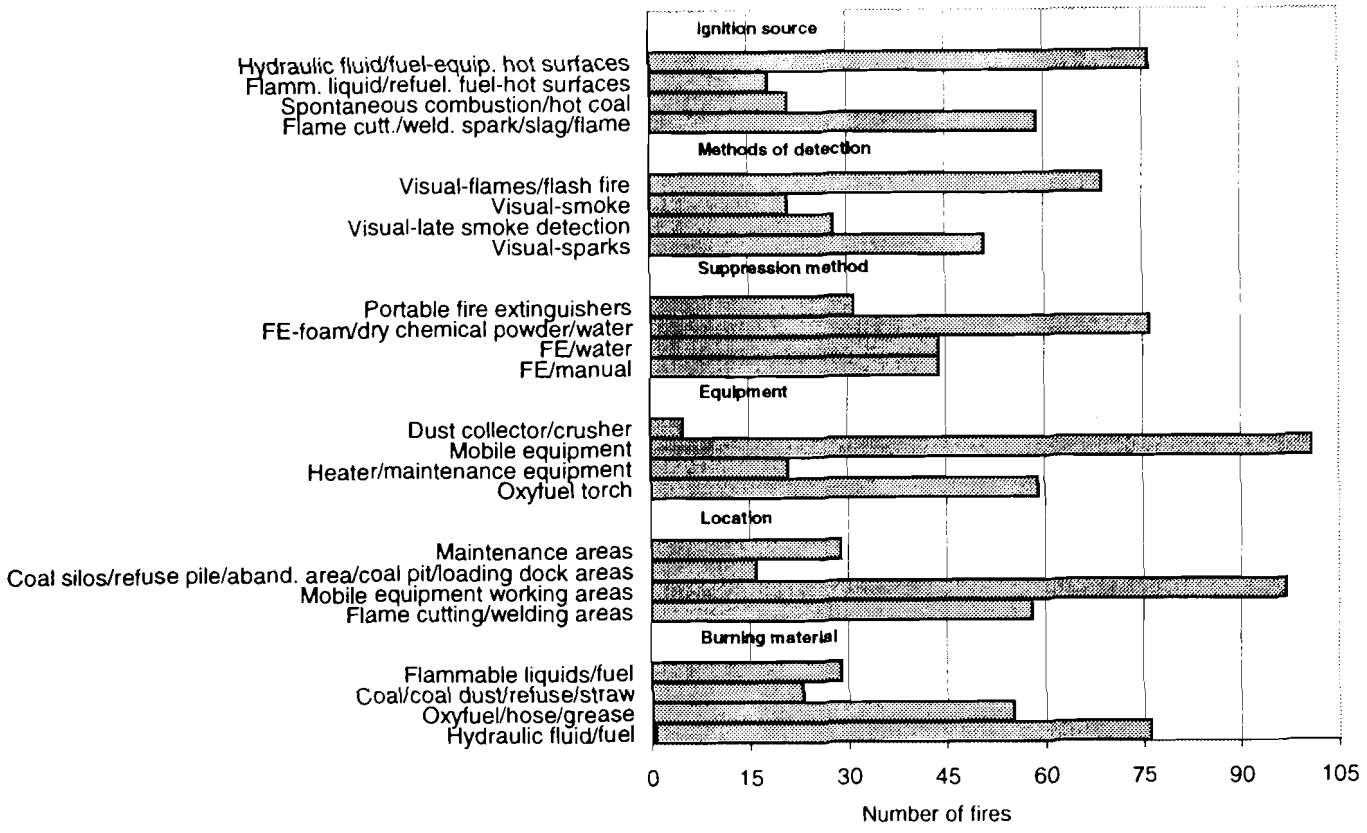

Figure 9.—Major variables for surface coal mine fires, 1990–1999. (FE = portable fire extinguisher)

Table 22.—Number of fires for surface coal mines by method of detection and time period, 1990–1999

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
Visual method:						
Flames/flash fires	22	9	17	14	7	69
Smoke	4	8	—	5	4	21
Smoldering	1	—	—	—	—	1
Late smoke detection	6	2	7	9	4	28
Glow	—	—	1	—	—	1
Sparks	20	8	11	7	5	51
Electrical/mechanical sparks	1	5	—	—	1	7
Radiator smoke/oil mist spray	1	—	—	1	—	2
Undetected	4	2	4	2	1	13
Fire alarm/electrical trip warning	1	—	—	1	—	2
Smelled smoke	—	1	2	—	—	3
Explosion	5	—	2	—	1	8
Power loss	—	1	—	—	1	2
Popping sound	2	1	3	1	—	7
Total	67	37	47	40	24	215

Table 23.—Number of fires for surface coal mines by suppression method and time period, 1990–1999

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
Manual/FE[1]	16	7	10	7	4	44
Portable fire extinguisher	8	8	1	10	4	31
FE-water	15	3	15	5	6	44
FE-water/foam/dry chemical power	23	15	18	15	5	76
Coal spread-water-compaction-removal[2]	—	—	—	2	—	2
FSS-dry chemical powder-water	2	—	—	1	2	5
Destroyed/heavily damaged[3]	3	4	3	—	3	13
Total	67	37	47	40	24	215

FE Portable fire extinguisher
FSS Machine fire suppression system
[1]Methods used by welders to extinguish clothing or oxyfuel/grease fires.
[2]Methods used to extinguish spontaneous combustion/hot coal fires.
[3]Due to failure of other firefighting methods, late fire detection, or undetected fires.

Table 24.—Number of fires for surface coal mines by equipment involved and time period, 1990–1999

Equipment	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
Air compressor	2	—	—	—	—	2
Oxyfuel torch	20	12	14	7	6	59
Heater/maintenance equipment	8	1	5	3	4	21
Beltline/drive/pulley	—	—	2	1	—	3
Crusher/dust collector	1	—	2	2	—	5
Facility	1	—	1	1	—	3
Other/unknown	4	2	5	6	4	21
Mobile equipment[1]	31	22	18	20	10	101
Total	67	37	47	40	24	215

[1]Includes haulage/utility trucks, loaders, dozers, drills, shovels, backhoes, buckets, excavators, scrapers, auger/miners, and excavators.

Table 25.—Number of fires for surface coal mines by location and time period, 1990–1999

Location	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
Flame cutting/welding areas[1]	21	12	13	7	5	58
Coal silos/loading dock/refuse pile/abandoned coal pit areas	1	2	6	4	3	16
Beltline area	1	—	2	2	—	5
Dust collector/baghouse/crusher areas	2	—	2	2	—	6
Facility	1	—	1	1	1	4
Maintenance areas	11	3	5	6	4	29
Mobile equipment working areas[2]	30	20	18	18	11	97
Total	67	37	47	40	24	215

[1]Includes coal chute, beltline, bucket/transfer house, shaft, dust collector and coal chute areas, and mobile equipment maintenance areas.
[2]Includes mining, haulage, loading, and drilling areas.

Table 26.—Number of fires for surface coal mines by burning material and time period, 1990–1999

Burning material	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
Oxyfuel/hose/grease/clothing	20	9	13	8	5	55
Coal/coal dust/straw/refuse	5	2	7	4	5	23
Crusher/dust collector/furnace/baghouse	3	—	1	2	—	6
Belt/idler/pulleys	1	—	2	2	—	5
Facility/content	1	—	1	1	—	3
Flammable liquid/refuel fuel	9	4	4	7	5	29
Hydraulic fluid/fuel	23	16	19	12	6	76
Electrical system/batteries/collector ring/breaker	2	5	—	4	1	12
Air compressor/transmission oil	2	1	—	—	1	4
Natural gas/chemicals	1	—	—	—	1	2
Total	67	37	47	40	24	215

Table 27.—Number of fire injuries per number of fires causing injuries and total fires at surface 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	11	38	11	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
	3		3	Heat source-flammable liquid	Heater/air compressor	Refuse/maintenance areas.
	1		1	Mechanical friction	Mobile equipment[2]	Drilling area.
	3		3	Hydraulic fluid/fuel on equipment hot surfaces	Mobile equipment[2]	Haulage area.
	1		1	Flammable liquid on hot surfaces	Mobile equipment[2]	Maintenance area.
1991[3]	4	29	4	Heat source-flammable liquid	Heater/furnace	Furnace room/maintenance area.
	6		5	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas/ coal chute areas.[1]
	4		4	Hydraulic fluid/fuel on equipment hot surfaces	Mobile equipment[2]	Loading/haulage/ drilling/ mining areas.
1992	5	20	5	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
	3		3	Hydraulic fluid/fuel on equipment hot surfaces	Mobile equipment[2]	Drilling/mining areas.
	1		1	Flammable liquid on hot surfaces	Mobile equipment[2]	Maintenance area.
1993	4	17	4	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
	1		1	Heat source-flammable liquid	Heater	Maintenance area.
	1		1	Engine malfunction	Mobile equipment[2]	Maintenance area.
	2		2	Hydraulic fluid/fuel on equipment hot surfaces	Mobile equipment[2]	Haulage area.
1994	4	27	4	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
	2		2	Heat source-flammable liquid	Heater/maintenance equipment.	Maintenance area.
	1		1	Conveyor belt friction	Beltline	Beltline area.
	2		2	Hydraulic fluid/fuel on equipment hot surfaces	Mobile equipment[2]	Mining area.
1995	2	20	2	Heat source-flammable liquid	Heater	Refuse area.
	4		4	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
	4		4	Hydraulic fluid/fuel on equipment hot surfaces	Mobile equipment[2]	Drilling/haulage/mining areas.
1996	3	20	3	Hydraulic fluid/fuel on equipment hot surfaces	Mobile equipment[2]	Loading/hopper areas.
	1		1	Engine malfunction	Mobile equipment[2]	Haulage areas.
	3		3	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
	2		2	Heat source-refueling fuel	Heater	Maintenance area.
1997	1	20	1	Heat source-flammable liquid	Heater	Maintenance area.
	2		2	Flammable liquid on hot surfaces	Mobile equipment[2]	Maintenance area.
	4		4	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
1998	3	13	3	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
	1		1	Flammable liquid on hot surfaces	Heater	Maintenance area.
	1		1	Hydraulic fluid/fuel on equipment hot surfaces	Mobile equipment[2]	Haulage area.
	1		1	Gas explosion	Mobile equipment[2]	Mining area.
1999	2	11	2	Flammable liquid on hot surfaces	Heater	Maintenance area.
	1		1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
Total	94	215	94			

[1]Includes beltline area, bucket and transfer houses, coal chute and dust collector areas, and mobile equipment maintenance areas.
[2]Includes trucks, dozers, loaders, drills, shovels, and buckets.
[3]During 1991, there was 1 fire fatality.

Ignition Source

The number of fires and fire injuries by ignition source and time period is shown in tables 21 and 27. The leading sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces (76 fires or 35% with 22 injuries), followed by flame cutting/welding spark/slag/flames (59 fires or 27% with 44 injuries), spontaneous combustion/hot coal (21 fires or 10%), and flammable liquid/refueling fuel on hot surfaces (18 fires or 8% with 7 injuries). Other ignition sources were engine/mechanical malfunctions/friction/explosions (11 fires), heat sources (10 fires), electrical short/arcing (8 fires), overheated oil (4 fires), conveyor belt friction (3 fires), and natural gas explosions (2 fires). Three ignition sources were unknown. The flame cutting/welding spark/slag/flame ignition source caused fires usually involving welders' clothing or oxyfuel/grease (grease embedded in the equipment's mechanical components). However, in four instances undetected hot slag caused coal belt ignitions. In another instance, undetected hot slag caused a coal chute smoldering fire, which, upon application of water, produced a flashback accompanied by a gas explosion (causing one fatality).

Forty-two of the mobile equipment hydraulic fluid/fuel fires became large fires, which at times required fire brigades and fire department interventions. On at least five occasions, the cab was suddenly engulfed in flames, forcing the operators to exit under hazardous conditions, probably due to the ignition of flammable vapors and mists that penetrated the cab. Of note is that most of the hydraulic fluid/fuel fires were caused when hydraulic fluids sprayed onto equipment hot surfaces; subsequently, these fires involved the fuel lines.

During the first through fourth periods, the largest number of fires were caused by hydraulic fluid/fuel sprayed onto equipment hot surfaces. During the fifth period, the largest number of fires were caused by hydraulic fluid/fuel sprayed onto equipment hot surfaces and flame cutting/welding spark/slag/flame sources (see table 21).

Method of Detection

Table 22 shows the number of fires by method of detection and time period. The most frequent methods were operators who saw the fires when they started as flames/flash fires, welders who saw sparks, miners who saw smoke long after the fires had started, and miners who saw smoke shortly after the fires had started. Thirteen fires were undetected. Other methods of detection were miners who heard an explosion, operators who heard a popping sound, miners who saw electrical/mechanical sparks or smelled smoke, operators who saw radiator white smoke/oil mist spray or experienced power loss, and miners who heard an electrical trip warning or fire alarm. The largest number of fires were detected by flames/flash fires throughout the periods (table 22).

Suppression Method

Table 23 shows the number of fires by suppression method and time period. The most common methods were portable fire extinguishers, foam, dry chemical powder, and water. These were followed by manual methods with or without portable fire extinguishers and water or portable fire extinguishers alone. Five pieces of mobile equipment involved in fires had machine fire suppression systems. Dual activation (three activations) of machine fire suppression and engine shutoff systems succeeded in temporarily abating the fires. However, the flames reignited, fueled by the flow of pressurized fluids entrapped in the lines (not affected by the engine shutoff operation), which hindered the operators' safe escape. Most of the mobile equipment hydraulic fluid/fuel fires became large fires, which required at least 15 fire brigade and fire department interventions because of the continuous flow of fluid/fuel from the pumps due to engine shutoff failure, lack of an emergency hydraulic line drainage system, difficulty in activating available emergency systems at ground level, or lack of effective and rapid local firefighting capabilities. (Fire-resistant hydraulic fluid is not required for equipment use at surface coal operations.) Other methods included coal spread, water, compaction, and removal. Fire brigades and fire departments, which were required in at least 26 instances, fought the mobile equipment fires and other large fires with foam, dry chemical powder, and water. However, 13 fires destroyed or heavily damaged equipment (including six pieces of mobile equipment) because of failure of other firefighting methods, late fire detection, undetected fires, or fire size.

During the first through fourth periods, the largest number of fires were suppressed with portable fire extinguishers, foam, dry chemical powder, and water. During the fifth period, the largest number of fires were suppressed with portable fire extinguishers and water (see table 23).

Equipment Involved

Table 24 shows the number of fires by equipment involved and time period. The equipment most often involved was mobile equipment (trucks, dozers, loaders, drills, shovels, backhoes, buckets, scrapers, excavators, and augers). This was followed by oxyfuel torches, heaters, and maintenance equipment. Other equipment included crushers and dust collectors; beltlines, drives, and pulleys; facilities; and air compressors. The largest number of fires involved mobile equipment throughout the periods (table 24).

Location

Table 25 shows the number of fires by location and time period. The most common locations were mobile equipment working areas (mining, haulage, loading, and drilling areas). These were followed by flame cutting/welding areas (at beltline

areas, shaft, coal chute and dust collector areas, bucket and transfer houses, and mobile equipment maintenance areas) and maintenance areas. Other fire locations included coal silos, loading docks, refuse piles, abandoned and coal pit areas, dust collectors, baghouses, crushers and beltline areas, and facilities. The largest number of fires throughout the periods occurred at mobile equipment working areas (table 25).

Burning Materials

Table 26 shows the number of fires by burning material and time period. The material most often involved was hydraulic fluid/fuel, followed by oxyfuel/grease/clothing, flammable liquids, coal and coal dust, and straw and refuse. Other burning materials included electrical systems, batteries, collector rings and breakers, dust collectors, baghouses, and furnaces. Belts, idlers and pulleys, air compressors, transmission oil, facilities and contents, and natural gas and chemicals also burned during fires. The largest number of fires involved hydraulic fluid/fuel throughout the periods (table 26).

Fire Injuries

Table 27 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location during 1990–1999. Overall, there were 93 injuries and 1 fatality caused by 94 fires.

The greatest number of fire injuries occurred in 1990 (19 injuries caused by 19 fires) and 1991 (13 injuries and 1 fatality caused by 14 fires). The ignition sources that caused most of the fire injuries were flame cutting/welding spark/slag/flames and hydraulic fluid/fuel sprayed onto equipment hot surfaces. These were followed by flammable liquid on hot surfaces and by heat sources and pressurized can explosions. Other ignition sources were engine/mechanical malfunctions/friction and conveyor belt friction. The equipment most often involved included oxyfuel torches, mobile equipment, heaters, maintenance equipment, dust collectors and samplers, and beltlines. The locations where most of the fire injuries occurred were flame cutting/welding and mobile equipment working areas. Other fire locations were maintenance, dust collector, and beltline areas.

The fire fatality in Montana in 1991 was caused by a flashback accompanied by a gas explosion that engulfed the mechanic who was hosing down a coal chute smoldering fire. The smoldering of coal was due to undetected hot slag produced during flame cutting/welding operations [MSHA 1991b].

COAL PREPARATION PLANT FIRES

Table 28 and figure 10 show the number of fires and fire injuries for coal preparation plants by state during 1990–1999. Table 28 also shows the risk rates, employees' working hours, and lost workdays by state. For coal preparation plants, 91 fires occurred in 11 states during 1990–1999. Twenty-three of those fires caused 25 injuries (the yearly average was 9.1 fires and 2.5 injuries). Ten fires and eight injuries involved contractors. The Ewhr value was 241 × 10^6 hr (Irr = 0.021), and the LWD value was 198.

Pennsylvania had the most fires (24 fires and 4 injuries), whereas West Virginia (22 fires and 7 injuries) and Kentucky (22 fires and 7 injuries) had the most fire injuries. Among these states, Kentucky had the highest injury risk rate value (Irr = 0.025).

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 decreased during most of the periods (an increase is seen only during the last period). The number of fire injuries show a decrease followed by an increase during the periods, accompanied by a decline in employees' working hours throughout the periods. The Irr values follow patterns similar to those shown by the injury values (see table 29 and figure 11).

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 during 1990–1999. 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

The number of fires and fire injuries by ignition source and time period is show in tables 30 and 36. The leading source was spontaneous combustion/hot coal (24 fires or 26%). This was followed by flame cutting/welding spark/slag/flames (15 fires or 17% with 8 injuries), hydraulic fluid/fuel sprayed onto equipment hot surfaces (10 fires or 11% with 6 injuries), and conveyor belt friction (9 fires or 10% with 1 injury). The flame cutting/welding spark/slag/flame ignition source caused fires usually involving welders' clothing or oxyfuel/grease (grease embedded in the equipment's mechanical components). However, in one instance undetected hot slag caused a storage facility fire. Other ignition sources were electrical short/arcing (nine fires), flammable liquid/refueling fuel on hot surfaces (six fires), engine/mechanical malfunctions/friction (three fires), overheated oil (two fires), and a chemical explosion (one fire). Eight ignition sources were unknown. The spontaneous combustion/hot coal fires were detected long after the fires had started due to lack of continuous and early combustion gas/smoke detection systems. Two of the mobile equipment hydraulic fluid/fuel fires became large fires, which at times required fire brigade and fire department interventions. In two instances the cab was suddenly engulfed in flames, forcing the operators to exit under hazardous conditions, probably due to the ignition of flammable vapors and mists that penetrated the cab. Of note is that most of the hydraulic fluid/fuel fires were caused when hydraulic fluids sprayed onto equipment hot surfaces; subsequently, these fires involved the fuel lines.

During the first, third, fourth, and fifth periods, the largest number of fires were caused by spontaneous combustion/hot coal. During the second period, the largest number of fires were caused by spontaneous combustion/hot coal and by flame cutting/welding spark/slag/flames (see table 30).