Table 61.—Number of fires for stone mills 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]	14	13	6	14	2	4	53
Kiln/chute/hopper/silo areas	—	3	6	1	1	5	16
Mobile equipment working areas[2]	4	—	3	3	1	1	12
Beltline areas	—	2	1	2	3	2	10
Maintenance areas/pump station	3	3	1	—	—	1	8
Preheat/cooling areas/bagging station/pit/bin/waste fuel areas	—	2	2	1	1	1	7
Electrical control room/shop/substation	4	—	1	—	1	—	6
Dust collector/chute/crusher areas	1	1	—	1	—	1	4
Facility areas	1	—	1	—	—	—	2
Total	27	24	21	22	9	15	118

[1]Includes hopper, crusher, elevator shaft, chute and kiln areas, and maintenance areas.
[2]Includes pumping station, shop and crusher areas, drilling, loading, haulage, transportation, and fuel preparation areas.

Table 62.—Number of fires for stone mills 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]	14	13	6	14	2	4	53
Belt/kiln/clinker hot materials	—	4	6	3	3	3	19
Flammable liquid/oil/refueling fuel	3	3	1	1	—	4	12
Rubber tires/refuse/waste fuel	2	1	3	3	1	1	11
Electrical wires/cables/transformer/battery	4	2	1	—	3	1	11
Hydraulic fluid/fuel	3	—	1	1	—	1	6
Chute/dust collector liners/hopper	—	1	2	—	—	1	4
Facility/content	1	—	1	—	—	—	2
Total	27	24	21	22	9	15	118

[1]Includes rubber hoses, pipelines, dust collector and chute liners, and kiln and shaft materials.

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

The major fire and fire injury findings for all metal/nonmetal mining categories for 1990–2001 are shown in tables 64–65. Table 66, partly illustrated in figure 22, shows the number of fires, fire injuries, fire fatalities, risk rates, employees' working hours, and lost workdays for all metal/nonmetal mining categories by time period.

For all metal/nonmetal operations (including stone and sand and gravel), a total of 518 fires occurred during 1990–2001; 296 of those fires caused 308 injuries and 4 fatalities (Ewhr = 4,012 × 10^6 hr, Irr = 0.015, LWD = 36,204). Thirty fires and 26 injuries involved contractors. The greatest number of fires and fire injuries occurred at surface operations; the highest risk rate values were also calculated for surface operations. The number of fires increased during the first four 2-year time periods (1990–1991, 1992–1993, 1994–1995, and 1996–1997), then decreased during the last two periods (1998–1999 and 2000–2001). The number of injuries showed a decrease throughout the periods, accompanied by an increase in employees' working hours.

Twenty-five firefighting interventions by mine rescue teams in underground mines and at least 30 interventions at surface operations were required to combat these fires. However, 45 fires destroyed or heavily damaged facilities and equipment (including 19 pieces of mobile equipment) because of failure of firefighting methods, late fire detection, undetected fires, or fire size. Ninety-seven fires were detected late, and 30 fires were undetected.

The ignition sources that caused the greatest number of fires were flame cutting/welding spark/slag/flame (169 fires or 33% with 137 injuries), hydraulic fluid/fuel sprayed onto equipment hot surfaces (89 fires or 17% with 46 injuries and 3 fatalities), heat source/explosion and flammable liquids/ gas/refueling fuel on hot surfaces (98 fires or 19% with 73 injuries), electrical short/arcing (51 fires or 10% with 16 injuries), and spontaneous combustion/hot material (46 fires or 9% with 17 injuries).

The flame cutting/welding spark/slag/flame source caused fires usually involving welders' clothing or oxyfuel/grease and other materials (including chute and dust collector liners, flammable liquids, belt material, crusher, hopper and shaker deck materials, washer plants, equipment mechanical components, stampler breaker, hydraulic fluid, rubber tires and hoses, gear boxes, bin feeder, dump rope cables, screen liner and screen panel, kiln and shaft material, pipelines, liquor pumps, wood pallets, electrical junction boxes, handrails, grease, refuse, shop and wood). The spontaneous combustion/hot material and electrical fires were usually detected late due to lack of combustion gas/smoke detection systems. At least 55 of the 89 mobile equipment hydraulic fluid/fuel fires became large fires (requiring 12 mine rescue team interventions in underground

mines and at least 6 interventions at surface operations) 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 the ground level, or lack of effective and rapid local firefighting response capabilities. Ten pieces of mobile equipment involved in fires had machine fire suppression systems. Dual activations (two activations) of machine fire suppression and engine shutoff systems succeeded in temporarily abating the fires, which reignited, fueled by the flow of pressurized fluids entrapped in the lines. In at least 13 instances the cab was suddenly engulfed in flames, forcing the operators to make an unsafe exit, 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.

The major findings for each metal/nonmetal mining category are discussed below.

1. In underground metal/nonmetal and stone mines, 65 fires occurred; 6 of the fires caused 9 injuries (Ewhr = 260 × 10^6 hr, Irr = 0.007, LWD = 83). The leading ignition sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces (16 fires or 25%), flame cutting/welding spark/slag/flame (13 fires or 20%), and electrical short/arcing (12 fires or 19%). The flame cutting/welding spark/slag/flame source caused fires involving oxyfuel/clothing/grease and other materials (including rubber tires and hoses, hydraulic fluid, shop, refuse, wood, chute liner, and shaft material). The electrical fires were usually detected long after the fires had started due to lack of combustion gas/smoke detection systems. Thirteen of the 16 mobile equipment hydraulic fluid/fuel fires became large fires (requiring 12 mine rescue team interventions) because of the continuous flow of fluids 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. In two instances during these fires, the cab was suddenly engulfed in flames, probably due to the ignition of flammable vapors and mists that penetrated the cab. Four pieces of equipment involved in fires had machine fire suppression systems. Dual activations (two activations) of machine fire suppression and engine shutoff systems succeeded in temporarily abating the fires; however, the flames reignited, fueled by the pressurized fluids entrapped in the lines.

Table 63.—Number of fire injuries per number of fires causing injuries and total fires for stone mills 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	19	15	11	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
			1	Heat source	Heater	Maintenance area.
			1	Flammable liquid on hot surfaces	Refueling pump	Pump station.
			2	Hydraulic fluid/fuel on equipment hot surfaces	Truck	Haulage area.
1991	8	6	2	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
			1	Heat source	Heater	Maintenance area.
			2	Flammable liquid on hot surfaces	Maintenance equipment	Maintenance area.
			1	Hydraulic fluid/fuel on equipment hot surfaces	Loader	Loading area.
			1	Electrical short/arcing	Locomotive	Transportation area.
1992	10	7	5	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
			1	Hot material	Chute	Chute area.
			1	Heat source	Heater	Hopper area.
1993	14	10	6	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
			2	Flammable liquid on hot surfaces	Maintenance equipment	Maintenance area.
			1	Hot material	Preheat system	Preheat tower.
			1	Heat source	Heater	Maintenance area.
1994	9	8	6	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
			1	Hot material	Beltline	Beltline areas.
			1	Hydraulic fluid/fuel on equipment hot surfaces	Truck	Haulage area.
1995	12	5	1	Electrical short/arcing	Electrical system	Electrical control room.
			2	Hot material	Hopper/kiln-chute	Hopper/kiln chute/loading areas.
			1	Refueling fuel on hot surfaces	Kiln	Kiln area.
			1	Heat source	Heater	Maintenance area.
1996	14	10	9	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
			1	Hydraulic fluid/fuel on equipment hot surfaces	Truck	Haulage area.
1997	8	4	4	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
1998	6	—	—	—	—	—
1999	3	2	2	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
2000	6	4	3	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
			1	Mechanical friction	Kiln	Kiln area.
2001	9	5	2	Refueling fuel on hot surfaces	Kiln	Kiln area.
			1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
			6	Hot material	Beltline	Kiln/beltline areas.
			1	Heat source	Heater	Maintenance area.
Total	118	76	82			

[1]Includes hopper, shaft, piping, chute and kiln areas, and mobile equipment maintenance areas.

Table 64.—Major fire findings for all metal/nonmetal mining categories, 1990–2001

Variables	Underground metal/nonmetal and stone mines	Surface of underground metal/nonmetal and stone mines	Surface metal/nonmetal mines	Surface sand and gravel mines	Surface stone mines	Metal/nonmetal mills	Stone mills
GT: No. fires: 519 No. fires causing injuries: 296 LWD: 36,204	No. fires: 65 No. fires causing injuries: 6 LWD: 83	No. fires: 12 No. fires causing injuries: 5 LWD: 75	No. fires: 79 No. fires causing injuries: 45 LWD: 13,134	No. fires: 71 No. fires causing injuries: 59 LWD: 6,921	No. fires: 97 No. fires causing injuries: 68 LWD: 7,399	No. fires: 77 No. fires causing injuries: 37 LWD: 6,681	No. fires: 118 No. fires causing injuries: 76 LWD: 1,911
Ignition source	Hydraulic fluid/fuel on equipment hot surfaces Flame cutting/welding spark/slag/flame Electrical short/arcing	Flame cutting/welding spark/slag/flame Electrical short/arcing Heat source	Hydraulic fluid/fuel on equipment hot surfaces Flame cutting/welding spark/slag/flame Electrical short/arcing	Flame cutting/welding spark/slag/flame Heat source Hydraulic fluid/fuel on equipment hot surfaces	Flame cutting/welding spark/slag/flame Heat source-flammable liquid Hydraulic fluid/fuel on equipment hot surfaces	Flame cutting/welding spark/slag/flame Spontaneous combustion/hot material Electrical short/arcing	Flame cutting/welding spark/slag/flame Hot material/spontaneous combustion Electrical short/arcing
Method of detection	Visual-late smoke detection Visual-flames/flash fires Visual-smoke	Visual-sparks Visual-smoke/fumes Visual-late smoke detection	Visual-flames/flash fires Visual-smoke Visual-sparks	Visual-flames/flash fires Visual-sparks Visual-smoke	Visual-flames/flash fires Visual-sparks Visual-smoke	Visual-late smoke detection Visual-sparks Visual-flames/flash fires	Visual-sparks Visual-late smoke detection Visual-smoke Visual flames/flash fire
Suppression method	FE-DCP/foam/water Water FE	Water Manual with or without FE FE	FE-foam/DCP/water FE Manual with or without FE	Manual/FE FE-foam/DCP/water Water	Manual with or without FE Water FE-DCP/foam/water	Water FE Manual with or without FE	Manual with or without FE Water FE
Equipment	Mobile equipment[1] Oxyfuel torch Beltline/drive/pulley	Oxyfuel torch Facilities Heater	Mobile equipment[1] Oxyfuel torch Heater	Oxyfuel torch Mobile equipment[1] Heater/burner	Mobile equipment[1] Heater/maintenance equipment/burner Oxyfuel torch	Oxyfuel torch Dust collector/other Pump/oil vaporizer	Oxyfuel torch Kiln/preheat/cooling system Mobile equipment[1] Electrical system
Location	Mobile equipment working areas[2] Flame cutting/welding areas[3] Mine face/other areas	Flame cutting/welding areas[3] Facility/garage/other Fan housing	Mobile equipment working areas[2] Flame cutting/welding areas[3] Maintenance areas/other	Flame cutting/welding areas[3] Maintenance areas Mobile equipment working areas[2]	Maintenance areas/other Flame cutting/welding areas[3] Mobile equipment working areas[2]	Flame cutting/welding areas[3] Dust collector/other areas Maintenance areas	Flame cutting/welding areas[3] Kiln/other areas Kiln/chute/hopper/silo Mobile equipment working areas[2]
Burning material	Hydraulic fluid Oxyfuel/clothing/grease/other Electrical cord/wire/cable/battery	Oxyfuel/clothing/grease/other Facility/content Wood	Hydraulic fluid/fuel/oil Oxyfuel/clothing/grease/other Flammable liquid/material	Oxyfuel/clothing/grease/other Hydraulic fluid/fuel Flammable liquid/gas	Oxyfuel/clothing/grease/other Hazardous material/chemical/other Hydraulic fluid/fuel	Oxyfuel/clothing/grease/other Belt material Flammable liquid/refueling fuel	Oxyfuel/clothing/grease/other Belt/kiln/clinker hot materials Flammable liquid/refueling fuel/oil

DCP Dry chemical powder. FE Portable fire extinguisher. GT Grand total.

[1]Includes golf and ore carts, locomotives, loaders, scoops, shuttle cars, power scalers, trolleys, trucks, drills, dozers, shovels, scrapers, dredges, buckets, tankers, and forklifts.

[2]Includes haulage, loading, mucking, decline slopes, panel and tunnel areas, transportation, drilling, mining, excavating areas, pumping stations, shop and crusher areas, fuel preparation and dredging areas.

[3]Includes shops, mainways, boreholes, shafts, stations, slusher bucket, chute, dust collector, hopper, crusher and kiln areas, maintenance areas, junction boxes, facilities and shops, head frame, walkways, pipeline, dump rope, crowd platform, storage bin, baghouse, pelletizer building, liquor pump, beltline, generator housing, deck and bin feeder, stampler breaker and screen shaft and compactor areas, and washer plants.

NOTE.—Variables are listed in descending order of occurrence.

Table 65.—Major fire injury findings for all metal/nonmetal mining categories, 1990–2001

Variables	Underground metal/nonmetal and stone mines	Surface of underground metal/nonmetal and stone mines	Surface metal/nonmetal mines	Surface sand and gravel mines	Surface stone mines	Metal/nonmetal mills	Stone mills
GT: No. fire injuries: 308 No. fire fatalities: 4 Ewhr, 10^6 hr: 4,012 Irr: 0.015	No. fire injuries: 9 Ewhr, 10^6 hr: 260 Irr: 0.007	No. fire injuries: 5 Ewhr, 10^6 hr: 58 Irr: 0.017	No. fire injuries: 44 No. fire fatalities: 2 Ewhr, 10^6 hr: 546 Irr: 0.016	No. fire injuries: 60 Ewhr, 10^6 hr: 741 Irr: 0.016	No. fire injuries: 67 No. fire fatalities: 1 Ewhr, 10^6 hr: 689 Irr: 0.02	No. fire injuries: 41 No. fire fatalities: 1 Ewhr, 10^6 hr: 845 Irr: 0.01	No. fire injuries: 82 Ewhr, 10^6 hr: 873 Irr: 0.019
Ignition source	Hydraulic fluid/fuel on equipment hot surfaces Flame cutting/welding spark/slag/flame Overheated oil on hot surfaces	Flame cutting/welding/ spark/slag/flame	Hydraulic fluid/fuel on equipment hot surfaces Flame cutting/welding spark/slag/flame Flammable liquid/ refueling fuel/oil on hot surfaces	Flame cutting/welding spark/slag/flame Heat source Hydraulic fluid/fuel on equipment hot surfaces	Flame cutting/welding spark/slag/flame Heat source Hydraulic fluid/fuel on equipment hot surfaces	Flame cutting/welding spark/slag/flame Flammable liquid/ refueling fuel on hot surfaces/explosion Hot materials	Flame cutting/welding spark/slag/flame Hot material Flammable liquid/gas/ refueling fuel on hot surfaces
Method of detection	Visual-flames/flash fires Visual-sparks Visual-smoke	Visual-sparks	Visual-flames/flash fires Visual-sparks Visual-smoke	Visual-sparks Visual-smoke Visual-flames/flash fires	Visual-sparks Visual-smoke Visual flames/flash fires	Visual-sparks Visual-flames Visual-late smoke detection	Visual-sparks Visual-smoke Visual-flames
Suppression method	FE-DCP/foam/water Manual with or without FE FE	Manual with or without FE	FE-foam/DCP/water Manual with or without FE FE	Manual with or without FE Water FE-foam/DCP/water	Manual with or without FE FE FE-foam/DCP/water	Manual with or without FE FE Water	Manual with or without FE Water FE
Equipment	Mobile equipment Oxyfuel torch Air compressors/ mobile equipment	Oxyfuel torch	Mobile equipment Oxyfuel torch Maintenance equipment/mobile equipment	Oxyfuel torch Heater Mobile equipment	Oxyfuel torch Heater Mobile equipment	Oxyfuel torch Maintenance equipment/liquor pump Product cooling system	Oxyfuel torch Beltline/chute/kiln/preheat system Maintenance equipment/refueling pump/ mobile equipment
Location	Mobile equipment working areas Flame cutting/welding areas Mine face/panel section	Flame cutting/welding area	Mobile equipment working areas Flame cutting/welding areas Maintenance areas	Flame cutting/welding areas Maintenance/refuse/ beltline areas Mobile equipment working areas	Flame cutting/welding areas Beltline/maintenance/ working areas Mobile equipment working areas	Flame cutting/welding areas Maintenance/liquor/ pump/refinery areas Product cooler area	Flame cutting/welding areas Preheat /kiln/chute/ beltline areas Maintenance areas/ pump station
Burning material	Hydraulic fluid/fuel Oxyfuel/clothing/ grease/other Oil	Oxyfuel/clothing/ grease/other	Hydraulic fluid/fuel Oxyfuel/clothing/ grease/other Flammable liquid/ refueling fuel/oil	Oxyfuel/clothing/ grease/other Refuse Hydraulic fluid/fuel	Oxyfuel/clothing/ grease/other Refuse/hazardous material Hydraulic fluid/fuel	Oxyfuel/clothing/ grease Flammable liquid/ refueling fuel Material/belt	Oxyfuel/clothing/ grease/other Material/belt Flammable liquid/gas/ refueling fuel

DCP Dry chemical powder.
FE Portable fire extinguisher.
GT Grand total.
NOTE.—Variables are listed in descending order of occurrence.

Table 66.—Number of fires, fire injuries, fire fatalities, and risk rates for all metal/nonmetal mining categories 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]	92	115	100	93	54	64	518
Number of fire injuries[1]	62	69	61	53	28	35	308
Number of fire fatalities[1]	—	1	2	—	—	1	4
LWD[2]	941	7,014	13,510	6,864	1,026	6,849	36,204
Ewhr,[2] 10^6 hr	652	650	664	681	677	688	4,012
Irr[3]	0.019	0.02	0.018	0.016	0.008	0.01	[3]0.015

[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.

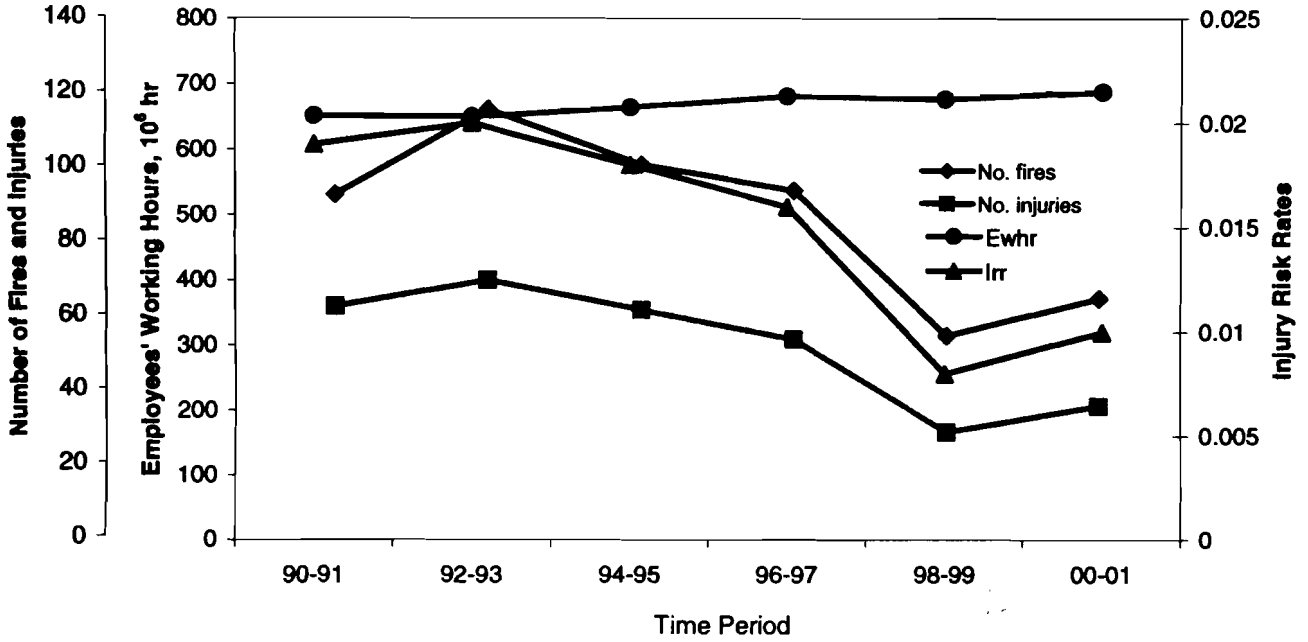

Figure 22.—Number of fires, fire injuries, risk rates, and employees' working hours for all metal/nonmetal mining categories by time period, 1990–2001.

Upon mine/section evacuation (required 30 times), mine rescue teams (required 25 times), often hindered by dense smoke in reaching the fire location, fought the fires (including 12 mobile equipment fires) with dry chemical powder, rock dust, and water; in one instance, foam was also used. However, five 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. Eighteen fires were detected late, and two were undetected.

The ignition sources that caused the underground fire injuries were hydraulic fluid/fuel sprayed onto equipment hot surfaces, flame cutting/welding spark/slag/flame, and overheated oil. The equipment involved in fire injuries included mobile equipment, oxyfuel torches, and air compressors. The locations where fire injuries occurred were mobile equipment working areas, flame cutting/welding areas, and mine face and panel section.

2. At surface of underground metal/nonmetal and stone mines, 12 fires occurred; 5 of the fires caused 5 injuries (Ewhr = 58 × 10^6 hr, Irr = 0.017, LWD = 75). The leading ignition source was flame cutting/welding spark/slag/flame (7 fires or 58%), followed by electrical short/arcing and heat source. The flame cutting/welding spark/slag/flame source caused fires involving oxyfuel/clothing/grease and other materials (including electrical junction boxes, handrails, grease, flammable liquids, rubber tires, and equipment mechanical components). In all, three fires destroyed or heavily damaged equipment. Two fires were detected late, and three fires were undetected. The ignition source that caused the fire injuries was flame cutting/welding spark/slag/flame.

3. At surface metal/nonmetal mines, 79 fires occurred; 45 of the fires caused 44 injuries and 2 fatalities (Ewhr = 546 × 10^6 hr, Irr = 0.016, LWD = 13,134). The leading ignition source was hydraulic fluid/fuel sprayed onto equipment hot surfaces (35 fires or 44%), followed by flame cutting/welding spark/slag/flame (13 fires or 17%) and electrical short/arcing (8 fires or 10%). The flame cutting/welding spark/slag/flame source

caused fires involving oxyfuel/clothing/grease and other materials (involving rubber hoses, grease, equipment mechanical components, dump rope cables, screen liner, and shaft materials). Twenty-two of the 35 mobile equipment hydraulic fluid/fuel fires became large fires because of the continuous flow of fluid/fuel from the pumps due to engine shutoff failure, lack of an emergency line drainage system, difficulty in activating available emergency systems at ground level, or lack of effective and rapid local firefighting response capabilities. In at least five instances the cab was suddenly engulfed in flames, probably due to the ignition of flammable vapors and mists that penetrated the cabs. Five pieces of mobile equipment involved in fires had machine fire suppression systems. Dual activation (one activation) of machine fire suppression and engine shutoff systems succeeded in temporarily abating the fires; however, the flames reignited, fueled by the flow of fluids entrapped in the lines.

In at least five instances, including one mobile equipment fire, fire brigades and fire departments fought the fires with foam, dry chemical powder, and water. However, nine fires destroyed or heavily damaged equipment (including seven pieces of mobile equipment) because of failure of firefighting methods, late fire detection, undetected fires, or fire size. Eight fires were detected late, and three fires were undetected.

The ignition sources that caused most of the fire injuries were hydraulic fluid/fuel sprayed onto equipment hot surfaces, flame cutting/welding spark/slag/flame, and flammable liquid/refueling fuel/oil on hot surfaces. The equipment most often involved in fire injuries included mobile equipment, oxyfuel torches, and maintenance equipment. The locations where most of the fire injuries occurred were mobile equipment working areas, flame cutting/welding areas, and maintenance areas.

4. At surface sand and gravel mines, 70 fires occurred; 59 of the fires caused 60 injuries (Ewhr = 741 × 10^6 hr, Irr = 0.016, LWD = 6,921). The leading ignition sources were flame cutting/welding spark/slag/flame (29 fires or 41%), heat source/ explosion (15 fires or 21%), and hydraulic fluid/fuel sprayed onto equipment hot surfaces (14 fires or 20%). The flame cutting/welding spark/slag/flame source caused fires involving oxyfuel/clothing/ grease and other materials (including chute liners, washer plant, crusher, hopper and shaker deck, flammable liquids, equipment mechanical components, and belt materials). Five of the 14 mobile equipment hydraulic fluid/fuel fires became large fires because of the continuous flow of fluid/fuel from the pumps due to engine shutoff failure, lack of an emergency line drainage system, difficulty in activating available emergency systems at ground level, or lack of effective and rapid local fire response capabilities. In two instances the cab was suddenly engulfed in flames, probably due to the ignition of flammable vapors and mists that penetrated the cab. 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, four fires destroyed or heavily damaged equipment (including two pieces of mobile equipment) because of failure of firefighting methods, late fire detection, undetected fires, or fire size. Eight fires were detected late, and four fires were undetected.

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. The equipment most often involved in fire injuries included oxyfuel torches, heaters, and mobile equipment. The locations where most of the fire injuries occurred were flame cutting/welding areas, maintenance areas, and mobile equipment working areas.

5. At surface stone mines, 97 fires occurred; 68 of the fires caused 67 injuries and 1 fatality (Ewhr = 689 × 10^6 hr, Irr = 0.02, LWD = 7,399). The leading ignition sources were flame cutting/welding spark/slag/flame (25 fires or 26%), heat source/explosion-flammable liquid/gas (24 fire or 25%), and hydraulic fluid/fuel sprayed onto equipment hot surfaces (16 fires or 17%). The flame cutting/welding spark/slag/flame source caused fires involving oxyfuel/clothing/grease and other materials (including screen panel and chute liner, crusher and hopper, stampler breaker, rubber hoses, gear boxes, bin feeder, hydraulic fluid, and shaft material). None of the mobile equipment involved in fires had machine fire suppression systems. Ten of the 16 mobile equipment hydraulic fluid/fuel fires became large fires because of the continuous flow of fluid/fuel from the pumps due to engine shutoff failure, lack of an emergency line drainage system, or lack of effective and rapid local firefighting response capabilities. In two instances the cab was suddenly engulfed in flames, probably due to the ignition of flammable vapors and mists that penetrated the cab.

In at least six instances, including one mobile equipment fire, fire brigades and fire departments fought the fires with 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. Four fires were detected late; eight were undetected 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. The equipment most often involved in fire injuries included oxyfuel torches, heaters, and mobile equipment. The locations where most of the fire injuries occurred were flame cutting/welding areas, maintenance areas, refuse and fire pot areas, and mobile equipment working areas.

6. At metal/nonmetal mills, 77 fires occurred; 37 of the fires caused 41 injuries and 1 fatality (Ewhr = 845 × 10^6 hr, Irr = 0.01, LWD = 6,681). The leading ignition sources were flame cutting/welding spark/slag/flame (29 fires or 38%), hot material (12 fires or 16%), and flammable liquid/refueling fuel/oil on hot surfaces (9 fires or 12%). The flame cutting/welding spark/ slag/flame source caused fires involving oxyfuel/clothing/grease and other materials (including liquor pumps, belt material, pipelines, flammable liquids, dust collector and chute liners, wood pallets, crusher, and screen panel). The hot material fires and electrical fires were usually detected long after they had started due to lack of combustion gas/smoke detection systems. One of the three mobile equipment hydraulic fluid/fuel fires became a large pump

fire because of the continuous flow of fluid from the pump due to engine shutoff failure. In this instance the cab was suddenly engulfed in flames, probably due to the ignition of flammable vapors and mists that penetrated the cab.

In at least five instances, including one mobile equipment fire, fire brigades and fire department fought the fires with foam, dry chemical powder, and water. However, six fires destroyed or heavily damaged equipment (including one piece of mobile equipment) because of failure of firefighting methods, late fire detection, undetected fires, or fire size. Twenty-six fires were detected late, and four were undetected.

The ignition sources that caused most of the fire injuries were flame cutting/welding spark/slag/flame, flammable liquids/refueling fuel on hot surfaces/explosion, and hot material. The equipment involved in fire injuries included oxyfuel torches, maintenance equipment, refueling and liquor pumps, and product cooling system. The locations where the fire injuries occurred were flame cutting/welding areas, maintenance areas, pump housing and liquor pump areas, and product cooling area.

7. At stone mills, 118 fires occurred; 76 of the fires caused 82 injuries (Ewhr = 873 × 10^6 hr, Irr = 0.019, LWD = 1,911). The leading ignition sources were flame cutting/welding spark/slag/flame (53 fires or 45%), hot material (24 fires or 20%), and electrical short/arcing (11 fires or 9%).

The flame cutting/welding spark/slag/flame source caused fires involving oxyfuel/clothing/grease and other materials (including rubber hoses, pipelines, dust collector and chute liners, and shaft and kiln materials). Four of the five hydraulic fluid/fuel fires became large fires because of the continuous flow of fluids from the pumps due to engine shutoff failure, lack of an emergency line drainage system, difficulty in activating emergency systems at ground level, or lack of effective and rapid local firefighting response capabilities. In one instance the cab was suddenly engulfed in flames, probably due to the ignition of flammable vapors and mists that penetrated the cab. Of the six pieces of mobile equipment involved in fires, one had a machine fire suppression system, which, upon activation with the engine shutoff system, succeeded in temporarily abating the fire.

In at least 11 instances, including 2 mobile equipment fires, fire brigades and fire departments fought the fires with foam, dry chemical powder, and water. In two instances, emergency foam fire suppression systems were used. However, seven fires destroyed or heavily damaged equipment (including one piece of mobile equipment) because of failure of firefighting methods. Thirty-one fires were detected late, and six fires were undetected.

The ignition sources that caused most of the fire injuries were flame cutting/welding spark/slag/flame, hot material, and flammable liquid/gas/refueling fuel on hot surfaces. The equipment most often involved in fires included oxyfuel torches, kilns, beltlines, chute, preheat system, and maintenance equipment. Most of the fire injuries occurred at flame cutting/welding areas, kiln, beltline and chute areas, preheat areas, and maintenance areas.

CONCLUSIONS

During 1990–2001, a total of 518 fires occurred in all metal/nonmetal mining categories; 296 of those fires caused 308 injuries and 4 fatalities. Surface operations had the most fires and the highest injury risk rate values. Forty-five fires destroyed or heavily damaged facilities and equipment (including 19 pieces of mobile equipment) because of failure of firefighting methods, late fire detection, undetected fires, or fire size.

In the future, many of these fires and injuries might be prevented or detected and extinguished at their earliest stage by improving current fire safety procedures, adopting existing/improved fire detection and suppression technologies, and/or developing new technologies. Several strategies for reducing and/or preventing the number of fires and fire injuries follow.

1. Increase vigilance, improve safety procedures, and develop new technologies in order to prevent fires and injuries caused by flame cutting and welding operations.

2. Improve equipment hydraulic/fuel/electrical systems inspection programs; adopt fire-resistant hydraulic fluids and electrically powered motors for use in underground mines; develop new technologies (equipment/cab rapid fire detection/prevention/suppression systems, emergency line drainage systems, and fire barriers); adopt an optimal ground level location for the activation of emergency systems; improve operator's fire preparedness training programs; and develop effective and rapid local firefighting response capabilities.

3. Adopt existing/improved systems for continuous and early detection of combustion gases and smoke along beltlines.

4. Adopt existing/improved technologies for monitoring equipment (beltlines) operational functions.

5. Increase vigilance and adopt improved safety procedures for handling flammable liquids and refueling fuel in the vicinity of heat sources.

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