Proportionate Mortality Among Unionized Construction Operating Engineers

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This report presents the results of proportionate mortality ratios (PMR) and proportionate cancer mortality ratios (PCMR) among 15,843 members of the International Union of Operating Engineers who had died between 1988–1993. Operating engineers represent one of the 15 unions in the Building and Construction Trades Department and are responsible for the operation and maintenance of heavy earthmoving equipment used in the construction of buildings, bridges, roads, and other facilities. Using U.S. proportionate cancer mortality as the referent, statistically significant elevated mortality was observed for cancers of the lung (PCMR = 1.14, 95% confidence interval (CI) = 1.09–1.19) and bone (PCMR = 2.14, CI = 1.19–3.52). Using U.S. proportionate mortality as the referent, statistically significant elevated mortality was observed for other benign and unspecified neoplasms (PMR = 1.54, CI = 1.09–2.13), emphysema (PMR = 1.37, CI = 1.20–1.55), other injuries (PMR = 1.43, CI = 1.20–1.70) (which included crushing under/in machinery, tractor rollover, run over by crane), and suicide (PMR = 1.22, CI = 1.06–1.40). The PMR for leukemia and aleukemia (PMR = 1.19, CI = 1.02–1.37), but not the PCMR (1.07, CI = 0.92–1.24), was also significantly elevated. Some of the occupational exposures that may have contributed to these excesses include diesel exhaust, asphalt and welding fumes, silica dust, ionizing radiation, and coal tar pitch. The present study underscores the need to control airborne exposures to these substances and for injury prevention efforts aimed at operating engineers in the construction industry. Am. J. Ind. Med. 32:51–65, 1997. *© 1997 Wiley-Liss, Inc.*†

KEY WORDS: operating engineer; construction; proportionate mortality; lung cancer; bone cancer; leukemia; injuries; mesothelioma

INTRODUCTION

The purpose of this proportionate mortality ratio (PMR) study is to identify those causes of death in excess among Operating Engineers as a starting point for possible prevention and intervention activities. The International Union of Operating Engineers (IUOE) was founded in 1896 and, from its relatively small beginning, the IUOE has grown to approximately 375,000 members with more than 200 local unions within nine regions throughout the United States (Appendix A). The IUOE is composed of members who work as heavy equipment operators and mechanics in construction and related industries, as well as operators and maintainers of physical plant systems in factories, office buildings, hospitals, schools, and other facilities. The former are called ‘‘hoisting and portable engineers’’ (also known as “Operating Engineers,” the name used in this study); the latter are called “Stationary Engineers.” Operating Engineers comprise more than 70% of the union membership (approximately 270,000 members) and are the focus of this investigation.

Operating engineers are those members who, in general, operate and maintain heavy earthmoving equipment such as cranes, bulldozers, graders, and backhoes (Appendix B). This equipment is used in four main activities: (1) the building of roads, bridges, tunnels, and dams (Heavy and Highway, 40% of membership); (2) the construction of buildings and power plants (Building Trades, 30% of membership); (3) the removal of earth materials and grading

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earth surfaces and in the replacement of concrete, blacktop, and other paving materials (Grading and Paving, 20% of membership); and (4) the constructing of drainage systems, pipelines, and other related activities, such as blasting (Pipeline, 10% of membership). (For a more detailed description of the Operating Engineers' duties, see Appendix C.) Because Operating Engineers perform many varied duties, Operating Engineers have potential for exposure to numerous chemical, physical, and biological agents. Often these exposures can be episodic in nature. A survey conducted during 1981–1983 among a representative sample of 4,500 U.S. industrial facilities with eight or more employees (employing nearly 1.8 million workers) recorded potential worker exposure to chemical, physical, or biological agents [NIOSH 1988, 1990a,b; Sieber et al., 1991]. The results of the survey by the percentages of Operating Engineers exposed to various agents are available upon request from the author. Some of the potential toxic exposures included diesel exhaust, asphalt and welding fumes, cutting fluids, solvents, carbon monoxide, silica, and various other types of dusts. Based on these exposures, causes of death hypothesized to be elevated in the cohort included lung cancer and nonmalignant respiratory diseases. A potential excess risk of deaths from skin cancer was also hypothesized due to the Operating Engineers' exposure to both asphalt and to the sun. Furthermore, excess death from occupational injury was predicted due to the heavy earthmoving equipment used and its potential for rollover. Because Operating Engineers work side by side with other construction trade craftspersons and laborers, whose tasks and work practices vary widely, Operating Engineers may also be exposed to other hazardous materials. Therefore, other causes of death were also examined.

METHODS AND MATERIALS

Study Population

Our study population consisted of all deceased Operating Engineers who (1) had been active paying dues members of the IUOE for at least one continuous year; (2) were actively paying into the death benefit fund at the time of their death whether they were currently employed, unemployed or retired; and (3) had died in the United States between January 1, 1988 and December 31, 1993. Because there were only 13 female members in the file, they were eliminated from analysis.

The Operating Engineers' death claim file has been computerized since October 1980 and consists of all member deaths since 1975—more than 55,000 deaths. The Operating Engineers also maintains a computerized demographic file and a separate computerized work history file of all its members since 1960. We chose to study only those deaths occurring between January 1, 1988 and December 31, 1993 for the following two reasons: (1) prior to 1988, all records of deceased members from the demographic and work history files were purged; and (2) the number of deaths for which a claim had been filed for 1988–1993 was estimated at approximately 16,000, which would give us adequate statistical power to examine even relatively rare causes-of-death.

The study population was identified from the computerized demographic file maintained at the international headquarters of the Operating Engineers in Washington, D.C. Information used from this file included the member's name, Social Security number, membership number, date of birth, and date of initiation into the union. The information obtained from the work history file included the local unions where each member worked, the time period for which dues were paid in each local, and the regional office of the local. Unfortunately, specific type of work activity for each member was only available, in most cases, from the individual locals and there were more than 200 locals representing Operating Engineers included in this study. Obtaining work activity information for each member would have been a very arduous and time-consuming task. Therefore, specific work history information from each local was not obtained. From the death claim file we obtained the member's date of death, death claim number, and whether the claimant was actively working immediately prior to his death.

The study group included all eligible members for whom a death benefit claim had been filed as well as a few members known to be deceased by the Operating Engineer's local and placed on the death beneficiary file, but for whom a death benefit claim had not been filed by the beneficiary (N = 161). As death certificates were obtained, the underlying and contributory causes of death were coded according to the Ninth Revision of the International Classification of Diseases [WHO, 1977] by an experienced and qualified nosologist.

Statistical Analyses

Three types of PMR analysis were conducted using the National Institute for Occupational Safety and Health's (NIOSH) Life-Table Analysis System (LTAS): one that evaluated the overall proportionate mortality, a second that evaluated the proportionate cancer mortality [Steenland et al., 1990], both using underlying causes of death, and a third that evaluated the proportionate mortality using all causes of death (multiple causes) as listed on the death certificate [Steenland et al., 1992]. The PMR methodology was used in lieu of the Standardized Mortality Ratio (SMR), which gives an approximation of the relative risk of disease, because we did not have information on the entire population at risk. The number of deaths in the study population, by cause, was compared with the number of deaths expected. Expected rates were based upon the race and cause-specific proportionate mortality experience of the U.S. male population for the 5-year calendar time periods 1984–1989 and 1990–1994, and by 5-year age groups from 15–19 through 80–84 and then for 85 and older. The PMRs were then calculated by dividing the observed number of deaths by the number expected and multiplying the results by 100. Statistical significance of the results was determined using the Poisson distribution and 95 percent confidence intervals. If the observed number of deaths was greater than 6, the Byar approximation to the exact test was used; if the observed number of deaths was ≤ 6, exact confidence limits were used [Rothman, 1979]. PMRs were calculated for tenure in the union (dues paid), which was used as a surrogate for duration of exposure, year of entry into the union, and age at death. Although age is accounted for in all analyses, we were interested in examining specifically PMRs by age in order to observe any specific mortality trends by age among the members. Proportionate cancer mortality ratios (PCMRs) were calculated using cancer-specific observed deaths among our study population and comparing these results with the cancer-specific proportionate mortality of the U.S. population with similar time periods and age groups as previously used for the PMR analysis. PCMR analysis was conducted to correct for possible biases in the cancer mortality PMR due to elevations or deficits from other nonmalignant causes, particularly a possible deficit of deaths from heart disease due to the ‘‘healthy worker effect.’’ A multiple-cause analysis using all causes-of-death as coded on the death certificate was conducted to examine any disease excesses not identified using only underlying causes-of-death. This analysis includes the usual underlying cause-of-death as well as contributory causes and other significant conditions at time of death which the physician or other medical provider noted on the death certificate and compares these results with those expected using multiple cause-of-death referent rates. Good candidates for multiple cause analyses are diseases that are of long duration, not necessarily fatal, yet serious enough to be noted on the death certificate.

RESULTS

Characteristics of the Study Population

A total of 16,668 deaths among Operating Engineer members of the IUOE were initially identified from the Operating Engineers' death beneficiary file. From this total were excluded the following 825 deaths: (1) 37 deaths that occurred before 1988; (2) 35 deaths that occurred outside the United States; (3) 13 deaths among female members; and (4) 740 deaths for whom a death certificate could not be obtained (151 of these were from New York City). A total of 15,843 deaths were eligible for inclusion in the present analysis.

The general characteristics of the study population show that of the 15,843 male deaths, only 233 (approximately 1.5%) were among nonwhites. Included in the category of white males were 57 of Hispanic origin and 56 of American Indian origin. The mean age first entering the union was 36 years and the average number of years of union membership was 34. The average age at death was 74.

Cause-Specific Mortality Analysis

Table I presents the number of deaths, cause-specific PMRs, and 95% confidence levels for the 15,843 eligible deaths in the study. There were statistically significant elevations in deaths due to all malignant neoplasms combined mainly due to significant elevations of cancers of the lung, leukemia and aleukemia, cancers of the bone, and cancers of ‘‘other and unspecified sites.’’ This latter category included 10 deaths due to head, neck, and face cancer, and 18 deaths in which the underlying cause was coded as ‘‘malignant mesothelioma’’ (note that Mesothelioma is coded as unspecified if it is not specifically stated as either pleural or peritoneal). The remaining cancers in the ‘‘other and unspecified sites’’ category were coded as metastases from a primary site, unspecified. Also significantly elevated were deaths due to benign and unspecified neoplasms, emphysema, other respiratory diseases, suicides, and ‘‘other injuries.’’ The category ‘‘other injuries’’ included injuries caused by machinery, which comprised 36 of the 133 deaths (27%) in this category.

Those diseases that were found significantly lower than expected were as follows: cancer of the thyroid gland; diseases of the blood; mental, psychoneurotic, and personality disorders; diseases of the nervous system and sense organs; diseases of the heart; pneumonia; diseases of the digestive system; diseases of the genitourinary system; and falls. The PMRs for melanoma and for ‘‘other skin cancers’’ were about as expected.

Those diseases most related to excessive drinking, i.e., alcoholism and liver cirrhosis, had PMRs below expectation (0.73 and 0.88, respectively). PMR results for those diseases that have been most associated with smoking were, for the most part, elevated. The PMR for lung cancer ($P < 0.01$), emphysema ($P < 0.01$) and bronchitis were higher than expected; however, the PMR for diseases of the heart was lower than expected ($P < 0.01$).

A proportionate cancer mortality ratio (PCMR) analysis was conducted to correct for possible distortions in the PMR due to significant increases or decreases in nonmalignant causes of death (Table II). In the PMR analysis, the category all malignant neoplasms had a statistically significantly elevated PMR of 1.11. By definition, the PCMR changes the all malignant neoplasms category to 1.00 which, consequently, changes the site-specific cancer results. Two of the four categories of site-specific cancers which were significantly elevated in the PMR analyses remained significantly elevated in the PCMR analyses; cancers of the trachea, bronchus and lung and cancers of the bone. Leukemia and aleukemia and cancer of ‘‘other sites,’’ which were also statistically significantly elevated in the PMR analysis, were still elevated in the PCMR analysis but were not statistically significant.

TABLE I. Observed Number of Deaths, Proportionate Mortality Ratios, and 95% Confidence Intervals Among Male Unionized Operating Engineers Who Died 1988–1993

Causes of death (ICDA-9)	Observed no. of deaths	PMR	95% CI
All causes (000–999)	15,843	1.00	0.98–1.02
Tuberculosis (010–018)	0	0.00	0.00–0.00
All malignant neoplasms (140–208)	4,816	1.11*	1.08–1.14
Buccal cavity and pharynx (140–149)	68	0.86	0.66–1.08
Cancer of the stomach (151)	124	1.01	0.84–1.20
Cancer of larynx (161)	59	1.24	0.95–1.61
Cancer of trachea, bronchus, and lung (162)	1,915	1.26**	1.20–1.31
Cancer of bone (170)	15	2.39**	1.33–3.94
Cancer of kidney (189.0–189.2)	121	1.18	0.98–1.41
Cancer of other and unspecified sites (194–199)	339	1.15**	1.03–1.28
Leukemia and aleukemia (204–208)	182	1.19*	1.02–1.37
Benign and unspecified neoplasms (210–240)	65	1.43**	1.10–1.82
Diabetes mellitus (250)	272	0.90	0.80–1.02
Diseases of the blood (280–289)	46	0.74*	0.54–0.99
Mental, psychoneurotic, and personality disorders (290–319)	115	0.79**	0.65–0.95
Alcoholism (303)	25	0.73	0.47–1.07
Diseases of the nervous system (320–389)	220	0.80**	0.70–0.92
Diseases of the heart (400–429)	5,603	0.96**	0.94–0.99
Ischemic heart disease (410–414)	4,580	0.96**	0.93–0.99
Cerebrovascular disease (430–438)	838	0.95	0.89–1.01
Diseases of the respiratory system (460–519)	1,700	1.04	0.99–1.09
Pneumonia (except newborn) (480–486)	427	0.82**	0.74–0.90
Bronchitis (490–491)	43	1.28	0.93–1.73
Emphysema (492)	240	1.37**	1.20–1.55
Asthma (493)	20	0.96	0.59–1.48
Pneumoconioses and other respiratory diseases (470–478, 494–519)	958	1.11**	1.04–1.19
Asbestosis (501)	4	0.84	0.23–2.16
Silicosis (502)	3	1.49	0.30–4.34
Diseases of the digestive system (520–579)	480	0.91*	0.83–0.99
Liver cirrhosis (571)	179	0.88	0.76–1.02
Diseases of the genitourinary system (580–629)	223	0.87*	0.76–0.99
Diseases of the skin (680–686)	14	0.87	0.47–1.45
Diseases of the musculoskeletal system (710–739)	39	1.24	0.88–1.69
Injuries (800–949)	355	1.04	0.93–1.15
Transportation injuries (E800–848)	142	1.05	0.88–1.24
Poisoning (E850–869)	12	0.87	0.45–1.52
Falls (E880–888)	58	0.71**	0.53–0.91
Other injuries (E890–928)	133	1.43**	1.20–1.70
Suicide (E950–959)	206	1.22*	1.06–1.40
Homicide (E960–978)	18	0.61*	0.36–0.96

CI, confidence interval; PMR, proportionate mortality ratio.
*$P < 0.05$.
**$P < 0.01$.

The PMRs in the multiple cause-of-death analysis were found to be have similar results to those in the underlying cause-of-death analysis and, therefore, are not tabulated. However, these results are available from the author upon request.

Years of Union Membership

PMRs by years of union membership, a surrogate for duration of exposure, examining diseases of specific interest

TABLE II. Observed Number of Deaths, Proportionate Cancer Mortality Ratios, and 95% Confidence Intervals Among Male Unionized Operating Engineers Who Died 1988–1993

Causes of death (ICDA-9)	Observed no. of deaths	PCMR	95% CI
All malignant neoplasms (140–208)	4,816	1.00	0.97–1.03
Buccal cavity and pharynx	68	0.77*	0.60–0.97
Lip (140)	2	1.47	0.18–5.32
Tongue (141)	17	0.87	0.50–1.39
Other parts of buccal cavity (142–145)	16	0.65	0.37–1.06
Pharynx (146–149)	33	0.76	0.53–1.07
Digestive organs and peritoneum (150–159)	1,025	0.90**	0.84–0.95
Esophagus (150)	102	0.83	0.68–1.01
Stomach (151)	124	0.90	0.75–1.08
Intestine except rectum (152–153)	395	0.88*	0.80–0.97
Rectum (154)	86	1.10	0.88–1.36
Biliary passages, liver, gallbladder (155.0, 155.1)	67	0.79*	0.61–0.99
Liver not specified (156–155.2)	28	0.90	0.60–1.29
Pancreas (157)	211	0.94	0.82–1.08
Peritoneum and other digestive (158–159)	12	0.71	0.36–1.23
Respiratory system	1,983	1.13**	1.08–1.18
Larynx (161)	59	1.12	0.85–1.45
Trachea, bronchus, and lung (162)	1,915	1.14**	1.09–1.19
Others respiratory (160, 163–165)	9	0.62	0.28–1.18
Male genital organs	536	0.91	0.83–0.99
Prostate (185)	535	0.91*	0.83–0.99
Testes (186)	1	0.56	0.12–3.12
Urinary organs	244	0.97	0.85–1.10
Kidney (189.0–189.2)	121	1.06	0.88–1.27
Bladder and other urinary (188, 189.3–189.9)	123	0.89	0.74–1.06
Other and unspecified	527	0.96	0.88–1.04
Skin melanoma (172)	53	0.84	0.63–1.10
Skin (173)	22	0.85	0.53–1.29
Eye (190)	2	0.83	0.10–3.00
Brain and nervous system (191, 192)	77	0.80	0.63–1.00
Thyroid gland (193)	1	0.15*	0.00–0.81
Bone (170)	15	2.14*	1.19–3.52
Connective tissue (171)	18	0.82	0.49–1.30
Other sites (187, 194–199)	339	1.03	0.93–1.15
Lymphatic and hematopoietic	430	1.00	0.90–1.10
Non-Hodgkin's lymphoma (200–202)	163	0.96	0.82–1.12
Hodgkin's disease (201)	12	1.17	0.60–2.04
Leukemia and aleukemia (204–208)	182	1.07	0.92–1.24
Myeloma (203)	73	0.90	0.71–1.14

CI, confidence interval; PCMR, proportionate cancer mortality rate.
*$P < 0.05$.
**$P < 0.01$.

among the Operating Engineers are presented in Table III. PMRs for lung cancer declined slightly with increasing years of union membership, while PMRs for leukemia and aleukemia peaked in the categories 10–20 and 20–30 years. PMRs for emphysema were elevated in each 10-year category of union membership and were significantly elevated after 20 years. Significant elevations after 30 years as a union member were observed for laryngeal cancer, benign neoplasms, and suicide. With regard to injuries, there were deficits in risk of fatal falls but increased risks for ''all other

TABLE III. Observed Number of Deaths and Proportionate Mortality Ratios for Selected Causes by Years of Union Membership Among Male Operating Engineers Who Died, 1988–1993

	Years of union membership									
	<10		10–20		20–30		30+		Total	
Causes of death	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR
All cancers	103	1.20	378	1.13	1,357	1.10*	2,978	1.11**	4,816	1.11**
Lung	39	1.36	155	1.36**	576	1.28**	1,145	1.23**	1,915	1.26**
Laryngeal	2	2.30	4	0.80	13	0.97	40	1.40**	59	1.24
Bone	0	—	2	4.08	6	3.17	7	1.85	15	2.39**
Leukemia and aleukemia	3	0.97	16	1.33	58	1.37**	105	1.10	182	1.19*
Benign neoplasms	2	2.18	7	1.91	9	0.72	47	1.65**	65	1.43**
Heart disease	107	0.86	443	0.94	1,543	0.99	3,510	0.96*	5,603	0.96**
Bronchitis	0	—	1	0.39	12	1.46	30	1.41	43	1.31
Emphysema	7	1.87	17	1.25	60	1.32*	156	1.39**	240	1.37**
Transportation injuries	0	—	12	0.98	59	1.18	71	1.01	142	1.05
Falls	2	1.08	5	0.69	15	0.71	36	0.69*	58	0.71**
Other injuries	1	0.59	12	1.48	55	1.80*	68	1.24	133	1.43**
Suicide	5	1.79	14	0.97	60	1.00	127	1.40**	206	1.22**

OBS, observed (number of deaths); PMR, proportionate mortality ratio.
*$P < 0.05$.
**$P < 0.01$.

types of injuries'' after 10 years as a union member. No significant trend with years of union membership was observed for heart disease or any other cause of death using the chi-square test for trend [Breslow et al., 1983].

Age at Death

PMRs for selected causes by 10-year, age-at-death categories after age 40 are presented in Table IV (prior to age 40 there were only five deaths). For all cancers combined and for cancers of the lung there were statistically significant elevated risks of death for each category after age 50. Deaths due to bone cancer and leukemia and aleukemia were elevated for each 10-year age category. Deaths from emphysema and suicide were significantly elevated after age 60. With regard to fatal injuries, the category ''other injuries'' showed statistically significant increased risks in age groups 40–49 and 50–59, whereas deaths due to falls were well below expectation for each 10-year age period except for age 40–49, in which only 2 deaths occurred. For all fatal injuries combined, the average age at death among Operating Engineers was 67.8 (standard deviation = 12.6) as compared to 73.8 (standard deviation = 9.5) for all other causes of death, a difference that was not found to be statistically significant using the z-test.

Geographic Region

Geographic regional analysis of mortality was conducted to examine any unusual patterns (Table V). The one striking feature of this analysis was the statistically significant elevated risks ($P < 0.01$) for cancers of the bone, and for leukemia and aleukemia in Region 2. In fact, 9 of the 15 deaths due to bone cancer in the entire study were observed in Region 2, an almost sixfold excess. Region 2 comprises the midwestern states (Appendix A).

Race

Among the 233 deaths for nonwhite males, PMRs were significantly elevated for only two causes: all cancers combined (N = 85, PMR = 1.25, CI = 1.00–1.54) and kidney cancer (N = 6, PMR = 5.48, CI = 2.00–11.92). Causes that were elevated included lung cancer (N = 30, PMR = 1.29, CI = 0.87–1.85), stomach cancer (N = 7, PMR = 2.24, CI = 0.90–4.61), and rectal cancer (N= 3, PMR = 3.21, CI = 0.66–9.40).

DISCUSSION

Statistically significant elevated PMRs among the Operating Engineers were observed for cancer of the trachea,

TABLE IV. Observed Number of Deaths and Proportionate Mortality Ratios for Selected Causes by Age at Death Among Unionized Male Operating Engineers Who Died, 1988–1993

	Age at death											
	40–49		50–59		60–69		70–79		80+		Total	
Causes of death (ICOA-9)	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR
All cancers	61	1.27	428	1.19**	1,437	1.07*	1,980	1.12**	1,908	1.13**	4,816	1.11**
Lung	18	1.18	178	1.23*	609	1.11*	849	1.38**	261	1.31**	1,915	1.26**
Laryngeal	1	2.00	5	0.94	17	0.98	21	1.20	15	2.34*	59	1.24
Bone	1	5.88	1	1.43	4	2.35	5	2.00	4	3.45	15	2.39**
Leukemia and aleukemia	5	2.35	11	1.05	55	1.32	71	1.10	39	1.16	182	1.19*
Benign neoplasms	0	—	0	—	20	1.79	26	1.40	19	1.59	65	1.43**
Heart disease	66	1.10	379	0.99	1,399	1.02	2,149	0.93*	1,610	0.95*	5,603	0.96**
Bronchitis	0	—	1	0.83	9	1.32	15	1.00	18	1.82	43	1.31
Emphysema	1	2.13	7	1.00	58	1.31*	118	1.42*	56	1.41*	240	1.37**
Transportation injuries	21	1.48	36	1.36	31	0.82	38	0.99	16	0.83	142	1.05
Falls	2	1.25	3	0.57	9	0.64	19	0.72	25	0.73	58	0.71**
Other injuries	11	2.08*	30	2.22**	33	1.33	34	1.20	24	1.23	133	1.43**
Suicide	12	0.92	25	0.83	57	1.17	69	1.31*	43	1.74*	206	1.22**

OBS, observed (number of deaths); PMR, proportionate mortality ratio.
$^{*}P < 0.05$.
$^{**}P < 0.01$.

TABLE V. Observed Number of Deaths and Proportionate Mortality Ratios for Selected Causes by Geographic Region[a] Among Unionized Male Operating Engineers Who Died 1988–1993

	Region 1		Region 2		Region 3		Region 4		Region 6		Region 9		Region 10		Region 97		Region 98	
Cause of death	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR
Cancers																		
Larynx	17	1.89*	16	1.34	5	3.29*	2	0.47	3	0.85	5	1.30	9	0.79	0	—	1	1.37
Lung	344	1.20**	475	1.25**	56	1.15	201	1.45**	115	1.00	176	1.40**	469	1.28	35	1.25	40	1.71**
Bone	2	1.69	9	5.64**	0	—	0	—	2	4.12	1	1.90	1	0.65	0	—	0	—
Leukemia and aleukemia	25	0.92	55	1.50**	4	0.87	16	1.16	15	1.26	19	1.44	38	1.03	5	1.81	3	1.33
Benign neoplasms	4	0.95	6	1.05	1	1.41	5	2.25	4	2.02	5	2.28	8	1.32	2	4.56	2	5.67
Heart disease	1,045	1.01	1,402	1.00	181	1.04	546	1.02	461	0.97	477	0.91*	1,298	0.89	86	0.81	81	0.94
Bronchitis	3	0.51	14	1.75	2	2.03	2	0.64	4	1.43	3	0.96	15	1.75	0	—	0	—
Emphysema	32	1.02	51	1.21	2	0.37	23	1.42	23	1.61*	25	1.57*	76	1.72	4	1.22	4	1.52
Transportation injuries	16	0.61*	34	0.95	7	1.63	15	1.18	7	0.70	14	1.35	40	1.28	4	1.78	6	2.76*
Falls	15	1.07	12	0.62	0	—	1	0.13**	8	1.16	4	0.53	14	0.68	2	1.39	1	0.84
Other injuries	20	1.14	32	1.35	3	1.03	18	2.09**	11	1.56	13	1.73	30	1.35	0	—	4	2.79
Suicide	23	0.70	44	0.99	10	1.90	17	1.08	16	1.27	18	1.36	66	1.68	3	1.04	4	1.45
All cancers	893	1.12**	1,206	1.13**	130	0.96	437	1.11*	369	1.10*	418	1.13	1,164	1.10	92	1.16	81	1.24

[a]Region, see Appedix A.
OBS, observed (number of deaths); PMR, proportionate mortality ratio.
$^{*}P < 0.05$.
$^{**}P < 0.01$.

bronchus and lung, for bone cancer, for leukemia and aleukemia, and for deaths due to ''other and unspecified cancers.'' These categories were all elevated in the PCMR analysis with the former two remaining statistically significant. For noncancer deaths, significantly elevated risks were observed for benign and unspecified neoplasms, pneumoconiosis and other respiratory diseases, emphysema, suicide, and all other injuries.

Lung Cancer

The study found a significantly elevated PMR for malignant neoplasms of the lung; however, this result was not found to be related to duration of union membership. The small decrease in risk of lung cancer by duration of union membership may, however, have at least been partially related to the slight increase of heart disease risk with duration of union membership.

Possible contributors to the overall increase in lung cancer may include diesel engine exhaust, asphalt fumes, silica, welding fumes, asbestos, and smoking. Operating Engineers may be exposed to diesel engine exhaust emitted from the heavy-duty trucks and equipment they operate. Diesel exhaust is a highly complex mixture of gases, vapors, and of particles (soot) that has been shown to be carcinogenic. The particles are of most importance in considering the toxicity of diesel exhaust because (1) they are small and readily inhalable and can therefore reach the lower respiratory system where they are retained; (2) several thousand organic compounds can be absorbed on the surface of the carbon particle aggregates, many of which are cytogenic, carcinogenic, or mutagenic; and (3) they tend to be retained for long periods of time in the lower respiratory tract where they accumulate, favoring induction of chronic pulmonary effects such as respiratory impairment and carcinogenesis [Health Effects Institute, 1995].

The National Institute for Occupational Safety and Health (NIOSH) has recommended that ''whole diesel exhaust be regarded as a potential occupational carcinogen in conformance with the Occupational Health and Safety Act (OSHA) Cancer Policy (29 CFR 1990),'' although currently there is no OSHA standard specifically for diesel exhaust. The NIOSH recommendation was based on the results of both animal studies [Ishinishi et al., 1986] and studies of occupational groups exposed to diesel exhaust. The IARC [1989] states that there is sufficient animal data but limited human evidence for the carcinogenicity of diesel engine exhaust. Most epidemiologic studies have suggested an association between occupational exposure to whole diesel exhaust and lung cancer; several studies [Boffetta et al., 1988; Carstensen et al., 1989; Garshick et al., 1987; Edling et al., 1987; Hayes et al., 1989; Wong et al., 1985; Decoufle et al., 1977] have observed excess lung cancer risk specifically among heavy equipment operators. Boffetta et al. [1989] conducted a prospective study of over 476,000 men exposed to diesel exhaust in various occupations. The results showed a positive trend by duration of exposure between diesel exhaust and lung cancer for those men with 16 or more years of exposure (relative risk (RR) = 1.21) and a significantly elevated risk of lung cancer specifically among heavy equipment operators (RR = 2.60, 95% CI = 1.12–6.06). Carstensen et al. [1989] examined data from the Swedish Cancer Registry for the incidence of lung cancer among 97 specific occupations from 1961–1979. Data regarding smoking habits in different occupational groups were obtained from a random sample of 1% of the survey group. After adjustments for smoking, only 3 of the 97 occupations showed a significantly increased relative risk of lung cancer with time worked: foundry workers ($P = 0.02$); stationary engineers ($P = 0.04$); and construction operating engineers ($P = 0.02$). The authors suggested that the increased risk in lung cancer incidence among operating engineers was most likely due to diesel exhaust exposure. In a case-control study of lung cancer in which occupations and smoking histories were evaluated, Hayes et al. [1989] found a smoking-adjusted odds ratio of 2.1 (CI = 0.6–7.1) among heavy equipment operators who had worked 10 years or longer.

Two previous studies conducted specifically among Operating Engineers reported elevated mortality from lung cancer. Wong et al. [1985] conducted a retrospective cohort study of more than 34,000 men with at least 1 year of membership in the Operating Engineers' union of Locals 3 and 3A, which included northern California, Utah, Nevada, Hawaii, and Guam. The overall standardized mortality ratio (SMR) among the cohort was statistically significantly below expectation at 0.81. However, the authors reported a significant trend toward increasing lung cancer risk with duration of union membership as well as a statistically significant elevated risk of lung cancer among all retired members (SMR = 1.64) and among those retiring at or after age 65 (SMR = 1.30). Decouflé et al. [1977] conducted a PMR study of Operating Engineers selecting those members where a death benefit had been paid in 1967. The overall risk from cancer of all sites was significantly elevated, at 1.12 ($P < 0.01$); this result was similar to the PMR of 1.11 ($P < 0.01$) observed in our analysis. For lung cancer, the risk in the Decoufle study was 1.30 ($P < 0.01$); our study observed a PMR of 1.26 ($P < 0.01$).

Approximately 20% of Operating Engineers are involved on a full-time basis in grading, paving, resurfacing, and repaving highways, roads, and streets. Asphalt, which is a mixture of paraffinic, naphthenic, cyclic, and aromatic hydrocarbons as well as heteroatomic compounds containing sulfur, nitrogen, and oxygen, is the major paving application on these surfaces [Asphalt Institute, 1990]. Asphalt has also been shown to contain relatively small amounts of carcinogenic benzo(a)pyrene [Craft, 1983].

Dermal and airborne exposures to asphalt fumes have been shown to pose a carcinogenic risk in experimental animals and asphalt fumes have been classified as a possible human carcinogen by the IARC (IARC group 2B). NIOSH presently recommends that asphalt fumes be considered a potential occupational carcinogen [NIOSH, 1988] and that the airborne exposure limit be kept below 5 mg/m^3. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends a threshold limit value (TLV) for asphalt fumes of 5 mg/m^3 as an 8-hr time-weighted average (TWA) [ACGIH, 1995] to ‘‘reduce the risk of possible carcinogenicity’’ [ACGIH, 1992]. OSHA has has not established a permissible exposure limit (PEL) for asphalt fumes.

Laboratory studies have shown chemical extracts of asphalt fume to have cancer-causing and mutagenic properties. Painting of asphalt extracts on mouse skin produces tumors that increase with dose [NIOSH, 1989]. Other laboratory studies show DNA changes in mouse lung and skin cells [Schoket et al., 1988a] and in human fetal cells exposed to asphalt fumes [Schoket et al., 1988b].

The human epidemiological studies, however, have been less definitive than the animal data in suggesting an association between occupational exposure to asphalt and lung cancer. The IARC monograph on asphalt [IARC, 1985] stated that there was ‘‘inadequate evidence that bitumens alone are carcinogenic to humans.’’ A 1991 review by Chiazze et al. of studies regarding the carcinogenicity of asphalt in humans since the IARC monograph, also suggested that ‘‘epidemiological data . . . do not fulfill the criteria for showing a causal association between exposure to asphalt and development of cancer.’’ Nevertheless, studies by two investigators [Hansen, 1989, 1991; Engholm et al., 1991] have reported elevated lung cancer incidence and mortality among workers exposed to asphalt. Hansen [1989] examined the cancer incidence of asphalt workers who had been involved in road paving between 1959 and 1984. Among those workers with a minimum latency period of 15–20 years, the standardized incidence ratio for lung cancer was 3.4 (95%CI = 2.3–5.0). The excess incidence persisted after correction for smoking habits. In a later study, Hansen et al. [1991] reported on the mortality of the same cohort; the results showed a significant excess risk of lung cancer mortality (SMR = 2.9, CI = 1.9–4.3). Engholm et al. [1991] has also reported slightly elevated mortality (SMR = 1.10) and incidence (SIR = 1.24) of cancer of the lung among road pavers using asphalt, although the numbers, 7 and 8 cases, respectively, were small and the results not statistically significant. A further analysis was reported in the paper regarding a case-control study of lung cancer within the cohort that showed a relative risk estimate among asphalt pavers to be in the order of 3 when adjustments were made for smoking and population density. However it should be pointed out that the Hansen and Engholm studies were based on European data, which may be a different exposure than received by U.S. workers.

Other agents to which Operating Engineers may be exposed that are also considered possible or confirmed human lung carcinogens, include silica dust [Steenland et al., 1996; Kurppa, 1986; Westerholm, 1986; Goldsmith, 1982], coal tar pitch [Steenland et al., 1996; Chang et al.,1992; Partanen et al., 1994; Silverstein, 1985], which had been previously used in asphalt in the United States, welding fumes [Beaumont et al., 1981; Stern, 1987; Singleton et al., 1986; Simonato et al., 1991] and asbestos [Steenland et al., 1996; Selikoff, 1969; Selikoff et al., 1965]. The possible relationship between smoking and increased lung cancer mortality is discussed in the section Smoking-Related Deaths.

Bone Cancer

The elevated PMR for bone cancer among this population was statistically significant (N = 15, PCMR = 2.14, CI = 1.19–3.52). Furthermore, 9 of the 15 bone cancer deaths occurred in Region 2 where an almost sixfold excess risk of bone cancer was observed. Bone cancer has been induced in animals by various chemicals, although internal exposures to bone seeking radium isotopes is the only occupational exposure that has been associated with bone cancer [Kessler et al., 1987]. However, at least two previous epidemiologic studies have associated bone cancer with silica exposure. Forastiere et al. [1989] found a statistically significant excess risk of bone cancer mortality (odds ratio = 4.1, CI = 1.3–9.5) among workers exposed to silica dust as did Steenland et al. [1986] in a cohort of granite cutters (PMR = 3.14, CI = 1.15–6.85).

Leukemia and Aleukemia

Leukemia and aleukemia were statistically significantly elevated in the PMR analysis but were only elevated in the PCMR analysis. One previous study examining the incidence of leukemia by occupation over a 15-year period in more than one million U.S. residents observed a statistically significant elevated risk ($P < 0.01$) among heavy equipment operators, the result being the highest risk among all occupations evaluated [Morton et al., 1984]. Potential exposures among Operating Engineers that may be associated with leukemia include ionizing radiation exposures from X-ray testing of pipeline welds, electromagnetic field exposure associated with welding, and asphalt fume exposure.

A small percentage of Operating Engineers perform X-ray testing of pipeline welds (welding two joints together and X-raying the weld [radiography]) and, therefore, may be exposed to ionizing radiation. It has been shown that radiographers, on average, have an annual dose equivalent of approximately 430 mrem (4.3 mSv) and that 22% have annual dose equivalents of 500 mrem (5.0 mSv) or more [NCRP, 1989]. The current standard for radiation exposure is an annual total effective dose equivalent not to exceed 5,000 mrem (50.0 mSv) [CFR, 1991]. According to the union, all the Operating Engineers who perform X-ray testing of pipeline welds in the United States are from Region 2 (Appendix A), which had the highest PMR for leukemia of all the regions examined. These Operating Engineers are required to wear badges to record their radiation exposure. Being considered is a plan to investigate this potential association further with a nested case-control study that will allow a better assessment of actual job duties and exposures.

Elevated leukemia mortality has also been observed among workers with electromagnetic field exposures, including welders [Savitz et al., 1995; London et al., 1994; Guenel et al., 1993; Ciccone et al., 1993; Preston-Martin, 1988; Juutilainen et al., 1990; Stern, 1986]. In addition to welding on pipelines, Operating Engineers may also weld equipment when necessary for repair.

In at least one epidemiologic study, asphalt fumes were associated with leukemia. Bender et al. [1989] analyzed cancer mortality during 1945–1984 in a cohort of 4,849 highway maintenance workers exposed to various substances including asphalt. The SMR for leukemia for those workers with 30–39 years of work experience was 4.3 (CI = 1.7–8.8).

Skin Cancer

No excess risks of death from melanoma or other skin cancers were observed in the current study. Elevated skin cancer mortality was of concern because operating engineers spend a great deal of their time outdoors exposed to the sun [Kricker et al., 1995; Armstrong et al., 1995; Vitasa et al., 1990] and because they are exposed to asphalt [Niemeier et al., 1988; Bull et al., 1985; Robinson et al., 1984]. Niemeier et al. [1988] showed that exposure to asphalt fume condensates causes skin tumors in two strains of mice. Bull et al. [1985] and Robinson et al. [1984] showed similar results using an asphalt-based paint solution. However, both Bull and Robinson concluded in their studies that the asphalt-based paints used contained insufficient PAHs to produce the tumorigenic responses noted and that some other component may have initiated the tumors. The epidemiologic study of mastic asphalt workers by Hansen [1989] did not show an excess risk of skin cancers despite the fact that the workers had been primarily employed outdoors.

Nonmalignant Respiratory Diseases

The PMR for emphysema was statistically significantly elevated for deaths occurring after 20 years membership within the union. Higher risks of emphysema are associated with both smoking and occupational exposure to heavy airborne concentrations of fumes, dusts, and gases [Wong et al., 1985; Sullivan et al., 1995]. The first authors had found a statistically significant elevated risk of emphysema (SMR = 1.65, $P < 0.01$) among members of Local 3 and 3a of the Operating Engineers union, two of the many local unions included in our analysis. The emphysema risk increased with duration of union membership and was especially high among retirees where the SMR reached 2.77. Since a random sample of union members in Locals 3 and 3A did not indicate any difference in smoking habits between the union members and the general U.S. population, Wong concluded that smoking was considered ‘‘not a likely significant confounding factor’’ for this result. Sullivan et al. [1995] calculated prevalence rates and rate ratios of respiratory conditions among construction workers based on data from the 1988 National Health Interview Survey. For emphysema, Sullivan observed a prevalence rate of 25.8 per 1,000 male construction workers and a rate ratio of 1.34 when comparing construction workers with other workers in the survey.

The role of dust exposure as it relates to emphysema in this population is unclear. However, it has been reported that members of this union historically have been exposed to concentrations of respirable dust, especially silica, substantially in excess of permissible levels from bridge, road, and tunnel construction; concrete and granite cutting; and blasting operations, among others [NIOSH, 1992]. The PMR for deaths from silicosis was elevated but not statistically significant 1.49 ($P > 0.05$).

Fatal Injuries

We observed a statistically significant elevated risk of 43% over expected for the death category ‘‘other injuries.’’ From examination of the death certificates, we observed that many of the deaths were due to crushing under/in machinery, tractor rollover, run over by crane, thermal burns due to gas explosion, and struck by object while operating a bulldozer. The injury mortality rate in the construction industry, in general [Toscano et al., 1995], and among Operating Engineers, specifically, is one of the highest among all major industries and occupations in the United States. A previous NIOSH analysis of cause-of-death from death certificates for the years 1984–1986 from 19 U.S. states has shown that Operating Engineers have a statistically significantly elevated risk from ‘‘other types of injuries’’ ($P < 0.05$) [Robinson et al., 1995]. Parsons [1989] examined the risk of nonfatal and fatal injuries among all occupations within the construction industry and numerically ranked the occupations by risk factor, accident type with related costs, and employment. Operating Engineers were ranked third among all high-risk occupations, behind only laborers and carpenters. Other studies which examined disability and/or mortality results by occupation have also shown that Operating

Engineers have an increased risk of death from fatal injuries [Decoufle, 1977; Guralnick, 1963; USDHHS, 1967; Registrar General, 1958, 1971; Buskin, and Paulozzi 1987]. Decoufle [1977] observed a threefold excess risk of fatal accidents occurring at places other than home among Operating Engineers. In a 1950 study of mortality by occupation [Guralnick, 1963], a significantly high rate of death from injuries occurred ‘‘while at work’’ for men categorized as ‘‘cranemen, hoistmen, and construction machinery operators’’; relative mortality was 173% greater than the national average. A 1961 Registrar General’s report on occupational mortality for England and Wales showed a fourfold risk of dying from nontransportation injuries among ‘‘operators of earth moving and other construction machinery’’ [Registrar General, 1971]. Buskin and Paulozzi [1987] in a study of fatal injury in Washington State between 1973–1983 found that construction operating engineers had one of the highest PMR of all construction jobs evaluated (PMR = 2.36; CI = 1.54–3.46). It was interesting to note that Pollack et al. [1996], in an analysis of various construction trades, noted that only 5% of fatal injuries among operating engineers were due to falls, while transportation injuries and ‘‘contact with objects and equipment’’ comprised 48.2% and 33.3%, respectively, of all fatal injuries. In this study, a similar result was observed; the death category due to falls was significantly lower than expected, whereas the ‘‘other injury’’ category was significantly elevated.

Smoking-Related Deaths

Workers in the construction industry may have a greater risk of smoking-related diseases because of their excessive smoking experience [Walrath et al., 1985; Hrubec et al., 1992] and the potential synergistic effects between smoking and various exposures. Information regarding smoking status or amount of cigarette smoking among members of this group of Operating Engineers was not available. PMR results for those diseases that have been most associated with smoking were, for the most part, elevated. The PMRs for lung cancer and emphysema were significantly higher than expected, and the PMR for bronchitis was higher (but not significantly) than expected, while the PMR for diseases of the heart was significantly below expected, PMR = 0.96 but higher than expected for a working population. Since lung cancer and nonmalignant respiratory disease may be associated with smoking and also with some of the agents present in the operating engineers’environment, the relative contributions of smoking and occupational exposure cannot be accurately evaluated.

Strengths and Limitations

Like all epidemiologic studies, this study has some potential limitations and strengths that should be considered. The representativeness of the group studied relative to all operating engineers in general is an important strength. We chose all deaths for the years 1988–1993 for those members of the IUOE as our study group for the following reasons. First, the IUOE is the largest single group of operating engineers in the world. Second, the number of deaths in the study, 15,843, had sufficient power for examining the results from even the rarest causes of death. Third, the deaths from 1988–1993 were the most recent and, therefore, the most representative of both current and past work practices and exposures of Operating Engineers. Fourth, all membership data had been computerized since 1988 making the study more accurate, as well as more efficient to complete. Finally, and probably most importantly, the local dues that an operating engineer was required to contribute went to the International Union to pay into the death beneficiary fund. Even when a worker retired, he still was required to pay into the fund although at a reduced amount. Therefore, we believe that our study of deceased operating engineers who received death benefits was reasonably representative of all operating engineers who had worked long enough to be vested (1 year).

A second strength of this PMR study is derived from the existence of the death benefit fund in the International union. Studies comparing PMRs with SMRs have shown that PMRs are useful indicators of disease risk, showing a high correlation, in most cases, with SMRs and especially when there is a financial interest for survivors to report deaths [Roman, 1984; Beaumont, 1981; St. Claire, 1981]. Beneficiaries of deceased active and retired Operating Engineers receive a death benefit, the amount of which varies depending on the member’s years of service, upon notification of a member’s death.

A potential limitation in the PMR methodology is that the magnitude of each cause of death is dependent upon the magnitude of the PMRs for other causes of death. This can be especially important if a specific common cause has a relatively high or low mortality. If the PMR for the common cause of death is high, the PMRs for other causes are artificially deflated and vice versa. Typically in a working population, the risk of heart disease is lower than expected due to the so called ‘‘healthy worker effect’’ and, therefore, in a PMR study the other causes would be artificially elevated. In this study, the risk of heart diseases had a borderline statistically significant low PMR of 0.96 (CI = 0.94–0.99), with 5,603 observed deaths and 5,810 expected deaths. The difference of the 207 deaths would have been spread over the remaining 99 causes but would have been differentially distributed, mostly to lung cancer, and, therefore, only would have slightly increased the PMRs for the other remaining causes of death.

Another possible limitation of this study, as in most PMR studies, is the fact that members who terminate their employment prior to retirement or death are not included in the analyses. It has been shown [Fox and Collier, 1976; Redmond and Breslin, 1975] that these individuals tend to have different mortality patterns than individuals who remain employed until retirement. In current employees, relatively fewer cancer deaths are found as compared with terminated employees because cancer deaths are not sudden and cancer patients will usually leave employment some time prior to death. Therefore, it is possible that malignant neoplasms were underestimated in this study since workers who left the union before retirement or death were not included in our analyses.

PMR studies are retrospective and, therefore, use existing records as the basis for analysis. Specific exposures to which individual operating engineers would be exposed are sometimes difficult to evaluate, since many local unions do not track sites, specific job tasks performed, or exposures, when an operating engineer is dispatched to a particular construction job. A nested case-control study would be more suited to evaluate the types, intensity, and length of exposures of the members. A nested case-control study is being considered to examine the excess bone cancer and leukemia and aleukemia deaths from Region 2, which were found to be statistically significant.

There are several additional limitations. First, PMR study results are based on death certificate data, which have little information on potential confounding factors such as tobacco, alcohol use, and socioeconomic status. Second, some causes of death (i.e., skin cancer) are normally not fatal and, therefore, a mortality study would not necessarily observe an increase in risk. An incidence study would be better suited to evaluate the risks for these types of diseases. Finally multiple significance testing may result in associations that arise from chance alone. Since PMR studies are exploratory in nature, the significant results found should be confirmed in additional studies.

SUMMARY AND RECOMMENDATIONS

Our results among 15,843 members of the IUOE in this study seem to confirm earlier findings of increased risk of death from lung cancer among operating engineers. Some of the excess lung cancer risk may have been due to occupational exposures to diesel exhaust, asphalt and/or welding fumes, silica dust, or possibly coal tar pitch or some other toxic agent. Excess cigarette smoking, however, cannot be ruled out as a possible contributing factor. The reasons for the excess deaths from bone cancer and from leukemia and aleukemia are unknown; however, at least one of the potential exposures in the operating engineers' environment, ionizing radiation, has been associated with these diseases in other studies. The increased risk of death from injuries is believed to be related to the heavy-duty equipment/machinery being used by Operating Engineers. PMRs for heart disease were slightly, but significantly, lower than expected.

Based on the results of this study, the following recommendations may help reduce morbidity and mortality from job-related causes. First, study the causes of injuries among operating engineers. Such studies are necessary to identify risk factors and to assist in the development and targeting of injury prevention and intervention strategies. (Routinely collecting data on the makes and models of heavy equipment involved in fatal accidents will help safety engineers redesign equipment with reduced crushing, rollover, and electrocution hazards.) Second, reduce exposures to diesel fumes to the lowest feasible concentration using state-of-the-art engineering controls and work practices. Third, use engineering control, containment measures, and improved work practices to reduce workers' exposure to silica, welding, and asphalt fumes, asbestos, and other hazardous materials during renovation, demolition, and maintenance work. Fourth, conduct a case-control analysis for bone cancer and for leukemia and aleukemia, both diseases for which ionizing radiation can be considered a potential cause, by obtaining work history data and radiation badge readings that may render some clue as to why the results in Region 2 were significantly elevated. Fifth, provide periodic medical examinations to those workers who have exposure to known hazardous agents. Finally, develop health promotion programs to include efforts aimed at smoking cessation because of the well known harmful effects from smoking and the potential interaction between smoking and other exposures in the workplace of operating engineers.

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APPENDIX A. Regional Areas

Region	States included
1	Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont
2	Indiana, Illinois, Kentucky, Kansas, Michigan, Missouri, Ohio, Oklahoma
3	District of Columbia, Maryland, North Carolina, South Carolina, Virginia, West Virginia
4	Arkansas, Alabama, Florida, Georgia, Louisiana, Mississippi, Tennessee
6	Iowa, Minnesota, Nebraska, North Dakota, South Dakota, Wisconsin
9	Montana, Oregon, Washington, Wyoming
10	Arizona, California, Colorado, Hawaii, Nevada, New Mexico, Utah
97	Arkansas,[a] Louisiana,[a] Texas[a]
98	Texas

[a]Petroleum-related work only.

APPENDIX B. Description of Operating Engineers' Equipment

The following power equipment and machinery is recognized as with the jurisdiction of the International Union of Operating Engineers. The International Union of Operating Engineers claims jurisdiction of all equipment as granted by the AFL Convention, November 11–23, 1907, Resolution No. 124, and also claims jurisdiction of any new equipment introduced to the industry. This listing is not to be considered exclusive.

Air Compressor	Incinerators
Associated Monitoring Instruments	Pugmill
Backhoe	Pump & Treat Systems
Barrel Grappler Devices	Pumpcrete Machine
Batchplant	Power Shovel
Boom Truck	Power Machine
Concrete Breaker	Robotic Equipment Clamshell
Concrete Pump	Scraper (Self-propelled)
Concrete Saw	Side Boom Tractor
Crane	Skid Steer Loader
Crusher	Slip Form Paver
Dozer	Sloper Paver
Grader	Sweeper
Endloader	Tractor
Farm Tractor	Trencher
Fork Lift	Vibrating Compactor
Generator	Welder
Gradall	Welding Machine
Grader	Well Drilling Rig
Heater	

APPENDIX C. Description of Operating Engineers' Duties

1. *Highway, road, street and sewer construction, and grading and paving work:* Defined as all phases of work pertaining thereto, including overpasses, underpasses, bridges, except pile driving, bridge alterations, sewer and water pipelines, or any other pipeline work, oilostatic high-voltage underground cable lines and transportation mainline pipelines, duct lines, street grading, drainage, curb setting, sidewalks, grade separations, land improvement, site clearing, grading and paving, resurfacing and repaving (excepting bistate pipelines, water crossings, bridges, and tunnels). Excavation, embankment, grading, paving, and drainage around and adjacent to bridge structures are included in this category.

2. *Heavy construction work:* Heavy construction is defined as construction and alteration of Oil Refineries, Power Plants, Chemical Plants, Sewage Disposal Plants, Filtering Plants, Incinerators, Atomic Energy Plants, Missile Bases, all work performed under compressed air, airports, foundations, pile driving, piers, abutments, retaining walls, viaducts, water crossings pertaining to pipe line work, shafts, tunnels, subways, track elevations, elevated highways, resurfacing work on bistate bridges and tunnels, reclamation projects, sanitation projects, aqueducts, irrigation projects, water power development, hydroelectric development, transmission lines, locks, dams, dikes, docks, levees, revetments, channels, channel cutoffs, intakes, dredging projects, jetties, breakwaters, harbors, offshore terminals, power plants and other installations, excavation and disposal of earth, garbage and rock projects in connection with the above, and any other bridges and drainage structures, including the assembly, operation and maintenance and repair of all equipment, vehicles and other facilities used in connection with, and serving, the aforementioned work and services.

3. *Building construction work:* Building Construction is defined as construction of building structures, including modifications thereof, or additions or repair thereto, intended for use for shelter, protection, comfort or convenience. Building construction includes the demolition of, and excavation and foundations for, building construction.

4. *Oilostatic cables and transportation mainline pipelines (including testing):* Oilostatic high-voltage underground cables and transportation mainline pipelines are defined as all phases of work pertaining to oilostatic high-voltage underground cable lines and transportation mainline pipelines, the construction, installation, treating, reconditioning, testing, taking-up, relaying or relocation of cross-country pipelines or any segments thereof transporting coal, gas, oil, water, or other transportable materials, vapors or liquids, including portions of such pipelines within private property boundaries, up to the first metering station or connection, as well as gathering lines that connect directly from the wells to the mainline pipe lines and gathering lines to or from gasoline extraction and gas dehydration plants and water flood lines up to the first metering station or connection are likewise included.

The phase, ''first metering station or connection'' means that point that divides mainline transmission lines or higher pressure lateral and branch lines from lower pressure distribution systems. If a metering station or connection is located on a mainline transmission line, the work covered includes the construction of all pipelines up to the point at which lower pressure distribution systems take off from higher pressure lateral and branch lines.

5. *Sewer construction work:* Sewer Construction is defined as construction, repair, and alteration of storm sewers; sanitary sewers; combined storm sewers and sanitary sewers; telephone, gas and electric, fiberoptics, (excluding drainage systems and telephone, gas and electric and fiber optics lines that are part of overall road, street and highway construction, or heavy construction or building work); and pump stations with a cost not in excess of $4,000,000.00. Sewer agreement manning applies to all projects with a cost of $3,000,000.00 or less. Outfalls are considered heavy construction work.