Proportionate Mortality Among Unionized Roofers and Waterproofers

Frank B. Stern, BBA, MS,[1] Avima M. Ruder, PhD,[1] and Guang Chen, MD[2]

Background *The United Union of Roofers, Waterproofers, and Allied Workers (UURWAW) is one of the 15 building and construction trades departments in the AFL-CIO. The U.S. roofing industry, including both roofing and waterproofing applications, both unionized and nonunionized, comprises about 25,000 firms, employing approximately 300,000 people, about 200,000 of whom are involved in the application of roofs. The specific toxins to which roofers may be exposed at the job site include, among others, bitumens (asphalt and/or coal tar pitch) as well as asbestos and fiberglass from roof removal operations. Excess deaths from occupational injuries are also of concern.*

Methods *This study evaluated causes of mortality among 11,144 members of the UURWAW. Age-adjusted proportionate mortality ratios (PMRs) were computed with 95% confidence intervals (CI) using U.S. age-, gender-, and race-specific proportional mortality rates for the years of the study, 1950–1996.*

Results *Statistically significant increased PMRs were found for all injuries (PMR = 142, CI = 134–150), especially falls (PMR = 464, CI = 419–513) and other injuries (PMR = 121, CI = 107–137), cancers of the lung (PMR = 139, CI = 131–148), bladder (PMR = 138, CI = 111–170), esophagus (PMR = 134, CI = 107–166), larynx (PMR = 145, CI = 106–193), and cancers of other and unspecified sites (PMR = 130, CI = 112–149), pneumoconioses and other nonmalignant respiratory diseases (PMR = 115, CI = 103–128), and homicides (PMR = 153, CI = 135–172). The occupational exposures which may have contributed to the excess risks of malignant and nonmalignant respiratory diseases include, among others, asphalt fumes, coal tar pitch volatiles and asbestos; however, cigarette smoking must also be considered a contributing factor.*

Conclusions *The present study underscores the need to control airborne exposures to hazardous substances and especially to examine fall prevention efforts within the roofing industry.* Am. J. Ind. Med. 37:478–492, 2000. *Published 2000 Wiley-Liss, Inc.*†

KEY WORDS: roofer; waterproofer; construction; proportionate mortality ratio; injuries; cancers

INTRODUCTION

The United Union of Roofers, Waterproofers, and Allied Workers (UURWAW) is one of the 15 building and construction trades departments in the AFL-CIO. The UURWAW began in 1903, with two separate organizations totaling 1600 members. The union was the leading labor

[1]Division of Surveillance, Hazard Evaluations, and Field Studies, National Institute for Occupational Safety and Health, 4676 Columbia Parkway, Cincinnati, Ohio 45226.
[2]Division of Safety Research, National Institute for Occupational Safety and Health, ALOSH Building, 1095 Willowdale Road, Morgantown, West Virginia 26505.
E-mail: FBS1 @CDC.GOV

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representative for roofers as well as waterproofers and various other related trades. In 1919 the two early organizations merged and by 1944 had over 7000 members. By 1978 the UURWAW had a membership of over 28,000, approximately the same number as today. Currently the U.S. roofing industry, including both roofing and waterproofing applications, both unionized and non-unionized, comprises about 25,000 firms, employing approximately 300,000 people, about 200,000 of whom are involved in the application of roofs (NIOSH, 1996a). As of 1995, approximately 144,000 of these roofers were estimated to be exposed to either asphalt or coal tar fumes or both, with approximately 50,000 conducting hot asphalt work (NIOSH, 1996a).

UURWAW members perform three distinct work processes: commercial, industrial and residential roofing and waterproofing. Roofing is the process of covering building structures with various types of roofing materials, other than sheet metal, such as asphalt and gravel, composition shingles or sheets, slate, tile or wood shingles. Waterproofing, on the other hand, is a system applied to a structure (mainly the foundation) as a permanent barrier to water under hydrostatic pressure or as a protection against the penetration of water with no hydrostatic pressure. (For a more detailed description of the duties of roofers and waterproofers see Appendix I.) Union records do not list trade or changes in trade for individual members; however, we were advised that members of nine of the 92 locals perform a larger amount of waterproofing while members of most other locals perform mainly roofing.

Roofers have potential for exposure to various toxic chemical and physical agents due to the work they perform. A survey conducted during 1981–1983 among a representative sample of 4500 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, 1990b; Sieber et al., 1991]. The results of the survey for roofers by their percentages exposed to various agents are presented in Appendix II. The specific toxins to which roofers may have been exposed at the job site included, among many others, bitumens (asphalt and/or coal tar pitch) as well as asbestos and fiberglass from roof removal operations. Based on the aforementioned exposures, causes of death hypothesized to be elevated in this cohort included lung cancer and various other malignant and nonmalignant respiratory diseases. Excess deaths from occupational injuries were also predicted based upon the literature [Parsons et al., 1986; Bobick et al., 1990; Sorock et al., 1993; Robinson et al., 1995; Suruda et al., 1995; Pollock et al., 1996; Burnett et al., 1997] which has shown that roofers have been known to fall through roof openings and from roof edges as well as from scaffolds and ladders.

This proportionate mortality ratio (PMR) study of the UURWAW was conducted in response to a request from the Center to Protect Workers' Rights, a research arm of the Building and Construction Trades Departments, AFL-CIO. This study is part of a larger initiative to examine the health and safety risks of construction workers in general undertaken in 1991 by the National Institute for Occupational Safety and Health (NIOSH). The purpose of this PMR study is to identify those causes of death in excess among members of the UURWAW as a starting point for possible prevention and intervention activities.

METHODS AND MATERIALS

Study Population

The present study was based on the death benefits file maintained by the UURWAW. The death benefits file consisted of records of deceased members who had been active dues-paying members of the UURWAW and had, therefore, been contributing to the death benefit fund at the time of their deaths, whether they were currently employed or retired. These members must also have been in good standing and not suspended for misconduct or for any violation under the constitution and by-laws of the union. The national union administers the death benefit and requires the local union to submit a death certificate as proof of death to obtain benefits. We chose to study the approximately 11,000 members who died between January 1, 1950, and December 31, 1996. This number of deaths was determined to give adequate statistical power for examining most causes of death. There were no records maintained of workers who stopped paying dues to the UURWAW, so these former union members could not be identified and included in the study.

The UURWAW membership file had been computerized since 1986 and included for each member continuously paying dues since that time (over 45,000 members), name, date of birth, date of death (if deceased), sex, current local, membership number, and retirement status. The UURWAW also maintained a separate computerized audit file of all active members since 1986 with a separate record indicating each date of initiation or reinitiation, each local union worked in, and the time period having worked in each local. The union also maintained microfilm rolls of deceased members who died between 1950 and 1996 and were eligible for a death benefit. The rolls included a copy of the member's application and work history data and, in most cases, a copy of the member's death certificate. If death certificates were not available on microfilm, we obtained copies from the vital statistics office of the state where the member had died.

All causes of death on the death certificates were coded by an experienced and qualified nosologist according to the revision of the International Classification of Diseases in effect at the time of death. The few members who died outside the United States were excluded from the study due to the unavailability of appropriate death rates for analyses.

Statistical Analyses

Due to the limitations of the records available (no records for members who had left the union and had stopped paying dues), proportionate mortality ratio (PMR) analyses were chosen as the appropriate method for study. Two analyses were conducted using the NIOSH Life Table Analysis System (LTAS); one which evaluated the proportionate mortality using underlying causes of death [Steenland et. al., 1990], and a second which evaluated proportionate mortality using all causes of death as listed on the death certificate [Steenland et al., 1992].

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 beginning in 1950–1954 and ending in 1990–1994 (rates for 1990–1994 were also used for deaths in 1995–1996), and by 5-year age groups from 15 to 19 through 80–84 and then 85 years 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 a 95% confidence interval. 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 less than or equal to 6, exact confidence limits were used [Rothman and Boice, 1979]. PMRs were calculated for all causes of death grouped into 92 categories for deaths from 1950 to 1996. For some additional causes, expected death rates were only available from 1960 to 1996; these are specifically noted in the text. PMRs were also calculated for the decade of first membership, the decade of death, age at death, roofing vs. waterproofing, and race.

The multiple cause-of-death analyses using all the causes of death were conducted to reveal any disease excesses not identified using only underlying causes of death. These analyses included the usual underlying cause of death as well as all other causes of death which the physician or other medical provider had noted on the death certificate. These results were compared with those expected using multiple cause-of-death referent rates. Good candidates for these analyses were diseases of long duration, not necessarily fatal, yet serious enough to be noted on the death certificate.

Since the LTAS we used in our analyses currently only examines six injury-related death categories, a reanalysis of injury deaths into 35 detailed categories and sub-categories was undertaken to obtain more cause-specific death information [Dubrow et al., 1993]. The referent population used for this reanalysis was derived from the National Occupational Mortality Surveillance (NOMS) database. This database covers 28 states which have provided death certificate coded data to the National Center for Health Statistics. From 1979 to 1993, 7,240,105 death certificates had been received; of this number, approximately 2 million deaths were of blue collar workers as identified by the United States Bureau of Census Occupational Codes [Bureau of the Census, 1982]. A PMR analysis of the UURWAW file was run for the years 1979–1993 using the entire NOMS database and then using only the blue-collar referent population. The NOMS database had been previously compared with that of the LTAS and the results were found to be remarkably similar [Chen et al., 2000]. Ninety-five percent confidence intervals were used in determining the statistical significance of the results.

RESULTS

Characteristics of the Study Population

A total of 11,370 male deaths among members of the UURWAW was initially identified from the union's membership file and the 40 rolls of microfilm of deceased members. We eliminated 72 deceased members (0.6%) for whom a death certificate could not be obtained leaving a total of 11,298. Date of entering the union could not be determined for 152 members and an additional two members died after the study end date, so these individuals were subsequently eliminated from the analyses. Because there were only eight female members in our file they were eliminated from the analyses. Of the 11,144 total eligible for analysis, there were 10,042 white males (90%) and 1102 (10%) nonwhite males (Table I).

The mean age on first entering the union was 36.6 years (standard deviation {SD} = 10.4) and the mean age at death was 62.3 years (SD = 16.0).

TABLE I. Distribution by Gender and Race of Roofers Union Members Who Died 1950–1996

Gender and race	Certificates available	Certificates analyzed[c]
White males[a]	10176	10042
Nonwhite males[b]	1122	1102
White females	3	–
Nonwhite females	5	–
Total	11306	11144

[a] White includes Caucasian, Latino, Unknown race.
[b] Nonwhite includes Black, Asian, Native American, Other races.
[c] Nearly all the rejections were for missing Date First Employed.

TABLE II. Roofers Union Proportionate Mortality Ratios (PMRs), 1950–1996, Males

Cause of Death (ICDA-9)	Deaths	PMR	95% CI
All causes (000–999)	11144	100	98–102
All malignant neoplasms (140–208)	2691	114**	110–119
Cancer of buccal cavity and pharynx (140–149)	72	111	87–140
Cancer of esophagus (150)	84	134*	107–166
Cancer of stomach (151)	103	99	81–120
Cancer of biliary passages, liver, gall bladder (155.0, 155.156)	53	134*	100–175
Cancer of larynx (161)	46	145*	106–193
Cancer of trachea, bronchus, lung (162)	1071	139**	131–148
Cancer of bone (170)	15	164	92–270
Cancer of skin (172, 173)	33	69**	48–97
Cancer of prostate (185)	181	91	78–105
Cancer of testes (186)	17	130	76–208
Cancer of bladder (188, 189, 3-189.9)	89	138**	111–170
Cancer of kidney (189.0–189.2)	50	90	67–119
Other & Unspecified sites (194–199)	195	130**	112–149
Hodgkin's disease (201)	19	82	50–129
Leukemia (204–208)	79	85	67–106
Diabetes mellitus (250)	118	69**	57–82
Alcoholism (303)	33	72	50–102
Ischemic heart disease (410–414)	3005	89**	86–93
Cerebrovascular Disease (430–438)	602	86*	79–93
Respiratory Disease (460–519)	799	107*	100–115
Pneumonia (except newborn) (480–486)	260	96	85–108
Bronchitis (490–491)	33	123	85–172
Emphysema (492)	150	119	99–139
Pneumoconiosis/other resp.(470–478, 494–519)	326	115**	103–128
Diseases of digestive system (520–579)	485	97	89–106
Cirrhosis of the liver (571)	249	99	87–112
Disease of the genitourinary system (580–629)	118	74**	61–89
Diseases of the skin (680–686)	6	62	23–134
Musculoskeletal diseases (710–739)	14	71	39–120
Symptoms and ill-defined conditions (780–799)	137	101	85–120
All injuries (800–869, 880–929)	1196	142**	134–150
Transportation injuries (E800–848)	484	99	91–109
Poisoning (E850–869)	67	142**	110–180
Falls (E880–888)	381	464**	419–513
Other injuries (E890–928)	258	121**	107–137
Suicide (E950–959)	281	99	87–111
Homicide (E960–978)	264	153**	135–172

*$P < 0.05$.
**$P < 0.01$.

Cause-Specific Mortality Analysis

The number of deaths, cause-specific PMRs [WHO, 1977], and 95% confidence levels for the 11,144 eligible members in the study are presented in Table II. There were statistically significant elevations in PMRs due to all malignant neoplasms combined (N = 2,691, PMR = 114, $P < 0.01$). Lung cancers (N = 1,071, PMR = 139, $P < 0.01$) had the greatest excess risk; however, cancers of the esophagus, bladder, larynx, and "other and unspecified sites" were also significantly elevated. For nonmalignant deaths, significant elevations were observed for pneumoconioses and other respiratory diseases, falls, poisoning, other injuries, and homicide. Those diseases with PMRs significantly lower than expected included diabetes, ischemic heart disease, cerebrovascular disease, and diseases of the genitourinary system.

In a separate analysis of deaths from 1960–1996 using a rate file with 99 (vs. 92) causes of death, there were nonstatistically significant excesses of asbestosis (2 deaths, PMR = 141, 95% CI = 17–507) and cancer of the nasal cavity (3 deaths, PMR = 399, 95% CI = 82–1167) and significant deficits for melanoma (17 deaths, PMR = 52, 95% CI = 30–83) and non-Hodgkin's lymphoma (50 deaths, PMR = 70, 95% CI = 52–92).

The diseases most related to excessive drinking, i.e. alcoholism and liver cirrhosis, had PMRs lower than 100. PMRs for those diseases most associated with smoking, i.e., lung cancer, emphysema, bronchitis, and cancer of the buccal cavity and pharynx were all higher than expected, with the lung cancer PMR being significantly elevated.

A total of almost 25,000 causes of death was used in the multiple cause-of-death analysis. These PMR results were found to be quite similar to the underlying cause-of-death analysis and, therefore, are not presented here.

PMRS BY DECADE OF FIRST MEMBERSHIP IN UNION

Analysis by decade of first membership in the union was conducted to ascertain whether worker exposures and/or lack of adequate health and safety protection in the earlier decades may have contributed to an increase in mortality (Table III). The excess risks for injuries, especially falls, were statistically significantly elevated in each decade and the PMRs were slightly higher in the latter decades vs. the earlier decades. Lung cancer was also statistically significantly elevated in each time period. The risk of respiratory diseases fell in the latter periods beginning in 1955–1964. The one unusual finding was a significant increase in esophageal cancer for those who became members in 1975 and after.

PMRs by Decade of Death

Analyses of PMRs for cancers by decade of death did not reveal any statistically significant differences. The PMRs for falls were significantly elevated in each decade with the highest elevations in the earlier decades of the 1950s and 1960s (Table IV).

PMRs by Age at Death

PMRs for selected causes by 10-year age-at-death categories are shown in Table V. For all cancers combined, cancers of the lung, and esophagus and cancers of other and unspecified sites, there were statistically significant elevated risks of death for each age category after age 50. The statistically significant PMRs due to fatal falls were highest in age categories below 60 and declined with increasing age category. The average age at death for all fatal injuries was 42.9 years (median = 40.5, SD 15.5) as compared with 64.6 years (median = 66.1, SD = 14.5) for all other causes of death, a statistically significant difference at $P < 0.001$.

PMRs by Race

Approximately 10% of the deceased members in the study were nonwhite. The PMR results for white males and nonwhite males were, for the most part, remarkably similar for almost all causes of death. The PMR for all cancers

TABLE III. Observed Causes of Death (OBS) and Proportionate Mortality Ratios (PMR) by Decade of First Membership in Union Among Roofers Who Died, 1950–1996

	Decade of First Membership in Union													
	< 1935		1935–1944		1945–1954		1955–1964		1965–1974		>1975		Total	
Causes of Death (ICDA-9)	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR
All cancers (140–208)	224	126**	571	126**	1052	120**	524	120**	239	119**	86	113	2691	114*
Esophageal cancer (150)	6	152	17	156	29	126	18	141	6	90	8	445**	84	134*
Laryngeal cancer (161)	5	213	9	144	21	171*	5	99	4	142	1	–	46	145*
Lung cancer (162)	63	141*	232	170**	418	139**	219	142*	108	153**	32	169*	1071	139**
Bladder cancer (188, 189.3–189.9)	12	151	24	146	30	123	17	193*	5	162	1	–	89	138**
Other cancer sites (194–199)	18	108	58	125	131	128**	59	99	24	73	21	115	195	130**
Respiratory diseases (460–519)	96	123	228	132**	316	115*	109	98	41	89	9	59	799	107*
Injuries (E800–E949)	29	111	93	132*	276	145**	287	144**	253	149*	260	154**	1196	142*
Falls (E880–E888)	19	214**	50	316**	110	437**	81	564**	74	827**	47	754**	381	464**
All Deaths (001–999)	1027	101	2296	103	4011	104*	2044	106**	1107	106	671	112**	11144	100

*$P < 0.05$; **$P < 0.01$.

TABLE IV. Observed Causes of Death (OBS) and Proportionate Mortality Ratios (PMR) by Decade of Death Among Roofers Who Died, 1950–1996

	Deaths by Decade											
	1950–59		1960–69		1970–79		1980–89		1990–96		Total	
Causes of Death (ICDA-9)	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR
All cancers (140–208)	185	116 *	485	119 **	709	115 *	793	113 *	519	110 *	2691	114 *
Esophageal cancer (150)	9	216 *	14	134 *	21	129 *	20	108	20	151 *	84	134 *
Laryngeal cancer (161)	4	160	15	238 *	11	123	11	128	5	94	46	145 *
Lung cancer (162)	60	166 *	163	153 *	281	136 **	353	143 **	214	132 *	1071	139 **
Bladder cancer (188, 189.3–189.9)	9	183	18	147 *	32	181 *	21	119	9	76	89	138 **
Other cancer sites (194–199)	19	218 **	30	130 *	45	124 *	63	125 *	38	120	195	130 **
Respiratory diseases (460–519)	50	113	146	114 *	201	101	241	109	161	101	799	107 *
Injuries (E800–E929)	157	150 *	319	154	324	128 *	279	137 *	117	157 **	1196	142 **
Falls (E880–E888)	61	604 **	116	544 **	96	421 **	83	461 **	25	258 *	381	464 **

*$P < 0.05$. **$P < 0.01$.

TABLE V. Observed Causes of Death (OBS) and Proportionate Mortality Ratios (PMRs) by Age at Death Among Roofers Who Died, 1950–1996

	Age at Death													
Causes of Death (ICDA-9)	< 40		40–49		50–59		60–69		70–79		80+		Total	
	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR
All cancers (140–208)	84	77	194	100	590	120 **	871	118 **	711	116 **	241	114 *	2691	114 *
Esophageal cancer (150)	2	235	8	151	26	155 *	28	127 *	20	145 *	0	–	84	134 *
Laryngeal cancer (161)	0	–	5	312	7	81	17	150 *	13	189 *	4	212	46	145 *
Lung cancer (162)	10	85	71	114	264	145 **	364	133 **	290	154 **	72	154 *	1071	139 **
Bladder Cancer (188,189.3–189.9)	2	571	2	87	19	218 *	18	95	36	163 *	12	112	89	138 **
Other cancer sites (194–199)	5	82	20	157 *	45	141 *	56	121 *	51	135 *	18	126 *	195	130 **
Respiratory diseases (460–519)	14	45 *	29	73 *	86	92 *	185	98	301	127 *	184	231 **	799	107 *
Injuries (E800–E929)	582	130 **	236	174 **	187	174 **	122	116 *	50	100	19	69 *	1196	142 **
Falls (E880–E888)	120	739 **	90	808 **	84	633 **	53	388 **	23	162 **	11	82 *	381	464 **

*$P < 0.05$.
**$P < 0.01$.

combined was 125 for nonwhite males vs. 113 for white males, mainly due to a higher PMR (156 vs. 138) among nonwhite males for lung cancer. All of these PMRs were statistically significant at $P < 0.01$. Pneumoconioses and other respirable diseases was the one category which showed a divergent result with white males having a PMR of 120 ($P < 0.01$) and nonwhite males a PMR of 72.

PMRs for Roofing vs. Waterproofing

PMR analyses were conducted of nine local unions which we were advised had a relatively large number of members involved in waterproofing building foundations and the results are presented in Table VI. We acknowledge that we did not know the percentage of roofers vs. waterproofers nor the number of waterproofers in these locals who had used coal tar materials. However, waterproofers would likely be more exposed to coal tar and its derivatives than would roofers. The risk for all cancers combined was slightly greater among members in these locals (N = 2804) than among the 8334 deaths of members from those locals not doing a large amount of waterproofing; PMR = 116 vs. 114. The risk for lung cancer was also slightly greater for these locals; a PMR of 146 vs. a PMR of 137. The PMRs for esophageal and pharyngeal cancers were 210 ($P < 0.01$) and 186 ($P < 0.05$), respectively, among members of these locals vs. 107 and 116 (not significant) among members not from these locals.

TABLE VI. Roofers Union PMRs: Waterproofers versus Roofers Locals, Males Only, 1950–1996

	Waterproofing locals[a]			Roofing locals		
Causes of Death (ICDA-9)	Deaths	PMR	95% CI	Deaths	PMR	95% CI
All causes (000–999)	2804	100	96–104	8334	100	98–102
All cancers (140–208)	705	116 **	107–125	1985	114 **	109–119
Pharyngeal (146–149)	14	186 *	102–312	27	116	76–169
Esophageal (150)	32	210 **	144–297	51	107	80–141
Trachea, Bronchus, Lung (160)	294	146 **	130–164	778	137 **	128–147
Bladder (188, 189.3–189.9)	18	104	62–165	71	150 **	117–189
Skin (172, 173)	5	39 *	13–91	27	78	51–130
Other & Unspecified (194–199)	54	139 *	104–181	138	124 *	104–146
Diseases of the Heart (410–414)	959	90 **	84–96	2778	90 *	87–93
Other Dis. of Circulatory (420–430)	219	83 **	73–95	655	85 **	79–92
All Injuries (E800–869, E880–848)	251	130 **	114–147	946	145 **	136–155
Poisoning (E850–869)	22	198 **	124–300	44	122	88–163
Falls (E880–888)	82	410 **	326–509	300	483 **	430–541
Other injuries (E890–928)	46	98	72–130	214	128 **	112–147
Suicide (E950–959)	55	78	59–101	226	105	92–120
Homicide (E960–978)	39	129	92–177	225	157 **	137–179

[a]For six members, there were no data on local affiliation.
*$P < 0.05$; **$P < 0.01$.

PMRs using NOMS Data for Injury Results

We compared the 622 deaths due to injuries and 3690 deaths due to illnesses in the UURWAW using the NOMS database (deaths from 28 states between 1979–1993) (Table VII). The injury PMR was 135 ($P < 0.01$), while the illness PMR was 96 ($P < 0.01$). These PMRs were very similar to those obtained from the overall LTAS for the years 1950–1996: PMR = 142 ($P < 0.01$) for all injuries and PMR = 96 ($P < 0.01$) for all illnesses.

The PMRs for falls had the highest excess risks among all causes of death (N = 103, PMR = 426, $P < 0.01$). All of the excess risks occurred to UURWAW members less than 65 years of age at death, the age category that most likely includes actively employed roofers (N = 93, PMR = 799,

TABLE VII. Observed Causes of Death (OBS) and Proportionate Ratios (PMR) by Age at Death Among Roofers Who Died of Injuries, 1979–1993

	Age at Death					
Causes of Death (ICD-9)	15–64		65+		Total	
	OBS	PMR	OBS	PMR	OBS	PMR
All illnesses					3690	96**
All injuries (800–999)	558	142**	64	97	622	135**
Falls (880–888)	93	799**	10	80	103	426**
Falls to lower level (880–884)	84	1247**	3	100	87	905**
Falls from stairs (880)	3	196	1	61	4	126
Falls from ladder (881)	9	872**	0	—	9	872**
Falls from building (882)	68	3442**	1	270	69	2942**
Falls from one level to another (884)	4	196	1	119	5	173
Falls to same level (885–886)	1	213	0	—	1	65
Unspecified falls (887–888)	8	181	7	82	15	115

**$P < 0.01$.

$P < 0.01$) (Table VII). Among the sub-categories of falls, the highest PMR for the roofers less than 65 years of age was for falls from a building (PMR = 3442). Analyses of these same data using blue collar rates as a comparison showed statistically significant similar results although the PMRs were not quite as high. We reviewed a 10% random sample of death certificates for those members who had died due to an injury to determine if the injury truly occurred while at work. Slightly more than 85% of the death certificates examined specifically indicated that the injury had occurred in the work environment.

DISCUSSION

Overall Mortality

The most notable mortality risk among roofers documented in the study was due to falls, for which the PMR was significantly elevated reaching almost five times that expected. Additionally statistically significant PMRs were found for other types of injuries, cancers of the lung, esophagus, bladder and larynx, respiratory diseases and homicide.

Fatal Injuries

The PMR finding for deaths due to all injuries combined was 142; the PMR for deaths due to all falls was 464. For roofers younger than 65 at death, the PMR for falls from a building was 3442; over 34 times higher than expected.

These findings are consistent with those in the literature which have shown the fatal injury rate, in general, and the fatal fall rate, specifically, to be higher among members of the construction industry and especially among roofers than in other major industries and occupations in the United States. Some of these studies are shown in Table VIII. Approximately half of all work-related fatal falls now occur in the construction industry, where deaths due to falls have increased nearly 25% over the last 5 years [U.S. DOL, 1996]. Falls currently make up nearly a third of all construction-related fatalities and lead all other ways in which construction workers have been fatally injured. Falls from a roof make up slightly more than half of all fatal construction falls [U.S. DOL, 1996]. It is evident from the current study results that roofers have an extraordinarily risk of death from fatal falls. One out of every five members of the UURWAW incurs a job-related injury every year, half of these being at least serious enough to be off work 20 days or more with some of these injuries being fatal (John Barnhard, UURWAW Safety and Health Director, unpublished communication).

This study has demonstrated that roofers suffer many deaths due to injuries, especially falls, most of which could likely have been prevented. Deaths due to injuries usually occur at much younger ages than deaths due to most diseases, as was observed in this study. The ‘‘potential life lost’’ for injuries, therefore, is often much greater than that for other causes of death and its relative impact should be considered. For example, the category of lung cancer had a PMR of 139 with a total of 1071 deaths while the category of injuries had a PMR of 142 with 1196 deaths. While the rate ratios and number of deaths were similar for these two death categories, the ‘‘potential life lost’’ for injuries would be markedly different than that for lung cancers since the median age of deaths due to injuries was 40.9 years as compared to 65.4 for lung cancers.

Cancer of the Lung

The lung cancer risk was statistically significantly elevated among members in locals performing mainly

TABLE VIII. Literature Review of Falls in the Construction Industry

Author (Year)	Type of Investigation	Findings
Burnett, et al. [1997]	Work related fatal injuries, 24 states	Injury among roofers: PMR = 120, $P < 0.01$
		Falls among roofers: PMR = 300, $P < 0.01$
Pollock, et al. [1996]	Work related construction deaths	Roofers had highest fatality rate for falls.
Robinson, et al. [1995]	Work related fatal injuries, 19 states	Falls among roofers: PMR = 287, $P < 0.01$
		Falls from buildings: PMR = 1167, $P < 0.01$
Suruda, et al. [1995]	Work related deaths, 1980–1985	80% of falls occurred in construction
		Roofers had highest fatal fall rate
Sorock, et al. [1993]	Work-related fatal injuries among roofers	Roofers rate was 9 × construction rate
Bobick, et al. [1990]	Work related deaths, 1980–1985	48% of deaths from falls in construction
		41% of falls were from buildings
Parsons et al. [1986]	Fatal & non-fatal injuries in 15 Building & Construction Trades	Roofers, 4th highest among all trades, 1st in falls from elevations
		35% due to falls from roofs

roofing and slightly more significantly elevated among members in those locals in which waterproofing is more heavily performed. Two of the major exposures of roofers are to asphalt and /or coal tar pitch fumes. Although asphalt, a product derived from crude petroleum oil, is a more universal roofing material today, coal tar had been used extensively in the past and is still used today, especially on some built-up commercial roofs which comprise approximately 24% of the commercial roofing market [NRCA, 1995] with about 7% of those (2% of total) being applied with coal tar (Frank Moore, Manager, Roofing Technology Group, Koopers, Inc., unpublished communication). The greatest potential exposure to hot asphalt or coal tar fumes occurs during the application process where kettle operators tend to have the highest exposure to these substances [Susi and Schneider, 1995]. Excessive fuming can be caused by overheating, failure to keep kettles covered, failure to keep equipment maintained, improper procedures, and /or stagnant air conditions.

Coal tar pitch was among the first substances detected as a human carcinogen and successfully tested for its carcinogenicity in animals [NIOSH, 1977b]. Coal tars and pitches are rich in polycyclic aromatic hydrocarbons (PAHs), some of which are recognized as carcinogens, such as BaP [Hammond et al., 1976; NIOSH, 1977b; King et al., 1984]. Coal tar pitch has been determined by IARC to be carcinogenic in both animal studies and epidemiologic evaluations [IARC, 1985; ACGIH, 1991; NIOSH, 1992]. EPA concluded that the evidence for carcinogenicity of coal tars in animals was sufficient and the evidence for the carcinogenicity in humans was limited bordering on sufficient [EPA, 1984]. The OSHA PEL for airborne coal tar roofing pitch volatile is 0.2 mg/m^3 as the benzene soluble fraction of total particulate [OSHA, 1985].

Asphalt has been shown to be an animal carcinogen and may be carcinogenic to humans, but this has not been definitively established [Brubacher, 1997; IARC, 1985, 1987]. Asphalt fumes have also been shown in laboratory-generated settings to have cancer-causing and mutagenic properties, although they have a much lower content of PAHs than do fumes from coal tar-derived products [Niemeier et al, 1988; Brubacher, 1997]. Laboratory-generated asphalt fumes can be and often are different from field fumes [NIOSH, 2000]. The likelihood of the presence of carcinogens in asphalt fumes at worksites increases as the temperature of asphalt application increases. The American Conference of Governmental Industrial Hygienists (ACGIH) currently recommends a threshold limit value (TLV) for fumes emitted from hot asphalt, measured as total particulate, of 5 mg/m^3 as an 8-hour, time-weighted-average (TWA) "to reduce the risk of possible carcinogenicity" [ACGIH, 1991]. In 1977, NIOSH published a criteria document on asphalt fumes establishing a recommended exposure limit (REL) of 5 mg/m^3, as a 15-minute ceiling limit, for fumes emitted from hot asphalt, measured as total particulate [NIOSH, 1977a]. However, NIOSH did not consider asphalt a potential occupational carcinogen. Currently, there is no OSHA permissible exposure limit (PEL) for asphalt fume, only a proposed rule for a PEL of 5 mg/m^3, although some authorities suggest that this should be lowered to 0.5 mg/m^3 [Chong et al., 1989].

Some studies have suggested that roofers are at an increased risk of asbestos-related lung diseases due to their exposures to asbestos. Asbestos has been used in the past as a filler in asphalt and in roofing felts and mastics. The National Roofers Contractors Association estimated that as of 1994, 20% of built-up roof felts and over 90% of the flashings, coatings, cements and mastics on commercial low-sloped roof jobs contained asbestos [Barnhard, 1994]. Removal or "tear-off" of commercial roofs often involves using power machines which remove all layers, including the felt or insulation barrier. Therefore, exposure to asbestos and other dusts and particles could occur during roofing tear-off procedures.

A cross-sectional medical survey of Local 33 of the UARWWW in Boston, Massachusetts, examined active and

TABLE IX. Literature Review of Lung Cancer Among Roofers

Author (Year)	Type of Investigation	Findings
Partanen and Boffetta [1994]	Meta-analysis of 20 studies among roofers	Roofers have two-fold increase in lung cancer
Engholm, et al. [1991]	Deaths among 704 roofers after 12 years follow-up	Lung Cancer SMR = 3.6 ($P < 0.05$)
Hansen [1989,1991]	Asphalt workers exposed, 1959–1984	SIR = 344 ($P < 0.05$) SMR = 290 ($P < 0.05$)
Singleton and Beaumont [1989]	Deaths from various jobs in California (adj. SES, smoke, alcohol)	Roofers lung cancer SMR = 193 ($P < 0.05$)
California DOH [1987]	Deaths among various jobs in California (unadjusted)	Roofers lung cancer SMR = 329 ($P < 0.01$)
Menck and Henderson [1976]	2,161 death certificates mentioning lung cancer	Roofers lung cancer SMR = 496 (2nd highest after asbestos workers)
Hammond et al. [1976]	6,000 members in Roofers union at least 9+years	Roofers lung cancer SMR = 158 after 20 years Roofers lung cancer SMR = 266 after 40 years

retired roofers with 10 or more years in the trade. The survey included a physical examination, chest x-ray, spirometry, and detailed occupational and medical history. A significant relationship was observed between years as a roofer and the prevalence of pleural disease. Of the roofers who participated, 67% had radiologic abnormalities characteristic of asbestos-related pleural disease and 80% of those with 20 or more years in the trade had evidence of pleural abnormalities [Christiani and Greene 1990]. Our study found only two deaths due to asbestosis. Six deaths were found due to pleural mesothelioma.

Findings from the epidemiological studies that have examined the lung cancer risk among roofers are summarized in Table IX. These studies, similar to ours, have lacked detailed exposure information but have demonstrated an increased risk of lung cancer among roofers. Four case-control studies have also addressed the risk of lung cancer among workers in various occupations [Schoenberg et al., 1987; Vincis et al., 1988; Zahm et al., 1989; Morabia et al., 1992]. All four found elevated risks for lung cancer among roofers even after adjustments were made for age and cigarette smoking.

Smoking is among the greatest risk factors for a variety of diseases, especially lung cancer. In an analysis of smoking by occupation using the National Health Interview Surveys, Nelson et al., [1994] showed that roofers had the highest cigarette smoking prevalence among all occupations included in the survey: a prevalence of 57.8%. This result was 10 times greater than the prevalence among the lowest occupational group, physicians (5.5%), and almost 50% greater than that of blue collar workers as a whole (39.2%). Unfortunately information on the smoking history for union members was not available to directly evaluate how much smoking might have contributed to the elevated lung cancer risk.

Cancers of the Bladder, Esophagus and Larynx

Statistically significant excess PMRs were also observed among members from the UURWAW for cancers of the bladder, esophagus and larynx. Hammond et al. [1976] were among the first researchers to examine the cancer risk among roofers and waterproofers because of their potential heavy occupational exposures to BaP. For members who had been in the union for 20 or more years, the SMR for bladder cancer was 168 and for cancer of the oral cavity, larynx and esophagus (grouped) the SMR was 195: both results were statistically significant. Milham [1983] also observed a highly elevated risk for laryngeal cancer among roofers, PMR = 270, based upon four deaths. In a study of the possible risk of cancer during the manufacturing of asphalt mixes and roofing materials with similar exposures to the roofing industry itself, Hansen [1989] observed an elevated SMR of 301 for bladder cancer based upon five deaths. Partanen and Boffetta [1994] in their meta-analysis of 20 epidemiologic studies documented 11 cohort studies which indicated an increased risk for bladder cancer and eight case-referent studies which indicated a significant risk for bladder cancer among asphalt workers. In a recent analysis on the epidemiologic evidence for the relationship between PAH and cancer, Boffetta et al. [1997] reported excess risks for bladder cancer and stated that roofers, in general, had a higher bladder cancer risk from PAH exposure than other asphalt-exposed workers.

Smoking is also considered a risk factor for bladder, esophageal and laryngeal cancer (in addition to lung cancer) and may have had some influence on these PMR results. Another risk factor for esophageal cancer is excess drinking [Gustavsson et al., 1993]. However, if the drinking rate in the UURWAW population were higher than in the U.S. population, one would also expect an increase of deaths from alcoholism and cirrhosis of the liver. Neither of these PMRs was high.

Skin Cancer

It has been estimated that approximately 38,000 Americans would develop skin cancer in 1996 and that 20% of those would eventually die from this disease [American Cancer Society, 1996]. Roofers are exposed dermally to PAHs during coal tar pitch and, to a lesser extent, asphalt roofing applications and removals [Emmett, 1986]. Thayer et al. [1981] have shown that asphalt volatile was almost as tumorigenic and carcinogenic to the skin of mice as was coal tar pitch volatile and that the higher the temperature of the asphalt volatile the greater the tumorigenic activity. The other major risk factor among roofers for skin cancer is sunlight exposure. Hammond et al. [1976] in their study of almost 6000 members of the Roofer's Union had observed five deaths from skin cancer with only 1.18 expected (SMR = 423).

This study did not find an excess risk of skin cancer among the roofers. One possible explanation is the current high survival rate for this disease. Another possible explanation is that in the last 20 years more people are being made aware of the dangers of sun exposure, both off and on the job, and how to protect themselves from ultraviolet radiation using protective clothing and/or sun screens. Finally, many individuals are now more informed regarding the necessity of having skin tumors examined and treated.

Homicide

The risk among roofers for death by homicide was statistically significantly elevated among both white and nonwhite members of the union. During 1980–1992, roofers as an occupational group had a work-related homicide rate of 0.2/100,000 workers vs. the construction industry rate of 0.37/100,000 workers and the national average rate of 0.7/100,000 workers. Work-related homicide rates for the 10 most dangerous occupations range from 2.1–15.1/100,000 workers [NIOSH, 1996b]. When a random sample of death certificates for the 264 deaths due to homicide were reviewed, none of the deaths occurred on the job. Factors outside the workplace appear to be the cause of this elevated PMR.

Limitations and Strengths

This study, like all epidemiologic studies, had some potential limitations and strengths that need to be considered. For the PMRs to be considered a good approximation of the SMRs, the all-cause mortality rate should be the same for both the group under study (UURWAW members) and the comparison group (U.S. population); that is, the all-cause SMR should be 100 [Decoufle et al, 1977]. If the all-cause SMR for the roofers would actually be greater than 100, the PMR analysis would tend to underestimate the true risk and might not detect all real associations (and vice versa, if the overall SMR was less than 100). The COMS study [California DOH, 1987] for roofers observed an overall SMR of 231 (CI = 207–257), the third highest SMR of all occupations examined in the study. If those results estimated the true relative risk estimates for roofers, the PMRs in the current study may have underestimated the true cause-specific mortality results among UURWAW members. However, the COMS study cohort was somewhat different than ours. The COMS study included both nonunion and union roofers and was limited to roofers who died aged 16 through 64 in the State of California between 1979–1981. These differences in the study populations could have produced somewhat different mortality results.

A strength of this PMR study is derived from the existence of the death benefit fund in the UURWAW. 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 [Beaumont and Okun, 1981; St. Claire and Butler, 1981; Roman et al., 1984]. Beneficiaries of deceased active and retired UURWAW members receive a death benefit 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 for heart disease is lower than expected due to the so-called "healthy worker effect" and, therefore, in a PMR study the PMRs for causes other than heart disease, e.g., cancers, would be artificially elevated. In this study, heart disease had a statistically significantly low PMR of 89 with 3005 observed deaths and 3365 expected deaths. This difference of 360 deaths spread over 92 causes would have tended to slightly increase the PMRs for the other remaining causes of death. However, the low PMR for heart disease is more than balanced by the high PMRs for injuries and homicide. There were 1196 observed injury deaths and 843 expected, a difference of 353 deaths. There were also 264 observed and 173 expected homicide deaths, a difference of 91 deaths. Therefore, the statistically significant PMR results for cancers of the lung, bladder, larynx, and esophagus were probably not artificially elevated and it was concluded that proportionate cancer mortality ratio (PCMR) analyses were not necessary.

PMR studies are retrospective and therefore use existing records as the basis for analysis. Specific substances to which individual roofers would be exposed, are difficult, if not impossible, to evaluate since local unions, in general, do not track sites, specific job tasks performed or exposures when a roofer is dispatched to a particular construction job. Therefore, it was not possible to separate out different types of roofing by roofers. Different types of roofing may present different risks and exposures. The types, intensity, and length of exposures of the members were, therefore, unknown.

Additional limitations: (1) PMR study results are based on death certificate data which have no information on potential confounding factors such as tobacco, alcohol use and socioeconomic status. (2) Some diseases (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. (3) Multiple significance testing may result in associations that arise from chance alone. (4) Since PMR studies are exploratory in nature, the significant results should be confirmed in additional studies.

SUMMARY

In summary, our study of 11,144 deceased members of the UURWAW observed statistically significant elevated risk for roofers from injuries, especially falls. This is possibly due to the types of jobs roofers perform, the heights at which these activities occur, possibly inadequate safety training, the failure of workers to wear adequate fall protection devices or of employers to equip the site with fall protection equipment. The excess risks for cancer of the lung, bladder, esophagus, and larynx may have been due to occupational exposures of asphalt and/or coal tar pitch fumes. In addition, many roofers may have also been exposed to asbestos in tearing off old roofing materials made from this compound as well as exposure in prior years to this material used in roofing. Excess cigarette smoking also cannot be ruled out as a possible contributing factor to these excesses.

The roofing industry has made a concerted effort in trying to improve safety and health performance among their constituents including the roofing industry coalition effort to work with NIOSH in the development of work practices, controls and educational materials to reduce exposure to asphalt fumes. In addition, starting in 1998 a ‘‘Roofing Industry Partnership Program for Safety and Health’’ was being developed to encourage roofing contractors to improve their safety and health performance. Those organizations that have agreed to support and participate in this pilot program include: OSHA, The National Roofing Contractors Association (NRCA), the UURWAW, CNA Insurance Companies, and the National Safety Council. That program may recommend more intensive health and safety programs for roofers and their employers.

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APPENDIX I

Description of Roofer and Waterproofer Duties[1]

Within the unionized industry there exist two distinct work processes, roofing and waterproofing. Trade skills overlap between the two. In some cases a worker may perform both types of work but, for the most part, roofers do roofing and waterproofers do waterproofing. The most junior roofers are usually assigned the least desirable tasks, which are very frequently those with the greatest exposure to fumes and dusts. While laying down a new roof workers may act as foreman, insulation layer operator, hot asphalt machine operator, hot pitch machine operator, felt pitch machine operator, header and flashing operator, gravel pitch machine operator, broom man, and on the ground, hoisting operator, ground-hot-pitch and asphalt operator, and general ground crew. During removal of an old roof workers may act as foreman, scratching machine operator, power-broom operator, hot-pitch patching and flashing operator, and utility operators. Even during the same shift, a single worker may perform several different tasks.

Roofers work on all types of construction—industrial, commercial and residential. ‘‘Residential’’ can be described as single and multi-family residence (up to four stories). The work can be designated new construction, re-roof or repair.

New construction is defined as any structure built ‘‘from the ground up,’’ which would include foundations, structural steel or concrete and other components, including the roofing system that protects such structures. Re-roofing is the application of a new roof over an existing roof or the removal of an existing roof (known as tear-off) and then re-laying a new roof over the substrate. Repair (the patching and maintenance of existing roofs) makes up a much smaller portion of the overall dollar value of total work than do new construction and re-roof; albeit some roofers specialize in repair and may spend their entire careers performing such work.

The types of roofing used are built-up roofing, single-ply, slate, tile and shingles. For example, a roofer could apply shingles to a new residential construction or apply built-up on an industrial re-roof. A roofer is known by the type of roofing work he performs, such as built-up roofer, single-ply roofer, slater, tileman and shingler. Built-up roofers and single-ply roofers are sometimes referred to as flat roofers because the majority of buildings they work on have low pitched roofs (less than 1/6 pitch or 4″ in 12″ slope), whereas slaters, tilemen and shinglers are oftentimes referred to as steep roofers because the buildings that they work on have high (steep) pitched roofs.

Built-up roofers (more commonly known as ‘‘hot’’ roofers) perform the most labor-intensive work, require the greatest degree of skills and have the longest apprenticeship periods, typically 3–5 years. A ‘‘hot’’ roofer applies continuous, semi-flexible membranes (felts) in laminations, or plies, alternated with layers of hot bitumen (asphalt or coal tar pitch) and then surfaces the product with mineral aggregate or asphaltic materials. Within the ‘‘hot’’ roofer classification falls the sub-classification of kettle operator, a worker who fires the asphalt and coal tar kettles that melt the bitumen used in the roofing process. Over the last 20 years this sub-classification has been phased out in some areas of the country and the job has been merged with the regular duties of the journeyman hot roofer.

Single-ply roofers perform work of a similar nature and on the same kinds of buildings as hot roofers. The major difference is the materials used, the training received, and the expertise and equipment used to apply single-ply materials properly. These systems are constructed from elastomeric sheeting that is joined together at laps on the roof by means of heat or solvent welding, contact cements, adhesives or other methods depending on the chemical make up of the product. Single-ply roofers are a relatively new breed in the industry. Single-ply roof systems emerged

[1] From the Constitution and By-Laws of the United Union of Roofers, Waterproofers and Allied Workers.

in the 1970s, becoming one of the mainstay processes of the industry during the early 1980s eventually accounting for 40–50% of the flat roof market.

"Hot" roofers and single-ply roofers co-mingle at the shop (company office and yard), on the job and away from the job. They see themselves as part of the same culture of work. In fact many "hot" roofers and single-ply roofers are trained in both processes.

Slaters are highly skilled specialists who work predominately on commercial buildings applying a dense, tough, durable quarried rock material (slate) that is practically nonabsorbent. Because slate can last for a long time, slaters may rarely if ever work on a re-roof. Due to the fact that architects are specifying slate roofs less and less in modern building plans, slaters have become a very small segment of the roofing trade. Some in the industry believe working with roofing slate could become a lost art over time.

Tilemen lay concrete or clay roof tiles on new construction projects. Their work is primarily on residential units and an occasional commercial project. Tilemen seldom work on a re-roof. Like slaters, the materials they apply may last the lifetime of the building.

Shinglers work mostly on residential units and occasionally on a commercial project. Unlike tilemen and slaters, they work on as many number of re-roofs as new construction projects because the life expectancy of the materials they apply is from 10 to 25 years, depending on the original quality of shingles and local weather conditions. Shinglers apply asphalt shingles with a fiberglass or an organic mat fastened in a randomly spaced stair step fashion. They also apply single layers of mineralized asphalt roll roofing held in place by fasteners.

In some areas of the country shinglers apply wood shingles and shakes. Generally carpenters have received the jurisdictional awards for wood shingles and shakes, but in the Northwest and Southwest, where roofers have traditionally performed the work, they continue to steadfastly maintain their claim and control of the work.

Waterproofing is a highly skilled and specialized segment of the trade requiring the same level of apprenticeship classroom training as that of the "hot" roofer. Waterproofers work only on new industrial and commercial construction, using many of the same materials applied in built-up and single-ply roofing. Their work comprises two main processes, waterproofing and dampproofing. Waterproofing is a system applied to a structure as a permanent barrier to water under hydrostatic pressure. Dampproofing is protection against the penetration of water resulting from occasional exposure to moisture with no hydrostatic pressure. Waterproofers perform below and above grade work.

"Hot" and single-ply roofers, slaters, tilemen, shinglers and waterproofers work in groups referred to as a crew (west coast jargon) or a gang (east coast jargon) made up of foremen, journeymen, apprentices and pre-apprentices. In the roofing trade, foremen are working members of the bargaining unit.

APPENDIX II

Potential Physical Exposure Agents and Ergonomic Hazards Among Roofers Surveyed in 1982–83, Sorted by Decreasing Percentage of Employees Estimated Exposed[a]

Physical agents	Percent exposed
Asphalt	71.6
Limestone	48.0
Asbestos	47.9
Fiberglass, NEC	42.8
Stoddard solvent	40.9
Talc	29.3
Quartz	26.4
Formaldehyde	21.9
Oxidized asphalt (Petroleum)	16.2
Gasoline-unleaded	15.7
Fiberglass, insulation	15.1
Coal tar pitch	13.4
Roofing paper	4.0
Ergonomic hazards	**Percent exposed**
Lifting postures	42.8
Shoulder transports	46.2
Arm-transports	31.6
Awkward postures	23.4
Hand/wrist manipulations	18.3
Finger manipulations	8.4

[a]From National Occupational Exposure Survey. (Sieber et. al, 1991).
Note: The entire list is not included. Also, the data reflect results during the survey years, 1981–1983 only.

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