PLAINTIFF'S EXHIBIT

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MORTALITY EXPERIENCE OF INSULATION WORKERS IN THE UNITED STATES AND CANADA, 1943–1976*

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In 1964, we reported data concerning the mortality experience of a cohort of asbestos insulation workers in the New York-New Jersey metropolitan area 1943–1962.[1] Significant increases in deaths of lung cancer, mesothelioma, gastrointestinal cancer and asbestosis were found. Findings were limited to observation of only 632 men, however. On January 1, 1967, a larger cohort was enrolled for prospective observation and included all 17,800 men on the rolls of the insulation workers' union (International Association of Heat and Frost Insulators and Asbestos Workers, AFL-CIO, CLC) in the United States and Canada on that day. This second cohort included the survivors of the original 632 New York-New Jersey men. Observation has been maintained and an interval report of deaths in this group since January 1, 1967 has been made.[2] The present analysis details findings among these men through December 31, 1976.

Asbestos Insulation in the United States

Asbestos, as a mixture of fiber and sodium silicate, was first used as an insulation material in 1866 and as asbestos cement about 1870. Magnesia with asbestos as a binder soon followed and air-cell covering, using corregated asbestos paper, was introduced in 1898.

The first union of insulation workers in the United States was formed in New York City in 1883 under a charter issued by the Knights of Labor (predecessor of the American Federation of Labor), as "The Salamander Association of Boiler and Pipe Felters." The present union of insulation workers in this country as chartered by the AFL in 1910, as the International Association of Heat and Frost Insulators and Asbestos Workers, by the amalgamation of the Salamanders Association of New York with other independent locals throughout the country. Members of this union are insulation workers, primarily employed in the building trades doing construction insulation work but also employed as insulation workers in refineries, industrial plants,

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shipyards and powerhouse construction and repair. Much of their work is in the open but sometimes, as in shipyards, in rather tight quarters. The men generally work in all parts of the trade, with few specialists at one or another part of it. Conditions of work vary from job to job and from company to company, with fewer than 10% of the men remaining with one company during their working lifetimes.[1] Data published concerning work practices in other countries suggest that asbestos exposure in insulation work has been approximately the same the world over.[4]

Asbestos exposure to which insulation workers are subject has been limited, varied and intermittent. Some of the materials used have contained no asbestos. In the early part of the century, magnesia pipe coverings used shredded rope as a binder, with no asbestos. Somewhat later, wool-felt, cork and rock wool were used. Starting during World War II, fibrous glass products came into increasing use and, during the 1970s, their utilization was greatly expanded, as asbestos content of insulation materials sharply decreased. Magnesia block insulation, including molded pipe coverings, usually contained approximately 15% asbestos, while asbestos cement generally had 15-20% or less of asbestos. Asbestos paper products contained a higher asbestos content, but were used in much smaller quantities.

Until approximately the early 1940s, chrysotile alone was utilized in the manufacture of the asbestos insulation products used by these men. Amosite began to be used in the mid-1930s in small quantities but became more widely utilized during World War II and subsequently.[2]

Few dust counts were made in insulation work until the mid-1960s. However, analysis of available data, including reconstruction of work situations and extrapolation to the past of observations made more recently, suggest that insulation workers would have been exposed to dust levels of 4–12 fibers/ml (as time weighted

TABLE 1A

MEMBERSHIP OF NEW YORK AND NEW JERSEY INSULATION WORKERS' UNION* JANUARY 1, 1943. CLASSIFIED BY AGE AND YEARS FROM FIRST EXPOSURE TO ASBESTOS DUST

Age, Years	Total Number of Members	Number of Years Since First Exposure to Asbestos									
		0–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50+
15–19	2	2									
20–24	14	14									
25–29	38	19	19								
30–34	122	2	94	26							
35–39	76	1	21	47	6	1					
40–44	74	1	4	28	30	10	1				
45–49	77		1	19	29	24	4				
50–54	82	1	2	9	24	18	24	4			
55–59	65		1	4	9	11	20	19	1		
60–64	41		2	5	8	3	13	6	4		
65–69	23		1	2	2	1	3	8	4	2	
70–74	13					2	2	2	2	2	3
75–79	3								3		
80–84	2							1	1		
Total	632	40	145	140	108	70	67	40	15	4	3

*Locals 12 and 32 of the International Association of Heat and Frost Insulators and Asbestos Workers, AFL-CIO.

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TABLE 1B

MAN-YEARS OF OBSERVATION, JANUARY 1, 1943-DECEMBER 31, 1962, OF JANUARY 1943 MEMBERSHIP OF NEW YORK AND NEW JERSEY INSULATION WORKERS' UNION* CLASSIFIED BY ATTAINED AGE AND YEARS FROM FIRST EXPOSURE TO ASBESTOS DUST

Attained Age, Years	Total Man-years	Years from Onset		
		<20	20–34	35+
15–19	4	4	—	—
20–24	44	44	—	—
25–29	165	165	—	—
30–34	542	542	—	—
35–39	1,068	773	295	—
40–44	1,339	253	1086	—
45–49	1,588	74	1510	4
50–54	1,562	39	1368	155
55–59	1,344	28	782	534
60–64	1,142	22	361	759
65–69	849	17	175	657
70–74	513	9	72	432
75–79	242	—	33	209
80–84	84	—	1	83
85+	29	—	—	29
Total	10,515	1970	5683	2862

*International Association of Heat and Frost Insulators and Asbestos Workers, AFL-CIO

averages).[3] While there might have been periods of little or no exposure, there could also have been times of peak exposures much higher than the calculated averages.

MORTALITY EXPERIENCE OF NEW YORK-NEW JERSEY INSULATION WORKERS 1943–1976

On January 1, 1943, there were 632 men registered as members of the two locals of the International Association of Heat and Frost Insulators and Asbestos Workers in the New York-New Jersey metropolitan area (Locals 12 and 32). Their age distribution according to years from onset is contained in TABLE 1A and man-years of observation 1943–1962 are shown in TABLE 1B.

Each of these men was traced to December 31, 1962; expected and observed deaths are found in TABLE 2. Nine men died before reaching 20 years from first employment, and they are excluded from TABLE 2, which is limited to the 623 men who achieved that point. While deaths related to asbestos exposure of the kind experienced by insulation workers may sometimes occur in less than 20 years from onset of employment (lung cancer, asbestosis and, occasionally, mesothelioma) these are not common and we consider that analyses of experiences beyond the 20-year point more clearly define the influence of such exposure. It was of interest, parenthetically, that there was no excess in total deaths of all causes during the first 10 years of observation, 1943–1952, in the post 20 years from onset experience–(although an excess was seen for lung cancer specifically), as example of the "healthy worker effect."[1]

Observation of the survivors of the original cohort has continued prospectively and by December 31, 1976, 478 of the original 632 men had died. The same overall pattern of causes of death has continued, although distribution of deaths by cause has changed

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TABLE 2

EXPECTED AND OBSERVED DEATHS AMONG 623 ASBESTOS INSULATION WORKERS NEW YORK–NEW JERSEY, 20 OR MORE YEARS AFTER ONSET OF WORK JANUARY 1, 1943–DECEMBER 31, 1962 (8545 Man-years of Observation)

Underlying Cause of Death	Expected*	Observed
Total deaths-all causes	195.4	253
Total cancer-all sites	32.1	95
Cancer of lung	6.0	42
Pleural mesothelioma	†	3
Peritoneal mesothelioma	†	4
Cancer of esophagus, stomach, colon-rectum	9.7	29
Cancer of larynx, pharynx, buccal cavity	1.7	2
Cancer of kidney	0.7	0
All other cancer	14.0	15
Noninfectious pulmonary diseases, total	4.0	14
Asbestosis	†	12
All other causes	159.3	144

*Expected deaths are based upon white male age-specific U.S. death rates of the U.S. National Center for Health Statistics, 1949–1962. Rates for specific causes of death for 1943–1948 were extrapolated from rates for 1949–1955.

†Rates are not available, but these have been rare causes of death in the general population.

somewhat, reflecting a number of epidemiological influences. Thus, pleural and peritoneal mesothelioma, which tend to occur somewhat later than bronchogenic carcinoma, became proportionately more common (TABLE 3). This change in preponderance also reflects the smaller proportions of older men who ever smoked cigarettes, and also a "survivor effect." Since the cigarette smokers in the original group had

TABLE 3

EXPECTED AND OBSERVED DEATHS AMONG 632 NEW YORK–NEW JERSEY ASBESTOS INSULATION WORKERS JANUARY 1, 1943–DECEMBER 31, 1976 (13,925 Man-years of Observation)

Underlying Cause of Death	Expected*	Observed
Total deaths, all causes	328.9	478
Total cancer, all sites	57.0	210
Cancer of lung	13.3	93
Pleural mesothelioma	†	11
Peritoneal mesothelioma	†	27
Cancer of esophagus	1.4	1
Cancer of stomach	5.4	19
Cancer of colon-rectum	8.3	23
Cancer of larynx, pharynx, buccal cavity	2.8	6
Cancer of kidney	1.3	2
All other cancer	24.5	28
Noninfectious pulmonary diseases, total	9.3	45
Asbestosis	†	41
All other causes	262.6	223

*Expected deaths are based upon white male age-specific U.S. death rates of the U.S. National Center for Health Statistics, 1949–1976. Rates for specific cause of death for 1943–1948 were extrapolated from rates for 1949–1955.

†Rates are not available, but these have been rare causes of death in the general population.

increased mortality risk (especially from lung cancer and cardiovascular disease) there would likely have been comparatively fewer men with a history of cigarette smoking and still fewer who continued smoking at least the same amount, among the cohort survivors, as the years went by. Except as influenced by other factors associated with advancing lapsed time since onset of asbestos work, this would make for fewer deaths of lung cancer,[6] with more men at risk of dying of other asbestos-associated disease.

Lung cancer remained the most important cause of excess deaths, with 93 such deaths observed vs. 13.3 expected. Thirty-eight deaths occurred of mesothelioma, 11 pleural and 27 peritoneal. The increase in gastrointestinal cancer originally reported in 1964 was again seen, with 43 deaths observed, 15.1 expected. There were 41 deaths of asbestosis. In addition, 4 deaths were observed of other noninfectious pulmonary diseases. Apart from cancer, asbestosis, and other noninfectious pulmonary diseases, observed deaths were fewer than expected of all other causes; only 223 seen, approximately 40 fewer than anticipated.

This experience, with 19% of deaths due to lung cancer, 8% the result of mesothelioma, 9% of gastrointestinal cancer and 9% of asbestosis and other noninfectious pulmonary diseases, begins to provide a broad outline of the total mortality experience of insulation workers employed under conditions of the past (much less asbestos insulation was used in new construction after 1972, although variable and intermittent asbestos exposure would be expected to have continued to occur during repair work). 76% of the original cohort enrolled in 1943 had died by the end of 1976.

Variations in distribution of deaths by cause over time may be seen in TABLE 4. Among the 9 deaths listed before 20 years from onset of exposure, there was none of lung cancer, mesothelioma, gastrointestinal cancer, or asbestosis and other noninfectious pulmonary diseases. Variations are also evident in the two periods, 20–34 years and 35 or more years from onset. Although the proportion of deaths due to cancer of all sites was virtually identical in the two periods (44.5% and 44.3%), the specific neoplasms were quite different in proportional distribution. Lung cancer accounted for 49% of the cancer deaths in the shorter period but only 43% later. There were 7 deaths of mesothelioma in the 6263 man-years of observation during the 20–34 year span but 31 such deaths in the 5692 man-years later on. It is of interest, too, that the proportion of mesotheliomas that were pleural in location also changed over time; 4 of the 7 were pleural in the earlier period, against only 7 of 31 in the second period. It is clear that unless opportunity for prolonged observation is available, it will be difficult to fully evaluate the distribution of deaths by cause among asbestos-exposed groups. Concomitantly, such analysis will be enhanced by considering deaths in each period of duration from onset, separately.

Not unexpectedly, deaths of asbestosis were again largely concentrated in the 35 or more years from onset period; 38 of the 41 such deaths were found at this time.

It has been of interest to inquire concerning the experience of those insulation workers whose exposure began after 1943, since this would reflect postwar conditions. Eight hundred and ninety men joined the New York-New Jersey metropolitan area locals of the union during the period January 1, 1943–December 31, 1962. Most (833) had had no prior asbestos employment before entering the union. These men have been observed prospectively from the time of admission to the union to December 31, 1976 (TABLES 5A and 5B). Our experience with their pre-1943 predecessors had demonstrated that we were to expect relatively few deaths before 20 years from onset of their work. Still, because of the importance of evaluating postwar experience among men not exposed in earlier years, we undertook this study. TABLE 6 details their mortality experience from first employment to December 31, 1976. In the 15,520 man-years of observation during the less than 20-year period, there was no unusual mortality experience. Altogether, there were fewer deaths than expected (again, the "healthy

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TABLE 4

EXPECTED AND OBSERVED DEATHS AMONG 632 NEW YORK-NEW JERSEY ASBESTOS INSULATION WORKERS JANUARY 1, 1943–DECEMBER 31, 1976

Number of Men Attaining Category / Man-years of Observation / Underlying Cause of Death	Less than 20 Years: 325, 1970 — Expected*	Less than 20 Years — Observed	20–34 Years: 561, 6263 — Expected*	20–34 Years — Observed	35 or More Years: 498, 5692 — Expected	35 or More Years — Observed
Total deaths, all causes	9.0	9	80.4	119	239.5	350
Total cancer, all sites	1.1	2	13.5	53	42.4	155
Cancer of lung	0.2	0	3.0	26	10.1	67
Pleural mesothelioma	†	0	†	4	†	7
Peritoneal mesothelioma	†	0	†	3	†	24
Cancer of esophagus	0.02	0	0.4	0	1.0	1
Cancer of stomach	0.1	0	1.5	6	3.8	13
Cancer of colon–rectum	0.2	0	1.9	7	6.2	16
Cancer of larynx, pharynx, buccal cavity	0.05	2	0.8	2	1.9	2
Cancer of kidney	0.03	0	0.4	0	0.9	2
All other cancer	0.5	0	5.5	5	18.5	23
Noninfectious pulmonary disease, total	0.1	0	1.6	4	7.6	41
Asbestosis	†	0	†	3	†	38
All other causes	7.8	7	65.3	62	189.5	154

*Expected deaths are based upon white male age-specific U.S. death rates of the U.S. National Center for Health Statistics, 1949–1976. Rates for specific causes of death for 1943–1948 were extrapolated from rates for 1949–1955.

†Rates are not available, but these have been rare causes of death in the general population.

NEW YORK AND NEW JERSEY INSULATION WORKERS OBSERVED JANUARY 1, 1943–DECEMBER 31, 1962, AND SUBSEQUENTLY TO DECEMBER 31, 1976

(Number of Men Attaining Category)

Period	Union Members Jan. 1, 1943 Years from Onset: Total	<20	20–34	35+	Men Joining Union 1943–1962 Years from Onset: Total	<20	20–34	35+
1943–1952	632	325	523	190*	412	412	—	—
1953–1962	542	40	393	321	833	833	—	—
1963–1969	370	—	154	328	828	828	258	—
1970–1976	234	—	32	224	811	561	515	—

TABLE 5B

MAN-YEARS OF OBSERVATION OF NEW YORK AND NEW JERSEY INSULATION WORKERS, 1943–1976

(Number of Man-years)

Period	Union Members Jan. 1, 1943 Years from Onset: Total	<20	20–34	35+	Men Joining Union 1943–1962 Years from Onset: Total	<20	20–34	35+
1943–1952	5928	1682	3253	993	1658	1658	—	—
1953–1962	4587	288	2430	1869	5906	5906	—	—
1963–1969	2088	—	418	1670	5752	5156	596	—
1970–1976	1322	—	162	1160	5485	2800	2685	—

TABLE 6

EXPECTED AND OBSERVED DEATHS AMONG 833 NEW YORK-NEW JERSEY ASBESTOS INSULATION WORKERS FIRST EMPLOYED JANUARY 1, 1943-DECEMBER 31, 1962, AND OBSERVED FROM FIRST EMPLOYMENT-DECEMBER 31, 1976

(Duration from Onset of Employment)

Number of Men Attaining Category / Man-years of Observation / Underlying Cause of Death	Less than 20 Years: 833, 15,520 — Expected*	Less than 20 Years — Observed	20–34 Years: 523, 3281 — Expected*	20–34 Years — Observed
Total deaths, all causes	39.8	23	24.8	39
Total cancer, all sites	5.1	5	5.0	15
Cancer of lung	1.1	2	1.8	8
Pleural mesothelioma	†	0	†	2
Peritoneal mesothelioma	†	0	†	1
Cancer of esophagus, stomach, colon-rectum	0.7	1	0.8	2
Cancer of larynx, pharynx, buccal cavity	0.2	1	0.3	1
Cancer of kidney	0.1	0	0.1	1
All other cancer	3.0	1	2.0	0
Noninfectious pulmonary diseases, total	0.5	0	0.6	7
Asbestosis	†	0	†	6
All other causes	34.2	18	19.2	17

*Expected deaths are based upon white male age-specific U.S. death rates of the U.S. National Center for Health Statistics, 1949–1976. Rates for specific causes of death for 1943–1948 were extrapolated from rates for 1949–1955.

†Rates are not available, but these have been rare causes of death in the general population.

worker effect") and there was no increase in cancer deaths. No mesotheliomas were seen, nor deaths of asbestosis. There was no significant increase of either lung cancer or gastrointestinal cancer. Since the 20-year point, we have begun to see the changes predicted by our earlier studies. In the 3281 men-years of observation 20–34 years from onset, there were approximately three times as many cancer deaths as expected, primarily due to lung cancer. Mesotheliomas were now first seen and some deaths of asbestosis occurred. These had occurred primarily during the period 1970–1976 (TABLE 7).

When the post-1943 workers were compared with those first exposed before that time, and evaluation was limited to observations less than 20 years from first exposure, it was found that neither group had unusual lung cancer, mesothelioma or asbestosis experience. TABLE 8 demonstrates that among 325 pre-World War II men who had not reached 20 years from onset of exposure during their period of observation, covering 1970 man-years, no excess of these diseases was seen. Similarly, among the 833 post-war men, with 15,520 man-years of observation during the shorter than 20-year from onset point, and with exposures starting 1943–1962, neither mesothelioma nor asbestosis deaths occurred and there were not significant excess deaths of lung cancer. This is of interest in that, by and large, only chrysotile exposure had occurred before 1943 for the first group, while amosite was added to chrysotile in terms of potential exposure from 1943 on. The after-1943 group was potentially exposed to both types of asbestos throughout their work experience. These data indicate that amosite did not shorten the period of clinical latency for asbestos-associated disease in these insulation workers. Further, taken together with the data in TABLES 6 and 7, these observations suggest that the mortality experience of insulators exposed to both chrysotile and amosite will be in the same direction as those originally exposed only to chrysotile and later to insulation dusts also containing amosite. TABLE 9, reviewing deaths of selected causes 20–34 years from onset in the post-1943 group, and comparing the findings with observations in the pre-1943 group for the same time span, suggests that this will be the case.

MORTALITY EXPERIENCE OF INSULATORS IN THE UNITED STATES AND CANADA 1967–1976

There were 17,800 men on the rolls of the asbestos workers union in the United States and Canada on January 1, 1967†. A good deal of information concerning these men was available, including date of birth, date of first insulation work, employment status on January 1, 1967. Additional information was obtained by questionnaire from a majority of the men concerning current symptoms, respirator use, smoking habits, work practices.

We have maintained observation of this cohort since 1967, with the valuable assistance of the local and international officers of the union. The men are registered in approximately 120 local unions in the various parts of the United States and Canada, including Alaska and Hawaii. Whenever an insulation worker associated with the union dies, we are notified. In most instances, a death certificate is forwarded; if not, it is obtained. As with the New York-New Jersey group, information is then sought concerning the details of the circumstances of death,[1,2] including clinical data, roentgenograms, histological material obtained at surgery or autopsy. The clinical and

†International Association of Heat and Frost Insulators and Asbestos Workers, AFL-CIO, CLC.

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TABLE 7

EXPECTED AND OBSERVED DEATHS AMONG 833 NEW YORK AND NEW JERSEY ASBESTOS INSULATION WORKERS FIRST EMPLOYED JANUARY 1, 1943–DECEMBER 31, 1962, AND OBSERVED FROM FIRST EMPLOYMENT–DECEMBER 31, 1976

	Lung Cancer		Pleural Mesothelioma	Peritoneal Mesothelioma	Noninfectious Pulmonary Diseases, Total		Asbestosis
	Expected*	Observed			Expected*	Observed	Observed
1943–1952	0.0	0	0	0	0.0	0	0
1953–1962	0.2	0	0	0	0.2	0	0
1963–1969	0.7	2	0	1	0.3	1	1
1970–1976	2.0	8	2	0	0.6	6	5

*Expected deaths are based upon white male age-specific U.S. death rates of the U.S. National Center for Health Statistics, 1949–1976. Rates for 1943–1948 were extrapolated from rates for 1949–1955.

TABLE 8

EXPECTED AND OBSERVED DEATHS OF SELECTED CAUSES AMONG 632 NEW YORK–NEW JERSEY ASBESTOS INSULATION WORKERS FIRST EMPLOYED BEFORE JANUARY 1, 1943, AND 833 WORKERS FIRST EMPLOYED JANUARY 1, 1943–DECEMBER 31, 1962, OBSERVED FROM JANUARY 1, 1943 OR DATE OF FIRST EMPLOYMENT–DECEMBER 31, 1976

			Deaths from Selected Causes Less than 20 Years from First Exposure to Possible Amosite and/or Chrysotile Asbestos Exposure‡							
					Mesothelioma†		Noninfectious Pulmonary Diseases, Total		Asbestosis†	
Less than 20 Years from First Exposure to:	Number of Men in Category	Man-years of Observation	Lung Cancer Exp*	Lung Cancer Obs.	Obs.	Rate per 1000 Man-years	Exp*	Obs.	Obs.	Rate per 1000 Man-years
Chrysotile only before 1943, plus amosite after 1943	325	1,970	0.2	0	0	0	0.1	0	0	0
Chrysotile and amosite	833	15,520	1.1	2	0	0	0.5	0	0	0

*Expected deaths are based upon white male age-specific U.S. death rates of the U.S. National Center for Health Statistics, 1949–1976. Rates for 1943–1948 were extrapolated from rates for 1949–1955.

†Rates are not available, but these have been rare causes of death in the general population.

‡Amosite insulation materials were first introduced shortly before and during World War II.

TABLE 9

EXPECTED AND OBSERVED DEATHS OF SELECTED CAUSES AMONG 632 NEW YORK–NEW JERSEY ASBESTOS INSULATION WORKERS FIRST EMPLOYED BEFORE JANUARY 1, 1943, AND 833 WORKERS FIRST EMPLOYED JANUARY 1, 1943–DECEMBER 31, 1962, OBSERVED FROM JANUARY 1, 1943 OR DATE OF FIRST EMPLOYMENT–DECEMBER 31, 1976

			Deaths of Selected Causes 20–34 Years from Onset of Exposure							
					Mesothelioma†		Noninfectious Pulmonary Diseases, Total		Asbestosis†	
First Exposure	Number of Men in Category	Man-years of Observation	Lung Cancer Exp*	Lung Cancer Obs.	Obs.	Rate per 1000 Man-years	Exp*	Obs.	Obs.	Rate per 1000 Man-years
Before 1943										
1943–1952	523	3253	1.1	9	1	0.31	0.7	0	0	0
1953–1962	393	2430	1.4	11	4	1.65	0.7	3	2	0.82
1963–1969	154	418	0.3	5	1	2.39	0.1	1	1	1.42
1970–1976	32	162	0.2	1	1	6.17	0.1	0	0	0
Total	561	6263	3.0	26	7	1.12	1.6	4	3	0.48
1943–1962										
1943–1952	—	—	—	—	—	—	—	—	—	—
1953–1962	—	—	—	—	—	—	—	—	—	—
1963–1969	258	596	0.2	2	1	1.68	0.1	1	1	1.68
1970–1976	515	2685	1.6	6	2	0.37	0.5	6	5	1.86
Total	523	3281	1.8	8	3	0.91	0.6	7	6	1.83

*Expected deaths are based upon white male age-specific U.S. death rates of the U.S. National Center for Health Statistics, 1949–1976. Rates for 1943–1948 were extrapolated from rates for 1949–1955.

†Rates are not available, but these have been rare causes of death in the general population.

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TABLE 10

MEMBERSHIP OF ASBESTOS INSULATION WORKERS' UNION*, JANUARY 1, 1967, CLASSIFIED BY AGE AND BY YEARS FROM FIRST EXPOSURE TO ASBESTOS DUST

Age, Years	Total Number of Members	Number of Years Since First Exposure to Asbestos								
		0–9	10–14	15–19	20–24	25–29	30–34	35–39	40–49	50+
15–19	244	244								
20–24	1,695	1695								
25–29	2,412	2066	345	1						
30–34	2,762	1065	1356	341						
35–39	2,988	313	1141	1342	192					
40–44	2,260	79	424	1026	591	139	1			
45–49	1,589	49	131	433	442	487	47			
50–54	1,297	27	88	214	332	377	182	77		
55–59	984	13	49	129	206	176	146	193	72	
60–64	703	1	21	59	131	126	87	99	179	
65–69	419	—	6	18	41	58	45	29	201	21
70–74	255	—	—	6	14	22	21	16	105	71
75–79	111	—	1	—	4	8	4	7	37	50
80–84	52	—	—	—	—	2	1	2	16	31
85+	29							2	7	20
Total	17,800	5552	3562	3569	1953	1395	534	425	617	193

*Membership in the United States and Canada of the International Association of Heat and Frost Insulators and Asbestos Workers, AFL-CIO, CLC.

roentgenological data are reviewed and the pathological material examined. Most of the presentation for this cohort is in terms of underlying cause of death categorized according to best evidence available (BE). Further details are also given in the tables for underlying cause assigned on the basis of death certificate information only (DC).

At the outset of the study, a majority of the men were below the age of 40 (10,101 of 17,800). The majority, too, had yet to achieve 20 years from first exposure (12,683 of 17,800) (TABLE 10).

During the period January 1, 1967–December 31, 1976, the cohort changed its age and duration from onset distribution with the passage of time. Many of the men who started in the less than 20 year from onset group achieved 20+ years from onset during the decade of observation (TABLE 11). Altogether, 12,683 men, with 89,462 man-years of experience, suffered 325 deaths in the period before 20 years. There

TABLE 11

OBSERVATION OF 17,800 ASBESTOS INSULATION WORKERS IN THE UNITED STATES AND CANADA JANUARY 1, 1967–DECEMBER 31, 1976

	Total	<20 Years from Onset	20+ Years from Onset
Number of men	17,800	12,683	12,051
Man-years of observation	166,853	89,462	77,391
Deaths	2,271	325	1,946
Average age during observation	44.4	36.3	53.8

occurred 1946 deaths among 12,051 men who had achieved 20+ years from onset, with 77,391 man-years of observation. The average age during observation was 36.3 years for the shorter group and 53.8 years for those with longer duration from onset.

During the decade of observation 2271 deaths occurred (TABLE 12), whereas only 1658.9 deaths were expected (based upon white male age specific mortality data of the U.S. National Center for Health Statistics). The excess deaths were primarily the result of an increased number of instances of cancer of several sites. Investigation of the deaths found 486 due to bronchogenic carcinoma, between 4 and 5 times the number anticipated. There were 175 deaths of mesothelioma, 63 pleural in location

TABLE 12

DEATHS AMONG 17,800 ASBESTOS INSULATION WORKERS IN THE UNITED STATES AND CANADA JANUARY 1, 1967–DECEMBER 31, 1976

NUMBER OF MEN 17,800

MAN-YEARS OF OBSERVATION 166,853

Underlying Cause of Death	Expected*	Observed		Ratio o/e	
		(BE)	(DC)	(BE)	(DC)
Total deaths, all causes	1658.9	2271	2271	1.37	1.37
Total cancer, all sites	319.7	995	922	3.11	2.88
Cancer of lung	105.6	486	429	4.60	4.06
Pleural mesothelioma	†	63	25	—	—
Peritoneal mesothelioma	†	112	24	—	—
Mesothelioma, n.o.s.	†	0	55	—	—
Cancer of esophagus	7.1	18	18	2.53	2.53
Cancer of stomach	14.2	22	18	1.54	1.26
Cancer of colon-rectum	38.1	59	58	1.55	1.52
Cancer of larynx	4.7	11	9	2.34	1.91
Cancer of pharynx, buccal	10.1	21	16	2.08	1.59
Cancer of kidney	8.1	19	18	2.36	2.23
All other cancer	131.8	184	252	1.40	1.91
Noninfectious pulmonary diseases, total	59.0	212	188	3.59	3.19
Asbestosis	†	168	78	—	—
All other causes	1280.2	1064	1161	0.83	0.91

*Expected deaths are based upon white male age-specific U.S. death rates of the U.S. National Center for Health Statistics, 1967–1976.

†Rates are not available, but these have been rare causes of death in the general population

(BE): Best evidence. Number of deaths categorized after review of best available information (autopsy, surgical, clinical)

(DC): Number of deaths as recorded from death certificate information only.

and 112 peritoneal. There was a modest increase in deaths of gastrointestinal cancer (esophagus, stomach, colon-rectum).

Cancers of several other sites were also significantly increased over the number expected. There were 11 deaths of cancer of the larynx, 21 of the buccal cavity and oro-pharynx, as well as 19 deaths of cancer of the kidney. In each instance, this was twice the number anticipated. Comment had previously been made[1] concerning interest in these sites but, at the time, there were inadequate data for evaluation. Additional experience has indicated that the early hints were predictive

Review of information concerning the deaths allowed a distinction to be made between deaths caused by asbestosis and those of other noninfectious pulmonary

diseases, including emphysema and cor pulmonale. Thereby, 168 deaths were assigned to asbestosis and 44 were attributed to other noninfectious pulmonary diseases, compared with a total expectation of 59.0 in the general population. The question of whether noninfectious pulmonary diseases, other than asbestosis, are or are not increased in asbestos workers is a complex problem. Continuing questions of nomenclature of "chronic obstructive lung disease" in general, and uncertainties of designation and pathological categorization were recently well reviewed by C. M. Fletcher.[7]

Chronic nonspecific lung disease, particularly that due to cigarette smoking, may have an influence on the course of the asbestosis, providing an added burden to damaged lungs. We have evidence that there is such influence.[8] On the other hand, diffuse interstitial parenchymal fibrosis or diffuse pleural fibrosis would be disadvantageous for individuals with extensive chronic obstructive lung disease, particularly with superimposed pulmonary infections or other physiological stress. Such disadvantageous additional contributions, in individual cases, may play important roles in determining the adequacy of a patient's respiratory reserve. Categorizing deaths in terms of a single underlying cause, however, does not allow for inclusion of nuances of interaction among the several factors, nor to depict the full spectrum of such interacting disease, from cases in which little other than asbestotic pulmonary fibrosis may be involved to those in which all evidence indicates that cigarette smoking and chronic obstructive lung disease were the principal factors.

For causes other than cancer and asbestosis and other noninfectious diseases, there were fewer deaths than expected, 1064 against 1280.2. In particular, there were fewer deaths of arteriosclerotic cardiovascular disease and its consequences. This is further considered elsewhere,[8] and it may well be that the active physical work associated with employment as insulation workers is advantageous in preventing or delaying death of cardiovascular disease, although the influence of initial selection upon admission to the trade cannot be disregarded.

It is evident that most excess deaths in this cohort were due to cancer (675) rather than to asbestosis and other noninfectious pulmonary diseases (153). This is noteworthy, since the present United States Standard for occupational exposure to asbestos is in large part derived from reported recommendations designed to prevent asbestosis.[9]

Deaths of Less Common Malignant Neoplasms

Apart from lung cancer, mesothelioma, gastrointestinal cancer, cancer of the larynx, pharynx and oral cavity and cancer of the kidney, there was still as excess of cancer of other sites, with 184 observed, compared with 131.8 expected. Table 13 provides information concerning expected and observed deaths for a number of other sites. For some, there was no evidence of increased incidence, as with leukemia, lymphoma, primary cancer of the liver, testes, bladder. Relatively small increases were suggested for brain, skin, pancreas, prostate. The overall increase is of some interest, especially in view of the known possibility of asbestos fibrils being disseminated to virtually all organs following inhalation or ingestion.[10,11] We have long been properly accustomed to seeking verification of increases beyond chance expectation ("statistically significant") in incidence of cancers of defined sites. This perspective does not contradict the potential importance of more general increases in cancer incidence of a large variety of sites, perhaps not reaching levels of statistical significance in any one location but still yielding definite increases of the overall cancer burden of the groups investigated.

Multiple Cancers

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From a purely statistical point of view, in view of the increased incidence of cancer of several sites among asbestos insulation workers, we would expect that a proportion of these men would suffer multiple cancers simultaneously, even beyond the tendency of such findings to be made among individuals with cancer, in general.[12] Again, this would not be reflected in tabulations of causes of death by single underlying cause, as is the usual practice. Analysis of our experience demonstrated one hundred malignant neoplasms present but not causing death (Table 14). Sometimes these additional neoplasms were mentioned on the death certificate but as an "other significant condition," not in the section on the underlying cause of death. Forty were present among the 1064 cases where death was due to causes other than cancer or asbestosis

Table 13

Deaths Among 17,800 Asbestos Insulation Workers in the United States and Canada January 1, 1967–December 31, 1976

Number of Men 17,800

Man-years of Observation 166,853

Underlying Cause of Death	Expected*	Observed (BE)	Observed (DC)	Ratio o/e (BE)	Ratio o/e (DC)
Total deaths, all causes	1658.9	2271	2271	1.37	1.37
Cancer, all sites	319.7	995	922	3.11	2.88
Deaths of less common malignant neoplasms					
Pancreas	17.5	23	49	1.32	2.81
Liver, biliary passages	7.2	5	19	0.70	2.65
Bladder	9.1	9	7	0.99	0.77
Testes	1.9	2	1	—	—
Prostate	20.4	30	28	1.47	1.37
Leukemia	13.1	15	15	1.15	1.15
Lymphoma	20.1	19	16	0.95	0.80
Skin	6.6	12	8	1.82	1.22
Brain	10.4	14	17	1.35	1.63

*Expected deaths are based upon white male age-specific U.S. death rates of the U.S. National Center for Health Statistics, 1967–1976.

(BE): Best evidence. Number of deaths categorized after review of best available information (autopsy, surgical, clinical).

(DC): Number of deaths as recorded from death certificate information only.

(Table 15). Among the 168 deaths of asbestosis, cancer was also present in 7, 6 of these being bronchogenic carcinoma. Analysis of the circumstances leading to death, however, indicated that the underlying cause was asbestotic pulmonary insufficiency, and that the lung cancers were present but with no decisive influence at the time of death. Nineteen other cancers were present among the 486 deaths of lung cancer and 10 other cancers accompanied the 175 deaths of mesothelioma. There were 9 "incidental" neoplasms among the 99 deaths of gastrointestinal cancer. Although experiences are so far limited, it may not be wholly unexpected that there were proportionately more incidental neoplasms accompanying deaths of colon-rectum cancer, compared to those of lung cancer (8.5% vs. 3.9%). One may speculate that this

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TABLE 14

MORTALITY EXPERIENCE AMONG 17,800 ASBESTOS INSULATION WORKERS IN THE UNITED STATES AND CANADA 1967–1976: OBSERVATIONS IN 2271 CONSECUTIVE DEATHS

Malignant Neoplasms Present, but not Causing Death* Site	Number
Lung	24
Pleural mesothelioma	2
Peritoneal mesothelioma	1
Esophagus	0
Stomach	1
Colon	19
Oropharynx	3
Larynx	5
Kidney	3
Other	42†
	100‡

*Twenty-one of these neoplasms were mentioned on the death certificate (but were not categorized as underlying cause of death).

†Including leukemia 5, lymphoma 3, bladder 5, prostate 13, thyroid, etc.

‡In 92 individuals; total includes multiple cancers in eight cases

could be due to the longer clinical course of many patients with colon-rectum cancer, compared to lung cancer, with greater opportunity, simply in terms of time, to develop additional disease.

Multiple cancers were present, overall, in 2.1% of deaths among these asbestos insulation workers (48 of 2271). It is perhaps to be expected that this was more likely to be the case among those for whom cancer was the primary cause of death (4.5%) while only 3 of the 1276 other deaths had this finding.

From a clinical point of view, in the management of patients with asbestos-associated disease, the potential for incidental or multiple cancers is of some importance, and awareness of the possibility may assist in both the diagnostic investigation and long-term surveillance of individuals with history of significant asbestos exposure.

LAPSED PERIOD

It is now well appreciated that most asbestos associated disease is first seen after considerable periods from onset of exposure in both occupational and environmental circumstances. This is true both for the presence and extent of parenchymal fibrosis and pleural fibrosis and/or calcification,[3,13] and for asbestos-associated neoplasms.[14]

Data obtained in this investigation now provide a more complete overview of this question. Broadly, we saw some limited excess disease in less than 20 years from onset of exposure (TABLE 16). Among 12,683 men with such experience, covering 89,462 man-years of observation, the number of cancer deaths was about doubled, with 42.6 deaths expected and 83 observed. There were no excess deaths of gastrointestinal cancer and only 5 deaths of mesothelioma, with these in the 15–19 years from onset category. Age, year and sex specific mortality data of the U.S. National Cancer for Health Statistics indicated that 11.9 deaths of lung cancer were to be expected. Thirty-six occurred. There were 8 deaths of asbestosis.

On the other hand, extensive disease was seen among the 12,051 men who had reached 20 or more years from onset during the decade of study. Here, 1376.0 deaths were anticipated; 1946 occurred. There were 160 deaths of asbestosis and 912 of cancer. It was at this time that bronchogenic carcinoma made its heaviest contribution, with 93.7 such deaths expected and 450 observed. One hundred and seventy deaths of mesothelioma were then seen and the increase in gastrointestinal cancer found. TABLE 17 depicts these data in some detail, in five-year periods from onset of employment. Lung cancer data are given as both expected and observed numbers of death. This practice cannot be followed for mesothelioma, where expected deaths cannot be computed for the general population. Instead, we have provided data in both number of deaths of pleural and peritoneal mesothelioma, as well as in terms of number of deaths of these causes per thousand persons years at risk. The latter does not take into account variations in achieved age, but this may have less influence than achieved duration from onset of employment. It will be seen that very major increases in numbers of deaths of lung cancer are first seen at 15–24 years from onset of work, with continued further increases. The extraordinary increase in deaths of mesothelioma, both of the pleura and the peritoneum, is not observed until somewhat later, reaching 2.78 deaths per thousand person-years at risk for pleural mesothelioma at 35–39 years from onset of work, and 5.47 deaths of peritoneal mesothelioma per thousand person-years at 45+ years from onset.

In another reflection of the clinical concerns among these workers, TABLE 18 indicates that approximately one-third of all deaths were due to lung cancer at 30–34 years from onset, while mesothelioma accounted for 13% of all deaths at 35–39 years.

TABLE 15

MORTALITY EXPERIENCE AMONG 17,800 ASBESTOS INSULATION WORKERS IN THE UNITED STATES AND CANADA 1967–1976: OBSERVATIONS IN 2271 CONSECUTIVE DEATHS NUMBER OF INCIDENTAL MALIGNANT NEOPLASMS (NOT CAUSING DEATH) IN RELATION TO UNDERLYING CAUSE OF DEATH AS ESTABLISHED BY BEST EVIDENCE (BE)

Underlying Cause of Death	Number of Deaths of Underlying Cause	Incidental Malignant Neoplasms	
		No. of Deaths	Total Cancers
Cancer all sites	995	45	50
Cancer of lung	486	17	19
Pleural mesothelioma	63	4	4
Peritoneal mesothelioma	112	5	6
Cancer of esophagus	18	1	1
Cancer of stomach	22	3	3
Cancer of colon-rectum	59	5	5
Cancer of larynx	11	0	0
Cancer of pharynx, buccal cavity	21	2	3
Cancer of kidney	19	0	0
All other cancers	184	8	9
Noninfectious pulmonary diseases, total	212	10	10*
Asbestosis	168	7	7*
All other causes	1064	37	40
Total	2271	92	100

*Six of these were lung cancer.

TABLE 16

DEATHS AMONG 17,800 ASBESTOS INSULATION WORKERS IN THE UNITED STATES AND CANADA JANUARY 1, 1967–DECEMBER 31, 1976. ANALYSIS BY DURATION FROM ONSET OF EMPLOYMENT

Total Men Man-years of Observation	Before 20 Years from Onset 12,683 89,462					20 or More Years from Onset 12,051 77,391				
		Observed		Ratio o/e			Observed		Ratio o/e	
Underlying Cause of Death	Expected*	(BE)	(DC)	(BE)	(DC)	Expected*	(BE)	(DC)	(BE)	(DC)
Total deaths, all causes	282.9	325	325	1.15	1.15	1376.0	1946	1946	1.41	1.41
Cancer, all sites	42.6	83	77	1.95	1.81	277.1	912	845	3.29	3.05
Cancer of lung	11.9	36	32	3.03	2.69	93.7	450	397	4.80	4.24
Pleural mesothelioma	†	2	2	—	—	†	61	23	—	—
Peritoneal mesothelioma	†	3	0	—	—	†	109	24	—	—
Mesothelioma, n.o.s.	†	0	1	—	—	†	0	54	—	—
Cancer of esophagus	0.6	1	1	—	—	6.5	17	17	2.64	2.64
Cancer of stomach	1.5	1	0	—	—	12.7	21	18	1.65	1.42
Cancer of colon-rectum	4.1	4	4	—	—	34.0	55	54	1.62	1.59
Cancer of larynx	0.4	2	2	—	—	4.3	9	7	2.09	1.63
Cancer of pharynx, buccal	1.3	3	2	—	—	8.8	18	14	2.05	1.59
Cancer of kidney	1.1	3	3	—	—	7.0	16	15	2.29	2.14
All other cancer	21.7	28	30	1.29	1.38	110.1	156	222	1.42	2.02
Noninfectious pulmonary diseases, total	5.2	8	11	1.54	2.12	53.8	204	177	3.78	3.28
Asbestosis	†	8	2	—	—	†	160	76	—	—
All other causes	235.1	234	237	1.00	1.01	1045.1	830	924	0.79	0.88

*Expected deaths are based upon white male age-specific U.S. death rates of the U.S. National Center for Health Statistics, 1967–1976.
†Rates are not available, but these have been rare causes of death in the general population.
(BE): Best evidence. Number of deaths categorized after review of best available information (autopsy, surgical, clinical).
(DC): Number of deaths as recorded from death certificate information only.

TABLE 17

DEATHS AMONG 17,800 ASBESTOS INSULATION WORKERS IN UNITED STATES AND CANADA, JANUARY 1, 1967–DECEMBER 31, 1976. ANALYSIS BY DURATION FROM ONSET OF EMPLOYMENT

			Lung Cancer					Pleural Mesothelioma			Peritoneal Mesothelioma		
				Observed		Ratio o/e		Number		No./1000 Person-years	Number		No./1000 Person-years
Duration from Onset (Years)	Number of Men	Person-years of Observation	Exp.*	(BE)	(DC)	(BE)	(DC)	(BE)	(DC)	(BE)	(BE)	(DC)	(BE)
<10	8,190	26,393	0.7	0	0	—	—	0	0	0	0	0	0
10–14	9,063	29,003	2.7	7	5	2.55	1.82	0	0	0	0	0	0
15–19	9,948	34,066	8.5	29	27	3.40	3.17	2	2	0.06	3	0	0.09
20–24	8,887	31,268	17.0	59	57	3.48	3.36	6	4	0.19	3	2	0.10
25–29	6,596	20,657	21.0	105	96	5.00	4.58	13	5	0.63	19	3	0.92
30–34	3,547	11,598	18.4	112	103	6.08	5.59	9	3	0.78	23	6	1.98
35–39	2,020	5,403	11.5	65	57	5.68	4.98	15	4	2.78	19	5	3.52
40–44	1,108	3,160	8.1	40	131	4.93	3.82	4	3	1.27	16	3	5.06
45+	1,448	5,305	17.8	69	53	3.89	2.98	14	4	2.64	29	5	5.47

*Expected deaths are based upon white male age-specific U.S. death rates of the U.S. National Center for Health Statistics, 1967–1976. Smoking habits not taken into account.
(BE): Best evidence. Number of deaths categorized after review of best available information (autopsy, surgical, clinical).
(DC): Number of deaths as recorded from death certificate information only.

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TABLE 18

DEATHS AMONG 17,800 ASBESTOS INSULATION WORKERS IN THE UNITED STATES AND CANADA, JANUARY 1, 1967–DECEMBER 31, 1976. ANALYSIS BY DURATION FROM ONSET OF EMPLOYMENT

Years from Onset of Employment	Total Deaths	Percent of All Deaths: Lung Cancer (BE)	Lung Cancer (DC)	Mesothelioma: Pleural (BE)	Pleural (DC)	Peritoneal (BE)	Peritoneal (DC)	Total (BE)	Total (DC)
<10	51	0	0	0	0	0	0	0	0
10–14	85	8.2	5.9	0	0	0	0	0	0
15–19	189	15.3	14.3	1.1	1.1	1.6	0	2.7	1.6
20–24	320	18.4	17.8	1.9	1.3	0.9	0.6	2.8	2.5
25–29	388	27.1	24.7	3.4	1.3	4.9	0.8	8.3	5.2
30–34	340	32.9	30.3	2.7	0.9	6.8	1.8	9.4	6.5
35–39	253	25.7	22.5	5.9	1.6	7.5	2.0	13.4	7.9
40–44	203	19.7	15.3	2.0	1.5	7.9	1.5	9.9	6.4
45+	442	15.6	12.0	3.2	0.9	6.6	1.1	9.7	4.1
Total	2271	21.4	18.9	2.8	1.1	4.9	1.1	7.7	4.6

*Total includes mesothelioma not specified as either pleural or peritoneal.
(BE): Best evidence. Number of death categorized after review of best available information (autopsy, surgical, clinical).
(DC): Number of deaths as recorded from death certificate information only.

Altogether, lung cancer was responsible for 21% of all deaths observed by us in this cohort and mesothelioma for 8%.

INVESTIGATION AND CATEGORIZATION OF CAUSES OF DEATH

It is widely known that causes of death as recorded on death certificates may be in error and that, even when accurate, these may be coded with considerable variation among different agencies, despite the existence of agreed upon international rules and recommentations.[15] Yet death rates based upon large series of causes of death as recorded on death certificates are nevertheless useful, and are widely utilized. This distinction, however, leads to the understanding that comparisons between observed causes of death and those expected from national or local "death rates" should not be considered in rigid exact terms, especially when considering the mortality experience of very specific groups. For these, there are no perfect "controls" that would take into account their age distribution, ethnic derivation, smoking habits, economic circumstances, prior personal and social history, and so on.

The matter is further complicated by the fact that deaths in the general population, which provide the basis for established comparison death rates, are not verified by investigation or examination of available data concerning the circumstances associated with the deaths. Of course, one may elect to treat the deaths in the study population in exactly the same way, with no attempt to review data other than that recorded on the death certificate, explicitly accepting whatever errors might exist in causes of death recorded and implicitly hoping that whatever errors exist are very much the same in the two sets of data, deaths in the general population and those in the group under investigation. Certainly this latter method is simpler, cheaper, much less time consuming.[16]

But this approach has a number of drawbacks. First, where the distribution of causes of death in the group being studied is different than that found in the general population, one may expect that the distribution of inherent error might also be different. Second, data may be available which can shed much light on the causes of death under investigation and not including such information permits the risk of reporting results which are simply inaccurate. It is perhaps inadequate comfort to skirt this difficulty by clearly stating that only death certificate diagnoses are reported, this only gives the reason for potential inaccuracy. There are also technical issues, and these are of particular concern among asbestos-exposed groups, in the sixth, seventh and eighth revisions of the International Classification of causes of death. There have been no clear categories for the diffuse malignant mesotheliomas of the pleura and peritoneum which occur, and while some improvements have been made in the ninth revision now being introduced, we fear that these will still not resolve the problem.

Just as there are no perfect controls, there is also no single perfect solution, and it is unlikely that there will be such in the foreseeable future, especially since data available for ascertainment of cause of death, even when investigations during life and at autopsy have been undertaken, are not always complete and are surely not uniform.

TABLE 19

MORTALITY EXPERIENCE AMONG 17,800 ASBESTOS INSULATION WORKERS IN THE UNITED STATES AND CANADA 1967–1977: OBSERVATIONS IN 2271 CONSECUTIVE DEATHS WITH UNDERLYING CAUSE OF DEATH CODED ACCORDING TO DEATH CERTIFICATE INFORMATION ONLY AND ACCORDING TO BEST EVIDENCE

Underlying Cause of Death	Expected*	Death Certificate (DC): No.	DC: o/e	Best Evidence (BE): No.	BE: o/e	% of Best Evidence
Cancer all sites	319.7	922	2.88	995	3.11	93
Cancer of lung	105.6	429	4.06	486	4.60	88
Pleural mesothelioma	†	25	--	63	—	40
Peritoneal mesothelioma	†	24	--	112	—	21
Mesothelioma, n.o.s.	†	55	—	0	—	—
Cancer of esophagus	7.1	18	2.53	18	2.53	100
Cancer of stomach	14.2	18	1.26	22	1.54	82
Cancer of colon-rectum	38.1	58	1.52	59	1.55	98
Cancer of larynx, pharynx, buccal cavity	14.8	25	1.69	32	2.16	78
Cancer of kidney	8.1	18	2.23	19	2.36	95
Cancer of prostate	20.4	28	1.37	30	1.47	93
Cancer of bladder	9.1	7	0.77	9	0.99	78
Cancer of pancreas	17.5	49	2.81	23	1.32	213
Cancer of liver	7.2	19	2.65	5	0.70	380
Cancer of brain	10.4	17	1.63	14	1.35	121
Noninfectious pulmonary diseases, total	59.0	188	3.19	212	3.59	89
Asbestosis	†	78	—	168	—	46
All other causes	1280.2	1161	0.91	1064	0.83	109

*Expected deaths based on white male age-specific U.S. death rates of the U.S. National Center for Health Statistics, 1967-1976.
†Rates not available, but these have been rare causes of death in the general population
(BE): Best evidence. Number of deaths categorized after review of best available information.
(DC): Number of deaths as recorded from death certificate information only.

We have elected to approach this problem by providing data in more than one way, including causes of death as recorded on the death certificate in our cases, for comparison with "expected" deaths based upon the data of the U.S. National Center for Health Statistics, as well as causes of death established after detailed review of all available information. Such data were retrieved in 1961 of the 2271 deaths. However, detailed information was not equally available for all categories of causes of death. This was to be expected, in the nature of things. As a rule, the best available information for establishing the cause of death was considered to be autopsy findings, with pathological information derived from surgical intervention next, and, in their absence, clinical and roentgenological observations made during life, particularly in the period before death. Where no such details were available, the cause of death as recorded from death certificate information was then utilized. Among the 995 cases of cancer, we were required to depend upon the death certificate alone in only 28, with other information available in 967 cases (97%). In all 175 cases of mesothelioma, surgical and/or autopsy findings were utilized. We depended upon death certificate information alone in 10 of the 486 cases of lung cancer.

Similarly, in 166 of 168 deaths of asbestosis, information was available in addition to the death certificate, leaving dependence of the latter in only 1%. In contrast, for causes other than cancer and asbestosis, additional information was available in only three-quarters of the cases. Analysis of the distribution of deaths within this category showed that this was by no means unexpected. Sudden death attributed to myocardial infarction or cerebrovascular accident is often not further investigated nor need clinical abnormalities have preexisted. It was therefore no surprise that in 156 cases the medical attendant or the medical examiner warranted such death certificate diagnosis without other information being available. It would seem difficult to avoid differences in quality of ascertainment, under such varied circumstances.

Analysis of our data suggests that, by and large, death certificate diagnoses were not far off the mark. This speaks highly for the diagnostic acumen and quality of care provided to these men by their medical attendants. Cancer as the underlying cause of death was indicated by the death certificate in 922 instances compared with 955 so categorized after considering all available information (TABLE 19). The specific diagnosis of cancer of the lung and cancer of the several sites of gastrointestinal cancer, as well as cancer of the larynx, oro-pharynx and kidney was also generally well predicted by the death certificate diagnosis.

In a number of instances, however, there was important disparity between causes of death as recorded on the death certificate and those judged to be the case after review of available clinical and pathological material. This was true for pleural and peritoneal mesothelioma, asbestosis, cancer of the pancreas, primary cancer of the liver, cancer of the brain and chronic obstructive lung disease.

In 49 cases, cancer of the pancreas was listed on the death certificate as cause of death. Only 17.5 such deaths were expected (TABLE 14). If we were to accept cause of death as listed on the death certificate to establish the "observed" number of deaths for this disease, we would have to conclude that cancer of the pancreas is significantly increased as a cause of death among asbestos insulation workers. But this is not the case; when all available material was reviewed, it was found that only 23 deaths compared with the 49 so categorized on the death certificate were due to cancer of the pancreas. Four were the result of metastatic lung cancer, 15 were found on review of histological material to be cases of peritoneal mesothelioma and 5 were best categorized as abdominal carcinoma, primary site not established. Two were due to cancer of the colon. This is not to say that we have established that there is no increased incidence of cancer of the pancreas among asbestos workers. It is possible there is some limited increase and we are cognizant of the uncertainties inherent in the

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computation of "expected" rates for cancer of the pancreas since it may well be that some of the cases so categorized in the general population from which the expected rates were derived, might really be instances of lung cancer, colon cancer and even, perhaps, peritoneal mesothelioma. Since these deaths in the general population have not been investigated to verify death certificate cause of death, it is not possible to know whether such inaccuracy exists, nor its degree.

Asbestosis was another example where categorization by death certificate would be misleading since only 78 deaths of this disease were so categorized compared with 168 after review. A variety of other diagnoses were offered in the discrepant cases, primarily those of "chronic obstructive lung disease," or other noninfectious respiratory disease, acute infections, and, in two cases, cancer of the lung. It was of interest that in 16 of the 97 cases called asbestosis after review but in which asbestosis was not listed as the underlying cause of death, it was mentioned on the death certificate under the rubric of "other significant conditions." In 129 other cases, asbestosis was again mentioned on the death certificate, but not as underlying cause of death. Altogether, asbestosis was mentioned in 230 of the 2271 death certificates.

In 7 cases, asbestosis so categorized by death certificate designation was reassigned to other categories after review, with death found due to lung cancer in 5, peritoneal mesothelioma in one and myocardial infarction in another.

Accuracy of diagnosis of mesothelioma, and its being recorded on death certificates, is a special problem. First, there are the difficulties and subtleties of pathological diagnosis, of particular importance when cases of this neoplasm are seen throughout the United States and Canada by pathologists with varied experience. Sometimes, there is the added difficulty of extending the pathological diagnosis to the death certificate, not infrequently completed by a physician who may or may not have been the regular medical attendant and fully cognizant of pathological findings; to this could be added the problem occasioned by the fact that the death certificate must often be completed before there has been full consideration of postmortem findings. When these differ with the death certificate diagnosis, an amended certificate is expected to be filed. In our experience, this is rarely done. When to these are added the administrative uncertainties and insecurities of classification, it is not surprising that only about one-quarter of the deaths of mesothelioma in this series were correctly recorded on death certificates as pleural or peritoneal, although 104 of the 175 cases were recorded as "mesothelioma," even if not with full details.

We are presently analyzing the 175 deaths of pleural and peritoneal mesothelioma, and the results will be reported. In 108 of the 112 cases of peritoneal mesothelioma, surgical and pathological material was submitted to us for review and this was the case as well as 61 of the 63 pleural mesotheliomas (96.5% and 96.8%).

The association of pleural and peritoneal mesothelioma with prior asbestos exposure is so striking[1] that it is not surprising that overdiagnosis might now sometimes occur. We found such to be the case in this study. In 8 cases in which mesothelioma was recorded as underlying cause of death on the death certificate, review of the histological material showed the diagnosis to be other than mesothelioma (cancer of the lung in 5 cases, metastatic carcinoma in 1 and Wegener's granulomatosis involving the pleura in another). In the eighth case, pleural mesothelioma was present but was not the cause of death, which was better attributed to concurrent cancer of the stomach.

Where mesothelioma appeared as the diagnosis on the death certificate, depending upon the exact phrasing used, this might be coded in the eighth revision of the International List in categories 158.9 (malignant neoplasm of peritoneum), 163.0 (malignant neoplasm of pleura), 197.0 (secondary malignant neoplasm of lung), 195.0 (malignant neoplasm of abdomen), 198.9 (secondary malignant neoplasm, specified as

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secondary), 199.0 (multiple malignant neoplasm [carcinomatosis, disseminated cancer]), 199.1 (malignant neoplasm without specification of site) and, not infrequently, 228 (benign neoplasm of other and unspecified organs and tissues). There is at the moment no reliable way to extract the numbers of pleural and peritoneal mesotheliomas from death certificate data categorized and recorded by health statistics agencies in the past, using the several revisions of the International Classification of causes of death.

We might add that, overall, pathologists' diagnoses were much more accurate than death certificate characterization of causes of death would lead one to believe. This again bespeaks a high degree of competence on the part of pathologists in the United States and Canada (we are aware, of course, that diagnostic suspicion may be increased in those instances in which it is known that asbestos exposure had occurred, as with individuals among whom occupational history indicated such exposure; this could perhaps have accounted for some of the over-diagnosis). However this might be, it is clear that a problem exists in translating the information obtained in pathological study to the death certificate diagnosis, as well as a problem of subsequent coding of the stated cause of death.

Conclusions

Asbestos insulation workers in the United States and Canada suffer an extraordinary increased risk of death of cancer and asbestosis, associated with their employment. This includes increases in death of lung cancer, pleural mesothelioma, peritoneal mesothelioma, cancer of the esophagus, colon and rectum, cancer of the larynx, oro-pharynx, kidney and perhaps stomach. Some increases were seen in cancer of several other sites, as well, but data are inadequate at this time to permit characterization of their significance, although attention is called to such wider increase.

Little increase in cancer deaths, nor of asbestosis, was observed in less than 15–19 years from onset of exposure. In general, the period of latency between onset of exposure and death was 2, 3, 4, or more decades. Large increases in lung cancer occurred at 15–35 years from onset while pleural and peritoneal mesothelioma showed their greatest incidence somewhat later. Under the conditions of exposure which obtained, the period of clinical latency for asbestosis was also prolonged and in many cases was 30–40 years or more from onset of employment. It would appear that in studies of the effects of such asbestos exposure it would be advantageous to analyze the experience of exposed individuals in duration-from-onset exposure categories, with particular reference to durations of more than 30 years. If this is not done, the risk is run of obscuring the neoplastic effects of asbestos exposure by the co-mingling of later deaths with those which may have occurred much earlier and which would be much less likely to have been influenced by asbestos exposure. In the same way, studies should include, whenever possible, the opportunity for observation of the mortality experience of the individuals at risk at least 30–35 and preferably 40 or more years from onset of their exposure. Again, unless this is possible, only the very limited early effects will be identified and the full import of the exposures may not be appreciated.

Our experiences demonstrate the advantages of review of all available information concerning the circumstances associated with the deaths that occur. Depending entirely upon death certificate diagnosis can lead to erroneous reports of causes of death, a problem that can be mitigated by characterizing causes of death according to the best available information. Using this approach, we found that the apparent increased incidence of cancer of the pancreas among asbestos insulation workers, indicated by death certificate diagnosis, did not really exist, and that many so designated were due to other causes. The same was found for primary cancer of the liver and cancer of the brain, both of which would have been considered of increased incidence using solely death certificate diagnosis, but were not so established following review of histological material. This, of course, could well be anticipated with exposures to agents which increase the risk of neoplasms known to metastasize to these sites (bronchogenic carcinoma, gastrointestinal cancer).

Our experiences do not indicate that the addition of amosite asbestos exposure during and after World War II to the chrysotile asbestos exposure which existed before then, and which continued, demonstrably altered the nature of the asbestos-induced diseases which resulted, nor their extent. Further, limited experiences suggest that asbestos insulation employment begun 1943–1962 carried the same type of long-term risk as that begun before that time. We have no information concerning the nature or extent of risk among insulation workers whose employment began after 1963.

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ASBESTOS EXPOSURE: FACTORS ASSOCIATED WITH EXCESS CANCER AND RESPIRATORY DISEASE MORTALITY

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We have previously reported on the mortality experiences at ages 65 and over of a group of 1348 men who completed their working lifetimes as production or maintenance-service employees with a United States asbestos company and retired with a company pension.[1-3] These men were exposed to asbestos dust in varying degrees during the course of their employment, sometimes at dust levels in excess of 50 million particles per cubic foot of air. The average duration of employment in the asbestos industry was 25 years, with a range of 3–51 years. By combining personnel records with asbestos dust level estimates for each job and time period, it was possible to reconstruct the asbestos dust exposure history for each man, assign a measure of his cumulative dust exposure at the time of retirement, and relate this value to his mortality experience following retirement.

In previous reports, this cohort was followed through December 31, 1969 by use of information available in company records on deaths among their retirees. For this report, we have cleared names of all men believed to be alive on January 1, 1970 with Social Security files and have determined deaths that occurred during the years 1970–3 inclusive. This method of following the cohort could be used only for men who worked in the United States, so that of the 1348 men in the previous reports, 273 had to be excluded since their only known employment was in Canada. For the remaining 1075 men, 781 deaths have been identified by the combined methods of clearing with company records for deaths that occurred prior to 1970 and for those alive on January 1, 1970 with Social Security files through 1973. The check with Social Security was, in part, a validation of the completeness of death notations in company files, because nearly all of the deaths of united States retirees that occurred during the period 1941–73 would be known to the Social Security Administration. Two deaths were discovered in the cohort of 1075 that occurred prior to 1970 and that were missed in previous reports, one due to arteriosclerotic heart disease and one due to emphysema.

Of the 781 deaths identified, death certificates could be located for 749. Since the number of missing death certificates is small (32), no attempt has been made to allocate these deaths to cause of death groupings in the material presented here.

The cohort on which this paper is based consists of all men who retired during the years 1941–67. Included were three types of retirees: those who retired normally at age 65, those who retired before age 65 for personal reasons but lived to age 65, and men who retired prior to age 65 because of a disability but who lived to be 65. Observed mortality among this cohort was compared with an expected mortality based on the experience of the entire United States white male population living at the same ages and time periods as the retired population under study. The modified life table method, described in detail in an earlier report, was used for computing the expected number of deaths.[4] Inclusion of disabled retirees improves comparability with the

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