

Asbestos-associated Disease in United States Shipyards

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CLINICAL LATENCY OF ASBESTOS-ASSOCIATED CANCER

During the past 15 years the important disease potential of asbestos exposure has been clarified. The principal hazards have been demonstrated to be cancer of a number of sites, and asbestosis. Among asbestos workers, approximately 20 percent of all deaths are due to lung cancer, six percent or seven percent to pleural and/or peritoneal mesothelioma, and there is an excess found in several other categories (e.g., cancer of the esophagus, stomach, colon-rectum, oropharynx, larynx, kidney). Table 1 provides an analysis of causes of death among 17,800 asbestos insulation workers in the United States and Canada followed prospectively from January 1, 1967 to January 1, 1977.

Risk of asbestos-associated disease has also been observed in workers in other trades where asbestos exposure occurs—

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for example, where individuals simply working near "asbestos workers" are exposed to the same dusts. Risk extends even to individuals not employed in an asbestos-contaminated environment; mesothelioma has been found among family contacts of asbestos workers residing in the same households, as well as among people living within a quarter of a mile or so of asbestos plants or other facilities which have used asbestos-containing materials.

Although mesothelioma is not necessarily the most common disease resulting from asbestos exposure, it provides a very useful index of such problems, since it is only uncommonly seen as a result of exposure to other agents or without identified cause. Large scale investigations of series of cases of mesothelioma in France, Great Britain, the Netherlands¹⁻³ and elsewhere have demonstrated that the large majority of these cases can be traced to prior asbestos exposure.

For these neoplasms, as for all cancers due to asbestos exposure (and, indeed, for extensive asbestosis as well), a rather uniform characteristic has been found: the disease usually does not become clinically evident for 15, 25, 35 or more years from onset of asbestos exposure. The initial decades are periods of grace with no illness or disability. While some early X-ray changes may be seen after five to 15 years, they are limited in extent and not usually accompanied by significant symptoms. They merely dem-

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TABLE 1 Deaths among 17,800 asbestos insulation workers in the United States and Canada January 1, 1967-January 1, 1977		
Number of men Man-years of observation		17,800 166,855
	Expected*	Observed
Total deaths, all causes	1,660.96	2,270
Total cancer, all sites	319.90	994
Lung cancer	105.97	485
Pleural mesothelioma	**	66
Peritoneal mesothelioma	**	109
Cancer of esophagus	7.01	18
Cancer of stomach	14.23	22
Cancer of colon-rectum	37.86	59
All other cancer	154.83	235
Asbestosis	**	162
All other causes	1,351.06	1,114
*Expected deaths are based upon white male age specific mortality data of the U.S. National Center for Health Statistics for 1967-1975 and extrapolation to 1976. **These are rare causes of death in the general population. The membership of the International Association of Heat and Frost Insulators and Asbestos Workers, AFL-CIO, CLC, was enrolled on January 1, 1967, and has been observed since.		

onstrate that enough asbestos exposure has occurred to produce such changes. In this sense, they are harbingers of future risk of clinical disease.

Tables 2-5 illustrate the characteristic *latency* of asbestos disease. In one group of 1,117 asbestos insulation workers in the New York metropolitan area, most of 725 workers with less than 20 years from onset of exposure (Table 2) had normal X-rays. When changes were present, they were minimal in extent. On the other hand, after the 20-year point, most X-rays were found to be abnormal, frequently exten-

sively so.⁴ Tables 3-5 show that few mesotheliomas and little excess cancer of the lung occurred less than 20 years from onset. Most occurred 30 or more years from onset of exposure. A young man may begin work at the age of 18; his risk of asbestos-associated cancer does not become substantial until he is 40, 50 or older.

EARLY STUDIES: MESOTHELIOMA IN SHIPYARDS

In 1968, the first warning that asbestos

TABLE 2 X-ray changes in asbestos insulation workers⁴						
Onset of exposure (yrs.)	No.	% Normal	% Abnormal	Asbestosis (grade)		
				1	2	3
40+	121	5.8	94.2	35	51	28
30-39	194	12.9	87.1	102	49	18
20-29	77	27.2	72.8	35	17	4
10-19	379	55.9	44.1	158	9	0
0-9	346	89.6	10.4	36	0	0
Total	1,117	51.5	48.5	366	126	50

disease might be a serious problem in shipyards was sounded by Harries⁵ in Great Britain and Stumphius⁶ in the Netherlands when they reported instances of mesothelioma among shipyard workers. What was worrisome was that the men were not "asbestos workers" but rather, individuals employed in other trades. At the Devonport shipyard of the Royal Navy, for example, mesothelioma in a boilermaker, a fitter, a shipwright, a welder and a laborer were described.

This raised the important question of whether asbestos use in shipyards might result in the exposure of the workers employed in many trades, to dust derived from the few "asbestos workers" in their midst. In 1943, in the United States, for example, approximately one in 500 shipyard workers was an insulator. The other 499 included welders, shipfitters, machinists, pipefitters, electricians, boilermakers and painters (Table 6). The significance of this question is made apparent by the fact that during World War II, approximately 4,500,000 men and women worked in our shipyards, many of them under conditions in which exposure to asbestos was possible. After World War II the total number of shipyard workers rapidly decreased from a high of 1,700,000 in the last months of 1943 to 200,000 or so. During the period

of 1946-1976, total employment remained in this range, fluctuating with economic conditions and the country's shipbuilding program. The 200,000-250,000 figure characterized the total number in the yards at one time; however, there was much turnover, and the total number of different individuals was much larger. There are no accurate data readily available which could tell us how many different people—carpenters, riggers, electricians, draftsmen, welders, etc.—were so employed. Nevertheless, the early observations (soon augmented by later studies⁷⁻⁸) pointed to a potentially serious problem.

Harries has recently published his further observations at Devonport, through 1973.⁹ By the end of the year, he had observed 55 cases of mesothelioma in that shipyard alone. Again, trades other than "asbestos workers" gave evidence of the hazard. Only two of the 55 worked directly with asbestos (lagger, sprayer). The other 53 included 14 shipwrights, nine boilermakers, eight fitters and eight electricians (Table 7).

John Edge of High Carley Hospital has published similar data from shipyards in Barrow (Table 8)¹⁰; his most recent observations are particularly disturbing.¹¹ In Barrow, 429 individuals were seen, be-

TABLE 3
Deaths among 17,800 asbestos insulation workers in the United States and Canada January 1, 1967-January 1, 1977: Analysis by duration from onset of employment

Total men	12,683	12,051			
Man-years of observation	89,466	77,389			
	Before 20 years from onset	20 or more years from onset			
	Expected*	Observed	Expected*	Observed	
	Total deaths, all causes	283.93	324	1,377.01	1,946
	Cancer, all sites	42.65	83	277.25	911
	Lung cancer	12.03	36	93.94	449
	Pleural mesothelioma	**	2	**	64
	Peritoneal mesothelioma	**	3	**	106
	Cancer of esophagus	0.66	1	6.35	17
	Cancer of stomach	1.56	1	12.67	21
	Cancer of colon-rectum	4.07	4	33.79	55
Asbestosis	**	8	—	154	

* Expected deaths are based upon white male age specific mortality data of the U.S. National Center for Health Statistics for 1967-1975 and extrapolation to 1976.

** These are rare causes of death in the general population.

tween 1964 and 1971, with radiologically evident pleural plaques; these plaques were considered to signal prior shipyard employment. Controls were 429 men from a neighboring city (Carlisle), matched for age and date of X-ray; they had no plaques on their roentgenograms. Both groups were observed through 1976, i.e., for a minimum of five years. Among the 429 men with pleural plaques, there were 127 deaths; those with no plaques suffered 74 deaths. The excess was primarily in two categories, lung cancer and mesothelioma. There were 19 deaths from lung cancer and 23 from mesothelioma among the

former shipyard workers. As for the controls, four died of lung cancer and none died of mesothelioma.

Findings of an extraordinary increase of mesothelioma were also reported last year from the French shipyard area in Western Brittany. Lajarte et al. analyzed cases of pleural mesothelioma in Nantes. In the period 1957-63, there were two cases; from 1964-1970 there were 12; and from 1971-1974 there were 24.¹² This was interpreted as consistent with the markedly increased shipbuilding program during and after World War II, and with its attendant risk of asbestos exposure.

TABLE 4 Deaths among 17,800 asbestos insulation workers in the United States and Canada, Jan. 1, 1967-Jan 1, 1977: Analysis by duration from onset of employment						
Duration from onset (years)	Num- ber of men	Person- years of observation	Lung cancer		Pleural mesothelioma No./1000 person-years	Peritoneal mesothelioma No./1000 person-years
			Expected*	Observed		
<10	5,552	26,393	0.69	0	0	0
10-14	9,063	29,003	2.77	7	0	0
15-19	9,948	34,069	8.57	29	0.06	0.09
20-24	8,887	31,269	17.03	59	0.19	0.10
25-29	6,596	20,657	21.04	104	0.73	0.87
30-34	3,547	11,598	18.48	112	0.86	1.90
35-39	2,019	5,401	11.47	66	2.96	3.33
40-44	1,108	3,160	8.12	39	1.27	5.06
45+	1,030	5,305	17.82	69	2.45	5.47
* Expected deaths are based upon white male age specific mortality data of the U.S. National Center for Health Statistics for 1967-1975 and extrapolation to 1976: Smoking habits not taken into account.						

ASBESTOS DISEASE IN U.S. SHIPYARDS

There has been comparatively little written concerning the potential for asbestos-disease hazards in U.S. shipyards. In part, this may have been due to the fact that in the latter part of World War II a survey directed to this question failed to demonstrate the prevalence of significant asbestos disease. At that time, 1,074 insulation workers employed in U.S. yards were examined and, with few exceptions, no evidence of disease was found.¹³ Unfortunately, the significance of the fact that the very large majority of men had begun working only a short time before was not appreciated; neither was it understood that X-ray evidence of disease could not be expected to appear until one or two decades later.

During the 1960's, evidence accumulated that "asbestos workers" (insulation)

employed in shipyards had unhappy disease experience, with markedly increased death rates of cancer (lung cancer, pleural mesothelioma, peritoneal mesothelioma, gastrointestinal cancer) and asbestosis.¹⁴ These observations, however, were confined to insulation workers, and while they pointed to a possible accompanying difficulty among other shipyard trades, especially in view of British experience, detailed observations concerning other workers were not available.

The potential for asbestos disease in U.S. shipyards was further highlighted by accumulating knowledge that the workers who manufactured the asbestos insulation materials used in U.S. yards during and after World War II were themselves found to suffer serious asbestos disease. Investigations of the employees at one such plant showed markedly increased risk of neoplastic disease and asbestosis, including increased risk of death of cancer with as little as one month of employment.^{15, 16}

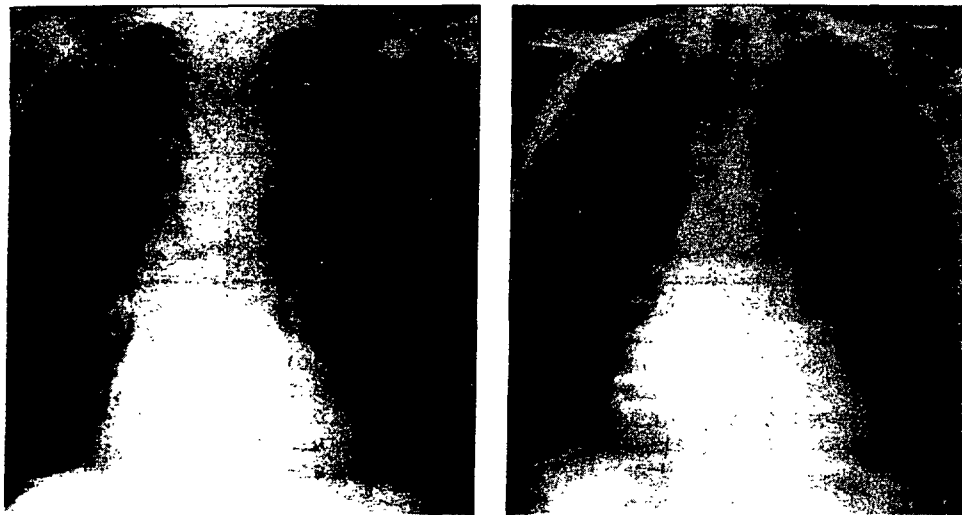


Fig. 1 S.P. & J.M. Extensive bilateral pleural calcification in former shipyard workers. Asymptomatic. No part of pleura is immunecostal; diaphragmatic, mediastinal, pericardial. Bilateral calcification of this sort rarely seen except with prior asbestos exposure.

Even wives and children of the employed workers showed evidence of asbestos disease, indicating that exposure of lesser intensity might be seriously hazardous as well.¹⁷

RECENT SURVEY OF SHIPYARD WORKERS, GROTON, CONNECTICUT

Cases of asbestos-associated disease among workers employed in a shipyard in Groton, in 1974-1975, were brought to our attention. Against the background of what was already known concerning the potential for asbestos disease in shipyards, it appeared useful to obtain information concerning whether there was the likelihood of a high incidence of such disease or whether the cases seen were isolated, random exceptions.

Lung cancer, mesothelioma, extensive asbestosis and other serious complications of asbestos exposure are late findings. Limited X-ray change (parenchymal, with-

in the lung, or pleural) often precede these serious consequences. While such changes may occur to an extent visible by X-ray without subsequent cancer or disabling asbestosis, their appearance among a group of workers provides evidence of prior significant asbestos exposure. Absence of such X-ray changes is no guarantee that important asbestos exposure has not occurred. Many workers may have had asbestos exposure sufficient to cause death from mesothelioma, for example, without showing X-ray change. Nevertheless, taken as a whole, absence of X-ray change in a group of workers suspected of having been exposed to asbestos provides some evidence that the exposure was limited. On the other hand, the presence of characteristic asbestotic X-ray abnormalities is *prima facie* evidence that, overall, there was important asbestos exposure in the group.

In light of this, we sought to ascertain whether there was significant prevalence of asbestotic X-ray abnormalities among Groton shipyard workers. Examinations



Fig. 2 J.B. Both fibrotic plaques and pleural calcification in x-ray of former shipyard worker. Asymptomatic. Their presence is merely evidence of prior asbestos exposure and not indicative that mesothelioma will necessarily follow.

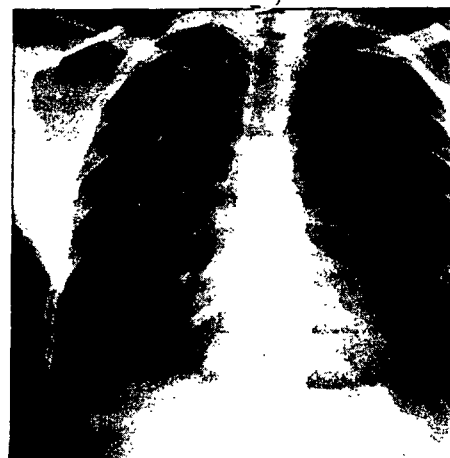


Fig. 3 J.W. Age 49, 1975. Truck driver until 1960, when he became "pipe coverer" in a shipyard. X-ray, fifteen years later, shows reticular (irregular) opacities of moderate profusion (2/2 in the ILO U/C Classification). Some shortness of breath on exertion. Note: infiltrate in lower lung fields, upper lobes clear. This is common.

were largely limited to those whose employment had begun 15 or more years before; all were volunteers. A caveat is in order: there is no way of knowing, under these circumstances, whether those who volunteered were necessarily representative of the entire work force, or even of their specific employment category. Altogether, 1,000 men were examined, including 157 boilermakers, 121 pipefitters, 73 insulators, 82 painters, 69 carpenters, 117 welders, 104 electricians, 108 outside machinists, as well as laborers, molders, lead bonders, office workers, draftsmen, guards, and decontamination technicians.

Films were categorized using the International Classification of Radiographs of Pneumoconioses (ILO U/C) (Appendix 1).

Overall, approximately half of the workers examined showed X-ray evidence of pulmonary and pleural changes of the sort regularly seen following direct or indirect occupational exposure to asbestos (pulmonary asbestosis, pleural asbestosis). The findings are outlined in Tables 9 and 10. One or another abnormality was

present in 274 of 636 workers with less than 20 years from onset of exposure (43.1 percent) and among 185 of 364 shipyard workers 20 or more years from onset (50.8 percent). Parenchymal disease was seen in 29.6 percent of the former group and 36.8 percent of the latter. Pleural changes were found in 23.1 percent of the less experienced workers and in 29.7 percent of the men with longer experience. The high prevalence of pleural changes was not unexpected, having been found previously among shipyard workers in Britain and elsewhere.¹⁸

The importance of duration from onset of exposure is clearly seen in Table 10, where it is found that among 303 workers who began work only in 1961 or later, 115 (38.0 percent) had abnormalities on X-ray. In contrast, among 166 workers whose employment began in 1950 or before, 85 (51.2 percent) were abnormal.

No trade was immune to changes. Tables 11 and 12 indicate that this was as true for painters as it was for electricians, for carpenters as for machinists, and for

TABLE 5 Deaths among 17,800 asbestos insulation workers in the United States and Canada, Jan. 1, 1967-Jan. 1, 1977: Analysis by duration from onset of employment					
Years from onset of employment	Total deaths	Percent of all deaths			
		Lung cancer	Mesothelioma		
			Pleural	Peritoneal	Total
<10	51	0	0	0	0
10-14	85	8.24	0	0	0
15-20	188	15.43	1.06	1.60	2.60
20-24	320	18.44	1.88	0.94	2.82
25-29	388	26.80	3.86	4.64	8.40
30-34	340	32.94	2.94	6.47	9.41
35-39	253	26.09	6.32	7.11	13.43
40-44	203	19.21	1.97	7.88	9.85
45+	442	15.61	2.94	6.56	9.50
Total	2270	21.37	2.90	4.80	7.70

boilermakers as for welders. Review of work practices makes this quite understandable, of course. The conditions of shipyard work have been such that it is likely that asbestos exposure would have occurred among all individuals at a work site where the material was being installed, repaired or removed. Data are less certain for the less common crafts, where fewer workers were examined. Although evidence of asbestotic changes was found among some of these men and women as well, one can estimate a proportion only with less assurance.

Thus, exposure to asbestos under past conditions, of an intensity sufficient to cause significant asbestotic X-ray change, was common at the shipyard in Groton. As a result, a large number of workers now have pulmonary changes associated with such exposure. The prevalence of such a high proportion of asbestotic X-ray

changes raises the question of increased risk of asbestos-associated neoplasms in the future. Those to be considered include cancer of the lung, pleural mesothelioma, peritoneal mesothelioma, and esophageal, stomach, colorectal, oropharyngeal, laryngeal and renal cancer. The extent of this risk is not now known.

CURRENT SITUATION

In terms of public health, the overwhelming problem is the undoing, ameliorating or modifying of both current and anticipated results of past mistakes. The problems are straightforward and, simultaneously, complex. To a considerable degree, the complexity derives from the fact that we have had little experience to guide us in such matters, especially on the scale found in the present situation.

The following recommendations —

necessarily incomplete and tentative — are offered:

1. Knowledge concerning asbestos exposure:

■ *Dissemination of information:* understanding the disease potential of asbestos exposure (past and future) would be valuable for both worker and management.

■ *Avoidance of additional exposure:* appropriate engineering and industrial hygiene methods are crucial; removal or repair of asbestos materials now in place presents a problem for the future.

2. Medical surveillance programs:

■ *Asbestosis:* awareness of the presence of this disease by both the patient and the treating physician would be important, since most deaths of asbestosis are due to intercurrent respiratory infections, rather than to progressive pulmonary fibrosis. Pulmonary infections can be well treated, and experience has shown that many lives can be saved.

■ *Lung cancer:* early diagnosis can increase the likelihood of successful treatment to some extent (by no means as much as we would like). It is not known whether more energetic surveillance (as with frequent sputum cytology examination) will increase the percentage of those successfully treated. Studies are now in progress to investigate this possibility.

■ *Colorectal cancer:* early diagnosis increases the likelihood of cure.

■ *Oropharyngeal, laryngeal or renal carcinoma:* awareness of the increased risk of these cancers improves chances for early study and diagnosis of the presence of these conditions, which can be cured in many cases.

■ *Pleural and/or peritoneal mesothelioma:* effective therapy is not now available and early diagnosis does not significantly increase the likelihood of survival. However, research concerning therapy is now underway in the United States, Great Britain and France, and it may be hoped that improved treatment methods will become available.

■ *Education programs:*

Smoking: lung cancer risk is greatly

TABLE 6
Percentage distribution of trades
in private shipyards, June 1943

Trade	Percentage
Welders	15.3
Shipfitters	11.0
Machinists	8.1
Pipefitters	7.2
Electricians	6.6
Carpenters	6.1
Laborers	5.5
Burners	3.8
Painters	3.1
Sheetmetal workers	3.0
Riggers	2.8
Chippers and caulkers	2.8
Boilermakers	2.3
Crane operators	1.3
Pipe coverers	0.2
All other	21.1

Source: Bureau of Labor Statistics, Bulletin 824

multiplied by asbestos exposure.¹⁹ It is urgent that this information become available to workers who have been exposed to asbestos, and that every assistance be afforded them to help in their efforts to control and eliminate smoking, especially cigarette smoking. Some data are also available suggesting that cessation of smoking will, after a number of years, reduce the risk of lung cancer, even with a history of prior cigarette smoking. Should these experiences be confirmed, it will be even more urgent to identify and alert former shipyard workers, to acquaint them with the important risk of lung cancer should they continue cigarette smoking. Cigarette smoking also increases the risk of serious disability associated with pulmonary fibrosis, and of the develop-

TABLE 7 Mesothelioma tumors in Devonport Dockyard, England, 1964-1973*				
Asbestosis (disability)		Occupation	Mesothelioma (deaths)	
No.	%		No.	%
16	10.3	Sprayers	1	1.8
36	23.1	Ladders	1	1.8
15	9.6	Shipwrights	14	25.5
4	2.6	Boilermakers	9	16.4
15	9.6	Engine fitters	8	14.5
11	7.1	Electricians	5	9.1
6	3.8	Caulkers-Riveters	3	5.5
5	3.2	Welders	3	5.5
48	30.8	All others	11	20.0
156			55	
*Harries, P.G., Envir. Res. 11:261-267, 1976.				

TABLE 9 X-ray abnormalities among workers employed in shipbuilding and ship repair					
TYPE OF ABNORMALITY	Less than 20 years from onset of shipyard employment (636)		20 or more years from onset of shipyard employment (364)		Total
	Number	%	Number	%	Number %
Any abnormality	274	43.1	185	50.8	459 45.9
All parenchyma	188	29.6	134	36.8	322 32.2
Parenchyma only	127	20.0	77	21.1	204 20.4
Parenchyma & pleura	61	9.6	57	15.7	118 11.8
All pleura	147	23.1	108	29.7	255 25.5
Pleura only	86	13.5	51	14.0	137 13.7

TABLE 8 Mortality experience of 429 shipyard workers in Barrow, England with pleural plaques on x-ray (1964-1971) compared with control men in Carlisle, without pleural plaques		
Tracing to December 31, 1976	Plaques	Controls
Alive	299	347
Dead	127 (30%)	74 (17.2%)
Not traced	3 (0.7%)	8 (1.9%)
	429	429
Causes of death	Plaques	Controls
Lung cancer	19	4
Mesothelioma	23	0
G. I. cancer	7	4
All other cancer	13	7
Ischemic heart disease	34	29
Chronic bronchitis	9	9
All other causes	22	21

TABLE 10 X-Ray abnormalities among workers employed in shipbuilding and ship repair: analysis by duration from onset of work					
Onset of work	Total	NORMAL		ABNORMAL	
		No.	%	No.	%
< 1950	166	81	48.8	85	51.2
1951-1955	198	98	49.5	100	50.5
1956-1960	333	174	52.2	159	47.8
> 1961	303	188	62.0	115	38.0
	1000	541	54.1	459	45.9

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TABLE 11 X-Ray abnormalities among shipyard workers employed in shipbuilding and ship repair: major crafts					
CATEGORY	Years from onset of shipyard work				
	All groups		20 or more years		
	Number	Abnormal Number	%	Abnormal Number	%
All crafts	1000	459	45.9	185	50.8
Painters	82	44	53.7	10/25	40.0
Machinists (outside)	108	58	53.7	12/32	37.5
Pipefitters	121	66	54.5	25/34	73.6
Insulators	73	38	52.0	2/7	28.6
Electricians	104	55	52.9	23/34	67.8
Boilermakers	157	80	51.0	41/84	48.8
Welders	117	42	35.9	25/48	52.1
Carpenters	69	38	55.1	12/33	36.4
	831				
Total	1000	459	45.9	185/364	50.8

ment of cancer of the esophagus. Again, educational programs would be of value.

3. Assessment of the potential for shipyard asbestos disease:

- *Household contact asbestos disease:* while families of asbestos workers are at risk, it is not known whether shipyard workers tended to contaminate their homes with appreciable amounts of asbestos in the past, and whether this has resulted in disease risk. Such

information is required for proper clinical surveillance.

- *Necessary additional data:* appropriate studies of mortality experience, status of retired workers and effects of minimal exposure are required for complete evaluation of the potential for future shipyard asbestos disease. Nevertheless, enough is now known to warrant rapid development of effective medical surveillance programs. Further research can proceed apace. ©

TABLE 12 X-Ray abnormalities among workers employed in shipbuilding and ship repair: less common crafts			
	No.	Abnormal	%
Heavy equipment operators	13	8/13	62
Laborers	7	1/7	14
Inside machinists	30	15/30	50
Molders	12	4/12	33
Lead bonders	21	7/21	33
Decontamination technicians	12	5/12	42
Guards w/o previous job in yard	12	3/12	25
Office workers - Draftsmen w/o previous job in yard	37	16/37	43

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