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G-515

THE ACTUAL CONTRIBUTION OF GARLOCK ASBESTOS GASKET MATERIALS TO THE OCCUPATIONAL EXPOSURE OF ASBESTOS WORKERS

CARL A. MANGOLD, C.I.H.

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Mangold
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H. Thurman, CSR

ABSTRACT

Hard-pressed or encapsulated asbestos gasket materials manufactured by Garlock release only small amounts of fibers during handling, processing or removal in industrial operations. A recent Department of the Navy study confirmed that the total occupational exposures related to gasket materials are at the minimum risk levels compared to current Federal standards.

This study, commissioned by Garlock Inc, shows that work area contamination - i.e., ambient pollution from other sources in industrial areas, asbestos-laden clothing, and general atmospheric pollution - far exceeds any contributions from such gasket materials and makes emission from gaskets insignificant by comparison.

When these nongasket sources of contamination are minimized the actual occupational exposure of the gasket materials is in the range of the levels of exposure expected in downtown city streets on dry summer days experienced by the public.

The breathing zone concentrations of asbestos fibers from Garlock, Styles 7021, 900/7735 and 605 gasket materials prepared as they were in the 1940-1970's are near the lower limit of detection. To the extent they are measureable, the values average 1/100th of the current allowable exposure of two fibers per cubic centimeter greater than five-micrometers in length as determined by phase contrast microscopy and based on an eight-hour time-weighed average work day.

The actual contribution of the Garlock asbestos gasket materials described and evaluated in work environments constitute a negligible exposure and risk to workers. The occupational exposures, are often lower than contamination levels of industrial work areas where asbestos is processed, or the exposure to the general population living near those industrial areas, or in downtown city streets on dry summer days.

DISCLAIMER

The author is solely responsible for the contents and conclusion in this report which may not necessarily reflect the official opinion of contributors, the U.S. Department of Navy, or U.S. Department of Labor.

ACKNOWLEDGEMENTS AND CONTRIBUTORS

1. J. D. Wendlick, Corporate Industrial Hygenist, The Weyerhaeuser Company, Tacoma, Washington.

2. Zidell Corporation, Tacoma, Washington.

3. Northwest Health Services, Richland, Washington.

4. Devine Diving & Salvage, Portland, Oregon.

5. Dorothy Gockel, Researcher, Department of Community Medicine, University of Washington, Seattle, Washington.

6. Mine Safety & Appliance Company, Seattle, Washington.

TABLE OF CONTENTS

1255G

HISTORY

Asbestos is one of our most plentiful, useful, and cheap industrial minerals. Consequently, because of its high thermal stability and resistance to corrosion it appears in more than 3,000 manufactured goods in the United States. Estimates are that at least 30,000,000 tons have been used in construction and manufacturing since the year 1900. This common use of asbestos has led to the exposure of millions of Americans at levels that may have a significant impact on their health. Today, large numbers of Americans are exposed to asbestos both in industry, as well as in our environment. Environmental exposure occurs in our cities, near industrial complexes, from soil high in asbestos content, and even in rural areas affected by natural erosion of asbestos containing rock. Therefore, most Americans receive at least some regular low-level exposure to asbestos in their lifetimes. However, some experience much higher levels from occupational sources or have had high exposures in past years.

The concerns about the role of asbestos in the development of the lung disease, known as asbestosis, began in the United States in the 1930's and progressed slowly as more was learned of the pathogenesis of the disease. Most of the attention was centered on disabled workers with an obvious work-related exposure pattern involving exposure to raw fiber. Few, if any controls, were followed so that time and intensity factors led to clear cases of asbestosis. This continued until the 1960's when signs of asbestos-related cancers began to reshape thinking and action about occupational exposures to asbestos. Today the exposures of workers have been markedly reduced through various means of voluntary controls and legislation that led to the first Federal standards in 1972.

In 1964, Marr [1] concluded that asbestos-associated disease was an important problem among insulators working in naval shipyards. However, the methods of assessment weakened the conclusions. Pioneer work was begun at Puget Sound Naval Shipyard (PSNS) in 1965, culminating in a conclusive report by Mangold, Beckett & Bessmer in 1970 [2, 3]. Most of the attention was directed at the products and operations that produced high-level exposures to asbestos workers and associated trades. The conclusions were that the threshold limit was still too high at 5 million particles per cubic foot (mppcf) (equivalent to approximately 50 fibers per cubic centimeter (cc)) and that intermittent peak exposures were far more important than previously considered. Both have been corroborated by more recent literature. About 1964, Selikoff [4, 5] and others began reporting the appearance of asbestos specific cancers in work groups with high exposures to asbestos and long work histories.

Since that time, wide attention has been given to the diseases of asbestos by physicians, scientists, and researchers and driven by Federal Regulation that lead to the lowering of allowable occupational exposure levels and the marked increase in claims based on previous high-level exposures.

In 1978, Dr. Irving Selikoff of the Mount Sinai Hospital and a team of medical scientists conducted a study on the Disability Compensation for Asbestos-Associated Diseases in the United States [6]. The study was completed in 1982 and clearly defines the latent effects of exposure and probable dose-response relationship based on time and intensity of exposure. However, J. E. Craghead, et al. [7], M. R. Becklake, W. J. [8], Nicholson, et al. [9], raise reasonable questions about the validity of the probable dose-response relationship because of the latency factors and the ill-defined responses to low-level exposure. Nicholson [9] observes that the long lapse time from exposure to the onset of asbestosis, or asbestos-related cancers, creates significant difficulties in attempting to establish a dose-response relationship. The disease incidence today is from decades past when few measurements of asbestos concentrations were made, exposures were high, and controls were few. Churg [10] described the relatively high level of asbestos fibers in the lungs of city dwellers not occupationally exposed. This suggests a typical sigmoid, or "s" shaped form found in dose-response relationships where a lower no-effect level is reached, rather than the direct dose-response curve which takes the form of a straight line.

There is a linearity of effect with increasing amounts of asbestos inhaled for related asbestos induced cancers. There are differences in the slopes of the dose-response curves and some literature implies that a linear, or direct response exists at any level of exposure. In reality, these are extrapolations from epidemiological data on deaths which resulted from unknown, or previous high level exposures to asbestos. Fiber exposures of long ago are of more importance in determining the risk of cancer than more recent exposures.[6] They do not relate to very low concentration exposure patterns, therefore extrapolations that approach the idea in the single-hit mathematical model is extreme, and without solid proof to ascertain the actual occupational exposure from individual products. The discovery that elevated levels of exposure to asbestos fibers may lead to related cancer, and the trends in Tort claims requires a knowledge of the exposure potential of each product.

Obvious attention is now given to lower levels of exposure than ever before. As technology and preventive work practices lower occupational exposure, the contributions of each asbetsos product becomes important. When high-level exposure occurred during uncontrolled work situations or even at allowable exposures of 5 mppcf (50 fibers/cc) under the prior recommended TLV, contributions from encapsulated gaskets were fractional and negligible. In short, the extremely low level contribution from such gaskets is obscured by the high background levels from other asbestos sources, or their residual contamination.

II.

BACKGROUND

The earlier works of Marr [1] and others [11] used methods and instruments which are now unsuitable for the assessment of asbestos exposure based on the current Federal occupational standard of two fibers per cubic centimeter greater than five micrometers in diameter as collected on a membrane filter and counted by phase contrast microscopy at 400X. When the asbestos dust levels were elevated, little attention was given to background contamination and the sampling and counting errors because of their negligible effects. As the allowable exposure levels were reduced over the years, effects of background contamination have become important factors in assessment of exposures that are in the range of these sources of contamination. The current Federal standard requires evaluation that is approaching the lower limits of detection by phase contrast microscopy within acceptable statistical limits. In fact, R. D. Zumwalde and J. M. Dement [12] observe that 0.1 fibers/cc greater than five micrometers in diameter is the lower limit of detection that may be used with any reliability. These assumptions are based on the counting limitations by phase contrast microscopy and the known random sampling errors. Reported values below 0.1 fibers/cc become suspect unless rigorous procedures are followed to avoid large errors and the effects of contamination. Therefore, it is useful to reevaluate previously reported exposures to asbestos gasket materials [15], to validate them and to judge the effect of these factors.

Kenneth A. Busch, et al. [13], further describes the limitations of the method and the potential for large co-efficients of variation when low levels of asbestos are measured.

Earlier determinations of the low level of fibers released from encapsulated gasket materials must be revised to still lower values because prior measurements did not accurately take account of contamination in the work area, and other bias such as the limitations of the counting method, or arbitrary sampling considerations.

III.

INTRODUCTION

Because naval shipyards were large-volume users of asbestos products, the occupational exposures in the 1940's, 1950's and 1960's were often elevated [1, 2, 3, 6]. Most of the evaluation, engineering, change or work practices, and personal protective measures were directed toward these obvious sources of exposure. Each of the asbestos products were used in a unique way ranging from blankets of asbestos used for thermal insulation that caused high exposures to the negligible exposures caused by gasket materials. Products like gaskets contributed a comparatively small, almost unmeasureable, proportion to the overall occupational exposure. Therefore, little attention was given to these low-level sources of exposure because the high volume, high-exposure level sources needed primary attention.

In 1946, the American Conference of Governmental Industrial Hygenists (ACGIH) adopted a Threshold Limit Valve (TLV) for particulate in air based on 5 million particles per cubic foot (mppcf) for an 8 hour time-weighted average workday, which remained in effect until 1969, when it was reduced to 2 mppcf. The analytical procedure required that air samples were drawn through midget impingers containing distilled water at a rate of .1 cubic foot per minute. An aliquot of the solution was transferred to a microscope counting cell in the laboratory and the particles counted by light field microscopy at 100X power.

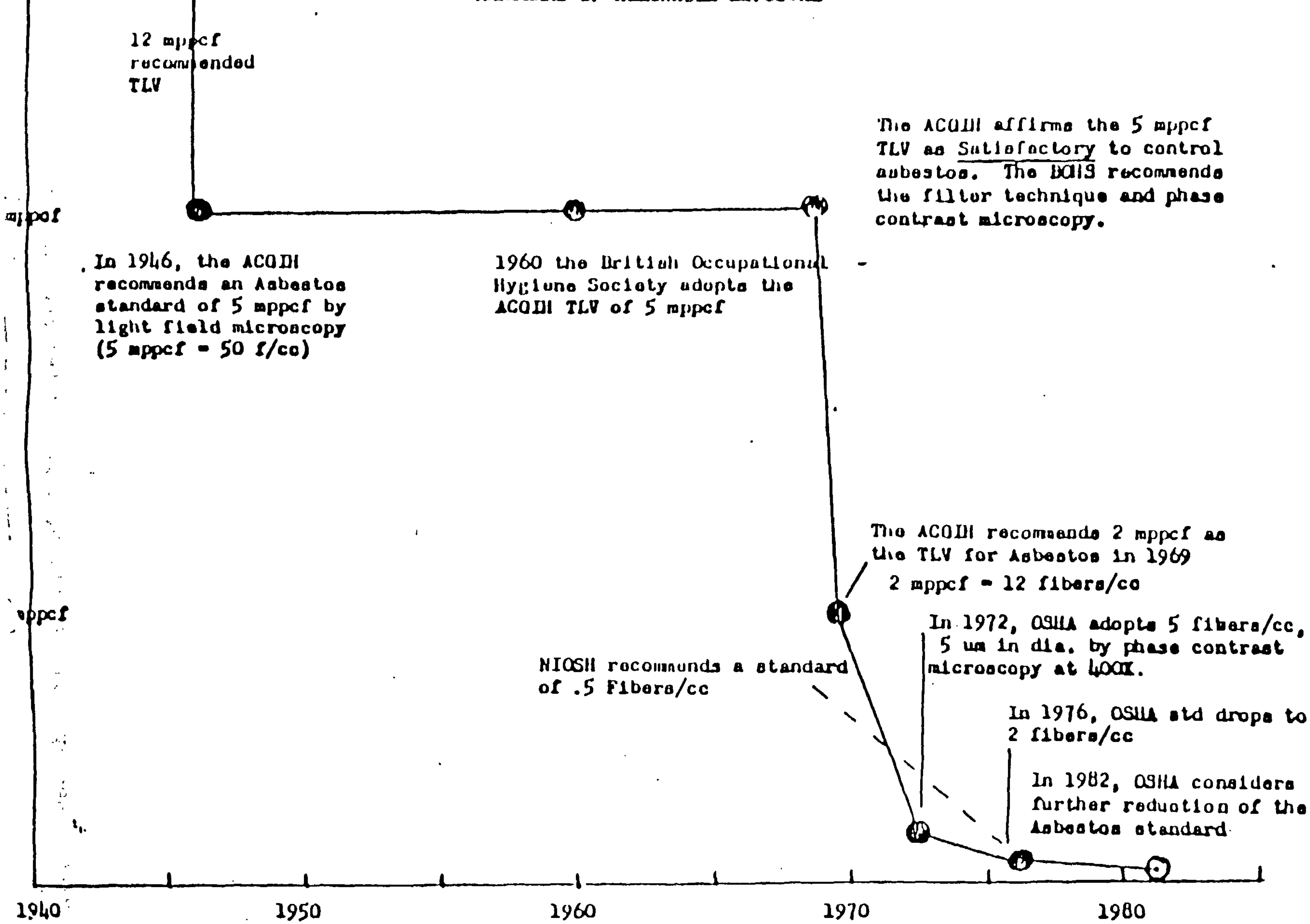
Ayer at. al. (14) conducted comparative sampling in asbestos plants in 1965 using the impinger/light field microscopy technique and the current membrane filter/phase contrast microscopy method. They concluded that 50 asbestos fibers/cc, greater than five micrometers in diameter by the membrane filter method was comparable to 5 mppcf by the impinger/light field microscopy technique. This comparison is important to show the comparatively high allowable level of occupational exposure to asbestos fibers in air during 1946 through 1969 when the 5 mppcf TLV was applied.

Accordingly, standard shipbuilding and repair practices such as magnesia block cutting and installation, or asbestos cement mixing created equivalent fiber counts ranging from 167 to 475 fibers/cc on an eight-hour time-weighted average basis [2,3]

Because of these high contamination levels from all other sources, Mangold, Beckett & Bessmer justifiably ignored the gasket contribution in their studies culminating in the 1970 PSNS report [3]. It was not until 1978, that the Department of Navy [15], as part of a continuing evaluation program set about evaluating asbestos exposures to workers from storing, handling, and processing asbestos gaskets of all kinds. The Puget Sound Naval Shipyard (PSNS) was selected as the lead shipyard in the evaluation which produced the 1978 report. This evaluation is important because there exist few such publications that identify and estimate the occupational exposure to asbestos gasket materials. The report concludes that even the simplest of general housekeeping controls or work practices are sufficient to maintain occupational exposure below the current Federal standard for an eight-hour TWA exposure of two fibers/cc, greater than five micrometers in diameter or the proposed NIOSH standard of 0.5 fibers/cc, greater than five micrometers in diameter. In fact, many of the exposures were found to be less than 0.1 fiber/cc at which level medical examinations are no longer required [16], according to a current interpretation of the Federal Standard for Asbestos.

It is reasonable to conclude that the same types of gasket materials used in the same manner from 1940-1970 would produce the same negligible contribution to the overall occupational exposure. Secondly, the contribution from encapsulated gaskets was much below generally accepted allowable exposures. For example, the recommended threshold limit value (TLV) was 12 mppcf (120 fibers cc) until 1946 when it was reduced to 5 mppcf (about 50 fibers cc) until 1969, when it was further reduced to to two mppcf (about 12 fibers/cc). In 1972, a still more stringent Federal standard of five fibers/cc, greater than 5 mm in diameter on an eight-hour time-weighted average was adopted, and this too was later reduced to two fibers/cc in 1976. Thus encapsulated gaskets, found to emit less than .01 fibers/cc, are at levels more than 200 times below the current Federal standard and thousands of times less than earlier accepted standards. Page 10 depicts a graph illustrating the manyears of allowable exposure to asbestos fibers from 1946 to 1982.

MANYEARS OF ALLOWABLE EXPOSURE



Source: Rajhans, O.H. Bragg, Engineering Aspects of A[illegible]os Dust Control
[illegible]bor Science Publishers, 1978

However, the techniques and methodology used in the PSNS gasket report may provide misleading information that would cause higher levels of asbestos exposure in the breathing zone of workers to be reported than actually exists in a work day from processing asbestos gasket materials.

The 1978 PSNS report [15] does achieve the intended purpose to determine the exposure to any and all asbestos in the breathing zone of workers but does not determine the actual contribution from the gaskets alone. Samples were collected in some work areas under uncontrolled conditions and later in the same work area under controls without regard to potential prior contamination. While exposures were reduced by cleanup, the contamination from past operations would be present in the air and/or redisbursed from previous activities. Tiny fibers of asbestos remain airborne indefinitely under such conditions of turbulence [17, 18, 19, 20, 21, 22]. Because the airborne concentrations reported in the PSNS gasket report [15] are extremely low, often .01 fibers/cc or less, the potential for contamination is certain and would be expected to substantially skew reported values upward. The sample periods in the PSNS report range from six minutes to 132 minutes which is another factor which limits the precision of the method. Also, the limitations in the counting techniques [12, 26, 27, 28, 29] indicates that at least ten fibers/100 microscope fields within an effective microscope counting area of .005 mm2 must be viewed to remain within the very large co-efficient of variation of 0.41 at that concentration [25]. Additionally, single samples collected for short sample times and using an arbitrary lower cutoff of .01 fibers counted introduced unequal and wide systematic error by the report's own statements [15] on page 3. Furthermore, membrane filters like the Millipore AA, .8u pore size have a background of 0.1 fibers per microscope Porton recticle field or ten fibers/100 fields [29]. Therefore, larger air volumes must be collected to be able to measure the airborne contribution with any certainty when airborne asbestos levels are in the ranges reported. The report assumes 0.01 fibers counted as a lower limit for low values regardless of actual existence of the fibers, thereby introducing the systematic error.

The sample periods were limited to actual exposure time during the sample period and may not reflect a complete unit operation or an eight-hour time-weighted exposure, and more likely reflect intermittent peak exposures.

The report concludes that exposures do not exceed the current Federal standard of two fibers/cc, on an eight-hour TWA. This is misleading since only the intermittent peak exposures of single or parts of an operation were reported. These intermittent peak values may be several orders of magnitude higher than the actual eight-hour time-weighted average, based on a 40-hour week, and adjusted for background contamination.

In some cases, only single samples were collected for an operation. Such single samples only serve as indicators and are not relevant nor statistically significant.

The low-exposure levels reported do not consider pre-existing contamination, and therefore do not necessarily represent the actual airborne contribution from the gasket materials.

Section XII of the 1978 PSNS report shows consistently higher reported values for samples collected at Long Beach Naval Shipyard by the Naval Regional Medical Center, Oakland, than reported by PSNS. There is no evaluation or comparison of this data.

The 1978 PSNS report is unique because there are only a few such reports that evaluate the contribution of various types of asbestos gasket to the occupational exposure according to the state-of-the-art work practices conducted in large shipyards by highly mobile work forces. Nonetheless, the data shows only a small contribution by gasket materials to the overall occupational exposures which include atmospheric pollution, contamination, redispersion of fallen asbestos fibers and dirty clothing, and reflects higher intermittent peak exposures of unit operations. Although the 1978 PSNS Gasket Report is an important work, a redefinition is needed to show the actual exposure of gasket products. This would exclude other sources of exposure or make adjustments for them because there is a common thread of error of assumption, namely that the sampling of low-level airborne asbestos levels in a highly contaminated environment reflects the actual gasket exposure pattern.

The technical objections previously stated introduce large systematic errors from counting assumptions and background contamination that skew the actual airborne exposure levels substantially upward. Therefore, the values are overstated and do not reflect actual eight-hour time-weighted exposure patterns. The accumulated contamination is a function of location, operation, use rate and work practices.

The 1978 PSNS report makes arbitrary sampling and microscope counting decisions that affect the lower limit of detection of the methodology. For example, a 15 minute sample has a lower limit of detection of .06 fibers/cc at 1 fiber/100 microscope fields counted. Valves below .01 fibers counted were assumed to be .01 fibers found. This was done for convenience but nonetheless leads to higher values reported than actually found. Insufficient fibers collected on the filter caused by short sample periods would introduce large counting errors using the above assumption.

The NIOSH Revised Recommended Asbestos Standard of 1976 [30] shows that under the most optimum conditions using a microscope field counting area of .0071 mm2, the lower limits of detection range from .04 fibers/cc, greater than 5 um in length for a 15-minute sample up to .001 fibers/cc, greater than 5 um in length for an eight-hour time-weighted exposure. This is equivalent to the discovery of the adjusted net count of one [1] asbestos fiber, greater than 5 um in length in 100 microscope fields. The gross count is adjusted for fibers already on the membrane filter as stated by the manufacturer [29]. There is no basis or current procedure that justifies identification of less than one [1] fiber in 100 fields counted. The NIOSH Revised Recommended Asbestos Standard of 1976 [30] shows the procedure fails due to large errors when less than one [1] fiber/100 fields is considered based on known variabilities from:

(1) Uneven distribution of fibers on the filter surface;

(2) Variance of distribution on any given filter wedge counted;

(3) Variability in microscopes;

(4) Differences in technique and ability of analyst;

(5) Variations between laboratories.

Regardless of its limitations, phase-contrast microscopy is the only reasonable technique available for routine asbestos fiber counting and is the only method that relates directly to the Federal standard that sets allowable occupational exposures to airborne asbestos fibers, and the requirements for medical examinations. [24, 25, 26, 28, 30, 31, 32]

Since 1964 when the threat of asbestos-related cancers were defined (4,5) and with the increasing knowledge about asbestos exposure, the focus has shifted to the concept of reduction to lower and lower allowable occupational exposures. However, there is some question about the extrapolation of data from studies conducted at much higher levels of exposure to these lower levels of exposure with the same expected dose-response relationship.

The technical ability to measure low airborne concentrations of asbestos fibers have been made possible by phase contrast microscopy but the analytical method approaches the limits of accuracy and precision (12) when lower levels of asbestos fibers are measured.

Some products like asbestos gasket materials contribute negligibly to the overall occupational exposure of workers. But these small contributions are confounded or obscured by high background contamination levels where asbestos products are processed, such as, nearby dusty operations, contaminated clothing, and atmospheric pollution. Consequently, the actual contribution of gasket materials that produce only low level exposure to the overall occupational exposure of workers becomes important and because few studies have attempted to differentiate the actual exposure from these sources of contamination.

The average overall asbestos dust levels in cities and near industrial areas often reach levels in the range of the contribution of certain industrial products like gasket materials. Therefore, the need to study and determine the actual contribution of gasket materials to the potential occupational exposures to asbestos is readily apparent, and to place the previous studies of Mangold [3], and Beckett [15] in perspective.

Because of this, a comparative evaluation was developed to measure the actual contribution of Garlock asbestos gasket materials to the occupational exposure of workers in large industrial settings based on the eight-hour time-weighted average.

IV.

METHODS OF INVESTIGATION

The low results of some of the gasket operations evaluated in the 1978 FSNS report at the .01 to .04 fiber/cc levels suggest that other sources of airborne asbestos fibers were part of those reported values, as well as some of the more elevated values or single samples reported. The sources of sample contamination are:

(1) General atmospheric pollution;

(2) Redispersion of fallen dust in the work area;

(3) Sources of asbestos dust from adjacent operations;

(4) Contaminated work clothing. (The sample cassette is attached to the lapel as a standard practice [32].)

(5) Contaminated sampling equipment that introduces fibers into the air where cassettes are opened for processing.

The comparative evaluation commissioned by Garlock Inc was intended to:

(1) Sample typical gasket materials under rigorously controlled conditions to exclude contaminated sources, and to collect enough samples to ensure the validity of the findings.

(2) Specify Garlock products manufactured in the same manner as in the period 1940-1970. Styles 900/7035, 7021, and 605 were used because they best represent materials used in industrial operations during the period 1940-1970.

(3) Relate the sample data to the Federal standard of two fiber cc, greater than 5 um in diameter for an eight-hour TWA, and the 0.1 fiber/cc level that requires medical surveillance by interpretation of the standard [16, 32].

(4) Preferentially examine hand punching, machine punching, machine shearing, nibbling, and flange gasket processes to clear anomalies in the 1978 PSNS gasket report [15].

(5) Collect samples in city streets to show the common exposure to the population of city dwellers and establish the levels for comparison to the occupational exposure

contributions of gasket materials on an eight-hour time-weighted basis.

(6) Collect samples in the work areas to establish that the airborne contamination levels of asbestos before gasket materials are processed. Otherwise, data would reflect both sources without distinction.

(7) Determine the contribution of contaminated clothing during sampling of low-level exposures such as gasket handling and processing. Contaminated clothing is known to contribute to the overall daily exposure of asbestos workers [19, 20, 34, 35].

(8) Use sampling techniques, laboratory procedures for sample mounting, and fiber counting by phase-contrast microscopy [25, 26, 27, 28, 32, 36] that relate findings to the Federal Asbestos Standard.

(9) Compare street and work area exposure data to actual or adjusted gasket exposure data to show relevant contributions from each source.

V.

FINDINGS

A. Exposure to City Dwellers.

Tables I and II show the concentrations of airborne asbestos fibers collected at the breathing zone level during July and August 1982, in Portland, Oregon, and Seattle, Washington. The same sampling equipment and counting procedures were used to evaluate the street data in order to make direct comparisons to occupational exposures in Tables IV, V and VI. Each sample was collected over an eight-hour period during the work day.

Table III shows substantially higher levels of airborne asbestos fibers at the public street level adjacent to Puget Sound Naval Shipyard, Bremerton, Washington. The samples were collected during dry days in August 1982, at a location in the city up-and-down-wind from the shipyard and near the boundary of PSNS within the city.

The data shows surprisingly high levels on certain days, and substantially elevated airborne levels near the industrial area of PSNS several blocks from the shop that processes asbestos products.

The findings are corroborated by data reported by G. S. LeMoine in 1981 [22] in the City of Seattle, for ambient asbestos levels.

Brake lining, construction, industrial processes, and demolition are the most probable sources of these airborne concentrations of asbestos fibers. However, redispersion plays an important part in continuing levels of airborne asbestos found at the street level.

TABLE I

Downtown Portland, Oregon

Sample #	Asbestos Fibers/Cubic Centimeter, greater than 5 um in Diameter Based on an 8-hour TWA
1. 3d Street	.005
2. 3d Street	.008
3. 3d Street	.010
4. 3d Street	.010
5. 4th Street	.009
6. 4th Street	.020
7. 5th Street	.005
8. 5th Street	.008
9. 5th Street	.010
10. 5th Street	.008
10-day average	.009 = .01

TABLE II

Downtown Seattle, Washington

Sample #	Asbestos Fibers/Cubic Centimeter, greater than 5 um in Diameter Based on an 8-hour TWA
1. 1st Ave.	.050 (downwind from building construction)
2. 1st Ave.	.005
3. 1st Ave.	.010
4. 2d Ave.	.050 (building demolition in vicinity)
5. 2d Ave.	.050
6. 2d Ave.	.050
7. 3d Ave.	.010
8. Alaska Way	.004
9. Alaska Way	.005
10. Post Street	.009
10-day average	.024* = .02

*During this period of dry weather, one large building on Second Avenue was in demolition and others on First Avenue were under refurbishment. G. S. Lemoine [22] found an average airborne asbestos count of .004 f/cc for downtown commercial areas and up to .004 f/cc for highways, which makes these findings even more profound.

TABLE III

Downtown Bremerton, Washington, Downwind from Puget Sound Naval Shipyard

(August 1982)

Sample #	Asbestos Fibers/Cubic Centimeter, greater than 5 um in Diameter Based on an 8-Hour TWA
1. Burwell Street - North	.002
2. Burwell Street - North	.020
3. Burwell Street - North	.015
4. Burwell Street - Center	.020
5. Burwell Street - Center	.050
6. Burwell Street - Center	.025
7. Burwell Street - South	
8. Burwell Street - South	.015
9. Burwell Street - South	.010
10. Pacific Avenue	.002
10-day average	.016* = .02

*Dry day sampling includes emissions from the industrial operations in the PSNS shipyard, redispersion of asbestos fibers, and city sources, such as brakelining, construction or demolition.

The 1981 findings of LeMoine [22] and this data show that the general population has common exposure to asbestos even in western cities like Portland, Oregon, and Seattle, Washington, with good weather clearance and relatively low astmospheric inversion factors. The data in Tables I, II and III also show that the levels may be elevated during summer or dry days and because most downtown construction occurs then. The levels of exposure are significant because they are in the same range of exposure level as produced by gasket materials shown in Table VI.

Recent reviews of asbestos fibers in the lungs of the general population show a substantial exposure by measured retention. The review by Churg and Warnock [10] conclude that city dwellers receive a significant exposure from the general environmental contamination. This will contribute to the overall exposure of workers engaged in industrial operations, especially those handling asbestos products. It is obvious that any evaluation of the contribution of a single product to the occupational exposure of workers must consider these elevated exposures from other sources so as not to obscure the true lower values and produce misleading information.

E. Effects of Asbestos-contaminated Clothing.

Current methods of sampling require that occupational exposures of workers be determined by personal samplers attached to the body operating at two liters per minute and drawing air at the breathing zone through a 0.8 micron pore size, 37 millimeter diameter, AA-type membrane, open-faced filter held in a cassette [15, 19, 23, 32].

There is no specified technique for placement of the cassette containing the filter, other than common sense. Generally, technicians attach the cassette and hose by a clip snapped on the lapel of the street clothes or outer protective clothing of asbestos workers. During movement the cassette rests against the clothing in a downward position. The clothing forms one edge of a baffle causing some measure of uneven distribution of capture on the filter, thus affecting the variation in fiber counts from different wedges taken from that filter [25].

Clothing, highly contaminated with asbestos fibers, may lead to results up to two fibers/cc, greater than 5 um in diameter based on an eight-hour TWA when no other source of asbestos is present. These values were detected in earlier studies by the author and studied by J. Wendlick, Corporation Industrial Hygenist, Weyerhaeuser Company, in a cooperative exchange [18, 35]. Devices were developed to hold the filter away from the clothing and reduce the contribution of fibers at the surface of the clothing which showed upward skewing of data dependent on the degree of clothing contamination.

Not only can this procedure give positively skewed results when evaluating the actual contribution of a single product, but asbestos contaminated clothing is a serious source of occupational exposure to asbestos workers.

Table IV shows the various levels of asbestos fibers collected on the open-faced filter placed on the lapel of contaminated work clothes and pointed downward as required [32]. Contaminated cloth coverall work clothes were collected from various industrial operations where asbestos was in use. The clothing was placed on the workmen in clean environments during an eight-hour period in which no asbestos material was handled in order to determine the actual exposure from the asbestos contaminated clothing.

TABLE IV

Contribution of Asbestos-Contaminated Personal Protective Clothing to the Occupational Exposure

Description of Clothing	Concentration of Asbestos fibers/cc, greater than 5 um in Diameter Based on an 8-hour TWA, Collected on an Open-faced .8micron pore-sized 37 mm diameter-type AA millipore filter[*1]	
	8-Hr. TWA	Average f/cc
Heavily contaminated coveralls used during rip-out of pipe insulation	1.0 1.8 1.5	1.4
Medium contaminated coveralls worn three days before change	.2 .5 .8	.5
Lightly contaminated coveralls worn three days before change	.1 .2 .05	.1
Coveralls worn during gasket handling and other small asbestos parts	.05 .05 .03	.05
New coveralls in controlled area	.002 .003 .003	.003[*2]

*1 Represents contributions from air pollution, and positive upward skewing of results by baffling effects from contaminated clothing.

*2 Represents expected atmospheric pollution in the city and approaches the lower limit of detection of the sampling and counting methodology.

These values show that improper placement of the cassette and heavily contaminated coveralls can;

1. Provide a substantial contribution to the overall exposure of asbestos workers from failure to regularily change clothing contaminated with asbestos.

2. Result in values that do not reflect the true breathing zone exposure level. The baffling effect of the edge of the coveralls to the open-faced cassette is known to cause uneven collection of fibers on the filter, and to collect more fibers on the filter because of the proximity to the surface contamination in the coveralls [30].

3. Cause the collection of large amounts of asbestos fibers that may obscure the lower actual airborne concentrations released from encapsulated, or pressed asbestos gasket materials.

This affected early sampling results where standards did not require the regular changing of asbestos-contaminated clothing. The Department of the Navy, a leader in asbestos control development in the 1960's and 1970's, did not seriously require protective clothing control until about 1969-1972, as introduced in the works of Marr [1] and of Mangold, Beckett, and Bessmer [2, 3] and later by directive. Such practices did cause gross contamination of street and protective clothing adding a significant contribution to the total exposure. Workmen wearing highly contaminated clothing therefore carried a significant source of exposure wherever they went during the work day.

C. Workplace Contamination Levels of Airborne Asbestos Fibers.

The earlier works of Mangold, Beckett, and Bessmer [2, 3, 36] ignored consideration of gasket materials as a contribution to the potential occupational exposure to asbestos workers and associated trades. The asbestos control program was directed at known high level and uncontrolled sources of airborne asbestos fibers related to known work practices.

The 1978 PSNS report conducted by Liukonen, Still and Beckett [15] was aimed at the total occupational exposure of workers to airborne asbestos fiber concentrations while conducting unit operations related to the use of asbestos gasket materials. The report relates the unit operation peak exposure and states that the values are not comparable to the current Federal standard of 2f/cc greater than 5 um in diameter on a time-weighted basis because of the short sample duration. However, such comparisons are made later in the report. Therefore, the values are much higher than expected when nonexposure periods during the workday are included in the eight (8) hour time-weighted average and contamination factors are considered.

Secondly, the intermittent peak exposure values necessarily reflect any concentration of airborne asbestos fibers in the breathing zone of the worker because the 1978 PSNS report did not consider contributions from other sources of airborne asbestos fibers such as contamination.

The PSNS report does not reflect the level of airborne contamination before the samples were collected or makes any adjustment in the data. Therefore, the values reported reflect the airborne fibers released by gasket handling and processing including all other sources of production, redispersion, or atmospheric pollution present at the time. This consideration is important because some of the values reported in the 1978 PSNS report [15] are near the lower limit of detection of the sampling method and are in the range of known work area contamination levels. In order to determine the low-level contribution of the Garlock encapsulated gasket materials, air samples were collected in work areas used for asbestos, but when no gasket processing was in progress. Samples were then collected in the same work area when the asbestos products were processed. The difference in results are shown in Tables V and VI.

Table V shows the effects of ventilation, air turbulence, movement of materials and the motion of employees in a work area contaminated with asbestos fibers. The data represents the eight-hour time-weighted average exposure due to contamination or nearby sources. The background contamination levels of asbestos are substantial as expected from accumulation of fibers redispersed to, or contained in the ambient air. Such high levels of contamination obscure the small contribution caused by gasket processing as shown in Table VI.

TABLE V

CONTAMINATION LEVELS

Airborne asbestos concentrations in work areas from atmospheric contamination, redispersion of fallen fibers, or nearby sources. No gasket operations conducted.

Location & Sample	Fibers/cc greater than 5 um in diameter, Eight-Hour TWA
STORAGE OF GASKET MATERIAL	
1	.01
2	.02
3	.01
4	.02
5	.04
5-day average	.02
HAND PUNCHING AREA	
1	.02
2	.02
3	.05
4	.08
5	.02
5-day average	.04
HAND OPERATED MECHANICAL PUNCH AREA	
1	.01
2	.02
3	.02
4	.02
5	.02
5-day average	.02

MACHINE PUNCH AREA

1	.08
2	.02
3	.10
4	.20
5	.05
5-day average	.09

HAND SHAPING TABLE AREA

1	.01
2	.02
3	.02
4	.08
5	.02
5-day average	.03

MACHINE SHEARING AREA

1	.03
2	.08
3	.10
4	.07
5	.05
5-day average	.07

NIBBLER MACHINE WORK AREA

1	.08
2	.08
3	.10
4	.20
5	.10
5-day average	.11

BOILER HEAD GASKET
INSTALLATION AREA

1	.02
2	.03
3	.03
3-day average	.03

BOILER HEADER REMOVAL

1	.06
2	.04
3	.05
3-day average	.05

FLANGE OPENED
NO SCRAPING

1	.03
2	.02
3	.02
3-day average	.02

FLANGE OPEN
GASKET PREVIOUSLY REMOVED

1	.03
2	.03
3	.03
3-day average	.03

D. Garlock Asbestos Gasket Processing.

Breathing zone samples of workers processing Garlock gasket materials were collected under the following conditions:

1. Methods specified by NIOSH and OSHA that relate to the Federal Standard, 29 C.F.R. §§ 1910.1001, Asbestos, were used [23, 30, 32].

2. Samples were collected in the breathing zone of the workers using a wire device to hold the filter cassette away from the clothing.

3. Workers wore clean outer clothing or plastic-impregnated coveralls during each day of the test period.

4. This study, commissioned by Garlock, specified asbestos gasket materials which were used because they were prepared in the same manner as products used in the period 1940-1970.

TABLE VI

GARLOCK ASBESTOS GASKET PROCESSING

Location and Operation and Sample #	Total Exposure to all sources of asbestos during Gasket Operations, Garlock Materials	Background Contamination Levels (Table V) Subtraction	Actual Contribu- of Gasket Operation to the Occupational Exposure, 5 fibres/cc greater than 5 um in Length, on an 8-Hr. TWA
HAND PUNCHING			
1	.05		
2	.05		
3	.06		
4	.06		
5	.04		
Average	.06	- .04	.02

HAND OPERATED
MECHANICAL PUNCH

1	.05		
2	.01		
3	.02		
4	.02		
5	.02		
Average	.02	- .02	
	Negligible		

MACHINE PUNCHING

1	.05		
2	.18		
3	.09		
4	.09		
5	.14		
Average	.11	- .09	.02

HAND SHAPING

1	.08		
2	.05		
3	.03		
4	.04		
5	.02		
Average	.04	- .03	.01

MACHINE SHEARING

1	.05		
2	.07		
3	.15		
4	.10		
5	.10		
Average	.09	- .07	.02

MACHINE NIBBLING

1	.20		
2	.08		
3	.15		
4	.19		
5	.10		
Average	.14	- .11	.03

GASKET INSTALLATION
(Clean Surface)

1	.01		
2	.04		
3	.05		
Average	.03 Negligible	- .03	

BOILER HEADER
REMOVAL

1	.10		
2	.05		
3	.22		
Average	.12	- .05	.07

FLANGE SURFACE
HAND SCRAPING
WITH KNIFE

1	.04		
2	.03		
3	.02		
Average	.04	- .02	.02

FLANGE GASKET
REMOVAL AND
SCRAPING WITH KNIFE

1	.08		
2	.03		
3	.05		
Average	.05	- .03	.02

E. Flange Gasket Operations.

Other laboratory testing of Garlock asbestos gasket materials, styles 7021 and 900 show a low contribution to exposure for gasket preparation, installation and disassembly ranging from none detected for die cutting to .06 fibers/cc for hammer cutting.

In order to validate the findings, three large flanges were cut from dismantled ships' piping and cleaned. Garlock asbestos gasket material style 7021 was hand punched in a location where ambient levels were at the lower limit of detection, or about .002 fibers/cc. Nine gaskets were hand punched over a two-hour period to provide a typical operation work pattern. The breathing zone concentrations of airborne asbestos fibers did not exceed .01 fibers/cc, greater than 5 um in diameter. This reflects an actual exposure devoid of background contamination. This is a two-hour intermittent peak exposure that falls in the same range as contaminated shop work areas, or downtown streets on dry summer days.

One of the nine gaskets was placed on each of the three flanges, bolted and torqued to about 60 pounds, which gives a flange face pressure of about 3,000 pounds. The three flanges took two hours to assemble. The breathing zone concentration of asbestos fibers did not exceed .02 fibers/cc, greater than 5 um in diameter, and reflects a two hour intermittent peak exposure that is in the same range as contaminated work areas or downtown streets on dry summer days. An eight-hour time-weighted average of this actual contribution by the gasket materials would be expected to be even lower.

The three flanges were then heated to 200°F in a furnace for 48 hours, cooled and disassembled. The asbestos materials were cleaned from the surfaces by scraping. The disassembly took two hours. The breathing zone exposure to airborne asbestos fibers during the disassembly did not exceed .02 fibers cc, greater than 5 um in diameter. This is an intermittent peak exposure likely to be less on a eight-hour time-weighted average.

This gasket cutting, assembly and disassembly of three typical large flanges, as used on ships piping, did not produce an overall breathing zone exposure exceeding .02 fibers/cc, greater than 5 um in diameter. The hard pressed surface and encapsulation of the asbestos fibers on the Garlock, style 7201 asbestos gasket material release insignificant quantities of asbestos fibers.

This validation of previous evaluations of Garlock asbestos gasket materials and Beckett's [15] findings is lower because extra care was given to potential sources of contamination, and longer sample times were conducted.

In summary, each of the operations of gasket cutting, installation and removal did not exceed contamination levels in industrial work areas or busy downtown streets on dry summer days. The exposures are about 1/100 of the Federal standard of 2 fibers/cc, greater than 5 um in diameter based on an eight-hour time-weighted basis.

VI

CONCLUSIONS

The accumulations of asbestos fibers in the workplace from sources other than encapsulated gasket materials plus the presence of asbestos fibers on work clothing and the asbestos fibers generally present in the atmosphere, obscure the actual low level contribution of asbestos fibers to the environment from Garlock encapsulated gasketing material. Some current epidemiological data suggests there may be a small risk to health as long as there are airborne asbestos fibers in the environment of the magnitude of that existing naturally such as that in soil, water, and natural atmospheric pollution. Nevertheless, an allowable exposure has been set since 1946, and defined as an index, based on the theory that low-level exposures may be tolerated without incurring undue risk [37]. The eight-hour time-weighted average exposure currently allowed by the Federal Standard is 2 fibers/cc, greater than 5 micrometers in diameter.

This report shows that hardpressed or encapsulated Garlock asbestos gasket products release insignificant levels of asbestos fibers into the breathing zone of workers. In fact, the exposure levels caused by the handling and use of these products are often well below exposures caused by contaminated work areas, asbestos laden clothing, or downtown exposures to the public on dry summer days.

Garlock asbestos gasket materials, styles 7021, 900/7735, and asbestos cloth, style 605, handled in the same manner as in heavy industry, like shipyard operations, averages 1/100 or less of the current Federal standard. The materials reflect exposure in previous years because they were prepared in substantially the same manner as Garlock prepared the materials in the 1940's to 1970's.

The levels of occupational exposure to asbestos fibers in the breathing zone from the use of these asbestos gasket products actually approach the lower limit of detection of the sampling and microscopy methods required by the Federal standard. They are about 50% of the values reported in the 1978 FSMS Report [15] because contamination levels were not factored into that report to relate to the actual occupational exposure of these types of gasket materials, and because the FSMS data reflects intermittent peak exposure, not eight-hour time-weighted averages.

The 1950 to 1970 occupational exposure of workers handling asbestos material in industrial settings were elevated, often uncontrolled, and at an allowable level of 5,000,000 particles per cubic foot or about 50 fibers/cc. Other data shows [3] at least ten times that Threshold Limit Value (TLV) for certain industrial operations have been observed. Therefore, pressed and encapsulated asbestos gasket materials contribute insignificantly to the overall exposure of workers. The actual contribution is in the range of ambient pollution levels of asbestos in industrial areas and often at ambient asbestos fiber levels experienced by city dwellers on dry days for which there is no significant impact on their health.

VII.

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