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ASSESSMENT OF ASBESTOS CONCENTRATION ON MARINE VESSELS: MAINTENANCE AND REPAIR OPERATIONS

Also, this report does not state this, but Andy Oberta actually did the field measurements.

Add to Insert 2 p 436

Barry - I saw your reference to the 1979 IIT Phase I Study but not this one. Good data on winch brake operation + cleaning, gaskets, valves.

U.S. DEPARTMENT OF COMMERCE/MARITIME ADMINISTRATION

OFFICE OF RESEARCH AND DEVELOPMENT

Technical Report

ASSESSMENT OF ASBESTOS CONCENTRATION ON MARINE VESSELS: MAINTENANCE AND REPAIR

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Prepared For:

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Office of Research and Development

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1. SUMMARY

The objective of this study was to identify exposures of shipboard personnel to airborne asbestos fibers during typical on-board repair and maintenance operations. Asbestos fibers have been causally related to several respiratory diseases and were extensively used in shipbuilding until 1975. A previous study[1] detected the presence of low concentrations of asbestos in ships' enginerooms. This present study measured the exposure levels to the ships' personnel performing routine maintenence/repair operations. Recommendations are made on how to modify work practices and the application of ventilation control and/or personal protective devices--e.g., respirators.

The first step in the project was to identify possible sources of airborne asbestos fibers aboard ship and to rank the probability of disturbing the asbestos-containing material. Literature sources were reviewed and asbestos-containing materials were evaluated for fiber releasability, frequency of disturbance, and categorization of materials. This effort resulted in the selection of the following operations as candidates for evaluation:

- pipe lagging repair
- boiler or turbine insulation repair
- clutch or brake maintenance
- hotel system repair
- electrical rewiring and repair
- welding operations.

The final selection from the list of candidate operations was done during two trips on U.S. Flag Vessels. One trip was a long coastal voyage and the other a North Atlantic trip. The actual tests monitored were:

- pipe lagging repair
- pipe repair
- welding operations

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[1] Jones, D. *Assessment of Asbestos Concentrations in the Engineroom Environment of Marine Vessels: Phase I*, IIT Research Institute Report J6449C01, IIT Research Institute, Chicago, Ill. 60616. 1979.

- brake cleaning and operation
- valve rebuilding operations
- clean-up procedures for asbestos waste.

In addition, the ships' background fiber concentration and the exposure of crew members standing watches were measured.

The samples were analyzed using the Occupational Health and Safety Administration (OSHA) specified NIOSH Analytical Method P&CAM 239.[2] This procedure enumerates all fibers greater than 5 µm in length present on filter samples using phase-contrast microscopy. The method does not specifically identify asbestos fibers. The fiber counts obtained are combined with the volume of air filtered to determine the concentration of fibers in the air. The concentration--in fibers/cubic centimeter (fibers/cc) of air--is then compared to two limits. The first is the 8-hour time weighted average (TWA) and the second is the ceiling exposure limit (CEL), both defined in 29 CFR 1910.1001. Currently the limits are 2.0 fibers/cc for the TWA and 10.0 fibers/cc for the CEL.

The results of the fiber enumeration showed that during several test operations, concentrations exceeding 2.0 fibers/cc were measured. These operations were performed over short time periods. If these or similar operations were conducted over an 8-hour time period, the exposure levels would exceed the OSHA TWA limit.

One test situation, brake cleaning, resulted in exposures in violation of the OSHA CEL for airborne asbestos fibers. A concentration of about 70 fibers/cc was measured during cleaning which used high-velocity air to blow the accumulated dust out of the brake box. The cleaning of brake enclosures using forced air blowing should be stopped.

The following procedures resulted in airborne fiber concentrations above the 2.0 fibers/cc limit and are considered "potentially hazardous operations" depending on the duration of the operation:

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[2] U.S. Department of Health, Education and Welfare; National Institute for Occupational Safety and Health, Revised Recommended Asbestos Standards; 77-169, 1977. Available from Public Health Service, Robert H. Taft Laboratories, 4676 Columbia Parkway, Cincinnati, OH 45268.

- clean-up after piping or lagging repair with broom (up to 3.4 fibers/cc)
- operation of an open brake drum inside the ship (2.1 fibers/cc)
- welding (5 fibers/cc)

Currently, OSHA has proposed a reduction of the TWA to 0.5 fibers/cc. If this proposed change in the rule becomes effective, the term "potentially hazardous operation" will also apply to:

lagging removal
(0.2-1.1 fibers/cc)

vacuum clean-up of piping repair waste
(0.2-0.9 fibers/cc)

Background samples collected in various areas of the engineroom and living quarters of the ship were below or near the detection limit for the analytical method. On two successive nights, however, higher levels of airborne fibers were detected in the engineroom fidley. Four samples of twelve collected on two nights showed elevated fiber concentrations with the highest fiber concentration being 1.0 fibers/cc. The cause of the elevated levels is believed to be the lagging on a vertical pipe entering the bottom of the deaerator which had eroded to the extent that the insulation inside the wrapping had worn to an eliptical shape almost touching the outside wrap. Since the affected samples were collected on successive nights, the elevated airborne fiber levels probably existed for 24 hours. This type of potential exposure could contribute to long-term health effects.

The following conclusions are drawn from the study:

- It is unlikely that the OSHA TWA of 2.0 fibers/cc is exceeded during routine repair by ship's personnel.
- The current practice of blowing dust from brake enclosures exceeds the CEL limit and is not a safe work practice.
- The next highest exposures were measured during clean-up after repairs.
- There are many sources of exposure to airborne fibers during routine repair and maintenance operations involving asbestos-containing materials.

- A housekeeping problem is present as a result of open brake operation in non-ventilated areas.
- Spontaneous generation of significant airborne fiber concentration can result from eroding lagging caused by the ship's motion or vibration.
- Disposable or self-powered respirators are adequate protection during most repairs involving asbestos-containing materials.
- Work rules to minimize emissions can be readily formulated.

The following recommendations are made:

- Respirators should be used when cutting or exerting mechanical force on asbestos-containing materials.
- Clean-up should use vacuum cleaners equipped with High Efficiency Particulate Air (HEPA) filters or wet methods to minimize emissions. Vacuum cleaners with low-efficiency filters should not be used.
- Control of access to repair areas should be part of each type of task. Scrap and dust generated during repairs should be contained by drop cloths and local ventilation.
- Procedures for the disposal of asbestos-containing materials should be developed and implemented.
- Stricter personal hygiene procedures should be adopted; the procedures should include methods to change and launder outer clothing, extensive wash or shower before eating or smoking after working with asbestos-containing materials, and a continuing education program to alert the personnel to the potential hazards of asbestos.
- Consideration of local exhaust ventilation in the shop areas to prevent accumulation of dust which may contain asbestos fibers.

2. INTRODUCTION

There is an increasing awareness of the significance of environmental factors in causing illness. The fibrous minerals known as asbestos, used in many applications and products, have entered the environment in both occupational and non-occupational settings. The lung disease, asbestosis, and some cancers of the lung, abdomen, and other parts of the body are clearly related to asbestos exposure.[3] Asbestos was used in the shipbuilding industry; shipyard workers, both those who worked directly with asbestos and those who were indirectly exposed, have a higher incidence of asbestos-related diseases than the general population.[4] Recently, there is evidence that some ships' personnel are exhibiting symptoms typical of asbestos exposure.[5] This evidence led to the study, *Assessment of Asbestos Concentrations in the Engineroom Environment of Marine Vessels: Phase I*, with the limited objective of establishing the feasibility of measurement methods and developing a plan to survey the U.S. Merchant Marine fleet. The study was conducted by IIT Research Institute for the U.S. Maritime Administration under Contract No. 5-38072. The final report on the study was issued in January 1979.*

This study found airborne asbestos fibers in the enginerooms of ships. The measured fiber concentrations were well below current and proposed regulations governing the occupational exposure to workers. However, no safe level of asbestos has been established, and it is impossible at this time to confidently estimate the degree of risk associated with low-level exposures.† The U.S. Environmental Protection Agency (EPA) and the scientific community

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[3] Anon. *Asbestos-Containing Materials in School Buildings: A Guidance Document: Part I*, U.S. Environmental Protection Agency, Office of Toxic Substances, Washington, D.C. 20460. March 1979.

[4] Selikoff, I.J., *et al. Asbestos Disease in United States Shipyards*, Annals of the New York Academy of Science, Vol. 330, 1979. The New York Academy of Science, 2 East 63rd St., New York, N.Y. 10021.

[5] Dr. Robert N. Jones. Testimony before the House Subcommittee on Coast Guard and Navigation. Available from the subcommittee librarian H2550, House Annex 2, Washington, D.C.

* See Reference 1, page 1.

† See Reference 2, page 2.

believe that any exposure to asbestos involves a degree of risk. Critique of the Phase I study indicated that an extensive program to assess asbestos fiber concentrations aboard ship was needed. More crucial, however, was the determination of asbestos exposures during routine repair and at-sea maintenance operations involving asbestos-containing materials. Therefore, the current study was undertaken.

The objectives of the current study were to define the repair or maintenance operations which could result in potentially hazardous exposures to airborne asbestos concentrations, to test several typical operations, and to provide data needed to improve work rules and practices that would reduce or eliminate potentially hazardous exposures. During the study, the major uses of asbestos-containing materials aboard ship were identified. Repair and maintenance operations involving asbestos-containing materials were performed under existing work practices, albeit with adequate worker protection. Samples were collected to determine exposure levels and work practices were observed to determine where revisions might reduce asbestos exposure.

Asbestos in the workplace is regulated by the Occupational Safety and Health Administration (OSHA). The current OSHA time weighted average (TWA) for an 8-hour exposure is 2.0 fibers/cc (greater than 5 μm in length). The ceiling exposure limit (CEL) is 10 fibers/cc.* Reduction in the permissible levels is under consideration.

* The current limits are found in 29-CFR-1910.1001.

3. ASBESTOS-CONTAINING MATERIALS

Asbestos and asbestos-containing materials were used extensively during the construction of ships from World War II until recently. Ships completed as late as 1975 contain some asbestos materials. The uses of asbestos on-board ships are numerous due to the excellent fire retardancy, resistance to thermal degradation, and durability of asbestos fibers. Table 1 lists materials containing asbestos which may be found aboard ship. A releasability ranking[7] is given; the numerical rankings mean:

1. Free fibers--not locked in at all.
2. Fibers locked in but releasable in normal use or where handling is such that intentional abrasion, cutting, sanding, etc., is expected to occur. Fiber release may occur if there is a defect in the product's performance.
3. Fibers locked in and not likely to be released in normal use. Potential for release exists if a user engaged in repair, accidental abrasion, modification, or if deterioration occurs because of aging or wearing of the product.
4. Fibers locked in and unlikely to be released under almost all foreseeable circumstances.

Table 1. POTENTIAL SOURCES OF ASBESTOS ABOARD SHIPS[6] (Partial List)

Source	Releasability Ranking[7]
Pipe lagging and wraps	3
Gloves	2
Paint	3
Gaskets	3
Fire resistant/retardant wallboard	3
Floor tile	3
Spray-on thermal insulation	2
Electrical insulation	3
Electrical tapes	3

[6] Ase, P. *et al. Exposure to Asbestos*, IITRI Report No. C6438C01, IIT Research Institute, Chicago, IL 60616. February 8, 1979. USEPA Grant R806269010, Special Report prepared for Office of Toxic Substances, USEPA, Washington, D.C.

[7] Simpson, F. *Memorandum, U.S. Consumer Product Safety Commission.* May 10, 1978.

In consultation with persons having shipboard experience, the asbestos-containing materials on-board ships were placed in the following categories:

- Pipe lagging and wraps
- Spreadable insulation (boiler/turbine)
- Friction products (clutch/brake)
- Caulks and joint compounds
- Personal protection (gloves/fire-fighting suits)
- Construction materials
- Miscellaneous

An estimate of the repair/maintenance frequency and dust emission level of typical operations performed at sea with asbestos-containing materials in each of the above categories is given in Table 2. Frequent repair/maintenance work includes repair of pipe insulation, welding, gasket making, repacking valves, and the use of gloves. High dust levels are associated with repairs involving welding, spreadable insulation, friction materials, and pipe insulation.

Several attempts were made to rank the exposure potential for each category shown in Table 2. However, the current data base was judged insufficient to support a sound ranking system. In addition, shipboard observations showed that large variations existed in the physical condition of very similar materials, the spatial restrictions under which repair or maintenance was performed, and the ventilation in the areas. Based on the limited repair/maintenance operations observed and sampled during this program, an empirical exposure rank was developed, Table 3. The exposure rank indicates the relative exposure from current work practices and serves to set priorities for reducing or eliminating exposure to airborne asbestos fibers. Note that cleaning the brake housing, an infrequent maintenance practice at-sea, and clean-up after insulation repair, a frequent practice, head the list.

Table 2. ASBESTOS CATEGORIES

Type of Material	Frequency of Repair/ Maintenance or Use	Dust Level
Pipe Insulation		
Lagging	High	Moderate to high
Wraps	High	Low
Trowled or Spread Insulation		
Boilers	Low	High (during removal only)
Turbines	Low	High
Friction Materials		
Clutches or Brakes	Low	Very high
Caulks & Joint Compounds		
Air Duct Joints	Low	High (dust frequently located in poorly ventilated areas)
Personal Protective Devices		
Gloves	High	Low
Construction Materials		
Marinite Wallboard	Low	Moderate
Transite	Low	Moderate
Electrical Enclosures	Low	Moderate
Paints	Low	--
Welding	High	High
Miscellaneous		
Gaskets	High	Low
Packing	High	Low
Floor Tile	Low	Low

Table 3. EMPIRICAL RANKING OF EXPOSURE POTENTIAL DURING REPAIR OR MAINTENANCE OF ASBESTOS-CONTAINING SHIPBOARD MATERIALS *

Type of Repair or Maintenance	Rank
Cleaning of Brake Housing	1
Cleaning after Insulation Repair	2
Handling Asbestos-Containing Scrap	3
Removal of Insulation	4
Reinsulating Procedures	5
Shop Operations with Noninsulation Materials	6
Routine Clean-up of Area	7

* Using existing work practices.

4. PROCEDURES

The equipment, the sampling and analytical procedures used in this study are described. Safety and personal protective devices are discussed in Section 4.1; sampling and analytical equipment and procedures are discussed in Section 4.2; Quality Assurance is discussed in Section 4.3.

4.1 PROTECTIVE DEVICES

The test plans included provisions to protect both the ships' personnel and IITRI engineers from exposure to airborne asbestos fibers. The protective devices available included:

- MSA 9910 disposable face masks
- MSA Type F self-powered respirators
- 3M-W298-50 (system) half-face compressed air respirators
- Tyvek Model 2127Z impermeable hooded jump suits with attached Model 2200 shoes
- Plastic sheeting and bags for containment of asbestos-containing wastes, contaminated filters, respirators, and clothing.

Although no specific regulations are in place for shipboard repair/maintenance operations, the protective equipment was selected based on the guidelines appearing in 29 CFR 1910.1001. The protective equipment was made available to the ships' personnel; IITRI recommended, but could not mandate, its use. The Tyvek jump suit was unsuitable for use in the warmer parts of the engineroom. The repair/maintenance operations were restricted in scale, in part by consideration of ships' personnel safety and decontamination problems.

4.2 SAMPLING

4.2.1 Personal Samples

Both MSA (Model G) and DuPont (Model P-4000) battery-operated, personal sampling pumps were used to sample the airborne dust levels. Samples were collected on Millipore® 37 mm diameter, 0.45 μm pore size, membrane filters at flowrates from 1.7 to 2.5 liters per minute (ℓpm). The filter holders were open-faced and oriented face-down during sampling. Sampling protocols specified by the National Institute for Occupational Safety and Health (NIOSH) were followed.[8]

4.2.2 Area Sampling

Area samples were collected with the same portable, battery-operated pumps used for personal samples. Area samplers were open-face filters operated at flowrates of 2.5 ± 0.2 lpm. Area sampling sites were selected based on each of the test site locations, traffic patterns, and air flow patterns.

4.3 ANALYSIS

Evaluation of the airborne fiber concentration was by phase-contrast optical microscopy. The method, required by the Occupational Safety and Health Administration (OSHA), is the NIOSH procedure described in DHEW (NIOSH) Publication No. 79-127.[8] Basically, all fibers greater than 5 μm in length are enumerated by optical microscopy at 400-500X magnification using phase-contrast illumination. The membrane filter is cleared and the phase-contrast optics enhance the contrast between the fibers and the filter, thus facilitating counting of the fibers. The method was developed for use in assessing the exposure to asbestos fibers of asbestos workers. <u>The method assumes all particles meeting the prescribed definition of a fiber and exceeding 5 μm in length are asbestos; no positive identification of the fibers is made. The concentration measured and reported thus represents the maximum and in many cases the actual asbestos fiber concentration will be lower.</u>

4.3.1 Filter Preparation

Prior to counting the fibers, a wedge is cut from the membrane filter and cleared. The clearing process involves saturating the pores of the membrane with a liquid to collapse the filter structure. A solvent mixture of equal portions of n-hexane, dichloroethane, and p-dioxane is used, as recommended by Millipore Filter Corporation.[9] The saturated collapsed membrane filter is

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[8] Leidel, N. et al. *Membrane Filter Method for Evaluating Airborne Asbestos Fibers*, HEW (NIOSH) Document 79-127, Robert Taft Laboratories, Cincinnati, OH 45226. February 1979.

[9] Procedure TS0018, Millipore Filter Corporation, Bedford, MA.

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Lightly loaded samples present the microscopist with the special problem of locating and maintaining the filter surface in the focal plane. Iron oxide spheres, 1 µm in diameter, were added to these samples to insure that counts were made in the correct plane. Blank samples with the iron oxide spheres demonstrated that no artifact fibers were introduced with the spheres. This procedure is similar to the addition of aluminum oxide particles to the suspensions used for preparation of the PAT samples. (PAT described in Section 4.4, Quality Assurance.)

4.3.2 Counting Rules

Prescribed fiber counting rules are used to assure valid statistical results. Fields of view are selected for fiber counting at random along a traverse line. The fields of view are defined by a Porton graticle placed in the eyepiece of the microscope. The graticle is calibrated using a stage micrometer. The specific counting rules are:

1. All fibers (particles with an aspect ratio of 3:1) completely contained in the field of view and over 5 µm in length are counted.
2. Fibers with one end within the field of view and over 5 µm in length are counted as ½ fibers.
3. A minimum of 20 fields of view are counted to insure valid counting statistics.
4. Counting continues until 100 fibers are enumerated or 100 fields are examined.

4.3.3 Computations

The concentration of airborne fibers is computed using the following equation:

$$C = \frac{FA_f}{nA_eV_s}$$

where

C = airborne fiber concentration, fibers/cm³

F = number of fibers counted in all fields of view

A_c = effective filtration area of the filter, cm^2

n = number of fields of view counted

A_f = area of field of view defined by graticle, cm^2

V_s = volume of air sampled, cm^3

V_s is the product of the sampling rate, r, and the sampling time [illegible]. The sampling rate is usually measured in lpm and the time in minutes. The conversion [illegible] 1000 cm^3/l must be used to provide consistent units.

The counting precision is ±10% when a single laboratory performs the analysis.*

4.4 QUALITY ASSURANCE

One of the objectives of any study is to document the reliability of [illegible] information in the study. There were two precautions used in this study to [illegible] maximum accuracy in the results. These were:

- participation in the Proficiency Analysis Testing (PAT) program run by NIOSH
- calibration of all sampling equipment in the field

IITRI enrolled in the PAT program for asbestos counting, submitted [illegible] [illegible] rounds (61, 62, 63) of this quarterly program, and was rated [illegible] [illegible] in asbestos counting. IITRI's statistics show good internal [illegible].

The estimated fiber concentration can be no better than the accuracy [illegible] [illegible] of the sample train. A calibration stand consisting of a [illegible] [illegible] was set-up aboard each ship visited. Each pump was routinely [illegible] [illegible] at the desired flow with a sample filter in line. [illegible] [illegible] of the pumps were made frequently, including both pre- and post-[illegible] [illegible]. One sample was lost due to pump failure but redundant samples [illegible] [illegible] of information.

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*See Reference 3, page 11.

5. TEST OPERATIONS AND RESULTS

The test plan submitted during the early portion of this program identified sources of asbestos-containing materials aboard ship and the routine repair/maintenance tasks associated with these materials that were performed by ships' personnel at sea. The final selection of tasks to be monitored was made on-site based on both crew availability and location of a suitable test site. The tasks monitored were:

- Lagging repair
- Piping repair
- Welding
- Enclosed brake box cleaning
- Open brake operation
- Valve rebuilding

In addition, clean-up procedures and ships' background fiber levels were monitored.

5.1 LAGGING AND PIPE REPAIRS

Two separate repairs involving lagging were carried out during this program. These repairs are described below.

5.1.1 Lagging Repair

Operations--A short section of steam pipe immediately behind a valve was partially exposed. The steam line was not active during the repair, thus everything was cold. The exposed section was irregular, and it was necessary to cut away a portion of the existing lagging prior to repair. After an 8 in. section of lagging was removed and the end squared off, a total length of about 18 in. of new lagging was installed.

Personnel Protection and Sampling--Prior to beginning the test activity, a respirator--half-face, self-powered--was issued to each of the crew members performing the test. Both the crew members and IITRI personnel decided against using the impermeable Tyvek suits on the basis of the small size of the operation and the potential for heat stress in the area.

In preparing for this task, one crew member had difficulty in fitting the respirator. With assistance, the respirator was fitted and sealed before beginning the test. The experience brought home an important fact: the facial characteristics of various personnel must be considered when selecting styles and sizes for respirator inventories.

During the repair task, the crew member performing the test and the two observers wore personal samplers. Two area monitors, one upwind of the repair site and one downwind, were also operated. The filters were changed at specified intervals to obtain samples representing the following activities:

- removal of the old lagging
- installation of the new lagging
- clean-up (after initial removal of the large pieces of lagging and gross dust)*

Additional area samples were collected during the time the area was hosed down and mopped. Background samples had been acquired prior to the repair.

The results of the test samples are shown in Table 4. The highest value (0.87 fibers/cc) was measured directly downwind of the work area. The worker and downwind ~~observer~~ observer were exposed to lower levels of airborne fibers.

Table 4. TEST OPERATION: PIPE LAGGING REPAIR--REMOVAL AND REPLACEMENT

Sample				Fiber Concentration (f/cc)
Code	Type	Duration (min)	Location or Description	
010211	Area	24	Approximately 3' from work area air draft toward this pump	0.87
010208	Area	24	Approximately 7' from work area	0.08
010221	Personal	24	Observer--on upwind side of test area	ND*
010220	Personal	24	Observer--downwind of work area	0.19
010216	Personal	24	Worker sample	0.08
010214	Area	37	as 010211 } Samples taken after lagging repair and prior to cleanup	0.09
010215	Area	37	as 012008 } Samples taken after lagging repair and prior to cleanup	ND

* ND = no fibers detected.

* The sample collected during this period is considered an independent test operation in the category of cleaning practices.

5.1.2 Pipe Repairs

The pipe repair task consisted of repairs to an in-line strainer and valve in the steam whistle system. This repair was performed in port, since the system could not be isolated and shut down at sea. American Flag vessels do not use shore personnel in foreign ports except for essential repairs; thus, this task was within the purview of the program.

The section of 1 in. pipe which required stripping was about 15 in. in length. The lagging was badly deteriorated due to a steam leak; however, the lagging was dry. The stripped lagging covered a short length of pipe, a valve and an in-line strainer. After stripping the lagging, inspection showed that the only steam leak was from the strainer seal; thus, the valve was not torn down. The strainer seal was repaired, a new gasket installed and the parts reassembled. The steam line and fittings were cleaned for relagging. The replacement lagging was clearly labeled "asbestos free" and was, therefore, not included in the test.

Personnel Protection--Prior to the test, each person whose presence was required was fitted with either a disposable "asbestos approved" respirator or a half-face, self-powered respirator. The deck mechanic performing the repair was instructed to take special precautions to avoid dropping the lagging and to wash thoroughly (preferably to shower) and change clothes immediately upon completion of the task.

Sampling--Due to the specific geometry of the test site, the deck mechanic was not fitted with a personal sampler. However, one IITRI observer was stationed within 3-4 feet of the operation, and a second approximately 6-9 feet away. Both IITRI observers wore personal samplers. Three area samplers were located in the area. One of the samplers was placed within 2 feet of the removal, another near one exhaust duct, and the third about 10-12 feet from the operation. The third sampler was mounted on a rail in the center of the access route to the work area through the deck below the work area and at a height of about 5-6 feet above the deck.

The results of analysis of the samples are presented in Table 5.

The highest fiber concentration (1.14 fibers/cc) was measured at the exhaust ventilator intake. The exposure of the worker and observer were about

0.4 fibers/cc. This was higher than the exposures measured during the lagging repair test, which averaged 0.14 fibers/cc.

Table 5. TEST OPERATION: PIPE REPAIR OPERATIONS--
LAGGING REMOVAL AND DISMANTLING OF PIPE SYSTEMS

Sample				Fiber Concentration (f/cc)
Code	Type	Duration (min)	Location or Description	
010405	Area	360	Background prior to operations-- Breathing zone near repair site	0.05
010713	Area	360	Background near exhaust ventilator	0.01
010718	Area	23	Near repair area	0.50
010506	Area	23	Near exhaust ventilator intake	1.14
010719	Personal	23	Observer near worker--(2-3 feet)	0.35
010507	Personal	23	Observer about 7' from worker just below exhaust intake	0.44

5.2 WELDING OPERATIONS

The welding operations were evaluated in two steps; first in the shop where a new support frame for the emergency radio was assembled, and second during the installation of the support frame to the deck in the emergency generator room. The material being welded was standard angle iron to itself and to the ships' deck. It has not been determined whether or not the welding rods used contained asbestos as part of the outer flux coating.

Both area and personal samples were collected at each location. The personal sampler worn by the welder was attached to his shirt front outside his welder's helmet.

Personal protective devices for asbestos were not used during the welding tests. IITRI judged the exposure levels to be low in the welding areas and felt the welder's helmet afforded some protection.

Significant quantities of fumes were emitted during the welding operations. In addition to a potential asbestos hazard, welding fluxes emit fluorides and metal fumes which are of industrial hygiene concern, especially in poorly ventilated or enclosed areas. One common technique used to control welding fume emissions is to incorporate a local exhaust ventilation system into the welding electrode. Such equipment is commercially available and can be readily adapted to shipboard use. Its capability to remove asbestos fibers can be measured and, if required, improved. Such equipment could reduce several potential health problems. The results are presented in Table 6.

Table 6. TEST OPERATION: WELDING OPERATIONS

Sample Code	Sample Type	Sample Duration (min)	Sample Location or Description	Fiber Concentration (f/cc)
010404	Personal	16	Worn by observer acting as assistant	4.5-5.0 est.*
010606	Area	26	Dust background during set-up for welding port wall 15' from test site	0.2
010511	Personal	10	Worn by observer acting as assistant	2.2 est.*
010522	Area	120	Port wall--15' from test site 2 hr sample following test	0.4
010722	Area	120	Port wall--followed previous area sample	0.2

* Concentration too heavy to count accurately due to large total particle loading.

Two of these samples, 010404 and 010511, presented the analyst with a special problem. Welding fumes form straight chain agglomerates. These chain agglomerates are counted as fibers when adhering strictly to the NIOSH procedure. The fiber concentrations reported are estimates of the fibers present excluding the welding agglomerate artifacts. The concentrations reported represent about 10% of the total fiber count obtained using the NIOSH procedure. Due to the difficulty in the analysis and the heavy loading of non-fibrous metal fumes, it was concluded that these tests do not permit the assessment of exposure to airborne asbestos fibers from welding operations. It is again mentioned that welding produces fluoride and heavy metal-containing fumes that are subject to OSHA regulations.

5.3 BRAKE CLEANING AND OPERATION

One of the most common uses of asbestos is in friction materials such as brake shoes and clutches. Asbestos emissions resulting from a large number of brake applications have been measured in the ambient air near toll-road collection points by Murchio.[10] During one voyage, an open brake drum in an enclosed (minimal ventilation) cordage storage area was tested, as was a winch motor whose brake was enclosed.

5.3.1 Enclosed Brake Box Cleaning

It was determined that the anchor winch brake box had not been opened for cleaning or repair for slightly over one year and arrangements to clean the brake enclosure were made. The method suggested was to moisten the dust and then brush or wipe the dust into a bucket of water. The assigned personnel elected to use a portable blower to save time.

High exposure levels were anticipated from this air blowing technique and all nonessential personnel were removed from the area; those whose presence was required were stationed upwind of the operation and fitted with respirators.

Upon application of the blower, dense black clouds of particles were emitted. The initial cloud obscured one observer's view of the blower operator's legs on the opposite side of the cloud.

The operation was interrupted and not completed for two reasons:

- the presence of rain squalls in the area
- the intervention of the first engineer at IITRI's request to cease the test.

Even though the cloud dissipated rapidly, it was the concensus of the technical observers that an alternative technique must be developed to clean enclosed brake boxes. That the potential exposure from this operation was high was confirmed by the visible discoloration of the area sampler filter.

The sample collected from the dust cloud presented an analytical problem. Since it was very heavily loaded with material, a dilution step was necessary prior to analysis of the sample. A wedge representing one-fourth of the

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[10] Murchio, J.C., *et al. Asbestos Fibers in Ambient Air of California*, California Air Resources Board, Sacramento, CA. March 1973.

filter was cut and suspended in particle-free water; an ultrasonic bath was used to remove the particles from the filter wedge and suspend them in the water. The suspended particles were filtered onto a second filter which, after drying, was analyzed in the usual manner. The accuracy of the result, given in Table 7, is considered to be ±25 to 30% with a tendency to be below the true value due to losses of material during the dilution process.

Table 7. TEST OPERATION: BRAKE OPERATIONS

Sample				Fiber Concentration (f/cc)
Code	Type	Duration (min)	Location or Description	
010513	Area	4	Approximate 1 ft from dirty area of brake	70 est.*
010501	Area	4	Within 10-12" of operating open brake drum. The brake was operated 10 times in a 10 min. period	2.09

* This sample was heavily loaded and the sample could only be counted after a fourfold dilution.

The concentration level, 70 fibers/cc, found in the cloud generated by blowing out the brake enclosure was the highest found during the study, and exceeded the ceiling exposure of 10 fibers/cc. It is concluded that brake cleaning by forced air blowing should be stopped.

5.3.2 Open Brake Operation

The winch used to take-up the hawser used at the dock to tie-up the ship had an open brake drum located in a room in the stern of the ship. Asbestos release during braking has been a matter for controversy in the scientific community. One report[11] states that the asbestos in brake linings is coverted to non-asbestos minerals by the temperature rise due to the friction during operation. Another study[10] shows a significant rise in ambient asbestos levels observed near toll booths where use of vehicle brakes is mandated. Since

[11] Jacko, M.G., *et al.* *How Much Asbestos Do Vehicles Emit?*, Auto Engr., 81(6), 38-40, 1973.

it is possible that fiber emissions may result from use of an open brake, a test was made to measure fiber emissions during use of the brake. An area sampling pump was set up with the filter suspended near the brake. The open-face filter was suspended face-down at a distance of 12-15 in. from the nearest edge of the brake shoe. The test personnel went to the controls on the stern and, during a 10-minute period, operated the winch ten times. The sample was then secured and the test operation ended.

As can be seen in Table 7, the operation of the open brake produced concentrations of 2.09 fibers/cc. If personnel were exposed to this concentration for an 8-hour period, the OSHA standard of 2 fibers/cc would be exceeded. While use of the brake system results in allowable fiber concentrations in the room during operation of the winch, the lack of adequate ventilation to remove the airborne asbestos fibers generated will result in an accumulation of asbestos fibers in the area through settling. These settled emissions can be reentrained when the area is cleaned or the cordage disturbed for use. The material can also spread throughout the ship.

It is recommended that such rooms be unoccupied during use of the winch and brake to prevent direct exposures or the brake enclosed to eliminate the direct emissions. The latter solution is dependent on the development of brake cleaning techniques combining dry vacuum cleaning, wet wiping, drop cloths, and other good housekeeping practices. This action would eliminate open brakes as sources of airborne asbestos emissions within the working and living quarters of ships as well as avoid extreme exposures during routine cleaning of the enclosed brakes located on the open deck.

5.4 VALVE REBUILDING OPERATIONS

There are several steps required to remove, rebuild, and reinstall a valve or to regasket a flange; two of the more common crew-performed repairs involving asbestos-containing materials. The basic steps required are:

- valve or flange removal
- flange cleaning and/or packing removal
- gasket cutting
- packing, cutting, and shaping (valve repair only)
- assembly
- installation

The first two and the last two steps are part of pipe and insulation repairs. The shop operations of gasket cutting for the flanges and preparing new packing rings for valves are the steps included in this test.

A valve was selected for the test from the spare parts storage area. The valve was a 2 in. packed valve. The worker spent time attempting to cut two gaskets for the flanges from an old, dried piece of gasket material. This material was labeled as containing asbestos and tore rather than cut. The gaskets were then cut from Everseal HP jointing material, which also had an asbestos caution label.

The gaskets were cut using a pin and blade, compass-type device. Each gasket required an inside and outside cut. The bolt hole locations were marked and the material removed using a punch.

In preparation for fabrication of the packing rings, the worker brushed the scraps and crumbs of gasket material out of his way. The packing rings were prepared by tightly wrapping packing around the valve stem seven or eight times, cutting the rings to length, and flattening the square packing with a hammer prior to shaping the circular rings. The tools used were a homemade knife (sharpened hacksaw blade) and a hammer.

Samples of the two gasket materials, shop area samples, and personal samples measuring the exposure of the worker were obtained during this operation. The results of analysis of the air samples are given in Table 8.

Table 8. TEST OPERATION: VALVE REPAIR AND GASKET CUTTING

Sample				Fiber
Code	Type	Duration (min)	Location or Description	Concentration (f/cc)
010605	Personal	33	Worn by operations participant	0.23
010602	Area	29	Near work bench about 5' from operations	0.17
010601	Area	360	Background after test; includes clean-up	0.02

The levels of exposure found were low, well below the current OSHA exposure level (2.0 fibers/cc) and the proposed OSHA level (0.5 fibers/cc). What is most interesting about this test is the detection of fiber levels above background. While this test shows that, according to OSHA rules, valve rebuilding results in an acceptable exposure level, logic and experience indicate that gasket removal from a flange, or clean-out of aged packing rings from a valve would be far dustier operations. Another important fact is the similarity between the area and personal samples, which indicates that the machine shop work area was at a relatively uniform concentration. The effect of cleaning the shop after the valve rebuilding operation showed no detectable rise above background of the airborne fiber count.

5.5 CLEANING AND MISCELLANEOUS OPERATIONS

Several cleaning operations and miscellaneous shipboard activities were monitored during the study. Specifically, they are:

- clean-up from the piping and lagging repairs
- routine cleaning by a wiper
- monitoring of the watch standers during the daytime work period and during the night watch.

The watch standers were monitored to measure airborne fiber differences that may exist between the day work period and the night watch period. Any differences would be attributable to all activities, including cleaning, and their aftereffects. During the day work period, no repair activities were observed near the control area.

5.5.1 Piping and Lagging Repair Clean-Up

There were two repairs performed during this study that required cleanup of asbestos-containing waste materials. The clean-up operations were performed using the equipment and procedures routinely used by the workers on the ship.

The two clean-up procedures began with the same step. The relatively large chunks of lagging which had fallen onto or near equipment or deck areas were gathered by hand and deposited in a bucket (lined with a plastic bag by [illegible] personnel). The materials were not wetted nor was water put in the bucket. The scraps were thrown or dropped into the scrap buckets with no precautions taken to minimize dust release.

After the larger scraps were picked up, the two clean-up procedures diverged. In one instance, the superficial dust and smaller chips were swept into a dust pan and dumped into the scrap bucket. In the other clean-up procedure, a standard shop vacuum was used to pick up the dust from all surfaces including adjacent equipment and the personnel. This procedure should have been superior to the first, but the vacuum either had a faulty bag or the bag was an inefficient filter. A visible dust cloud could be seen entering the air from the vacuum cleaner exhaust. This resuspension of dust into the air where it can be inhaled is unsatisfactory. The vacuum cleaner should be powerful and fitted with a High Efficiency Particulate Air (HEPA) filter. Under these conditions, a vacuum cleaner is the best available dry cleaning method.

The crew that used a broom completed cleaning by hosing-down the area. Preliminary data indicate that the hose-down may have been too vigorous. Improper application of a water jet can aerosolize the dust it is intended to wet down and wash away.

Table 9 presents the results of samples collected during the lagging repair clean-up; Table 10 presents the results of samples collected during the clean-up after the piping repair.

Table 9. TEST OPERATION: CLEAN-UP AFTER LAGGING REPAIR

Sample				Fiber Concentration (f/cc)
Code	Type	Duration (min)	Location or Description	
010210	Area	4	Approximately 3' downwind of repair	2.5
010219	Area	4	Approximately 7' upwind of repair	2.6
010218	Personal	4	Observer--downwind of clean-up	3.3
010212	Personal	4	Observer--general area of clean-up	2.4
010213	Personal	4	This pump failed to function properly	-
010223	Area	120	3' from work area	ND*
010222	Area	120	7' from work area--included the final hosedown	0.12

* ND = No fibers detected.

Table 10. TEST OPERATION: CLEAN-UP FROM PIPING REPAIR

Sample				Fiber Concentration (f/cc)
Code	Type	Duration (min)	Location or Description	
010912	Area	22	Located one deck below repair site	0.11
010720	Area	22	Near exhaust ventilator intake	0.86
010917	Area	22	Near repair site	0.27
010716	Personal	22	Observer near wiper cleaning up lagging	0.24
010508	Personal	22	Observer near vacuum cleaner exhaust	1.92
010701	Personal	4	Worker transferring lagging waste for final disposal--a 3-5 min period during which clouds of dust were visible	3.40

The clean-up procedures following the two operations involving the removal of pipe lagging show some of the highest exposure levels measured during the program. The magnitude of the exposure levels suggests that asbestos waste clean-up procedures are inadequate and need to be modified. Dry sweeping or dumping of these wastes should be avoided since exposure levels exceeding the OSHA limit for an 8-hour work shift may be generated.

The vacuum clean-up of the work area after the piping repair operation generated exposure levels lower than after the lagging repair. The greatest exposure was near the vacuum cleaner and resulted from dust penetrating the filter bag. Attachment of a more efficient filter, such as a HEPA filter, to the vacuum cleaner is recommended for clean-up of asbestos-containing debris.

5.5.2 Routine Duties of a Wiper

During one watch a wiper wore a personal sampling pump and filter while performing his routine duties.

The duties performed during the monitoring period included:

- wet mopping.
- dusting and sweeping of machine shop (done both in the morning and afternoon)
- cleaning area where welding had been performed
- storing the arc welder power cables
- cleaning electrical shop
- conducting miscellaneous cleaning chores.

The total monitoring time associated with the wiper's engineroom cleaning work was approximately 2½ hours. A fiber concentration of 0.11 fibers/cc was measured as seen in Table 11.

5.5.3 Monitoring of Watch Standing Personnel

Much of the project activity consisted of collecting background samples and samples of specific activities being done aboard the ship. On one day, when the personnel involved in the test operations were occupied with essential duties, two of the IITRI staff stood a watch wearing personal samplers. One trailed the deck mechanic and the other the watch engineer. The engineer and mechanic shared the duties of making the rounds. During the inspection and data logging trips, the watch personnel inspected most of the areas in the three lowest decks of the engineroom, the rooms containing refrigeration equipment, and the steering mechanism at the stern. Personal sampling pumps were operated throughout the watch.

A similar test was performed at night. A personal sampler was worn by the mechanic on duty during the watch.

The results of monitoring engineroom personnel during normal duties (given in Table 11) showed that the wiper, whose routine duties include dusting and mopping, was exposed to a low but significantly higher than background level of airborne fibers. The watch standers had exposure levels of 0.01 to 0.04 fibers/cc during the 4-hour watch periods.

Table 11. TEST OPERATION: MONITORING OF ENGINEROOM PERSONNEL

Code	Type	Duration (min)	Location or Description	Fiber Concentration (f/cc)
010610	Personal	150	Worn by wiper during normal cleaning duties	0.11
010519	Personal	240	Worn by engineer--12-4 pm watch	0.01
010512	Personal	240	Worn by mechanic--12-4 pm watch	0.04
010414	Personal	240	Worn by mechanic standing 8-12 pm watch	0.01

5.6 BACKGROUND MEASUREMENTS

Table 12 presents the results from background samples collected each night in the engineroom and at other selected locations (and times) during the program. With four exceptions the levels are very low, ranging from no fibers detected to 0.06 fibers/cc for the 6-hour sampling periods.

On October 3, 1980 a high fiber concentration of 1 fiber/cc was obtained near the bottom of the deaerator (sample 010515). A concentration of 0.13 fibers/cc was obtained on level 7, one level above the deaerator. On the following night, October 4, 1980, elevated fiber concentration levels were obtained two levels below the deaerator (sample 010518) and at the intake of the engineroom exhaust fan (sample 010608).

On October 9, 1980 it was noted by the IITRI staff and the first engineer that a long section of lagging had eroded. It is believed that the high fiber concentrations were a direct result of the erosion. This apparent relationship between at-sea ships' motion and elevated background fiber counts may be a potential source for regular, relatively high exposure to airborne fibers. These exposures would be independent of any personnel activities.

5.7 EVALUATION OF SAFETY PRECAUTIONS

The specific safety precautions taken during all of the test operations consisted of using either disposable or self-powered air purifying respirators. The use of such equipment for personnel protection is approved for concentrations

Table 12. BACKGROUND ENGINEROOM SAMPLES*

Sample Date	Sample Code	Location	Fiber Concentration† (f/cc)
9/23/80	010204	Control console area	0.01
	010207	Near front side boiler	0.03
	010203	Near starboard side boiler	0.04
	010206	Lower level--starboard boiler	0.06
	010202	Lower level--port boiler	0.01
	010205	Field blank	ND
10/3/80	010709	Control console area	0.01
	010604	Turbine generator area	ND
	010810	Level 1--near steam return manifold	0.01
	010515	Level 6--port side near deaerator	1.00
	010609	Level 7--foreward hot water return	0.13
10/4/80	010521	Control console area	0.02
	010611	Level 3--in machine shop	0.03
	010518	Level 4--crosswalk--2' above deck	0.13
	010614	Level 5--crosswalk--1' above deck	ND
	010608	Level 8--near starboard exhaust ventilator	0.41
10/5/80	010710	Control console area	ND
	010607	Level 2--near boilers	ND
	010817	Level 3--near boilers--visible damage to insulation	0.01
	010818	Level 6--attached to lube oil gravity tank	ND
	010705	Level 8--near starboard exhaust ventilator	0.03
10/6/80	010709	Control console area	0.03
	011613	Level 5--starboard stairs--near wall	0.01
	010902	Level 8--starboard exhaust ventilation	0.03
10/6/80	010422	Air conditioner intake plenum	0.06
	010421	Control console area	0.02
	010417	Level 5--foreward	0.02
	010416	Level 8--starboard exhaust ventilator	ND
10/7/80	010520	Control console area	0.01
	010601	Machine shop	0.02
	010413	Open brake cordage storage area	0.03
	010510	Level 8--near starboard exhaust ventilator	0.01
	010612	Daytime--emergency generator room	0.01
10/8/80	010603	Control console area	0.01
	010412	Level 3--afternoon--behind boilers	0.02
	010423	Level 8--starboard exhaust ventilator	0.03
	010702	Air conditioner intake plenum--daytime	0.05
10/9/80	010724	Control console area	0.03
	010405	Level 8--near prospective repair area	0.05
	010713	Level 8--starboard exhaust ventilator	0.01

* Background sampling time = 6 hours.
† ND = no fibers detected.

up to ten times the permissible exposure limits (PEL). During the work in the enclosed spaces, no concentrations exceeding these values were found, thus the respiratory protection used was adequate. While the estimated local concentration during the brake box cleaning exceeded the limits, the working and observing personnel were not breathing the highly concentrated dust cloud. Only one person was close to the cloud, and a brisk breeze swept the cloud away from his breathing zone.

Personal sanitation and laundering of contaminated clothing were not under the direct control of the IITRI personnel; however, instruction, advice, and the benefit of good examples were used to encourage the use of proper practice in these important areas. All contaminated respirators were cleaned and the disposable filters or respirators packed in plastic bags, sealed, and labeled "asbestos waste" by IITRI staff. The bags were given to the ships' crew for ultimate disposal.

The protective devices used during this study adequately protected the personnel involved in conducting and observing the operations. However, all the operations were small in size. Potential repair zones were observed where fiber concentrations might exceed those experienced in the present study due to combinations of local ventilation and the magnitude of the repair/maintenance operation. Ships' personnel informed the IITRI staff that the more extensive repairs are usually done in American ports or dry-dock by shore personnel. Since this study was limited to repairs routinely carried out by shipboard personnel, no effort was made to have the crew undertake larger repairs on this study. However, since larger repairs may be made by shipboard personnel in emergency situations, the potential hazards of larger operations should be considered when revising work practices.

5.8 DISCUSSION OF OPERATIONS

During the tests, current work practices were observed and recommendations formulated to minimize emissions and exposures. There are two categories of repair to piping and other insulated systems--emergency and routine maintenance. Emergency repairs were not part of this study, although emergency repairs can result in similar exposure of ships' personnel to airborne asbestos fibers. Routine maintenance of piping and insulation at-sea is performed selectively based on manpower and safety considerations, and the priority of repairs to other operating systems aboard ship.

When repairs involving the removal or disturbance of lagging or insulation are performed, several precautionary measures not currently used are recommended to reduce emissions and limit exposure to asbestos. These include the following:

- Personnel not actually involved in the repair should be excluded from the work area.
- Plastic sheets should be arranged to catch falling insulation
- Insulation, insofar as practical, should be wetted prior to removal.
- The removed pieces of lagging or insulation should be placed in a plastic bag which contains water.
- All personnel whose duties require them to enter or pass within 15-20 feet of the operation should wear respiratory protection.
- Ships' personnel engaged in the repair should wear either disposable or special clothing; upon completion of the repair, the clothes should be changed and personnel should shower immediately.
- All clean-up of asbestos-containing waste should be done using wet methods or vacuums fitted with high-efficiency particulate air (HEPA) filters.
- Contaminated clothing should be placed in clearly marked containers.
- Protocols for the final disposal of asbestos debris and contaminated articles need to be developed.

Shipboard personnel were noted to have varying attitudes regarding working with asbestos. The attitudes range from avoidance to "so what, it's too late for me."

6. CONCLUSIONS AND RECOMMENDATIONS

In this section, the conclusions based on all the data are detailed first, followed by IITRI's recommendations.

6.1 CONCLUSIONS

The test data clearly indicate several shipboard repair and maintenance operations that involve exposure to airborne fibers. At this point, the data do not reveal that shipboard personnel are frequently exposed. Neither the 8-hour time weighted average (TWA) OSHA limit of 2.0 fibers per cc (f/cc) or the ceiling exposure limit (CEL) of 10 fibers/cc is regularly exceeded.

The data show that during certain repair/maintenance operations and the associated clean-up, fiber concentrations exceed 2 fibers/cc. The operations monitored involved time periods of less than a full work shift; thus, the TWA is below OSHA limits. However, if these operations or similar tasks were conducted over longer time periods, the potential to exceed the OSHA limits exists. One operation, the cleaning of brake boxes using air, exceeded the CEL limit. The existence of a situation where either the TWA or the CEL exposure limits can be expected to be exceeded requires an industry covered by OSHA regulations to eliminate or control the emissions. Thus, this brake box cleaning procedure should be eliminated, controlled, or modified to reduce the emissions.

In several operations, fiber concentrations were measured at levels sufficient to warrant concern by MarAd, the ship owners, and the personnel performing the tasks. Clean-up procedures used after lagging or pipe repair represent the greatest cause for concern, followed by lagging removal. The short term exposure levels measured during these operations exceeded 2 fibers/cc. Welding operations require further study. Due to the heavy fume emissions, the fiber counts reported are questionable. However, asbestos is not the only nor, perhaps, even the primary respirable material emitted during welding. Potential health hazards associated with other emissions may govern any action taken.

Two non-maintenance/repair events were observed that require attention.

These are: erosion of lagging and the operation of open brakes within enclosed spaces.

Common ship operations and routine daily clean-up gave fiber concentrations above background levels but well below current OSHA standards.

Crew and officer attitudes toward asbestos hazards should be of concern. The training of personnel and enforcement of any preventive and protective measures taken will require methods more effective than those currently in place.

The conclusions are summarized below:

- The time weighted average of shipboard workers does not exceed 2.0 fibers/cc, the current allowable maximum.
- One operation, brake box cleaning using air to blow the accumulated dust from the enclosure, exceeds the ceiling exposure limit of 10.0 fibers/cc.
- Higher exposures were measured during the clean-up of asbestos lagging materials than during the removal operations.
- Asbestos waste clean-up procedures produced short term concentrations exceeding 2.0 fibers/cc.
- The use of a vacuum cleaner reduced the exposure of the clean-up personnel at the point of pick-up; but increased exposure at the vacuum cleaner exhaust.
- The standard vacuum cleaner very efficiently puts fibers into the air. Vacuum cleaners used to clean asbestos debris should be fitted with HEPA filters.
- Detectable concentrations of airborne fibers are generated during small tasks such as gasket cutting and repacking of valves.
- Personnel who perform routine cleaning stir up small quantities of fibrous dust.
- Open brakes on winches and hoists emit measurable quantities of fibrous dust.
- Ship vibration and/or motion can erode lagging, causing higher than normal fiber concentrations in localized areas for at least 24 hours.
- Most minor repairs in ventilated areas require only the use of a disposable or self-powered respirator to provide adequate protection for the worker.

(continued)

- Some changes in work practices and in equipment would eliminate most of the exposures found during the study.
- Additional emphasis on crew awareness of asbestos hazards are needed and a method to enforce safety rules is essential.

6.2 RECOMMENDATIONS

A number of standard work practices aboard ship should be modified to reduce the overall exposure of shipboard workers to airborne asbestos fibers; one practice should be abandoned. Recommendations are given below.

Based on the data, the cleaning of any enclosure containing a mechanical brake by means of air blowing or a compressed air hose and nozzle should be prohibited unless all personnel in the area are equipped with full-powered respirators, impervious protective coveralls, and the area itself is isolated from the balance of the ship. Isolation includes all air intakes and passages available to any unprotected personnel. A negative pressure airlock, shower room, and change area would also be required for this practice to be acceptable.

The development and use of an alternate cleaning procedure is recommended. Candidates are: water jet cleaning, which would include a thorough wetting of the dust before hosing; application of a cleaning fluid, followed by manual wiping and brushing of the dampened dust; a combination of these two methods, i.e., wetting the dust, with scraping and wiping of the bulk of the material into a container followed by high-pressure water cleaning of the enclosure; or vacuum cleaning of the enclosure using a high-velocity nozzle. Any procedure selected should be evaluated to determine exposure levels and the need for personal protection. Any vacuum cleaner used to clean up wastes suspected to contain asbestos must be fitted with HEPA filters. Protocols for a safe method to empty the bag and dispose of the hazardous waste resulting from collection of asbestos-containing materials must be developed and implemented.

Based on the observed distribution of the labor time, it is possible that exposure levels exceeding OSHA standards could result during larger repairs where more lagging is removed and more time is spent on a particular job, or when the repairs are conducted in poorly ventilated locations. These factors, plus evidence supporting a lowering of the TWA as proposed by OSHA, indicate that an educational program should be implemented for shipboard personnel.

The educational program should provide an awareness of the hazard, skill in use of personal protective devices, and knowledge of appropriate disposal procedures and good work practices.

The shipboard work rules should include:

- Use of approved respirators when handling, cutting, or removing materials known or suspected to contain asbestos
- Limitation of clean-up methods and equipment to approved vacuum cleaners and wet methods
    - vacuum cleaners must be of a type approved for asbestos collection
    - wet methods must include prewetting procedure before general hose-down
- Special instruction on personal hygiene
    - use of either disposable clothes or change and special laundering procedures
    - full shower or thorough clean-up immediately following asbestos contact and prior to eating or smoking
- Control of access to areas when asbestos-containing materials are being worked
- Control of spread of waste asbestos by means of drop cloths; local ventilation, when needed, and wetting of all asbestos waste upon primary pick-up
- Modifications to disposal methods to minimize emissions during removal or handling of asbestos wastes
    - make a single repository available
    - clearly label waste containers as an asbestos hazard

Personnel may be exposed to asbestos and other airborne particulate matter (welding fumes in particular) in the shop area. If well ventilated, the shop area may not be a significant source of exposure. It is recommended that efforts be made to assure that each shop is well ventilated and that the ventilation is designed to exhaust air from the bench, grinder, lathe, and other potential emission sources out of the ship. It is recommended that the ventilation be ducted into the boiler or independently exhausted, rather than blown into other larger spaces for dilution.

The results of this program indicate that some additional effort is needed to determine the number of open brakes in enclosed spaces, and that effort be made to eliminate the potential exposure from these open sources of emissions. At a minimum, shipboard personnel should be kept out of the area when the equipment is operating. The preferred solutions are either to enclose the brake completely, or to exhaust the emissions through a hood. Since enclosing the barke leads back to the worst case emissions found during the study, the recommendation of this report is to provide electrically interlocked exhaust hoods to remove the airborne asbestos fibers from the area as they are generated. Asbestos-free, non-toxic brake shoes should be obtained, if available. The replacement of all enclosed brake shoes with alternate asbestos-free, non-toxic material is the best long-term solution to this problem.

The study also indicates that an immediate, on-going inspection of pipe lagging for actual and potential erosion or vibration wear should be begun. The pipe lagging erosion noted during this study, if repeated with different ventilation and/or traffic patterns, could produce a significant exposure to shipboard personnel.

The recommendations are summarized and highlighted as follows:

- *URGENT*--Change the cleaning procedures for enclosed brake boxes.
- Prepare and put into practice work rules to include:
    - Use of self-powered respirators during disturbance to suspected asbestos-containing material.
    - Use of special equipment and procedures during clean-up of suspected asbestos-containing materials.
    - Improve personal hygiene and laundry practices for personnel working with suspected asbestos-containing materials.
    - Control access to work sites.
    - Improve waste disposal and handling practices.
- Measure and, if required, improve ventilation in the shop area.
- Take measures to eliminate or enclose open brakes operating in enclosed spaces.

- Institute an inspection and maintenance program to locate and repair eroding asbestos-containing materials.

IITRI recommends that any future tests be under greater control of the personnel responsible for the test. Control of test conditions should include:

- authority over personnel, especially with regard to equipment and work practices
- control of access to the test site
- control of decontamination and waste disposal operations
- scheduling and site selection.

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16. Abstract (Limit: 200 words)

This report contains a listing of asbestos-containing materials on-board ships and the repair or maintenance tasks during which the materials might be disturbed. Tests to measure the potential exposure to airborne asbestos fibers during routine repair and maintenance operations were done. Included in the test operations were pipe repairs, shop work, welding, and cleaning; both routine and of asbestos-containing wastes. Background fiber concentrations were measured.

The primary exposure risks were found during cleaning operations and removal of pipe lagging. One routine operation, cleaning brake enclosures, produced airborne fiber concentrations exceeding the ceiling exposure limit and several operations have potential to exceed the permissible exposure limit for airborne fibers.

Exposures can be minimized by proper use of personal protective equipment and of modified work practices.

17. Document Analysis a. Descriptors

Asbestos
Fibers
Exposure
Procedures

Hazardous Emissions

b. Identifiers/Open-Ended Terms

Occupational Exposure

c. COSATI Field/Group

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19. Security Class (This Report)

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22. Price

(See ANSI-Z39.18)

See Instructions on Reverse

OPTIONAL FORM 272 (4-77)
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