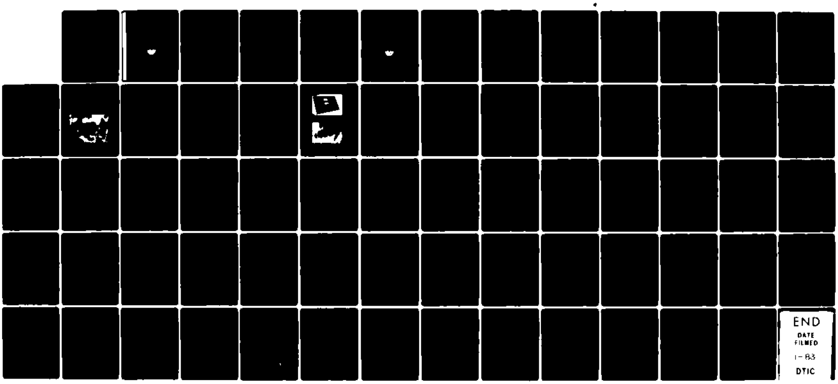
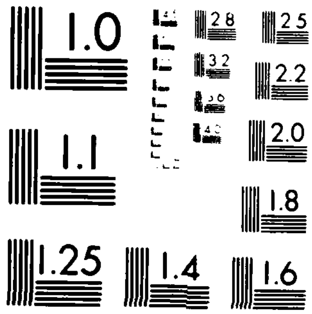
AD-A122 347 REMOVAL OF PRE-FORMED ASBESTOS INSULATION A PROJECT OF THE MANUFACTURING TECHNOLOGY PROGRAM(U) SOUTHWEST RESEARCH INST SAN ANTONIO TX OCT 82 DNS-686 1/1

UNCLASSIFIED N00604-80-C-A265 F/G 8/7 NL





MICROCOPY RESOLUTION TEST CHART

(5)

Report No. DNS-686

October 1982

REMOVAL OF PRE-FORMED ASBESTOS INSULATION

A Project of the Manufacturing Technology Program

Naval Sea Systems Command

FINAL REPORT

Approved for Public Release
Distribution Unlimited — Unclassified

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
WASHINGTON D C 20362

IN REPLY REFER TO
SEA 07032/RNW
SER 309

DEC 0 6 1982

From: Commander, Naval Sea Systems Command
To: Distribution

Subj: NAVSEA Manufacturing Technology (MT) Project, DNS-686, Removal of Pre-formed Asbestos Insulation; forwarding of final report.

Encl: (1) Final Report

1. NAVSEA under the Manufacturing Technology Program has successfully developed impregnation equipment for the removal of preformed asbestos insulation, that is inexpensive to obtain and simple to operate. Naval shipyard workers using this system, (under controlled conditions), have successfully removed shipboard asbestos insulation without causing airborne fiber concentration to exceed hazardous levels, which is described in detail in enclosure (1).

2. The prototype system has been shipped to the Pearl Harbor Naval Shipyard for immediate full-scale production tests and economic analysis. Naval shipyard personnel have been trained in the use of this new equipment and technique.

3. In response to your request, enclosure (1) is forwarded for your review.

W. N. GINN, JR.
By direction

Distribution:

Office of the Under Secretary of Defense, Research & Engineering (Mr. James H. Kordes)
Office of the Under Secretary of Defense, Research & Engineering (Mr. Burton E. Bartsch)
Office of the Assistant Secretary of Army for Research, Development and Acquisition (Mr. William Takakoshi)
U.S. Army Material Development and Readiness Command
Occupational Safety & Health Shipbuilding & Logistics
Naval Operations (OP 987)
Manufacturing Technology Program, Naval Material Command (Code 064)
Office of the Under Secretary of Defense, Research and Engineering (Dr. Lloyd L. Lehn)
DARPA/OSD (MATS)
Office Deputy Chief of Staff for Research, Development and Acquisition (Mr. Richard Barnett)
Manufacturing Technology Division, Industrial Base Engineering Activity
Chief of Naval Operations (OP45)
Naval Material Command Industrial Resources Detachment
Naval Air Systems Command (AIR-5162C)
Naval Sea Systems Command (Code 05R43)
Naval Electronic Systems Command (ELEX-8134)
General Electric Company (David E. Kinney)
ODASD Office of Safety and Occupational Health (Mr. George Siebert)
Supervisor of Shipbuilding, Pascagoula (Code 600)
Naval Sea Systems Command (Code 07C)
Naval Sea Systems Command (Code 921)
Naval Sea Systems Command (Code 941)
Subship-Boston U.S. Navy (Code 140)
Naval Submarine Medical Center (Code C12)
Office of the Assistant Secretary of the Air Force (RD&L)
HQ Air Force Systems Command
Naval Sea Systems Command (Code 04E)
Naval Sea Systems Command (Code 05E)
Naval Sea Systems Command (Code 90M)
Naval Sea Systems Command (Code 931)
Naval Sea Systems Command (Code 942)
Naval Submarine Base, Bangor (Code N912)
Heaquarters, US Air Force Pentagon (RDCM)
Air Force Wright Aeronautical Lab (MT Division)
National Bureau of Standards Manufacturing Systems
NASA Headquarters (Manufacturing Technology Utilization)
Production Resources, National Science Foundation
Office of Pesticides, Environmental Protection Agenscy (Kurt Wright)
Director of Manufacturing Engineering, Newport News Shipbuilding (Mr. T.J. O'Donohue)

Distribution (Continued):

Naval Weapons Center, China Lake (Code 5515)
Puget Sound Naval Shipyard PERA (CV) (Code 1821)
American Defense Preparedness Association (Rudy F. Rose)
Office of Cooperative Generic Technology, Department of Commerce
Department of the Navy (BUMED)
Naval Environmental Health Center (R.A. Nelson)
Office Of Ship Construction, Maritime Administration (Edward Karlson)
Bath Iron Works (David Blais)
U.S. Environmental Protection Agency (John Copeland)
Lord Kenmatics Inc., American Institute of Industrial Engineers, (Robert Hettrick)
Lockheed Corporation, American Society for Quality Control (Walter Hurd)
Universal Systems Inc. (Robert W. Oliver)
Society of Manufacturing Engineers (Bernard Sallot)
Systems Engineering Associates Corporation (SEACOR) (M. Arcel)
Office of the Mayor, Baltimore, Md. (Philip Yaffee)
Naval Facilities Engineering Command (Code 102)
Office of Marine Operations (Frederick Sergio)
Charleston Naval Shipyard (Code 380)
Noroflk Naval Shipyard (Code 380)
Portsmouth Naval Shipyard (Code 380)
Mare Island Naval Shipyard (Code 380)
NAVSSES 053B
Society of Naval Architects & Marine Engineers (Ellsworth Peterson)
Fiber Materials Inc. (Gordon J. Schuller)
Armstrong World Industries, Inc. (I.I. Bezman)
First Coast Guard District (LTSG J. Bowers)
Naval Facilities Command (Code 11230)
Long Beach Naval Shipyard (Code 380)
Philadelphia Naval Shipyard (Code 380)
Puget Sound Naval Shipyard (Code 380)
Texas Research Institute Inc. (Dennis D. Berrett)
Defense Documentation Center

Report No. DNS-686

October 1982

REMOVAL OF PRE-FORMED ASBESTOS INSULATION

A Project of the Manufacturing Technology Program

Naval Sea Systems Command

FINAL REPORT

Approved for Public Release
Distribution Unlimited — Unclassified

TABLE OF CONTENTS

LISTING OF ILLUSTRATIONS

LISTING OF ILLUSTRATIONS (Cont'd)

ACKNOWLEDGEMENTS

This report was prepared by Southwest Research Institute under Navy Contract N00604-80-C-A265 which was initiated by the Pearl Harbor Naval Shipyard and sponsored by NAVSEA's Manufacturing Technology Program.

The program manager gratefully acknowledges the contribution of Mr. Joel Halop who served as project manager until his recent departure from the Pearl Harbor Naval Shipyard to take a position with the Marine Corps.

I especially wish to thank all of those persons at the Pearl Harbor and Long Beach Shipyards for their contributions and assistance to Mr. Halop and myself in making this a successful project. Many people contributed to the success of this project. Many thanks.

Roy N. Wells, Jr.
NAVSEA 07032
Program Manager

SECTION I. EXECUTIVE SUMMARY

A. Overview

Removal of asbestos thermal insulation from Naval vessels has become one of the most critical elements in the ship repair process. Extensive Personnel Protective Equipment (PPE) is required to reduce exposure to airborne asbestos fibers. Sealed containments must be constructed, access is rigidly controlled and comprehensive breathing safeguards are employed during the removal/clean-up process. These safeguard measures significantly increase cost and time of removal. A conservative estimate for the additional manpower expended using current safeguards to minimize exposure is approximately 30% of the total labor used for actual set-up, rip-out, and clean-up of the machinery spaces involved.

Productivity would be greatly increased if a simplified technique could be developed for asbestos removal that would maintain airborne fiber generation below the Permissible Exposure Limit (PEL) and Navy Medical Surveillance Action Level (MSAL). In 1978 a proposal was prepared at Pearl Harbor Naval Shipyard to investigate this process. Approval and funding from Naval Sea Command followed in 1979. Feasibility of an impregnation/entrapment process was first demonstrated in a laboratory environment. A full-scale hardware development and testing program was then undertaken. This report provides the results of that program.

B. Development and Test Program

This program was established as a Research, Development, Test and Evaluation Contract to devise a process and produce hardware capable of full-scale production based on the laboratory study. Various models were developed, refined, tested, and redesigned as part of the formal program presented in the contractor's solicitation. Each model was tested on board a naval vessel (while maintaining strict compliance with Navy Occupational Safety and Health (OSH) requirements) to evaluate the design. In this way, the Preproduction Prototype Model evolved through the various phases of engineering development, as described in Section III of this report.

C. Results

Five (5) shipboard tests were conducted to evaluate each improvement in equipment and technique during the development program. Air samples were recorded for all pre-test, injection, rip-out/clean-up and post-test operations using approved National Institute of Occupational Safety and Health (NIOSH) sampling procedures and qualified personnel. Both area samples and breathing zone samples were recorded to obtain ceiling levels and time-weighted-average (TWA) airborne concentration values. Airborne concentrations of ethylene glycol mist/vapor was also recorded.

All air sample data obtained during the rip-out/clean-up sequences is summarized below:

1. Asbestos

a. Environmental Sampling (f/cc)

Concentration	No. of Samples	Range	Mean	95% C.L.
TWA	25	0-0.22	0.04	0.19
Ceiling	2	0-0.43	0.22	0.82

b. Personal Sampling (f/cc)

Concentration	No. of Samples	Range	Mean	95% C.L.	PEL	MSAL
TWA	15	0-0.15	0.04	0.24	2	0.5
Ceiling	89	0-3.59	0.30	2.32	10	10.0

2. Ethylene Glycol

No. of Samples	Range	Mean	95% C.L.	PEL
44	(All values less than 0.01 mg/m3)			125 mg/m3

The data clearly reflects airborne concentrations significantly lower than both the Permissible Exposure Limits (PEL) and the Medical Surveillance Action Level (MSAL). A statistical survey of the 131 asbestos data points produces fiber concentrations at 95% confidence well below the PEL and MSAL. Additional data recorded during the "injection" phase showed airborne concentrations less than 0.01 f/cc.

D. Conclusions

The impregnation equipment and technique has been developed into a system that is inexpensive to obtain and simple to operate. Navy shipyard workers using this system have successfully removed shipboard asbestos insulation without causing airborne fiber concentration to exceed hazardous levels. There have been no undesirable aftereffects to the environment and no other hazards are created from this technique. The current requirement for air-fed respirators, containments, exhausters, water spray, etc. can be substantially revised to accommodate the reduced fiber concentration levels attainable with this new system. Significant manpower savings are then possible. A nominal value of $280,000 per ship has been calculated, using historic data available at Pearl Harbor Naval Shipyard, and is discussed in Section V of this report.

E. Recommendations

The documented results obtained from this two-year project provide ample justification to:

- Approve this system for immediate full-scale production tests and economic analysis at a naval shipyard;

- Support continued research and development to expand this technique for use in asbestos control in the shore industrial establishment, e.g., in the removal of sprayed-on ceilings of buildings; and

- Modify Navy asbestos control instruction commensurate with production test results and based on approvals required.

SECTION II. INTRODUCTION

A. Background

The dangers of asbestos are well-known. The fact that it causes asbestosis, lung cancer, mesotheliona and possibly other diseases is now well documented. There has always been an attempt by scientists to establish a hygienic standard for asbestos that is biologically most appropriate in limiting the hazard. However, since asbestos was established as a human carcinogen, it has been difficult to establish a no-risk level of exposure. There is always some small risk to health as long as there are any airborne fibers in the environment. An allowable exposure level (airborne concentration), however, must be determined and defined by an index with resulting exposure based on the theory that certain levels can be tolerated without incurring undue risks. This occupational level is normally referred to as Permissible Exposure Limits (PEL), generally based on an 8-hour and a 15-minute exposure duration. Repeated exposure day after day at or below these levels should not adversely affect nearly all the work force. Various agencies and individuals have completed studies over the last 30 years leading to the following current Occupational Safety and Health Administration (OSHA) standard:

> "Occupational exposure to airborne asbestos dust shall be controlled so that no worker shall be exposed to more than 2.0 asbestos fibers per cubic centimeter (cc) of air based on a count of fibers greater than 5 micrometers (<5 μm) in length determined by the membrane filter method at 400-450X magnification (4mm objection) phase contrast illumination, as described, determined as a time-weighted average (TWA) exposure for an 8-hour day, and no peak concentration of asbestos to which workers are exposed shall exceed 10.0 fibers/cc <5 μm as determined by a minimum sampling time of fifteen minutes."

Presently, removal of asbestos insulation on board ship is accomplished by using containments, exhaust ventilation systems, a fine water spray to control dust particles and extensive use of personal protective equipment (PPE). Although safeguards are used to minimize the spread of asbestos dust particles, there is no way they can be contained completely without costly precautions being taken. Exposure to asbestos occurs by inhalation of asbestos fibers produced as a fine dust during these operations. Inhalation of even small amounts of invisible asbestos fibers can lead to serious health impairment and is the main factor for eliminating asbestos as an insulation material on piping, ducts and boilers where suitable alternative asbestos-free thermal insulation materials are available.

Use of the current safeguards has substantially reduced exposure but at the expense of elaborate and costly PPE, which in turn increases the rip-out cost and duration (see Figure 1). The current Navy regulation

(OPNAV 6260.1B) requires the use of this PPE since airborne concentrations during present day rip-out may exceed the OSHA allowable concentration levels.

B. Manufacturing Technology Proposal

In 1978, a proposal was prepared at Pearl Harbor Naval Shipyard and submitted to NAVSEA 07D to investigate the feasibility of a technique to rigidify or bind the asbestos fibers, during the removal process, so as to prevent generation of airborne concentrations in excess of the allowable limits. If such a process could be developed, that was not extremely complicated or expensive, the Manufacturing Technology Program could provide funding for research and development of a workable device for safe, easy asbestos removal with substantially reduced PPE.

FIGURE 1. CURRENT SHIPBOARD RIP-OUT OPERATIONS

The feasibility study was approved for contract accomplishment and Southwest Research Institute (SwRI) of San Antonio, Texas, submitted the successful bid. Feasibility was demonstrated, and a second contract was then awarded for hardware/process development, using the concepts proven in the laboratory study. This second contract also provided for several shipboard rip-out tests including a final demonstration during an actual ship repair.

C. Purpose

The purpose of this report is to provide complete documentation of the entire project.

D. Scope

The scope of this phase of the project has been limited to removal of preformed asbestos material found in naval vessels, and to the various naval repair facilities currently performing removal operations. Various other federal agencies and private sector organizations have been monitoring the progress of this project so that expanded applications are already being considered.

SECTION III. TECHNICAL APPROACH

A. Project Plan

A readily accessible Naval vessel that contained preformed asbestos insulating material was the first order of business. An ideal "test bed" was located at the Long Beach (California) Naval Base. The vessel (YR-85) was scheduled to remain at Long Beach therefore permission was obtained to use the YR-85 for this project. Other local Naval facilities (Shipyard, NRMC, etc.) were also able to support the testing effort.

Shortly after the contract was awarded, the Long Beach test site was inspected by contractor/Navy personnel to obtain physical characteristics and establish all necessary working arrangements. Design of an Advanced Development Model was then ititiated, followed by construction and operational testing at SwRI. A field test of the Advanced Development Model was then conducted on the YR-85. All such testing was done under the jurisdiction of an SwRI Test Conductor, the Navy Contracting Officer Technical Representative (COTR), and a Navy Industrial Hygienist, in accordance with the contract Statement of Work and an approved Air Monitoring Plan. Operational characteristics and ability to reduce airborne asbestos fiber concentrations were observed and recorded to permit improvements and modifications to the equipment and technique.

This cycle was then repeated by redesign, modification, and shipboard testing of an Engineering Development Model, a Preproduction Prototype and finally a Prototype unit. Size/weight reduction, automation, fail-safe characteristics, etc., were continuously improved through these various cycles. Navy personnel were trained to operate the equipment and a training manual was also developed. A special demonstration was conducted, using the Preproduction Prototype unit, for Naval Sea Systems Command/Naval Environmental Health Center representatives at mid-contract.

An end-of-contract (EOC) demonstration and acceptance test was planned for completion at the Norfolk Naval Shipyard, due to the proximity of the various agencies involved in this project. Unfortunately, a schedule could not be established so the EOC demonstration was held aboard the LKA-116 at San Diego. The project plan also provided for complete periodic documentation of all tests and equipment development, as well as preparation and delivery of operation/training manuals, full procurement data and delivery of the prototype unit to the Navy.

B. Advanced Development Model

The Advanced Development Model was the first unit produced for preliminary experimentation:

- To demonstrate the technical feasibility of the design,
- To determine the ability to meet the design requirements in the Statement of Work.
- To secure engineering data for use in further development, and
- To refine the nature and scope of specific technical problems related to further development.

The Advanced Development Model was used principally to determine the effectiveness of the techniques for on-board application. Minimal consideration at that point was given to reliability, maintainability, or human factors related to design and construction of a finished piece of hardware.

C. Engineering Development Model

The Engineering Development Model was then constructed using the experience gained during the on-board testing of the Advanced Development Model. The Engineering Development Model was used in tests to determine applicability (and problems)related to the use of the equipment in real environments onboard the ship. This model closely approximated the final design in that it met design objectives for size and form. To the degree possible, it incorporated standard parts and achieved design objectives for reliability and maintainability.

D. Preproduction Prototype

The Preproduction Prototype Model was then developed to be suitable for complete evaluation of the form, fit, and on-board performance. It was in final form in all respects, utilizing standard parts to the degree possible and fully representative of the final equipment. This unit was used in the on-board testing and training at the end of the project and for the EOC demonstration (see Figures 2 and 3).

E. Prototype

It is planned to deliver a complete Prototype unit upon direction of the Navy COTR. This Prototype unit will incorporate any minor revisions identified during the final training phases; however, only modest changes are anticipated after the conclusion of the EOC demonstration. The Prototype unit will consist of:

- A reservoir and pump assembly with supply hose.
- A central control console including injection pump, surge tank and distribution manifold with all necessary control devices and indicators to operate the system.

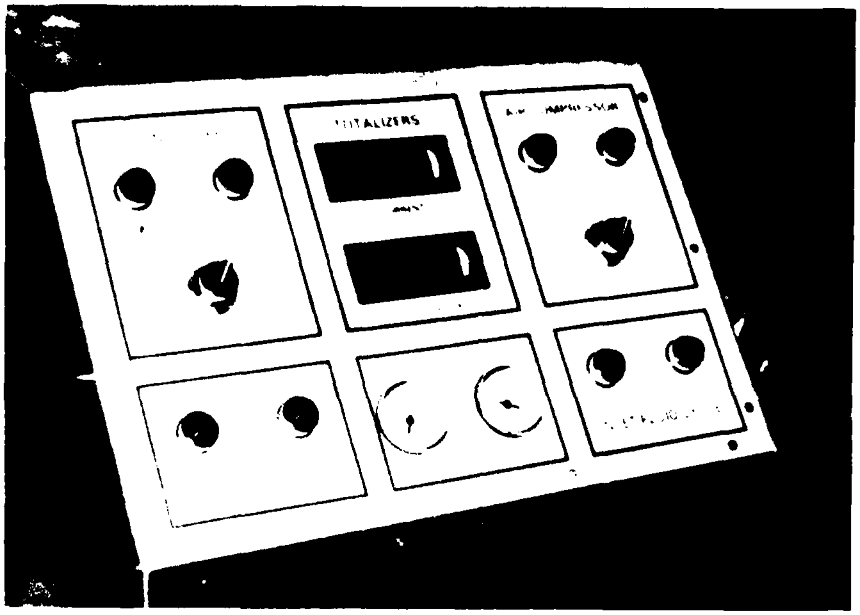


FIGURE 2. ARS CONSOLE

FIGURE 3. ARS INJECTOR PROBES

- Five (5) distribution manifolds, each with ten (10) injector probes and all necessary hoses, etc.

- An electrical Saturation Verifier.

- A foam generator/applicator device.

- Complete operating and training manuals.

All equipment will have been tested and will be ready to operate.

F. Specific Technical Objectives

On the basis of the research and development work to identify an impregnant and a delivery mechanism, the following list of technical objectives has been established. These objectives represent design problems which were incorporated into the contract in order to produce reliable, safe, and cost-effective equipment:

1. Identification of effective impregnant.

2. Identification of effective impregnant delivery probe(s).

3. Design of effective impregnant transport mechanism.

4. Design of an insulation cutting tool.

5. Identification of a technique for asbestos particle suppression during cutting.

6. Design of equipment to deliver particle suppressant during cutting operations.

7. Selection of techniques for metering penetrant flow rates.

8. Design of readout for indication to operator of penetrant flow rate.

9. Identification of a method for safe handling of impregnated asbestos after removal.

10. Identification of technique for final cleanup of asbestos from pipes, fittings and surfaces.

11. Design of equipment to reduce size, optimize reliability, and facilitate maintainability of all equipment.

12. Design packaging for equipment to provide protection in transport, to facilitate shipboard handling and to provide protection for long-term storage.

13. Develop lesson plan and training materials for operational training of Navy personnel.

14. Develop methods and techniques for cleanup and asbestos decontamination of equipment.

15. Develop operational techniques for isolation of impregnant to avoid contamination of insulation not intended for removal.

16. Develop operational procedures for safe handling of overflow or spills resulting from migration of impregnant through cracks or voids in the insulation.

17. Identify any deleterious effects of the impregnant or the removal process on the materials which are protected by the asbestos insulation.

18. Identify a method for determining whether the asbestos is completely impregnated prior to cutting.

19. Determine if there are any health risks to personnel using ethylene glycol as an impregnant.

SECTION IV. TEST RESULTS

A. Measurement of Airborne Asbestos Fibers

1. Optical Microscopy Examination

The phase contrast microscopy examination of the asbestos fibers collected on this project was conducted in the SwRI Houston Laboratories. These laboratories are equipped with six (6) Leitz microscopes, including the Leitz Dialux microscope equipped for phase contract microscopy. Appropriate reticle sizes for particulate analysis are available as are ocular micrometers for determining asbestos size/length.

Analysis of asbestos concentrations was conducted in accordance with the NIOSH manual. Briefly, millipore filters are cut to remove a pie-shaped wedge which is placed on a microscope slide. The slide was covered with a solvent solution which dissolves the Millipore filter and increases the visibility of the asbestos fibers. All fibers meeting the length-to-width ratio of 3 to 1 and measuring greater than 5 μm in length are counted under phase contrast microscopy at 400 magnifications using a Porton reticle (area = 0.004 mm^2 unless otherwise noted). Random fields are examined in the pie-shaped piece of filter material until 200 fibers have been enumerated or 100 fields have been counted. From the area examined with the reticle and the number of fields examined to reach 200 fibers, the number of fibers per filter can be estimated. This information is then related back to the total number of fibers produced per volume of air flow in the environmental chamber or the number of fibers produced by the cutting operation.

The size-class distribution analysis of asbestos is accomplished using a methodology similar to that required for the fiber counts, with the exception that the individual particles are measured for length using an ocular micrometer. These particles may be classified into fractional groups based on 5 μm size-class, a histogram is constructed to show the distribution of the size of particles obtained for a particular operation. It is estimated at least 400 particles will be required in order to determine a satisfactory level of accuracy of the size-class distributions. Particle size analysis will include fiber lengths of 50 μm and less.

Representative particles have been photographed on 35-mm slides on cameras attached to the microscope and are available upon request. One-tenth of the counts of size-class distribution and of the counts for quantity analysis were duplicated to provide a check against unseemly variances between counts.

2. Electron Microscopy Examination

Additional samples of asbestos deposited on filters were analyzed using electron microscopy for quantity as well as particle size distribution. These samples included filters used to collect the asbestos fibers generated while cutting and removing untreated insulation as well as filters used during the evaluation of the selected impregnant and foaming agent. Selected samples were evaluated using the electron microscopy technique. These analyses were performed by:

Walter S. McCrone Associates, Inc.
2820 S. Michigan Avenue
Chicago, Illinois 60616

This organization has the requisite experience and facilities to perform the analyses on the transmission electron microscope (TEM). The filter, sampling flow rate, and the effective filter area were provided for each analysis and are available upon request. For analysis by TEM and phase contrast microscopy, all asbestos samples were collected on 37 mm diameter, 0.8 um pore size cellulose-ester Millipore filters.

B. Field Test of Advanced Development Model

1. This first field test was conducted on the YR-85 barge located at Long Beach Naval Shipyard. All of the asbestos injection and removal was done by SwRI personnel with representatives of Pearl Harbor and Long Beach Naval Shipyards present. The boiler room was selected for the first series of tests conducted December 9-11, 1980. The boiler room and part of the generator room were selected by Long Beach Shipyard personnel to establish a containment. The boiler room was where the work was done and the polyethylene screened area in the generator room was designated as a change room.

Six (6) locations in the boiler room were selected for the air sampling pumps. Locations 1, 2, and 3 were on the right side of the boiler room facing forward and locations 4, 5, and 6 were on the left side. Pump locations 1, 2, and 3 were 3-1/2 feet above the floor on a shelf. Pump location 4 was 2 feet above the floor. Pump location 5 was 5-1/2 feet above the floor and pump location 6 was on the floor. Location sketches are identified below for each test sequence. (Porton reticle area for this test = 0.045 mm^2.)

2. Sequence Number 1

The initial air sampling series was conducted before any injection or rip-out was done by the SwRI team. The purpose of this series was to determine if there was any background airborne concentration of asbestos fibers in the boiler room before the test was started.

Four (4) MSA portable air sampling pumps were installed in the boiler room at the locations indicated in Figure 4. The pumps were calibrated before and after the test using an Altech Associates 1000 cc soapfilm flow meter. Each pump was outfitted with a Millipore Corporation aerosol monitoring case and 37 millimeter diameter, 0.8 micron pore size, mixed ester of cellulose and support pad manufactured by Millipore Corporation.

The filter samples were analyzed by phase contract microscopy by trained SwRI personnel in accordance with the procedures specified by the National Institute of Occupational Safety and Health.

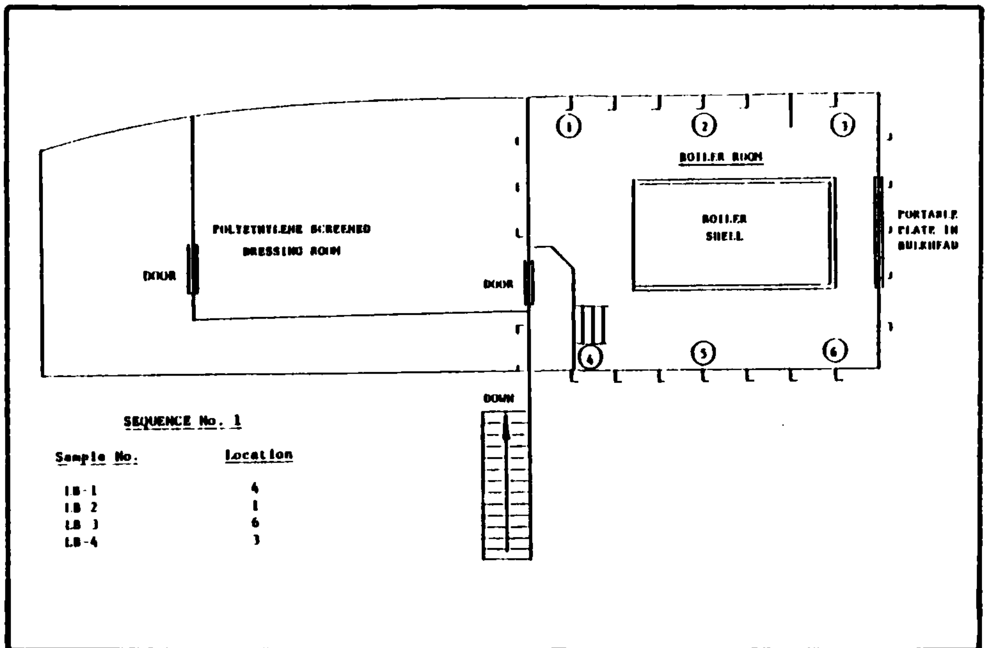


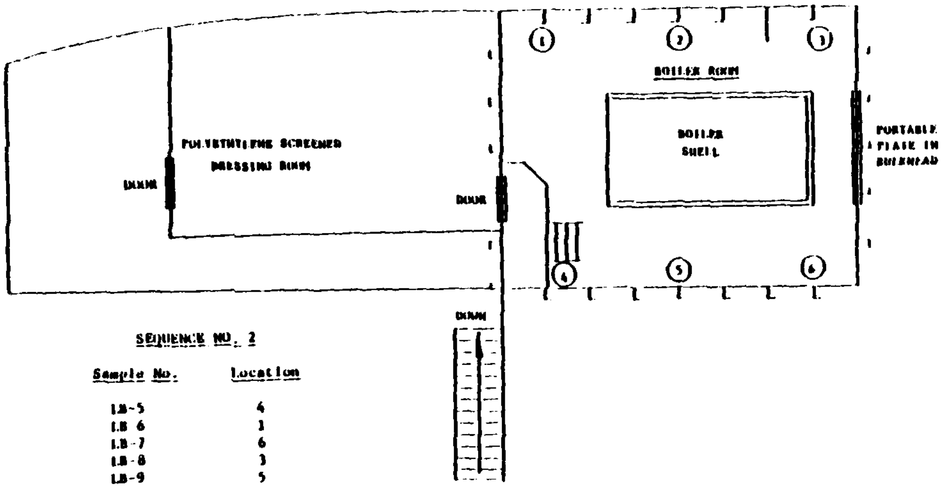
FIGURE 4. AIR SAMPLE PUMP LOCATIONS
Test Series 1, Sequence 1

3. Sequence Number 2

Five (5) air sampling pumps were placed in the boiler room indicated in Figure 5. Fifty-four (54) pounds of ethylene glycol/water (EGW) with a ratio of 1 part ethylene glycol to 5 parts of water were mixed in a 5-gallon pressure pot. The pot was then pressurized to 15 psig using shipboard compressed air supply and maintained using a regulator.

The areas of asbestos pipe insulation that had obvious holes where the injection liquid would leak out were taped closed using duct tape prior to the injection. The single nozzle injector used during the demonstration on the earlier project at SwRI was used during this initial injection. A total of 48 pounds of 1:5 EGW was injected into the 12 feet of 4-inch insulation indicated in Figure 6. This asbestos pipe insulation was located in the corner of the boiler room above pump location number 3.

Even though several potential locations for leaks were taped closed prior to the injections, there were several locations where the liquid leaked out of the insulation. When this occurred, the injection of liquid was stopped and the 1/4-inch diameter needle withdrawn from the insulation until leakage stopped. The insulation was saturated with the liquid as a result of injecting the mixture along the length of pipe at approximately 6-inch intervals. There appears to be no difference in the rate at which the liquid could be injected in the horizontal and vertical runs of insulation. A flow meter was located in the liquid line near the pressure pot. The rate of flow during the injection was between 0.05 and 0.10 gallons per minute.



SEQUENCE NO. 2

Sample No.	Location
LB-5	4
LB 6	1
LB-7	6
LB-8	3
LB-9	5

FIGURE 5. AIR SAMPLE PUMP LOCATIONS
Test Series 1, Sequence 2

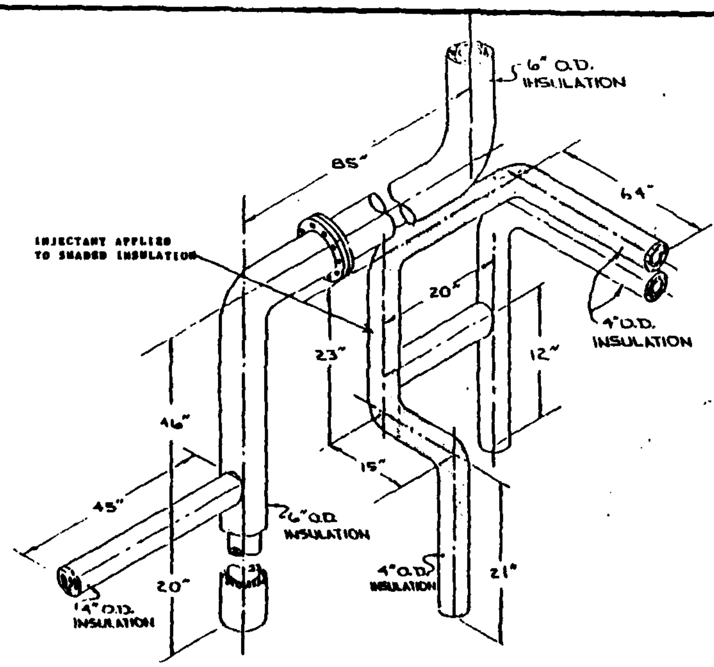


FIGURE 6. PIPING CONFIGURATION (Sequence 2)

4. <u>Sequence Number 3</u>

Four (4) air sampling pumps were installed in the boiler room at the locations indicated in Figure 7. Fifty-one (51) pounds of 1:5 EGW mixture were injected into the 4-inch and 6-inch insulation as indicated in Figure 8. The injection rate was again between 0.05 and 0.10 gallons per minute when the single injection nozzle was used.

The asbestos "pad" covering the flange on the horizontal run of the 6-inch O.D. insulation was removed. It was noted at this time that the line was hot because steam was flowing through the pipe with the 6-inch insulation.

A manifold injector with five (5), 5/16-inch diameter injections needles was used to inject the liquid into the asbestos insulation. It was found that the needles were a little long on this unit because the probes were approximately 1-1/4 inch long and the insulation was only 1 inch thick. As a result, the probes had to be inserted tangentially to the pipe rather than radially.

It was discovered that the steam lines were so hot that the 1:5 EGW mixture boiled after it was injected into the insulation on the 6-inch line.

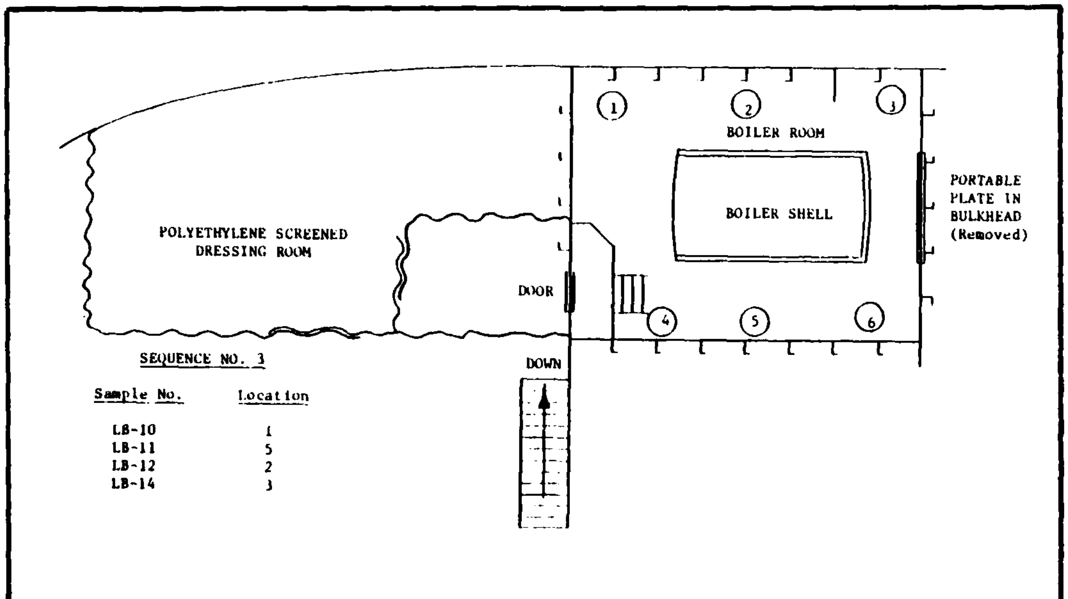


FIGURE 7. BOILER ROOM SAMPLE PUMP LOCATIONS
TEST SERIES NUMBER 1 SEQUENCE 3

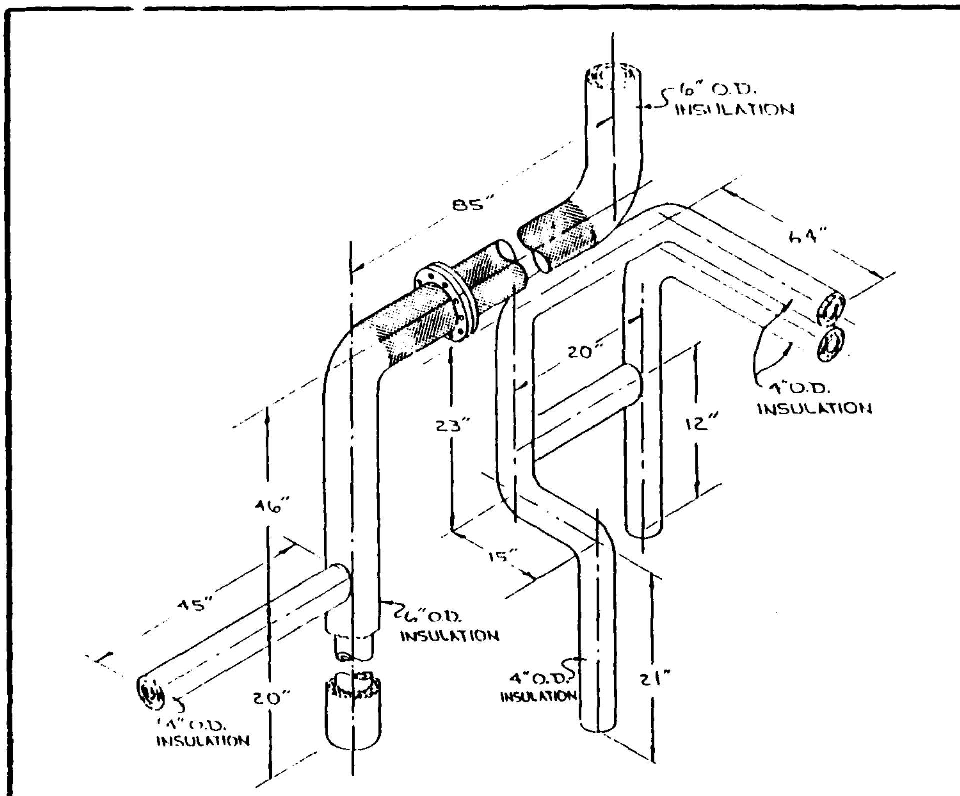


FIGURE 8. PIPING CONFIGURATION (Sequence 3)

A second mixture of 1:5 EGW was prepared and injected into the insulation. A total of 40 pounds of this mixture was injected. This mixture also boiled in place. During the injection and boiling process there was some impregnated material discharged from the covered insulation near the flange and through the hole made during the injection process.

5. <u>Sequence Number 4</u>

Four (4) air sampling pumps were installed in the boiler room as indicated in Figure 9. The mixture injected during this sequence was 1:5 ethylene glycol/water. The asbestos insulation injected during this sequence is indicated in Figure 10 and 11. The insulation indicated in Figure 11 was the vertical run on the left side of the doorway and over the entrance. Approximately five (5) pounds of liquid was injected into the 6-inch diameter insulation after the steam had been turned off and the pipe allowed to cool. Thirty-five (35) pounds of liquid was injected into the 4-inch insulation shown in Figure 11.

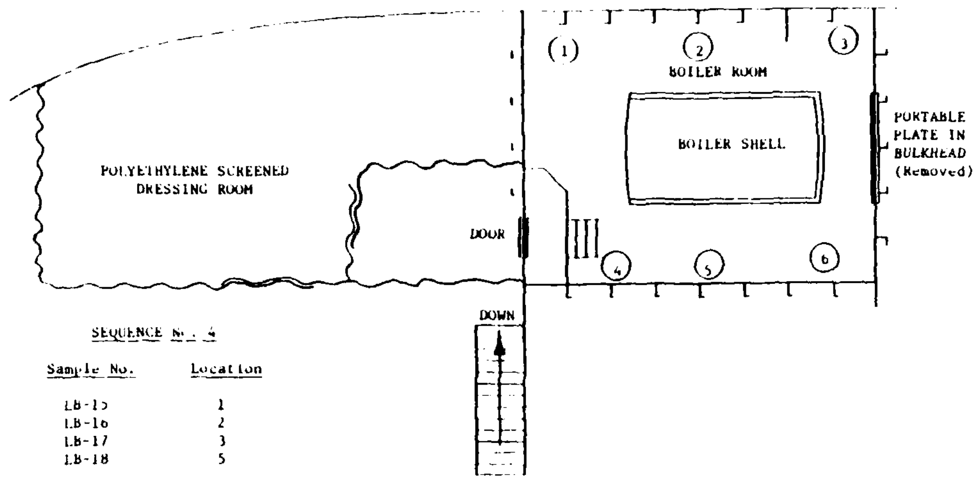


FIGURE 9. BOILER ROOM SAMPLE PUMP LOCATIONS, TEST SERIES NUMBER 1, SEQUENCE 4

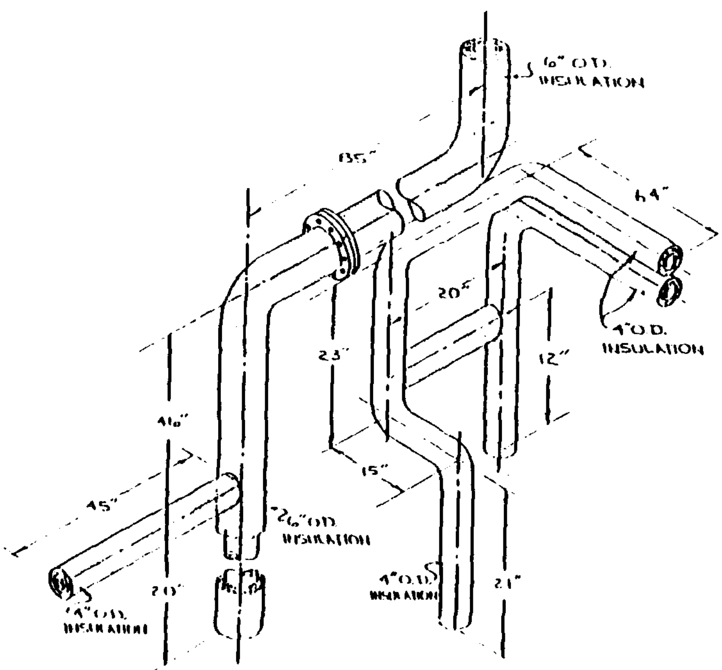


FIGURE 10. PIPING CONFIGURATION, SEQUENCE 4

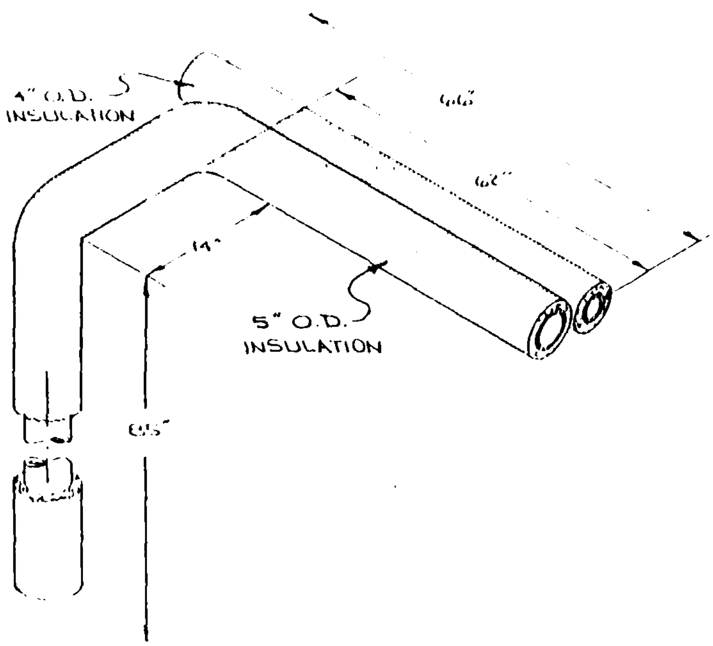


FIGURE 11. PIPING CONFIGURATION, SEQUENCE 4

6. Sequence Number 5

During this period, air sampling pumps were located in the boiler room as shown in Figure 12, and one (1) pump was attached to one of the individuals working in the room.

All of the asbestos insulation injected during sequences 2, 3, and 4 were removed during this sequence. Razor blades, knives, and an electric cast cutter were used to cut the lagging on the insulation. The wire wrapping on the insulation could be cut with the cast cutter, but a wire cutter had to be used to cut the wire when razor blades and knives were used.

Aqueous foam was used in conjunction with the cast cutter to prevent any asbestos from becoming airborne during the cutting. The aqueous foam was dispensed from a 14-ounce aerosol can through a valve. It was hard to control the quantity of foam being dispensed because the control valve was located at the aerosol can and not at the cutter. An excessive amount of foam was dispensed; however, the foam contained the asbestos dust in the one area where the cast cutter hit dry asbestos insulation.

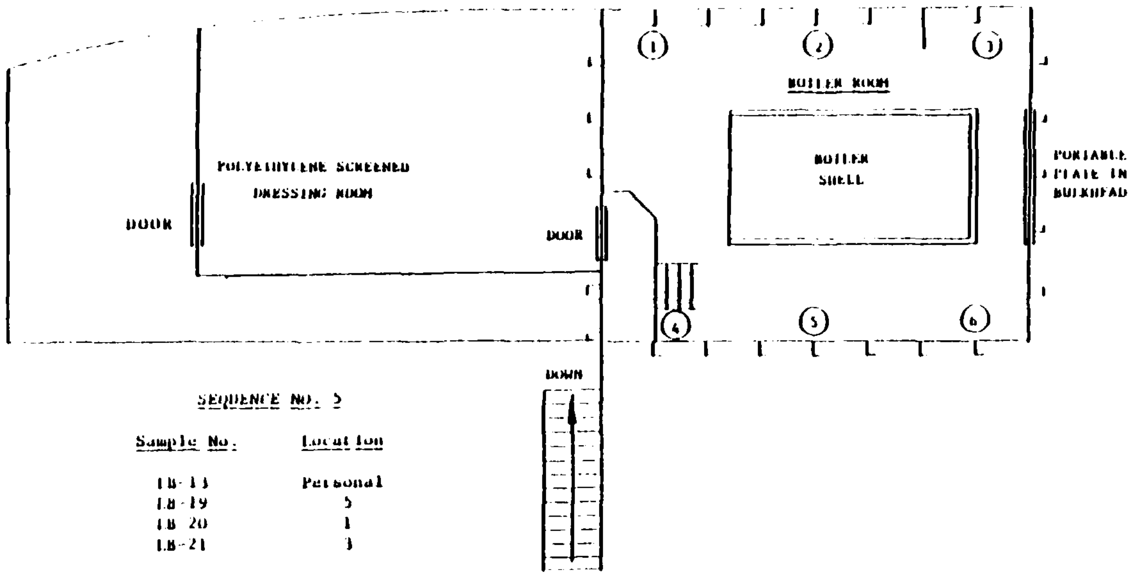


FIGURE 12. AIR SAMPLE PUMP LOCATIONS
(TEST SERIES 1, SEQUENCE 5)

7. Data Summary

The results of all air sampling measurements are recorded in Table 1. Air sample data for this test are summarized below:

		TWA (f/cc)		
Sequence	No. of Samples	Range	Mean	95% C.L.
Pre-test	4	None Detected	0	0
Injection	13	0.00 - 0.007	0.001	0.005
Rip-Out/Clean-up:				
BZ	1	0.026	0.026	0.026
GA	3	0.0 - 0.017	0.007	0.038

TABLE 1 - AIR SAMPLING DATA*

Sample No.	Sample Type	Duration (Min.)	Pump Rate (L/M)	Total Fibers (20 Fields)	TWA (f/cc)	Sequence
LB-1	GA	71	1.96	ND	--	Pre-test
LB-2	GA	71	1.89	ND	--	" "
LB-3	GA	71	1.98	ND	--	" "
LB-4	GA	71	1.98	ND	--	" "
LB-5	GA	55	1.96	ND	--	Injection
LB-6	GA	108	1.90	ND	--	" "
LB-7	GA	108	1.93	ND	--	" "
LB-8	GA	108	1.50	ND	--	" "
LB-9	GA	108	1.87	ND	--	" "
LB-10	GA	253	2.04	ND	--	" "
LB-11	GA	253	1.97	1	0.001	" "
LB-12	GA	253	1.96	0	--	" "
LB-14	GA	253	1.98	4	0.004	" "
LB-15	GA	171	1.65	2	0.007	" "
LB-16	GA	171	2.03	7	0.007	" "
LB-17	GA	171	2.09	ND	--	" "
LB-18	GA	171	2.17	ND	--	" "
LB-13	BZ	198	2.02	26	0.026	Rip-Out/ Clean-up
LB-19	GA	244	2.03	4	0.004	" "
LB-20	GA	244	2.11	ND	--	" "
LB-21	GA	198	1.99	17	0.017	" "

*Conditions:

Boiler room established as containment, with exhauster installed to maintain negative interior pressure. Exhauster OFF during the pre-test only. Air pumps calibrated by SwRI. Standard PPE employed. Rip-out by SwRI personnel. Entry monitor and clean-up certification by LBNSY.

NOTES:

1. Concentration levels were calculated using the following formulas:

$$\text{Concentration (f/cc)} = \frac{0.855n}{ATRF}$$

where n = No. of fibers counted
A = reticle area (mm^2)
T = duration (min.)
R = pump rate (L/min.)
F = No. of fields counted

$$\text{TWA} = \frac{\text{Concentration (f/cc) X Test Duration (min.)}}{480\text{(Min.)}}$$

2. Statistical values in Section IV-B.7 were calculated using standard formulas.

3. Key: ND = None Detected
GA = General Area
BZ = Breathing Zone
TWA = Time-Weighted Average (3-hour)

C. Field Test of Engineering Development Model

1. This test was conducted on the YR-85 barge located at Long Beach Naval Shipyard. The same boiler room used for the first series of tests on December 9-11, 1980 was again used to conduct the second series on February 26-27, 1981.

Four (4) MSA portable air sampling pumps were used during the course of the test. The pumps were calibrated before and after the test using an Altech Associates 1000 cubic centimeter soap film flow meter. Each pump was outfitted with a Millipore Corporation aerosol monitoring cassette and 37 millimeter diameters, 0.8 micron pore size, mixed ester of cellulose with support pad manufactured by Millipore Corporation.

Half of the samples taken during the tests were analyzed at Southwest Research Institute. The other half were sent to McCrane Laboratories for independent evaluation. The two (2) sets were divided evenly so that good correlation could be obtained.

2. Sequence No. 1

The first air samples were taken in the boiler room before any injection or asbestos removal were done. Two (2) area samples were obtained during the 2-1/2 hour background measurement period. The pumps were placed on opposite sides of the boiler room. All area sample locations are shown in Figure 13. Each pump was placed approximately 3 feet above the deck of the compartment. Air sample Nos. 100 and 101 were taken during this sequence.

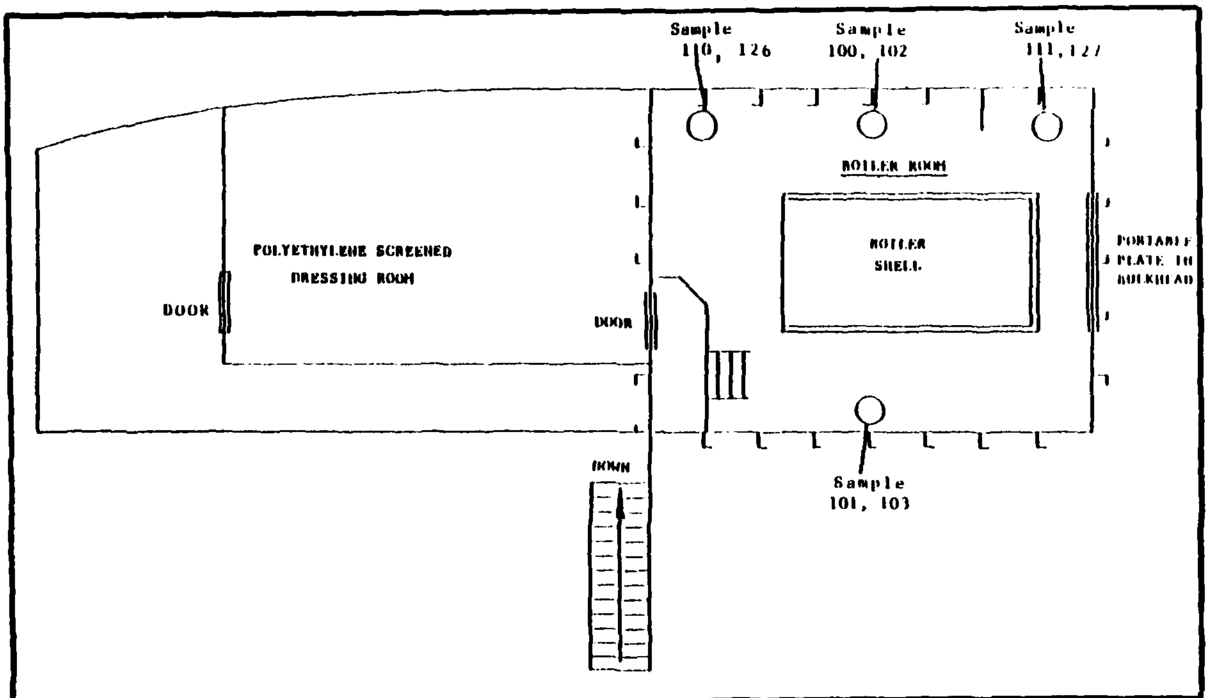


FIGURE 13. AIR SAMPLE PUMP LOCATIONS
TEST SERIES 2

3. Sequence No. 2

The second sequence in this test series involved the injection of 86 pounds of EGW (1:5 ratio) into a 7-inch diameter asbestos insulation over a 4-inch diameter steel steam pipe. The fluid was injected through 20 specially made 14-gauge needles spaced approximately 6 inches apart along the pipe insulation (see Figure 14). The injection process required 4 hours and 55 minutes to complete.

The saturated asbestos insulation was allowed to soak for a period of 3-1/2 hours after the injection process was completed before the rip-out was started. There were no dry spots of insulation found in the 10 feet of insulation removed. Air sample Nos. 102 through 115 were taken during this sequence.

4. Sequence No. 3

A vertical section of pipe insulation requiring an estimated 105 pounds of 1:5 EGW solution to saturate was selected for the next removal test. The injection of solution into this vertical section of pipe insulation was started 2 hours and 40 minutes before the removal of the 10 foot long horizontal section of insulation was started. The vertical pipe section in this sequence was across the room from the horizontal section referred to in Sequence No. 2.

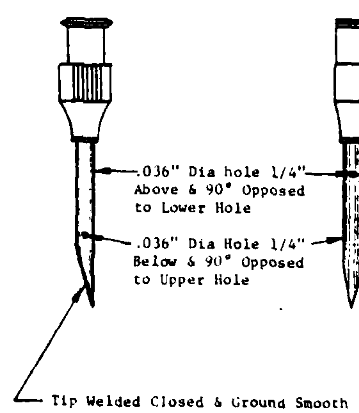


FIGURE 14. INJECTION NEEDLE DESIGN

After 86 pounds of solution had been injected into the vertical pipe insulation, the rip-out of the horizontal pipe insulation (Sequence No. 2) was completed. Even though only a little over 80% of the estimated amount of solution required to saturate the insulation had been injected, it was decided to remove the insulation from the vertical pipe insulation.

This was done to determine the degree of saturation obtained by this amount of solution and to determine if the dwell time (time after injection and before rip-out) was required.

It was found that the upper 2/3 of the pipe insulation being injected was saturated, however, the lower 1/3 had several dry spots. Indications were that with the additional 19 pounds of solution and a dwell time of 3 to 4 hours, the dry spot could have been avoided.

Air sample Nos. 116 through 125 were collected during removal of the insulation.

5. Sequence No. 4

A vertical section of pipe requiring approximately 52 pounds of solution to saturate was injected. The injection was started at 2300 hours and the solution was injected through 10 needles. At this rate, approximately 6 hours were required to complete the injection. An additional 4 hours was allowed for dwell time. The asbestos insulation was removed the next morning and the material was completely saturated. Air sample Nos. 126 through 133 were taken during this sequence.

During the course of these tests a simple electrical conductivity measurement device was evaluated to determine the degree of saturation of the asbestos insulation. Preliminary results indicate that this type of instrument could be effectively used for this purpose.

6. Data Summary

The results of all air sampling measurements are recorded in Table 2. Air sample data for this test are summarized below:

TIME WEIGHTED AVERAGE (f/cc)				
Sequence	No. of Samples	Range	Mean	95% C.L.
Pre-test	2	0.002 - 0.003	0.003	0.005
Injection	2	0.003 - 0.010	0.007	0.017
Rip-out/Clean-up:				
BZ	2	0.003	0.003	0.011
GA	2	0.013 - 0.018	0.016	0.023
CEILING CONCENTRATION (f/cc)				
BZ	24	0 - 0.845	0.171	0.603
GA	2	0 - 0.429	0.215	0.822

Table 2 - Air Sampling Data

Sample No.	Sample Type	Duration (Min.)	Pump Rate (L/M)	Total Fibers (100 Fields)	Clg. Conc. (f/cc)	TWA (f/cc)	Sequence
100	GA	150	1.82	1		0.002	Pretest
101*	GA	150	1.65	1		0.003	"
102	GA	335	1.82	4		0.010	Injection
103*	GA	339	1.65	1		0.003	"
104	BZ	30	1.93	2	0.074		"
105*	BZ	30	1.76	ND	0.000		"
106	BZ	15	1.69	2	0.170		Rip-out/Clean-up
107	BZ	115	1.70	1		0.003	" "
108	BZ	15	1.87	11	0.845		" "
109*	BZ	115	1.70	1		0.003	" "
110	GA	115	1.71	7		0.018	" "
111*	GA	115	1.79	5		0.013	" "
112	BZ	15	1.69	1	0.085		" "
113	BZ	15	1.87	ND	0.000		" "
114*	BZ	15	1.69	5	0.425		" "
115	BZ	15	1.87	ND	0.000		" "
116*	BZ	15	1.69	ND	0.000		" "
117	BZ	15	1.87	1	0.077		" "
118	BZ	15	1.69	2	0.170		" "
119	BZ	15	1.87	2	0.154		" "
120*	BZ	15	1.69	ND	0.000		" "
121	BZ	15	1.87	1	0.077		" "
122*	BZ	15	1.69	1	0.090		" "
123	BZ	15	1.87	ND	0.000		" "
124*	BZ	10	1.69	ND	0.000		" "
125	BZ	10	1.87	3	0.346		" "
126*	GA	30	1.80	ND	0.000		" "
127*	GA	30	1.84	11	0.429		" "
128	BZ	15	1.92	4	0.299		" "
129*	BZ	30	1.97	2	0.073		" "
130	BZ	30	1.81	3	0.119		" "
131*	BZ	15	1.92	ND	0.000		" "
132	BZ	15	1.92	7	0.523		" "
133*	BZ	15	1.92	2	0.150		" "

*McCrone lab data

D. Field Test of Preproduction Prototype Model

1. Preparation

The preproduction prototype of the Asbestos Removal System (ARS) is shown in Figures 15 and 16. During the preliminary checkout of this equipment it was found that as many as five manifolds could be easily connected to the equipment and have a uniform flow of EGW solution to 50 injection needles. The rate of injection is a function of the reservoir pressure. It was found that a reservoir pressure of 20 psi would allow a uniform dispensing rate through each of the injectors regardless of height as long as the maximum difference in height between the lowest and the highest injection needle was no more than 10 feet. The injection rate was approximately 10 cc per needle per minute. Therefore, the average flow rate through the entire system was a little more than 1 pound of EGW solution per minute, which approximates the migration rate through the asbestos.

On May 6, 1981 the equipment was transported to Long Beach and provisions were made to saturate the asbestos insulation on board the YR-85 barge located in the U. S. Naval Long Beach Shipyard. The asbestos to be removed was located on pipes in the generator room on board the YR-85. A 55-gallon reservoir of EGW 1:5 solution was located on the dock adjacent to the YR-85. The material was pumped to the injection equipment through a hose using a gear pump. The gear pump was driven by a one (1) horsepower electric motor, with a relief valve installed in the fluid line to allow recirculation of the solution during the period of time the solenoid valve, located on the automatic asbestos injection apparatus was turned off.

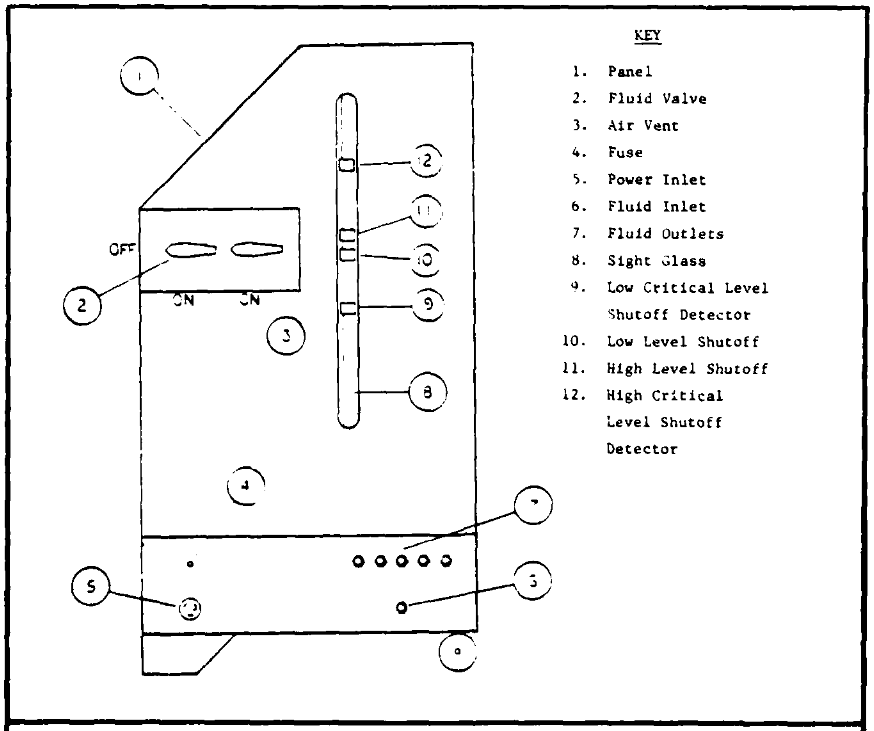


FIGURE 15. ASBESTOS REMOVAL SYSTEM CONSOLE (PREPRODUCTION PROTOTYPE MODEL)

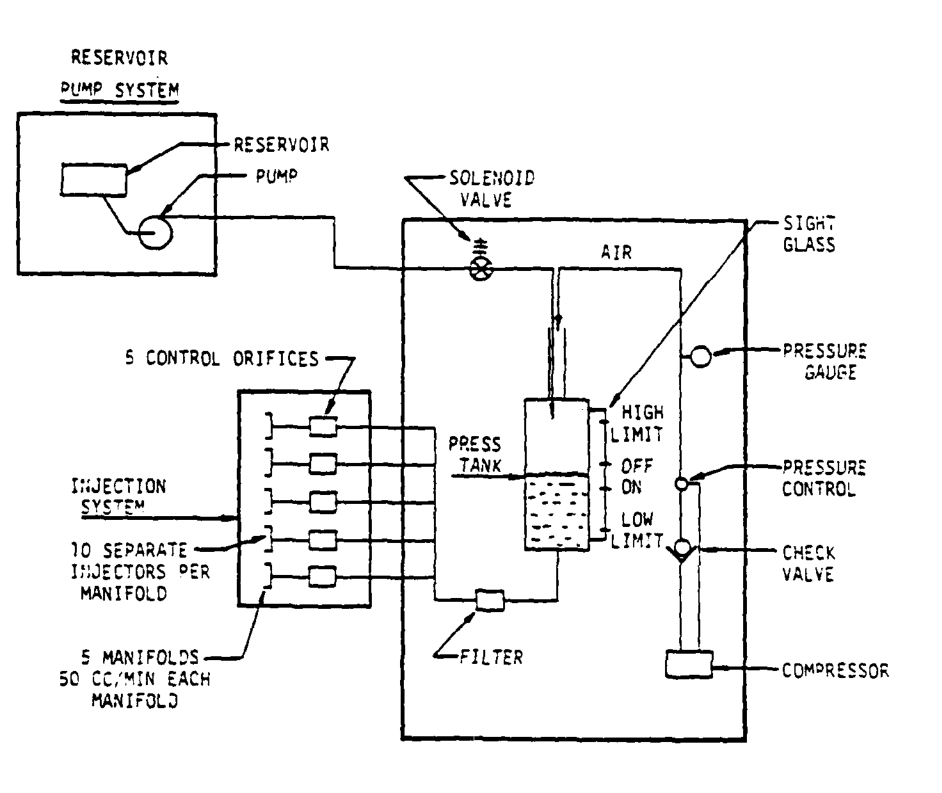


FIGURE 16. ASBESTOS REMOVAL SYSTEM SCHEMATIC
(PREPRODUCTION PROTOTYPE)

A schematic of the generator room on board the YR-85 is shown in Figure 17. A containment was constructed by the Long Beach Naval Shipyard personnel to separate the generator room into three compartments. One compartment was the work area, the second compartment was a change room and the third compartment was the clean room. The automatic asbestos injection apparatus was located in the clean room. Six (6) generators were located in the work area. It was decided to remove the asbestos insulation from the four (4) largest generators. These were generator Nos. 1, 2, 5, and 6, indicated on Figure 17. The asbestos insulation to be removed from these generators is shown in Figures 18 through 21.

Another area of asbestos pipe that was selected for injection and removal was overhead, parallel to the ceiling of the generator room. This asbestos insulation was located above generator Nos. 2, 3, and 4 (see Figure 22).

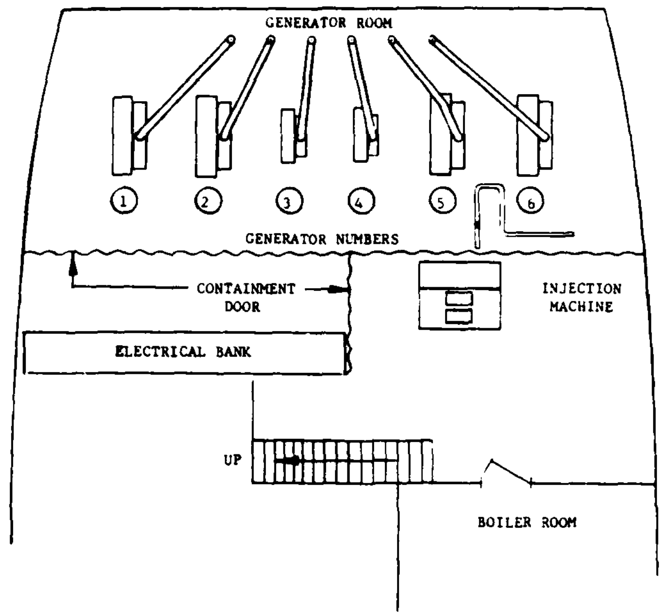


FIGURE 17. ASBESTOS INJECTION AREA
TEST SERIES NUMBER 3

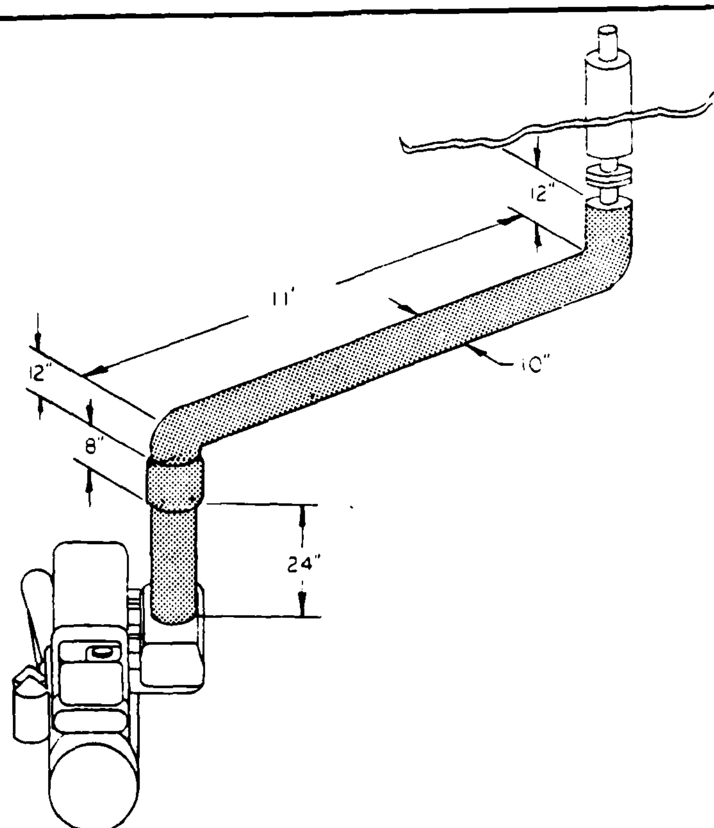


FIGURE 18. INSULATION ON EXHAUST STACK OF GENERATOR NO. 1

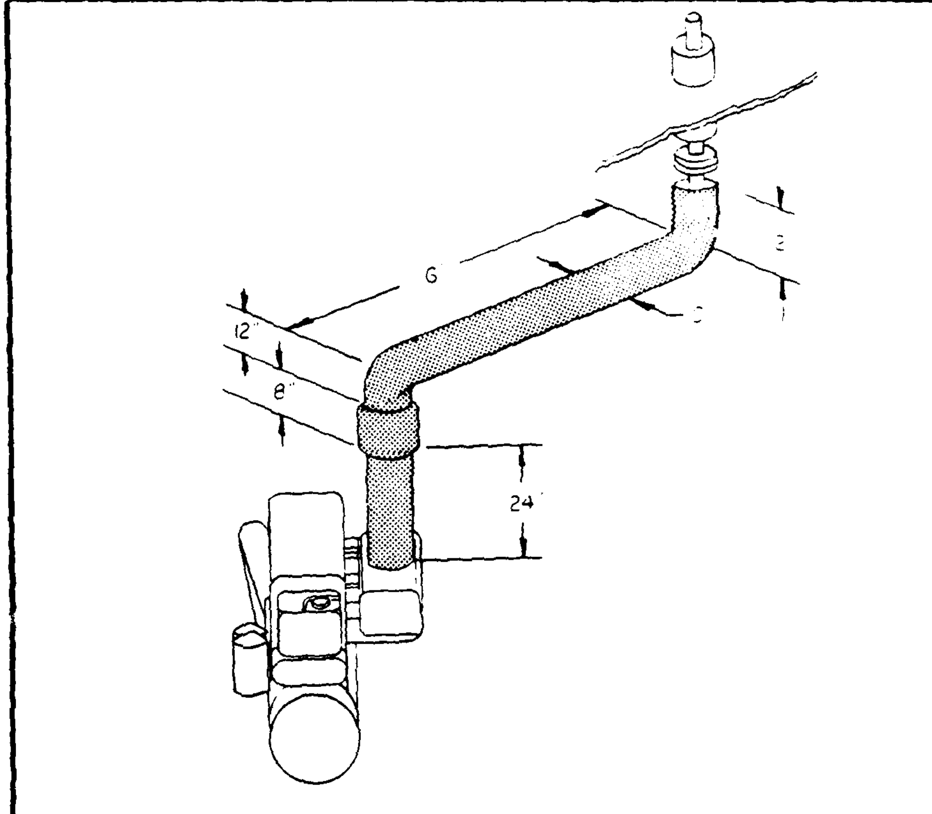


FIGURE 19. INSULATION ON EXHAUST STACK OF GENERATOR NO. 2

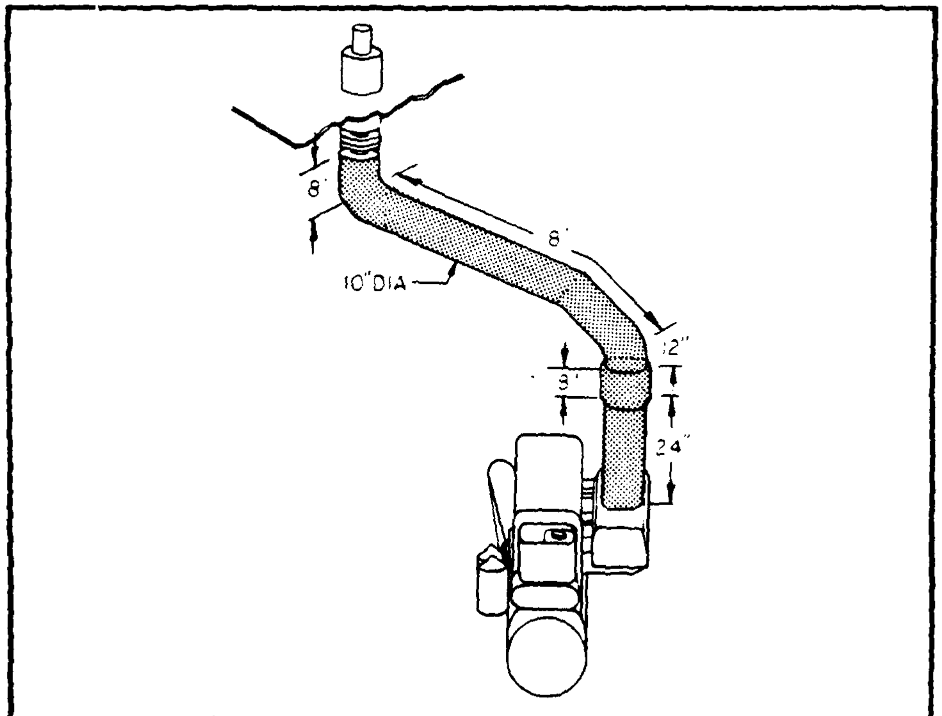


FIGURE 20. INSULATION ON EXHAUST STACK OF GENERATOR NO. 5

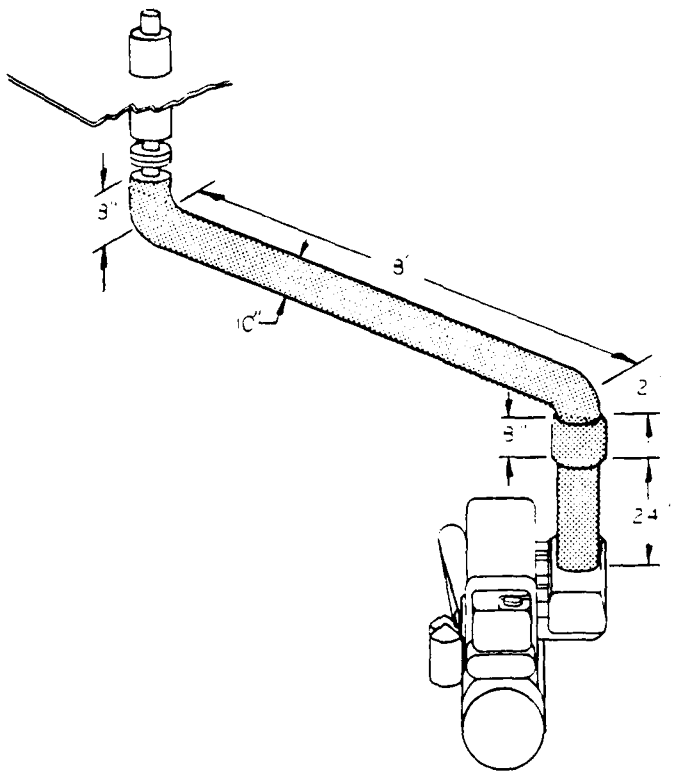


FIGURE 21. INSULATION ON EXHAUST STACK OF GENERATOR NO. 6

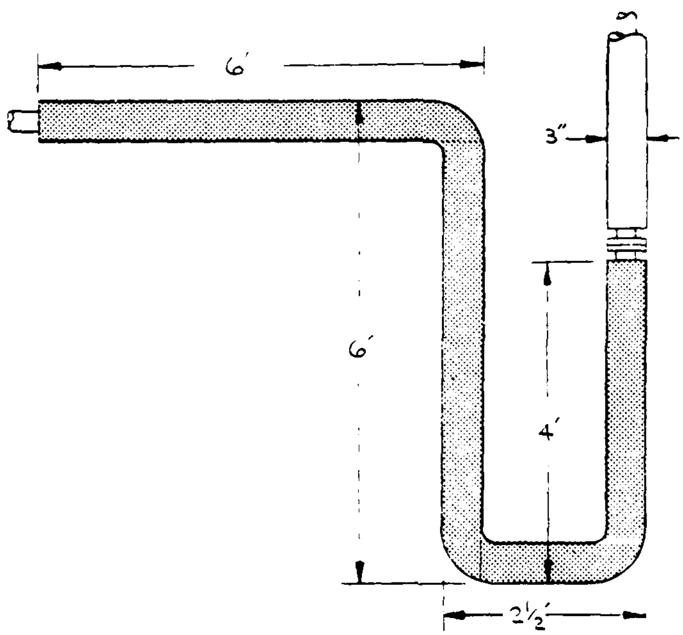


FIGURE 22. INSULATION ON OVERHEAD PIPE

2. Injection

The initial injection was into the insulation on generator Nos. 5, 6, and the overhead areas. The calculated amount of solution to be injected into these three sections of insulation was 457 pounds. After approximately 300 pounds of solution had been injected into the insulation, the fluid began to leak from several points. This continued even though the rate of injection was reduced. This overspill was rather surprising since less than the required amount calculated to saturate the insulation had been injected. A total of 450 pounds was put into the insulation and allowed to saturate the material overnight. A second injection was initiated on the insulation associated with generator Nos. 2 and 3. The calculated amount to be injected into these two (2) sections of insulation was 296 pounds. Again, the amount of solution needed to saturate the insulation could not be injected without the system leaking. There was a number of attempts to block the leaks--this included the use of a vinyl tape and caulking compound. Even though this material was somewhat successful in preventing leaks in the area where it was applied, it did not totally stop the leakage.

After the injection was completed, the degree of saturation was monitored using the saturation probe developed by SwRI in this program. In all cases the probe indicated that there was moisture present in all areas tested. The system was allowed to "soak" for 14 hours (overnight) before rip-out was initiated.

The Industrial Hygiene Section of the Naval Regional Medical Clinic (NRMC) at Long Beach provided assistance in the collection and analysis of the air samples. NRMC supplied four (4) air sampling pumps and associated cassettes for the experimental work. The following air sampling equipment was used:

a. Sampling pumps: MSA Model S identified as:

   1A, 2A, 3A, 4A (NRMC equipment)
   1, 2, 3, 4 (SwRI equipment)

b. Filters: Millipore Type AA (0.8 micrometer pore size)

c. Pumps calibrated using 1000 millimeter bubblemeter

d. Microscope: Bausch and Lomb Ballplan equipped with a contrast 400X magnification.

e. Porton reticle counting field area:

   $0.003\ mm^2$ (NRMC)
   $0.063 \times 0.063 = 0.004\ mm^2$ (SwRI)

3. Rip-Out

Data was collected during a 2 hour and 22 minute period while the insulation was being removed from all five (5) pipes. A total of four (4) people were in the containment room during the entire removal process. Two (2) of these people were from SwRI and two (2) were representatives from Pearl Harbor Naval Shipyard. One (1) of the naval personnel from Pearl Harbor had first-hand extensive experience in removing asbestos materials. The two (2) personnel from SwRI had been involved in the two (2) previous tests conducted at Long Beach and had removed asbestos at SwRI during the course of this project. Complete hazard protection procedures were employed/monitored in accordance with applicable NIOSH/Navy requirements.

Prior to initiating the removal of the insulation, the floors and generators were covered with a lightweight canvas dropcloth to facilitate cleanup operations. Each of the four (4) people working in the containment were fitted with two (2) of the MSA pumps. The two (2) naval personnel utilized the Navy pumps. The two (2) SwRI personnel utilized the SwRI pumps. One (1) of the sample pumps from each of the personnel was used for time-weighted average (TWA) data and the other pump was utilized to determine the ceiling concentration. The ceiling concentration filters were replaced approximately every 15 minutes during the course of the removal exercise.

After the personnel began to remove the insulation, it was found that only the insulation on the overhead pipe illustrated in Figure 23, and the insulation covering the two (2) feet immediately above the generator was asbestos. The remaining material insulation was glasswool. Since the glasswool does not have the capacity to absorb as much solution as asbestos insulation, the excess amount of the solution leaked out during the injection phase.

Core sampling prior to injection of the insulation would have determined the presence of the glasswool (which was not suspected). Random core sampling undertaken earlier in the year had not revealed the presence of any glasswool. Pre-test core sampling should be employed on all future removal operations. It was decided to remove the impregnated insulation and take data even though only part of the material was asbestos.

Figure 23 illustrates the method by which the glasswool insulation was attached to the pipe; namely, the insulation was placed around the pipe, and then an expanded metal cage surrounded the insulation over which a thin coating of cementitious lagging was applied. A sewn asbestos jacket was then applied over the cementitious lagging.

A great deal of difficulty was encountered in removing the expanded metal; ultimately it had to be cut with a pair of large sheet-metal shears. As a result of having glasswool rather than asbestos insulation on the pipe, it was found that several areas of the lagging and asbestos were not completely saturated with the solution. In addition, the glasswool was not saturated with solution. As a consequence, a great deal of free glasswool fibers were present in the containment and were collected on the filters.

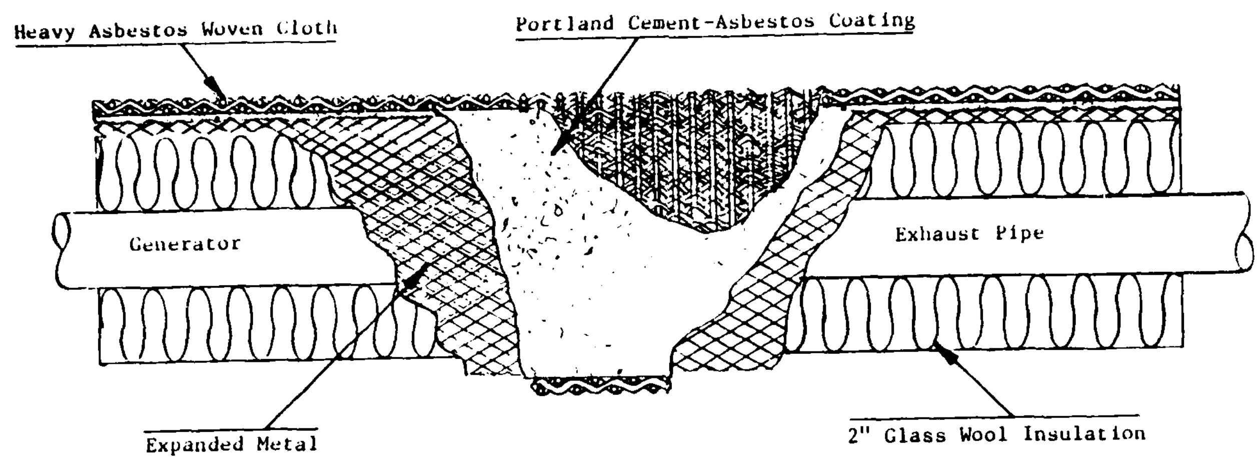


FIGURE 23. GLASSWOOL INSULATION CONSTRUCTION

Approximately two (2) hours after initiation of rip-out, it became apparent to the personnel removing the insulation that most of the remaining material was glasswool rather than asbestos. There was an acceleration of activity and the insulation was more violently removed than is normally done in practice. It became apparent that due to the violent ripping methods used in removing the insulation, that more free debris was generated in the environment than is normally the case. This unorthodox removal procedure was due to the lack of experience of three of the personnel involved in the removing of asbestos insulation and the desire to quickly complete the job and be able to leave the containment area and remove the respirator equipment. After the sudden bursts of activity, the personnel were told to calm down and remove the material in an orderly fashion. The removal procedure was completed approximately 30 minutes after the flurry of activity in the containment. In several instances, one of the personnel working in the containment was directly below another person who was removing and dropping the insulation, thus causing the high concentration of fibers due to direct contact as opposed to air infiltration onto the filters.

4. Data collection

At the conclusion of the removal procedure, the filters were collected and cut into two halves by the personnel at NRMC. Half of the filters were retained by them for analysis and the remaining half were returned to SwRI for analysis. Figure 24 is a graphical presentation of this data which shows that the fiber count rose sharply approximately 30 minutes prior to the completion of the removal procedure. This was the period of time between 11:45 and 12:15.

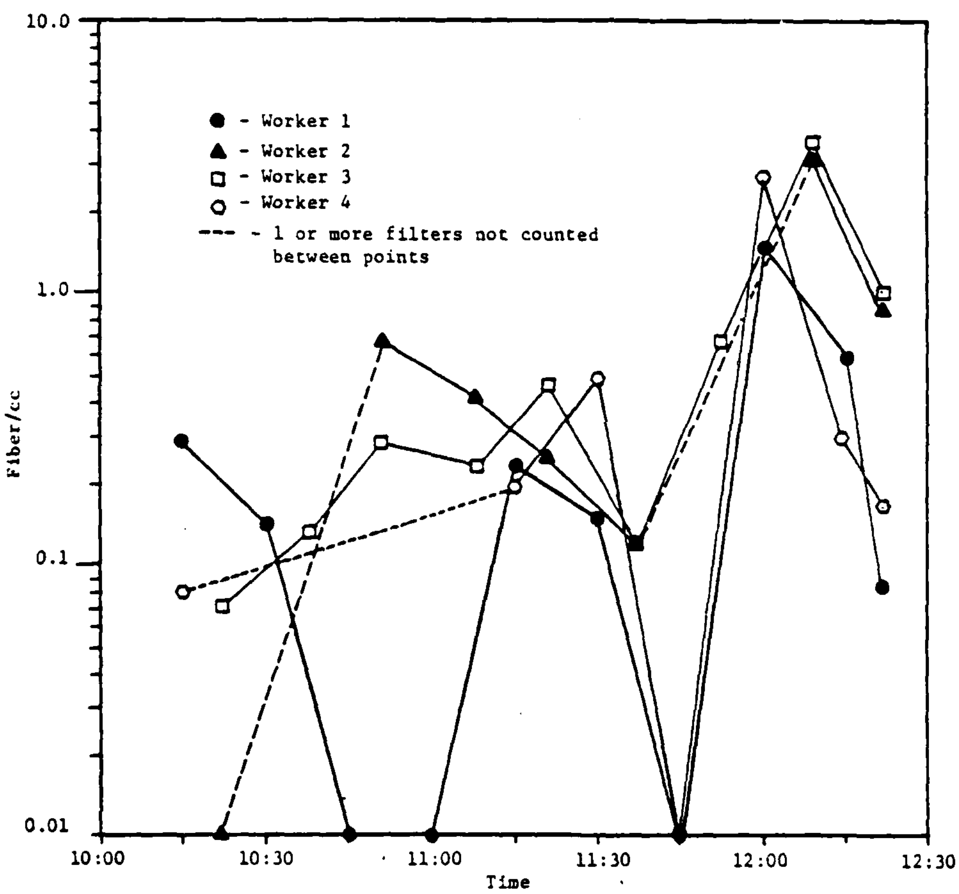


FIGURE 24. CEILING CONCENTRATION DISTRIBUTION (Test Series 3)

In the report received from LCDR. R. E. Pavlik, MSC, USN, of NRMC Long Beach, giving the results of their analysis, the following was stated:

> "Regarding the fiber counts, all particulates with a length to diameter ratio of 3 to 1 or greater, and a length greater than 5 micrometers were counted, as is specified in the standard NIOSH method. Based on my experience, and that of Mr. R. W. Kong, who performed most of the counting, most of the fibers collected on the filters did not resemble asbestos fibers in size and appearance."

The NIOSH analytical method for the asbestos filters states the following:

> "3. Interferences
>
> In an atmosphere known to contain asbestos, all particulates with a length to diameter ratio of 3 to 1 or greater, and a length greater than 5 micrometers should, <u>in the absence of other information</u>, be considered to be asbestos fibers and counted as such."

Using this guideline, the personnel counting the filters at SwRI disregarded the fibers which were obviously glasswool fibers on the filters and only counted those which were obviously asbestos and those that could not be identified as glasswool. As a consequence, the fibers count in most cases on a number of filters is somewhat lower for the SwRI count than was found by the naval personnel. Airborne concentration calculations were based on SwRI data.

5. <u>Data Summary</u>

The results of all air sampling measurements are recorded in Table 3. Air sample data for this test are summarized below:

Sequence	No. of Samples	Breathing Zone (f/cc) Range	mean	95% C.L.
Rip-out/Clean-up				
CC	33	0 - 3.59	0.56	2.32
TWA	3	0.05 - 0.15	012	0.24

Table 3 - Air Sampling Data

Sample No.	Sample Type	Duration (Min.)	Pump Rate (L/M)	Total Fibers (100 Fields) **1	Total Fibers (100 Fields) **2	Concen. (f/cc) CC **3	Concen. (f/cc) TWA	Sequence	Time In - Time Out
1	GA	83	1.78	0.5	2	0.002		Pre-test	8:32 - 9:55
2	BZ	19	1.96	ND	ND			Rip-out/ Clean-up	10:03 - 10:22
4	BZ	15	2.17	1	2	0.07		"	10:07 - 10:22
5	BZ	135	1.78	61	130		0.15	"	10:07 - 12:22
7	BZ	15	2.17	0.2	2	0.13	--	"	10:22 - 10:37
8	BZ	14	1.96	8.5	2	0.67	--	"	10:37 - 10:51
9	BZ	14	2.17	4	5	0.28	--	"	10:37 - 10:51
10	BZ	17	1.96	6.5	3	0.42	--	"	10:51 - 11:08
11	BZ	17	2.17	4	14	0.23	--	"	10:51 - 11:08
12	BZ	13	1.96	3	2	0.25	--	"	11:08 - 11:21
13	BZ	13	2.17	6	3	0.46	--	"	11:08 - 11:21
14	BZ	16	1.96	2	5	0.14		"	11:21 - 11:37
15	BZ	16	2.17	2	4	0.12	--	"	11:21 - 11:37
17	BZ	15	2.17	10	14	0.66	--	"	11:37 - 11:52
18	BZ	17	1.96	47	39	3.04	--	"	11:52 - 12:09
19	BZ	17	2.17	61.5	87	3.59	--	"	11:52 - 12:09
20	BZ	13	1.96	9	24	0.76	--	"	12:09 - 12:22
21	BZ	13	2.17	13	17	0.99	--	"	12:09 - 12:22
22	GA	134	1.96	1	2	--	0.003	Post-test	12:32 - 14:46
201	BZ	142	2.32	26.5	30	--	0.05	Rip-out/ Clean-up	10:00 - 12:22
202	BZ	142	1.98	68	112.5	--	0.15	"	10:00 - 12:22
203	BZ	15	1.88	1	0.5	0.08	--	"	10:00 - 10:15
204	BZ	15	2.08	4	1	0.28	--	"	10:00 - 10:15
206	BZ	15	2.08	2	1	0.14	--	"	10:15 - 10:30
208	BZ	15	2.08	ND	2	0	--	"	10:30 - 10:45
210	BZ	15	2.08	ND	1	0	--	"	10:45 - 11:00
211	BZ	15	1.88	2.5	4	0.19	--	"	11:00 - 11:15
212	BZ	15	2.08	3	2	0.23	--	"	11:00 - 11:15
213	BZ	15	1.88	7	8	0.48	--	"	11:15 - 11:30
214	BZ	15	2.08	2	ND	0.15	--	"	11:15 - 11:30
215	BZ	15	1.88	ND	ND	0	--	"	11:30 - 11:45
216	BZ	15	2.08	ND	1	0	--	"	11:30 - 11:45
217	BZ	15	1.88	38	89	2.62	--	"	11:45 - 12:00
218	BZ	15	2.08	19	43	1.45	--	"	11:45 - 12:00
219	BZ	15	1.88	4	4.5	0.28	--	"	12:00 - 12:15
220	BZ	15	2.08	7.5	9.5	0.57	--	"	12:00 - 12:15
221	BZ	7	1.88	2	3	0.14	--	"	12:15 - 12:22
222	BZ	7	2.08	1	1	0.008	--	"	12:15 - 12:22

*Conditions

Generator room established as containment with exhauster installed to maintain negative pressure within. Exhauster OFF during pre-test only. Air pumps calibrated by NRMC. Standard PPE employed. Rip-out by SwRI/PHNSY personnel. Entry monitor and clean-up certification by LBNSY.

**Notes

1 SwRI fiber count; asbestos fibers only.
2 NRMC fiber count; includes glasswool fibers.
3 Column 1 data used to calculate concentration levels.

E. Special Demonstration of Preproduction Prototype Model

After the prototype equipment was successfully employed for rip-out, it was decided to provide an informal advance demonstration for various Naval Sea Systems Command and Naval Environmental Health Center representatives. This demonstration was scheduled for 24 June 1981 on the YR-85 at Long Beach, California.

1. Preparation

Approximately 13 feet of 6-inch OD insulation (see Figure 25) was selected inside the boiler room from among the pipe runs previously used in this test series. A PRE-TEST air sample was collected and a containment (with change room) was established. A 4-foot by 6-foot section of one bulkhead had been removed so this "view port" was sealed with plexiglass to permit direct observation of the actual rip-out from outside of the containment. Pearl Harbor Naval Shipyard (PHNSY) personnel were employed for this rip-out to permit training in the injection technique. OSHA compliance and monitoring were maintained by NRMC Pearl Harbor Naval Shipyard as in previous tests.

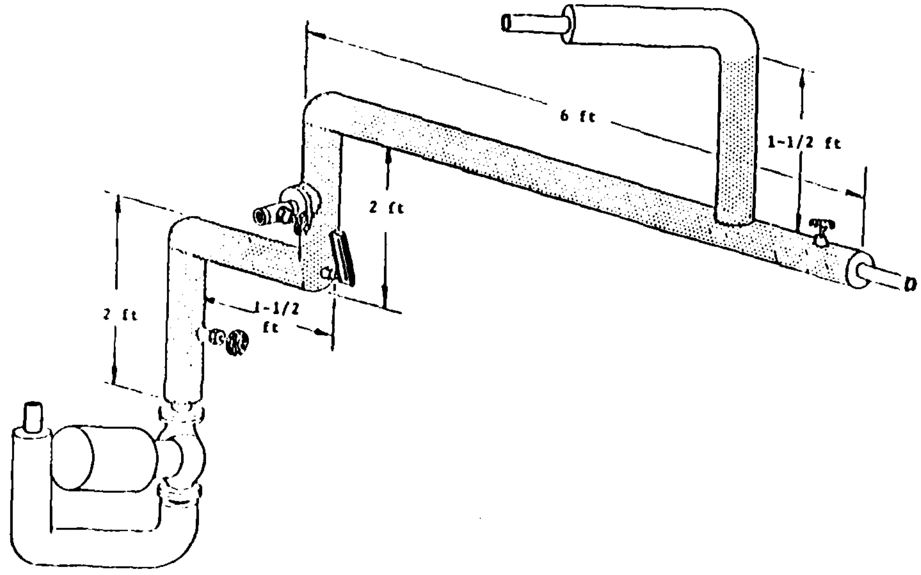


FIGURE 25. ASBESTOS INSULATION REMOVED DURING TEST SERIES NUMBER 4

The contractor conducted an extensive equipment/process familiarization session for the PHNSY technicians. All phases of the operation were reviewed including the improvements incorporated since the last test. The complete test plan was reviewed using draft procedures provided by the contractor. Previous test results were reviewed as well as the various anticipated minor refinements planned for the final model.

The PHNSY technicians completed the necessary sealing to insure retention of the impregnant. "Hose clamp" restrictors were then placed around the insulation at the end-points of the selected section to limit migration (see Figure 26). Air sampling pumps were prepared for area and breathing zone data to be recorded before, during, and after the operations. Drop cloths and debris bags were placed within the containment.

2. Injection

Approximately 24 gallons of EGW was mixed and loaded into the reservoir. Circulation was verified and all interlocks and controls were checked for operation. Thirty (30) needles were placed and injection was started. The injection process was completed in approximately three (3) hours. Saturation was then verified using the conductivity device; 100% saturation was indicated.

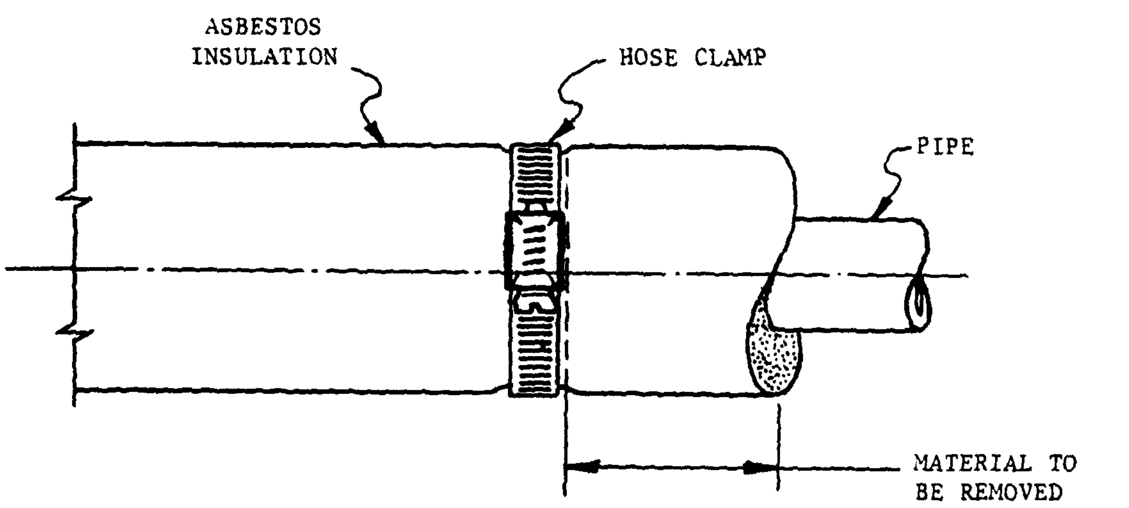


FIGURE 26. HOSE CLAMP CONSTRICTOR BAND

3. Rip-Out

Rip-out was undertaken using the "foam-dispensing" knives to demonstrate usage. After approximately 10 minutes it was clear that these knives were both tedious and unnecessary so standard removal knives were used for the remainder of the demonstration. Some sections of the insulation were cementitious and extremely well bonded to the pipe. It was necessary to scrape and chip to remove this material. Some of this material could be seen falling to the floor.

Clean-up was started after all the insulation had been removed, including wipe-down of the newly-exposed pipes, using rags soaked with EGW. All loose material and drop cloths were collected, double-bagged and removed. Exposed ends of the remaining insulation were taped and the demonstration was completed.

The debriefing record included comments by the two (2) PHNSY laggers as follows:

> "...the rip-out was much easier than normal because the insulation was wet and saturated... and...the rip-out moved faster with ethylene glycol...."

The area was certified clean by the NRMC Industrial Hygienist after determining that the post-test air sample filter contained less than 0.04 fibers per cc.

4. Data Collection

At the conclusion of the removal procedure, the filters were collected and cut into two (2) halves by the personnel at NRMC. Half of the filters were retained by them for analysis and the remaining halves were returned to SwRI for analysis. Porton reticle field area:

NRMC - $0.006 mm^2$

SwRI - $0.00397 mm^2$

5. Data Summary

The results of all air sampling measurements are recorded in Table 4. Air sample data for this test are summarized below:

Sequence	No. of Samples	TWA (f/cc) Range	Mean	95% C.L.
Rip-out/Clean-up				
BZ	4	0.008 - 0.026	0.016	0.033
GA	8	0.001 - 0.013	0.051	0.147
		Ceiling Concentration (f/cc)		
BZ	16	0.0 - 0.041	0.19	0.43

Table 4 - Air Sampling Data*

Sample No.	Sample Type	Duration (Min.)	Pump Rate (L/M)	Total Fibers (100 Fields)	Concen. (f/cc) CC	Concen. (f/cc) TWA	Sequence	Observations
DE1	BZ	80	2.56	15	--	0.026	Rip-out/ clean-up	
DE2	BZ	15	1.12	1.5	0.19	--	"	
DE3	BZ	15	1.12	2	0.26	--	"	
DE4	BZ	15	1.12	2.5	0.32	--	"	SwRI data; Pre-test,
DE5	BZ	35	1.12	7.5	0.41	--	"	Post-test and
EA1	BZ	80	2.04	3.5	--	.008	"	Injection samples
EA2	BZ	15	2.06	3	0.21	--	"	yielded insigni-
EA3	BZ	15	2.06	1	0.07	--	"	ficant fiber count
EA4	BZ	15	2.06	ND	0	--	"	
EA5	BZ	35	2.06	7	0.21	--	"	
1	GA	81	1.90	4.5	--	0.011	"	
2	GA	81	2.03	6	--	0.013	"	
3	GA	81	1.90	1	--	0.002	"	
4	GA	81	1.93	0.5	--	0.001	"	
DE1	BZ	80	1.93	9	--	0.010	"	
DE2	BZ	15	1.93	1	0.08	--	"	
DE3	BZ	15	1.93	2	0.17	--	"	
DE4	BZ	15	1.93	3	0.25	--	"	NRMC data; Pre-test,
DE5	BZ	35	1.93	11	0.40	--	"	Post-test and
EA1	BZ	80	1.93	13	--	0.019	"	Injection samples
EA2	BZ	15	1.93	1	0.05	--	"	yielded insigni-
EA3	BZ	15	1.93	1	0.05	--	"	ficant fiber count
EA4	BZ	15	1.93	3	0.14	--	"	
EA5	BZ	35	1.93	8	0.16	--	"	
1	GA	81	1.93	4	--	0.006	"	
2	GA	81	1.93	3	--	0.004	"	
3	GA	81	1.93	5	--	0.008	"	
4	GA	81	1.93	4	--	0.006	"	

* Conditions:

Boiler room established as containment with exhauster installed to maintain negative pressure within. Exhauster OFF during pre-test only. Air pumps calibrated by NRMC. Standard PPE employed. Rip-out by PHNSY personnel. Entry monitor by PHNSY and clean-up certification by NRMC.

F. End-of-Contract Demonstration

The End-of-Contract Demonstration was conducted on 19 November 1981 aboard the U.S.S. St. Louis (LKA-116) docked at San Diego, California. The ship was in port for repairs and modification. As part of the official work package on the vessel, some of the asbestos insulation had to be removed. Permission was obtained to allow SwRI to remove a section of this asbestos insulation to provide an End-of-Contract Demonstration for this project.

Present at the demonstration were representatives from the Portsmouth Naval Shipyard, Philadelphia Naval Shipyard, Mare Island Naval Shipyard, Naval Weapons Center China Lake, NAVSEA, NAVSSES, EPA Research Triangle Park, Pearl Harbor Naval Shipyard, and SUPSHIP San Diego.

1. Core samples were taken and analyzed by NRMC San Diego; Amosite was identified. Site preparation for the test was started. Ships force had already cleaned/secured the remaining equipment in the engineering spaces. A boundary was established to separate the test area for the purpose of OSHA compliance. The contractor set up all equipment and prepared the insulation for treatment. All air pumps were calibrated and the PRE-TEST air sample was taken. An approved open-face containment was used based on the configuration of the insulation to be removed. A Model 86NAS145 asbestos vacuum cleaner manufactured by Pullman and Holt was used to obtain a slight negative pressure within the containment. The rip-out was done by SwRI personnel who wore standard PPE. The sentry was an Industrial Hygienist from Pearl Harbor Naval Shipyard. The air sampling pumps were modified for this test to include silica gel tubes in order to monitor ethylene glycol concentration (see Figure 27).

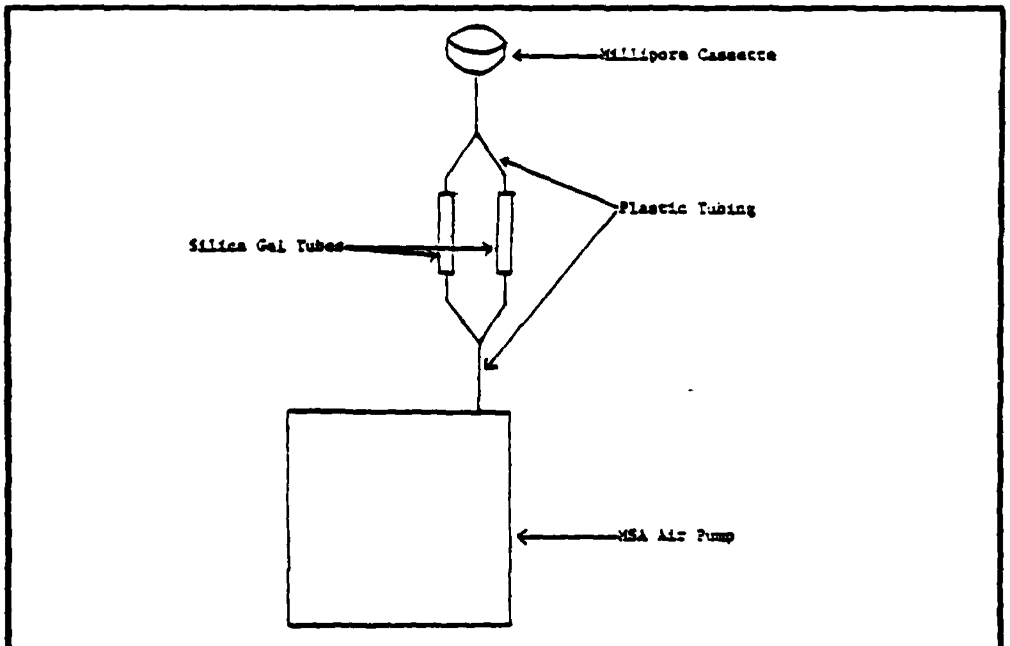


FIGURE 27. AIR PUMP CONFIGURATION USED TO MONITOR ASBESTOS FIBERS AND ETHYLENE-GLYCOL VAPOR

2. <u>Injection and Rip-Out</u>

The section of asbestos insulation removed during the demonstration is illustrated in Figure 28. Two (2) air sampling filters were placed in the containment, two (2) sets of air sampling monitors were worn by each of the two (2) SwRI rip-out crew members and four (4) area air samples were obtained during the course of the test. Figure 29 indicates the location of the air sampling equipment on this test series.

The impregnation was started and all test parameters were recorded by the contractor. The insulation that was removed for the test was contained between flanges so all EG-impregnated insulation was removed.

On 20 November 1981, the test site was cleaned and sampled for asbestos residue. None was found so the containment was dismantled and all debris was double-bagged and transported to an asbestos dumpster for disposal.

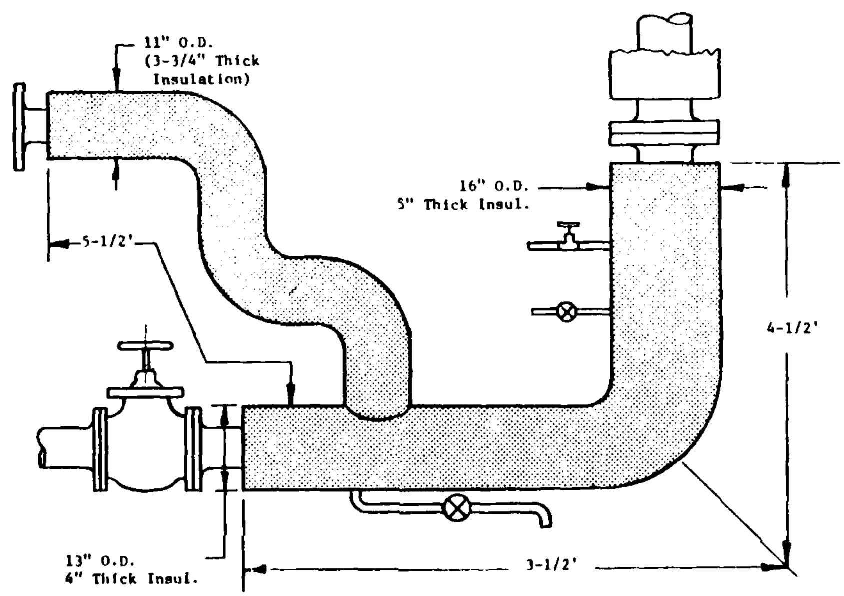
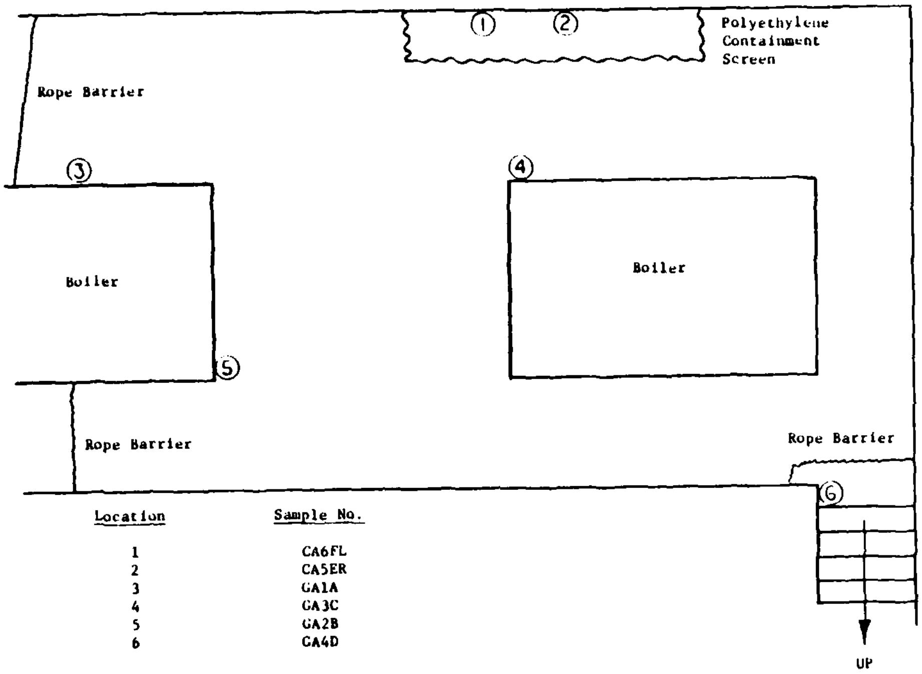


FIGURE 28. ASBESTOS PIPE INSULATION REMOVED DURING TEST SERIES NUMBER 5



Location	Sample No.
1	CA6FL
2	CA5ER
3	GA1A
4	GA3C
5	GA2B
6	CA4D

FIGURE 29. AREA AIR SAMPLING LOCATIONS DURING TEST SERIES NUMBER 5

3. Data Collection

At the conclusion of the removal procedure the filters were collected and cut into two (2) halves by the personnel at NRMC. Half of the filters were retained by them for analysis and the remaining half were returned to SwRI for analysis. NRMC San Diego processed the silica gel tubes.

4. Data Summary

The results of all air sampling measurements are recorded in Table 5. Air sample data for this test are summarized below:

Table 5 - Air Sampling Data*

Sample** No.	Type	Duration (Min.)	Pump Rate (L/M)	Total Fibers (100 Fields)	Concen. (f/cc) CC	TWA	Sequence
CA5ER	GA	221	2.0	11		0.02	Rip-out/ Clean-up
CA6FL	GA	221	2.0	29		0.04	"
DJ1A	BZ	210	2.0	10		0.02	"
DJ2A	BZ	20	2.0	1	0.04		"
DJ3C	BZ	20	2.0	1	0.04		"
DJ4D	BZ	20	2.0	ND	0		"
DJ5E	BZ	20	2.0	ND	0		"
DJ6F	BZ	20	2.0	ND	0		"
GA1A	GA	220	2.0	2	0		"
GA2B	BZ	220	2.0	0.5		0	"
GA3C	BZ	220	2.0	2.5		0	"
GA4D	GA	220	2.0	1.5		0	"
JB1A	BZ	215	2.0	20.5		0.03	"
JB2B	BZ	15	1.85	1	0.04		"
JB4D	BZ	20	1.85	ND	0		"
JB5E	BZ	20	1.85	ND	0		"
CA5ER	GA	221	2.0	77		0.17	"
CA6FL	GA	221	2.0	99		0.22	"
DJ1A	BZ	210	2.0	37		0.08	"
DJ2A	BZ	20	2.0	2.5	0.09		"
DJ3C	BZ	20	2.0	3	0.11		"
DJ4D	BZ	20	2.0	1	0.04		"
DJ5E	BZ	20	2.0	4.5	0.16		"
DJ6F	BZ	20	2.0	1	0.04		"
GA1A	GA	220	2.0	ND		0	"
GA2B	GA	220	2.0	6.5		0.01	"
GA3C	GA	220	2.0	10.5		0.02	"
GA4D	GA	220	2.0	ND		0	"
JB1A	BZ	215	2.0	25.5		0.06	"
JB2B	BZ	15	1.85	ND	0		"
JB4D	BZ	20	1.85	3	0.11		"
JB5E	BZ	20	1.85	1	0.04		"

*Conditions:

Boiler room sectioned off by barrier. Open-face containment constructed around worksite. Small vacuum used to maintain negative pressure within containment. Air pumps calibrated by NRMC. Standard PPE used. Rip-out by SwRI personnel. Monitor and clean-up certification by NRMC.

**(First data group is from NRMC, second is from SwRI)

Data Summary Test Series 5				
a. Asbestos Concentration				
		TWA(f/cc)		
Sequence	No. of Samples	Range	Mean	95% C.L.
Rip-out/Clean-up				
BZ	4	0.02 - 0.08	0.05	0.12
GA	12	0 - 0.22	0.04	0.19
		Ceiling Concentration (f/cc)		
BZ	16	0 - 0.16	0.04	0.14

b. Ethylene Glycol Concentration*			
No. of Samples	Range	Mean	95% C.L.
44	(All values less than 0.01 mg/M^3)		

*NOTE: 1981 ACGlld TLV for EG vapor is 125 mg/M^3

g. Thermal Conductivity Test

A sample of asbestos insulation for a 1" pipe was tested for its thermal conductivity at SwRI. This asbestos pipe insulation was 1-1/2" thick. One-half of a pipe section was saturated with a mixture of one (1) part ethylene glycol and five (5) parts water to simulate the injection of this material into the pipe insulation during a removal procedure. The sample of insulation was allowed to come to equilibrium and then removed from the ethylene glycol/water bath. The sample was weighed and then put into an oven at 220° and allowed to bake for a period of 48 hours simulating the effect of having steam pass through a line for that period of time.

The sample of asbestos insulation was removed from the oven and again weighed. The two (2) pieces of insulation (the test sample and the control sample) were then attached to a 1" steam line and tested to determine the thermal conductivity. Iron-constatan thermocouples were used to monitor the temperature of the pipe and the outside temperature of the insulation. The results are as follows:

Summary of Thermal Conductivity Test Data

Material:

Asbestos Pipe Insulation

Size:

1" Pipe X 1-1/2" Wall Thickness
12" Long

Weight:

Test Specimen:	Control Specimen:
Dry = 350.4 grams	341.5 grams
Wet = 1584 grams	
Dried = 346.5 grams	

Mean Equilibrium Temperature:

Pipe 288°F
Outside Insulation:

Control = 121°F
Test = 116°F

Thermal Conductivity:

Control = 0.058 BTU/hrft°F
Test = 0.056 BTU/hrft°F

H. Corrosion Test

The corrosion tests on this program were conducted in accordance with the procedure set up in ASTM 1384 "Corrosion Test for Engine Coolants in Glassware."

In this method, metal specimens are partially immersed in the test EGW solution. The concentrations of ethylene glycol to water were selected on the basis of what might be encountered in the field. These percentages were as follows:

Ethylene Glycol (%)	Water (%)
0	100
10	90
20	80
30	70
40	60

The metal specimens tested were SAE 1020 carbon steel, stainless steels 304, 308, and 316, and copper pipe.

The specimens were cut to fit in a 120 cc jar. The cut surfaces were sanded, burrs were removed and then the specimens were washed with a pumice cleanser, rinsed in tap water, then rinsed with acetone, dried, and weighed to the nearest 0.1 milligram.

Each specimen was then placed in individual 120 cc jars. Then a sufficient quantity of the prescribed solution of EGW mixture was added to cover approximately 50% of the specimen. This allowed inspection of any corrosion that took place at the interface, in the vapor phase, and in the liquid phase. Once a week the jars were shaken so that the entire specimen would be wet with the solution.

The specimens were removed approximately every 30 days, rinsed with tap water and acetone and cleansed with a brass-bristle brush followed with a wet-bristle brush and a pumice cleanser to clean the specimen completely. They were then rinsed again in water and acetone and dried. The specimens were then weighed to the nearest 0.1 milligram. The result of these tests over a six (6) month test period is presented in Table 6. Since PRESTONE II® was used as the ethylene glycol source in the field test, it was also used in the corrosion test.

It can be seen from the data in Table 6 that the ethylene glycol used to inject the asbestos was actually a corrosion inhibitor.

® Registered trademark of Union Carbide

TABLE 6

PIPE CORROSION DATA WITH VARIOUS SOLUTIONS OF ETHYLENE GLYCOL RATIOS

Metal/Solution	Original Weight (Grams)	Final Weight (Grams)	Difference (Grams)
Carbon Steel (1020)			
0% E.G.*	38.0117	38.5646	-0.4471
10% E.G.	38.7452	38.6696	-0.0756
20% E.G.	38.6091	38.6071	-0.0020
30% E.G.	38.4632	38.4622	-0.0010
40% E.G.	40.6281	40.6268	-0.0013
Stainless Steel 304			
0% E.G.	40.6118	40.6124	+0.0006
10% E.G.	41.9221	41.9231	+0.0010
20% E.G.	40.9670	40.9677	+0.0007
30% E.G.	41.1730	41.1730	0.0000
40% E.G.	40.4743	40.4736	-0.0007
Stainless Steel 308			
0% E.G.	35.4266	35.4259	-0.0007
10% E.G.	35.7359	35.7350	-0.0009
20% E.G.	37.2242	37.2239	-0.0003
30% E.G.	36.2618	36.2610	-0.0008
40% E.G.	35.9260	35.9259	-0.0001
Stainless Steel 316			
0% E.G.	62.6561	62.6583	+0.0022
10% E.G.	62.2120	62.2111	-0.0009
20% E.G.	63.7585	63.7584	-0.0001
30% E.G.	63.5901	63.5893	-0.0008
40% E.G.	62.8513	62.8512	-0.0001
Copper Pipe			
0% E.G.	36.6948	36.6946	-0.0002
10% E.G.	37.4375	37.4370	-0.0005
20% E.G.	37.5284	37.5282	-0.0002
30% E.G.	36.3205	36.3203	-0.0002
40% E.G.	36.9619	36.9626	+0.0007

*PRESTONE II was used in this experiment for ethylene glycol (E.G.).

I. Quantity of Solution Required

A number of experiments were conducted to determine the amount of 1 to 5 ethylene glycol to water solution required to saturate a section of preformed asbestos insulation used to insulate pipes. It was determined that 1 pound of solution would saturate 26 cubic inches of asbestos insulation. The quantity of solution that is required to saturate a given section of pipe can be determined by using the following formula:

$$Q = \frac{\pi(D_o^2 - D_i^2)\ell}{4} \times \frac{1\text{-lb.}}{26 \text{ in.}^3}$$

where

Q = Quantity of solution required, lbs.

π = 3.14

D_o = Outside diameter, in.

D_i = Inside diameter, in.

ℓ = Length, in.

An alternative to this is to use the graphs presented in Figure 30.

J. Time Delay Required

The results of tests conducted at SwRI indicated a solution of 1:5 EGW would migrate approximately 12 inches from a solution reservoir in 2 hours through typical asbestos pipe insulation due to capillary action. These tests were conducted on both 1 and 2 inch thick asbestos insulation with the same results. Since the injection points in the asbestos insulation should be spaced 12 to 18 inches apart, the area between the injection points should become saturated within 2 hours. However, in order to be certain that the asbestos insulation to be removed is competely saturated it is recommended that it not be removed until 4 hours after completion of the injection of the solution.

K. Toxicity

The two major components being injected into the asbestos insulation are water and ethylene glycol. During the course of the experimental work, SwRI has used commercially-available antifreeze which is predominantly ethylene glycol with rust inhibitors added. The brand of antifreeze that has been used for these tests was PRESTONE II®. Ethylene glycol is a material used in virtually every automobile. It does not vaporize readily at normal temperatures and, therefore, does not constitute a

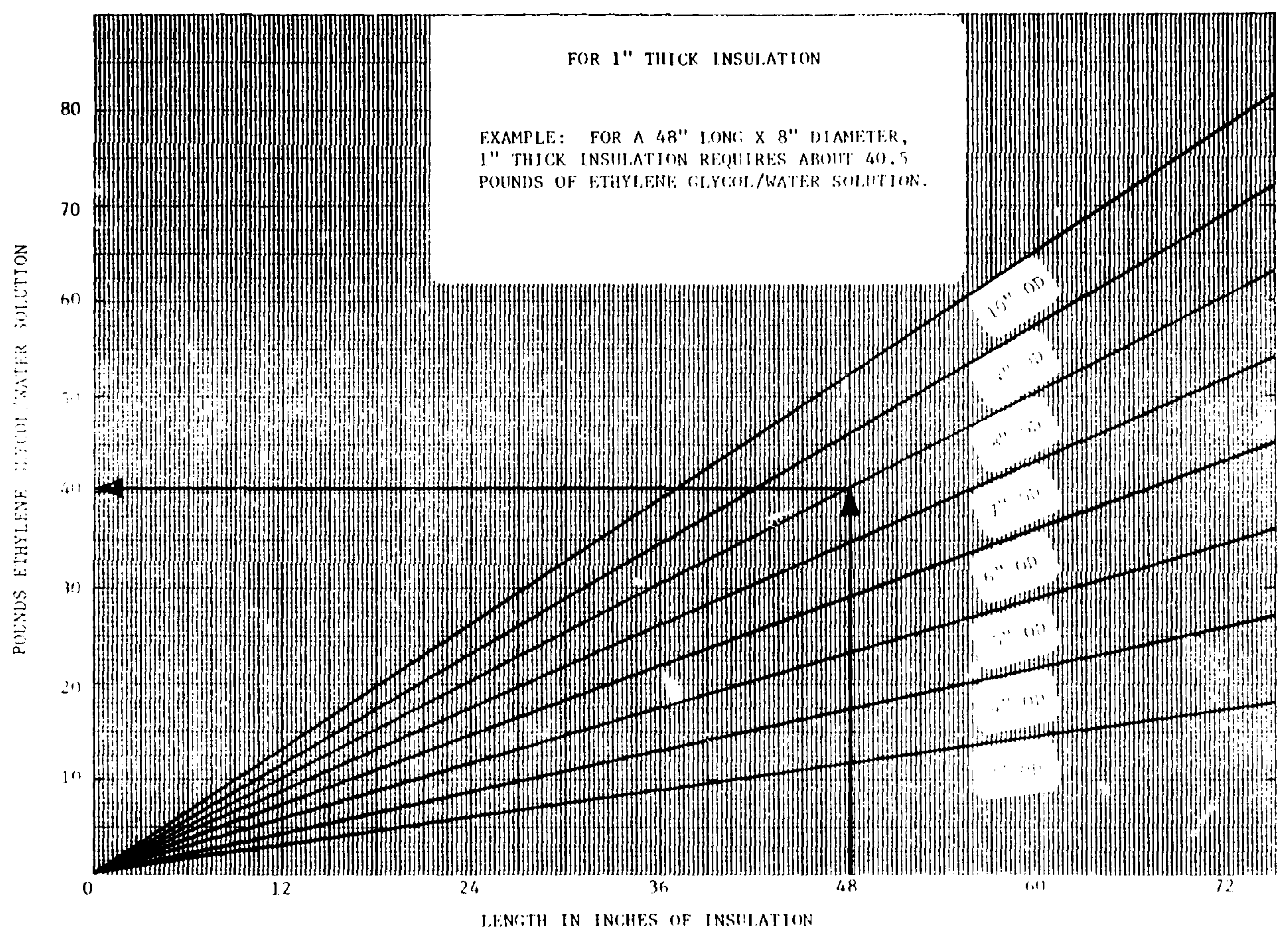


FIGURE 30. SATURATION CHART

hazard from inhalation. Tests conducted on rabbits indicate that ethylene glycol solutions do not present a hazard by skin contact because it does not penetrate the skin in harmful amounts. In addition, it is not an active skin irritant. Glycol of any kind should not be used for internal consumption; serious injury or death may result from swallowing as little as 100 milliliters.

The following tabulated data, Table 7, taken from Union Carbide Corporation's handbook on "Glycols", and only ethylene glycol is present here. The data indicates the relative degree of toxicity to animals as measured by single doses or contacts. Results of repeated feedings of ethylene glycol are also included in this table. The results may be indicative of the effects to be expected on human subjects but cannot be directly applied to humans without the use of suitable safety factors.

L. Migration Limitation

During the course of a rip-out process there are times when only a portion of the asbestos insulation must be removed. Therefore, a means of limiting the migration of the EGW solution had to be developed. It was found that constrictor bands placed at the termination points adjacent to the ends of the rip-out zone would limit the migration of the EGW solution. The constrictor bands that were used and found to be acceptable are large metal (automobile) hose clamps which can be tightened using a screw driver. It was found that this procedure was completely satisfactory. The maximum distance that the solution migrated beyond the constrictor bands was found to be approximately 4-1/2 inches. This was true even on sections of pipe insulation which were two (2) inches thick

M. Foam Application

Several different aqueous foam solutions were evaluated for potential use as a secondary asbestos fiber-capturing mechanism. The foam would only be necessary in the event that a dry pocket of asbestos was cut into during the rip-out procedure. The mechanism by which the foam was applied during the course of the program was to lay a bead of foam down the length or around the circumference of the insulation in the area where it was to be cut then the cutting tool was pushed through the foam bead into the asbestos insulation. In this manner, the aqueous foam would surround the cutting tool being utilized and capture any loose asbestos fibers that might escape during the cutting and rip-out process. It was found, however, that a thorough evaluation of the saturation condition could be completed using the conductivity probe (developed after the first site test) prior to the rip-out. Sections of dry asbestos were never again produced (or located) after the injection technique was perfected; therefore, the aqueous foam application proved to be redundant and was never used again.

Table 7

Toxicity Ethylene Glycol(1)

Single Oral LD_{50} Dose(2) Rats ml/kg	Repeated Oral Feeding Rats Acceptable Level In g/kg/day Diet and Duration	Single Skin Penetration LD_{50} Dose(3) Rabbits ml/kg	Single Inhalation Concentrated Vapor(4) Rats	Primary Skin Irritation (5) Rabbits	Eye Injury(6) Rabbits
7.40	0.18 (30 days)	20	8 hrs killed none of 6	None	None

(1) The National Research Council defines toxicity as the capacity of a substance to produce injury. Hazard is the probability that injury will result from the use of the substance in the quantity and manner proposed.

(2) The term LD_{50} refers to that quantity of chemical which kills 50 percent of dosed animals within 14 days. For uniformity, dosage is expressed in grams or milliliters per kilogram of body weight.

(3) Single skin penetration refers to a 24-hour covered skin contact with the liquid chemical.

(4) Single inhalation refers to the continuous breathing of a certain concentration of chemical for the stated period of time.

(5) Primary irritation refers to the skin response 24 hours following application of 0.01 ml. amounts to uncovered skin.

(6) Eye injury refers to surface damage produced by the liquid chemical.

Toxicity is only one indication of the existence of hazard in handling a chemical. Other factors, such as physical properties and extent of exposure are equally important in determining the hazard.

If any "dry spots" were to be located, that section should be reinjected until saturation was completed.

N. Special Hazards

There were no special hazards that were discovered during the course of this program which would restrict or limit the use of this new asbestos rip-out technique.

SECTION V. ECONOMIC ANALYSIS

While the principal benefit derived from this new asbestos control technique is reduced exposure to airborne fibers, substantial cost savings are also anticipated. This section examines the various development, new equipment and rip-out costs associated with shipboard asbestos removal.

A. Current Rip-Out Operations

Asbestos removal procedures/equipment employed by Naval shipyards are in response to the personnel protection requirements of OPNAVINST 6260.2B. This usually requires the construction of a sealed containment around the work site including a change room, a large exhauster to create negative pressure within the containment, and controlled access. All workers entering the work site must wear fully protective clothing and the appropriate respirator. The actual rip-out process may be conducted by teams of three (3) workers: one cuts/removes the asbestos, one applies an external waterspray onto the asbestos being removed, and one holds a small exhaust sucker such that any dust generated is "vacuumed" away. Drop cloths are used extensively to catch as much debris as possible.

Full body-protective suits are hot to work in, the various air lines create movement problems, and the waterspray produces a messy work site. Further, any fibers entrapped by the running water can be carried off to present a hazard at whatever point the water settles and dries up.

The insulation is removed by first cutting through the preformed insulating material with a knife then snipping the wire loop that holds the insulation in place. Screwdrivers and other "prying" tools may also be used to free the insulation from the substrate. The material and debris thus removed are placed in bags for disposal. The site is cleaned and the containment is dismantled after verification of an acceptable level of asbestos concentration.

Representative manhour values for these operations are presented below:

Ship	Install/Rem Exhauster	Set-Up/Rem Containment	Rip-Out	Vacuum/ Clean-up	Total
DDG	500	2,900	29,200	1,700	34,300
FF	400	2,300	23,100	400	27,200
SSN	200	1,400	13,500	800	15,900
Avg	400	2,200	21,900	1,300	25,800

B. Projected Rip-Out Operations Using the Asbestos Removal System

Since the impregnation technique has demonstrated that airborne fiber concentrations can be maintained well below current OSHA Persmissible Exposure Limits, the personnel protective equipment and procedures can be modified. It is proposed that air-fed respirators, external waterspray, individual "suckers", the containment, the containment exhauster, and the need for evacuation by other trades may be eliminated. Certain PPE will still be required, as recommended below:

- Elbow length rubber gloves with cuffs.
- Eye goggles.
- A "8710" nose mask.
- A rope barrier to protect the impregnation equipment.
- Plastic coveralls and booties.
- Drop cloths and double trash bags.

The labor for the same operation described under Section V-A above is therefore reduced by the manhours required for exhauster set-up/removal, containment set-up/removal, reduced PPE and simplified rip-out/clean-up procedures.

Observations of shipboard tests to date have shown that the overall rip-out and clean-up cycle under the current system takes approximately 30% longer than impregnation, rip-out, and clean-up using the new techniques. Using the average values in Section V-A above, the following comparison is obtained:

Operation	Current System (Manhours)	Proposed System (Manhours)
Exhauster	400	--
Containment	2,200	--
Rip-Out/Clean-Up	23,200	17,800
TOTAL	25,800	17,800

C. Equipment Costs

The equipment currently in use, i.e., the large exhauster, air-fed respirators, breathing air manifolds, various tools, etc., have already been purchased and can undoubtedly be used in other applications. There is no savings generated here as the acquisition, maintenance, and storage costs of this equipment will continue in support of other needs. These costs, therefore, are considered sunk costs, not reduceable or eliminated.

The new equipment expense is estimated as:

Cost of one (1) complete impregnator system - $7,900

Useful life - 7 years

Average cost of annual maintenance/storage - $ 750

D. Projected Savings

The calculated cost savings for asbestos removal for an "average" ship, produced from the use of the proposed technique over the current method, is $280,000. This figure is based on an overall manpower savings of 8,000 manhours, exclusive of materials and computed at $35 per hour. Clearly, these savings would vary by ship, e.g., from a small rip-out in a barge up through major rip-outs in a carrier. This figure represents savings in shipyard operational costs only and does not include payback for the R&D costs listed above. It can be seen that additional savings would be generated as successful application in these areas extends the use of the impregnation technique beyond Naval shipyards.

SECTION VI. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

Extensive laboratory work was completed at SwRI including additional asbestos impregnation and removal operations at a nearby abandoned school facility. This was followed by the five (5) shipboard impregnation/removal tests discussed in Section IV. Over two (2) years of RDT&E has provided substantial evidence of the feasibility of this asbestos removal technique leading to the following conclusions:

1. Preformed asbestos insulation material that is normally found on board naval vessels can easily be impregnated and saturated with a controlled quantity wetting agent solution (impregnant).

2. This solution inhibits the generation of airborne asbestos fibers during removal of the insulation material to concentrations well below hazardous levels.

3. The impregnant is a diluted solution of a commercially-available product that is already accepted/approved for use by the civilian population (e.g., already satisfied OSHA standards).

4. The impregnant does not produce any deleterious effects to the insulated systems or adjacent environment nor does it reduce the effectiveness of treated insulation that remains in use, or produce any undesirable after effects.

5. The impregnation technique and equipment are relatively inexpensive and simple to operate, maintain and transport. All system parameters are displayed and controllable.

6. The saturated asbestos material is easily and safely removed, handled, transported and disposed of using existing procedures. Shipboard and shop removal capability has been successfully demonstrated.

7. A double fail-safe technique has been developed to insure entrapment of asbestos fibers, namely:

    a. Verification of saturation by electrical conductibity measurement before removal and

    b. Use of a "foam cover" during the removal process.

8. Four (4) qualified agencies have provided asbestos sampling and counting service in support of the results listed in this report.

9. Naval personnel have successfully trained in the use of this new equipment and technique. Operations Manuals will be made available to the U. S. Navy Shipyards.

10. One (1) complete system is currently available for use.

B. Recommendations

1. NAVSEA approve immediate use of this technique (as described in Section V-B) by qualified personnel on a case basis in naval shipyards.

2. NAVSEA direct development of an Alternate Criteria Standard to employ this system and expedite CNO approval.

3. Insure continued support for the investigation and development of the application of this technique for removal of friable asbestos instulation.

4. Expedite design and development of a serviceable version of this equipment for small non-production jobs.

DATE
ILME