APPENDIX D

SAMPLING AND ANALYSIS

Report No. MA-ENV-820-96003-D

Contract No. DTMA91-93-C-00004

U.S. Department
of Transportation

Maritime
Administration

JULY 1997

TABLE OF CONTENTS

This Page Intentionally Left Blank

LIST OF TABLES AND FIGURES

TABLES

FIGURES

EXECUTIVE SUMMARY

Three ships, EXPORT CHALLENGER, SHIRLEY LYKES and WAYNE VICTORY, in the Maritime Adminstration's James River Reserve Fleet at Fort Eustis, Virginia, were sampled for potentially hazardous materials that are subject to environmental, safety and health regulations.

Samples of electric cables, ventilation system gaskets and assorted nonmetallic materials, such as rubber and caulking, were recovered and analyzed for PCBs. PCBs at concentrations up to 18,900 parts per million, by weight, were found in all types of the materials that were sampled, but the types of materials with PCBs present varied from ship to ship. In WAYNE VICTORY, for example, no PCBs were found in electric cables but very high levels were found in ventilation system gaskets, while in EXPORT CHALLENGER, PCBs were found in both electric cables and gaskets. The types of materials used in each ship also varied. In SHIRLEY LYKES, for example, four kinds of materials were found in service as ventilation system gaskets and three contained PCBs, while in EXPORT CHALLENGER, seven kinds were found (only one appearing similar to a SHIRLEY LYKES material), two of which were contaminated with PCBs. No pattern emerged that was typical of all three ships.

Samples of thermal insulation, paint, fasteners, refrigerants, and other materials were recovered, and each sample was analyzed for one possible hazardous constituent. Thermal insulation samples, for example, were analyzed for asbestos, while fasteners were analyzed for evidence of cadmium plating, and antifreeze solutions for evidence of ethylene glycol. All three ships showed the same patterns of potential hazards, with high levels of asbestos in thermal insulation, cadmium plating on fasteners, and ethylene glycol as antifreeze.

These results show that environmental, safety and health controls will be required during breaking and recycling of these ships and that each ship presents unique problems with regard to PCBs and other potential hazardous materials.

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. MAR-ENV-820-96003-D	2.	3. Recipient's Accession No.

4. Title and Subtitle
Appendix D
Sampling and Analysis Report

5. Report Date
July 1997

6.

7. Author(s)

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Halliburton NUS Corp.
910 Clopper Rd.
Gaithersburg, MD 20878

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C) DTMA91-93-C-00004
(G)

12. Sponsoring Organization Name and Address
United States Maritime Administration
Office of Environmental Activities
Washington, DC 20590

13. Type of Report & Period Covered
Final

14.
February 1995-July 1997

15. Supplementary Notes

16. Abstract (limit: 200 Words)

Three ships, EXPORT CHALLENGER, SHIRLEY LYKES and WAYNE VICTORY, in the Maritime Administration's James River Reserve Fleet at Fort Eustis, Virginia, were sampled for potentially hazardous materials that are subject to environmental, safety and health regulations.

Samples of electrical cables, ventilation system gaskets and assorted nonmetallic materials, such as rubber and caulking, were recovered and analyzed for polychlorinated biphenyls (PCBs). PCBs at concentrations up to 18,900 parts per million (ppm), by weight, were found in all types of the materials that were sampled, but the types of materials with PCBs present varied from ship to ship.

Samples of thermal insulation, paint, fasteners, refrigerants, and other materials were recovered, and each sample was analyzed for one possible hazardous constituent. All three ships showed the same patterns of potential hazards, with high levels of asbestos in thermal insulation, cadmium plating on fasteners, and ethylene glycol as antifreeze. These results show that environmental, safety and health controls will be required during breaking and recycling of these ships and that each ship presents unique problems with regard to PCBs and other potential hazardous materials.

17. Document Analysis a. Descripters
Ship Breaking/Recycling
PCBs
Hazardous Materials

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Approved for Release National Technical Information Service Springfield, VA 22161	Unclassified	
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18)

See Instructions on Reverse

Optional Form 272 (4-77)
(Formerly NTIS-35
Department of Commerce

1.0 INTRODUCTION

This report and its References 1 through 8 are part of a technical environmental evaluation of ship breaking/recycling technologies in the United States, the purpose of which is to provide to the U.S. Maritime Administration (MARAD):

- A survey of hazardous substance contamination problems encountered when breaking typical MARAD vessels, accomplished through appropriate testing and analysis of candidate ships;
- A survey of currently available and advanced technologies for effective removal, handling and disposal of hazardous materials resulting from ship breaking/recycling;
- A survey of current federal, state and local environmental laws and regulations applicable to ship breaking/recycling;
- A baseline economic case for cost-effective ship breaking/recycling in the United States; and
- An environmental assessment for government ship breaking/recycling activities in the United States that satisfies National Environmental Policy Act (NEPA) requirements.

This document addresses the first of these items, reporting the results of sampling and sample analysis for three ships in MARAD's James River Reserve Fleet, Fort Eustis, Virginia. Another report, "Survey of Ships and Materials" (Reference 5), evaluates the data and identifies practical ways to remove, during ship breaking/recycling, the hazardous materials identified by the sampling and analysis.

1.1 BACKGROUND

Three retired cargo ships were selected by MARAD for the sampling and analysis program.

- EXPORT CHALLENGER was built in 1963 for MARAD by the Sun Shipbuilding & Drydock Company, Chester, Pennsylvania. This is a three-deck, general cargo ship having a light ship displacement[1] of 6,880 long tons,[2] an overall length of 470

[1] Taggart (ed.), "Ship Design and Construction" (1980), cites U.S. Coast Guard booklet CG-993 (Forms for Stability Test Reports) as defining light ship displacement as the weight of the ship, complete in every respect with water in boilers at steaming level and liquids in machinery and piping, but with all tanks and bunkers empty and no passengers, crew, cargo, stores, or baggage. This is not the weight used to calculate the sampling requirements.

[2] One long ton equals 2,240 pounds.

feet, and a beam of 73 feet. When fully loaded, it displaces 19,405 long tons at a draft of 30.6 feet. The ship is powered by two, oil-fired, superheating Babcock & Wilcox boilers feeding steam to a single two-stage General Electric steam turbine. The turbines provide up to 13,750 horsepower to a single shaft and a nonferrous propeller through a double reduction gear, driving the ship at a maximum speed of approximately 18.5 knots. The hull is assembled from welded and riveted steel and incorporates six cargo holds, each served by a hatch and cargo-lifting gear.[3]

- SHIRLEY LYKES was built in 1962 for MARAD by the Bethlehem Steel Corporation's Shipbuilding Division, Sparrows Point, Maryland. After serving for 10 years as a two-deck, general cargo ship, in 1972 it was lengthened approximately 95 feet by Todd Shipyards Corporation, Galveston Division, Galveston, Texas to incorporate a container hold. The ship has a light ship displacement of 8,606 long tons, an overall length of 592 feet, and a beam of 69 feet. When fully loaded, it has a displacement of 22,892 long tons at a draft of 30.1 feet. The ship is powered by two oil-fired, superheating Foster-Wheeler boilers feeding steam to a single two-stage General Electric steam turbine. The turbines provide up to 11,000 horsepower to a single shaft and a built-up stainless steel propeller through a double reduction gear, driving the ship at a maximum speed of approximately 18 knots. The hull is made of welded and riveted steel and incorporates six cargo holds. Five are served by hatches and cargo-lifting gear.[4]

- WAYNE VICTORY was built in 1945 by the California Shipbuilding Corporation, Los Angeles, California. This is a three-deck, general cargo ship having a light ship displacement of 4481 long tons, an overall length of 470 feet, and a beam of 73 feet. When fully loaded, it has a displacement of 15,200 long tons at a draft of 29.9 feet. The ship is powered by two oil-fired, saturated steam Henry Vogt boilers feeding steam to a single two-stage Allis Chalmers steam turbine. The turbines provide up to 6,600 horsepower to a single shaft through a double reduction gear, driving the ship at a maximum speed of approximately 15 knots. The hull is made of welded and riveted steel and incorporates five cargo holds, each served by a hatch and cargo-lifting gear.[5]

---

[3] American Bureau of Shipping, *RECORD 1990*, p. 489.

[4] Ibid., p. 1288.

[5] Ibid., p. 1490 and Sheet 4 of MARAD drawing VC2-S-AP2.

2.0 SAMPLING

Sampling was conducted between October 12, 1995 and November 7, 1995 aboard the three ships at their moorings at the James River Reserve Fleet, Fort Eustis, Virginia. The sampling was performed in accordance with the plan presented in Reference 1. Sampling for polychlorinated biphenyls (PCBs) followed specific, detailed guidelines provided by the U.S. Environmental Protection Agency (EPA) (Reference 8).

2.1 PCB SAMPLING DESIGN

Both the Sampling Plan and the EPA Guidance Document call for sampling materials for PCBs in three classes of materials:

- Electric cables. The Navy has found PCBs in many different kinds of electric cables. Cables contain an abundance of valuable copper and are considered an asset by ship recyclers. Therefore, to preclude inappropriate handling and dispositioning of electric cables during ship breaking/recycling, the EPA guidance requires special emphasis on cables.

- Ventilation system gaskets. Certain wax- or grease-impregnated felt gaskets are often used in shipboard ventilation systems. The felt is a commercial material used in other industrial applications. In its Guidance Document (Reference 8), EPA presumes felt gaskets will be found in commercial ship ventilation systems and therefore requires particular attention be given to them.[6]

- Other PCB materials. The Navy has found PCBs in a wide variety of nonmetallic materials used aboard U.S. warships and submarines. In its guidance document, EPA divides these materials into eight categories and requires samples of each category.

In addition, the EPA Guidance document specifies the total number and distribution of the samples that are to be taken. The number and distribution are defined as "quota" and "strata," respectively, as follows:

- Sample quota. The total number of samples is to equal the square root of the gross weight (GW) of the ship at the time it is offered for recycling.

- Deck quota. At least three samples must be taken from each deck of the ship, including decks below the weather deck (where the ship's engineers are located and the cargo is stored) as well as above the weather deck (where navigation and living

---

[6] A letter from the Assistant Secretary of the Navy (Installations and Environment) to the EPA dated 17 April 1995 provides detailed comments on the new PCB rules proposed by EPA in December 1994. The letter details Navy experience with PCBs in U.S. warships and submarines.

quarters are located). A simplified drawing showing the arrangement of the decks and holds of a typical cargo ship is presented as Figure 1.

- Compartment selection. Each compartment and passageway in the ship being sampled is assigned a number, and the compartments and passageways from which samples are recovered are selected by random from among all the compartments and passages, subject to meeting the deck quota.

- Sample stratum 1, electric cables. The number of cable samples must be 0.4 times the total number of samples, and at least 75% of the cable samples are to be recovered from engineering and electrical and electronics equipment spaces.

- Sample stratum 2, ventilation system gaskets. The number of ventilation gasket samples must be 0.4 times the total number of samples, and at least 50% are to be recovered from engineering spaces and areas where fuel, explosives, and munitions are stored and handled.

- Sample stratum 3, other PCB materials. The number of other materials sampled for PCBs must be 0.2 times the total number of samples. This stratum is further divided into eight categories of materials. At least one sample from each of the eight categories is to be selected from each ship.

2.1.1 EPA Guidance Document Requirements

The strata and quota criteria were developed by EPA from data provided by the Navy on the PCB materials contained in warships. There are significant differences between warships and commercial ships. Commercial cargo ships have much smaller engines and fewer crew quarters, simpler internal ventilation and electronics systems, no weapons systems, large interior cargo holds which are devoid of systems and machinery, and displacements which are often significantly greater than those of warships. To illustrate, Table 1 compares the features of SHIRLEY LYKES with those of a modern Navy cruiser, the USS TICONDEROGA, CG 47. When applied to a commercial ship, the EPA guidance (Reference 8) leads to a large number of samples with comparatively fewer opportunities to meet all of the quota and strata requirements.

Despite this problem, sampling was conducted, to the maximum extent practical, in conformance with the EPA guidance. The following sections discuss the problems encountered.

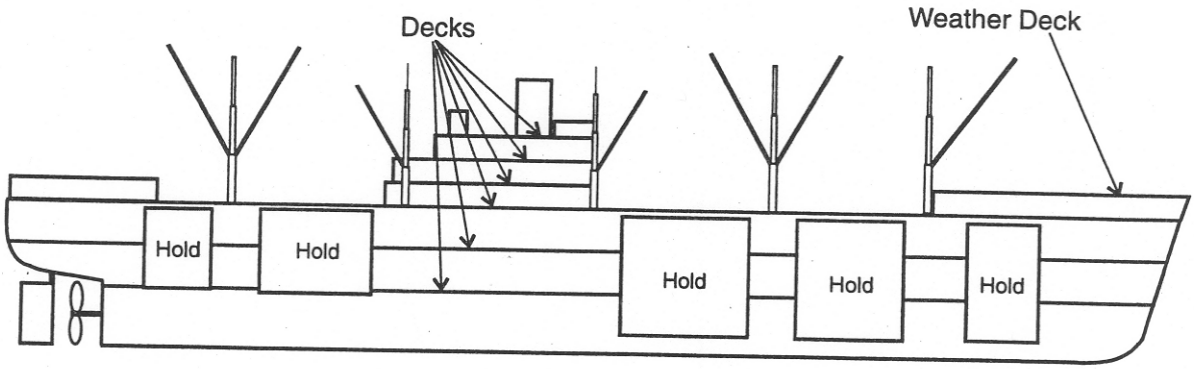

Figure 1. Typical Cargo Ship

Table 1. Features of SHIRLEY LYKES and USS TICONDEROGA

CHARACTERISTIC	SHIRLEY LYKES	USS TICONDEROGA[7]
Length	598 feet	568 feet
Engine Power	11,000 shaft horsepower	86,000 shaft horsepower
Number of Weapons Systems	0	25
Crew Size	25	362
Fuel and Cargo Capacity	14,286 tons	2,270 tons
Light Ship Weight	8,606 tons	7,260 tons
Full Load Displacement	22,892 tons	9,530 tons
Electric cable weight	<1% of LSW	~6% of LSW[8]
Ventilation gaskets	up to 200[9]	up to 4000[10]

2.1.1.1 Total Sample Quota and Strata Quota

Table 2 shows the GW of each of the three ships; the total sample requirements (the square root of GW); the number of cable, ventilation gaskets, and other samples required both by the EPA (Reference 8) and by the Sampling Plan (Reference 1); and the number of samples that were recovered and analyzed.

Note that the GW used for selecting the number of samples is not the same as light ship weight, discussed above. The EPA requires the weight of the ship as delivered for recycling to be used in the calculation, and this can differ from LSW because of differences in fluid loadings, removal of equipment and other factors.

---

[7] J. L. Couhat, ed., *Combat Fleets of the World 1986/87,* Naval Institute Press, Annapolis, Md., 1986, pp. 629-631.

[8] B. Jackson, Naval Sea Systems Command, January 1996.

[9] Based on a walkthrough inspection of SHIRLEY LYKES by MSCL representatives. Actual gasket counts have not yet been made.

[10] T. Pape, Westinghouse Machinery Technology Corporation, January 1996.

Table 2. Gross Weight, Strata Quota, and Number of Samples Collected

	EXPORT CHALLENGER				SHIRLEY LYKES				WAYNE VICTORY			
	GW	EPA Quota	Plan Quota	No. Collected	GW	EPA Quota	Plan Quota	No. Collected	GW	EPA Quota	Plan Quota	No. Collected
Totals	7700	88	88	93	5700	75	75	79	3400	58	58	60
Cables		36	36	35		31	31	31		23	23	24
Vent. Gaskets		36	36	30		31	31	27		23	23	23
Other		16	16	28		13	13	21		12	12	13

Table 2 shows that, except for cables and ventilation system gaskets in EXPORT CHALLENGER and ventilation system gaskets in SHIRLEY LYKES, the number of samples recovered and analyzed equals or exceeds the number recommended by EPA and required by the Sampling Plan (Reference 1). The number of cable and gasket samples taken was reduced in favor of samples of other PCB materials for four reasons:

- As sampling progressed, many samples of identical cables and ventilation gasket materials were being recovered. A full set of samples in accordance with the plan did not appear to be needed to identify PCB problems.

- Because the ventilation systems in the ships were small relative to military ships, it was judged that the criteria called for excessive sampling of gaskets.

- The criteria did not allow for adequate sampling in the "Other" category. With only 12 to 16 samples required for eight different categories of other materials, a good representation was not being recovered. Increased sampling in the "Other" category was considered appropriate, but the sampling and analysis budget would not accommodate a large increase. Some cable and gasket samples had to be eliminated to allow for the switch.

- The plan did not include samples for oil and grease, common PCB-contaminated materials in military ships.

Thus, the number of samples was adjusted to favor the Other category, and samples for oil and grease were added. Overall, the total number of samples exceeds by 11 the number specified in the Sampling Plan.

2.1.1.2 Deck Quota

The EPA Guidance Document (Reference 8) requires at least three samples from each deck. Tables 3, 4, and 5 show the number of samples taken from each deck of the three ships. Because of ship construction and deck nomenclature differences, a separate table is provided for each ship.

Table 3. Samples Taken From Each EXPORT CHALLENGER Deck

EXPORT CHALLENGER*	
Deck	**No. of Samples Taken**
Navigation Bridge & Boat Deck Top House Top	4
Aft House Top	2
Lower Bridge and Boat	3
Forward House Cabin	4
Aft House Bridge	11
Poop	14
Main	31
Second	11
Third	9
Orlop and Tank Top	2

*Two samples not identified as to deck

Table 4. Samples Taken From Each SHIRLEY LYKES Deck

SHIRLEY LYKES*	
Deck	**No. of Samples Taken**
Navigation Bridge	5
Boat Deck & Cabin	4
Upper, Foc'sle & Winch Platforms	14
Main	29
Upper Tween	8
Machinery Space	15

*Four samples not identified as to deck

Table 5. Samples Taken From Each WAYNE VICTORY Deck

WAYNE VICTORY*	
Deck	**No. of Samples Taken**
Top of Wheelhouse	2
Bridge	4
Cabin	6
Boat	6
Main	15
Second	8
First Platform	2
Machinery Space	15

*Two samples not identified as to deck

The deck quota requirement was met in nearly all cases. In those where it was not, this was due to the absence of the materials specified in the EPA Guidance Document (Reference 8). Most of the samples were taken in areas of the ships where there are concentrations of machinery, such as the main deck, machinery spaces, and decks where cargo handling machinery is mounted. These decks had a larger number of target materials than others. The cargo holds did not contain any of the materials specified in the EPA guidance.

2.1.1.3 Cable Sample Criterion

The EPA guidance (Reference 8) requires that 75% of all cable samples be recovered from "electric cable in engine compartments, auxiliary machinery compartments, areas having radio transmission and receiving equipment, x-ray equipment, radar equipment and any other high-voltage electrical equipment." The ship's spaces meeting this requirement in EXPORT CHALLENGER are the Navigation Bridge, the Lower Bridge, the Aft House Bridge and the Main, Second and Third Decks. In SHIRLEY LYKES, the compliant spaces are the Navigation Bridge, the Main Deck and the Machinery Space; and in WAYNE VICTORY, the First Platform, Machinery Space, the Bridge, and the Main and Second Decks.

Table 6 shows that only in WAYNE VICTORY does the actual sampling conform to the guidance criteria. The electrical and electronic systems contained in commercial ships are very simple compared to the Navy warships around which the EPA guidance was patterned and do not necessarily afford adequate sampling throughout, with minimal crew and passenger accommodations. Cable sampling in this ship met the criteria only because there are few spaces other than the types cited.

Most commercial cargo ships of the type sampled in this study have a single or only a few "engineering spaces," unlike that of typical Navy vessels. If sampling in these ships had conformed to the EPA guidance that 75% of all cables samples must be recovered from these defined spaces, a high number of samples would have been taken from a small percentage of the ship's cable "population." The remaining 25% of the samples would have to spread over the remaining non-engineering spaces of the ship, likely resulting in an underestimate/under sampling of cables in the berthing, crew and cargo areas.

Table 6. Cable Samples

	No. of Cable Samples	No. of Cable Samples Taken From Engineering & Electrical Spaces	%
EXPORT CHALLENGER	35	25	71
SHIRLEY LYKES	31	19	61
WAYNE VICTORY	24	20	83

2.1.1.4. Ventilation System Gasket Criterion

The EPA guidance (Reference 8) requires that 50% of all ventilation gaskets be recovered from "air handling systems gaskets [in] engine compartments, auxiliary machinery compartments, and in areas where . . . fuel, explosives and munitions were stored and handled." Table 7 compares this guidance with the actual sampling performed. Although there are no munitions or explosive handling areas on these ships, the sampling nonetheless met the EPA criteria.

Table 7. Ventilation Gasket Samples

	No. of Vent Gasket Samples	No. of Vent Gasket Samples Taken from Engineering, Fuel, and Munitions Spaces	%
EXPORT CHALLENGER	30	21	70
SHIRLEY LYKES	27	14	52
WAYNE VICTORY	23	14	61

2.1.1.5 Other PCB Materials Criterion

The EPA guidance divides the Other PCB Materials stratum into eight categories. To facilitate data sorting, MSCL assigned a number to each EPA category, as shown in Table 8.

Samples in each of these categories were recovered from the three ships except for categories 4 and 6 from WAYNE VICTORY, and category 8 from EXPORT CHALLENGER and WAYNE VICTORY, where no samples of those materials were found.

Table 8. Categories for Other PCB Materials

CATEGORY	MATERIAL
3	Rubber gaskets, other than ventilation system gaskets
4	Felt gaskets, other than ventilation system gaskets
5	Fiberglass, felt, foam, or cork thermal insulation
6	Sound-deadening felt
7	Grout, caulk, rubber isolation mounts, foundation mounts and adhesives (MSCL added valve packing and unused paint to this category)
8	Tapes
9	Pipe hanger liners
10	Rubber and plastic parts of all sizes and shapes, other than those listed above
11	Oil and grease.[11] The U.S. Navy finds PCBs in shipboard lubricants in about 3% of the samples recovered.[12]

2.2 NON-PCB SAMPLES

The sampling requirements for the other potential contaminants were developed from engineering judgment as to the types of contaminants that might be encountered in ships built before the mid-1960s. Many materials that are now regarded as hazardous were then in common use. Samples were taken of thermal insulation, floor and ceiling tiles, valve packing, gaskets, pipe hanger liners, caulks, mastics and electric cables for analysis for asbestos; metal parts for analysis for cadmium plating; coolants for ethylene glycol; refrigerants for Freon; fluorescent tubes for mercury; and paint for lead and organo-tin and coal tar residues. While the ships may contain many other potential contaminants (e.g., bilge water, rodent and bird feces) that are regulated by current laws, MSCL concluded that the sampling described above

---

[11] The EPA sampling requirements (Reference 8) do not specify requirements for sampling liquid PCBs; therefore, the Sampling Plan (Reference 1) does not require liquids to be sampled. However, the EPA guidance discusses more than sampling requirements for solid PCB materials, specifying as well the removal and proper dispositioning of all liquid PCB materials in vessels undergoing recycling. Because PCBs have been found in greases and lubricants in the past, MSCL considered it appropriate to obtain a few samples to determine whether greases or lubricants are likely to be a problem. Therefore samples were taken from the steering engines and a windlass on each ship. These samples are identified as category 11. The sampling for liquids reported herein is not statistically based and should not be used to draw firm conclusions about whether or not liquid PCBs are present. The results, which show no PCBs in the samples taken, indicate only that liquid PCBs may not be a significant problem in the ships that were sampled.

[12] Naval Sea Systems Command document, "INACTSHIP PCB Survey Results, Number of Samples by Range/Category, 11/30/95."

would be sufficient to indicate the presence or absence of significant potential environmental, safety and health issues.

3.0 ANALYSIS

3.1 PROCEDURES

Analysis of samples was conducted in accordance with the methods described in the Sampling Plan (Reference 1). Portions of each sample were weighed and tested and the results expressed in parts per million (ppm) by weight for PCBs, cadmium, lead, mercury and tin; in percent by weight for asbestos and ethylene glycol; and by refrigerant type for refrigerants. For cable PCB analysis, a short section of the cable sample was stripped of all metal components, including the lead covering where encountered. The remaining nonmetal components were then weighed and tested, with the results reported in parts per million PCBs. Toxicity characteristic leachate procedure (TCLP) tests were performed on cable samples prepared in the same manner as for PCB analysis, but with PCBs extracted using EPA Test Method 131, "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," found in EPA publication SW-846.

The analysis work was done by two laboratories. Environmental Testing Services Incorporated (ETSI) in Norfolk, Virginia, analyzed all ventilation gaskets, all other-PCB-material samples, and the initial cable screening analyses discussed in Section 4.1.2.2. Except for two cable samples from SHIRLEY LYKES, all final cable analyses were performed by ETS Analytical Services Incorporated of Roanoke, Virginia.

Quality assurance at ETSI (Norfolk) was performed in accordance with the quality assurance portion of the Sampling Plan (Reference 1). The laboratory plan calls for chain-of-custody records and periodic surrogate spikes, matrix spikes, blanks, and analysis precision determinations. The chain-of-custody records were provided with the final analysis results and were reviewed by MSCL and found to match the results. ETSI retains the records of the spikes, blanks, and precision determinations in-house; the laboratory manager certifies conformance with the quality assurance plan by signing each analysis report.

ETS Analytical Services' (Roanoke) quality assurance is not part of the Sampling Plan, because that laboratory was brought into the program toward the end of the analysis work in order to speed completion of the analysis of electrical cables. However, this is an EPA Contract Laboratory, and thus maintains high standards of quality. To verify quality, ETS Analytical Services has reported the results of surrogate analyses. These results, provided to MARAD under separate cover, show conformance to EPA criteria for surrogate recovery, i.e., the analysis results for surrogate chemicals that were added to the samples were within the required analysis range (50% to 150% of expected results for a least one surrogate), indicating adequate recovery of the PCBs and accurate PCB analyses.

One quality assurance criterion, completion of solid PCB analyses within 40 days of sampling, was not met. This was due to significant analysis difficulties which are discussed below. Inasmuch as the samples represented parts removed from the uncontrolled environment of the ships and placed in controlled storage at a laboratory, this is not judged to be a significant shortcoming.

3.2 DIFFICULTIES

The most common method for analyzing for PCBs in solid materials is first to extract the PCBs using EPA method 3550A, "Polychlorinated Biphenyls and Pesticides, Modified Extraction Procedure, Matrix: Soils," followed by analysis using EPA method 8080, "Standard Operating Procedure for Data Analysis of PCBs and Pesticides by GC/ECD." The extraction procedure takes a few minutes and is efficient at attacking and destroying most plastics and rubbers, extracting the PCBs, and producing a liquid extractant that can easily be processed for analysis by the GC/ECD process (Gas Chromatography with Electron Capture Detector).

In its guidance document (Reference 8), EPA specified use of the Soxhlet extraction apparatus with toluene as a solvent. This requirement created several difficulties, as follows:

- Toluene is a common environmental contaminant that is often the target of analysis. The presence of large amounts of toluene as a solvent in the laboratory risks cross-contamination with other samples. Special precautions were needed to avoid this problem.

- Toluene is not the normal solvent for the extraction of PCBs. Tests were necessary to ensure that the extracted PCBs could successfully be transferred to the proper solvent (n-hexane) required for final analysis. During analysis of epoxy glue and one sample of foam rubber (ETSI sample numbers 7517, 7518 and 7228, respectively) the toluene extract solidified, making PCB analysis impossible.

- The Soxhlet extraction procedure is slow. It takes one or two days for a single apparatus to complete an extraction and be made ready for the next extraction.

- The Soxhlet extraction apparatus requires a larger sample than the ultrasonic method; therefore, more sample preparation is required.

Very high PCB levels were encountered, (e.g., felt; cable), with some samples exceeding the calibration range of the gas chromatographs. When this occurred, samples had to be repeatedly diluted to reduce concentrations of PCBs to within the range of the instruments. To flush out residues remaining in the instruments after a high-level sample and avoid contamination of subsequent analyses, two blanks (PCB-free) were run between each sample, adding to the analysis time.

It is not clear that the extraction procedure effectively recovered all of the PCBs. The toluene solvent did not dissolve the plastic or rubber parts during the extraction, as is usually the case when methylene chloride is used. Therefore residual PCBs may have remained inside the materials, causing analysis results to be biased low.

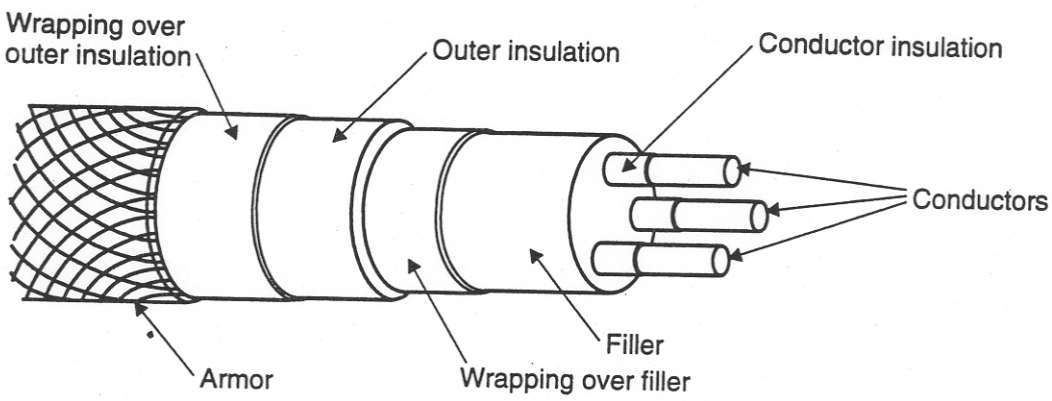

Figure 2. Typical Electric Cable

4.1.1.1 Metal Parts

Most shipboard cables have two distinctly different metal parts, the conductors and the armor. The electric conductors in all cable samples from the three ships were visually identified as copper. Braided metal armor on the outside protects the outermost plastic or rubber electrical insulation cover from damage during installation and subsequent maintenance. In EXPORT CHALLENGER and SHIRLEY LYKES, the armor often appeared to be bronze. Some armor in these ships was a gray metal which could have been steel or aluminum. In WAYNE VICTORY, steel armor was used, as evidenced by the severe rusting observed. Copper conductors and armor metals comprise 50 to 75% of the total weight of shipboard cables, and nonmetallic materials make up the rest.[14]

The copper in electric cables is one of the valuable items in a recycled vessel. While the amount of cable in a ship varies widely, a typical 5000-ton freighter will contain up to 25 tons. Of that, up to 19 tons could be copper having a current market value of $31,000 ($1,600/ton).[15]

[14] Personal communication from K. Ellis, Seawitch Salvage, to J. Burritt and S. Shaw, MSCL Inc., July 19, 1995.

[15] The *Iron Age Scrap Price Bulletin* of January 15, 1996 cites the dealer's price for copper wire scrap as ranging from $0.70 to $0.81 per pound. At $0.81 per pound, 30 tons of Number 1 wire scrap would have a value of $48,600.

4.1.1.2 Nonmetal Parts

The outermost nonmetal part of a typical cable is a thin plastic wrapping overlaying a thick plastic cover that provides the outermost electrical insulation for the assembly. Immediately inside this cover is often a thin plastic wrapping surrounding a fibrous, putty, or plastic material that fills the spaces between the conductors. Imbedded in the filler are from 1 to 30 conductors, each coated by one to three layers of plastic, fabric, or a mixture of both, to electrically insulate each from its neighbors. Sometimes, the coatings on the conductors are uniquely colored to aid in the proper connection of the wires.

There are from 1 to 93 individual nonmetallic parts in each of the cable samples taken from the three ships. See Tables 9, 10, and 11 and Appendix A for details. The average number of parts varied from 9 in EXPORT CHALLENGER and WAYNE VICTORY to 15 in SHIRLEY LYKES.

4.1.2 Cable Analysis

4.1.2.1 Change in EPA Guidance Requirements

EPA's guidance for sampling ships for PCBs (Reference 8) specifies the number of cable samples to be taken and requires that each individual nonmetallic part of each cable sample be analyzed for PCBs because each is regulated separately as a PCB item.[16] The PCB analysis requirement, coupled with the large number of nonmetallic parts in typical shipboard cables, presents vessel recyclers with a costing dilemma. The very high cost of analysis of the cables may exceed their value on the scrap market.

This problem was addressed in a letter to EPA (Reference 9) in which it was noted that individual parts of cables are not reused in the United States. Instead, cables are shredded for recovery of the copper, and the nonmetallic residue from the shredding is then disposed of separately. Because this project deals with domestic and not foreign ship recycling, where uses of recycled cables may differ, the letter recommended that EPA permit a single PCB analysis of a cross-section of the nonmetal materials in each cable sample as being most representative of the typical cable recycling process used in this country. This change would also significantly reduce the analysis cost of the project.[17] The letter also recommended that

---

[16] See References 3 and 4.

[17] The so-called EPA "fluff rule" permits automobile and white goods recyclers to evaluate nonmetallic "fluff" from shredding operations based on the average PCB concentration of the fluff rather than on the individual PCB concentration of any constituent in the fluff.

TCLP tests[18] be run on any cable sample found to contain concentrations of PCBs at or above 50 ppm. TCLP data would provide information to EPA for determining appropriate restrictions on land burial of PCB-contaminated cables. In its reply (Reference 10), EPA concurred with these recommendations. This change was subsequently agreed to by MARAD; therefore, this report presents the average PCB concentration in the nonmetallic parts of the cable samples and the TCLP results for any cable found to contain levels of PCBs at or above 50 ppm.

4.1.2.2 Selecting Cables for Individual Analysis

As noted above, the EPA guidance (Reference 8) specifies a unique cable analysis procedure. The procedure is cumbersome, slow and expensive. In addition, the cost for TCLP analyses is significant.[19] To reduce the total number of cable analyses, three sorting schemes were employed.

- Analysis by groups. Electric cables were not expected to contain high concentrations of PCBs.[20] Therefore, cable samples were to be sorted by ship, assembled in groups of 10 or fewer, and analyzed to a sensitivity of 5 ppm PCBs, or 1/10 of the EPA standard of 50 ppm. If the group was found to contain PCBs at less than 5 ppm, no single cable could possibly contain PCBs above 50 ppm and no further analysis of cables in the group would be needed. In practice, the analysis laboratory used a sensitivity of 4 ppm and found that only the 24 WAYNE VICTORY cable samples, analyzed in two groups of 10 and one group of 4, passed the test (i.e., no WAYNE VICTORY cable in any group could have contained levels of PCBs above 40 ppm). For EXPORT CHALLENGER and SHIRLEY LYKES, high PCB values were found in all the groups, indicating that at least one, and probably many, of the cables in each group contained PCBs at or above the EPA standard of 50 ppm.

- Elimination of duplicates. Each cable sample was visually examined. Many cables were found to look the same as others. This is not surprising. One type of cable will be used for many different services throughout a ship, and one single cable may service several compartments. The random sampling plan could therefore select the same cable or the same type of cable more than once. To eliminate analysis of duplicate samples, one sample from each group of duplicates was

---

[18] See 40 CFR 261 and EPA Test Method 1311 in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," EPA Publication SW-846, for a detailed description of the TCLP test and its place in regulation of hazardous wastes.

[19] Additional cable analyses were performed at a cost of $85 for PCBs and $160 for TCLP. The cost for additional cable analyses was less than the cost for each first analysis ($105) because much of the sample preparation work was already completed.

[20] The Navy has found that about 20 percent of the cables tested contain PCBs above 50 ppm.

chosen for further analysis. To test whether or not visually identical cables in fact had the same PCB levels, tests of some visual duplicates were performed. Results are shown in Table 12.

- Elimination of dry cables. No grease or wax residues could be seen or felt in the internal components of many of the WAYNE VICTORY cables, unlike the samples from the other two ships, and all cables tested contained levels of PCBs less than 50 ppm. During extraction of the two groups of ten, the solvent did not attack the dry parts, instead extracting only the waxy matter. Therefore, any cable which was free of a waxy or greasy material was eliminated from further analysis. This reduced from 50 to 35 the number of individual cables analyzed for PCBs.

The overall process for selecting cables for further analysis is illustrated in Figure 3.

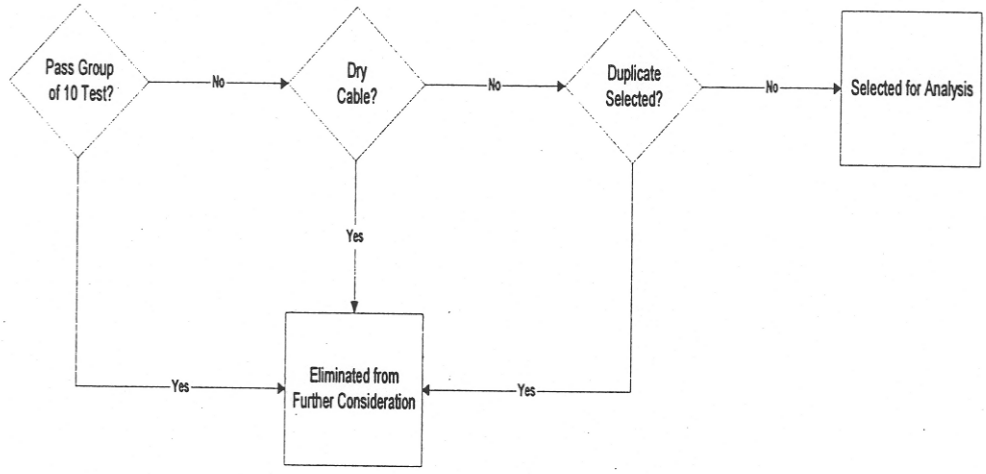

Figure 3. Process for the Selection of Cables for Further Analysis

4.1.3 Cable Analysis Results

Appendix A provides a detailed physical description of each of the cable samples. Descriptions for a few of the cables are not provided because the cables were undergoing analysis at the time the inspections were made and could not be made available.

A summary of the results of the chemical analyses and physical inspections of the cables are shown in Tables 9, 10, and 11. The data in the tables are organized in order of the ETSI number, and concentrations of PCBs at or above 50 ppm are highlighted in gray. Table headings are explained in Figure 4. Cable samples that were not individually analyzed are recorded as either "dry," indicating the sample exhibited no greasy or waxy impregnant, or as a four-digit number in brackets. This four-digit number is the ETSI sample number of the sample's visual twin.

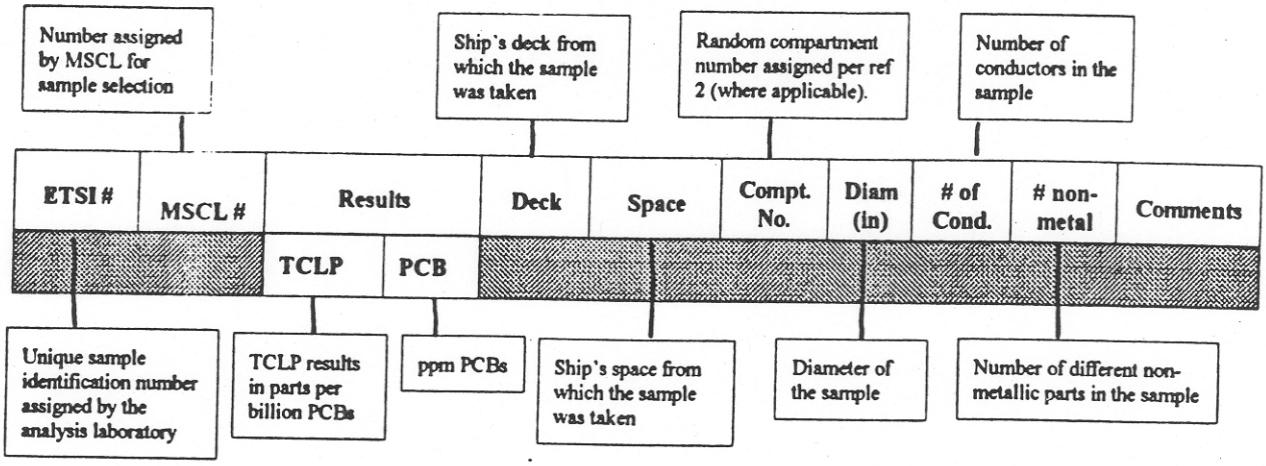

Figure 4. Key for Column Headings, Tables 9-11 and 13-18.

Table 9 summarizes results for EXPORT CHALLENGER. Ten of the 35 cable samples (28%) contained PCBs at or above 50 ppm. All TCLP analyses were less than 5 parts per billion.

Table 10 summarizes the results for SHIRLEY LYKES. Twenty-two of 31 cable samples (71%) contained PCBs at or above 50 ppm. All TCLP analyses were less than 5 parts per billion.

Table 11 summarizes the results for WAYNE VICTORY. No PCBs were found. Only in WAYNE VICTORY were lead-covered cables found (13 of 24 samples.) The internal nonmetallic components of all of the lead-covered cables were dry to the touch, with no evidence of a waxy or oily impregnating material. Some of the non-lead-covered cables evidenced a waxy or oily impregnating substance in the internal materials that was physically similar to the impregnant in the cables from the other two ships, but the impregnant did not contain PCBs.

4.1.4 Evaluation of Visually Identical Cable Groups

To test the assumption used to sort cables for analyses based on their visual appearance, individual PCB analyses were conducted on three cables in a set of four identical cables, and two cables in a second set of four identical cables. All the cables were from SHIRLEY LYKES. The results are shown in Table 12.

ETSI #	MSCL #	Results		Deck	Space	Compt. No.	Diam (in)	# of Cond.	# non-metal	Comments
		TCLP	PCB							
7068	1	n/a	Dry	Nav Bridge	Wheel House	1	1/2	2	5	depth sounder cable, aft bulkhead
7069	2	n/a	Dry	Nav Bridge	chart room	2	1	1	2	Radar power supply
7071	3	<5	65	Nav Bridge	gyro room	4	1/2	2	5	Fwd bulkhead
7072	4	n/a	Dry	Lower Bridge	Capts SR	1	3/8	3	6	lamp pwr cord
7074	6	n/a	Dry	Lower Bridge	radio room	7	1/2	19	20	cable behind console
7077	9	n/a	20	Fwd House Cabin	passageway	8	1/2	2	8	in locker
7078	8	n/a	<1	Fwd House Cabin	deck wing	3	3/4	7	17	cable on stbd wing
7079	10	n/a	Dry	Fwd House Cabin	forecastle deck	1	*	*	*	port cargo boom winch motor
7088	17	n/a	15	Aft House Bridge	officer's laundry	19	3/8	2	7	outlet power cable
7094	23	n/a	<1	Poop	bosun SR	11	1/2	2	4	in overhead
7095	24	n/a	[7099]	Poop	chief electr SR	12	1/2	2	4	in overhead
7097	25	n/a	[7078]	Poop	cook/baker SR	15	1/2	3	10	in overhead
7099	28	n/a	<1	Poop	F/W & oiler SR	18	1/2	2	4	desk lamp cable
7104	32	n/a	[7088]	Poop	cleaning gear lkr	35?	3/8	2	7	
7198	53	<5	48	Second	paint locker	15	1/2	2	7	switch in passageway
7200	44	<5	530	Main	dairy room	38	3/8	2	7	light switch wire
7201	49	n/a	[7227]	Main	cargo meat room	35	3/8	2	8	alarm switch wire
7202	39	n/a	Dry	Main	galley	39?	3/8	1	5	aft bulkhead receptacle wire
7203	36	n/a	Dry	Main	slop chest	31	1/4	1	1	aft bulkhead
7204	38	<5	70	Main	pantry	25	1/2	2	8	overhead
7205		<5	97	Main	soiled linen lkr	29	3/8	2	5	light switch cable
7206	42	n/a	[7205]	Main	dry stores	42	3/8	2	5	
7212	54	<5	660	Main	special cargo rm	4	1 7/8	3	10	light cord on overhead
7215	59	n/a	Dry	Main	MG room	12	1/2	1	2	battery cable
7220	62	<5	490	Main	hydraulic pump rm	16	1 7/8	3	10	large cable on switchboard
7222	64	<5	1100	Main	MG/fan room	17	2	3	13	switchboard cable
7224	67	n/a	[7226]	Second	bosun stores	1	5/8	3	9	
7226	66	n/a	18	Main	paint room	18	5/8	3	9	raceway
7227	82	<5	47		machinery space		3/8	2	9	
7230	69	n/a	Dry	Second	engr's workshop	13	1 1/4	3	10	fwd bulkhead
7243	74	n/a	Dry	Third	refrigerator room	2	1 1/4	3	13	motor power
7245	78	n/a	Dry	Third	machinery space		1	12	27	evporator, stbd
7247	72	n/a	[7227]	Third	machinery space		3/8	2	8	behind maneuvering panel
7249	79	<5	790	Third	machinery space		1	3	13	phone bell, fwd bulkhd by throttle
7251	73	n/a	[7249]	Tank Top	machinery space		1	3	13	
		* Sample not available for inspection			Average number of non-metal components				9	
		n/a = not analyzed		Dry = Sample not analyzed because internals were dry						
		[xxxx] = Sample not analyzed. Visually identical to [xxxx]								

Table 9. Summary of Results of EXPORT CHALLENGER Cable Sampling

Shaded text indicates PCB ≥50 ppm.

ETSI #	MSCL #	Results		Deck	Space	Compt. No.	Diam (in)	# of Cond.	# non-metal	Comments
		TCLP	PCB							
7166	1	n/a	Dry	Nav Bridge	Wheel House	1	3/8	1	2	Co-ax port side by door
7168	2	<5	3,900	Nav Bridge	Chart Room	2	3/4	8	28	Wind Indicator
7169	4	n/a	[7454]	Nav Bridge	Passageway	4	3/8	2	8	Wire to Alarm
7174	9	<5	360	Upper/Focsle/Winch	Dining Room	7	1/2	2	8	In Pantry
7176	21	n/a	Dry	Upper/Focsle/Winch	Chief Mate SR	19	1/4	2	4	Plastic Telephone
7178	20	n/a	[7454]	Upper/Focsle/Winch	3rd. Mate #2 SR	17	3/8	2	8	
7179	16	n/a	[7454]	Upper/Focsle/Winch	Jr. Asst Eng SR	12	3/8	2	8	In Overhead
7182	18	n/a	<1	Upper/Foclse/Winch	3rd. Asst Eng SR	14	3/8	2	8	
7185	11	<5	167	Boat/Cabin	Spare SR	10	1/4	3	6	Light Cable
7188	23	<5	2,400	Upper/Focsle/Winch	Winch Platform	23	1 3/4	2	8	Fr. 168-184 Motor Cable
7190	73	<5	2,710	Upper/Focsle/Winch	Weather Deck Port	8A	*	*	*	Boat Davit Motor
7193	43	<5	1,700	Main	MG Room	29	7/8	3	13	
7265	24	n/a	[7174]	Main	Windlass Room	2	1/2	2	8	Receptacle
7267	28	n/a	Dry	Main	Radar Room	4	3/8	1	2	Coaxial
7268	26	<5	2650	Main	MG Room	3	1 3/4	2	8	
7270	29	<5	56	Upper/Focsle/Winch	Deck penetration	5	1 7/8	2	7	
7271	30	<5	36	Main	MG Room	6	1/2	3	10	
7275	32	n/a	<1	Main	MG Room	7	7/8	2	8	
7281	34	n/a	[7174]	Main	Deck Util SR	17	1/2	2	2	Overhead
7283	36	<5	130	Main	EDG Room	22	1/2	3	10	
7291	42	<5	201	Main	SR	27	3/8	3	5	Lamp Wire
7293	46	n/a	[7442]	Main	Hoist Machy Rm.	40	1 3/8	30	93	
7295	75	n/a	[7283]	Main	Weather Deck	30A	1/2	3	10	Aft. Stbd Topping Winch
7431	56	<5	560	Machinery Space	Evaps	5	1/2	2	8	
7433	57	n/a	[7168]	Machinery Space	By SSTG Stbd.	5	3/4	8	28	
7436	55	<5	394	Machinery Space	LL Port (pump)	5	1/2	3	10	
7440	59	n/a	8.3	Machinery Space	SS Air Comp	5	1/2	3	10	
7442	58	<5	698	Machinery Space	Temp. Recorder	5	1 3/8	30	93	
7451	66	n/a	<1	Upper Tween	Eng. Stores	19	1/2	2	7	
7453	79	n/a	<1	Upper Tween	Deck spares	10	1/2	4	11	
7454	80	<5	320	Upper Tween	Deck spares	10	3/8	2	8	
		*Sample not available for inspection			Average number of non-metal components				15	
		n/a = not analyzed. Dry = Sample not analyzed because internals were dry								
		[xxxx] = Sample not analyzed. Visually identical to [xxxx]								

Table 10. Summary of Results of SHIRLEY LYKES Cable Sampling

Shaded text indicates PCB ≥50 ppm.

ETSI #	MSCL #	Results		Deck	Space	Compt. No.	Diam (in)	# of Cond.	# non-metal	Comments
		TCLP	PCB							
7460	50	n/a	<40	First platform	Machinery		*	*	*	
7461	39	n/a	<40	Machinery space	switchboard		1 1/4	2	7	
7463	38	n/a	<40	Machinery space			3/4	2	7	fwd bulkhead center
7464	32	n/a	<40	Machinery space	switchboard		7/8	1	3	stbd back of switchboard
7465	34	n/a	<40	Machinery space	SSTG		1/2	1	3	aft end of stbd SSTG
7467	35	n/a	<40	Machinery space	Distribution box		3/4	3	9	aft bulkhd port dist box
7475	42	n/a	<40	Machinery space	lower level port		3/4	3	9	main circ pump
7482	6	n/a	<40	Bridge	pilot house		5/8	6	15	
7484	4	n/a	<40	Bridge	chart room		7/8	6	15	port side fwd bulkhead
7485	3	n/a	<40	Bridge	pilot house		7/8	24	51	port side, cable to radar power supply
7486	1	n/a	<40	Top of Wheel House			5/8	2	7	starboard king post aft end
7488	11	n/a	<40	Cabin	machinery casing	6	5/8	2	7	fwd bulkhead alarm cable
7489	8	n/a	<40	Cabin	cabin center	4	1/4	3	6	fan cable, port side
7490	9	n/a	<40	Cabin	cabin stbd	16	5/8	2	5	armored fan power cord
7495	15	n/a	<40	Boat	cabin port side	4	1 1/8	2	7	overhead
7502	21	n/a	<40	Main	winch platform	4	1 1/16	2	5	stbd side of CL mast aft of house
7503	19	n/a	<40	Boat	winch platform	19	5/8	2	5	anchor windlass control pwr cable
7505	20	n/a	<40	Main	winch platform	43	5/8	2	5	port side of aft house
7506	31	n/a	<40	Second	room aft flat port fwd	35	5/8	2	5	light cable
7508	29	n/a	<40	First Platform	access to holds 4/5		5/8	2	5	port side main deck access to holds
7513	24	n/a	<40	Main	storeroom aft flat	33	3/8	2	5	fwd cabin port of CL, switch cable
7516	26	n/a	<40	Second	CO2 room port fwd	15	5/8	2	7	
7524	25A	n/a	<40	Main	locker port inboard	37	5/8	2	7	port inboard sink room, lite cable
7526	31	n/a	<40	Second	machinery space	22	1 1/8	3	9	stbd side raceway
		* Sample not available for inspection			'Average number of components				9	

Table 11. Summary of Results of WAYNE VICTORY Cable Sampling

Table 12. Analysis of Duplicate Cables

	ETSI #	ppm PCBs
First Quadruplicate Set	7271	36
	7283	130
	7436	394
	7295	n/a
Second Quadruplicate Set	7174	360
	7265	n/a
	7281	n/a
	7431	560

The results show that it may not be correct to select one cable from a group of visually identical cables to represent the group. Note that had sample 7271 been selected to represent the first group, all in the group would have been considered to contain levels of PCBs less than 50 ppm, whereas in fact at least two cables in the group contain levels above 50 ppm.

Assuming that the analysis presents the potential for all visually identical samples to show variability in PCB content, the PCB content of cables as shown in Tables 9, 10, and 11 may over or underestimate actual PCB content of a single cable. This study did not investigate the source of PCBs in cables. PCBs may have been present as part of the cable manufacturing process, or may have resulted from cable installation of operational maintenance.

4.2 VENTILATION SYSTEM GASKETS

4.2.1 Gasket Materials

Seven different kinds of ventilation system gasket materials were found in the three ships. Wax-impregnated felt was found exclusively in WAYNE VICTORY, while the other ships had some felt gaskets along with gaskets made of foam rubber, processed cork, cloth-inserted rubber, solid sheet rubber, a single example of wax-impregnated fabric (in EXPORT CHALLENGER), and a single example of a dry fibrous material (in SHIRLEY LYKES). Each sample was visually inspected in an attempt to determine the gasket materials. Some of the gaskets were severely damaged from many years of use, making identification difficult. With few exceptions, however (noted in the tables as simply "gasket"), identification could be made.

EXPORT CHALLENGER has a large number of similar gaskets that are identified in the table as "processed cork." It is not certain that the material is indeed made from cork; however, the material visually resembles cork—ground to fine particles averaging about 1/16

inch in diameter, mixed with a black rubbery substance, and spread between two sheets of cheesecloth to form a gasket.

4.2.2 Gasket Sampling Results

The results of the ventilation gasket sampling are shown in Tables 13, 14, and 15. (Refer back to Figure 4 for an explanation of the table headings.) Results have been organized into groups of similar materials, and each group is arranged in order of the ETSI sample number. Those containing PCBs at or above 50 ppm are highlighted in gray. Note that in all three ships, half or more of the ventilation system gaskets sampled contained concentrations of PCBs at or above 50 ppm.

Six different kinds of materials were found in the ventilation system gaskets of EXPORT CHALLENGER (Table 13), and two of the material types contained high levels of PCBs. The single felt sample from EXPORT CHALLENGER contained no PCBs.

Three different gasket materials were found in SHIRLEY LYKES (Table 14), and two contained high levels of PCBs.

Felt was the only type of ventilation gasket material found in WAYNE VICTORY (Table 15), and all but one sample showed high levels of PCBs.

4.3 OTHER PCB MATERIALS

4.3.1 Material Categories

Nine different material categories were sampled, as explained in Section 2.1.1.5, and the results are summarized in Tables 16, 17, and 18. Results showing concentrations of PCBs at or above 50 ppm are highlighted in gray. At least three categories of other PCB materials were found in the ships. All three ships had high PCB levels in door and hatch gaskets and machinery gaskets (category 3) and grout, caulk, and rubber isolation mounts (category 7). WAYNE VICTORY and EXPORT CHALLENGER also had high PCB levels in thermal insulation (category 5).

The results for EXPORT CHALLENGER are shown in Table 16. Concentrations of PCBs at or above 50 ppm were found in four of the eight categories sampled. While category 10 (miscellaneous materials) showed no high PCB levels, the processed cork machinery closure gaskets included in this category were visually identical to the processed cork found in ventilation gaskets, nine of which showed high PCB levels.

Results for SHIRLEY LYKES are shown in Table 17. Concentrations of PCBs at or above 50 ppm were found in three of the nine categories that were sampled in this ship. Of particular interest is the high PCB value found in silver duct tape (ETSI # 7292). The tape was fresh and flexible. It appeared to be no more than 1 or 2 years old.

ETSI #	MSCL #	Results	Deck	Space	Compt. No.	Type *	Comments
7098	26	641	Poop	cook/baker SR	15	cloth inserted rubber	head, in overhead
7107	33	763	Poop	able seaman	33	cloth inserted rubber	overhead vent
7209	88	133	Aft house top	fan room	7	cloth inserted rubber	overhead vent
7216	57	206	Main	MG room	12	cloth inserted rubber	center of compartment
7218	60	<42	Main	MG/fan room	6	cloth inserted rubber	fwd port corner
7223	65	<42	Main	MG/fan room	17	cloth inserted rubber	overhead vent
7242	80	<45	Second	machinery space		cloth inserted rubber	port
7199	87	<50	Main	passageway	35	felt, 1/8", gray	overhead vent
7234	70	<50	Second	reefer room	10	foam rubber	crumbled, black. Stbd side
7070	84	<47	Nav Bridge	gyro room		foam rubber, 1/8"	
7091	20	<50	Aft House Bridge	passageway	26	foam rubber, 1/8"	overhead vent
7251?	73	<50	Third	machinery space		gasket	vent gasket aft of maneuvering panel
7075	7	141	Fwd House Cabin	2nd Ofcr SR	5	processed cork	overhead vent
7086	15	88	Aft House Bridge	1st Asst Eng SR	17	processed cork	overhead vent
7090	19	254	Aft House Bridge	Jr Eng SR	25	processed cork	overhead vent
7092	21	365	Aft House Bridge	Ch Steward SR	27	processed cork	overhead vent
7100	29	202	Poop	wiper SR	20	processed cork	overhead vent
7102	31	160	Poop	messman SR	21	processed cork	overhead vent
7109	35	115	Poop	Able Seaman/quartermaster		processed cork	overhead vent
7112	43	109	Main	garbage room	43	processed cork	overhead vent
7096	27	223	Poop	chief elect SR	12	processed cork	overhead vent
7210	55	<50	Main	special cargo rm	4	processed cork	aft bulkhead overhead
7082	11	28	Aft House Bridge	3rd Asst Eng SR	15	processed cork	overhead vent
7093	22	<47	Aft House Top	emerg gen room	7	processed cork	overhead vent
7105	86	<38	Poop	messman SR		processed cork	overhead vent
7211	56	<29	Main	MG/fan room	6	processed cork	ducting
7236	71	<20	Third	reefer/dry cargo rm	9	processed cork	aft bulkhead
7080	12	33	Aft House Bridge	2nd Asst Eng SR	12	sheet rubber	overhead vent
7233	81	<33	Second	machinery space		sheet rubber	stbd by boiler
7214	89	<42	Main	MG room	7	wax impregnated fabric	vent duct

Table 13. EXPORT CHALLENGER Ventilation System Gaskets Sampling Results

*Based upon visual inspection
Shaded text indicates PCB ≥50 ppm.

ETSI #	MSCL #	Results	Deck	Space	Compt. No.	Material	Comments
7170	3	722	Nav Bridge	radio cabin	3	felt, 1/16", dark brown	Overhead
7175	10	1,500	Upper/Focsle	fan room	6	felt, 1/8", dark brown	
7192	48	18,900	Main	MG room	29	felt, 1/8", dark brown	
7269	27	4,890	Main	MG room	3	felt, 1/8"	Air Handler
7437	54	4,820	Machinery Space	LL aft. stbd	5	felt, 1/8", dark brown	
7441	53	17,100	Machinery Space	by switchboard	5	felt, dark brown	
7445	61	6,330	Machinery Space	boiler front	5	felt, 1/16", dark brown	
7448	65	6,780	Upper Tween	elect shop	12	felt, 1/8", dark brown	
7449	62	7,100	Upper Tween	deck spares	10	felt, 1/8", dark brown	
7450	64	8,810	Upper Tween	CO2 room	13	felt, 1/8", dark brown	
7452	67	13,620	Upper Tween	compartment	18	felt, 1/8", dark brown	
7455	76	174	Machinery Space	upper level	5	felt, 1/4", black	Port Side
7167	5	<44	Nav Bridge	cabin		felt, 1/8", black	about 8" diam.
7272	31	<23	Main	MG room	6	felt, 1/8", dark brown	
7294	74	<43	Main	weather deck	30A	felt, 1/2", dark brown	Aft Deckhouse Stbd
7191	44	1660	Main	deck locker	30	unidentifiable gasket	
7289	39	<39	Main	unnamed compt.	24	fibrous material	fr 144-151 stbd
7173	8	1600	Upper/Focsle/Winch	lounge	5	foam rubber	lightweight, thin, pale grey or light brown
7177	19	13,100	Upper/Focsle	Asst. Elect. SR	15	foam rubber	lightweight, thin, pale grey or light brown
7184	14	1,210	Upper/Focsle		10	foam rubber	lightweight, thin, pale grey or light brown
7187	13	1,470	Boat/Cabin	Ch. Eng. office	12	foam rubber	lightweight, thin, pale grey or light brown
7280	33	1,035	Main	messmen SR	14	foam rubber	lightweight, thin, pale grey or light brown
7282	35	1,162	Main	wiper SR	20	foam rubber	lightweight, thin, pale grey or light brown
7288	38	188	Main	hospital	23	foam rubber	lightweight, thin, pale grey or light brown
7290	41	967	Main	SR	26	foam rubber	lightweight, thin, pale grey or light brown
7181	17	<38	Upper/Focsle	Jr. Asst Eng SR	13	foam rubber	lightweight, thin, pale grey or light brown
7186	12	<37	Boat/Cabin	Chief Eng. SR	11	foam rubber	lightweight, thin, pale grey or light brown

Table 14. SHIRLEY LYKES Ventilation System Gaskets Sampling Results

Shaded text incidates PCB ≥50 ppm.

ETSI #	MSCL #	Results	Deck	Space	Compt. No.	Material	Comments
7459	37	3,600	Machinery space	port side		felt, 1/8"., dark brown	port side
7469	40	5,040	Machinery space	starboard side		felt, crumbled	stbd side
7476	43	11,240	Machinery space	lower level		felt, 1/8", dark green	port middle
7477	44	5,870	Machinery space	lower level		felt, gray	port fwd
7491	12	5,290	Cabin	fwd passageway stbd	17	felt, 1/8", dark green	
7493	10	9,510	Cabin	passageway		felt, 1/8", dark gray-green	
7494	13	5,490	Cabin	stbd aft passageway	11	felt	
7498	16	1,230	Boat	cabin port side	3	felt, 1/8", dark gray	head cntr line
7499	14	9,480	Boat	cabin stbd	1	felt, 1/8", dark green	fwd head
7500	23	3,116	Main	cabin port fr 89	15	felt, 1/8", dark green	port passage aft
7501	22	3,390	Main	cabin stbd fr 74	7	felt, 1/8", dark green	port inboard head
7507	30	157	Second	aft flat fr 155	37	felt, 1/8", dark green	
7509	52A	7,330	Main	mess deck	1	felt, 1/16", black	
7510	51	123	Main	galley, stbd side	44	felt, mottled brown	
7511	56	4,660	Main	galley	44	felt, 1/16", black	
7515	54	4,780	Main	head port inboard		felt, 1/16", dark green	
7519	27	3,910	Second	galley stores	16	felt, 1/8", dark brown	port outboard
7520	57	4,930	Second	galley	16	felt, charcoal gray	
7521	25	6,680	Second	port side ladder	na	felt, 1/8", dark green	ladder between main and 2nd deck
7527	32A	946	Second	machinery space	22	felt, 1/8", brown	
7528	49	673	First Platform	room fr 90-93	5	felt, 1/8", dark brown	switchboard vent gasket
7529	58	503	Main	engnrs. head		felt, dark brown	
7525	55	<17	Main	head stbd passageway	17	felt, 1/8", dark brown	

Table 15. WAYNE VICTORY Ventilation System Gaskets Sampling Results

Shaded text indicates PCB ≥50 ppm.

ETSI #	MSCL #	Results	Deck	Space	Compt. No.	Cat.	Material	Comments
7113	45	1,092	Main	dairy room	38	3	foam rubber 1"x1/2"	door gasket
7252	76	102	Tank top	machinery space		3	rubber	distribution box gasket
7197	52	251	Second	carpenter shop	14	3	solid rubber	loose rubber 0-ring gasket on work bench
7116	48	432	Main	cargo meat room	35	3	foam rubber, 1"x1/2"	door gasket
7115	47	1,840	Main	fruit & veg room	34	3	cloth inserted rubber	door gasket
7108	34	<11	Poop	Able Seaman	33	3	foam rubber	window gasket
7221	63	<36	Main	compartment fr131	20	3	solid rubber, 1/2"x1 1/4"	hatch gasket, deck fwd
7213	68	<38	Poop	focsle deck	1	3	solid rubber	winch motor port
7089	18	<47	Aft House Bridge	survival gear lkr	20	3	foam rubber, 1/8"	locker door gasket
7085	85	1880	Aft House Bridge	Officers Mess		4	felt, 1/8"	light fixture gasket
7110	41	<50	Main	galley	23	4	felt, 1/8", dark gray	exhaust fan gasket over fryer
7217	58	478	Main	fan room	14	5	foam rubber	thermal insulation
7087	16	7	Aft House Bridge	Officer's laundry	19	5	lagging cloth	hot water pipe
7228	83	*		machinery space		5	foam rubber	pipe insulation on reefer
7248	77	<47	Third	machinery space		6	air filter	felt filter, control air compressor
7114	46	2,240	Main	fruit & veg room	34	7	caulk	gray, solidified. Pipe thermal penetrator, fwd bulkhd
7196	51	<32	Second	steering gear rm	16	7	paint	paint in cans, fwd bulkhead
7083	14	<1	Aft House Bridge	3rd Asst Eng WC	16	7	water closet grout	shower base
7231	90	<34	Second	machinery space		7	caulk	elect. stuffing tube caulk
7117	50	<50	Second	steering gear rm	16	7	solid rubber, 7/8"x1"	rubber gasket at foot of ladder
7111	40	<45	Main	stbd fuel oil fill sta	26	9	felt, 1/8", dark gray	pipe hanger,aft bulkhead
7073	5	<34	Lower Bridge	Capt's WC	2	10	white rubber	rubber spacer on toilet seat
7219	61	<44	Main	hydraulic pump rm	16	10	processed cork	machinery closure, port side
7235	91	<39	Second	upper twin	5	10	processed cork	closure gasket
7793	105	<50	Main	forward windlass		11	oil	
7794	106	**		forward windlass		11	grease	
7795	107	<50		after steering		11	oil	
7796	108	**		after steering		11	grease	

* Could not be analyzed. Sample extract solidified.

** Could not be analyzed. Excessive impurities.

Table 16. EXPORT CHALLENGER - Other PCB Sample Results

Shaded text indicates PCB ≥50 ppm.

ETSI #	MSCL #	Results	Deck	Space	Compt. No.	Cat.	Type	Comments
7287	40	155	Main	SR	25	3	hard rubber, black	sink gasket
7284	37	661	Main	EDG Room	22	3	solid rubber, 1"x1/2"	water tight door gasket
7300	48	1,332	Machinery Space	Throttle Sta	5	3	solid rubber	red, 11 inch circle
7276	69	<43	Main	MG Room	7	3	cloth inserted rubber	machinery closure
7189	22	<50	Boat/Cabin	Fan Room	14	3	foam rubber, black	fan room closure, heavy, black
7264	49	<39	Upper/Focsle/Winch	Focsle	1	4	felt, 1/8", brown	winch controller closure
7279	68	<46	Main	Crew Lounge	9	5	fibrous gray insulation	from bulkhead
7298	49A	<47	Machinery Space	Reefer Plant	5	5	fiberous insulaiton	cold pipe thermal Insulation
7444	51	<23	Machinery Space	At Phone Booth	5	6	fiberous insulation	phone booth sound ampening
7297	52	466	Machinery Space	Watch Desk	5	7	foam rubber	dense, soft, vibration dampening
7274	71	<48	Main	Weather Deck	7A	7	stuffing tube caulk	hatch 3
7446	63	<4	Upper Tween	Elect Shop	12	7	paint thinner	unused
7292	45	759	Main	Dairy Room	34	8	duct tape	silver cloth
7266	25	<22	Main	Bosn Stores	1	8	duct tape	red cloth
7435	50	<10	Machinery Space	By Main Engine	5	9	felt	pipe hanger liner
7273	70	<1	Main	Weather Deck	7A	10	black plastic	hyd hose, Hatch 3, metal reinforced
7432	60	<44	Machinery Space	SWBD	5	10	solid plastic, black	General Electric switch plate cover
7789	101	<50		forward windlass		11	oil	
7790	102	*		forward windlass		11	grease	
7791	103	<50		after steering		11	oil	
7792	104	*		after steering		11	grease	

* Could not be analyzed. Excessive impurities.

Table 17. SHIRLEY LYKES - Other PCB Sample Results

Shaded text indicates PCB ≥50 ppm.

Concentrations of PCBs at or above 50 ppm were found in three of the six categories sampled in WAYNE VICTORY (Table 18).

4.4 NON-PCB SAMPLES

4.4.1 Materials and Results

Other samples were taken to look for asbestos, cadmium, ethylene glycol, freon, lead, mercury, polycyclic aromatic hydrocarbons, and tin (in organo-tin bottom paint). These materials were selected as representative of the types of materials that may be encountered in commercial ships which would have environmental, safety and health consequences.

- Asbestos was tested for in thermal insulation, putty, valve packing, deck tiles, gaskets, electrical insulation, pipe hanger liners, overhead (ceiling) tiles, and caulk. Asbestos results are reported in percent by weight total asbestos in the sample.

- Cadmium was once a common plating material. Samples of metal fasteners were recovered, the surface filed off, and the filings analyzed for total cadmium metal. The results are reported in parts per million cadmium, by weight in the filings.

- Most types of chlorofluorocarbon refrigerants and propellants (freon) will soon be banned because of international treaties. Samples of refrigerants from shipboard cooling systems were taken and analyzed to determine whether freon compounds were present, and if so, what type of Freon was found. R-12 (dichlorodifluoro-methane) was the only refrigerant found. Results are reported as R-12 (present).

- Lead was analyzed for in paint, gaskets and joint compound. Results are reported in parts per million, by weight.

- Mercury was tested for in a machinery system liquid level gauge and in some fluorescent light bulbs. Results are reported in parts per million by weight of the fluorescent tube and in parts per billion by weight of fluid recovered from the gauge.

- Organo-tin was once a common antifouling ingredient used in bottom paints on ships. Samples of hull paint from above the waterline were analyzed for tin. Note that when used as an antifouling agent, tin would be present in paint at concentrations of approximately 2% to 4% by weight.

All of the potential contaminants sampled for were found in the ships, except for tin in hull paint. While detectable, the levels of tin are far below those expected in organo-tin antifouling paint. This may be because this paint was not used or because the samples do not represent the bottom paint on the ships. The results for each ship are summarized in Tables 19, 20 and 21.

ETSI #	MSCL #	Results	Deck	Space	Compt. No.	Cat.	Type	Comments
7466	36	140	Machinery space			3	hard rubber	loose gasket
7478	41	69	Machinery space	lower level, port		5	lagging cloth	thermal insulation, w/paint and adhesive
7497	18	<50	Boat	vestibule	8	5	thermal insulation	port vestibule behind door
7472	52	10,620	Machinery space	lower level		7	caulk in fibrous mat	aft end of boiler casing, starboard
7473	46	653	Machinery space	lower level		7	stuffing tube caulk	black, dried, with paint residues
7487	2	<39	Top of Wheel House	stbd wing		7	stuffing tube caulk	two compounds, one gray, one brown
7517	48	*	Main	storeroom aft flat	33	7	epoxy	galley stores, unused
7518	28	*	Main	storeroom aft flat	33	7	epoxy	galley stores, unused
7496	17	33	Boat	machinery casing	18	9	rubber	stbd side gauge line pipe hanger
7471	45	<41	Machinery space	lower level		10	cloth insert rubber	V belt, aft stbd
7512	53	<47	Main	cabin, port	17	10	solid rubber	port hole deflector (on bunk)
7797	109	<50		after steering		11	oil	
7798	110	<50		after steering		11	grease	

* Could not be analyzed. Sample extract solidified.

Table 18. WAYNE VICTORY - Other PCB Sample Results

Shaded text indicates PCB ≥50 ppm.

ETSI #	MSCL #	Results	Contaminant	Material	Deck	Space
7084	M2	<1%	asbestos	deck tile	Aft House Bridge	3rd Asst Eng SR
7103	M4	35%	asbestos	ceiling tile	Main	crews' rec room
7106	M14	<1%	asbestos	electrical insulation, new	Poop	Messman/QM
7229	M7	<1%	asbestos	putty, vent blower shroud	Second	machinery space
7232	M6	30%	asbestos	loose roll of asbestos cloth	Machinery Space	engine room
7237	M9	85%	asbestos	heat shield	Third	SR 138
7238	M17	85%	asbestos	valve packing	Third	behind boiler
7239	M8	45%	asbestos	loose flexitallic gasket	Third	work bench
7240	M10	40%	asbestos	new valve packing	Third	
7246	M11	<1%	asbestos	pipe hanger liner	Fourth	machinery space
7847	M2	<1%	asbestos	deck tile	Aft house	Engr SR
7244	M18	206 ppm	cadmium	3/4" hex nut	Third	machinery space
7207	M15	59%	ethylene glycol	coolant from heating system	Poop	AB seaman
7208	M3	33%	ethylene glycol	emergency gen coolant	Aft House Top	Emerg Gen Room
7533	M5	R-12	freon	refrigeration system	Main	pantry
7534	M13	R-12	freon	reefer	Third	machinery space
7241	M12	69,900 ppm	lead	peeling paint on vent duct	Second	machinery space
7076	M1	24.6 ppm	mercury	flourescent tube	Aft House Bridge	2nd Ofcr SR
7225	M16	1100 ppm	PAH*	paint chips	Second	bosun
7535	M19	12.9 ppm	tin	hull paint	Hull	
	* Polycyclic aromatic hydrocarbons					

Table 19. EXPORT CHALLENGER Non-PCB Samples

4.0 RESULTS

Detailed results of the analyses performed by both laboratories have been forwarded to MARAD separately. A summary of the results is provided in the following sections. The very high PCB levels found in some of the samples were difficult to determine with accuracy. In some instances, the laboratory results were in excess of the calibration standards for the procedure. Values for these samples are reported as being equal to the highest calibration standard (thousands of parts per million), as their actual value lies outside the accepted calibration curve. Due to the potential for error, an extrapolated value is not acceptable. In some instances, the laboratory reported >xxx where xxx is a numerical value of thousands of parts per million for PCBs. In these instances, the value is reported in the tables as xxx. Also, the PCB values in the tables are reported as total PCBs (the sum of all detected Aroclors). All total PCB values in the tables at or above 50 ppm are highlighted in gray.

Consistent with the Sampling Plan, the data from the sampling and analysis program are reported in four groups: Electric cables, ventilation system gaskets, other PCB materials, and non-PCB samples.

4.1 ELECTRIC CABLES

4.1.1 Cable Construction

Based on its appearance, most of the cable in EXPORT CHALLENGER and SHIRLEY LYKES appears to conform to Institute of Electric and Electronic Engineers (IEEE) Specification 45, Type A/Z.[13] This is a standard commercial specification for shipboard cables used at the time of construction of these ships. Some of the cable in WAYNE VICTORY appears similar to that in EXPORT CHALLENGER and SHIRLEY LYKES, but much of it was built to an earlier, unknown specification calling for an outer lead cover in addition to armor braid and plastic or rubber insulation. Typical cable construction used in EXPORT CHALLENGER and SHIRLEY LYKES is illustrated below as Figure 2.

[13] B. Jackson, Naval Sea Systems Command, January 1996.

ETSI #	MSCL #	Results	Contaminant	Material	Deck	Space
7180	M1	70%	asbestos	overhead tile	Upper focsle	SR fr 146-148 port
7194	M7	55%	asbestos	flexirtallic gasket	Machinery Space	throttle control
7195	M11	55%	asbestos	face flange gasket	Machinery Space	desk
7277	M4	<1%	asbestos	floor tile	Main	galley
7278	M5	<1%	asbestos	mastic adhesve	Main	galley
7286	M3	<1%	asbestos	sound dampening	Main	EDG Room
7296	M6	70%	asbestos	pipe hanger liner	Machinery Space	evaporators
7299	M9	95%	asbestos	valve packing, unused	Machinery Space	workbench
7434	M12	35%	asbestos	caulk	Machinery Space	port throttles
7443	M8	<1%	asbestos	Thermal insulation, hot pipe	Machinery Space	lagging pad
7848	M4	<1%	asbestos	deck tile	Main, galley	
7439	M15	72.5 ppm	cadmium		Machinery Space	foundation bolt
7285	M2	36%	ethylene glycol	cooling system	Main	EDG Room
7536	M13	R-12	freon	A/C Compressors	Machinery Space	A/C plant
7537	M14	*	freon	Reefer Compressor	Machinery Space	reefer plant
7438	M10	2,680 ppm	lead	paint chips	Machinery Space	bilge
7447	M16	2.3 ppm	mercury	Fluorescent light tube	Upper Tween	elect. shop
7538	M17	12.6	organotin (tin)	paint chips	hull	
	* sample escaped, no analysis performed					

Table 20. SHIRLEY LYKES Non-PCB Samples

ETSI #	MSCL #	RESULTS	Type	Material	Deck	Space
7457	M6	55%	asbestos	flexitallic gasket on workbench		machinery space
7462	M9	40%	asbestos	stuffing tube putty	Upper flat	mach space, stbd
7479	M8	80%	asbestos	pipe hanger	Upper flat	mach space, stbd
7480	M10	40%	asbestos	steam valve packing	Upper flat	mach space, stbd
7481	M12	<1%	asbestos	main steam line insulation	Upper flat stbd	machinery space
7492	M14	35%	asbestos	cable covering	Cabin	radio room
7514	M3	<1%	asbestos	pipe lagging	Main stbd	fwd cabin
7849		90%	asbestos	packing		
7850		80%	asbestos	bulkhead insulation		
7851		85%	asbestos	bulkhead insulation		
7852		<1%	asbestos	bulkhead insulation		
7470	M11	18 ppm	cadmium	bolt from port turbine housing		mach space
7531	M5	R-12	freon	refrigerant	Lower flat	machinery space
7468	M13	229 ppm	lead	loose gasket	Upper flat	mach space, port aft
7474	M7	1,160 ppm	lead	boiler paint	Lower flat	mach space, stbd
7522	M2	2,160 ppm	lead	sink drain pipe joint	Main deck	stbd side head
7458	M1	>33 ppb	mercury	gauge	Upper flat	mach space
7532	M17	4.2 ppm	organotin (tin)	hull paint	Hull	
7504	M16	**	PAH*	paint	anchor locker	
	* Polycyclic aromatic hydrocarbons					
	** Attempted analyis for phenanthrine. Failed due to excessive contamination					

Table 21. WAYNE VICTORY Non-PCB Samples

This Page Intentionally Left Blank

5.0 CONCLUSIONS

Samples of various materials from EXPORT CHALLENGER, SHIRLEY LYKES, and WAYNE VICTORY were recovered and analyzed for polychlorinated biphenyls and other contaminants. Many samples showed the presence of contaminants at concentrations that will be impacted by environmental, safety and health rules during breaking and recycling of the ships.

There are many differences among the three ships in the types of materials used and the concentrations of potentially hazardous materials present, particularly with regard to PCBs. No pattern emerged that could be called typical of all three ships.

These results show that environmental, safety and health controls will be required during breaking and recycling of these ships, and that each ship presents unique problems. Reference 5 assesses the significance of the results.

This Page Intentionally Left Blank

REFERENCES

1. Sampling Plan for WAYNE VICTORY, EXPORT CHALLENGER and SHIRLEY LYKES, September 28, 1995.

2. Maritime Administration, Report MA-ENV-820-96003-C, *Current and Advanced Technologies for the Ship Breaking/Recycling Industry*, July 1997.

3. Maritime Administration, Report MA-ENV-820-96003-B, *Substantive Law on Environmentally Compliant Ship Breaking/Recycling in the United States*, July 1997.

4. Maritime Administration, Report MA-ENV-820-96003-A, *The Legal Environment for Environmentally Compliant Ship Breaking/Recycling in the United States*, July 1997.

5. Maritime Administration, Report MA-ENV-820-96003-E, *Survey of Ships and Materials*, July 1997.

6. Maritime Administration, Report MA-ENV-820-96003-F, *The Markets, Cost and Benefits of Ship Breaking/Recycling in the United States*, July 1997.

7. Maritime Administration, Environmental Assessment MA-ENV-820-96003, *Environmental Assessment on the Sale of National Defense Reserve Fleet Vessels for Scrapping,* July 1997.

8. EPA Guidance Document, *Sampling Ships for PCBs Regulated for Disposal.*

9. MSCL Inc. letter 95/207 of October 13, 1995 to Tony Baney, EPA.

10. EPA letter of October 26, 1995 to Denis Rushworth, MSCL Inc.

This Page Intentionally Left Blank