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APPENDIX E. SURVEY OF SHIPS AND MATERIALS

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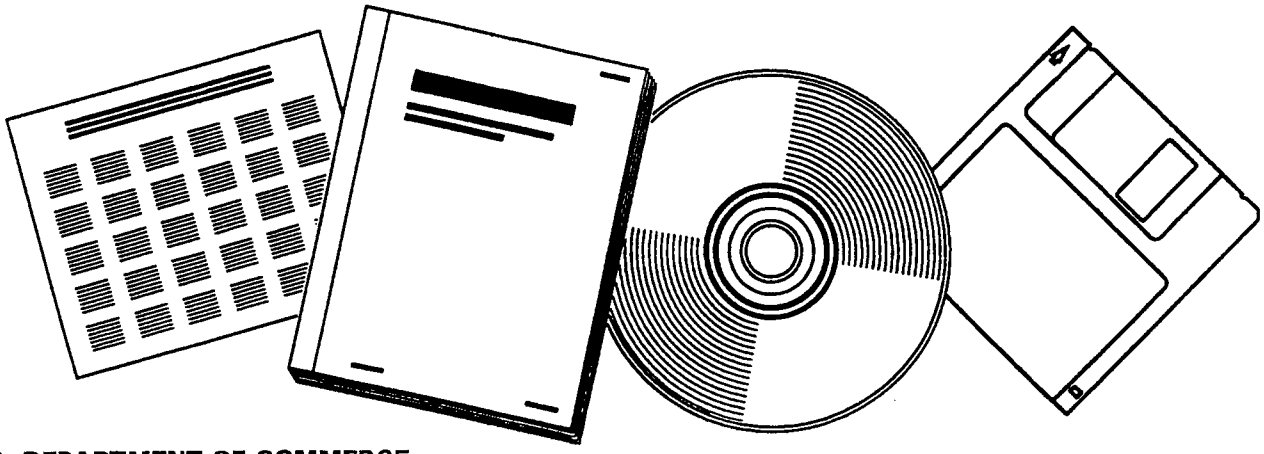

U.S. DEPARTMENT OF COMMERCE
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APPENDIX E

SURVEY OF SHIPS AND MATERIALS

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

Contract No. DTMA91-93-C-00004

U.S. Department of Transportation

Maritime Administration

JULY 1997

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Three inactive Maritime Administration ships were sampled for hazardous materials. An analysis determined the materials present and the problems presented to domestic ship breaking/recycling and to the export of ships for recycling overseas. Polychlorinated biphenyls (PCBs) and other hazardous materials were found in the ships. Based on the assumptions stated in the body of the report, it will cost approximately $71 per ton light ship weight to remove and dispose of most of the PCBs and other hazardous wastes from an otherwise intact ship.

The US Environmental Protection Agency's sampling guidance for PCB materials is reviewed based on the results from the three ships. Some shortcomings of the guidance are identified and alternative approaches are suggested.

New technologies and new regulatory approaches, such as on-site waste processing, new cutting techniques, and improved and minimized sampling requirements, may have an impact on cost and may substantially improve overall environmental compliance, whatever the ultimate use or disposition of the ships.

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EXECUTIVE SUMMARY

Three inactive Maritime Administration ships have been sampled for hazardous materials. An analysis determined the materials present and the problems presented to domestic ship breaking/recycling and to the export of ships for recycling overseas.

Polychlorinated biphenyls (PCBs) and other hazardous or potentially hazardous wastes were found in the ships. Based on the assumptions stated in the body of the report, it will cost approximately $71 per ton of light ship weight to remove most of the PCBs and other hazardous wastes from an otherwise intact ship. If removed before sale of the ships for recycling, this would relieve domestic scrappers of the need to manage these hazards and should significantly increase the value of the ships in the scrap market. Such removals might also allow other uses of ships such as for construction of artificial reefs and export overseas for scrapping. Our analysis shows that there are some small amounts of hazardous materials, particularly PCB materials, that cannot be removed without complete disassembly of the ship. Therefore, if alternative uses of largely intact ships are contemplated, some regulatory relief will be needed.

The EPA sampling guidance for PCB materials is reviewed based on the results from the three ships. Some shortcomings of the guidance are identified and alternative approaches are suggested.

New technology and new regulatory approaches (References 2, 4, and 5) may help overcome the high cost of environmental remediation in these ships. On-site waste processing, new cutting techniques, and improved and minimized sampling requirements may have an impact on cost and may substantially improve overall environmental compliance, whatever the ultimate use or disposition of the ships.

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1.0 INTRODUCTION

This report, along with the other reports of this series, References 1 through 7, provides technical, environmental, and cost/benefit evaluations of shipbreaking technologies in the United States. The purpose of the project is to provide to the U.S. Department of Transportation, Maritime Administration (MARAD):

- A survey of environmental 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 shipbreaking;
- A survey of current Federal, State and local environmental laws and regulations applicable to shipbreaking;
- A baseline economic case for cost-effective shipbreaking in the United States; and
- An environmental assessment for government shipbreaking in the U.S. that satisfies the National Environmental Policy Act (NEPA).

This report addresses the first of these items and provides an evaluation of the impact of the findings reported in the sampling and analysis report, Reference 3, for three ships in the MARAD James River Reserve Fleet. The inspection identified the nature and extent of the environmental problems revealed by the sampling reported in Reference 3. Other potential environmental problems not covered by the sampling and analysis report are identified.

This report includes cost estimates for removal of the hazardous materials from the three ships, in a manner that is consistent with domestic environmental law, from an otherwise intact ship. Removal of hazardous materials from an intact ship, before ship breaking/recycling begins, is not necessarily the approach a domestic recycler would use. A more common approach is to handle the hazardous materials as they are encountered during the reduction of the ship to scrap metals. However, we were unable to develop a cost estimate in this report for this more common process for a number of reasons:

- There is no domestic recycling of commercial ships being done in the United States at the present time that we could use as a pattern. While there is recycling of military surface ships underway on all three coasts of the Nation, all of the active recyclers may not be fully aware of all of the environmental problems inherent in the ships. Therefore, their current costs may not reflect a complete program.
- Reliable cost information for a very comprehensive environmental program is available from the Puget Sound Naval Shipyard with regard to recycling of

submarines. This is discussed in Reference 2. However, military vessels, particularly submarines, are much more complex than commercial vessels with far more extensive electrical, ventilation, and propulsion systems, and have, in addition, weapons systems. They must also be recycled with strict controls to prevent the unauthorized disclosure of classified information. Therefore, the cost to recycle submarines is not representative of the cost to recycle commercial vessels.

- The cost for dealing with environmental problems is affected by local labor rates, local environmental regulations, and other factors. We had ready access to cost information for work in the Norfolk, Virginia area but not for any area where commercial recycling of military surface ships is in progress.

Cost estimates for dealing with environmental problems in an intact ship would be useful for exploring other options, such as using ships for building artificial reefs, increasing the value of the ships by removing some or all of the hazards prior to sale, or preparing a ship for export for recycling. Therefore, we have developed costs for removal of hazardous materials from an otherwise intact ship, based on prices for various services in the Norfolk, Virginia area. The report provides estimates for the removal of cables, ventilation system gaskets, other polychlorinated biphenyl (PCB) materials, asbestos, and other environmental hazards found in the three ships. The report notes where removal of a known hazard from an otherwise intact ship either is not judged to be practical or is judged to be necessary to allow uses such as reef-building or export.

Where a cost estimate is provided, there is an implied assumption that environmental regulatory authorities will require removal of the material prior to the intended use of the ship. Environmental regulations allow for enforcement discretion; therefore, some regulators may not require all of the removal actions discussed in this report.

This report covers remedial actions and environmental costs for recycling small, break-bulk, steam-powered dry cargo ships built between 1945 and 1972. The report is organized such that information from all three ships is separated by material and usage: PCBs in electric cables and ventilation system gaskets, other PCB-bearing materials, and other hazardous materials. There are ship-to-ship differences between and within each of the four categories of information listed above. The three ships were built to different plans, in different yards, and, for one of them, at a very different time. Despite the differences, the average cost per ton of light ship weight for environmental remediation falls between $57 and $78 per ton.

1.1 BACKGROUND

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

- The EXPORT CHALLENGER (O.N. 6301775) was built in 1963 for MARAD by the Sun Shipbuilding & Dry Dock Company, Chester, Pennsylvania. She is a three-deck, general cargo ship having a light ship displacement[1] of 6,880 long tons,[2] an overall length of 494 feet, and a maximum beam of 73 feet. When fully loaded, the ship displaces 19,405 long tons at a draft of 30.5 feet. The ship is powered by two oil-fired superheating Babcock & Wilcox boilers feeding steam to a single, two-stage, General Electric main propulsion steam turbine. This turbine provides power to a single shaft and a nonferrous propeller through a double reduction gear. The hull is assembled from welded and riveted steel, and incorporates six cargo holds, each served by a hatch and cargo lifting gear.[3] The main machinery space in the EXPORT CHALLENGER is located as far aft as possible. Electric power is provided by two 700-kW steam powered electric generators and one 100-kW emergency diesel generator and is distributed through cable ways and electric distribution panels to services in the after house immediately above, to the forward house, and to other services such as lighting, and cargo handling gear. The ship is equipped with an extensive ducted ventilation system and carries about 12,500 tons of cargo.

- The SHIRLEY LYKES (O.N. 6203989) was built in 1962 for MARAD by the Bethlehem Steel Corporation, Shipbuilding Division, Sparrows Point, Maryland. She served from 1962 to 1972 as a two-deck, general cargo ship. In 1972, she was lengthened approximately 95 feet by Todd Shipyards Corp., 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 maximum beam of 69 feet. When fully loaded, the ship displaces 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 turbine provides up to 11,000 horsepower to a single shaft and a built-up stainless steel propeller through a double reduction gear. The hull is made of welded and riveted steel, and incorporates six cargo holds. Five are served by hatches and cargo lifting gear.[4] The SHIRLEY LYKES' main machinery space is located forward of the

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[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 (LSW) 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 on board.

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

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

[4] Ibid, p 1288.

aftermost cargo hold. Electric power is generated by two 600-kW steam powered electric generators and one 100-kW emergency diesel generator and is distributed through cable ways and electric power distribution panels to the after house, the forward house, and to other forward services such as lighting and cargo handling gear. The ship has an extensive ducted ventilation system and carries about 14,000 tons of cargo.

- The WAYNE VICTORY (O.N. 4509040) was built in 1945 for by the California Shipbuilding Corporation, Los Angeles, California. She 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, the ship displaces 15,200 tons at a draft of 28.6 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 turbine provides up to 6,600 horsepower to a single shaft through a double reduction gear. The hull is made of welded and riveted steel and incorporates five cargo holds, each served by a hatch and cargo lifting gear.[5] The main machinery space in the WAYNE VICTORY is located nearly amidship with the propeller being driven by a 165-foot long propeller shaft. Two of the WAYNE VICTORY's cargo holds are aft of the engine, three forward. Electric power is provided by two 300-kW steam powered electric generators and is distributed through cable ways and electric distribution panels to the single deck house directly above the main machinery space and to fore and aft services. The ship has very little ducted ventilation and carries about 11,000 tons of cargo.

Each of these ships was sampled for PCB-contaminated materials and for other potential environmental contaminants and the results reported in Reference 3. As discussed in Reference 3, the sampling for PCBs conformed as closely as practicable to guidance provided by the Environmental Protection Agency (EPA). PCBs are not the only environmental problem to be found in old ships. Built many years ago with the products in common use at the time, old ships contain asbestos, lead-bearing paint, chromate-bearing paint, cadmium plate products, and other potentially harmful accumulations of debris from many years of service. Because of the issues with PCBs and the restrictions their presence places on recycling of ships, on the sale of reusable products from ships, and on the cost of compliance with environmental rules, special attention was given to PCBs.

Following completion of the sampling and sample analysis, each ship was reinspected to estimate the extent of the environmental problems revealed by the sampling. Costs were estimated for the removal of hazardous materials from the ships prior to recycling. Additional interpretation of the data was performed to test the validity of the EPA sampling guidance.

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

Each ship was searched for legible drawings which might assist in these tasks. The ships are in poor physical condition. The drawings that remain aboard are damaged and in one case, the EXPORT CHALLENGER, few drawings were found. Drawings from a sister ship, the EXPORT CHAMPION, were used instead. Drawings of ventilation and electrical systems, material lists, insulation, and paint schedules were recovered and used in the evaluation. These drawings are identified in the sections which follow.

Only one drawing for the three ships was updated beyond initial construction. This drawing is a general outline showing the new container cargo hold added to the SHIRLEY LYKES in 1972. From an environmental perspective, walk-through inspections of the ships showed some readily apparent differences between existing configurations and those shown in drawings. In the WAYNE VICTORY, for example, each berthing and messing cabin was observed to be equipped with one or more wall-mounted oscillating fans, each cushioned by a PCB-bearing gasket. However, the ship's ventilation system construction drawing shows that each of these spaces is to be equipped with porthole-mounted ventilation fans, some with light louvers, yet none were found. Therefore, while such drawings can indicate potential environmental problems (or lack of them), they are not necessarily accurate.

The cost estimates that are developed in the following sections use a fully burdened labor rate of $112.50 per day and costs for waste management services in the Norfolk, Virginia area.[6] The costs are rounded to the nearest $1,000.

[6] Waste disposal costs were provided by Norfolk Naval Shipyard and are summarized in Appendix A.

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2.0 REGULATION OF POLYCHLORINATED BIPHENYLS IN THE UNITED STATES

The next three sections of this report focus on the problems caused by nonmetallic materials containing small amounts of PCBs. Problems with PCBs arise from the nature of this family of chemicals, the environmental problems they cause, and the law that has been created to deal with these issues. A complete discussion of the legal background behind current PCB regulation is provided in References 4 and 5. The following provides technical background to these reports.

- PCBs are a family of industrial oils and wax that are nearly inflammable, do not conduct electricity, have very high boiling points, do not coagulate, are good lubricants, and are resistant to chemical change. Because of these properties, PCBs were used, from their invention in 1929 until banned in the 1970s, in many services such as lubrication; heat transfer fluids in machines of all kinds (particularly large electric transformers); dielectric compounds in electrical components such as capacitors; plasticizer in plastic, rubber, adhesives, caulks, paints, and many other similar products; hydraulic fluids; and even in research laboratories for mounting specimens on glass slides. PCBs were used in the inks in carbonless paper used in cash register receipts.

- PCBs are slightly toxic to humans. However, when heated to modest temperatures such as those developed in household cooking, they form extremely toxic compounds called dioxins and furans. In the early 1970s, in two separate incidents in Japan and Korea, the inadvertent introduction of PCBs into cooking oil led to the death or permanent disablement of many people. These incidents, coupled with knowledge that PCBs also interfere with reproduction of some species and were becoming widespread environmental contaminants, led Congress, in the Toxic Substances Control Act of 1976, to ban production of PCBs in the United States and strictly control their continued use until they could be eliminated. The EPA implemented this law in a set of regulations appearing at 40 CFR 761.

- 40 CFR 761 contains the following key requirements.

  - PCBs and materials that contain them may not be purchased, possessed, sold or disposed of unless authorized by the EPA. The current EPA regulations do not authorize PCBs in many of the solid industrial products such as plastic and caulk that are known to contain PCBs. Persons who discover PCBs in such products are in a difficult position as they are in technical violation of the law, even for simple possession, and they must negotiate with the EPA to identify appropriate controls for use and disposal.

- For the most part the EPA regulates as PCB-materials products containing 50 or more parts per million (ppm) PCBs. Some States have their own PCB rules and regulate to lower levels. Virginia, for example, regulates to as low as 1 ppm.[1]

- PCB materials may not be exported from the United States. They may be imported by an authorized commercial storer or disposer of PCBs but only for the purpose of disposal and only when international agreements between the United States and the exporting country allow.

- PCB materials may not be resold in the United States for any purpose other than disposal. Disposal must be in a regulated landfill or at a licensed incinerator.

- PCB materials awaiting disposal or designated for disposal must meet strict storage requirements, storage time limits, and packaging and shipping requirements. Only licensed firms may receive and dispose of PCB materials.

- Beginning in 1990, the U.S. Navy began discovering PCBs in many common nonmetallic materials used in Navy ships. Before this, the Navy had no knowledge that their ships contained such materials. The Navy found PCBs in adhesive, caulk, rubber and plastic parts, the nonmetallic parts of electric cables, in cork and foam rubber insulation, in the paste used to glue down the outermost cover of pipe insulation as well as the top coats of paint, in impregnated felt ventilation systems and sound dampening gaskets and in other nonmetallic products. Except for felt gaskets, the Navy found PCBs in 10% to 30% of samples at levels in the hundreds or low thousands of parts per million (0.01% to 0.5%). In felt gaskets, the Navy found about 40% to contain PCBs above 50 ppm, with some containing as much as 500,000 ppm (50%) PCBs. Since the Navy's discovery, other Government and private organizations have also found PCBs in such products. Reference 3 identifies similar problems in MARAD ships.

- Reference 8 provides EPA guidance for handling of PCBs in ships being recycled. An earlier draft of Reference 8 was used to construct the PCB sampling plan of Reference 1. Reference 8 requires that " . . . all known sources of liquid PCBs . . . and all known uses of non-liquid PCBs [be] removed . . .", and properly disposed of during recycling or before ships are exported for recycling and requires " . . . impervious solid surfaces [to be] cleaned to less than 100 micrograms per 100 centimeters square PCBs if the material is to be smelted . . . [or] cleaned to [less than 10 micrograms per 100 centimeters square PCBs] if the surface is not going to be smelted . . ." The guidance allows recyclers to sample potential PCB materials to

[1] Virginia Code VRS 672-20-10, Pt. VII, §8.2 restricts disposal of wastes containing between 1 and 50 ppm PCBs to sanitary or industrial waste landfills equipped with leachate collection systems. Landfill operators are required to check wastes for conformance with this requirement.

determine whether or not they contain PCBs or to handle them in accordance with the guidance without sampling. The guidance defines "known sources of liquid PCBs" to include:

"electrical equipment - including transformers, capacitors, fluorescent light ballasts, voltage regulators, circuit breakers, liquid-filled cable, reclosers, and rectifiers; hydraulic equipment; heat transfer fluids; vacuum pump oil; air compressor lubricants; cutting oil; and grease;"

and defines "known uses of non-liquid PCBs" to include:

"non-conducting materials in electrical cables (such as plastic and rubber), gaskets in air handling systems, other rubber gaskets, other felt gaskets, thermal insulation material (including fiberglass, felt foam and cork), sound deadening felt, oil-based paints, grouting/caulking, adhesives, tapes, rubber isolation mounts, foundation mounts, pipe hangers, rubber and plastic parts of all sizes and shapes, and any other materials where plasticizers were used."

The EPA guidance also requires that EPA be informed of the dates and places of recycling and provided with detailed plans for removing, handling and disposal of potential PCB materials.

Thus the EPA guidance requires virtually all nonmetallic materials in ships to be treated as potential PCB materials or to be sampled to prove they are not.

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3.0 PCBs IN ELECTRIC CABLES AND OTHER ELECTRICAL AND ELECTRONIC EQUIPMENT

3.1 BACKGROUND

In the United States, most electric cables that are removed from old buildings, vehicles, equipment and other retired systems are recycled by shredding the cables to pea-sized or finer particles, separating the nonmetallic insulation materials from the granular copper, selling the copper for remelting and reforming into new products, and disposing of the nonmetallic residues as municipal waste. Some cables are stripped of their insulation by slitting machines that allow workers to physically separate the copper strand from the insulation. Old cables may contain asbestos insulation; therefore, shredding and separating systems are usually equipped with air control systems to ensure containment of asbestos dust.[1]

Because of PCBs in shipboard electric cables, EPA regulations make it difficult and often impossible to recycle the cables in accordance with established methods. One firm[2] has recently acquired the necessary permits to shred and recycle PCB-bearing cables; but, overall, the cable recycling industry has not yet responded to the problem, largely because of uncertain EPA regulations.[3]

Electrical and electronic equipment used in ships may also contain PCBs. Transformers and capacitors contain PCBs, and specific rules for their use and management are contained in EPA regulations. Lubricants, caulks and nonmetallic components used in such equipment may also contain PCBs to the same extent as comparable products used in non-electric services.

3.2 CABLES

The results of the sampling and analysis of electric cables are shown in Tables 9, 10, and 11 of Reference 3.

As can be seen in Table 11 of Reference 3, the WAYNE VICTORY cables contained no PCBs and, therefore, could be recycled for recovery of copper without concern for PCBs. Many WAYNE VICTORY cables also contain lead sheaths which would add to the revenue from recycling. Because of the absence of PCBs, no further efforts were made to explore cable issues in the WAYNE VICTORY.

---

[1] From TCI Incorporated, Pell City Alabama.

[2] H.E.L.P.E.R. Inc. of Madison, South Dakota.

[3] In December 1994, EPA proposed many changes to PCB regulations that would help resolve these problems; however, as of November 1996, appropriate rules have not been issued.

However, Tables 9 and 10 show that the other two ships have PCBs in cables, at levels as high as 3,900 parts per million by weight. In evaluating the available information from these ships, we have attempted to answer the following questions:

- How much cable is present, what is the value of the recoverable copper, and how and at what cost could it be removed in order to permit the ship to be exported for scrapping?
- What are the impediments to removal of the cable?
- Is there any method to visually discriminate PCB cables from PCB-free cables?

3.2.1 Estimates of the Amount of Cable Aboard the EXPORT CHALLENGER and the SHIRLEY LYKES

In accordance with the EPA guidance and as described in References 1 and 3, cable samples were taken at random in the ship's compartments that were selected at random. There was no attempt to direct samples to particular compartments or particular cables or to avoid multiple samples of the same cable. Cable samples were physically examined to determine the cable diameter, the number of nonmetallic components, the number of conductors and other distinguishing features that might help establish patterns. None of the cable samples contained any label information such as the cable type, the manufacturer, or date of manufacture for more exact identification. The available information from this inspection is recorded in Appendix A and Tables 9, 10 and 11 of Reference 3.

Additional information on the cables in the EXPORT CHALLENGER and the SHIRLEY LYKES was recovered from drawings. The length and types of cables in the EXPORT CHALLENGER electric power and feeder systems were determined from References 9, 10, and 11 and are summarized in Table 1. Only the electric feeder system drawing, Reference 12, could be found for the SHIRLEY LYKES. This information, coupled with information on cable details from Reference 13, is summarized in Table 2. The correlations needed to estimate cable weights shown in Tables 1 and 2 were provided by the Naval Sea Systems Command.[4]

[4] From B. Jackson, Naval Sea Systems Command, March 6, 1996. Mr. Jackson provided cable weight estimates for each of the cable types based on current weight information for modern Navy cables. While modern cables use different non-metallic materials than those used in the 1960s, the conductor mass (representing about 3/4 of the cable weight) is the same and the differences in density between new and old nonmetallic parts are not significant.

Table 1. Cable Type, Length and Weight in EXPORT CHALLENGER

Cable Type*	From Power Feeder List (Feet)	From Lighting Feeder List (Feet)	Total (Feet)	Weight (Lbs. per 1000 Feet)	Total Weight (Lbs.)
TSGB 4	3245	0	3245	175	568
DSGB 4 and DRA 4	271	8338	8609	175	1507
FSGB 4	0	770	770	175	135
TSGB 9	3041	80	3121	300	936
DSGB 9	155	5904	6059	300	1818
DSGB 16	0	1854	1854	420	779
TSGB 16	1459	0	1459	420	613
TSGB 20	50	77	127	530	67
DSGB 20	0	285	285	530	151
TSGB 26	770	230	1000	610	610
DSGB 26	0	285	285	610	174
TSGB 33	140	291	431	695	300
TSGB 41	878	295	1173	840	985
TSGB 52	1747	410	2157	980	2114
TSGB 66	616	2200	2816	1130	3182
TSGB 83	864	1945	2809	1400	3933
TSGB 106	224	100	324	1660	538
TSGB 133	42	340	382	1820	695
TSGB 168	718	835	1553	2180	3386
TSGB 212	2181	290	2471	2540	6276
TSGB 250	400	0	400	3340	1336
TSGB 350	10	30	40	4540	182
TSGB 400	100	0	100	5050	505
TOTALS	16911	24559	41470		30790

Table 2. Cable Type, Length and Weight in SHIRLEY LYKES

Cable Type*	Cable Diam. (in)	From Power Feeder List (Feet)	Weight (Lbs. per 1,000 Feet)	Total Weight (Lbs)
TSGB 4	0.499	5775	175	1011
DSGB 4	0.477	1060	175	185
FSGB 4	0.563	25	300	8
TSGB 9	0.625	2205	300	662
DSGB 9	0.594	285	300	86
TAVIB 10	0.890	5170	300	1551
DAVIB 10	0.847	95	300	28
TAVIB 16	0.990	1068	420	449
ICTIB 20	1.234	25	500	12
TAVIB 26	1.078	1027	610	626
TAVIB 33	1.171	725	695	504
TAVIB 41	1.230	992	840	833
TAVIB 52	1.293	615	980	603
TAVIB 66	1.478	225	1130	254
TAVIB 83	1.568	230	1400	322
TAVIB 106	1.661	505	1660	838
TAVIB 133	1.808	475	1820	865
TAVIB 168	1.958	385	2180	839
DAVIB 168	1.814	1140	2180	2485
TAVIB 212	2.089	200	2540	508
TAVIB 250	2.263	845	3340	2822
TAVIB 300	2.388	275	3920	1078
TAVIB 350	2.536	100	4540	454
TAVIB 400	2.642	60	5050	303
TAVIB 500	2.837	180	6160	1109
TAVIB 550	3.018	495	6975	3453
TOTALS		24182		21888

* The cable type designations in the first column of Tables 1 and 2 are explained as follows:

- The first letter, D, T, or F, refers to the number of electrical conductors, D for double or two conductors, T for three and F for four. The first letters IC refer to interior communication cables that contain a large number of small diameter conductors for ship communications systems.

- The last letter refers to the type of armor, in all cases B for bronze.

- The middle letters refer to the type of insulating material used. AVI refers to asbestos-varnished insulation and SG refers to silicon rubber insulation. In the EXPORT CHALLENGER drawings, type SG cable is referred to as "Navy cable."

- The number refers to the total cross sectional area of the electric conductors in thousands of circular mils, a measure of conductor diameters. The value 4 means 4,000 circular mils and is a cable about one half inch in diameter whereas the value of 166 means 166,000 circular mills, a cable of about two inches in diameter.

The cable weights summarized in Tables 1 and 2 are not the total weights of cables in the respective ships.

- Some cables are not included in the referenced drawings. The data in Tables 1 and 2 come from drawings showing the major electrical system connections from the power source in the main machinery spaces to the several power panels centers located throughout the ship, and in many cases, cables from the power panels to the served components. Cabling from lighting power panels to lights is not included in the source drawings, nor, except for one cable run in the SHIRLEY LYKES, is interior communications cable. The "missing" cables are, however, not extensive. Cabling from lighting power panels to lights and electric outlets are small diameter cables with short runs, usually no more than 20 feet. Interior communications cables may have long runs but usually only a few cables are required for communications. A multiplier of 1.1 (10% more cable), applied to the total cable weights in Tables 1 and 2, is considered appropriate to correct for these omissions.

- Some cables were added to the SHIRLEY LYKES that are not shown in the drawings. The SHIRLEY LYKES was lengthened by 95 feet just forward of the forward house, roughly at midship, to provide a container hold. Cable drawings for this enlargement are not available; but doubtless, cables to forward services, such as cargo winches and windlasses, were extended by at least 95 feet and added electric service was provided to the new hold. An additional multiplier, proportional to the lengthening of the ship from 497 feet to 592 feet (592/497 or 1.2), is considered appropriate to correct for this factor.

- Lighting system drawings for the SHIRLEY LYKES could not be found; therefore, many cables are missing from Table 2. There are 74 power panels shown for the SHIRLEY LYKES on Reference 14. Reference 12, from which the cable types and lengths in Table 2 are derived, include only the cables used to distribute power to and from 44 main and emergency power panels. There are no comparable drawings available for the missing 30 power panels. Therefore, to adjust the total cable weight for the missing information, a multiplier of 74/44 (1.7) is judged appropriate.

In the EXPORT CHALLENGER, the total cable weight in Table 1 of 30,790 pounds (about 14 long tons) is therefore adjusted by a multiplier of 1.1 to account for cables not shown on the available drawings for a total estimated cable weight of 15 long tons. This is equivalent to about 0.22% of the light ship displacement.

In the SHIRLEY LYKES, the total cable weight in Table 2 of 21,888 pounds (about 10 long tons) is adjusted by multipliers of 1.1(missing cables), 1.2 (lengthening of the ship) and 1.7 (missing lighting system drawings) for an estimated cable weight of 22 long tons. This is about 0.26% of the light ship displacement, about the same as the EXPORT CHALLENGER.

3.2.2 Removal of Cables from the EXPORT CHALLENGER and the SHIRLEY LYKES

Reference 15 shows that the EXPORT CHALLENGER main cable ways run a total of about 1200 feet and are laid in passageway overheads and a few of the vertical bulkheads where cables run from deck to deck. Comparable drawings for the SHIRLEY LYKES are not available. However, assuming the ship is built similarly to the EXPORT CHALLENGER and assuming the length of cable ways is in proportion to light ship weights, the SHIRLEY LYKES should have about 1500 feet of main cable ways. Passageway overheads and bulkheads are paneled in both ships, preventing ready access to the cable ways. Some cables between lights and outlets and their respective power panels, as well as other minor wiring, may not be routed through these cable ways; however, it is reasonable to assume that if the main ways were made accessible, the remaining cables could be pulled through the accesses.

There are no liners used in the cable way hangers of either ship, and therefore no concerns for PCBs in such products. However, there are some significant impediments to removal of the cables.

- In both the EXPORT CHALLENGER and SHIRLEY LYKES, many of the overhead and bulkhead panels are "Marinite," a hard, rigid asbestos composition wallboard common in old ships. Marinite is called out in Reference 15 for the EXPORT CHALLENGER and in Reference 12 for the SHIRLEY LYKES. The removal of the cable ways will require removal of this asbestos board. Based on the estimated length of cable way mains and panel widths, there are about 7,200 square feet of Marinite to remove from the EXPORT CHALLENGER and about 9,000 square feet to remove from the SHIRLEY LYKES. The cost to remove Marinite board will be up to $3 per square foot.[5]

- For the SHIRLEY LYKES, Reference 13 requires the use of caulking at the entry of every electric cable into stuffing tubes and requires deck and bulkhead stuffing tubes to be packed with caulking. The comparable drawing for the EXPORT CHALLENGER could not be located; however, caulk is used in similar locations throughout this ship. Table 16 of Reference 3 shows high levels of PCBs in pipe penetration caulking and levels <34 ppm in an electric stuffing tube caulk in the EXPORT CHALLENGER. In the SHIRLEY LYKES, Table 17 of Reference 3 reports a single caulking sample in a weather deck stuffing tube <48 ppm. In view of the mixed results for stuffing tube caulking, additional sampling is needed to establish whether the caulking is or is not subject to PCB controls. If PCBs ≥50 ppm are present, removal of the cables will entail removal of the stuffing tubes as well, adding to the cost.

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[5] Courtesy of Waco Inc., 118 39A Cannon Blvd, Newport News, Virginia 23606

- The engine room of the EXPORT CHALLENGER has a very large access opening to the uppermost deck, immediately above the main engine. This will provide excellent access for removal of cables from the engine room, where much of it exists. In SHIRLEY LYKES, the only removal access appears to be through a small access trunk, about six square feet. Withdrawing cables through such a small trunk will be more difficult.

Approximately one 10-person crew could remove all cable from either ship in about six weeks, without cutting major access openings, assuming suitable cranes are available to lift cables out.[6] The work in the EXPORT CHALLENGER may be faster because of excellent engine-room access, but work in both ships will be slowed by the need to remove the paneling. If cable recycling cannot be arranged, disposal of the cable will add to the recycler's cost.

Based on these assumptions, the cost to remove and dispose all electric cabling from both ships is estimated to be:

EXPORT CHALLENGER

Labor:	7,200 ft^2 of Marinite panel	≈$22,000
	Cable, 10-person crew for six weeks @ $112.50/day	≈ 34,000
Disposal:	15 long tons @ $0.69/lb.	≈ 23,000
	TOTAL	≈$79,000

[6] Based on a rough estimate from a James River Reserve Fleet electrician.

SHIRLEY LYKES

Labor:	9,000 ft^2 of Marinite panel	≈$27,000
	Cable, 10-person crew for six weeks @ $112.50/day	≈ 34,000
Disposal:	22 long tons @ $0.69/lb.	≈ 34,000
	TOTAL	≈$95,000

Approximately 75% of the weight of electric cables is copper that can be recovered by shredding and separation. It is not certain that recycling of PCB-containing cables can be arranged, and if so, at what cost or return as recycling these cables is not a developed industry. However, assuming a value of $0.10 per pound, the ship recycler would receive about $2500 for the cables from the EXPORT CHALLENGER and about $3700 for the cables from the SHIRLEY LYKES and would save the cost of cable disposal.

Using the PCB concentration data in Tables 9 and 10 of Reference 3 and the estimated cable weights above, and assuming that 25% of the cable weight are nonmetallic materials containing the PCBs, the EXPORT CHALLENGER cables average 142 ppm PCBs and contain a total of about 1.09 pounds of PCBs and the SHIRLEY LYKES cables average 732 ppm PCBs and contain a total of about 4.00 pounds of PCBs.

3.2.3 Cable Sample Data Trends

The information in this report on the PCB concentration in cables was obtained through sampling and chemical analysis of cable samples. Sample collection and analysis took several weeks and each cost more than $100. If the presence of PCBs in cables were associated with some visible characteristic, cables could be quickly identified and sorted for much less cost. Therefore, the data in Reference 3 were evaluated to determine whether there are any simple and obvious associations between visible cable characteristics and the measured PCB concentrations.

In Table 3, data for the EXPORT CHALLENGER and the SHIRLEY LYKES are sorted by measured cable diameter. The table displays the number of cable samples of each measured diameter and the number at or above 50 ppm PCBs. Entries for data at or above 50 ppm have been shaded gray for ready identification. The data suggest that there is no association between cable diameter and PCB presence or magnitude.

Table 3. Comparison of Electric Cable Diameter and PCB Concentration ≥50 ppm*

	EXPORT CHALLENGER		SHIRLEY LYKES	
Cable Diameter (inches)	# Cable Samples	# ≥50 ppm PCBs	# Cable Samples	# ≥50 ppm PCBs
1/4	1	0	2	1
3/8	10	3	8	5
1/2	11	2	11	7
5/8	2	0	0	NA
3/4	1	0	2	2
7/8	0	NA	2	1
1	4	2	0	NA
1 1/4	2	0	0	NA
1 3/8	0	NA	2	2
1 3/4	0	NA	2	2
1 7/8	2	2	1	1
2	1	1	0	NA

* Gray shade indicates that one or more cable samples of the indicated diameter contained PCBs at or above 50 ppm. The number in each box in the second and fourth columns is the number of cable samples taken that are of the indicated diameter.

In Table 4, data for the EXPORT CHALLENGER and the SHIRLEY LYKES are sorted by the number of electrical conductors. In the EXPORT CHALLENGER, there is a weak suggestion that PCBs may be concentrated in the cables with no more than three conductors; however, there are so few samples of many-conductor cables that no firm inference can be made. In the SHIRLEY LYKES many-conductor cables were found with PCBs at nearly the same frequency as two and three conductor cables.

Table 4. Comparison of Number of Cable Electric Conductors and PCB Concentration ≥50 ppm*

	SHIP			
	EXPORT CHALLENGER		SHIRLEY LYKES	
# of Electric Conductors	# Cable Samples	# ≥50 ppm PCBs	# Cable Samples	# ≥50 ppm PCBs
1	4	0	2	0
2	16	5	15	11
3	11	5	8	6
4	0	NA	1	0
7	1	0	0	NA
8	0	NA	2	2
12	1	0	0	NA
19	1	0	0	NA
30	0	NA	2	2

* Gray shade indicates that one or more samples containing the indicated number of conductors contained PCBs at or above 50 ppm. The number in each box in the second and fourth columns is the number of cable samples containing the indicated number of conductors.

Another potential association is between the number of nonmetallic components in a cable and PCBs. Table 5 presents this information. Again, there appears to be no association. PCBs were found in cables containing as few as 2 and as many as 93 nonmetallic parts.

Cable type and PCB presence is another potential association. Type SG (silicone rubber) cables and type AVI (asbestos varnish) cables are built with different materials. From Tables 1 and 2 it can be seen that the EXPORT CHALLENGER uses type SG cables for all sizes whereas the SHIRLEY LYKES uses type SG for cables up to size T9 and type AVI cables for sizes larger than T9. In Table 3, it can be seen that both types were found with PCBs.

In conclusion, there do not appear to be any meaningful associations between the diameter, number of conductors, number of nonmetallic parts, or types of cable in the EXPORT CHALLENGER and SHIRLEY LYKES, and the presence or absence of PCBs.

Table 5. Comparison of the Number of Nonmetallic Electric Cable Parts and PCB Concentration ≥50 ppm in the Parts*

	SHIP			
	EXPORT CHALLENGER		SHIRLEY LYKES	
# of Nonmetallic Parts	# Cable Samples	# ≥50 ppm PCBs	# Cable Samples	# ≥50 ppm PCBs
1	1	0	0	NA
2	2	0	3	1
4	3	0	1	0
5	5	3	1	1
6	1	0	1	1
7	4	1	2	1
8	4	1	11	9
9	4	0	0	NA
10	4	1	5	3
11	0	NA	1	0
13	4	3	1	1
15	0	NA	1	0
17	1	0	0	NA
20	1	0	0	NA
27	1	0	0	NA
28	0	NA	2	2
93	0	NA	2	2

* Gray shade indicates that one or more samples of cables containing the indicated number of nonmetallic parts contained PCBs at or above 50 ppm. The number in each box in the second and fourth columns shows the number of cable samples taken that contained the indicated number of nonmetallic parts.

3.3 OTHER ELECTRICAL AND ELECTRONIC EQUIPMENT

Electrical equipment other than cables may include parts containing PCBs. Fluorescent light ballasts often have PCBs in the potting compound in which the components are imbedded. The capacitors in electronic equipment were once made with PCB soaked dielectric materials. Transformers may contain PCB-impregnated insulation. Plastic O-ring seals on watertight closures, caulk, gaskets and other nonmetallic parts may contain PCBs. The insulation on wiring within electrical components may contain PCBs. Rubber switch push-buttons and rubber grommets may contain PCBs.

Current PCB regulations specify handling and disposal requirements for some of these components such as capacitors, but for the most part, nonmetallic PCB-bearing parts in electronic and electrical equipment are not approved uses. The ship sampling program did not include samples for electrical parts, other than cables; however, based on the age of the ships and the known presence of PCBs in comparable Navy components,[7] it is likely that many contain PCBs.

Ship recyclers are required by Reference 8 to assume that PCBs are present in most electrical components and handle them as PCB waste. For some large components with a significant resale value, PCB analysis of the nonmetallic parts may be warranted to determine whether a resale is permitted. For small, low value parts, the cost of analysis may exceed the resale value. The cost estimate below assumes that the recycler will choose to dispose of electric and electronic components.

The cost to remove and dispose of electric and electronic components will not vary much whether the ship is being stripped of PCBs or is being domestically scrapped. The vast majority of the parts are small and easily removed with the ship intact. For very large suspect components, the main seawater pump for example, removal of the suspect parts may be preferable to removal of the entire motor. To estimate the number of parts requiring removal, References 11, 14 and 17 from the EXPORT CHALLENGER and SHIRLEY LYKES were reviewed and a composite list, Table 6, was prepared. The estimated weight of the components is based on the average size of the components. It is estimated that a worker could remove approximately 20 devices per day.

[7] Navy experience with PCBs in shipboard components is summarized in Assistant Secretary of the Navy (Installations and Environment) letter of 17 April 1995 to the U.S. EPA that provided Navy comments on new PCB regulations proposed by EPA.

Table 6. Composite List of Electric and Electronic Equipment in EXPORT CHALLENGER and SHIRLEY LYKES

Component	Number (per ship)	Estimated weight (Lbs)	Total Weight (Lbs)
Fluorescent light fixtures	600	3	1800
Incandescent light fixtures	600	3	1800
Recepticals	300	1	300
Junction boxes	250	3	60
Small electric motors	200	50	10000
Power and lighting panels	50	20	1000
Large transformers	10	100	1000
Light switches	200	1	200
Circuit breakers	125	10	1250
Low or high voltage protection devices	150	2	300
Navigation and communications instruments	20	100	2000
TOTAL	2505		~20000

Assuming no PCB analysis expenses, the estimated cost to remove and dispose of electric and electronic components from any of the ships is:

EXPORT CHALLENGER, SHIRLEY LYKES, WAYNE VICTORY

Labor:	2505/20 items per worker per day @ $112.50/day	≃	$14,000
Disposal:	20,000 lbs. @ $0.69/pound	≃	14,000
	TOTAL	≃	$28,000

4.0 PCBs IN VENTILATION GASKETS

4.1 BACKGROUND

Ventilation gaskets are assigned special priority in Reference 8 because one particular ventilation gasket material, impregnated felt, was among the first nonmetallic shipboard materials found with PCBs. The levels found were very high, sometimes more than 50% by weight. Impregnated felt was produced by several manufacturers. The Navy used the material as gaskets in the flanges of ventilation ducts in many surface ship ventilation systems, and for sound dampening in many submarines. The U.S. Coast Guard also used the material for shipboard ventilation and sound dampening purposes. The Department of Energy uses it in ventilation systems at the Oak Ridge National Laboratory.

According to Navy data on surface ship ventilation system gaskets, about 40% of all felt ventilation gaskets contain PCBs above 50 ppm. Only chemical analysis can distinguish PCB felt from PCB-free felt.

Reference 8 requires that all "air handling system gaskets" to be suspect PCB materials. Therefore, samples were taken from gaskets in ventilation duct flanges, the grills on the outlets of the hot water and chill water heat exchangers (called ventilation induction units in Reference 22), the foundations of small oscillating fans mounted on bulkheads, and access ports in ventilation ducts.

From 23% to 38% of the total PCB samples taken in each ship were ventilation system gaskets. Each gasket sample was visually examined to identify the type of material and, where possible, its thickness and other visually identifiable properties. During the survey of the ships following the sampling, sampled locations were examined to ensure the information in the sampling report was correct. Ventilation system drawings were reviewed to help estimate the number of gaskets, possible removal methods, and removal costs. The ventilation system layout, thermal insulation materials, and other system characteristics were examined to help determine impediments to gasket removal.

4.2 VENTILATION SYSTEM GASKET MATERIALS

4.2.1 Gasket Material Types

The results of the gasket sampling work were reported in Tables 13, 14, and 15 of Reference 3. As shown in the seventh column of these tables, a variety of materials were found. Table 7 summarizes the different materials found in each of the ships. Gray-shaded panels indicate that PCBs at or above 50 ppm were found.

Table 7. PCB Contamination in Ventilation System Flange Gasket Materials*

Material	EXPORT CHALLENGER	SHIRLEY LYKES	WAYNE VICTORY
Felt	Yes	Yes	Yes
Cloth-Inserted Rubber	Yes	No	No
Foam Rubber	Yes	Yes	No
Sheet Rubber	Yes	No	No
Processed Cork	Yes	No	No
Wax-Impregnated Woven Fabric	Yes	No	No
Matted Dry Fiber	No	Yes	No
Unidentifiable	Yes	Yes	No

* Yes or No indicates that the material was or was not found in the ship. The gray shade indicates that PCBs ≥50 ppm were found in the material.

The EXPORT CHALLENGER has the greatest variety of gaskets, with seven different identifiable materials. The SHIRLEY LYKES has four different materials while the WAYNE VICTORY has only felt.

4.3 VENTILATION SYSTEM DESIGN FEATURES

4.3.1 System Arrangements

Comparing Reference 18 (a general ventilation drawing for the WAYNE VICTORY) with References 19 through 28, (detailed ventilation system diagrams for the EXPORT CHALLENGER and the SHIRLEY LYKES), it is seen that the WAYNE VICTORY has a comparatively simple ventilation system. There is no more than 500 feet of ventilation ducting in this ship, most providing ventilation to the main engine space and to heads, pantries, store rooms, and the galley to ventilate otherwise closed-in spaces. The ducted systems are fed air by two 20,000 cubic feet per minute (cfm) fans. Reference 18 shows that living spaces were originally planned to be ventilated by 40 porthole-mounted fans but there was no evidence of them seen on the ship. Instead, there are about 40 oscillating or fixed bulkhead-mounted fans, one or two per space. Each of the bulkhead fans is mounted with a 1/4 inch thick felt gaskets. Reference 18 states that all ventilation ducting in the WAYNE VICTORY is to be "portable," which suggests it can be easily removed. The bulk of the ship's ventilation is provided by the natural ventilation system, consisting of a total of 12 large ventilation cowls that gather air as the ship moves and feeds it below decks through vertical pipes, and eight natural exhausts that allow air from the spaces to escape.

Ventilation systems in the EXPORT CHALLENGER and the SHIRLEY LYKES are more complex. Most spaces in these ships are fed by a ducted ventilation system fed by multiple supply and exhaust fans and air-conditioning cooling coils. There is very little natural ventilation; this method being used only in obscure forward and aft storage spaces. From References 19 through 27, a composite view of typical ventilation system features in ships of this size has been assembled. Steel ventilation ducts feed air to the main engines and to nearly all spaces of the ships. Ducts are, in general, routed through the overheads in passageways of the ships living spaces and are insulated against sweating with fiberglass insulation. From the samples, a variety of gasket materials are used. Even in so simple a system as the four "natural ventilation" ducts shown in Reference 22 for the EXPORT CHALLENGER, two different gaskets are specified, rubber and cork with synthetic rubber, adhesive coated. (The cork material was often found to contain PCBs as shown in Table 13 of Reference 3). Ventilation ducts are hung from overhead decks with steel strip hangers and, in general, parallel the main cable ways discussed in Section 3.2.3. There are no ventilation duct hanger liners in either ship.

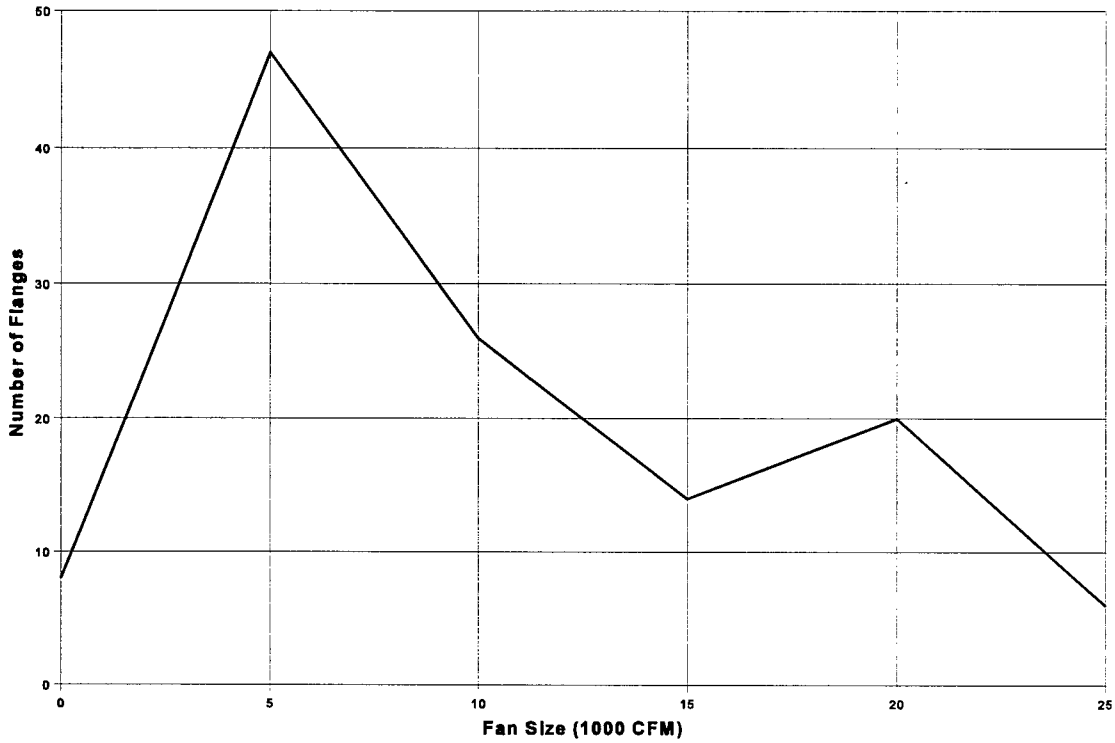
4.3.2 Estimated Number of Ventilation System Gaskets

An estimate of the number of gaskets can be made by actual count of the duct flanges and other gaskets; however, the bulkhead and overhead paneling in the ship's living spaces conceal many of the flanges from view. Therefore, this approach was discarded. Instead, drawings were sought from which gasket counts could be made. References 24 through 27 show there to be about 9000 feet of ventilation ducting in the SHIRLEY LYKES and, based on a walk through inspection of visible ducting, there are flanges every five to 15 feet. From this information, the number of flanges in the SHIRLEY LYKES is estimated to be between 600 and 1800. Reference 18 shows about 500 feet of ventilation ducting in the WAYNE VICTORY and, from the ship inspection, there are flanges every five to 15 feet. Based on these data, the WAYNE VICTORY has from 33 to 100 flange gaskets in addition to a gasket for each of 40 bulkhead-mounted fans. Ventilation system drawings were not available for the EXPORT CHALLENGER.

A novel method for estimating the number of ventilation system gaskets has been developed by the U.S. Navy. A few classes of ships have had full gasket counts made, and the number of gaskets has been related to the number and capacity, in cfm, of ventilation fans. The relationship is reproduced in Figure 1. The Navy found that small fans, below 1000 cfm, serve local ventilation needs and are usually coupled with short lengths of ducting having few gaskets. Fans having capacities around 5000 cfm are the most common and serve numerous spaces with complex ducts having many gaskets. Very large fans serve major ducting systems that branch to smaller systems with their own smaller fans or serve major consumers of air, such as the ship's boilers, with short lengths of large ducting having few gaskets.

FIGURE 1

Fan Size vs Number of Flanges



From Reference 19 the number and capacity of ventilation system fans in the EXPORT CHALLENGER were determined. Table 8 applies the Navy relationship to this information. A value of 10 flanges per 1000 cfm was selected for large fans beyond the range of the Navy correlation.

Table 8. Number of Ventilation System Gaskets in EXPORT CHALLENGER Based on Navy Fan/Gasket Correlation

Fan capacity, cfm	Number of fans	Gaskets per fan	Total gaskets
2000	3	22	66
2600	8	24	192
3235	1	30	30
3900	1	37	37
4005	1	38	38
4700	1	45	45
5230	1	47	47
6000	1	42	42
6200	1	41	41
6300	1	40	40
7980	1	30	30
8000	1	32	32
9990	1	23	23
30000	2	10	20
40000	2	10	20
		TOTAL	703

Information on the number and size of ventilation system fans in the SHIRLEY LYKES was not available. However, assuming that the number of ventilation system flanges in the SHIRLEY LYKES is proportional to the ratio of the SHIRLEY LYKES and EXPORT CHALLENGER light ship weights, the Navy correlation predicts:

$$(703 \times 8606)/6880 = 879$$

flanges for the SHIRLEY LYKES. This is within the range of the estimate based on duct length and approximate number of flanges per unit length. The Navy correlation applied to the WAYNE VICTORY (two 20,000 cfm ventilation fans serving a ducted system) predicts 40 ventilation flange gaskets (in addition to the 40 gaskets on the bulkhead fans).

The predicted number of flange gaskets from the Navy correlation is within the ranges based on estimated duct length. Therefore, the value from the Navy correlation is used to estimate the cost to remove the gaskets. The number of ventilation system gaskets in each ship is estimated to be:

EXPORT CHALLENGER	703
SHIRLEY LYKES	879
WAYNE VICTORY	80

4.4 REMOVAL AND DISPOSAL OF VENTILATION SYSTEM GASKETS

In accordance with Reference 8, "air handling system gaskets" are treated as a single class of material. As up to seven different gasket materials were found in the ships, some with and some without PCBs, all would have to be handled as PCB materials if one type showed PCBs (or if sampling was not performed). Negotiations with the regulator on specific recycling projects may result in a different interpretation than Reference 8. For example, in the EXPORT CHALLENGER, the ventilation system gaskets in the large ventilation ducts in the engine room appear to be woven asbestos fabric tape. Indeed, Reference 21 cites 883 feet of 1½ inch by ⅛ inch (Anchor Packing catalogue item PG-48) asbestos tape for gasket service in machinery space ventilation systems. This material was not sampled; however, it is visually dry with no evidence of a waxy or oily impregnant, therefore, it probably does not contain PCBs. If this gasket material would not need to be handled as a PCB material, machinery space ducting, comprising about 30% of the largest and heaviest ducting, could be left in place.

In estimating the cost to remove and dispose of ventilation system gaskets, it is necessary also to consider the cost to remove metal flange faces adjacent to PCB-felt gaskets found in the SHIRLEY LYKES and WAYNE VICTORY. Unlike other types of gaskets, the PCBs in the felt will cause the adjacent surfaces to be contaminated with imbedded PCB residues that, in Navy experience, requires grit blasting to remove to the standard of Reference 8 (100 micrograms of PCBs per 100 square centimeters). One current ship recycler reports successful solvent cleaning and recycling of PCB-contaminated aluminum flange faces removed from U.S. Navy ships.[1] It is not clear that the cleaning is done to the requirements of Reference 8 nor is it clear that the low value of steel flanges from commercial ships warrants the cost of cleaning by any method.

The following assumptions are incorporated in the removal cost estimates. These assumptions are based on observations made during sampling of the ship, the subsequent ship surveys, and the requirements of Reference 8.

- All gaskets must be removed and each weighs 1 pound on average.

[1] Wilmington Resources of Wilmington, North Carolina.

- The mating surfaces of felt flanges or fan gaskets that must be removed weigh 5 pounds each. The mating surfaces of other types of gaskets need not be removed.

- Marinite paneling, in way of most of the ducting, will have been removed as part of cable removal, as discussed in Section 3.2.2. No additional Marinite will require removal for access to the gaskets.

- On average, one worker can cut out or open and remove 15 ventilation system flanges or bulkhead-mounted fans per day. Some gaskets, such as the 54 induction unit grill gaskets in the SHIRLEY LYKES shown on Reference 22, could be removed by one worker in less than a day but others, such as the large flange gaskets on the main induction fans in the engine room, could take several workers a day to remove.

- The number of PCB felt gaskets to be disposed of in each ship is in proportion to the number of gaskets found in the ship; zero of 30 in the EXPORT CHALLENGER, 15 of 27 in the SHIRLEY LYKES, and all in the WAYNE VICTORY.

With these assumptions, the cost to remove and dispose of ventilation gaskets from each ship is as follows:

EXPORT CHALLENGER

Labor:	703 gaskets @ 15/worker-day x $112.50/day	≈	$5000
Disposal:	703 gaskets @ 1 lb. each x $0.69 per pound	≈	500
	TOTAL	≈	$6000

SHIRLEY LYKES

Labor:	879 gaskets @ 15/worker-day x $112.50/day	≈	$7000
Disposal:	879 gaskets @ 1 lb. each x $0.69 per pound	≈	600
	879 flange pairs x 15/27 x 5 lbs. each x $0.69 per pound	≈	1700
	TOTAL	≈	$9000

WAYNE VICTORY

Labor:	80 gaskets @ 15/worker-day x $112.50/day	≈	$600
Disposal:	80 gaskets @ 1 lb. each x $0.69 per pound	≈	60
	80 flange pairs x 5 lb. x $0.69 per pound	≈	300
	TOTAL	≈	$1000

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5.0 OTHER PCB MATERIALS

5.1 TYPES OF OTHER PCB MATERIALS

Reference 8 requires that, ". . . in the event that all of the . . . known sources of non-liquid PCBs . . . have not been removed from a vessel . . . " sampling is to be done to determine whether any materials that remain aboard contain PCBs that must be removed and handled as PCB waste. To simplify sampling, the EPA has lumped all of the listed materials into 10 categories:

1 - Electric cables
2 - Ventilation system gaskets
3 - Rubber gaskets (other than ventilation system gaskets)
4 - Felt gaskets (other than ventilation system gaskets)
5 - Fiberglass, felt, foam, or cork thermal insulation material
6 - Sound deadening felt
7 - Grouting, caulking, rubber isolation mounts, foundation mounts, and adhesives
8 - Tapes
9 - Pipe hangers
10 - Rubber/plastic parts of all sizes and shapes (other than listed above).

In the event that a sample in any category is found to contain PCBs at or above 50 ppm, Reference 8 requires all of the materials in the category to be removed and disposed of as PCB waste. Reference 8 also permits selective removal of materials within a category provided the category is resampled following removal to establish that the category no longer contains materials with PCBs.

While not required to be sampled by Reference 8, all known liquid PCB materials, including oils and greases, must also be removed from the ship; therefore, samples of a few of these materials were taken and assigned category 11.

The sampling data for materials other than cable and ventilation system gaskets were divided into Categories 3 through 11 and recorded in Tables 16, 17, and 18 of Reference 3. Table 9 summarizes all of the data in Reference 3, showing in gray shade the categories where one or more samples in the category contained PCBs at or above 50 ppm. The total number of samples taken in each category is indicated by the number. Note that four categories among the three ships were not sampled for the reasons given in Reference 3.

Table 9. PCBs Above and Below 50 ppm in Each EPA Item Category*

	Ship		
PCB Item Category	**EXPORT CHALLENGER**	**SHIRLEY LYKES**	**WAYNE VICTORY**
1 - Electric Cables	35	31	24
2 - Vent Gaskets	30	27	23
3 - Rubber Gaskets	9	5	1
4 - Felt, other than Vent Gaskets	2	1	0
5 - Fiberglass, Felt, Foam or Cork Thermal Insulation	3	2	2
6 - Sound Deadening Felt	1	1	0
7 - Grout, Caulk, Rubber Mounts and Adhesives	5	3	5
8 - Tapes	0	2	0
9 - Pipe Hanger Liners	1	1	1
10 - Misc. Rubber and Plastic Parts	3	2	2
11 - Oils and Greases	4	4	2

* Gray shade indicates that one or more samples in the category contained PCBs at or above 50 ppm. The number in each box shows the total number of samples taken in the category.

5.2 REMOVAL OF OTHER PCB MATERIALS

The actions and estimated costs to remove materials in Category 1 (electric cables) and Category 2 (ventilation system gaskets) were discussed in Sections 3 and 4, respectively. Categories 3 through 11 are discussed below.

5.2.1 Category 3, Rubber Gaskets Other Than Air Handling System Gaskets

As seen in Table 9, all three ships contain PCBs in this category. Rubber gaskets are used in most electrical and mechanical components and systems. Samples were taken of spare or installed gaskets for hatches, doors, windows, electric distribution boxes, machinery access ports, and piping systems. The ship surveys revealed the presence of rubber gaskets in the main seawater systems, condensate systems, fresh water systems and other piping systems of the EXPORT CHALLENGER and the SHIRLEY LYKES. They are probably used in comparable WAYNE VICTORY systems as well, but the lighting in the vessel was so poor during the resurvey that positive identification could not be made. PCBs were found in more than one half of the samples.

Some rubber gaskets, those installed in portholes, access port covers and other readily accessible installations, are relatively easy to remove but those in piping systems present particular problems. Removal of seawater system gaskets, for example, entails disassembly of heavy piping systems (some approaching two feet in diameter) and removing flanged fittings and access ports weighing hundreds or thousands of pounds, while providing some means to prevent flooding of the ship as the systems are opened.

The removal of rubber gaskets is a normal practice during the course of domestic recycling. All will be exposed and removed as the ships are cut up, the metals prepared for recycling and the reusables made ready for resale. The added cost to manage the gaskets as PCB materials should be small in this environment because the total weight of gasket material probably doesn't exceed 2000 pounds. However, removing all rubber gaskets from an intact ship does not appear to be practical. Piping systems containing rubber gaskets, including seawater, fresh water, fuel, and waste systems, would have to be disassembled without disturbing the outer hull. This would require many months of work by dozens of workers and might involve restoration of some systems to meet requirements for safe towing. Because of this, no costs are estimated for removal of rubber gaskets.

5.2.2 Category 4, Felt, Other Than Vent Gaskets

Only in the EXPORT CHALLENGER was material found in this category. (Category 4 was not sampled in the WAYNE VICTORY for reasons discussed in Reference 3.) PCB felt was found in a gasket of a decorative closure on a light fixture in the Officer's Mess and PCB-free-felt was found in a heat exhaust fan over the deep fat fryer in the galley. As noted in Section 3.3, there are about 1200 light fixtures in the EXPORT CHALLENGER and all may have PCB felt gaskets. As noted in Section 4.4, felt gaskets leave behind a residue which cannot be easily removed. Therefore, removal of Category 4 felt gaskets requires removal of metal surfaces on either side of the gasket along with the gasket. The estimated cost to remove Category 4 gaskets in the EXPORT CHALLENGER is:

EXPORT CHALLENGER

Labor:	1200 gaskets @ 15/worker-day x $112.50/day	≈ $9000
Disposal:	1200 gaskets @ 1 lb. each x $0.69 per pound	≈ 800
	1200 flange pairs x 5 lbs. each x $0.69 per pound	≈ 4,100
	TOTAL	≈$14,000

5.2.3 Category 5, Thermal Insulation

Both the EXPORT CHALLENGER and the WAYNE VICTORY had high PCB levels in samples representing this category. In the EXPORT CHALLENGER, the high PCB sample was foam rubber thermal insulation taken from a ship's air conditioning fan room pipe. In the WAYNE VICTORY, the high-PCB sample was high-temperature thermal insulation from the

main machinery room. At a minimum, Reference 8 requires removal of the foam rubber pipe insulation in the EXPORT CHALLENGER and the main engine thermal insulation from the WAYNE VICTORY.

References 28 through 31 show that the EXPORT CHALLENGER has approximately 1600 feet of air conditioning and refrigeration system piping, ranging from ¼ inch to 3⅝ inches in diameter, which is insulated with foam rubber insulation of the type found to contain PCBs. The insulated piping traverses several compartments. It is estimated that one worker could remove all the insulation in about five days, generating about 2000 pounds of PCB waste. The cost for removal and disposal of this insulation will therefore be:

EXPORT CHALLENGER

Labor:	1600 ft. @ 1 worker for 5 days @ $112.50/day	≈ $ 600
Disposal:	2000 lbs. @ 0.69/lb.	≈ 1400
	TOTAL	≈$2000

Table 21 of Reference 3 shows that the engine insulation in the WAYNE VICTORY is asbestos. In Section 6.2, the removal of asbestos from the main machinery space of both ships is discussed and cost estimates are provided. No additional costs would be involved in removal of WAYNE VICTORY insulation because of the presence of PCBs.

Following these actions, Reference 8 requires resampling of remaining Category 5 materials such as the thermal insulation in the EXPORT CHALLENGER engine and bulkhead insulation in the WAYNE VICTORY. Should any of the repeat samples reveal PCBs, additional removal would be required; therefore, the cost estimates in Section 6.2 represent the minimum cost for remediating PCB materials in Category 5.

5.2.4 Category 6, Sound Deadening Felt

As shown in Table 9, none of the samples from this category in the two ships where it was sampled showed PCBs; therefore, no remediation of this Category is required.

5.2.5 Category 7, Grout, Caulk, Rubber Mounts and Adhesives

Tables 16, 17, and 18 of Reference 3 show that all three ships had one or more samples in this category that are high in PCBs. Products in this category are widely used in ships. Nearly all electric cable penetrations in switches, junction boxes, power distribution panels and through bulkheads, decks and overheads are caulked. Piping penetrations through bulkheads, decks and overheads are often caulked. Caulk and grout are used to seal cracks in insulation, embed small components, seal portholes, stacks and other openings in topside surfaces, and for many other services. In the SHIRLEY LYKES electric system alone, Reference 12 allows not less than four different types of caulking, sealers and fillers (plastic sealer per MIL-I-3064 or equal, Johns

Manville caulking, Johns Manville sealer and asbestos cloth soaked in red-lead compound). For the EXPORT CHALLENGER, Reference 32 specifies "permanently plastic weatherproof sealant" and "plastic sealing compound" to seal joints between insulation sections on weather deck piping and requires Benjamin Foster 30-36 lagging adhesive (or equal) to glue lagging cloth to insulation, while Reference 36 specifies three different adhesives and bonding agents to be used for installing deck tiles.

Removal of materials in Category 7 presents problems similar to removal of materials in Category 3. The materials are so widely used that removal of all is impractical. From the available drawings, not less than ten different caulking compounds, grouts, and adhesives materials were used in the ships and the true number is probably in the dozens. The objective evidence from Reference 3 shows, however, only high PCBs in caulks and grouts used in piping penetrations in the EXPORT CHALLENGER and WAYNE VICTORY. The drawings showing the number and sizes of caulked pipe penetrations in these ships could not be found, but from visual surveys the number appears to be in the hundreds. For the purpose of estimating a removal cost, it is assumed that there are 500 such penetrations in EXPORT CHALLENGER, the average pipe size is 1 inch, the weight of each penetration, including the piping, is 20 pounds, and one worker can remove four penetrations per day. For WAYNE VICTORY, 250 penetrations are assumed and all other factors are the same.

EXPORT CHALLENGER

Labor:	500 penetrations @ 4/worker/day @ $112.50/day	≈ $14,000
Disposal:	500 penetrations @ 20 lbs. each @ $0.69/lb.	≈ 7,000
	TOTAL	≈ $21,000

WAYNE VICTORY:

Labor:	250 penetrations @ 4/worker/day @ $112.50/day	≈ $7,000
Disposal:	250 penetrations @ 20 lbs. each @ $0.69/lb.	≈ 3,500
	TOTAL	≈$10,500

In the SHIRLEY LYKES, the only Category 7 material found with PCBs (of three samples taken) was a foam rubber pad. There was only one such pad noted during the ship survey.

Reference 8 requires additional sampling of Category 7 materials after removal of piping penetrations. This sampling may reveal PCBs in other materials, requiring further removal. Therefore, the total cost for removal of Category 7 materials may be higher.

5.2.6 Category 8, Tapes

Only two small pieces of tape were found in the three ships, both in the SHIRLEY LYKES. Less than one worker-hour would be required to remove the tape.

5.2.7 Category 9, Pipe Hanger Liners

No PCBs were found in pipe hanger liners of any of the ships. No action is needed.

5.2.8 Category 10, Miscellaneous Rubber and Plastic Parts

This category intuitively includes a wide variety of products that might contain PCBs. But of the two to three samples taken in each ship, no PCBs were found. Therefore no action is needed.

5.2.9 Category 11, Oils and Greases

Reference 8 requires all ". . . known sources of liquid PCBs . . . " to be removed and defines the term to include ". . . hydraulic equipment; heat transfer fluids; vacuum pump oil; air compressor lubricants; cutting oil; and grease." To determine whether it is likely for such products to contain PCBs, samples were taken and the results reported in Tables 16, 17, and 18 of Reference 3. None of the grease samples were successfully analyzed for PCBs because of interference from impurities; however, hydraulic oil samples from the same machines showed no PCBs. These samples do not cover all of the known sources in the ships, but the results indicate that PCBs are probably not present in hydraulic fluids, lubricants and greases.

6.0 OTHER HAZARDOUS MATERIALS

6.1 INTRODUCTION

Tables 19, 20, and 21 of Reference 3 report the results of sampling of the three ships for potentially hazardous materials other than PCBs. Samples were taken for asbestos in insulation, gaskets, valve packing and electric cables; cadmium plating on metal fasteners; ethylene glycol in diesel cooling systems; chlorofluorocarbons in refrigeration systems; lead in paint chips and organotin in hull paint. With the exception of tin in hull paint (from the use of tributyl tin as an antifoulant), all of the potential hazardous materials were found in all three ships. Therefore, during domestic scrapping, all of the wastes generated that contain these materials will be subject to domestic regulation.

There are other potentially hazardous materials in old ships that were not included in the sampling program. These include sludge in fuel oil and cargo oil tanks, bilge water, and partially used containers of adhesives, paints, solvents and other consumable products left aboard. These materials may be subject to regulation as hazardous wastes when they are removed from ships or no longer have a function in the ship.

Concepts which allow continued use of largely intact scrap ships presents some unique problems. For reefbuilding, current regulations require the removal of materials which may pollute the marine environment. There are no explicit guidelines as to what must be removed and what may remain. Therefore, discussions with regulatory authorities are required.

For use overseas, including for scrapping overseas, hazardous materials also present unique problems. As noted in Section 2, materials containing PCBs may not be exported from the United States. Regarding hazardous wastes other than PCBs, 40 CFR 262, Subpart E, specifically prohibits their export unless both the EPA and the Government of the receiving country agree. Reference 4 discusses domestic and international law affecting ship breaking/recycling, noting that the exportation of ships for recycling is not prohibited but that, under the Basel Convention, importing nations may restrict the importation of hazardous materials and wastes.

The restrictions that an importing country will place on a scrap ship cannot be known in advance. However, the following estimates have been developed assuming that no importing country will knowingly permit the importation of large amounts (>1000 pounds) of hazardous wastes or materials that will generate large amounts of hazardous waste. The estimates are derived from the cost of services and waste disposal in the Norfolk, Virginia area (Appendix A). The labor rate is the same as used for the PCB cost estimates, $112.50 per day.

6.2 ASBESTOS

Asbestos is clearly a hazardous material in that it causes cancer, asbestosis, emphysema and other diseases. Because of its unique history, asbestos is heavily regulated in the United States. Asbestos waste is considered a hazardous waste by the Basel Convention, and many countries also regulate it under their own rules. Most thermal insulation in all three ships contains asbestos as seen in Tables 19, 20, and 21 of Reference 3. This is confirmed for the EXPORT CHALLENGER by Reference 32 where a large variety of asbestos products are specified. None of the insulation products in the ships appear to have any reuse potential. All are old, sometimes oil soaked, and fitted to particular systems. They are glued in place and cannot be removed in a manner that would retain any utility. Many scenarios regarding use of old ships may require removal of asbestos thermal insulation, including use of ships in public displays, as storage facilities, or for overseas recycling.

Removal of the many other asbestos products that might be encountered in the ships is not included in the estimate. Marinite wallboard that remains after removal of cables and ventilation gaskets is in excellent condition. Asbestos gaskets and valve packing are also not included as some gasketed machinery and valves, packed with asbestos, may be reusable.

Based on rough estimates from a Norfolk, Virginia area firm having experience in the removal of asbestos from military ships,[1] the cost to remove and properly dispose of asbestos from each of the three MARAD ships is $200,000. A breakdown between labor and disposal cost is not available.

This estimate is approximate. Much of the cost is in safely removing the asbestos from the engineering spaces once it is cut from the components and bagged. In the three MARAD ships, access within the machinery spaces is much better than in compact military ships, and therefore the cost might be lower.

6.3 CADMIUM

The cadmium results reported in Tables 19, 20 and 21 of Reference 3 were obtained by analyzing filings from the surfaces of small metal parts for total cadmium. It is not known whether the cadmium was from plating or from residues of a lubricant or paint (which may contain cadmium), nor were the parts tested to determine whether they fail the Toxic Characteristic Leachate Procedure test of Federal hazardous waste regulations. However, it is known that cadmium-plated metal will fail the test; therefore, it is likely that the parts will also.

The total amount of cadmium-plated parts in any of the three ships is not known. Only one sample was taken from each ship and all three samples showed evidence of cadmium. A brief review of available drawings indicated that cadmium plating was common at the time. Reference

[1] Courtesy of Waco Inc, 118 39A Cannon Blvd, Newport News, Virginia.

20 specifies, for example, cadmium plating of all air diffusers, registers and grills in the ship. From this evidence, it is likely that each of the ships contains hundreds or thousands of cadmium plated parts.

Because the cadmium-plated metal parts are in good condition and may be reusable in many different circumstances, no need to remove these parts is anticipated.

6.4 ETHYLENE GLYCOL

Ethylene glycol (antifreeze solution) was found in cooling systems in the two ships in which it was sampled. Nearly all of the cooling requirements in the ships are provided by seawater. Only specialized cooling needs such as the emergency diesel generator employ antifreeze. Drawings or other information which would allow the amount aboard each ship to be estimated were not available; however, it appears that not more than 200 gallons would be present based on the size of the systems involved. For the reefbuilding scenario, the fluid would probably need to be removed; however, there is so little aboard that the cost to remove it is judged to be insignificant. Because the cooling fluid has corrosion preventive properties, it is considered functional and could be reused in the machines. Therefore, for other scenarios, including export for recycling, the fluid would be left in place.

6.5 CHLOROFLUOROCARBON REFRIGERANTS

Both the EXPORT CHALLENGER and the SHIRLEY LYKES carry domestic air conditioning and cargo refrigeration systems. The systems in both ships are powered by multiple refrigeration compressors using R-12 refrigerant (dichlorodifluoromethane). References 28 and 30 cite a total R-12 charge of 580 pounds for all of the EXPORT CHALLENGER's refrigeration systems. Comparable drawings for the SHIRLEY LYKES could not be located but equivalent systems are anticipated. From physical inspection of the spaces, the WAYNE VICTORY has a minimal air-conditioning system and therefore should contain far less refrigerant. As seen in Tables 19, 20 and 21 of Reference 3, R-12 was confirmed to be present in the refrigeration systems of all ships. The amount left in the systems could not be determined.

Refrigerants such as R-12 are regulated by the international Montreal Protocol on Substances that Deplete the Ozone Layer. Domestic regulations that implement the protocol are in Title 40 of the Code of Federal Regulations, Part 82. These regulations require that the refrigerant in the ships be carefully collected for reuse or disposal by certified technicians if the machines are no longer being used. Venting of the refrigerant to the atmosphere is not permitted.

Whether or not the refrigerant would be removed depends on the ultimate disposition of the ship. For domestic recycling, the recycler may have a market for the refrigeration systems and the refrigerant as well. For reef-building or other uses of the ship that do not require the refrigeration systems to be operable, removal may be appropriate. Because we were unable to measure the

amount of freon present in the systems, we could not estimate with any accuracy the cost to remove it.

Regarding export of the ships, the export of any amount of R-12 to any country that has not signed the Montreal Protocol (and its subsequent amendments) is prohibited by EPA regulations. The three nations that have recently imported ships for recycling, Mexico, India and China have signed. Therefore, removal of R-12 would not be required before export, provided the export is made to one of those three nations.

6.6 LOOSE PAINT

Tables 19, 20 and 21 of Reference 3 show that high levels of lead exist in paint aboard all three ships. Although not analyzed, high levels of chromium are also expected because the use of chromium-containing primer paints was common during the time the three ships were built and operated. These paints are specified in paint schedules such as Reference 33. Lead and chromate bearing paints will fail the Toxic Characteristic Leachate Procedure test of Federal hazardous waste rules and will therefore be subject to regulation.

6.6.1 Interior Paint

The interior paints in all ships are in good condition. Paint which is tightly adhering to surfaces prevents corrosion and is therefore serving a function. A requirement to remove adherent paint is not anticipated.

6.6.2 Exterior Paint

Exterior paints on the EXPORT CHALLENGER and WAYNE VICTORY are in poor condition. Severe peeling and bubbling exist on nearly all weather surfaces. The decks of these ships hold large accumulations of paint chips mixed with rust. It is concluded that loose paint and accumulations of paint chips on decks must be removed regardless of the ultimate disposition of the ships.

Measurements of paint chip depth and extent were made on the decks of the WAYNE VICTORY and the EXPORT CHALLENGER. Paint chips cover the weather decks within two feet of the gunwales and all vertical deck-mounted structures on both ships. A sample of paint covering approximately ¼ square foot of such an area was collected and found to weigh about 0.3 lb., giving a paint chip loading of about 1.2 pounds per ft^2. The thickness of peeling paint on weather surfaces was measured at 1/32 inches with a bulk density of about 2 (128 lbs/ft^3). About half of the paint on weather surfaces was estimated to be loose. Estimates of the total weather

surface area were made from ships drawings, such as Reference 34, and from all of this information, the amount of loose paint was estimated. The results of these calculations are as follows:

EXPORT CHALLENGER

Total area of paint chips on decks	≈ 6400 ft^2	
Total pounds of loose paint on decks @ 1.2 lbs/ft^2		≈ 8000 lbs.
Total area of peeling paint	≈ 55,000 ft^2	
Fraction easily removable	≈ 1/2	
Volume of peeling paint	≈ 72 ft^3	
Total pounds of peeling paint		≈ 9000 lbs.
	TOTAL	≈ 17,000 lbs.

WAYNE VICTORY

Total area of paint chips on decks	≈ 3100 ft^2	
Total pounds of loose paint on decks @ 1.2 lbs/ft^2		≈ 4000 lbs.
Total area of peeling paint	≈ 35,000 ft^2	
Fraction easily removable	≈ 1/2	
Volume of peeling paint	≈ 46 ft^3	
Total pounds of peeling paint		≈ 6000 lbs.
	TOTAL	≈ 10,000 lbs.

Collecting loose paint from decks and scraping the topsides inboard of the gunwales should be straightforward work that could be accomplished by a crew of about 10 workers in five days (50 worker days).

Removing loose paint from the sides of the ships will require draping the ship's sides to prevent paint from falling into the harbor and will be done from scaffolds. This is judged to require double the effort of removing the other topside paint. Thus, the estimate for labor to remove paint chips and loose paint is 150 work days or about $17,000 for each ship. The condition of paint in the SHIRLEY LYKES is considerably better than either of the other two. There are small amounts of loose paint on the decks and most of the paint on the weather surfaces is still adhering. About ¼ of the work estimated for EXPORT CHALLENGER is judged to be needed to collect and dispose of loose paint on SHIRLEY LYKES.

The estimate for removal of paint chips and loose paint from each ship is:

EXPORT CHALLENGER

Labor:		≈$17,000
Disposal: 17,000 lbs. @ $0.58 /lb.		≈ 10,000
	TOTAL	≈$27,000

WAYNE VICTORY

Labor:		≈$17,000
Disposal: 10,000 lbs. @ $0.58 /lb.		≈ 6,000
	TOTAL	≈$23,000

SHIRLEY LYKES

Labor:		≈ $4,000
Disposal:		≈ 3,000
	TOTAL	≈ $7,000

6.7 POLYCYCLIC AROMATIC HYDROCARBONS

Polycyclic aromatic hydrocarbons (PAHs) were analyzed in asphaltic paint used in some wet lockers. PAHs are a family of coal or petroleum-derived hazardous materials often found in coal tar paints that are used where water resistance is imperative. Very small amounts of asphaltic paint were found. All was adherent and still functional; therefore, removal is not required.

6.8 ORGANO-TIN

Tributyl tin (TBT) was once used as the anti-fouling agent in ship bottom paint. Paint with TBT is extremely toxic. During removal, workers must wear protective suits and be provided with filtered breathing air. Removed paint must be handled as a hazardous waste. As the ships were afloat and the sampling plan called only for sampling of the ship's topsides, samples of paint from below the waterline were not taken. However, samples of paint were taken from as far down the side as could be reached. Tin at levels typical of anti-fouling paints (1% or more) was not found in these samples. Sampling of paint from below the ship's waterline is required to determine whether there is an issue with TBT.

6.9 FUEL AND CARGO TANK SLUDGE

Sludges from fuel and cargo tanks are regulated as hazardous wastes in the United States. If the tanks are full or partly full of usable oil, then the tanks contain reusable oils that are not regulated as hazardous wastes. But failing that, cleaning of the tanks to remove the residues will likely be required regardless of the ultimate disposition of the ships. Information on the status of the tanks

in all three ships was obtained from the James River Reserve Fleet.[2] Table 10 summarizes this information.

Table 10. Fuel and Oil Tank Status

	EXPORT CHALLENGER	SHIRLEY LYKES	WAYNE VICTORY
Date of last sounding	Nov 14, 1995	Nov 13, 1987	Oct 14, 1982
1 - Number of tanks	22	42	25
2. - Number full or partly full with water or sludge	5	1	2
3 - Number full or partly full with fuel or diesel oil	5	11	15
4 - Number requiring cleaning (row 1 minus row 3)	17	31	10
5 - Oil capacity	3882 tons[3]	3905 tons[4]	2888 tons[5]

Assuming that tanks that are full or partly full of fuel or diesel oil may be left uncleaned, the remaining tanks, shown in row four, require cleaning. The tanks in row two contain a mixture of water and oil sludge or oil sludge alone and must be pumped and then cleaned. Petroleum sludges often contain benzene and other hazardous constituents, or possess hazardous characteristics, as discussed in Reference 5, that cause them to be considered as hazardous wastes.

The cost to clean fuel tanks will be approximately $40 per ton of tank capacity.[6] The complexity and accessibility of the tanks and the amount of oily sludge and water that are encountered all affect the final cost. The capacity of each of the tanks could not be determined. Assuming the number of tanks to be cleaned is directly proportional to the total volume of fuel capacity in each ship, the estimated cost for cleaning the tanks in each ship is:

EXPORT CHALLENGER	17/22 x 3882 tons @ $40/ton ≈ $120,000
SHIRLEY LYKES	31/42 x 3905 tons @ $40/ton ≈ $115,000
WAYNE VICTORY	10/25 x 2888 tons @ $40/ton = $ 46,000

[2] The most recent Fuel Oil Tank Soundings, James River Reserve Fleet form MA2-58, were provided for each ship.

[3] From the ABS Record and John LaDage, "Principles of Naval Architecture."

[4] From Bethlehem Steel Company Plan Number 4588/S94-0-1, "List of Safety Devices."

[5] From Bruce Engineering Company Drawing VC2-S-AP2.

[6] Courtesy of Boiler Cleaning and Specialty Company, 14428 Columbus Avenue, Portsmouth, Virginia 23704.

A breakdown between labor and waste disposal cost is not available.

The tank sounding information shown in Table 10 may not reflect the current condition of the tanks. Because of restrictions on the discharge of unprocessed bilge water, the James River Reserve Fleet has recently been using onboard tanks to receive bilge water that accumulates in the ships, rather than pump it over the side. The tank soundings for the SHIRLEY LYKES and the WAYNE VICTORY date from many years ago and therefore do not reflect this fluid. The amount is unknown, but it could add substantially to the waste disposal costs.

6.10 BILGE WATER

Large volumes of bilge water in all of the ships were observed in the main machinery spaces, exceeding 1 foot in some areas. Not all bilge areas of the ships were observed. Based on the ship's dimensions and the depth observed, at least 15,000 gallons were present in each machinery space.

Bilge water can come from leakage through hull fittings and internal seawater systems, from condensation of moisture during the cold winter months and from rainwater that passes through openings in the weather decks and bulkheads. Bilge water is often a hazardous waste because of its heavy metal and organic chemical content. In some states, bilge water is listed as a hazardous waste and must be treated as such regardless of its composition.

Assuming the bilge water in the three ships is a hazardous waste and that it must be properly disposed of regardless of the ultimate disposition of the ships, the disposal cost is estimated to be $40,000.

EXPORT CHALLENGER, SHIRLEY LYKES, WAYNE VICTORY

15,000 gal x 8 lbs/gallon x $0.32/lb. ≈ $ 40,000

6.11 EXCESS SHIP'S STORES AND OTHER MATERIALS

In the United States, partly used containers of grease, adhesives, caulks, paints and other such products that have no use and possess hazardous characteristics are regulated as hazardous wastes. Many compartments in all three ships contained partly used containers of such materials that appeared to be for use during maintenance of the ships. Once maintenance ceases and the ships are designated for recycling, the materials have no use, and current regulations require them to be removed and properly disposed of. The amounts of material observed were small, and removing them is estimated to involve very little labor. Therefore, no estimates are provided for removing excess ships' stores.

SHIRLEY LYKES may have a unique problem with fixed ship's ballast. Reference 34 shows the 1375 long tons of "mud ballast" installed with a notation that the ballast is not to be removed

without the prior concurrence of the U.S. Coast Guard. The drawing goes on to describe the ballast as "fluid ballast" installed between frames 104 and 108, approximately midships. "Mud ballast" usually refers to drillers mud used in the petroleum drilling industry to lubricate drill bits and remove drilling debris. The mud is treated with lubricants and corrosion inhibitors. Used drilling mud has been used for ship's ballast. Mud ballast may also refer to concrete, rock, water, and other forms of locked-in ballast. There is no information available on the chemical nature of mud ballast in the SHIRLEY LYKES, but it is known that the U.S. Navy has used locked-in fluid ballast treated with sodium chromate to prevent corrosion of the ballast tanks. Sodium chromate is a hazardous material, and, if used in the SHIRLEY LYKES, the ballast could be subject to hazardous waste regulation. If so, the cost to dispose of the ballast could approach $1 million. There is no information available as to whether or not the EXPORT CHALLENGER and the WAYNE VICTORY contain mud ballast.

All three ships are heavily soiled with bird guano and bird carcasses. In some cases, birds have access to interior ships' spaces and have created deposits of guano and bird carcasses that are ankle deep. To the author's knowledge, this situation is not subject to environmental regulation but may be subject to local health standards at the site of recycling.

6.12 NONHAZARDOUS INDUSTRIAL WASTES

The recycling of ships generates large amounts of nonhazardous, solid industrial waste. Bedding, wood products, floor tiles, deck fillers, assorted nonrecyclable metal parts, and debris of many kinds are removed and placed in municipal or industrial waste landfills or processed by local waste management centers. For some scenarios involving use of largely intact ships, such as reefbuilding, loose materials such as bedding must be removed. For most others, no removal prior to ultimate disposition is needed. Because the cost of removing and handling such materials from an otherwise intact ship is judged to be small, we have not attempted to estimate a cost.

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7.0 SUMMARY AND CONCLUSIONS

This report describes the environmental problems attendant to breaking and recycling of small, break-bulk cargo ships of the types and sizes represented by the EXPORT CHALLENGER, SHIRLEY LYKES and WAYNE VICTORY in the United States. The report provides estimated costs for removing hazardous materials from otherwise intact ships so that they might be sold for recycling at a higher price, used for reefbuilding projects, or exported overseas for recycling. The cost estimates are tentative. A ship breaking/recycling firm, experienced in the trade, with trained workers, and with some assurance of repeat work lasting a few years or more, may be able to construct efficient processes for getting the work done for less. Table 11 summarizes the cost estimates developed in the previous sections.

This report, coupled with Reference 3, confirms that the environmental problems faced by recyclers of Navy ships and those who would try to recycle commercial ships are similar. PCBs in electric cables, gaskets, rubber and plastic products of all kinds are found in both groups of ships. Both have asbestos insulation problems, hazardous wastes, lead in old paint, and other comparable problems that touch on nearly every aspect of environmental regulation in the Nation. Some PCB problems appear to be unreconcilable under current regulations, and either regulatory changes or regulatory discretion appears needed to allow ships to be used for reefbuilding or be exported.

Appendix B demonstrates that the sampling guidance of Reference 8 does not appear to provide a clear and complete picture of the situation regarding PCBs in commercial ships. At the time of its preparation, the EPA had none of the data or information in this report or in Reference 3. Therefore, it is not surprising that the sampling guidance is not well suited to commercial ships. Section 6 shows that dealing with other hazardous materials is also difficult and expensive. Guidance is needed for this area, comparable in scope and intent to Reference 8. For all hazardous materials and wastes, a focused approach to sampling, based on reviews of ships' drawings and material lists, supplemented by ships' inspections, and based on the specific regulatory goals in mind, should provide greater precision for less sampling and analysis cost.

Table 11. Summary of Costs for Removal of Hazardous Materials from Ships Prior to Recycling

		EXPORT CHALLENGER		SHIRLEY LYKES		WAYNE VICTORY	
		$ Labor	$ Disposal	$ Labor	$ Disposal	$ Labor	$ Disposal
PCB Materials	Cables	56000	23000	61000	34000	0	0
	Other Electric	14000	14000	14000	14000	14000	14000
	Vent Gaskets	5000	1000	7000	2000	600	400
	Cat. 3, Rubber Gaskets	Note A	Note A	Note A	Note A	Note A	Note A
	Cat. 4, Other Felt Gaskets	9000	5000	0	0	0	0
	Cat. 5, Insulation	0	0	0	0	Note B	Note B
	Cat. 6, Sound Deadening Felt	0	0	0	0	0	0
	Cat. 7, Grout, Caulk, Adhesive	14000 Note C	7000 Note C	0 Note C	0 Note C	7000 Note C	4000 Note C
	Cat. 8, Tapes	0	0	0	0	0	0
	Cat. 9, Pipe Hangers	0	0	0	0	0	0
	Cat. 10, Misc. Rubber, Plastic	0	0	0	0	0	0
	Cat. 11, Oil & Grease	Note D	Note D	Note D	Note D	Note D	Note D
	Surface Cleanup	Note D	Note D	Note D	Note D	Note D	Note D
	PCBs Subtotal	$98000	$50000	$82000	$50000	$22000	$18000
Other Materials	Asbestos	200000		200000		200000	
	Cadmium	0	0	0	0	0	0
	Ethylene Glycol	0 Note E	0 Note E	0 Note E	0 Note E	0 Note E	0 Note E
	Refrigerants	0 Note E	0 Note E	0 Note E	0 Note E	0 Note E	0 Note E
	Loose Paint	17000	10000	4000	3000	17000	6000
	PAH	0	0	0	0	0	0
	Organotin	0	0	0	0	0	0
	Fuel & Oil Sludge	120000		115000		46000	
	Bilge Water	nil	40000	nil	40000	nil	40000
	Waste Ships Stores	0	0	0	0	0	0
	Mud Ballast	n/a	n/a	Note F	Note F	n/a	n/a
	Other Materials Subtotal	$387000		$362000		$309000	
	Grand Total	$535000		$494000		$349000	
	Cost per LSW ton	$77		$57		$78	
AVERAGE COST/LSW ton: $71							

Notes for Table 11.

Note A. The data suggest that removal of rubber gaskets from installed systems will be required to eliminate PCBs from the ships. This is judged to be not practicable in otherwise intact ships.

Note B. The cost for removal of the PCB-contaminated thermal insulation in WAYNE VICTORY is included in the cost of asbestos removal. In the event no asbestos removal is done, separate removal of the insulation to remediate the PCB problem will be required.

Note C. This estimate is based only on removal of caulked and grouted pipe penetrations. Removal of all caulking, grout and adhesive is not practicable.

Note D. Comprehensive sampling for oils and greases and for potential surface contamination problems were not performed. It is therefore not possible to estimate remedial costs.

Note E. There may be small costs for removal of these materials depending on the ultimate disposition of the ships.

Note F. If the mud ballast is found to be a hazardous waste, disposal cost could approach $1 million.

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16. Sun Shipbuilding and Dry Dock Company Drawing 623-765-13, "Paint Schedule."

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19. Sun Shipbuilding and Dry Dock Company Drawing 623-779-E, "List of Ventilating Fans, Steam Heating, Coils & Dx Cooling Coils."

20. Sun Shipbuilding and Dry Dock Company Drawing 623-779-H, "Ventilation and Air Conditioning Terminal List."

21. Sun Shipbuilding and Dry Dock Company Drawing 623-915-4, "Machinery Space Ventilation Arrg't. Material List."

22. Bethlehem Steel Company Plan Number 4588/S38-1-8, "Ventilation Induction Unit List."

23. Bethlehem Steel Company Plan Number 4588/S38-1-9, "Ventilation Terminal List."

24. Bethlehem Steel Company Plan Number 4588/S38-1-5, "Ventilation Diagram - Machinery Space."

25. Bethlehem Steel Company Plan Number 4588/S38-1-3, "Ventilation Diagram, Main & Upper Tween Dks."

26. Bethlehem Steel Company Plan Number 4588/S38-1-2, "Ventilation Diagram - Forecastle Dk, Upper Dk & Above."

27. Bethlehem Steel Company Plan Number 4588/S38-1-4, "Ventilation Diagram - Lower Tween Dk & Hold."

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APPENDIX A

COST FOR ENVIRONMENTAL SERVICES AND WASTE DISPOSAL IN THE NORFORK, VIRGINIA AREA

July 1997

APPENDIX A
COST FOR ENVIRONMENTAL SERVICES AND WASTE DISPOSAL IN THE NORFOLK, VIRGINIA AREA

The costs for waste disposal services at the Norfolk Naval Shipyard are provided below. The costs represent those charged to a large industrial facility that deals with large amounts of waste. The costs are based on the waste production rates estimated by the shipyard and vary with the concentration of PCBs and the anticipated volumes of materials in each concentration range. The cost for waste disposal services at other facilities may vary from these.

A.1 PCB WASTE

A.1.1 PCB Solid Waste

- Less than 50 ppm $0.41 per pound
- 50 to 499 ppm $0.93 per pound
- 500 to 4999 ppm $0.44 per pound

The report uses an average cost of $0.69 per pound for disposal of PCB solids, assuming that half falls within each range.

A.1.2 PCB Liquid Waste

- Less than 50 ppm $0.43 per pound
- 50 to 499 ppm $0.65 per pound
- 500 to 4999 ppm $0.42 per pound

A.1.3 PCB Liquid and Solid Mixtures

- up to 499 ppm $0.70 per pound
- 500 ppm or greater $3.00 per pound

A.2 HAZARDOUS WASTE LIQUIDS

A.2.1	Ignitable	$0.49 per pound
A.2.2	Corrosive	$0.51 per pound
A.2.3	Reactive	$2.33 per pound
A.2.4	TCLP	$0.72 per pound, in quantities up to 1000 gallons
A.2.5	TCLP	$0.32 per pound, in quantities >1000 gallons
A.2.6	Excess toxic chemicals	$0.46 per pound

A.3 HAZARDOUS WASTE SOLIDS

A.3.1	Ignitable	$0.81 per pound
A.3.2	Corrosive	$0.79 per pound
A.3.3	Reactive	$1.41 per pound
A.3.4	TCLP	$0.58 per pound
A.3.5	Excess toxic chemicals	$0.82 per pound

The report uses the cost for TCLP (Toxic Characteristic Leachate Procedure) wastes, assuming that most of the wastes generated by recycling will be of this kind.

A.4 INDUSTRIAL SOLID WASTE, NONHAZARDOUS

A.4.1	Solid Waste	$48.20 per ton

APPENDIX B

EVALUATION OF EPA GUIDANCE FOR SAMPLING ABOARD SHIPS

July 1997

APPENDIX B
EVALUATION OF EPA GUIDANCE FOR SAMPLING ABOARD SHIPS

B.1 INTRODUCTION

The sampling for PCBs aboard the EXPORT CHALLENGER, SHIRLEY LYKES and WAYNE VICTORY was performed, to the extent practicable, in accordance with the EPA guidance of Reference 8. Reference 8 states that the guidance is ". . . an interim method of determining whether polychlorinated biphenyls (PCBs) have been removed from ships . . . " destined for recycling. The guidance provides two basic options:

- remove all known sources of liquid and non liquid PCBs, or
- sample the ship to determine whether any known sources are aboard, remove those that are found, and resample to confirm that none remain.

The EPA defines "known sources" broadly. Electric cables, gaskets, caulks, rubber products, plastic products and nearly all other nonmetallic materials fall under the definitions. The guidance includes a sampling scheme that groups materials into 10 categories, specifies minimum numbers of samples to be taken in each category and allows a category to be dismissed from further consideration if no PCBs are found at or above 50 parts per million.

The guidance specifies that the total number of samples taken will be equal in number to the square root of the weight of the ship as sold for recycling. Typical MARAD ships destined for recycling weigh from 4,000 to 10,000 tons, leading to 63 to 100 samples. Two categories of materials, electric cables and ventilation system gaskets, are given special emphasis. Forty percent of all samples must be cables and 40% ventilation system gaskets. The remaining 20% are split among the remaining eight categories.

The guidance specifies in detail how the samples are to be selected. Ship's compartments are selected at random. Several sampling criteria are specified, such as the number of samples in each category, the minimum number of samples on each deck of the ship and so forth. Within the limits of the criteria, samples are taken at random. Other than the arrangement of ship's compartments, no prior knowledge of the ship's materials or methods of construction is required nor is the application of such knowledge permitted.

An effective sampling protocol should measure PCBs in the ships with a high degree of precision such that, after removals, there is a good chance that no more will be found. If significant amounts are missed during the first round of sampling, a recycler could be caught in repetitive cycles of removing materials and resampling, affecting the profitability of the project. This Appendix compares construction details from ship's drawings and from inspections of the ships

with the sampling results to determine, qualitatively, whether or not the sampling resulted in a precise measurement of PCBs and whether there are any categories of PCBs that are not covered.

B.2. SAMPLING FOR PCBs IN ELECTRIC CABLES

B.2.1 Introduction

PCBs were found in the cables of the EXPORT CHALLENGER and SHIRLEY LYKES. To determine whether the samples represent a fair cross section of all the cables in each ship, available ship's drawings were reviewed to determine the number and type of the cables actually installed in each ship, and the samples were then compared to the drawing information.

B.2.2 Cables in the EXPORT CHALLENGER and SHIRLEY LYKES

Section 3 discusses the drawings that were reviewed to establish, as best as practicable, the cable used in each ship and summarizes the information in Tables 1 and 2. None of the samples were marked with cable type. Cable tracing would allow cable samples to be associated with specific circuits and therefore specific cable types, but this is tedious and beyond the scope of the project. Instead, each two-, three-, and four-conductor cable sample was assigned an assumed type from the measured diameter and observed number of conductors (recorded in Appendix A of Reference 3). Because no cable diameter drawings were available for EXPORT CHALLENGER, the SHIRLEY LYKES data was used for both ships. Cable diameters were sometimes severely distorted by installation and years of service; therefore, the measurements may not be precise. Samples with one or five or more conductors are ignored.

Figures B-1 and B-2 present the results graphically. The Y axis of each table is the length, in feet, and weight, in pounds, of each type of cable as determined in Section 3 and shown in Tables 1 and 2. Each cable type is recorded on the X axis in abbreviated format. T4 indicates, for example, TAVIB4. The boxed numbers in the figures show the number of samples taken of the types intersected by the box. For example, the box in Figure B-1 that contains the number 18 indicates that 18 samples of cables having two, three, or four conductors and diameters equal to those of T4, D4 or F4 cables (0.477 to 0.563 inch) were taken.

Figure B-1 illustrates that in the EXPORT CHALLENGER, samples of cable types T16, T20 through T33, T52 through T106 and T212 through T400 were not taken. These represent approximately 35% of the cables by length and 66% of the cables by weight of all those shown in Table 1 of Reference 3. Similar omissions are shown in Figure B-2 for the SHIRLEY LYKES; samples of cable types D10 through T83 and D168 through T550 were not taken; representing approximately 33% of the cables by length and 72% of the cables by weight of all those shown in Table 2 of Reference 3.

Figure B1

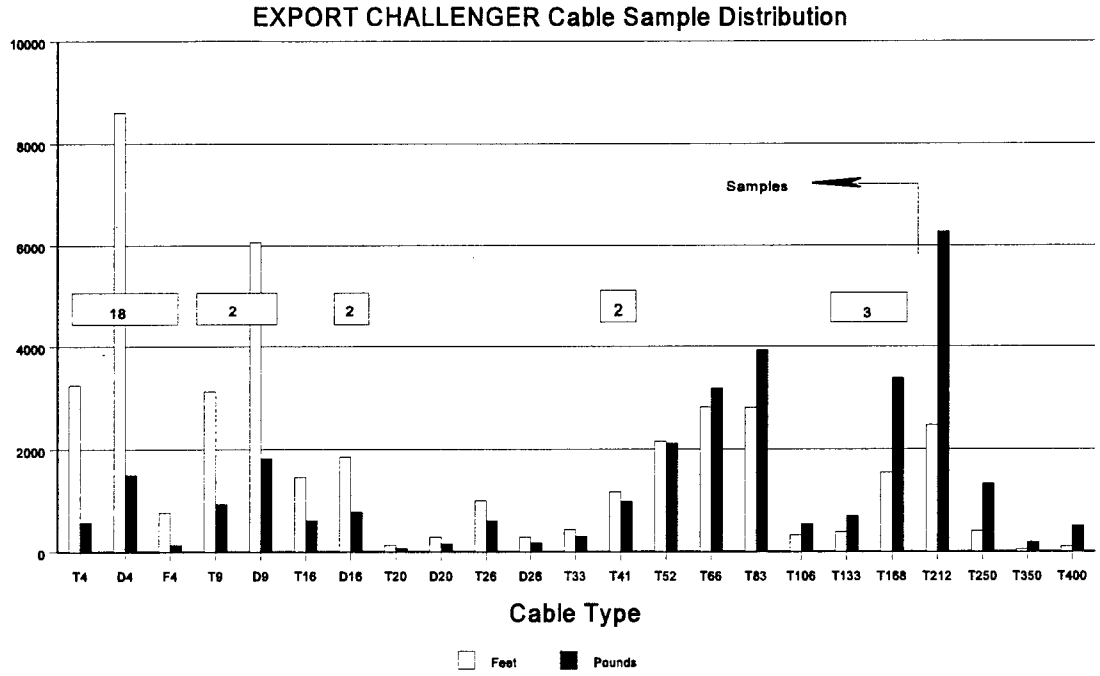
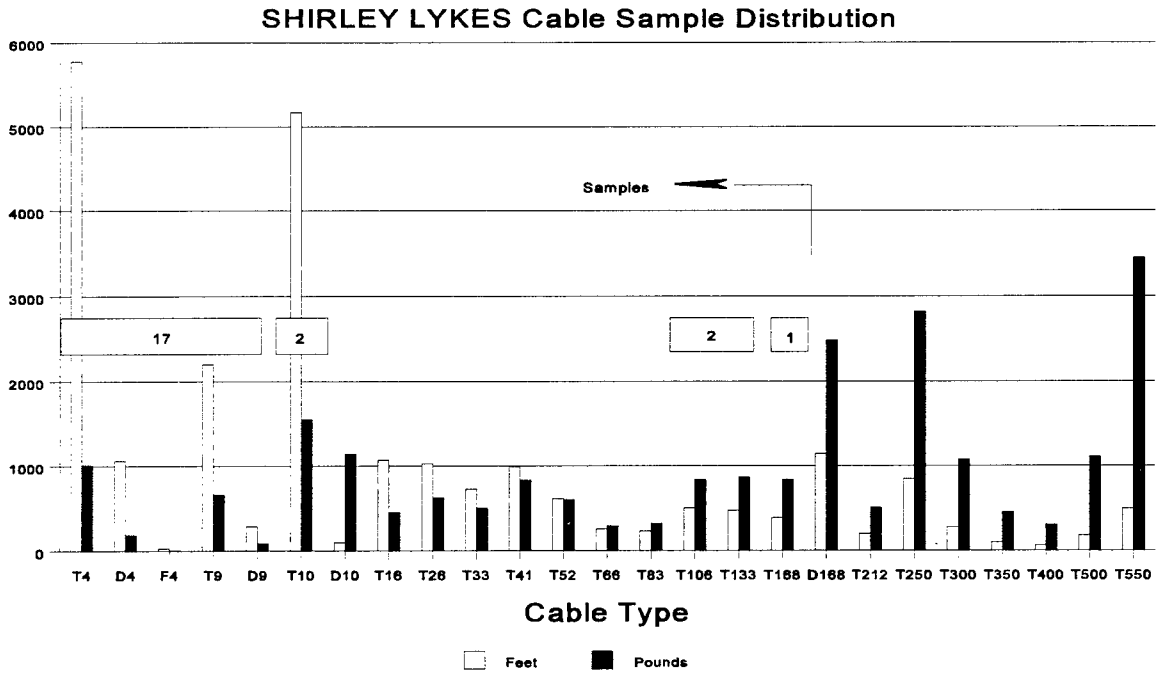


Figure B2



Reference 12 lists 95 different kinds of electric cables that are installed in the SHIRLEY LYKES. Many small diameter phone cables (¼ inches and less) and a variety of multiconductor interior communications cables are included on this list in addition to those covered in Tables 1 and 2 in Section 3. At best, the sampling plan would have called for 31 of the 95 types to be sampled, because no more than 31 samples were required. In fact, after identifying samples as to cable types as discussed above, it is likely that no more than nine different types of two, three and four conductor cables were sampled along with six other types of one conductor and greater-than-four conductor cables, for a total of 15 different types.

B.2.3 Conclusions

The EPA sampling guidance, as implemented in the EXPORT CHALLENGER and SHIRLEY LYKES, revealed the presence of PCBs in cables but may not provide enough information to guide cost-effective remediation. Many of the larger cables and dozens of speciality cables in both ships were not sampled, and it qualitatively appears that the sampling approach did not provide a truly random set of samples. Therefore, it is unlikely that removal of only the cable types shown as high in PCBs will be effective at removing PCB cables. Resampling, as required by Reference 8, is likely to reveal more problems. It can be speculated that in the WAYNE VICTORY, where some similar sampling biases exist (most samples are two- and three-conductor small diameter cables), the absence of PCBs is only a fluke of the sampling approach.

Sampling of the EXPORT CHALLENGER, SHIRLEY LYKES and WAYNE VICTORY using the guidance of Reference 8 is among the first applications of the guidance to commercial ships, and the experience suggests that alternate approaches may provide better data with fewer samples, and therefore less cost to the recycler. A sampling scheme based on random selection of cable samples from among those cables shown in drawings and other available information sources is one approach that may provide superior results with fewer samples. Alternately, if it can be established that a recycler will shred cables for copper recovery, or dispose of cables in an appropriate landfill, and not reuse them individually, a single analysis of a composite sample may provide sufficient information to regulate proper disposal and further reduce compliance cost.

B.3 SAMPLING PCBs IN VENTILATION SYSTEM GASKETS

Tables 13, 14 and 15 of Reference 3 present the results of ventilation gasket samples. As required by Reference 8, special emphasis was placed on sampling ventilation gaskets. Thirty-two to 40 percent of all samples were taken in this category. The sampling revealed a limited number of different gasket materials, ranging from one in WAYNE VICTORY to seven in EXPORT CHALLENGER, and multiple samples of apparently identical materials were taken. In accordance with Reference 8, the gasket samples were taken at random without reference to ship's drawings.

It appears that the number of samples exceeds that needed to identify PCBs in ventilation gaskets. It is understood that the emphasis afforded ventilation gaskets by Reference 8 is because of the frequent use of PCB-bearing felt in U.S. Navy ships. Felt is not necessarily used in all ships. Ventilation system materials of construction are often shown on material lists or system drawings. For example, Reference 22 for the EXPORT CHALLENGER specifies rubber gaskets and cork with synthetic rubber that is adhesive coated, and shows where the materials are installed. Sampling schemes based on such information may yield results in significantly fewer samples without sacrificing precision.

B.4 SAMPLING FOR OTHER PCB MATERIALS

Reference 8 requires that, ". . . in the event that all of the [. . .] known sources of non-liquid PCBs . . . have not been removed from a vessel" sampling is to be done to determine whether any that remain aboard contain PCBs and must be removed before export. To simplify sampling, the EPA has combined all materials other than cables and ventilation system gaskets into eight categories:

- Rubber gaskets (other than ventilation system gaskets),
- Felt gaskets (other than ventilation system gaskets),
- Fiberglass, felt, foam, or cork thermal insulation material,
- Sound deadening felt,
- Grouting, caulking, rubber isolation mounts, foundation mounts, and adhesives,
- Tapes,
- Pipe hangers, and
- Rubber/plastic parts of all sizes and shapes (other than listed above).

Reference 8 requires no more than 20% of all the PCB samples in the ship to be from these eight categories. For the three MARAD ships, this amounts to no more than one or two samples from each category. The results of the sampling of the eight categories are shown in Tables 16, 17 and 18 of Reference 3.

The sampling results show that the categories do not necessarily reflect the methods of construction of commercial ships and do not necessarily provide for effective remediation.

- Identical products are often used in two or more of the same EPA categories. For example, processed cork/rubber material was found in the ventilation systems (Category 2) and machinery closure panels (Category 10) of the EXPORT CHALLENGER; and felt was found in the ventilation systems, an electrical controller closure (Category 4) and a pipe hanger liner (Category 9) of the SHIRLEY LYKES.

- It is often difficult to assign a product to a particular category. The rubber part in the foot of the ladder in the EXPORT CHALLENGER steering gear room could be

described as a "rubber gasket" (Category 3), a "rubber isolation mount" (Category 7, where it was assigned) or a miscellaneous rubber part (Category 10). Assignment of a sample to an EPA category can be a very important decision. Had this part been found to contain PCBs (it did not), the entire category to which it was assigned to would require remediation and resampling.

- Some of the categories contain apparently unrelated products. There are no known similarities between rubber mounts and caulks, adhesives and grout (all in Category 7) that would warrant removal and resampling of these types of materials if one showed high PCBs.

- So few samples were taken of "Other PCB Materials" that many potential PCB materials were doubtlessly overlooked. Paint, for example, was intentionally not sampled (as directed by Reference 8), because paint on surfaces that are to be remelted need not be controlled. But paint is a well-known potential PCB material that is applied to many surfaces, such as thermal insulation that will never be remelted.

- The categories do not reflect a consistent approach to sampling. Some categories are specific materials (tape, for example), while others are services (pipe hanger liners, for example) that can be met by many different materials at the discretion of the ship's designer.

These problems can be resolved by a sampling scheme that focuses on materials rather than services and relies on reviews of ship's drawings, material lists, insulation schedules, paint schedules, etc., to select the materials and locations to be sampled. For example, a specific gasket material that is used in many services can be sampled in a few specific services, from known locations, to determine whether that material, in all of its applications, requires remediation. Such an approach is likely to provide a more comprehensive view of the PCB situation in a ship and a more thorough remediation in preparation for alternative use or export.

For domestic recycling, it may not be necessary to sample for "Other PCB Materials" prior to recycling. The results of the Toxicity Characteristic Leachate Procedure test for the nonmetallic parts of electric cables, reported in Tables 9, 10, and 11 of Reference 3, show that the PCBs do not leach even at levels as high as 3,900 ppm in the nonmetallic parts. Additional sampling of other types of PCB-bearing materials will likely show the same. Therefore, it appears that the materials can be safely handled in a recycling environment without prior knowledge of the PCB content. With very few exceptions, nonmetallic materials in the "Other PCB Materials" categories are not recycled. A regulatory scheme that allows them to be accumulated and tested for PCBs only when disposal (or reuse) is being arranged may significantly reduce analysis cost and improve overall environmental protection.

B.5 SAMPLING FOR PCB LIQUIDS

Reference 8 requires all ". . . known sources of liquid PCBs . . . " to be removed but does not specify any sampling for PCBs in liquids. Navy experience[1] shows that about 3% of the liquid samples taken have PCBs at or above 50 ppm. Therefore, a sampling program may have a high probability of finding no PCBs. EPA guidance should provide the sampling option for potential liquid sources of PCBs to the same extent as for solid nonmetallic materials. As with solid materials, review of ship's drawings may reveal the types of fluids used in the various affected systems and minimize the required number of samples.

B.6 SAMPLING FOR PCB SURFACE CONTAMINATION

Reference 8 specifies that

> "Impervious solid surfaces [. . .] which are contaminated with liquid PCBs, shall be cleaned to less than 100 micrograms per 100 centimeters square (<100 $\mu g/100\ cm^2$) PCBs if the material beneath the surface is to be smelted in a smelter { . . . }. If the material beneath the surface is not going to be smelted, then the surface shall be cleaned to $\leq 10\ \mu g/100\ cm^2$."

It further specifies that

> "Non-impervious solid surfaces { . . . } which are contaminated with liquid PCBs, shall not be evaluated for PCB removal by a surface sampling test, but cleaned to <50 ppm, [. . .] if the solid beneath the surface will be recycled by smelting [. . .]. If the solid beneath the surface will be recycled but not smelted { . . . }, the PCB cleanup level is <2 ppm as measured by a core or scrape sample."

None of the sampling guidance in Reference 8 covers sampling for these situations. The most common nonimpervious surface that may be contaminated with PCBs is insulation in engineering spaces. This material can contain PCBs from paint, particularly heat-resisting aluminum paint that is widely used in the three ships, or from spills. There is no simple way of distinguishing whether PCBs detected in such materials come from spills or from the original materials. With regard to impervious surfaces, Navy data[2] show that 24% of the surfaces that have been wipe-tested exceed 10 $\mu g/100\ cm^2$ and 6% exceed 100 $\mu g/100\ cm^2$. While the Navy data cover only Navy ships, many of the ships sampled are comparable to commercial ships (oil cargo ships, tugboats, yard craft), and therefore it is likely that comparable problems exist in commercial ships.

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[1] Naval Sea Systems Command Document, *Inact Ship PCB Survey Results*, November 30, 1995.

[2] Ibid.

Existing EPA guidance for wipe sampling of surfaces, such as Reference 35, is not necessarily applicable, because it applies to sampling following spills. Shipboard PCB surface residues, if any are present, are most likely the result of years of accumulations of oils, some from inadvertent spills and some from intentional design features of nearby equipment.

PCB surface contamination, unlike PCBs in solid materials, creates risk of exposure to the workers. Therefore, sampling and remediation of surface contamination are needed, whether or not a ship is to be exported for recycling or domestically recycled.

B.7 SAMPLING FOR OTHER HAZARDOUS MATERIALS

There is no EPA guidance for sampling or removal of hazardous materials, other than PCBs, in ships destined for alternative uses. As discussed in Chapter 6, there are many non-PCB potentially hazardous wastes that might require removal. The removal of some of these materials may be more costly than dealing with PCBs; therefore, regulatory guidance is needed. As with PCBs, a sampling plan based on review of available drawings or other ship's information will provide the best basis for developing the least costly and most effective sampling program.

B.8 CONCLUSIONS

The sampling of EXPORT CHALLENGER, SHIRLEY LYKES and WAYNE VICTORY for PCBs in accordance with the EPA guidance of Reference 8 identified PCBs in the three ships but may not have revealed the most significant sources or provided the information a recycler needs to perform effective removal of the PCBs. The information in this report provides the basis for developing an improved sampling strategy that overcomes these problems.

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