APPENDIX E

SURVEY OF
SHIPS AND MATERIALS

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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.

[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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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]

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[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.

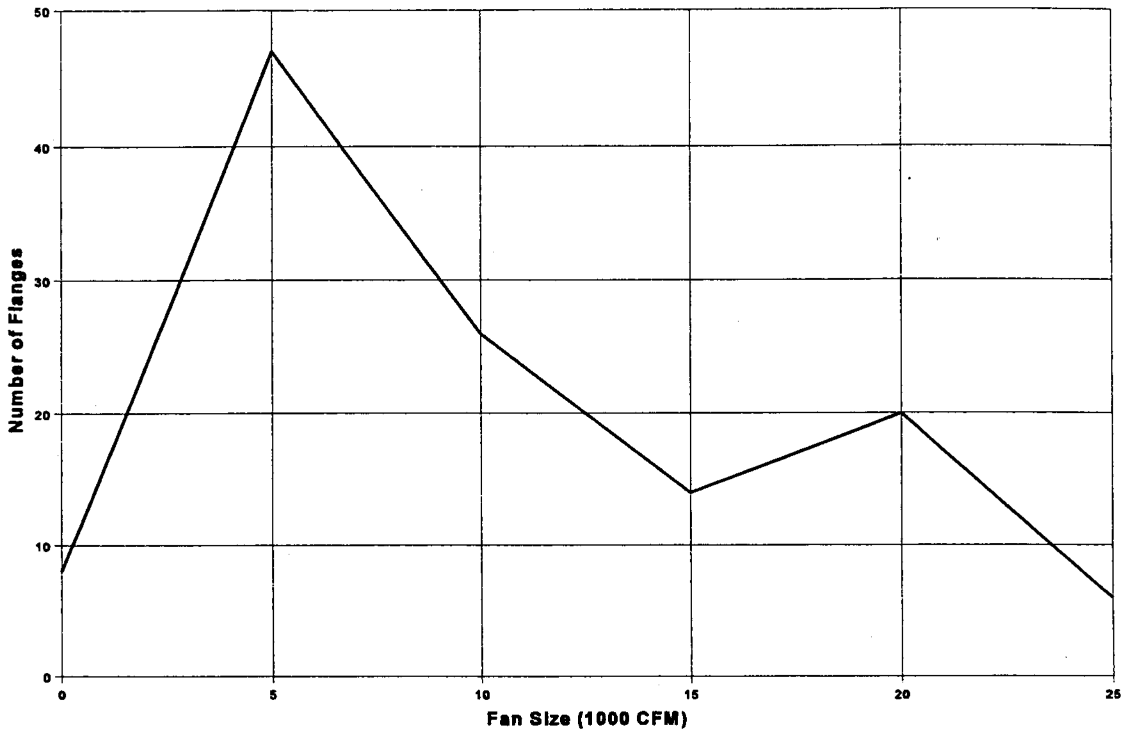
4.3.2 Estimated Number of Ventilation System Gaskets

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