# Final Report

# Polychlorinated biphenyls (PCB) Source Term Estimates

# for ex-FORRESTAL (CVA-59) Class

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# Introduction

The FY04 National Defense Authorization Bill (HR 1588 Sec 1013) permits decommissioned ships stricken from the Naval Vessel Register to be transferred to States for use as artificial reefs[1]. This new artificial reefing authority allows the Navy's Inactive Ships Program under PEO SHIPS to reduce their inventories of unneeded vessels.

The Navy's program objective is to reduce the size of the inactive ships inventory in a cost-effective and environmentally sound manner. The Navy will accomplish the environmental remediation of transferred vessels in accordance with draft EPA Best Management Practices[2]. The purpose of this report is to estimate the amount of PCB-containing material aboard a class of ships that are candidates for use as artificial reefs, in support of the Navy's objectives.

The candidate class discussed in this report is the ex-*Forrestal* (CVA 59) Class.

# Background

The *Forrestal* class of attack aircraft carriers includes the ex-*Forrestal* (AVT 59), ex-*Saratoga* (CV 60), ex-*Ranger* (CV 61), and ex-*Independence* (CV 62).

These ships have a displacement of 76,614 tons full load, as built, and approximately 81,500 tons at end of their service life. They had a crew compliment of over 4600 and a wing of over 80 aircraft.

The *Forrestal* class design replaced the cancelled *United States* (CVA 58) program. The initial design included an axial flight deck. The first two ships were laid down to the original design but altered while under construction to incorporate an angled flight deck. The *Ranger* and *Independence* were redesigned to include the angled deck and other minor modifications. The four were originally equipped with a heavy gun battery.

Details varied considerably, especially in later years. Gun armament was gradually reduced in service and eventually eliminated[3]. There was upgrading of electronics systems throughout the service life of the vessels. On 29 July 1967, *Forrestal* suffered a major fire that began among aircraft on the flight deck, igniting fuel and munitions, and spread into the hangar deck. After the crew had extinguished the blaze, the ship was left badly damaged. More than 130 crew lost their lives, 26 aircraft were destroyed and over 30 damaged[4]. The *Forrestal* required extensive repairs following the fire.

*Forrestal*, *Saratoga*, and *Independence* went through the Service Life Extension Program (SLEP) at the Philadelphia Naval Shipyard during the 1980's to extend their 30 year service lives to 40-45 years. SLEP for *Ranger* was scheduled but was cancelled. The overhaul included rehabilitation of all ship systems, upgraded electronics and weapons systems, but no significant changes to general configuration.

The ships' designation changed to CV when modified to operate ASW aircraft. *Forrestal* was redesignated AVT 59 in February 1992 as the Navy's training carrier. The first of the class was decommissioned in 1993, and all were decommissioned by 1998.

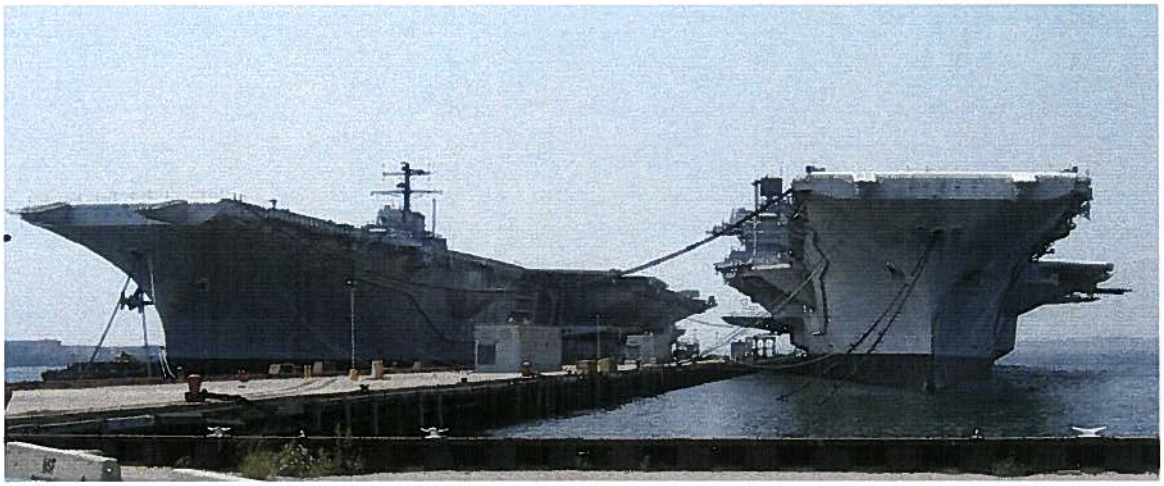

**Figure 1 ex-*Forrestal* (l) and ex-*Saratoga* (r) at Naval Station Newport, RI**

## Methodology

PCB-containing materials were identified aboard *Forrestal* class vessels through PMS 333's routine sampling protocol for vessels during the inactivation process[5, 6,7]. Materials/components found to contain PCBs at some concentration include paints, rubber products, electrical cable insulation, bulkhead insulation, ventilation gaskets, and lubricants. Therefore, the scope of this study is limited to quantifying, by the best available means, the amount of these materials aboard each vessel and calculating the PCBs available in these materials that could be potentially released into the environment if left aboard (the PCB source term).

Wherever possible, data from the *Forrestal* class was used in the quantification process. PCB concentration data from samples collected aboard ships of the class were used exclusively[5,6,7]. The ex-*Forrestal* was also visually inspected by CACI personnel in Newport, RI to verify the presence of targeted materials, and to ensure no other materials historically found to contain PCBs on Navy ships (such as impregnated felt) were aboard.

Where weight/quantity data was not directly available for the *Forrestal* class, data from surrogate vessels were used to approximate conditions found on the *Forrestal* class as closely as possible. Surrogate vessels were selected using the following criteria: 1. data readily available, 2. data from the *Kitty Hawk* (CV 63) class, 3. data from another aircraft carrier, 4. data from a large combatant built in the same era. The *Kitty Hawk* (CV 63) class was determined to be the best surrogate class for the *Forrestal* class because it was built on the Navy "improved *Forrestal*" carrier design; nearly identical to the *Forrestal* class.

Since no weight/quantity data was available from the *Forrestal* class to quantify the material aboard, the best available surrogate data was collected. Surrogate data was found for the *Kitty Hawk* (CV 63) class carrier ex-*America* (CV 66) and USS *Nimitz* (CVN 68). Specifically, a microfiche copy of the Final Weight Report (FWR) for ex-*America*[8] was acquired from NSWC Carderock Code 224, and the fan list data for USS *Nimitz* was acquired from Alion Science and Technology, Inc. The use of these documents, along with other estimating assumptions will be discussed in greater detail in the Results section of this report.

After determining the initial (as built) quantity of a given material on the surrogate, the material weight (in pounds) was adjusted by various factors, where necessary, to approximate as closely as possible the existing conditions aboard the *Forrestal* class. These correction factors include "growth rates" for materials that accumulate over the life cycle of the vessel, adjustment due to differences in subject and surrogate vessels, or conservative multipliers to account for undocumented material quantities.

The total estimated existing material weights were then multiplied by the mean and 95% upper confidence limit (UCL) PCB concentration of all samples of a given material to derive the weight of PCBs attributable to each type of PCB-containing material within the scope of the study. These Source Terms were then totaled to derive the mean and 95% UCL of the mean Total Weight of PCBs.

# Results

## *Bulkhead Insulation*

PMS 333 collected a total of thirty samples of bulkhead insulation for PCB analysis from the four *Forrestal* class ships. The samples were analyzed by, Norfolk Naval Shipyard, Puget Sound Naval Shipyard, and Spectra Laboratories of Tacoma, WA. Results reported as less than the method detection limit (MDL) were calculated as one half of the MDL for the purpose of determining the mean PCB concentration for the material.

**Table 1 Bulkhead Insulation Sample Results**

| Ship | Sample # | MDL ppm | PCBs ppm | Calculated PCBs ppm |
|---|---|---|---|---|
| | | | | |
| Forrestal | 94NN00570-32 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-42 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-49 | 5 | 3700 | 3700 |
| Forrestal | 94NN00570-53 | 5 | 10 | 10 |
| Forrestal | 94NN00570-55 | 5 | <5 | 2.5 |
| Forrestal | 98NN04425-41 | 5 | 7 | 7 |
| Forrestal | 98NN04425-42 | 5 | 6600 | 6600 |
| Forrestal | 98NN04425-43 | 5 | 14000 | 14000 |
| Forrestal | 98NN04425-44 | 50 | <50 | 25 |

| | | | | |
|---|---|---|---|---|
| Forrestal | 98NN04425-45 | 50 | <50 | 25 |
| Saratoga | 94NN05044-35 | 5 | <5 | 2.5 |
| Saratoga | 94NN05044-45 | 5 | 8 | 8 |
| Saratoga | 94NN05044-49 | 5 | <5 | 2.5 |
| Saratoga | 94NN05044-53 | 5 | 10 | 10 |
| Saratoga | 94NN05044-60 | 5 | <5 | 2.5 |
| Independence | Spectra - 41 | 0.3 | <0.3 | 0.15 |
| Independence | Spectra - 42 | 3 | <3 | 1.5 |
| Independence | Spectra - 43 | 50 | <50 | 25 |
| Independence | Spectra - 44 | 3 | <3 | 1.5 |
| Independence | Spectra - 45 | 3 | <3 | 1.5 |
| Ranger | 98PS08183-41 | 1 | <1 | 0.5 |
| Ranger | 98PS08183-42 | 1 | <1 | 0.5 |
| Ranger | 98PS08183-43 | 1 | <1 | 0.5 |
| Ranger | 98PS08183-44 | 1 | <1 | 0.5 |
| Ranger | 98PS08183-45 | 1 | 2.6 | 2.6 |
| Ranger | 98PS08185-41 | 1.2 | <1.2 | 0.6 |
| Ranger | 98PS08185-42 | 1.3 | <1.3 | 0.65 |
| Ranger | 98PS08185-43 | 1 | <1 | 0.5 |
| Ranger | 98PS08185-44 | 1 | <1 | 0.5 |
| Ranger | 98PS08185-45 | 1 | 1.2 | 1.2 |
| | | | **Mean** | 814.6 |
| | | | **95% UCL** | 1829.6 |

The estimated quantity of bulkhead insulation aboard the *Forrestal* class ships was determined from a review of the CV 66 FWR listing for Group 607 "Insulation" and 79 individual weight entries were summed to calculate a total weight of 919, 070 lbs of bulkhead insulation. This weight is assumed to be equivalent to the weight aboard each *Forrestal* class ship with no correction.

**Figure 2 Bulkhead insulation application.**

## *Rubber Products*

PMS 333 collected 24 samples of rubber products (door gaskets, pipe hangers, mounts, etc.) aboard the *Forrestal* class ships for PCB analysis. The samples were analyzed by Puget Sound Naval Shipyard, Norfolk Naval Shipyard, and Spectra Laboratories. Results reported as less than the method detection limit (MDL) were calculated as one half of the MDL for the purpose of determining the mean PCB concentration for the material.

**Table 2 Rubber Products Sample Results**

| Ship | Sample # | MDL ppm | PCBs ppm | Calculated PCBs ppm |
|---|---|---|---|---|
| | | | | |
| Independence | Spectra - 46 | 0.2 | 0.24 | 0.24 |
| Independence | Spectra - 47 | 0.15 | <0.15 | 0.075 |
| Independence | Spectra - 48 | 0.08 | <0.08 | 0.04 |
| Independence | Spectra - 49 | 0.5 | <0.5 | 0.25 |
| Independence | Spectra - 50 | 0.4 | <0.4 | 0.2 |
| Ranger | 98PS08183-46 | 1 | 46 | 46 |
| Ranger | 98PS08183-47 | 1 | 1.4 | 1.4 |
| Ranger | 98PS08183-48 | 1 | 1.1 | 1.1 |
| Ranger | 98PS08183-49 | 1 | 1.3 | 1.3 |
| Ranger | 98PS08183-50 | 1 | <1 | 0.5 |
| Ranger | 98PS08185-46 | 1 | 1.3 | 1.3 |
| Ranger | 98PS08185-47 | 5 | <1 | 0.5 |
| Ranger | 98PS08185-48 | 5 | 41 | 41 |
| Ranger | 98PS08185-49 | 5 | <1 | 0.5 |
| Ranger | 98PS08185-50 | 5 | 2.9 | 2.9 |
| Forrestal | 94NN00570-41 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-45 | 5 | 10 | 10 |
| Forrestal | 94NN00570-54 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-56 | 5 | 13 | 13 |
| Forrestal | 98NN04425-46 | 5 | 98 | 98 |
| Forrestal | 98NN04425-47 | 5 | <5 | 2.5 |
| | | | **Mean** | 9.7 |
| | | | **95% UCL** | 18.7 |

Door and other closure gaskets are the most abundant type of rubber product by weight, and is the basis of the rubber product estimate. The estimated quantity of rubber products aboard a *Forrestal* class ship was determined by a review of the *America* FWR listing for "Manholes, Doors and Hatches" Group 123 (non-ballistic) and 124 (ballistic). The total weight of Group 123 and 124 in the *America* FWR is 549, 020 lbs. This weight is assumed to be directly equivalent to the *Forrestal* class. There was no detailed sizing or count information for each closure listed in the *America* FWR, only a total weight for each group. If that information was available, the weight of door, hatch, manhole, and scuttle gaskets could be derived by counting the quantity of each size and category of closure from the Group 123 and 124 listing. The weight of gasket for each category

would derived by calculating the perimeter of each size closure (ft), multiplying by the number of closures of that type (count) and multiplying that by 0.34 lb/ft, the weight per foot of MIL-R-900 standard rubber gasket stock.

Since detailed closure sizing, count, and weight data was available for the ex-*Anchorage* (LSD 36)[9], and a precise gasket weight could be determined, that data was used to calculate a total closure weight to gasket weight ratio (weight of gaskets to weight of closures). That ratio was calculated to be 0.071 lbs gasket/lbs closure. That ratio was applied to the weight of closures estimates on the *Forrestal* class ships. Multiplying 0.071 lbs gasket/lbs closure by 549, 020 lbs of closures gives a weight of *Forrestal* class gaskets of 38, 980.4 lbs. To account for other rubber products (pipe hangers, mounts, etc.) that cannot be quantified by any available method, a conservative multiplier of two was applied to the calculated total weight of door/hatch gaskets (the most abundant source of rubber material) to account for unquantifiable rubber products. Therefore the estimated weight of rubber products a *Forrestal* class ship is 77, 961 lbs.

## *Paints*

PMS 333 collected 22 samples of paint on *Forrestal* class ships for PCB analysis. These samples were analyzed by Puget Sound Naval Shipyard, Norfolk Naval Shipyard, and Spectra Laboratories. Results reported as less than the method detection limit (MDL) were calculated as one half of the MDL for the purpose of determining the mean PCB concentration for the material.

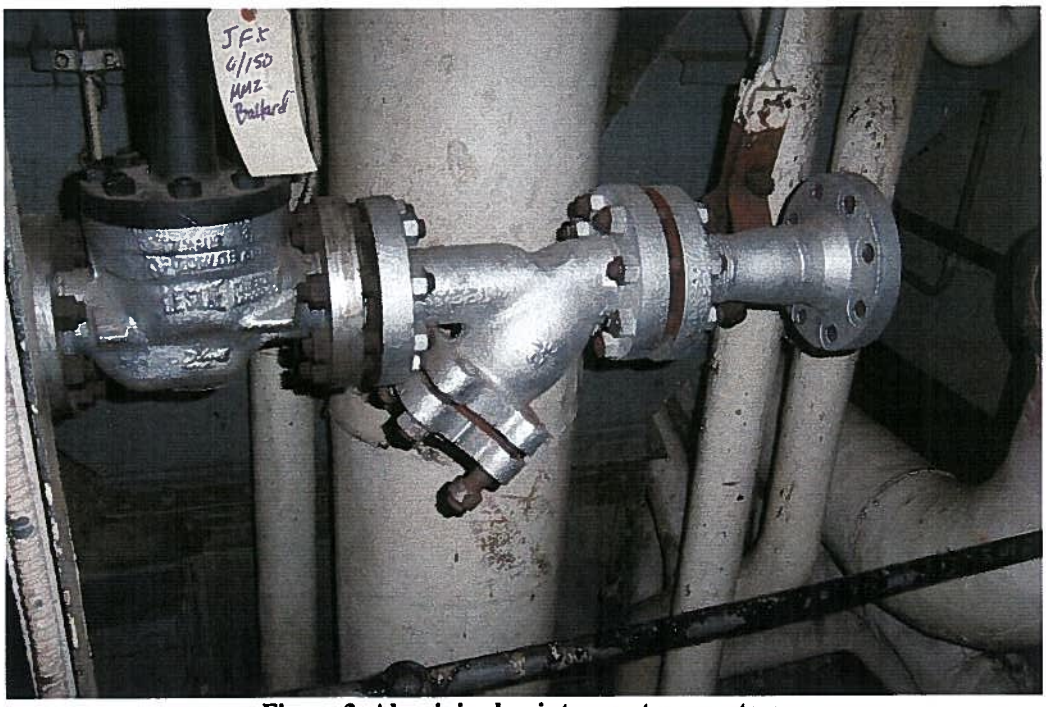

**Figure 3 Aluminized paint on a steam system.**

**Table 3 Paint Sample Results**

| | Sample # | MDL ppm | PCBs ppm | Calculated PCBs ppm |
|---|---|---|---|---|
| Forrestal | 94NN00570-36 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-37 | 5 | <5 | 2.5 |
| Forrestal | 98NN04425-56 | 5 | <5 | 2.5 |
| Forrestal | 98NN04425-57 | 5 | <5 | 2.5 |
| Forrestal | 98NN04425-58 | 5 | <5 | 2.5 |
| Forrestal | 98NN04425-59 | 5 | <5 | 2.5 |
| Forrestal | 98NN04425-60 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-38 | 5 | <5 | 2.5 |
| Saratoga | 94NN05044-41 | 5 | <5 | 2.5 |
| Saratoga | 94NN05044-42 | 5 | <5 | 2.5 |
| Saratoga | 94NN05044-43 | 5 | <5 | 2.5 |
| Independence | Spectra - 56 | 0.15 | <0.15 | 0.075 |
| Independence | Spectra - 57 | 0.15 | <0.15 | 0.075 |
| Independence | Spectra - 58 | 0.1 | <0.1 | 0.05 |
| Independence | Spectra - 59 | 0.15 | <0.15 | 0.075 |
| Independence | Spectra - 60 | 3 | <3 | 1.5 |
| Ranger | 98PS08183-56 | 1 | <1 | 0.5 |
| Ranger | 98PS08183-57 | 1 | <1 | 0.5 |
| Ranger | 98PS08183-58 | 1 | <1 | 0.5 |
| Ranger | 98PS08185-56 | 1 | <1 | 0.5 |
| Ranger | 98PS08185-57 | 1 | <1 | 0.5 |
| Ranger | 98PS08185-58 | 1 | <1 | 0.5 |
| | | | **Mean** | 1.5 |
| | | | **95% UCL** | 1.9 |

The estimated quantity of paint aboard *Forrestal* class ships was determined from a review of the *America* FWR listing for Group 605 "Painting" which lists a total weight of 1, 432, 480 lbs of paint. This weight is assumed to be equivalent to the weight aboard each *Forrestal* class ships with no correction.

## *Electrical Cable Insulation*

PMS 333 collected 120 samples of electrical cable/wire insulation from *Forrestal* class ships for PCB analysis. Samples were analyzed by Puget Sound Naval Shipyard, Norfolk Naval Shipyard, and Spectra Laboratories. Results reported as less than the method detection limit (MDL) were calculated as one half of the MDL for the purpose of determining the mean PCB concentration for the material.

**Table 4 Cable Insulation Sample Results**

| Ship | Sample # | MDL ppm | PCBs ppm | Calculated PCBs ppm |
|---|---|---|---|---|
| Forrestal | 94NN00570-1 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-2 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-3 | 5 | 15 | 15 |
| Forrestal | 94NN00570-4 | 5 | 15 | 15 |
| Forrestal | 94NN00570-5 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-6 | 5 | 10 | 10 |
| Forrestal | 94NN00570-7 | 5 | 18 | 18 |
| Forrestal | 94NN00570-8 | 5 | 15 | 15 |
| Forrestal | 94NN00570-9 | 5 | 18 | 18 |
| Forrestal | 94NN00570-10 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-11 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-12 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-13 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-14 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-15 | 5 | 88 | 88 |
| Forrestal | 94NN00570-16 | 5 | 12 | 12 |
| Forrestal | 94NN00570-17 | 5 | 26 | 26 |
| Forrestal | 94NN00570-18 | 5 | 8 | 8 |
| Forrestal | 94NN00570-19 | 5 | 19 | 19 |
| Forrestal | 94NN00570-20 | 5 | <5 | 2.5 |
| Forrestal | 98NN04425-1 | 5 | <5 | 2.5 |
| Forrestal | 98NN04425-2 | 5 | <5 | 2.5 |
| Forrestal | 98NN04425-3 | 5 | 41 | 41 |
| Forrestal | 98NN04425-4 | 5 | 22 | 22 |
| Forrestal | 98NN04425-5 | 5 | 13 | 13 |
| Forrestal | 98NN04425-6 | 5 | 82 | 82 |
| Forrestal | 98NN04425-7 | 5 | 15 | 15 |
| Forrestal | 98NN04425-8 | 5 | 9 | 9 |
| Forrestal | 98NN04425-9 | 5 | 8 | 8 |
| Forrestal | 98NN04425-10 | 5 | 35 | 35 |
| Forrestal | 98NN04425-11 | 5 | 9 | 9 |
| Forrestal | 98NN04425-12 | 5 | 16 | 16 |
| Forrestal | 98NN04425-13 | 5 | <5 | 2.5 |
| Forrestal | 98NN04425-14 | 5 | <5 | 2.5 |
| Forrestal | 98NN04425-15 | 5 | <5 | 2.5 |
| Forrestal | 98NN04425-16 | 5 | 5 | 5 |
| Forrestal | 98NN04425-17 | 5 | 11 | 11 |
| Forrestal | 98NN04425-18 | 5 | 13 | 13 |
| Forrestal | 98NN04425-19 | 5 | 8 | 8 |
| Forrestal | 98NN04425-20 | 5 | 9 | 9 |
| Saratoga | 94NN05044-1 | 5 | <5 | 2.5 |
| Saratoga | 94NN05044-2 | 5 | 14 | 14 |
| Saratoga | 94NN05044-3 | 5 | <5 | 2.5 |
| Saratoga | 94NN05044-4 | 5 | 40 | 40 |

| | | | | |
|---|---|---|---|---|
| Saratoga | 94NN05044-5 | 5 | 24 | 24 |
| Saratoga | 94NN05044-6 | 5 | 12 | 12 |
| Saratoga | 94NN05044-7 | 5 | <5 | 2.5 |
| Saratoga | 94NN05044-8 | 5 | 15 | 15 |
| Saratoga | 94NN05044-9 | 5 | 27 | 27 |
| Saratoga | 94NN05044-10 | 5 | 36 | 36 |
| Saratoga | 94NN05044-11 | 5 | 31 | 31 |
| Saratoga | 94NN05044-12 | 5 | 48 | 48 |
| Saratoga | 94NN05044-13 | 5 | 30 | 30 |
| Saratoga | 94NN05044-14 | 5 | 29 | 29 |
| Saratoga | 94NN05044-15 | 5 | 30 | 30 |
| Saratoga | 94NN05044-16 | 5 | 9 | 9 |
| Saratoga | 94NN05044-17 | 5 | 36 | 36 |
| Saratoga | 94NN05044-18 | 5 | 32 | 32 |
| Saratoga | 94NN05044-19 | 5 | 19 | 19 |
| Saratoga | 94NN05044-20 | 5 | 14 | 14 |
| Independence | Spectra - 1 | 2 | <2 | 1 |
| Independence | Spectra - 2 | 1.5 | <1.5 | 0.75 |
| Independence | Spectra - 3 | 1.2 | <1.2 | 0.6 |
| Independence | Spectra - 4 | 1.2 | <1.2 | 0.6 |
| Independence | Spectra - 5 | 4 | <4 | 2 |
| Independence | Spectra - 6 | 1 | <1 | 0.5 |
| Independence | Spectra - 7 | 1.6 | <1.6 | 0.8 |
| Independence | Spectra - 8 | 1 | <1 | 0.5 |
| Independence | Spectra - 9 | 1.2 | <1.2 | 0.6 |
| Independence | Spectra - 10 | 1 | <1 | 0.5 |
| Independence | Spectra - 11 | 0.6 | 0.6 | 0.3 |
| Independence | Spectra - 12 | 1 | <1 | 0.5 |
| Independence | Spectra - 13 | 50 | <50 | 25 |
| Independence | Spectra - 14 | 1.6 | <1.6 | 0.8 |
| Independence | Spectra - 15 | 1.6 | <1.6 | 1.6 |
| Independence | Spectra - 16 | 1.2 | <1.2 | 0.6 |
| Independence | Spectra - 17 | 0.5 | <0.5 | 0.25 |
| Independence | Spectra - 18 | 2 | <2 | 1 |
| Independence | Spectra - 19 | 3 | <3 | 1.5 |
| Independence | Spectra - 20 | 0.06 | <0.06 | 0.03 |
| Ranger | 98PS08130-1 | 1 | 4.6 | 4.6 |
| Ranger | 98PS08130-2 | 1 | 32 | 32 |
| Ranger | 98PS08130-3 | 1 | 20 | 20 |
| Ranger | 98PS08130-4 | 1 | 58 | 58 |
| Ranger | 98PS08130-5 | 1 | 25 | 25 |
| Ranger | 98PS08130-6 | 1 | 2.5 | 2.5 |
| Ranger | 98PS08130-7 | 1 | 33 | 33 |
| Ranger | 98PS08130-8 | 1 | <1 | 0.5 |
| Ranger | 98PS08130-9 | 1 | 20 | 20 |
| Ranger | 98PS08130-10 | 1 | 1.3 | 1.3 |

| | | | | |
|---|---|---|---|---|
| Ranger | 98PS08130-11 | 1 | <1 | 0.5 |
| Ranger | 98PS08130-12 | 1 | 2.4 | 2.4 |
| Ranger | 98PS08130-13 | 1 | 9.8 | 9.8 |
| Ranger | 98PS08130-14 | 1 | 1900 | 1900 |
| Ranger | 98PS08130-15 | 1 | 6.4 | 6.4 |
| Ranger | 98PS08130-16 | 1 | 14 | 14 |
| Ranger | 98PS08130-17 | 1 | 6.2 | 6.2 |
| Ranger | 98PS08130-18 | 1 | 2.5 | 2.5 |
| Ranger | 98PS08130-19 | 1 | 34 | 34 |
| Ranger | 98PS08130-20 | 1 | 51 | 51 |
| Ranger | 98PS08128-1 | 1 | 6.4 | 6.4 |
| Ranger | 98PS08128-2 | 1 | 17 | 17 |
| Ranger | 98PS08128-3 | 1 | 8 | 8 |
| Ranger | 98PS08128-4 | 1 | 19 | 19 |
| Ranger | 98PS08128-5 | 1 | 42 | 42 |
| Ranger | 98PS08128-6 | 1 | 38 | 38 |
| Ranger | 98PS08128-7 | 1 | 2.6 | 2.6 |
| Ranger | 98PS08128-8 | 1 | 5.7 | 5.7 |
| Ranger | 98PS08128-9 | 1 | 8.4 | 8.4 |
| Ranger | 98PS08128-10 | 1 | 7.7 | 7.7 |
| Ranger | 98PS08128-11 | 1 | 20 | 20 |
| Ranger | 98PS08128-12 | 1 | 25 | 25 |
| Ranger | 98PS08128-13 | 1 | 53 | 53 |
| Ranger | 98PS08128-14 | 1 | 1 | 1 |
| Ranger | 98PS08128-15 | 1 | 8.1 | 8.1 |
| Ranger | 98PS08128-16 | 1 | 320 | 320 |
| Ranger | 98PS08128-17 | 1 | 2.4 | 2.4 |
| Ranger | 98PS08128-18 | 1 | 280 | 280 |
| Ranger | 98PS08128-19 | 1 | 3.1 | 3.1 |
| Ranger | 98PS08128-20 | 1 | <1 | 0.5 |
| | | | **Mean** | 34.7 |
| | | | **95% UCL** | 66.2 |

The estimated quantity of electrical cable insulation aboard *Forrestal* class ships was determined from a review of the *America* FWR listing for Group 300 "Electrical Plant" and 400 "Communication and Control". The total reported weight of the electrical cable from 187 listings was 730, 718 lbs. A study of the Navy Cable Inventory conducted by Westinghouse MTD found that the percentage of insulation in any given quantity of bulk cable is 72.26% for a typical combatant. Multiplying the estimated weight of cable by the insulation percentage gives an estimated weight of cable insulation of 528, 017 lbs. This weight is assumed to be equivalent to the weight aboard *Forrestal* class ships with no additional correction.

## *Ventilation Gaskets*

The visual inspection of the ex-*Forrestal* Newport, RI revealed that impregnated felt material ventilation gaskets were present. Of all gaskets observed, 50% were rubber, and 50% were impregnated felt material. PMS 333 collected 48 samples of rubber ventilation gasket material and 3 samples of felt ventilation gasket material for PCB analysis. Samples were analyzed by Puget Sound Naval Shipyard, Norfolk Naval Shipyard, and Spectra Laboratories. Results reported as less than the method detection limit (MDL) were calculated as one half of the MDL for the purpose of determining the mean PCB concentration for the material.

**Figure 4 Open flange with rubber ventilation gasket exposed.**

**Table 5 Rubber Ventilation Gasket Sample Results**

| Ship | Sample # | MDL ppm | PCBs ppm | Calculated PCBs ppm |
|---|---|---|---|---|
| Forrestal | 94NN00570-31 | 5 | 14 | 14 |
| Forrestal | 94NN00570-35 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-46 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-48 | 5 | 2100 | 2100 |
| Forrestal | 94NN00570-51 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-57 | 5 | 42 | 42 |
| Forrestal | 94NN00570-58 | 5 | 160 | 160 |
| Forrestal | 94NN00570-59 | 5 | 30 | 30 |
| Forrestal | 94NN00570-60 | 5 | 400 | 400 |
| Independence | Spectra - 31 | 0.6 | <0.6 | 0.3 |
| Independence | Spectra - 32 | 1 | 43300 | 43300 |
| Independence | Spectra - 33 | 0.07 | 0.07 | 0.07 |
| Independence | Spectra - 34 | 0.5 | 0.53 | 0.53 |
| Independence | Spectra - 35 | 0.8 | <0.8 | 0.4 |
| Independence | Spectra - 36 | 1 | <1 | 0.5 |

| | | | | |
|---|---|---|---|---|
| Independence | Spectra - 37 | 1 | <1 | 0.5 |
| Independence | Spectra - 38 | 0.1 | 0.19 | 0.19 |
| Independence | Spectra - 39 | 0.1 | <0.1 | 0.05 |
| Independence | Spectra - 40 | 3 | <3 | 1.5 |
| Ranger | 98PS08130-31 | 1 | 26 | 26 |
| Ranger | 98PS08130-32 | 1 | 2 | 2 |
| Ranger | 98PS08130-33 | 1 | 1.7 | 1.7 |
| Ranger | 98PS08130-34 | 1 | 300 | 300 |
| Ranger | 98PS08130-35 | 1 | <1 | 0.5 |
| Ranger | 98PS08130-36 | 1 | 14 | 14 |
| Ranger | 98PS08130-37 | 1 | <1 | 0.5 |
| Ranger | 98PS08130-38 | 1 | <1 | 0.5 |
| Ranger | 98PS08130-39 | 1 | 4.1 | 4.1 |
| Ranger | 98PS08130-40 | 1 | 4.6 | 4.6 |
| Ranger | 98PS08128-23 | 1 | <1 | 0.5 |
| Ranger | 98PS08128-24 | 1 | <1 | 0.5 |
| Ranger | 98PS08128-25 | 1 | <1 | 0.5 |
| Ranger | 98PS08128-26 | 1 | 11 | 11 |
| Ranger | 98PS08128-27 | 1 | 95 | 95 |
| Ranger | 98PS08128-28 | 1 | 16 | 16 |
| Ranger | 98PS08128-29 | 1 | <1 | 0.5 |
| Ranger | 98PS08128-30 | 1 | <1 | 0.5 |
| Ranger | 98PS08128-31 | 1 | 19 | 19 |
| Saratoga | 94NN05044-33 | 5 | 14 | 14 |
| Saratoga | 94NN05044-36 | 5 | <5 | 2.5 |
| Saratoga | 94NN05044-37 | 5 | 21 | 21 |
| Saratoga | 94NN05044-44 | 5 | <5 | 2.5 |
| Saratoga | 94NN05044-48 | 6 | 6 | 6 |
| Saratoga | 94NN05044-52 | 5 | 30 | 30 |
| Saratoga | 94NN05044-54 | 5 | 9 | 9 |
| Saratoga | 94NN05044-57 | 5 | 10 | 10 |
| Saratoga | 94NN05044-58 | 5 | <5 | 2.5 |
| Saratoga | 94NN05044-59 | 5 | <5 | 2.5 |
| | | | **Mean** | 972 |
| | | | **95% UCL** | 2739 |

**Table 6 Felt Ventilation Gasket Sample Results**

| Ship | Sample # | MDL ppm | PCBs ppm | Calculated PCBs ppm |
|---|---|---|---|---|
| Forrestal | 94NN00570-43 | 5 | <5 | 2.5 |
| Forrestal | 94NN00570-44 | 5 | <5 | 2.5 |
| Ranger | 98PS08128-31 | 5 | 96000 | 96000 |
| | | | **Mean** | 32002 |
| | | | **95% UCL** | 94719 |

A review of the fan list of *Nimitz* (CVN 66) determined that, based on an algorithm developed by naval ventilation engineers using the number and size of fans to derive flange quantities and gasket weights. The algorithm was used to calculate a rubber ventilation gasket weight of 1204 lbs and felt ventilation gasket weight of 1562 lbs. This weight is assumed to be equivalent to the weight aboard each *Forrestal* class ship with no additional correction.

## *Lubricants*

PMS 333 collected 50 samples of lube oils, hydraulic oils, and greases aboard *Forrestal* class ships for PCB analysis. The samples were analyzed by Puget Sound Naval Shipyard, Norfolk Naval Shipyard, and Spectra Laboratories. Results reported as less than the method detection limit (MDL) were calculated as one half of the MDL for the purpose of determining the mean PCB concentration for the material.

**Table 7 Lubricant Sample Results**

| Ship | Sample # | MDL ppm | PCBs ppm | Calculated PCBs ppm |
|---|---|---|---|---|
| Forrestal | 94NN00570-21 | 1 | <1 | 0.5 |
| Forrestal | 94NN00570-22 | 1 | <1 | 0.5 |
| Forrestal | 94NN00570-23 | 1 | <1 | 0.5 |
| Forrestal | 94NN00570-24 | 1 | <1 | 0.5 |
| Forrestal | 94NN00570-25 | 1 | <1 | 0.5 |
| Forrestal | 94NN00570-26 | 1 | <1 | 0.5 |
| Forrestal | 94NN00570-27 | 1 | <1 | 0.5 |
| Forrestal | 94NN00570-28 | 1 | <1 | 0.5 |
| Forrestal | 94NN00570-29 | 1 | <1 | 0.5 |
| Forrestal | 94NN00570-30 | 1 | <1 | 0.5 |
| Independence | Spectra - 21 | 1 | <1 | 0.5 |
| Independence | Spectra - 22 | 1 | <1 | 0.5 |
| Independence | Spectra - 23 | 1 | <1 | 0.5 |
| Independence | Spectra - 24 | 1 | <1 | 0.5 |
| Independence | Spectra - 25 | 1 | <1 | 0.5 |
| Independence | Spectra - 26 | 1 | <1 | 0.5 |
| Independence | Spectra - 27 | 1 | <1 | 0.5 |
| Independence | Spectra - 28 | 1 | <1 | 0.5 |
| Independence | Spectra - 29 | 1 | <1 | 0.5 |
| Independence | Spectra - 30 | 1 | <1 | 0.5 |
| Ranger | 98PS08136-21 | 1 | <1 | 0.5 |
| Ranger | 98PS08136-22 | 1 | <1 | 0.5 |
| Ranger | 98PS08136-23 | 1 | <1 | 0.5 |
| Ranger | 98PS08136-24 | 1 | <1 | 0.5 |
| Ranger | 98PS08136-25 | 1 | <1 | 0.5 |
| Ranger | 98PS08136-26 | 1 | 190 | 190 |

| | | | | |
|---|---|---|---|---|
| Ranger | 98PS08136-27 | 1 | <1 | 0.5 |
| Ranger | 98PS08136-28 | 1 | <1 | 0.5 |
| Ranger | 98PS08136-29 | 1 | <1 | 0.5 |
| Ranger | 98PS08136-30 | 1 | <1 | 0.5 |
| Ranger | 98PS08148-21 | 1 | <1 | 0.5 |
| Ranger | 98PS08148-22 | 1 | <1 | 0.5 |
| Ranger | 98PS08148-23 | 1 | <1 | 0.5 |
| Ranger | 98PS08148-24 | 1 | 14 | 14 |
| Ranger | 98PS08148-25 | 1 | 38 | 38 |
| Ranger | 98PS08148-26 | 1 | <1 | 0.5 |
| Ranger | 98PS08148-27 | 1 | <1 | 0.5 |
| Ranger | 98PS08148-28 | 1 | 41 | 41 |
| Ranger | 98PS08148-29 | 1 | 8.6 | 8.6 |
| Ranger | 98PS08148-30 | 1 | <1 | 0.5 |
| Saratoga | 94NN05044-21 | 1 | <1 | 0.5 |
| Saratoga | 94NN05044-22 | 1 | <1 | 0.5 |
| Saratoga | 94NN05044-23 | 1 | <1 | 0.5 |
| Saratoga | 94NN05044-24 | 1 | <1 | 0.5 |
| Saratoga | 94NN05044-25 | 1 | <1 | 0.5 |
| Saratoga | 94NN05044-26 | 1 | <1 | 0.5 |
| Saratoga | 94NN05044-27 | 1 | <1 | 0.5 |
| Saratoga | 94NN05044-28 | 1 | <1 | 0.5 |
| Saratoga | 94NN05044-29 | 1 | <1 | 0.5 |
| Saratoga | 94NN05044-30 | 1 | <1 | 0.5 |
| | | | **Mean** | 6.3 |
| | | | **95% UCL** | 14.0 |

The estimated quantity of lubricants aboard *Forrestal* class ships was determined from a review of the *America* FWR listings for Group 551 "Auxillary System Fluids," Group 825 "Lube Oils Ship Service," and Group 853 "Lube Oils Aviation. These entries were summed to calculate a total weight of 609, 814 lbs of lubricants. The weight of miscellaneous lubricants (such as greases), are assumed to be an insignificant percentage of the total weight of other lube and hydraulic oil stores. This weight is assumed to be equivalent to the weight aboard each *Forrestal* class ship with no correction.

## *Baseline PCB Source Terms*

Extending the as-built estimated weights for the subject materials to reflect present day conditions aboard *Forrestal* class ships requires adjusting the as-built (FWR) derived estimates to reflect lifecycle increases in materials, where appropriate. If available, Navy standard growth rate have been applied.

For example, Navy material and weight experts estimate that the thickness of paint on vessels (and therefore weight), with repeated painting, stripping, and repainting activities,

increases by a factor of 3 over a 30-year life cycle. This is in contrast with rubber products and bulkhead insulation, which is relatively static, being removed and replaced as necessary in a one for one changeout, with no net change in quantity. Electrical and ventilation systems can experience modest growth, but generally as a result of installation of new systems or modification/modernization programs. Accordingly, a 10% growth rate has been applied to the ventilation gasket and electrical cable insulation weights in proportion to the 10% increase in overall ship displacement as a result of various modernization programs. An additional 10% is included to the cable growth rate to account for carrier tactical system upgrades. Lube oils are limited by the original design capacities of the systems they occupy.

The baseline PCB source terms, below, reflect lifecycle growth, but do not include any reductions as a result of the preparation of the vessel for use as an artificial reef. Also, there were a very limited number of felt ventilation gasket samples for use in this study and are not enough to make any determinations as to any ship specific variability, or to accurately characterize the population of felt gaskets in general.

**Table 8 Baseline Source Terms**

| Material | FWR Wt (lbs) | 30yr Growth | Avg.PCB Conc. ppm | 95% UCL | Lbs PCB | 95% UCL lbs |
|---|---|---|---|---|---|---|
| Paints | 1432480 | 3 | 1.5 | 1.9 | 6.3 | 8.3 |
| Bulkhead Insulation | 919070 | 1 | 814.6 | 1829.6 | 748.7 | 1681.6 |
| Door Gaskets/Misc. Rubber | 77961 | 1 | 9.7 | 18.6 | 0.8 | 1.5 |
| Cable Insulation | 528017 | 1.2 | 34.7 | 66.2 | 22.0 | 42.0 |
| Vent. Gaskets Felt | 1204 | 1.1 | 32001.7 | 94718.9 | 42.4 | 125.5 |
| Vent. Gasket Rubber | 1562 | 1.1 | 972.0 | 2739.3 | 1.7 | 4.7 |
| Lubricants | 609814 | 1 | 6.3 | 14.0 | 3.8 | 8.5 |
| | | | | Total | 825.6 | 1871.9 |

## Conclusions

The estimate shows the PCB source term related to bulkhead insulation accounts for 89% of the total PCB loading of *Forrestal* class ships. The next largest contributor, felt ventilation gaskets, account for 7 % and electrical cable insulation accounts for less than 3% of the total PCB load. Moreover, if cable, paint, rubber products, and lubricants were addressed in terms of a bulk product disposal (liquid waste rules for oils), they would be

unregulated based on their mean concentration, and cable would only be above regulatory limits at the very conservative 95% UCL of the mean concentration.

With regard to ship specific trends, it appears that there may be a significant difference between the bulkhead insulation PCB concentrations aboard ex-*Forrestal* and the remainder of the class. Additional data is required to determine the significance. If there is a demonstrable difference, the effect would be an increase in the source term loading on ex-Forrestal, but a dramatic decrease on Saratoga, ex-Ranger, and ex-Independence, since no samples on the latter three were over 50 ppm.

Similarly, the rubber ventilation gasket samples that show abnormally high PCB concentrations are likely to be outliers, and not representative of the material itself. Since felt ventilation gaskets are present on these vessels, these high concentration rubber gaskets may be due to contact with a contaminated flange where felt material was replaced with rubber before PCB Advisory for gasket replacement was implemented. Or there is a possibility that they may have been misidentified by the sampler as rubber, and were actually felt. If this can be demonstrated, these samples should be included with the felt gasket samples in the calculations, reducing the rubber ventilation gasket source term.

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