UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

This document is part of Appendix A, and includes the Stern Tube Seals and Underwater Bearing Lubrication: Nature of Discharge for the "Phase I Final Rule and Technical Development Document of Uniform National Discharge Standards (UNDS)," published in April 1999. The reference number is EPA-842-R-99-001.

Phase I Final Rule and Technical Development Document of Uniform National Discharge Standards (UNDS)

Stern Tube Seals and Underwater Bearing Lubrication: Nature of Discharge

April 1999

NATURE OF DISCHARGE REPORT

Stern Tube Seals & Underwater Bearing Lubrication

1.0 INTRODUCTION

The National Defense Authorization Act of 1996 amended Section 312 of the Federal Water Pollution Control Act (also known as the Clean Water Act (CWA)) to require that the Secretary of Defense and the Administrator of the Environmental Protection Agency (EPA) develop uniform national discharge standards (UNDS) for vessels of the Armed Forces for "...discharges, other than sewage, incidental to normal operation of a vessel of the Armed Forces, ..." [Section 312(n)(1)]. UNDS is being developed in three phases. The first phase (which this report supports), will determine which discharges will be required to be controlled by marine pollution control devices (MPCDs)—either equipment or management practices. The second phase will develop MPCD performance standards. The final phase will determine the design, construction, installation, and use of MPCDs.

A nature of discharge (NOD) report has been prepared for each of the discharges that has been identified as a candidate for regulation under UNDS. The NOD reports were developed based on information obtained from the technical community within the Navy and other branches of the Armed Forces with vessels potentially subject to UNDS, from information available in existing technical reports and documentation, and, when required, from data obtained from discharge samples that were collected under the UNDS program.

The purpose of the NOD report is to describe the discharge in detail, including the system that produces the discharge, the equipment involved, the constituents released to the environment, and the current practice, if any, to prevent or minimize environmental effects. Where existing process information is insufficient to characterize the discharge, the NOD report provides the results of additional sampling or other data gathered on the discharge. Based on the above information, the NOD report describes how the estimated constituent concentrations and mass loading to the environment were determined. Finally, the NOD report assesses the potential for environmental effect. The NOD report contains sections on: Discharge Description, Discharge Characteristics, Nature of Discharge Analysis, Conclusions, and Data Sources and References.

2.0 DISCHARGE DESCRIPTION

This section describes the stern tube seals and underwater bearing lubrication discharge and includes information on: the equipment that is used and its operation (Section 2.1), general description of the constituents of the discharge (Section 2.2), and the vessels that produce this discharge (Section 2.3).

2.1 Equipment Description and Operation

Vessels of the Armed Forces have one or two propeller shafts, except for aircraft carriers, which have four shafts. Stern tube seals, stern tube bearings, and intermediate and main strut bearings are components associated with the propeller shaft. Figure 1 shows the location of these components. The stern tube seals prevent seawater entry into the vessel at the inboard end of the stern tube bearing. Stern tube bearings support the weight of the propeller shaft where the shaft exits the vessel. Intermediate and main strut bearings are outboard bearings that support the weight of the propeller and shafting outboard of the vessel. Submarines do not have strut bearings. Instead, submarines have a self-aligning bearing aft of the stern tube that supports the weight of the propeller. Both stern tube and strut bearings are constructed with a bronze backing, and lined with rubber strips (called staves), or babbitt metal. Babbitt is an alloy of tin and lead and is commonly used as a bearing material. However, babbitted bearings are oil lubricated and the lube oil is circulated in a closed system with no discharge to the environment. Babbitt wear material is collected in the oil filter of stern tube oil lubricated systems. Depending on the vessel type, lubrication for the stern tube seals, stern tube, and strut bearings is accomplished by seawater, freshwater, or oil.[1]

Some small boats and crafts use surrounding seawater for cooling and a greased bearing for lubrication. As such, the surrounding seawater is at a greater pressure than the greased bearing on small boats, and if there is any leakage, seawater will leak into the bilge of the small boat instead of the grease being discharged to the surrounding seawater. Any grease released into the bilge of small boats and crafts is discussed in the Surface Vessel Bilgewater/OWS Discharge NOD report.

2.1.1 Seawater Lubrication

Seawater lubrication is used in all Navy and U.S. Coast Guard (USCG) vessels. Seawater is supplied from either the firemain or auxiliary machinery cooling water system on surface ships and is supplied from the auxiliary seawater system on submarines. Submarines flood their trim tanks with seawater and use this water to cool and lubricate the stern tube seals while in port. For all surface ships and submarines, seawater enters a seal cavity, where some of it is used to lubricate the seal faces. The remainder passes aft through channels between staves in the stern tube bearing, cooling and lubricating the bearing, and finally exiting to the sea at the aft end of the bearing. Seawater flow through the stern tube bearing is maintained at all times, except when conducting maintenance or disassembly, regardless of whether the vessel is in port or underway. The residence time of the seawater flow is short. For example, the residence time of water in the stern tube of a DDG 51 Class ship is approximately 13 seconds.[2] Similar short residence times for stern tube lubricating water on other vessel classes is expected. Strut bearings are not provided with forced cooling or lubrication. Instead, strut bearings use the surrounding seawater flow for lubrication and cooling when the vessel is underway.

On surface vessels, copper-nickel alloy (70% copper/30% nickel) piping is normally used for the stern tube seal lubrication system. On submarines, nickel/chromium piping is used. The lubricating seawater also comes into contact with the propeller shaft, bearing surfaces, zinc anodes, bearing staves, the seals, and bearing bushings.

Shafts are made of forged steel. Bearing surfaces are sleeved with copper-nickel (80% copper / 20% nickel) or fiberglass. Zinc anodes provide corrosion protection in the bearing housings. Stern tube and strut bearing staves are made of bonded synthetic rubber (typically Buna-N (nitrile)). The estimated life of the staves is 5 to 7 years. Although the staves surround the shaft on all sides, the bottom staves (approximately 40% of the staves) support the shaft weight and are susceptible to maximum wear. In submarines, the wear rate of the rubber is approximately 10 to 20 mils (one mil equals 0.001 inch) per year. In surface vessels with controllable pitch propellers, the wear rate is 40 mils per year, and in surface vessels with fixed pitch propellers, the wear rate is 20 to 30 mils per year.[3]

The rotating seat of a typical stern tube seal on a surface vessel is made of phosphor bronze (an alloy of bronze and phosphorous). The stationary face insert was originally made of Teflon-impregnated asbestos. However, a majority of the asbestos components have been replaced with a phenolic material.[1] Seals used in submarines are comprised of silicon carbide and carbon graphite because they are exposed to more severe operating conditions. The life of stern tube seals is approximately 5 years and they have a very small area exposed to wear, compared to the bearings. Therefore, wear products from seal components constitute a very small percentage of this discharge.

The lubricated components of a propeller shaft are shown in Figure 1. A cross-section diagram of a typical seal is provided as Figure 2.

2.1.2 Freshwater Lubrication

On very rare occasions in port, freshwater may be used for lubricating the shaft seal on submarines. This occurs on approximately four submarines per year, for one week each.[4] Normally, while a submarine is in port, shaft seal lubrication is provided from seawater stored in the submarine’s trim system. After an extended in port period, this supply of seawater will eventually become depleted. At that time, freshwater is used to fill the trim system to provide shaft seal lubrication. On these occasions, a potable water fill hose from the pier is connected to the trim tank. This freshwater is typically mixed with the residual seawater in the tank (estimated at a 50% mixture of seawater and freshwater), and is used for lubricating the shaft seals. The cooling water is discharged to the sea in the manner described in Section 2.1.1.

2.1.3 Ambient Water Lubrication

All Army watercraft use ambient water for lubrication of stern tube seals and underwater bearings. Ambient water, either freshwater or saltwater, is used in all operational locations, depending upon where the vessel is located (i.e., in fresh or saltwater). Army watercraft do not use potable water for lubrication while in port and do not use pressurized water to force feed underwater bearings.

2.1.4 Oil Lubrication

A number of Military Sealift Command (MSC) vessels are fitted with oil-lubricated stern tube and strut bearings, which do not produce any of the discharge described in this report. Oil-lubricated seals exist in a variety of configurations. All have anti-pollution design features, that prevent oil from leaking to the sea under normal operating conditions.[5] On the T-AO 187 Class ships, each of the two shaft systems contains 2,300 gallons of oil. Some common system design features to prevent oil releases are:[1]

- Use of multiple sealing rings at both the inboard and outboard ends of the stern tube.
- Methods to maintain pressure in the stern tube cavity lower than the sea water pressure outside. This ensures that, in the event that the outboard seal leaks, water will leak into the cavity rather than oil leaking out. Any water which accumulates as a result of a leak into the cavity is managed as Surface Vessel Bilgewater/OWS Discharge.
- Positive methods for determining seal leakage.

2.2 Releases to the Environment

For surface vessels, this discharge consists of seawater from the firemain system or auxiliary machinery water cooling water system with the additional constituents described in Section 2.1 that are entrained as the seawater flows through the system. The lubricating water is released to the environment through the after end of the stern tube bearing. In the case of submarines, the discharge will occasionally consist of freshwater with chlorine.

2.3 Vessels Producing the Discharge

Almost all classes of surface vessels and submarines of the Armed Forces have shaft seals and bearings that require lubrication. The exceptions are a few vessel classes such as the MHC 51 Class, that use unconventional means of propulsion such as cycloidal propellers.[1] Army watercraft use packing rings to seal hull penetrations of the shaft and do not use mechanical seals for this purpose.

3.0 DISCHARGE CHARACTERISTICS

This section contains qualitative and quantitative information that characterizes the discharge. Section 3.1 describes where the discharge occurs with respect to harbors and near-shore areas, Section 3.2 describes the rate of the discharge, Section 3.3 lists the constituents in the discharge, and Section 3.4 gives the concentrations of the constituents in the discharge.

3.1 Locality

Flow of water through the shaft seals and stern tube bearings is maintained at all times. Therefore, this discharge occurs both within and beyond 12 nautical miles (n.m.).

3.2 Rate

3.2.1 Seawater Lubrication

For surface ships, flow rates of seawater through the stern tube bearing are approximately 2 gallons per minute (gpm) per foot of bearing length and 3 gpm for seal lubrication. The seawater flow rate through submarine shaft seals while underway is 16 gpm for SSN 688 Class and 18 gpm for SSBN 726 Class submarines. A discharge of 10 to 20 gpm per shaft is typical for most vessels.[1] For purposes of this report, a flow rate of 20 gpm has been used. It was assumed that there are 274 surface ships, each with two shafts and 89 submarines, each with one shaft. Based on operational knowledge, 5% of the vessels' underway time is spent within 12 n.m. and 50% of the vessels' time is spent pierside.[6] These are conservative estimates, because most vessels have flow rates that are lower than 20 gpm and though there are 24 four-shaft vessels in the Navy, there are 65 single-shaft vessels that were considered to be two-shaft vessels. Thus, this analysis overestimates the number of shafts producing this discharge by 17. When surface ships are idle in port, full water flow is maintained through the stern tube bearing and seals. The total annual fleetwide discharge volume was calculated as follows:

Total fleetwide annual discharge (gallons/year) = (20 gallons/minute flow rate) (60 min/hr) (24 hr/day) (365 days/year) [(274 surface ships) (2 shafts/ship) + (89 submarines) (1 shaft per submarine)] (0.55 (5% of vessel's underway time is within 12 n.m. and 50% of vessels' time is in port)) = 3,682,879,200 gal/year

3.2.2 Freshwater Lubrication

When submarines are idle in port, flow is maintained at 4 gpm for attack submarines (e.g. SSN 688 Class) and 9 gpm for Missile Submarines (e.g. SSBN 726 Class).[3,7] Approximately 81% of active submarines are attack submarines (SSNs) and 19% are ballistic missile submarines (SSBNs). Hence, the weighted freshwater flow rate per submarine is approximately (0.81)(4 gpm) + (0.19)(9 gpm) ≈ 5 gpm.

Total fleetwide annual discharge (gallons/year) = (5 gallons/minute flow rate) (60 min/hr) (24 hr/day) (7 days/year) (1 week per year) [(4 submarines) (1 shaft per submarine)] = 201,600 gal/year

3.3 Constituents

3.3.1 Seawater Lubrication

Seawater for lubrication of stern tube bearings is supplied either from the firemain or the auxiliary seawater cooling main, depending on the vessel class. Additional information on firemain systems and the seawater cooling system can be found in their respective NOD reports.

When the shaft is turning, the most likely constituent to be present in the discharge is rubber. Metals, if any, can be present in the discharge and include copper and nickel, the materials of construction of the stern tube. The priority pollutants in this discharge include copper and nickel. None of the potential constituents in this discharge are bioaccumulators.

3.3.2 Freshwater Lubrication

Because the shaft is not turning under idle conditions, there is no wearing of the bearing materials. The freshwater from the port facility is typically chlorinated for disinfection. Therefore, the discharge could contain small amounts of chlorine plus the same priority pollutants listed in Section 3.3.1. None of the potential constituents are bioaccumulators.

3.4 Concentrations

Firemain and freshwater are used to lubricate stern tube seals and bearings. The lubricating water briefly contacts the bearings and seals when compared to the rest of the firemain; the firemain piping system is much longer than the length of the stern tubes (5.5 feet each) and hence the residence time of seawater in the firemain system is much greater than the 13 second residence time in the stern tube seal and bearing lubrication system of a typical surface vessel. Freshwater data were also used.

3.4.1 Seawater Lubrication

The concentrations of the constituents, as shown in Table 2, were estimated using corrosion rates for the materials of construction, the surface area of the materials exposed to seawater, and the rate of seawater lubricating the stern tube.[2]

3.4.2 Freshwater Lubrication

Water treatment plants typically add sufficient chlorine or monochloramine so that the finished water leaving the plant has a total residual chlorine (TRC) level of approximately 2.0 mg/L.[8] As water flows through the distribution system, TRC is depleted through its bactericidal action and due to reactions with other chemicals in the water and on piping and other surfaces.

By the time the water reaches the tap, TRC levels have been reduced to approximately 1.0 mg/L. After water is taken aboard a submarine into the trim tank and before its discharge after being used as a stern tube seal lubricant, several factors cause the TRC level to continue to decline. For example, the TRC-containing freshwater is mixed with the seawater that remains in the trim tank and as a result, is diluted by about 50% based on the fact that trim tanks are about 50% full of seawater while pierside. This results in an immediate reduction of the TRC concentration to approximately 0.5 mg/L. In addition, organic matter in the residual seawater in the trim tank will cause further rapid depletion of TRC levels. Although not measured specifically, the amount of TRC in the trim tank water used to lubricate the shaft seal is likely to be at least as low as the levels measured in the freshwater used to layup condensers in submarines. TRC levels in such systems were reduced from 1.2 mg/L to 0.028 mg/L in two hours. Please refer to the Freshwater Layup NOD report for additional information. Using the average flow rate from the trim tank, it requires approximately 17 hours to drain the trim tank.

The estimated contributions of the freshwater lubrication process to the discharge are unknown but thought to be minor. This is because the shaft is not turning while pierside so there is no bearing wear. In addition, the lubricating water only contacts the lubrication system components for a short period of time because of the constant flow of water from the trim tank, through the bearing, and then to the sea. For a typical surface ship (DDG 51 Class) the residence time of water in the stern tube is approximately 13 seconds[2] and similar residence times for stern tubes on other vessel classes is expected. With residence times of this order, there is little time to accumulate erosion or corrosion products from the bearing lubrication system materials of construction.

4.0 NATURE OF DISCHARGE ANALYSIS

Based on the discharge characteristics presented in Section 3.0, the nature of the discharge and its potential impact on the environment can be evaluated. The estimated mass loadings are presented in Section 4.1. In Section 4.2, the concentrations of discharge constituents after release to the environment are estimated and compared with the water quality criteria. In Section 4.3, the potential for the transfer of non-indigenous species is discussed.

4.1 Mass Loadings

4.1.1 Seawater Lubrication

An estimate of the rubber discharge was made based on data for DDG 51 Class vessels. The DDG 51 Class was chosen because it is a mid-size vessel with a significant population in the fleet. The available data includes:

	Stern Tube	**Strut**
Bearing Length	66 inches	96 inches
Number of Staves	26	26
Stave Width	3.18 inches	3.18 inches

Using this data, the total length of rubber material exposed to wear was calculated to be 351 feet per shaft by the equation:

((66 inches + 96 inches) bearing length per shaft) (26 staves per shaft)/(12 inches per foot) = 351 feet of bearing material per shaft

DDG 51 Class ships have two shafts; therefore, the total length of bearing material per ship is 702 feet. Because DDG 51 Class ships have controllable pitch propellers, a wear rate of 40 mils (0.04 inch) on each stave occurs per year. Approximately 40% of the staves carry the weight of the shafting and thus are subjected to this wear rate. The total volume of rubber that is worn annually from the staves per ship was calculated as follows:

Volume of Rubber Per Ship = (702 feet of rubber) (3.18 inches/(12 inches/foot) width of staves) (0.04 inch/(12 inches/foot) wear depth) (0.4 percentage of staves subject to wear) = 0.25 cubic feet

The density of Buna-N (nitrile) rubber is 61.8 pounds per cubic feet (lbs/ft^3). Therefore, 15.4 pounds [(61.8 lbs/ft^3) (0.25 ft^3)] of rubber are contained in the discharge from each ship annually. Based upon the assumptions described in Section 3.2.1, ships spend approximately 5% of their underway time within 12 n.m.[6] Thus, 0.76 pound of rubber is discharged by each vessel within 12 n.m. Bearing wear does not occur while the vessel is alongside the pier or at anchor because the shafts are not turning.

Using 0.76 pound of rubber as an average for each surface ship and 0.38 pound for each submarine (due to the single shaft configuration of submarines), the total annual mass loading for 274 ships (excluding boats and crafts) and 89 submarines was calculated by the equation:

Total Annual Mass Loading of Rubber = (0.76 pound/ship) (274 ships) + (0.38 pound/submarine) (89 submarines) = 242 pounds

A total of 242 pounds of rubber is discharged annually for all vessels. This is a conservative estimate because many vessels have a wear rate of less than 40 mils per year and many surface vessels do not have two shafts.

Concentrations of rubber were then calculated as follows:

Concentration of rubber in mg/liter = (242 pounds per year) (453,600 mg/pound) / [(334,807,200 gallons per year) (3.785 liters/gallon)] = 0.09 mg/liter

The total annual mass loadings for the metal constituents of seawater lubrication was calculated based on materials of construction in the stern tube, corrosion rates for those materials, and the surface area of the material exposed to seawater for a DDG 51 Class ship. The material of construction is a copper-nickel alloy (80% copper and 20% nickel). The available data includes[2]:

Surface area exposed to seawater = 7,254 square inches (in^2)
Corrosion rate of copper nickel = 7.0 micrometers per year (µm/yr)
Density of copper nickel = 8.9×10^6 grams per meter cubed (g/m^3)

Total Annual Mass Loading of Copper and Nickel = (corrosion rate) (density) (area) (percent of time within 12 n.m.) = 160.4 grams per year

Based on these analyses, one DDG 51 stern tube has the potential to discharge 128.3 grams or 0.28 pound of copper and 32.1 grams or 0.07 pound of nickel annually within 12 n.m. of shore. Applying this estimate to all vessels of the Armed Forces results in a total annual mass loading of 180 pounds of copper and 45 pounds of nickel.

4.1.2 Freshwater Lubrication

The weighted average of the freshwater flow rate to the stern tube bearings on a submarine is approximately 5 gallons per minute (19 liters per minute) when the submarine is idle in port. Assuming a 1.0 mg/L TRC concentration in the freshwater (see Section 3.4.2) and that the freshwater will be diluted by an equal amount of seawater remaining in the trim tank when the freshwater is added, the TRC mass loading per submarine per day was calculated by the equation:

TRC Mass Loading = (Freshwater flow rate) (TRC concentration) (Dilution factor) = (19 L/min) (0.001 grams/L) (50%) (60 min/hour) (24 hours/day)
= 13.7 grams TRC per day per submarine

Because submarines rarely use freshwater to lubricate the shaft seal, it is assumed that there are four submarines that use this method annually for shaft seal lubrication and each for a total of one week. Based on the assumptions in Section 2.1.2, the total annual TRC mass loading for submarines was calculated by the equation:

Annual TRC Mass Loading = (13.7 grams TRC/day/sub) (7 days/year) (4 subs) = 383 grams TRC/year = 0.383 kg TRC/yr = 0.84 pounds TRC/yr

The estimated mass loadings for this discharge are provided in Table 1.

4.2 Environmental Concentrations

Table 2 shows the concentration of the priority pollutants that are present in the discharge from seawater-lubricated bearings compared to acute water quality criteria (WQC). Only copper exceeds water quality criteria. – The concentration of copper is derived from corrosion rates for copper, the surface area of the material exposed to seawater, and the rate of seawater lubricating the stern tube.

The freshwater lubrication discharge from submarines consists of freshwater that could have low concentrations of TRC. Although not measured specifically, the amount of TRC in the trim tank water used to lubricate the shaft seal is likely to be at least as low as the levels measured in the freshwater used to lay up boilers and condensers in submarines. TRC levels in such systems were reduced from 1.2 mg/L to 0.028 mg/L in two hours.

The rubber staves are abraded during the shaft rotation into small particles that do not dissolve, are relatively inert, and hence are largely not bioavailable.

4.3 Potential for Introducing Non-Indigenous Species

The transport of non-indigenous species is not a concern for this discharge because the flow through the shaft seals is continuous, the residence time of seawater is 13 seconds for a DDG 51 Class ship, and the seawater is not held on board for this purpose; therefore, there is little opportunity to transfer non-indigenous species. Similar residence times are expected for all other vessel classes.

5.0 CONCLUSIONS

The constituents in stern tube seal and underwater bearing lubrication have a low potential to cause an adverse environmental effect because:

1) Oil lubricated stern tube seals and bearings cannot release oil to the environment under normal ship operations.

2) For seawater lubricated stern tube seals and bearings, there is very little contribution of constituents to the seawater lubrication fluid from the stern tube seal system, other than rubber, copper, and nickel because of the very short time that the fluid is in contact with the stern tube seal system. Rubber is released to the environment because the rubber bearing staves wear. Copper and nickel are introduced because they are materials of construction of the stern tube. While copper concentrations can exceed chronic WQC, the mass loadings are not considered sufficient to pose an adverse environmental effect.

3) Freshwater lubricated stern tube seals and bearings are used only on submarines and only rarely (estimated to be four submarines, each for one week per year) when the seawater in the trim tanks normally used for lubrication is exhausted. The freshwater lubrication discharge TRC concentration is expected to be as least as low as the levels measured in the freshwater used to lay up condensers in submarines.

6.0 DATA SOURCES AND REFERENCES

To characterize this discharge, information from various sources was obtained. Table 3 shows the sources of data used to develop this NOD report.

Specific References

1. UNDS Equipment Expert Meeting Minutes - Shaft Seal Lube/Stern Tube Seals/Underwater Bearing Lubrication. September 10, 1996.

2. Personal Communication Between Miles Kikuta (MR&S) and David Kopack (SEA 00T) and Gordon Smith (SEA 03L). December 11, 1998.

3. Personal Communication Between George Stewart (MR&S) and Sanjay Chandra (Versar). April 25, 1997.

4. Personal Communication between Bruce Miller (MR&S) and LCDR Warren Jederberg, Submarine Force, Pacific Environmental Officer of 15 October, 1997.

5. Personal Communication Between George Stewart (MR&S) and Sanjay Chandra (Versar). March 14, 1997.

6. UNDS Ship Database, August 1, 1997.

7. Commander Submarine Force, U.S. Atlantic Fleet Letter 5090 Serial N451A/4270 of 13 December 1996 in Response to UNDS Data Call.

8. American Water Works Association. Optimizing Chloramine Treatment. AWWA Research Foundation, 1993.

General References

USEPA. Toxics Criteria for Those States Not Complying with Clean Water Act Section 303(c)(2)(B). 40 CFR Part 131.36.

USEPA. Interim Final Rule. Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants; States' Compliance – Revision of Metals Criteria. 60 FR 22230. May 4, 1995.

USEPA. Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants. 57 FR 60848. December 22, 1992.

USEPA. Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California, Proposed Rule under 40 CFR Part 131, Federal Register, Vol. 62, Number 150. August 5, 1997.

Connecticut. Department of Environmental Protection. Water Quality Standards. Surface Water Quality Standards Effective April 8, 1997.

Florida. Department of Environmental Protection. Surface Water Quality Standards, Chapter 62-302. Effective December 26, 1996.

Georgia Final Regulations. Chapter 391-3-6, Water Quality Control, as provided by The Bureau of National Affairs, Inc., 1996.

Hawaii. Hawaiian Water Quality Standards. Section 11, Chapter 54 of the State Code.

Mississippi. Water Quality Criteria for Intrastate, Interstate and Coastal Waters. Mississippi Department of Environmental Quality, Office of Pollution Control. Adopted November 16, 1995.

New Jersey Final Regulations. Surface Water Quality Standards, Section 7:9B-1, as provided by The Bureau of National Affairs, Inc., 1996.

Texas. Texas Surface Water Quality Standards, Sections 307.2 - 307.10. Texas Natural Resource Conservation Commission. Effective July 13, 1995.

Virginia. Water Quality Standards. Chapter 260, Virginia Administrative Code (VAC) , 9 VAC 25-260.

Washington. Water Quality Standards for Surface Waters of the State of Washington. Chapter 173-201A, Washington Administrative Code (WAC).

The Water Quality Guidance for the Great Lakes System, Table 6A. Volume 60 Federal Register, pg 15366. March 23, 1995.

Committee Print Number 95-30 of the Committee of Public Works and Transportation of the House of Representatives, Table 1.

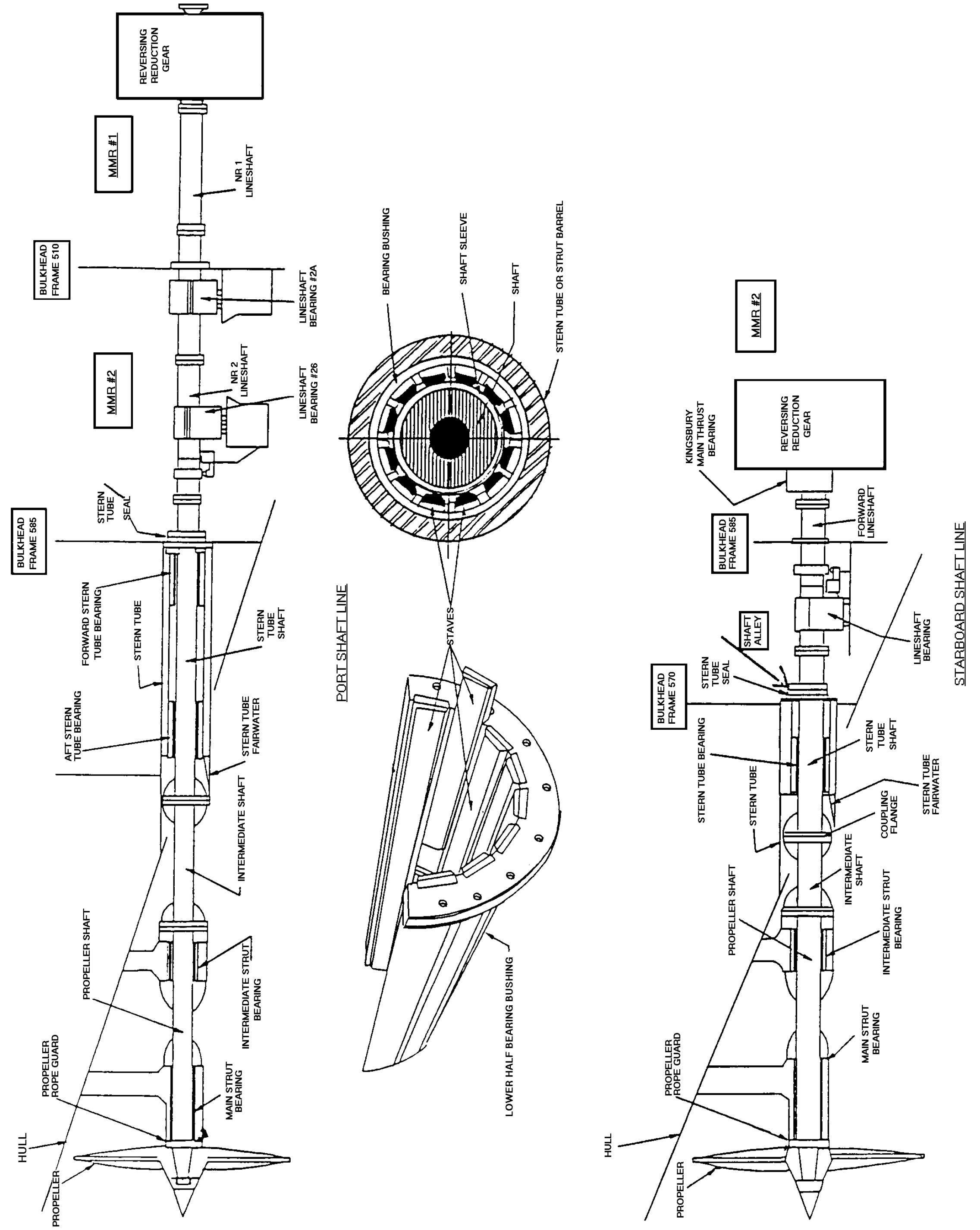

Figure 1. Port and Starboard Shaft Lines

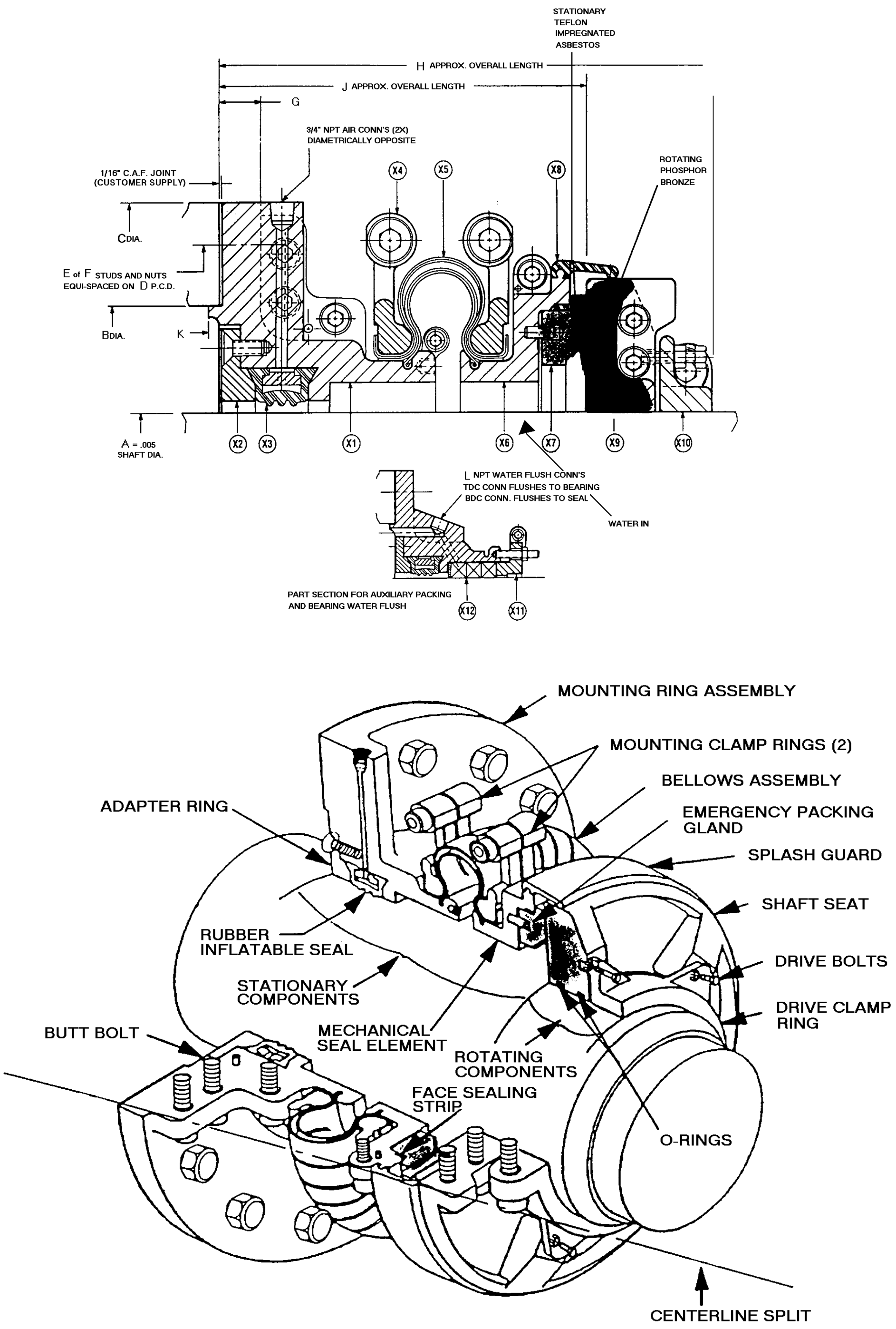

Figure 2. Type MX9 Inboard Water Lubricated Fully Split Seal

Table 1. Estimated Fleet-Wide Mass Loadings for Stern Tube Seals and Underwater Bearing Lubrication

Constituent	Estimated Mass Loadings (lbs/yr)
TRC	0.84
Rubber	242
Copper	180
Nickel	45

Table 2. Comparison of Calculated Data with Water Quality Criteria (μg/L)

Constituents	Calculated Concentration Log-normal Mean Effluent	Federal Chronic WQC	Most Stringent State Chronic WQC
TRC	NA*		7.5 (CT, HI, MS, NJ, VA, WA)
Total Copper	5.8	2.9	2.9 (FL, GA)
Total Nickel	1.5	8.3	7.9 (WA)

Notes:
Refer to federal criteria promulgated by EPA in its National Toxics Rule, 40 CFR 131.36 (57 FR 60848; Dec. 22, 1992 and 60 FR 22230; May 4, 1995)

CT = Connecticut
FL = Florida
GA= Georgia
HI = Hawaii WA = Washington
MS = Mississippi
NJ = New Jersey
VA = Virginia

NA* = Not available. Concentrations estimated in Section 3.4.2.

Table 3. Data Sources

	Data Source			
NOD Section	Reported	Sampling	Estimated	Equipment Expert
2.1 Equipment Description and Operation				X
2.2 Releases to the Environment				X
2.3 Vessels Producing the Discharge	UNDS Database			X
3.1 Locality				X
3.2 Rate			X	X
3.3 Constituents			X	X
3.4 Concentrations			X	X
4.1 Mass Loadings			X	X
4.2 Environmental Concentrations				X
4.3 Potential for Introducing Non-Indigenous Species				X