Elimination of a Ship Source Pollutant - STOP (Stern Tube Oil Pollution)

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This document reports the mechanism relating to stern tube oil pollution from ships and its impact and extent of stern tube oil pollution on the seas. The paper also looks at a proven, available technology that eliminates stern tube oil pollution by focusing on the performance of seawater lubricated stern tube bearings based on ship owner experience.

KEY WORDS
Stern tube oil pollution; water lubricated bearings; stern tube bearings; propeller shaft bearings; ship source pollution.

INTRODUCTION
During the last few decades, the pollution of the world's oceans has become a matter of increasing international concern. Zero tolerance for any kind of ship source pollution is now becoming the norm and international regulations are becoming more and more stringent. Since 1998, almost US $140m in criminal fines have been levied by US Courts against shipping companies found guilty of polluting US waters.

Currently, the majority of commercial ocean-going ships operate with a propulsion system using a propeller shaft typically supported by oil lubricated metal bearings with the oil contained in the stern tube by forward and aft shaft seals. According to seal manufacturers, the seal must leak (aft-into the sea or forward-into the ships bilge) at the shaft/seal interface in order for the seal to function properly. As well, simple fishing net or rope caught on a ships rotating shaft can also damage the aft seal allowing stern tube oil to flow out into the sea. According to seal repairers, this occurs on a frequent basis. Typical ocean-going ship stern tubes contain 1500L (396 US gal) of oil. **Even at a conservative leakage rate of 6L/day (from LR Class Society Seal Type Approvals), the amount of stern tube oil pollution is estimated to be over 80 million litres (21m US gal) annually from normal operations. In comparison, oil pollution from the *Exxon Valdez* oil tanker spill was 41.6m litres (11m US gal).**

Using a proven, available technology, there is an alternative to an oil lubricated sealed system that completely eliminates stern tube oil pollution. A seawater lubricated open system uses seawater as the lubrication medium in place of oil. The seawater is taken from the sea, pumped through non-metallic shaft bearings and returns to the sea. No stern tube oil is needed. Proven materials and new designs of non-metallic bearings now offer performance similar to metal shaft bearings. One significant difference, however, is that the mild steel propeller shaft requires corrosion protection from the seawater. This may mean a higher up-front cost for the stern tube bearing system. However, with the elimination of aft seal maintenance, the up-front costs are recouped in lower in-service costs along with no aft seal damage worries or oil pollution risk (fines).

HISTORY
Over fifty year ago, propeller shafts were supported by *lignum vitae* bearings made typically from a dense wood from South America and lubricated with seawater in what was called an "open system". The constant flow of water from the sea lubricated the stern tube bearings and then flowed back into the sea. There was only one shaft seal in an "open system" and this prevented seawater from coming into the ship.

However, in that era, seawater lubricated bearings did not have reliable wear life limits much beyond 5 years which meant withdrawing the shaft and replacing the bearings; an expensive task. In addition, most shaft seals of the day were packed stuffing boxes and these tended to score the bronze shaft liner in way of the packing. That meant skimming or replacement of the packing liner at the same time, which was another additional cost.

Improvements in sealing technology in the 1950's encouraged the move to an oil lubricated propeller shaft. White metal bearings offered a proven technology, which, in a sealed oil system, provided for predictable and controlled wear life and reduced maintenance of stern tube bearings. There were some issues with this oil system. Although stern tube bearing maintenance was reduced, the two shaft seals required frequent maintenance or oil would leak into the sea or into the ship. Some stern tube seal oil leakage was considered "normal operational consumption" and an acceptable practice. Oil in larger quantities also leaked to the sea if the seal was accidentally damaged due to a rope or fishing net caught on the ships rotating shaft or with propeller impact.
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WHAT IS STERN TUBE OIL POLLUTION?
In a typical sealed oil system, the bearings supporting the shaft are mounted inside a hollow tube that is sealed with a lip type seal at each end and filled with mineral oil as shown in Figure 1. Typical stern tubes contain 1500L (396 US gal) of oil. Stern tube propeller shaft seals are the only barrier between the oil and

the sea, and over time, the seals can become damaged or worn allowing oil leakage to occur into the sea, into an onboard containment system or to the engine room bilge.

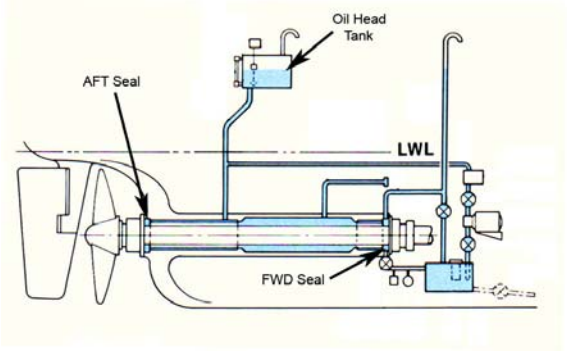

Figure 1. A typical oil lubricated stern tube bearing system

A propeller shaft sealing system is designed to prevent the ingress of water into the stern tube where it could damage the bearings. The seal is also designed to prevent the leakage of stern tube oil into the sea or into the engine room bilge. These sealing systems are costly to maintain because they are normally designed to withstand extreme conditions such as axial and radial shaft displacement, ship vibrations and operating periods of up to five years. The presence of sea water coming into the stern tube can also indicate that there is a good chance that oil is escaping out and polluting the seas.

WORDS FROM THE SHAFT SEAL MANUFACTURES/REPAIRERS AND OIL INDUSTRY

At the 2003 RINA International Conference for the Design and Operation of Container Ships, one of the largest shaft seal manufacturers, Wartsila Propulsion (Bearings & Seals) UK, stated that, “Consumption from the seal is controlled to the minimum acceptable to maintain an acceptable life, but by design it is essential to have oil at the mating surfaces. Oil consumption is always lost direct to the sea so contaminating the environment. The best estimates that can be made can only be based on seals in a lab condition running in clean and controlled environments but even this indicates an excess of 10,000,000 litres/year of oil is lost. Many organizations predict far higher in reality but it is difficult to prove with facts.”

At the 11th Shafting Symposium of the Society of Naval Architects and Marine Engineers in 2006, another large shaft seal manufacturer, Kobelco Eagle Marine Engineering Co. Ltd., Japan, stated that, “In stern tube bearings, the radial movement of the shaft is considerably larger than that of bearings for general industrial application. In addition, external disturbances such as rough seas and vibration are considerable. It is practically impossible to seal the stern tube oil perfectly. Therefore, one of the serious environmental issues in medium and large commercial vessels is stern tube oil leakage.” Dr. David Gilmour of BP-Castrol Marine Lubricants, a large supplier of stern tube oils, stated that "Environmental legislation can only get tougher, but even well maintained and managed ships will still leak oil."

In 2007, a major stern tube seal repairer, Simplex Americas LLC, repaired a large tanker stern tube seal that was damaged due to fishing line. This was the 21st stern tube seal repair job completed afloat by Simplex Americas LLC during 2007, allowing ship owners to renew their stern tube seals quickly on the spot. The various customer vessels included bulkers, tankers, and containerships. This statistic represented one seal repair company in North America, but it certainly gives an idea of the scope of problems that occur with stern tube seals.

In 2001, the European Commission DG Joint Research Centre reported on ship pollution totally based on spaceborne SAR remote sensing. It revealed for the first time the dramatic dimension of shipping pollution in the Mediterranean Sea, not as a result of accidents, but from routine unauthorized operational discharges.

In the commercial shipping industry, this type of "operational discharges" of oil is considered normal, but based on these leakage rates of ships trading in international waters, the amount of oil pollution from stern tubes may have a large detrimental impact on birds, fish and the marine environment given the following:
Assume: 45,000 commercial ships (>1000 DWT) presently in operation worldwide (source: LR-Fairplay PC Register)
Assume: 90% of these ships operate with oil lubricated stern tubes
Assume conservative number: average oil leakage = 6 litres/day (source: Lloyd's Register Type Approvals for stern tube seals)
Assume: 330 working days/year (according to IMO)
A conservative estimate would be:
45,000 ships x .90 x 6 litres x 330 days = 80.19 million litres/year of stern tube oil from operational discharge

Thus, an approximation of annual stern tube oil loss from the commercial shipping fleet is approximately 80 million litres per year (21 million US gal) and this does not include oil lost from damaged stern tube seals.

PROVEN AVAILABLE TECHNOLOGY TO ELIMINATE STERN TUBE OIL POLLUTION

Using a proven, available technology, stern tube oil pollution can be eliminated from the world’s oceans and seas. Two “conventional” alternatives currently in use claim to be environmentally friendly: 1) Seal manufacturers have developed more sophisticated multi lip seals which reduce the amount of oil that escapes, but shaft seals can still be damaged, and oil can still escape into the sea. 2) Biodegradable oils are also available, but they are still an “oil” and leave a sheen which is considered pollution.

A third, less conventional, but simple, option uses proven stern tube bearing technology from Thordon Bearings. The simplest way to completely eliminate oil from the stern tube is to use

seawater as the lubrication medium and Thordon non-metallic bearings in place of oil and white metal bearings. The seawater is taken from the sea, pumped through the bearings and returns to the sea. The seawater enters the forward section of the stern tube just aft of the seal. The seawater passes through the forward and then aft bearing prior to re-entering the sea as shown in Figure 2. The quality of the seawater supplied to the bearing is critical in ensuring long wear life. To ensure that abrasives are removed from the seawater supply, a water quality package is used. This package uses centrifugal forces to remove particulate from the sea water stream, then collects it and discharges it through a blow down line. Use of seawater lubricated bearings eliminates the aft seal, as well as the storage, sampling and disposal of oil. The potential impact of stern tube oil pollution is zero.

Figure 2. Thordon COMPAC seawater lubricated stern tube bearings – no oil required

Research presented at the 2007 RINA (Royal Institute of Naval Architects) conference noted the benefits of water lubricated propeller shaft bearings. The presenters from Fincantieri, a large shipyard in Italy, stated that, "Traditionally, the shaft line is oil lubricated, and located inside the tube case with a diameter larger than the shaft itself. An alternative solution is presented with water lubrication, which offers some consequent benefits. First of all, the inflow water meets a smaller diameter and so the wake peaks on the propeller plane are reduced. Furthermore, the water through frictional effect is trailed in rotation towards the propeller with a significant benefit for propulsion efficiency (about 2%). The water lubricated shaft line is also practically maintenance free and represents a 'green' solution as the risk of oil leakage is avoided."

An additional design consideration with seawater lubricated bearings is that the propeller shaft requires corrosion protection from the seawater. For economic and technical reasons, the shaft is typically steel which will corrode in (salt) seawater. To prevent this corrosion, bronze or stainless steel liners are generally placed over the shaft in way of the bearings. Between the liners a waterproof flexible coating is typically fitted to protect the shaft. Thor-Coat, a new 2-part epoxy shaft coating developed by Thordon Bearings, was specifically developed to complement seawater lubricated propeller shaft bearing systems with the objective of providing corrosion protection for a minimum ten-year period in service. Thor-Coat addresses the issue of current shaft coating systems not being sufficiently reliable to allow extension of shaft withdrawal periods beyond five years.

Currently there are over 500 commercial ships operating with Thordon seawater lubricated propeller shaft bearings with the first commercial installation in 1983. Some references/orders are presented below.

- Carnival Corp. (U.S.A.) - 9 cruise ships (108,000 to 115,000 GT) first delivered in 1998; 5 on order
- Flinter Groningen BV (Netherlands) - 19 dry cargo ships (4,000 to 9,000 DWT) first delivered in 2002; 6 on order
- Chemikalien Seetransport (Germany) - *Cinderella* (14,000 DWT) LNG Carrier since 1995
- BP Shipping (U.K.) – 4 tankers (185,000 DWT) since 2004
- Scanscot Shipping (Germany) – Four heavy lift cargo ships (9500 DWT) on order
- Upper Lakes Group Corp. (Canada) 2 bulkers (27,500 DWT) since 1999; 1 on order
- Interlake Steamships (U.S.A.) 4 bulkers (2-25,900 & 2-62,000 DWT) since 1999
- Palmali Group (Turkey) - 3 product tankers (8,000 DWT) since 1999
- Gypsum Transportation (U.S.A.) - *Gypsum Centennial* bulker (50,000 DWT) since 2001 and sister ship on order
- New York City Staten Island Ferries (U.S.A.) - 3 ships (5,900 GT) since 2004
- COSCO - China Ocean Shipping Group (China) - 4 car carriers (56,000 GT) and 1 bulker (32,000 DWT) on order
- The U.S., Canadian and Indian Coast Guard (oil pollution enforcement agencies) also use Thordon seawater lubricated stern tube bearings on over 65 of their ships with the first installation in 1983.

The world's largest cruise ship operator, Carnival Corporation through its operator Princess Cruises, has COMPAC seawater lubricated stern tube bearings currently installed on nine of their ships with five more on order. Mr. Chris Joly, Principal Manager, Marine Engineering for Carnival Corporation recently stated, "Seawater lubricated bearings are the present for many of our ships; I would like to see them for all of our future ships. In the Thordon COMPAC bearing, clean seawater is pumped to the 'A' bracket and the aft stern boss bearings as the lubricating medium and it flows through the bearings to the sea. No aft oil seal and no oil means lower in-service costs of the shaft line and, as important, no pollution worries. The added advantage is that the COMPAC tapered key system allows inspection of the bearing and shaft journal without pulling the shaft. To date, our experience is that COMPAC bearings with Inconel journals will mean worry free shaft lines for the life of the vessel."

BEARING WEAR LIFE PERFORMANCE EXPECTATIONS

Figures 3 and 4 are bearing wear life charts showing actual and expected wear life for seawater lubricated propeller shaft

bearings. Based on these actual results, seawater lubricated Thordon bearings can be expected to last for 15 to 20 years.

Figure 3. Seawater Lubricated Bearing Wear for *Disney Magic* after 10 years

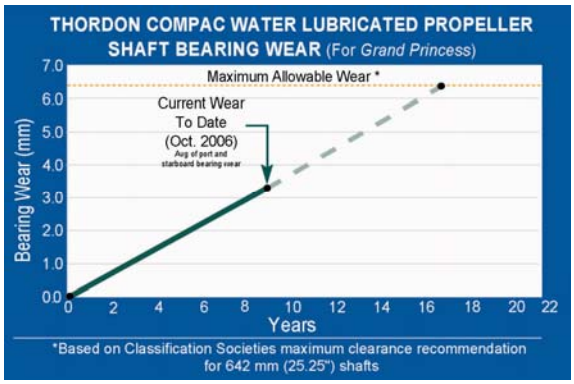

Figure 4. Seawater Lubricated Bearing Wear for *Grand Princess* after 9 years

LOWER FRICTION THAN OIL

Thordon COMPAC stern tube bearings have been designed to reduce running friction and improve low speed hydrodynamic film development. The lower (loaded) portion of the COMPAC bearing is smooth and the upper half is designed with water grooves for lubrication and cooling. Although start-up friction is initially higher, at rated shaft speeds drag on the rotating shaft resulting from the viscosity of the lubricating fluid is lower with water than with oil (see Figure 5), resulting in potential fuel savings.

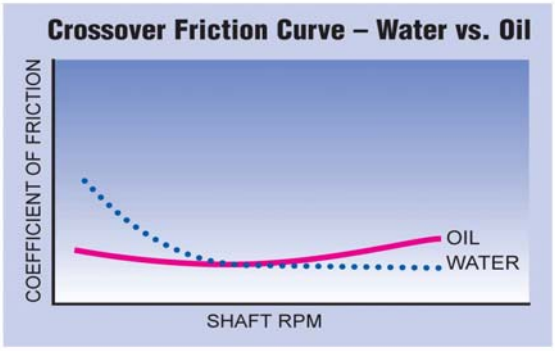

Figure 5. Crossover Friction Curve – Water vs. Oil

LIFE CYCLE COSTS

Non-metallic, seawater lubricated stern tube bearings typically may mean a higher up-front cost initially than comparable oil lubricated white metal stern tube bearing systems due to the need for corrosion protection of the shaft and addition of bronze liners. However, with the elimination of aft seal maintenance, the up-front costs are recouped with lower in-service costs. Based on existing user experience of COMPAC seawater lubricated propeller shaft bearings, the overall life cycle costs have been reduced for these ship owners.

CONCLUSION

Ships trading in the world's oceans and seas can now eliminate both operational and accidental stern tube oil pollution while reducing ship owner maintenance costs and saving money over the service life of the ship. The improvements using proven bearing designs and new technologies from Thordon Bearings have resulted in Thordon seawater lubricated stern tube bearings offering improved wear life, fitting and monitoring methods to meet Class Society approvals. The performance of seawater lubricated COMPAC bearings to date has been comparable to oil lubricated white metal stern tube bearings. It also eliminates any risk of criminal, civil and administrative penalties and other adverse reactions such as bad public relations for the ship owner that may occur from oil leaking from the stern tube.

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