OIL LUBRICATED STERN TUBE DISCHARGES:
THE PROBLEMS AND THE SOLUTION

WHAT IS STERN TUBE LUBRICATING OIL AND WHY IS IT AN ISSUE?

Currently, the majority of commercial ocean-going ships operate with a propulsion system using a propeller shaft typically supported by oil lubricated white metal bearings with the oil contained in the stern tube by shaft seals. This "sealed stern tube system" is filled with mineral oil and sealed typically with a forward and aft lip type seal at each end as shown in Figure 1. Typical stern tubes contain 1500L (396 US gal) of mineral oil. The white metal stern tube bearings in a sealed oil system, provide for predictable and controlled wear life of the shaft bearings. This system has been in use since the 1950's when it replaced seawater lubricated wood (lignum vitae) bearings where wooden bearing wear life was unpredictable and corrosion prevention was an issue.

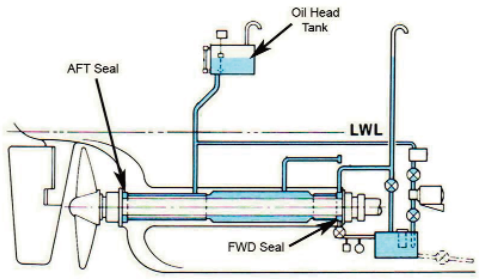

Figure 1. A typical oil lubricated stern tube bearing system

However, there are some issues with an oil lubricated stern tube bearing system and the issues have become much more prevalent today with concerns over any ship source pollution.

Operational Discharge

The two shaft seals containing the oil require frequent maintenance or oil will leak into the sea or into the ship. Stern tube seal oil leakage from a ship is considered "normal operational consumption" and typically an acceptable practice. 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.

Wartsila Propulsion (Bearings & Seals), UK

"Oil 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 liters/year of oil is lost. Many organizations predict far higher in reality but difficult to prove with facts."
Higgenbottom, Adrian. Wartsila Propulsion (Bearings & Seals) UK, "Coastguard Non-Polluting Stern tube Sealing System," presented at the RINA International Conference for the Design and Operation of Container Ships, 23-24 April 2003, London, UK , pp 53-60.

KEMEL, Japan

"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."
Sada, Hiroyuki, Seiji Yamajo, David W. Hawkins and Tsuyoshi Kawazoe. Kobelco Eagle Marine Engineering Co. Ltd., Japan, "An Environmentally Compatible Lubricant for Stern Tube Shafting and Bearing Systems," presented at the 11th Shafting Symposium of the Society of Naval Architects and Marine Engineers, Sept. 12-12 2006, Williamsburg, VA, U.S.A., pp 1.

Accidental Discharge

Ships operate all over the world in oceans, seas, lakes and harbours and propeller shafts are prone to come in contact with fishing line, net, rope, garbage, ice and even damage to a propeller by hitting the bottom. A simple fishing net or rope caught on a ships rotating shaft as shown in Figure 2 can damage the aft seal allowing stern tube oil to flow out into the sea or seawater to flow inboard contaminating the lubricating oil. The seals also wear over time allowing more oil to be discharged - seal manufacturers claim drip free operation of 2500 hours or 2 years, whichever comes first for replacement of seals. A typical commercial ship will operate 6000 – 8000 hours per year and drydock the ship 2.5 to 5 years for seal maintenance. Lloyd's Register reported:

"Defect statistics over the last 20 years indicate that the aft stern bush represents 10% of shaft line failures, with the forward stern bush representing 4% of total failures. Interestingly, the aft stern gland (seal) and forward stern gland (seal) represent 43% and 24% of failures respectively."

Smith, Andrew, Lloyd's Register Global Technology Leader-Engineering Systems., "Shaft Alignment Problems Analyzed," Marine Engineers Review April 2009, pp. 16

Figure 2: Rope tangled around propeller shaft causing seal damage

According to Emergency Seal Repair companies, this occurs on a frequent basis as reported in *Ship Repair Newsletter* published weekly by: A&A Thorpe, U.K., from 2007 to 2011, Issues 1108, 1117, 1121, 1126, 1127, 1162, 1171, 1182, 1196, 1207, 1227, 1306, 1307, 1318, 1332, 1334, 1342, 1345 and 1355.

HOW MUCH OIL IS BEING DISCHARGED?

A recent independent study done by a New York consulting firm showed that,

"Total annual inputs of lubricating oil worldwide from stern tube leakage into port waters is estimated to be between 37 million to nearly 61 million litres. If the same rates of discharge occur at sea as they do in port, the estimated worldwide annual inputs of lubricants to marine waters both in ports and harbours and at sea might be estimated to be about four times the port estimate. Thus, total worldwide use of stern tube lubricants from operational leaks and discharges would then be about 130 million to 244 million litres annually. "

Etkin, Dagmar Schmidt. Environmental Research Consulting "Worldwide Analysis of In-Port Vessel Operational Lubricant ," Arctic and Marine Oil Spill Program Technical Seminar of Environment Canada, 8 June 2010, Halifax, Canada

A directive from the European Maritime Safety Agency (EMSA) of the European Union is to use satellite imagery to detect oil spills. The EMSA Bulletin 2009 CleanSeaNet noted that in an 18th month period from 2007 to 2008:

"4,027 possible oil slicks were detected and reported to the authorities. The percentage of CleanSeaNet detections checked on site by aircraft or vessels confirmed as being mineral oil may vary from one region to the other but can reach values as high as 80%."

Marc Journal, European Maritime Safety Agency Bulletin 2009 CleanSeaNet: Satellite-based monitoring service for marine oil spill detection and surveillance in European waters, pp 48-51

Figure 3. North Sea CleanSeaNet oil slick detections via satellite in 2008

Most slicks are detected by CleanSeaNet along the main maritime traffic routes in Europe as shown in Figure 3. This indicates that illegal discharges from ships are still an important source of pollution that causes significant damage to the marine and coastal environment.
Most ship owners and operators believe stern tube oil leakage is minimal and consider the oil lost as "normal operating consumption". The only true numbers for stern tube oil leakage can be gained from those ship owners and operators who are also spending money on oil to keep their stern tube in working order.

WHAT ARE THE CONSEQUENCES OF STERN TUBE LUBRICATING OIL DISCHARGES FOR SHIP OWNERS AND OPERATORS?

First and foremost, stern tube lubricating oil discharges cost ship owners and operators money. Typical emergency seal repairs to fix/replace a leaking seal can be up to US$200,000. They can't afford to leak oil as pollution and the preservation of the environment are big concerns for the shipping industry. A growing number of new environmental regulations are being considered and enacted by a number of countries, particularly the United States, Canada and the European Union.

U.S.A.

Clean Water Act

The Clean Water Act requires that any spill or discharge that results in a sheen on the navigable waters in the contiguous zone (24 nautical miles from baseline) of the United States, be immediately reported to the National Response Center by telephone (1-800-424-8802) or other means.

Oil Pollution Act of 1990 (OPA '90)

The OPA'90 established limits of liability for cleanup costs and damages to be paid by responsible parties in oil spills. However, because of the availability of strict liability criminal sanctions as well as criminal sanctions for simple negligence under United States laws for spills in United States navigable waters, vessel crewmembers and corporate officers of corporations that own or operate vessels face potential criminal liability for practically any oil spill. This is true even when the spill is small or the resulting environmental damage is minor.

Polluters pay. The responsible party (the owner, operator or charterer of a vessel) must pay for the cleanup within certain liability caps. Parties that fail to notify the proper authorities of a spill are now subject to greater fines and longer prison terms. Civil penalties have also been toughened, with the owner of a vessel or facility that discharges oil or a hazardous substance liable for up to $37,500 a day in fines.

National Pollutant Discharge Elimination System (NPDES) Vessel General Permit (VGP) for Discharges Incidental to the Normal Operation of Vessels (Dec. 18, 2008)

The NPDES Vessel General Permit is issued pursuant to EPA's authority to issue permits under Clean Water Act Section 402. Clean Water Act Section 402 and its implementing regulations contain standards that govern EPA's imposition of NPDES permit conditions. The regulations cover 26 separate types of discharges-including some never before covered. Vessel owner/operators often use lubricants to maintain the functionality and structure of equipment such as wire rope and other mechanical equipment. As a requirement of this permit, vessel owner/operators must apply lubricants and maintain all seals so that discharges do not result in a visible sheen or are otherwise harmful.

They create new reporting requirements and carry "extensive" civil and criminal penalties for violations, including jail time. Violations can carry "extensive" civil and criminal penalties. These may include fines of up to $37,500 a day for each violation per vessel. Some violations carry jail sentences and could lead to debarment from federal contracts.
Penalties resulting from violations of federal, state or local environment laws in the United States come in many forms – criminal (such as fines or jail terms), civil (such as civil and judicial penalties) and administrative (such as loss of government contracts or permits). Additionally, there can be other adverse reactions such as bad public relations or insurance problems. Environmental enforcement remains one of the few areas in which government resources continue to GROW rapidly. Strict liability criminal statutes in the US applying to a large number of oil spills and other vessel source pollution incidents greatly increases the risk of potential criminal liability for these incidents. Even when environmental statutes require that the government prove intent or negligence in criminal prosecutions, the standard of intent or negligence is minimal.

Canada

In Canada, when an oil slick is detected within the Canadian 200-mile exclusive economic zone and a ship is suspected of being the source of the slick, MARPOL can be enforced. Under current Canadian legislation, oil polluters can be charged under the Canada Shipping Act (CSA), the Migratory Bird Convention Act (MBCA), the Canadian Environmental Protection Act (CEPA), and the Fisheries Act (FA). Dozens of reports concerning offshore oil pollution are received by Transport Canada and Environment Canada every year. Enforcement officers and pollution prevention officers (PPOs) are empowered to turn a ship back to any port to allow further investigation, and to detain the ship once it arrives in port.
The new Bill C-15 raised the maximum fines in the MBCA for illegal releases of harmful substances into areas frequented by migratory birds from $100 000 to $300 000 for a summary conviction and from $250,000 to $1,000,000 for an indictable offence.

European Union

International laws require enforcement:
1) MARPOL ANNEX 1
2) The European Union Directive on "Ship Source Pollution" [EU/2005/35]
   - The EU parliament claimed "that member states shall take the necessary measures to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest"
   - The OSPAR Commission called to "move towards the target of cessation of discharges, emissions and losses of hazardous substances by the year 2020.

Directive 2005/35/EC on ship-source pollution and on the introduction of penalties for infringements addresses the punitive side of non-compliance with MARPOL. It reproduces the MARPOL standards and provides that any intentional or seriously negligent infringement of those standards, whether in the coastal waters of the Member States or on the high seas, shall be effectively dealt with by EU Member States. (Marpol 73/78 discharge regulations relating to discharges of oil and noxious liquid substances, as referred to in Article 2.2).

MARPOL 73/78 legally recognized that certain sea areas have particular oceanographic and ecological characteristics, as well as conditions of sea traffic, that make them particularly vulnerable to ship-source

pollution and that therefore warrant a need for a higher level of protection. The Convention therefore introduced a special regime applicable to Special Areas (including Mediterranean sea, Baltic sea, Black sea and Northwest European waters), wherein more stringent standards would apply to the discharge of substances regulated in the different Annexes. In Special Areas under Annex I all discharges of oil or oily mixtures are by and large prohibited to almost undetectable levels, except for minor and well-defined exceptions (safety of life emergencies). All ships operating in the Special Areas have to be fitted with special equipment (e.g., oil separation equipment or filters), and must retain oil residues that cannot be discharged into the sea or discharge these residues at designated port reception facilities.

By requiring EU Member States to implement effective, proportionate and dissuasive penalties for infringements of the MARPOL rules, the Directive provides an additional disincentive for ship operators and others to pollute the seas. Directive 2005/35/EC also calls for the development of an information system to ensure its effective implementation, and for common practices and guidelines for the monitoring and early identification of ships engaged in unlawful discharges.

The European Union and its Member States are continuously monitoring European coastal waters with the objective of spotting pollution incidents and identifying the polluters. The monitoring is done by using surface vessels, surveillance aircraft and remote sensing satellites. These capabilities are improving all the time, although much still needs to be done before they are able to provide a fully comprehensive, consistent and reliable picture of pollution in EU waters. Via Directive 2005/35/EC, EMSA is involved in the development of technical solutions and in the provision of technical assistance in relation to the implementation of the Directive. This includes actions such as tracing discharges by satellite monitoring, and the EMSA CleanSeaNet system now supplies satellite images and information on pollution to Member States. CleanSeaNet has become an important part of the pollution monitoring network and is continually improving its capabilities.

OSPAR Convention

OSPAR is the mechanism by which fifteen Governments of the western coasts and catchments of Europe, together with the European Community, cooperate to protect the marine environment of the North-East Atlantic. The fifteen Governments are Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

The polluter pays principle is one of the central guiding principles of the OSPAR Convention and requires that the costs of pollution prevention, control and reduction measures must be borne by the polluter. The polluter pays principle is mainly implemented by means of command-and control approaches but can also be applied via market-based mechanisms, e.g. for the development and introduction of environmentally sound technologies and products. Recognised by the ministerial North Sea Conferences in 1984, the polluter pays principle was included in the 1992 OSPAR Convention. Internationally the polluter pays principle was introduced in the 1970s by the Organisation for Economic Co-operation and Development (OECD) and reaffirmed globally in the 1992 Rio Declaration on Environment and Development.

CAN STERN TUBE LUBRICATING OIL DISCHARGES BE ELIMINATED?

Two options claim to reduce stern tube oil pollution by using environmentally friendly variations on the standard oil lubricated white metal bearing system.

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, oil can still escape into the sea and owners still have to deal with any oil captured onboard.
2) Biodegradable oils are also available, but they are still considered a pollutant and leave a sheen which must be reported when leaked.

These two options are advertised and perceived by many as a solution to oil discharges, but the reality is that

they are just a variation of the same oil leakage problem.

One simple option exists that completely eliminates stern tube oil pollution. Using seawater lubricated Thordon non-metallic bearings in place of oil and white metal. The seawater is taken from the sea, pumped through the bearing positions and then flows to the sea as shown in Figure 4. No stern tube oil is needed. Thordon designs and manufactures non-metallic bearing materials that offer performance similar to oil lubricated bearings. Lower in service costs are also achieved with the elimination of the aft seal, oil and associated maintenance, along with no aft seal damage worries or oil pollution risk.

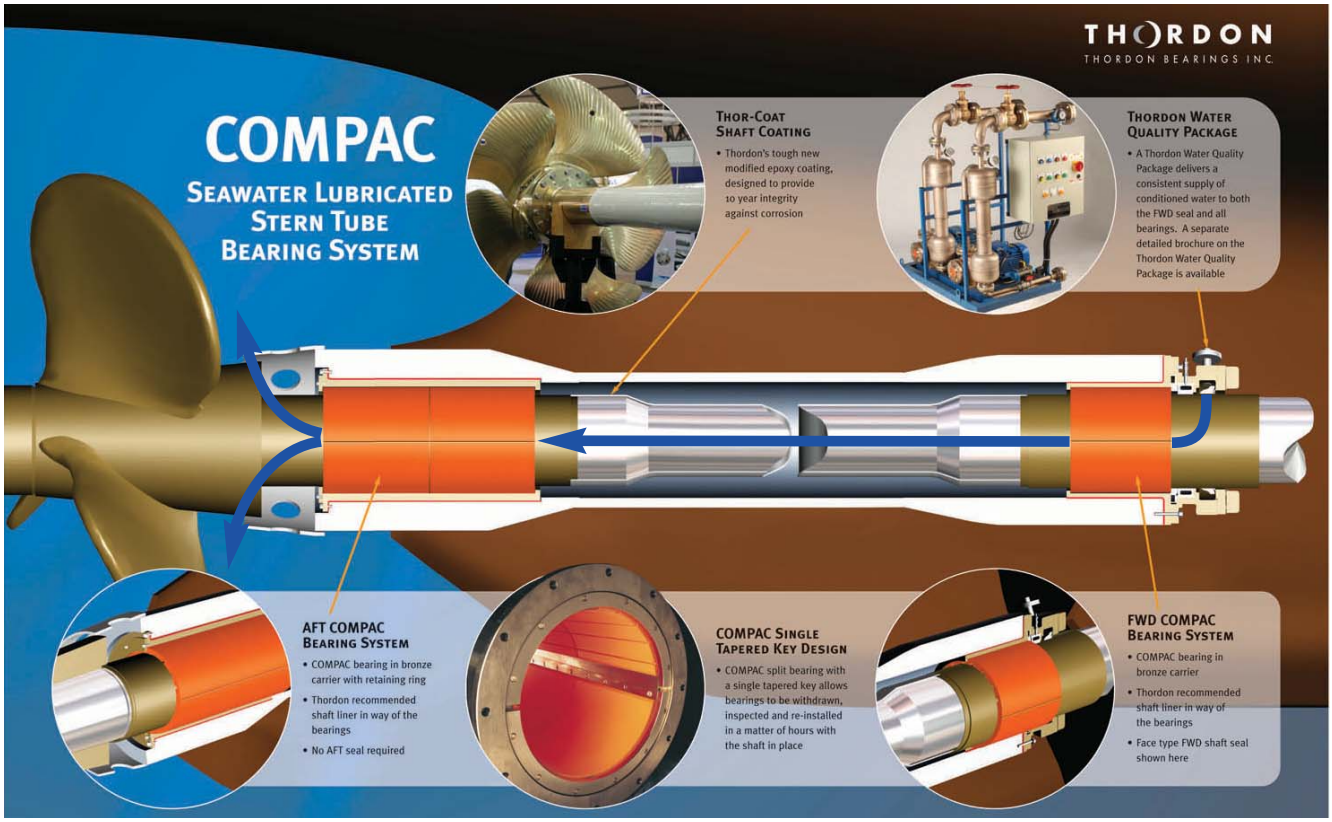

Figure 4. Thordon seawater lubricated stern tube bearings

Research presented at a recent RINA (Royal Institute of Naval Architects) conference noted the benefits of seawater lubricated propeller shaft bearings:

"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."
G. Lavini & L.Pedone, Fincantieri Cantieri Navali Italiani SpA, Italy, "Improvement on Hydrodynamic Performance of Conventional Passenger Ship Hulls Through RANSE Codes Application," presented at RINA's Design and Operation of Passenger Ships, part of Cruise & Ferry Conference, April 25, 2007.

Over 2000 ships use seawater lubricated stern tube bearings with zero risk of oil discharge

Currently, there are over 2000 ships operating with Thordon seawater lubricated stern tube bearings with the

first commercial ship installation in 1983. Some references are presented below:

- Carnival Corp. (U.S.A.) - 14 cruise ships (32,000 to 115,000 GT) first delivered in 1998; 2 on order
- BP Shipping (U.K.) – 4 tankers (193,000 DWT) since 2004
- Flinter Groningen BV (Netherlands) - 28 dry cargo ships (4,000 to 9,000 DWT) first delivered in 2002;
- Gypsum Transportation (U.S.A.) - 2 bulkers (50,000 DWT) delivered 2001 and 2009
- COSCO - China Ocean Shipping Group (China) - 3 car carriers (56,000 GT) and 10 bulk carriers (32,000 DWT)
- Scanscot Shipping (Germany) – 4 heavy lift cargo ships (9500 DWT) first delivered in 2009
- Algoma Corp. (Canada) - 5 bulkers (18,000 to 31,000 DWT) first delivered in 1999
- BC Ferries (Canada) - 5 ferries, first delivered in 2003
- Interlake Steamships (U.S.A.) - 6 bulkers (24,500 to 69,172 DWT) since 1999
- Oceania Cruises (U.S.A.) - 2 cruise ships (65,000 GT) since 2011
- Palmali Shipping Group (Turkey) - 10 product tankers (8,000 to 13,000 DWT) since 1999
- New York City Staten Island Ferries (U.S.A.) - 3 ships (5,900 GT) since 2004

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 propeller shaft bearings currently installed on 14 of their ships with 2 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."

Sources:

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www.marisec.org/pubs/pubslist.htm

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