

# Seawater Lubricated COMPAC Propeller Shaft Bearing System Product Manual



### **Table of Contents**

A. Corporate Profile1	
B. Stern Tube Oil Pollution - What are the Facts?2	
C. Introduction to COMPAC Seawater Lubricated Propeller Shaft Bearings	
<ul> <li>D. COMPAC Propeller Shaft Bearing System Description</li></ul>	
E. Existing Class Requirements9	I
F. Performance1	0
G. COMPAC Offers These Ship Owner Benefits1	1
H. Reference Stories1	4
I. References	4
J. Typical Drawings	4

The information contained in this document has been prepared from the company's many years of experience in the manufacturing and installing of Thordon Bearings worldwide.

This information is offered as part of our service to customers. It is intended for use by persons having technical training and skill, at their discretion and risk.

The company reserves the right to change or amend any specification without notice.

## ΤΗΟ ΠΟΝ

### **Corporate Profile**

Thordon Bearings Inc. is a leading designer and manufacturer of pollution free propeller shaft, rudder and deck equipment bearings and bushings. Thordon products are found on tankers, bulkers, dry cargo, dredge, container, cruise, yacht, offshore, ferry, naval and coast guard vessels. With 30 years of experience, Thordon offers worldwide technical support through an extensive sales, distribution and service network.

### Rudder Bearings

With over 4,000 rudder bearings installed, Thordon self lubricating SXL pintle, stock and carrier disc bearings offer a low coefficient of friction offering total freedom from grease for all rudder bearing applications above and below the waterline.



Thordon is the only bearing manufacturer to offer a 15-year rudder bearing wear life guarantee in new ships. Thordon also offers grease free fin stabilizer bearings, ThorPlas tiller arm, steering gear linkage and steering ram bushings.

### Deck Equipment Bearings

Thordon manufactures grease free ThorPlas bearings for tough deck equipment applications such as fairleads, capstans, sheaves, davits, trim tabs, pumps, door hinge, ramps, cranes, hoists and deck loading equipment. A direct replacement for bronze bushings, ThorPlas can operate in pressures up to 31 MPa (4500psi) and can easily be machined to fit any deck equipment bearing application.

### Propeller Shaft Bearings

Thordon Bearings offers several proven propeller shaft bearing system options each offering specific advantages in different water environments and operating conditions. Utilizing Thordon, a unique elastomeric polymer as the bearing wear surface, Thordon bearing systems offer elimination of the AFT seal, exceptional wear life, a low coefficient of friction, the lowest overall life cycle operating costs and increased propulsion system reliability.

SHIP OWNER BENEFITS OF THORDON PROP SHAFT BEARINGS:

- Eliminate stern tube oil pollution risk
- Excellent operational and proven wear performance
- Reduced shaft seal maintenance costs (no AFT seal)
- Ease of maintenance
- Survivability (non-catastrophic failure mode)

### Shaft Coating

To complement Thordon's water lubricated bearings, Thordon has developed Thor-Coat, a highly flexible, tough corrosion protection coating for propeller shafts designed to extend the shaft withdrawal period.

### Stern Tube Oil Pollution - What are the Facts?

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.

### Introduction to COMPAC Seawater Lubricated Propeller Shaft Bearings

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 \$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.

Using a proven, available technology, there is an alternative to an oil lubricated sealed system that completely eliminates stern tube oil pollution. A Thordon COMPAC 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 COMPAC propeller shaft bearings and returns to the sea. No stern tube oil is needed. COMPAC 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).

### **COMPAC Bearings**

A superior water lubricated bearing would be based on a bearing material with good selflubricity characteristics, excellent wear resistance and a design that encourages the rapid generation of a hydrodynamic film. Thordon COMPAC is an elastomeric polymer alloy produced by Thordon Bearings for the marine market. It was developed with a high self lubricity and based on the benefits calculated for an ungrooved bearing versus grooved bearing, a configuration with a smooth lower half and grooved upper half was selected. The COMPAC polymer in a 2:1 L/D configuration reduced breakout torque and operational friction translating into smoother operation, decreased wear and increased operating efficiency.

### **COMPAC Propeller Shaft Bearing System Description**

The Thordon COMPAC Propeller Shaft Bearing System Consists of:

- 1. Thordon COMPAC Water Lubricated Elastomeric Bearings
- 2. Bearing Carriers (as appropriate and recommended by Thordon Bearings)
- 3. Water Quality Package
- 4. Shaft Coating (Thor-Coat or other equivalent Class Approved coating)
- 5. Approved Shaft Liners
- 6. Forward Seal (No AFT Seal)



### 1. Thordon Water Lubricated COMPAC Elastomeric Bearings

The bearing wear surface is Thordon COMPAC, a non-metallic, elastomeric polymer alloy. Thordon high performance elastomeric bearings can:

- provide long bearing wear life
- eliminate oil
- withstand high shock loads and edge loading

To reduce start-up friction and eliminate stick-slip, COMPAC's formulation includes special lubricants to provide a low coefficient of friction. To promote early formation of a hydrodynamic film between the shaft and bearing, the lower (loaded) portion of the bearing is smooth, while the upper half of the bearing incorporates grooves for flow of the water lubricant/coolant.



COMPAC bearings are approved by all major Classification Societies.

Thordon COMPAC bearings are available in either full form tubes or in a split tapered key design. The split bearings are interference fit into a unique Thordon tapered key design one piece housing and then aligned and chocked into position. Thordon's split tapered key design has many advantages in service – the bearings can be removed, inspected and re-installed in just a few hours with the shaft still in place.



Thordon COMPAC Split Tapered Key Design



**COMPAC Key Extraction Illustration** 

### 2. Bearing Carriers (as appropriate and recommended by Thordon Bearings)

Thordon may recommend bearing carriers, if appropriate. There are several bearing carrier options for Thordon COMPAC bearings depending on the installation and alignment technique that is being used.

If the bearings are to be aligned individually, and resin chocked in position, they must be installed in a metal carrier. Full form bearings can be interference fit into a solid metal carrier or separate inner stern tube and then aligned and chocked into position.

On vessel conversion projects, interference fitting of full form tubes into the existing stern tube may also be considered.





### 3. Water Quality Package

A steady supply of relatively abrasive free water is an important element in ensuring long, predictable, bearing wear life. With this factor in mind, Thordon has developed a self-contained supply, conditioning and monitoring package to ensure that an adequate supply of clean water is consistently being delivered to both the forward seal and the bearings.

The Thordon Water Quality Package is designed to supply seawater to the stern tube bearings for lubrication and cooling at a minimum flow rate of 0.15 litre/minute/mm (1 US gallon/minute/inch) of shaft diameter and to condition sea water from the water supply by removing suspended solids with a specific gravity of 1.2 or higher and greater than 80 microns (0.003"). A flow alarm is incorporated to alert the operator to any low water flow condition to the bearings. The Thordon Water Quality Package is designed to operate on a stand-alone basis, or can be fully integrated into the ship's control and monitoring systems to allow operation in an unmanned machinery space.

Thordon offers three Water Quality Packages in configurations designed to deliver flow to suit a wide range of shaft sizes, and provide an appropriate degree of redundancy for the vessel involved. Thordon can, if required, work with integrators, designers and builders to meet special needs for specific installations.



### 4. Shaft Coating (Thor-Coat or Other Class-Approved Coating)

In a COMPAC water lubricated system, clean seawater is used as the lubricant. If there is any exposure of the shaft to salt water, the shaft must be protected by a corrosion-resistant coating. Existing epoxy-based shaft coatings have been an "Achilles heel" of open systems due to their tendency to crack (sometimes in locations where it is difficult to see the damage) and allow the shaft to corrode under the coating. To address this issue Thordon's polymer R&D lab has developed Thor-Coat, a toughened, modified epoxy coating without fabric designed to provide 10 year integrity – potentially eliminating the need for the 5 year shaft withdrawal and inspection.



### 5. Approved Shaft Liners

Since bearing "clearance" is the sum of both bearing wear, and wear of the shaft liner, a high quality shaft liner is an important component of a COMPAC system. Thordon Bearings recommends the following shaft sleeve materials in order to provide optimum wear performance in combination with Thordon COMPAC bearings.

- Inconel 625
- 70/30 Copper Nickel
- Gunmetal (typically CuSn10Zn)

### 6. Forward Seal (No AFT Seal)

Only a forward seal is required for the COMPAC bearing system. Thordon recommends a face seal or lip seal for use with the COMPAC water lubricated propeller shaft bearing system, however, other water lubricated seal options can be used. Thordon's new Sea Thigor mechanical face seal is a recommended option for shaft diameters up to 300 mm (12"). A separate detailed brochure on the Thordon Sea Thigor seal is available.

### **Existing Class Requirements**

Typically, oil lubricated propeller shafts with tailshaft condition monitoring have different class requirements than water lubricated propeller shafts. With water lubrication, the following must be completed every five years while the vessel is in drydock:

- MPI (magnetic particle inspection) of top of propeller cone or radius of flange
- Inspect bearing and journal surfaces
- Inspect end of liner and transition
- Examine shaft coating
- Record bearing wear down readings

As more Thordon water lubricated COMPAC propeller shaft bearing systems are installed and operational, Thordon is working with all Class Societies to extend the shaft withdrawal period.

The water lubricated COMPAC bearing system can allow for the following:

- MPI (magnetic particle inspection) of top of propeller cone or radius of flange
  - > FP propeller can be removed to inspect cone
  - > With CP propeller, radius is accessible under bolted cover
- Inspect bearing and journal surfaces

> COMPAC single key bearings can be removed with shaft in place to inspect bearing surface and also provides access to journal surface

- Inspect end of liner and transition
   > With open system, can be inspected with borescope techniques
- Examine shaft coating

> With open system, can be inspected visually with exposed parts of shaft or with borescope techniques

- Record bearing wear down readings
  - > Readings taken with poker gauge and feeler gauge

Currently, LRS and BV have exempted the COMPAC bearing system from a 5 year shaft withdrawal on a number of vessels reducing drydock cost over vessel life.

With proven longer bearing wear life, easy inspection of bearings and borescope techniques, Thordon is working with Class Societies to extend the shaft withdrawal period to 10 Years.

### Performance

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."

At the Marine Propulsion Conference in London, 2008, 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 mean 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." 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.

Bearing wear data has been recorded for several ships with shaft diameters over 500mm (20") that have been operating with the COMPAC bearing system for at least 5 years. Results have shown the bearings are expected to last 15 to 20 years as in the bearing wear charts below.



Disney Magic Cruise Ship





### Performance

Currently there are over 500 commercial ships operating with Thordon seawater lubricated propeller shaft bearings with the first commercial installation in 1983.

### **COMPAC Offers These Ship Owner Benefits**

### Zero Pollution Risk

The COMPAC propeller shaft bearing system eliminates stern tube oil, as the lubricant is seawater. There is no AFT seal, no storage of oil, no sampling of oil, no disposal of stern tube oil and no worry of ingressing seawater contaminating the oil. Expensive, multiple chamber AFT seals desiged to 'trap' oil leakage and drain it inboard for further processing and disposal are not required. Thordon's COMPAC system ensures ship owners/operators that there will be no environmental violations resulting from stern tube oil leakage.

### **Controlled Bearing Environment**

Thordon's Water Quality Package ensures an adequate supply of clean water is consistently being delivered to both the forward seal and the bearings. The lubrication is controlled and a long predictable bearing wear life is achievable. A controlled supply of clean water allows Thordon to offer a ten year bearing wear life guarantee.

### 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, resulting in potential fuel savings.



### **COMPAC Offers These Ship Owner Benefits**

### **Extensive References**

Thordon COMPAC bearing systems are extensively used in many Naval and Coast Guard applications. Today, commercial ship owners and operators around the world have chosen COMPAC for its pollution-free simplicity and proven reliability. There are over 1,000 ships equipped with Thordon water lubricated propeller shaft bearings plus many on order. A partial list of commercial ship references is on page 25.

### Simple Design for Newbuilds and Conversions

The COMPAC system was developed from improvements in non-metallic materials and bearing design combined with the proven principles of water lubrication technology that has existed since the earliest days of shaft driven propellers. The seawater is sourced from the ship's sea bay, pumped to the forward section of the stern tube just aft of the seal, through the forward and then aft bearings and returns to the sea.

### Increased Tolerance To Misalignment & Edge Loading

As a Thordon COMPAC bearing is 50 times more elastic than white metal and 3 times more compliant than other common non-metallic propeller shaft bearings, COMPAC deflects slightly under edge loading. The load is spread, and the localized pressure on the bearing is reduced, eliminating the bearing wiping that often occurs under these conditions.



### Survivability

If a serious bearing failure occurs with a white metal or reinforced plastic bearing, significant heat is often produced and there can be damage to the shaft as well as the bearing. As the Thordon COMPAC polymer softens at a lower temperature than metallic or or other non-metallic bearing materials, excessive amounts of heat are not produced in failure mode and shaft damage is avoided.

### **COMPAC Offers These Ship Owner Benefits**

### **Reduced Time In Dock With Key Design**

If specified, Thordon COMPAC's unique single tapered key design allows inspection or renewal of the bearings with the shaft in place. Originally developed for Disney Cruise Lines, the split bearing design allows the bearings to be withdrawn, inspected and reinstalled in a few hours.



COMPAC Bearing re-install on "Disney Magic" at Norshipco

### Lower Life Cycle Costs

COMPAC 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.

### **Easily Machined And Fitted**

Thordon COMPAC machines cleanly and produces no airborne machining debris. COMPAC is much lighter than white metal bearings and can be fitted quickly and easily by freezing in liquid nitrogen.



COMPAC bearing interference freeze fit installation into bronze carrier

### 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 new bearing designs and technologies from Thordon Bearings have resulted in Thordon COMPAC 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.

### **Reference Stories**

## **BULKER OPERATOR CHOOSES COMPAC**



Gypsum Integrity equipped with COMPAC stern tube bearings

The delivery last year of the 47,761 dwt self unloading bulk carrier *Gypsum Integrity* to Gypsum Transportation marked another success for the Thordon COMPAC seawater lubricated stern tube bearing system.

COMPAC is Thordon's open, seawater lubricated bearing system that has been designed to offer long life with a 15 year guarantee against excessive wear, no pollution concerns, elimination of an outboard stern seal and low friction. To promote early formation of a hydrodynamic film between the shaft and bearing, the lower (loaded) portion of the bearing is smooth, while the upper half of the bearing incorporates grooves to encourage flow of the seawater lubricant.

The ship is now operating as part of the gypsum trade on the east coast of the US and Canada with backhauls of coal from Columbia to the US Eastern seaboard.

Managed by Beltship Management Limited (BML) this new vessel is a sister

ship to *Gypsum Centennial* which, when launched in 2001, featured the first Wärtsilä RT-Flex engine and subsequently won awards for other innovative design concepts.

"In 1999 when the decision was made to

place an order for a new bulk carrier the owner wanted a state-of-the-art vessel that could be supported throughout a 30 year life with a strong emphasis on safety and the environment," explained John McMillan, technical director, BML.

BML has considerable experience in the self-unloading bulk carrier market having operated most types of self-unloaders from hybrid types to bespoke vessels of ground breaking design. Therefore, on behalf of the owner BML supervised the build while US based naval architect C R Cushing & Co handled the design.

Although Cushing has designed over 150 ships it also had experience of designing large vessels with water lubricated stern tube bearings. As this type of installation suited the requirements of the owner, extensive market research was conducted and, following consultation with Wärtsilä, the propulsion system supplier, the decision was made to run the 655 mm (25.79 in) diameter tailshaft on Thordon COMPAC bearings.

"Previous vessels had traded on the east coast of America carrying gypsum one way and returning empty," said Mr. McMillan. "Clearly this was not an ideal practice, so to take advantage of economy of scale it was decided to build larger vessels that could more easily attract return loads. The choice of water

lubricated bearings, although not that common for a vessel of this size, made perfect sense and was part of a conscious decision to minimise the impact the ship would have on the environment. Irrespective of how well trained and reliable a crew is, or how strictly the onboard procedures are adhered to, the integrity of an oil-filled stern tube can be compromised by circumstances outside of your control. Having water-lubricated stern tube bearings not only improves a company's environmental credentials but also eliminates the costs associated with maintaining an oil system and associated equipment."

As the vessel was not a standard shipyard design it was not easy to find a yard that would take on the project. However, around this time the Hyundai Mipo Dockyard (HMD) in South Korea had recently moved from shiprepair into shipbuilding and specialised in building niche vessels that required an innovative approach.

After several successful years of operating *Gypsum Centennial* it was decided to build a sister ship. However, due to the unprecedented demand for new ships HMD had adopted a mass production shipbuilding strategy and could not take on the project.

"Due to shipyards around the world having full order books we only really had a choice of three yards when the time came to sign a contract for *Gypsum Integrity*," said Mr McMillan. "Estaleiro Ilha SA in Rio de Janeiro was keen to take on the project as there had not been any major new orders from foreign owners for large vessels built in Brazil for around 10 years. Following the usual tendering procedures they were awarded the contract in 2005."

Although there were some modifications to the design of *Gypsum Integrity* incorporating the lessons learned from previous operational

### Bulker Operator Chooses COMPAC (cont'd. from cover)

experience, the new vessel would also be fitted with the COMPAC bearing system. The system had performed well onboard *Gypsum Centennial* but one tailshaft defect had become apparent during the first docking.

"During a routine tailshaft inspection on Gypsum Centennial it was discovered that the resin coating had failed, leading to minor corrosion," said Mr. McMillan. "However, this was not Thordon supply so the coating was removed and the tailshaft dressed to remove the corrosion to the satisfaction of the classification society. Thordon provided a representative to oversee the application of its Thor-Coat product that not only prevented more corrosion but also provided a guarantee against further failure."

Thor-Coat was specifically developed to complement Thordon's COMPAC water lubricated propeller shaft bearing system and to address the risk of traditional coating failures on water-lubricated propeller shafts. Thordon says that the toughened two-part epoxy coating is up to nine times more flexible than established products approved for use as propeller shaft coatings.

According to Thordon, during a 180degree bend test other products showed initial cracking at lower bend angles while Thor-Coat did not crack at all. If any of the coating is subject to mechanical damage it tends to fail locally, resulting in some of the coating remaining on the shaft and continuing to offer corrosion protection. If the coating is damaged to the point where corrosion does occur, says Thordon, the corrosion is limited to the damaged area only and will not migrate along the shaft under the coating. The one-coat application is by brush or blade, the coating then smoothed to a thickness of 2 mm (0.08 in).

The critical factors necessary to promote long, predictable, bearing wear life are water quality and flow rate. Since the first vessel was built Thordon has developed a self-contained water conditioning and monitoring package to provide an adequate supply of clean water to both the forward seal and the bearings. When Gypsum Centennial was built the bearing lubricating water was supplied from the seawater circulating system in the engine room but the new system utilises a standalone package. Incorporating dedicated pumps, cyclonic filters and flow monitoring equipment, the unit is designed to provide a high quality supply of water to the bearings at all times. BML reports that it is very happy with the COMPAC product and the aftersales support it has received from Thordon. Thordon bearings can also be found on the rudders of the vessels and in a recent incident when a bronze bearing failed on a lifting boom Thordon was able to supply a replacement component.

Mr. McMillan concluded, "When the US construction industry recovers from the

current recession there may be a requirement for another vessel of this type and Thordon COMPAC bearings would again be a serious contender for the stern tube installation."



**Thordon Water Quality Package** 

# **WORRY-FREE TRAVEL FOR SEABOURN ELITE**



Seabourn Odyssey installed with COMPAC seawater lubricated propeller shaft bearings

Vacationers on luxury cruises don't necessarily understand – or even care about – the propeller shaft bearings that help propel them to exotic destinations. Nor are they impressed when you cancel their cruise because of a bearing failure.

It was after this happened not once, but twice, that Carnival Corporation began for many of our ships," wrote Joly in a testimonial to Thordon Bearings Inc. "I would like to see them for all of our future ships."

By the time this article goes to print, Carnival will have Thordon COMPAC propeller shaft bearings on 10 of its Princess Class cruise ships.



the shift to Thordon COMPAC propeller shaft bearings. Chris Joly, Carnival's Principal Manager of Marine Engineering, was so impressed with the new bearings' performance that word quickly spread within the corporation.

"Water lubricated bearings are the present

"Once Carnival had installed COMPAC bearings on the first ships," says Stefano Resaz of Pedrotec, Thordon distributor in Italy, "they were so happy that all sister ships have been designed with the same bearings."

When Carnival introduced its upcoming line of extreme luxury vessels, Thordon Bearings was the obvious choice. Two Seabourn Cruise ships,

which Resaz describes as "superluxury megayachts," are set to install COMPAC propeller shaft bearings. The first of these is *Seabourn Odyssey*, which travels at a cruising speed of 19 knots, has a crew size of 335, guest capacity of 450, and gross tonnage of 32,000. The ship is targeted for delivery in June 2009 in

Genoa, Italy.

In the COMPAC propeller shaft bearing system, clean seawater is pumped to the "A" bracket and the aft stern boss bearings as the lubricating medium and flows through the bearings to the sea. No aft oil seal and no oil in the stern tube saves on shaft line servicing costs of the shaft line and eliminates the risk of stern tube oil pollution. Carnival Corporation have switched to Thordon Bearings for these reasons and more.

An open system makes it possible to inspect or change a bearing without removing the shaft. "The added advantage is that the COMPAC tapered key system allows inspection of the bearing and shaft journal without pulling the shaft," said Joly. "To date, our experience is that COMPAC bearings with Inconel journals will mean worry free shaft lines for the life of the vessel."

Seabourn's intimate, yacht-like cruisers promise highly personalized service, all-suite accommodations, superb cuisine and exceptional delivery of the most desirable destinations worldwide.

Travellers pay top dollar for the privilege of cruising with Seabourn. And they also benefit from durable, pollution-free bearings – whether they see them or not – that meet Seabourn's rigorous standards for top quality, *crème de la crème*, best of the best.



# **TANKER TO BULKER CONVERSION SPECIFIES**

In mid-2005 CSL International Inc (CSLI) invited Thordon Bearings to study the existing oil-lubricated sterntube system of its recently purchased 23 year-old tanker *Cabot*. The US-based company, part of Canada's CSL Group, planned to convert the ship into a self-unloading bulk carrier at the Shan Hai Guan Shipyard in China.

A key element of the project specification called for the conversion of the original oil-lubricated white metal propeller shaft bearings into a waterlubricated system guaranteeing zero risk of oil pollution from leaking sterntubes.

After reviewing all the drawings, Thordon prepared a conversion design proposal for CSLI, which then worked with the yard to finalise the project. All preparatory work was carried out while the ship was still afloat, and conversion of the existing system and installation of the Thordon COMPAC water-lubricated propeller shaft bearing system completed during dockings for the forebody conversion.

The new water-lubricated system was



COMPAC bearing cooled in liquid nitrogen and ready for freeze fit



Thordon Water Quality Package installed on CSL Acadian

designed for a propeller shaft diameter of 590mm and a shaft liner diameter of 645mm, the COMPAC bearings having length/diameter ratios of 2:1 aft and 1:1 forward.

Support for the yard, owner and Thordon was provided by Thordon's authorised distributor in China, Proco Marine Technology & Eng. Co. Ltd. Thordon's Manager of Engineering, Ken Ogle, who oversaw the project from start to finish, was also present during the system installation.

The overall conversion project was completed in March 2006, the former 67,208 dwt tanker *Cabot* emerging as the 74,000 dwt bulker *CSL Acadian* and arriving on the US west coast in mid-April.

"Thordon's approach and understanding of this project's needs were first class and their expertise in this field contributed to a smooth and fast turnaround," said Mr. Louis Martel, Vice President Technical Operations of CSLI.

Delivery of the bronze liner, seal and Thordon Water Quality Package took two months. Based on the *Cabot/CSL Acadian* project, a sterntube conversion could be easily completed in a week to 10 days if all parts are at the shipyard. Projects can be conveniently scheduled to match the tailshaft survey cycle.

In planning conversions from a whitemetal/oil-lubricated system to a COMPAC system, Thordon requires details of the existing sterntube and shaft arrangements, bearing drawings, shaft alignment and loading calculations, and the tailshaft drawing. A typical project calls for:

- assessment of the original bearing loading condition
- conversion design package and work procedure paper
- Thordon COMPAC water-lubricated bearings
- bronze shaft liners
- Class-approved shaft coating
- water-lubricated forward seal
- Thordon self-cleaning Water Quality Package

In a Thordon COMPAC bearing system, sea water is typically pumped by a maintenance-free self-contained pumping set from a sea chest through the Water Quality Package, which removes abrasive solids from the water supply (down to 40-50 microns) and ensures a flow for bearing lubrication and cooling. The flow is monitored by low flow alarms. Water enters the forward seal, flows through the COMPAC bearings and exits at the stern of the ship (there is no aft seal).

Clasification Society approved Thor-Coat shaft coating can provide tough corrosion protection for the propeller shaft, extending the period between shaft withdrawals.

Shaft liners are typically produced from gunmetal, bronze, Inconel 625 or stainless steel. Only a forward seal is

## **COMPAC TO REPLACE OIL LUBRICATED STERNTUBE**



lubricated COMPAC propeller shaft bearings, Thordon highlights:

Seven (+ three on order) Princess Cruises' ships, including Grand Princess, equipped since 1998; Chemikalien Seetransport's LNG carrier Cinderella (since 1996); Algoma Central Corporation's tanker Algonova (since 1997); Gypsum Transportation's bulk carrier Gypsum Centennial (since 2000); Disney Cruises' Disney Magic and sistership (since 1997 and 1998); two Grimaldi Group cruiseferries (since 2001); four BP Shipping tankers; Moby Lines' ferry Moby Rider (since 1997); three Staten Island ferries; and 12 Flinter Groningen-owned feeder container ships. N

required, which can be a face seal, lip seal or stuffing box.

Operational benefits for shipowners in specifying a Thordon COMPAC water-lubricated bearing system at the newbuilding stage or by retrofit include:

- Zero pollution risk (oil is eliminated from the sterntube)
- Controlled bearing environment using the Water Quality Package, guaranteeing a 10-year bearing wear life
- Reduced seal maintenance costs (forward seal only)
- Ease of maintenance
- No emergency dockings (long predictable wear life)
- Survivability (non-catastrophic failure mode allows ship to get to port).

Among over 460 diverse commercial and naval references for its water-



## **ROLLS-ROYCE MARINE'S 17-YEAR TROUBLE-FREE HISTORY WITH THORDON BEARINGS**

When Charles Rolls partnered with Henry Royce in 1906, they created a company that has remained on the leading-edge of industrial technology for almost a century. Rolls-Royce innovations make jets fly faster, cars run quieter, and ships move faster. They even built the engine that powered the first transatlantic flight. So it's no wonder that Rolls-Royce is careful when specifying components to be used in their systems. They have a reputation to protect.

"In the area of marine propulsion systems," says Roger Duwel, President of Duwel Tecno, Thordon Bearings distributor in Sweden, "no one in the world has a better name than Rolls-Royce. They take pride in that name and do everything they can to protect it."

Today, more than 20,000 commercial and 400 naval vessels use equipment developed at the Rolls-Royce Marine division. The company's product portfolio includes the most advanced systems available for the supply of power, propulsion and motion control.

### Selecting the best

Rolls-Royce has been using Thordon products for water lubricated stern tubes since 1987 and has been consistently impressed with the reliability and performance. "Thordon are a little more expensive than other bearings," says Jan Pahnke, Strategic Sourcing Specialist for Rolls-Royce Marine, "but they offer technical advantages that we feel are worth the extra money."

As Duwel puts it, "The folks at Rolls-Royce particularly appreciate the technical expertise." The knowledge base at Thordon Bearings goes well beyond bearing design and includes surrounding components and systems as well. "This is an important advantage for Rolls-Royce. They can send us shaft calculations, for example, and we can add value with our comments and suggestions."

As the pioneers in water-lubricated bearing technology, Thordon has more than a quarter century experience in a full range of applications in commercial and naval vessels. Thordon bearings are pollution free, highly resistant to abrasion, have low static and dynamic coefficients of friction, offer high resilience and impact resistance, and feature a long wear life.

"Thordon's track record in Rolls-Royce propulsion systems has been exceptional," says Duwel. "That's why they continue to specify Thordon in the systems they supply to their most important customers."

Here are just a few recent examples.

Thordon SXL water lubricated journal bearings are being used on waterjets from Rolls-Royce in a number of ships:

• YS2000 Visby Class 73 m Stealth Corvettes for the Swedish Navy - the first ships in the world to have fully developed stealth technology.



Swedish Navy YS2000 Visby Class Corvette

• A 210 ton carrying capacity ferry for Techno-Seaways of Japan. This vessel will be used to transport up to 700 passengers and cargo between Tokyo and the Ogasaware Islands.



Very Large Waterjet

Thordon COMPAC is the pollution-free water lubricated propeller shaft bearing of choice for a number of new vessels featuring Rolls-Royce systems:

- KBV 201 & 202 class multi-purpose patrol ships for the Swedish Coast Guard. To meet the demanding operational criteria, the propulsion design concept was evaluated at the Rolls-Royce Hydrodynamic Research Centre in Kirstinehamn, Sweden.
- Thordon COMPAC has been used by Rolls-Royce on over 10 different Navies, primarily in the Far East.
- Three new multipurpose container vessels currently being built at the Bodewes Shipyard in The Netherlands.
- New large tugs for the Bharati Shipyard - the largest private shipbuilder in India.
- New pusher tugs currently under construction at EISA Shipyard in Brazil.

It all comes down to trust. "We have had a good track record with the bearings," says Pahnke. "And there have never been any problems working with either Thordon or Duwel Tecno."

Obviously, one great name deserves another.

# Newswo RKS

### **ENVIRONMENTALLY FRIENDLY BEARING SOLUTIONS**

# **BP GOES OIL FREE ON TANKER PROP SHAFTS**

Safer than safe. That sums up the design philosophy on four 185,000 DWT Alaskan-class tankers that will soon be carrying oil along the U.S. West Coast. Currently being built in San Diego, USA by National Steel and Shipbuilding Company (NASSCO), a wholly owned subsidiary of General Dynamics, the BP Shipping-owned vessels feature the latest innovations in safe-ship design, including Thordon COMPAC water lubricated propeller shaft bearings.

"When moving oil by sea," says Stan Taylor, Technical Manager for BP, "our philosophy everywhere in the world has always been on safety." In fact, it is an expressed business policy of BP to aim "...to do no damage to people, or to the environment."

During the design phase of the vessels, BP was determined to leave no stone unturned in its quest to minimize the risk of oil leakage. This included building in multiple redundant systems, and eliminating the use of oil wherever possible. "The prop shaft is an area where, traditionally, some lubricating oil can leak into the sea," says Taylor. "So we needed to look for alternatives."

Traditionally, propeller shaft bearings on commercial tankers are made of white metal lubricated by oil. Although these systems work well, keeping the oil and water separate can be a challenge. If seawater contaminates the bearing area, prop shaft performance can be compromised. If oil escapes into the sea, that's pollution. "Even a small leakage from the prop shaft," says Taylor, "can result in a visible sheen when in port."

This is one of several reasons that made Thordon's pollution free alternative so appealing.

The Thordon COMPAC propeller shaft bearing systems now being installed on each of the BP vessels feature water lubrication (a renewed innovation pioneered for the 21<sup>st</sup> century by Thordon), no use of oil (and therefore zero risk of pollution), and an expected minimum 10 year bearing wear life based on systems currently in operation.

To ensure a steady supply of abrasive free seawater to the bearings, Thordon also supplied its integrated Water Quality Package. This maintenance free system includes pumps, flow alarms and a separator capable of eliminating particles down to 50 microns from the seawater lubricating the bearings.

"The Thordon system is the perfect choice for BP," says Taylor, "because its pollution free characteristics are consistent with the design philosophy of the ships." The first vessel is due to launch in Spring 2004 and because of a dedication to protecting the environment, these ships are set to carry oil by sea, *safely*, for decades to come.

BP Alaskan Class tanker to be equipped with water-lubricated COMPAC Propeller Shaft Bearing System



Thordon Bearings Inc. is the leading supplier of high performance, environmentally friendly propeller shaft and rudder bearing systems to the global marine market. Thordon bearings are available worldwide through over 70 agents and distributors. The company is a member of the Thomson-Gordon Group, a 3rd generation family-owned business founded in 1911.

# THORN THORN THORN THORN THORN RESULTED THORN ON COMPACING TO MAKE WAVES...

Thordon Bearings has recently supplied COMPAC water lubricated propeller shaft bearing systems for a number of commercial new build and conversion vessels. COMPAC, Thordon's high performance water lubricated bearing system for blue bearing system.

Gypsum Transportation of Bermuda has equipped its innovative, environmentally friendly 49,270 Dwt bulk carrier, *Gypsum Centennial*, with pollution-free



Gypsum Transportation's new ship Gypsum Centennial equipped with COMPAC

water operation, is designed for smooth start-up and superior bearing wear life. Stern tube oil is eliminated, as seawater is used to lubricate and cool the bearings making COMPAC the best choice for a simple, reliable and totally pollution free propeller shaft Thordon COMPAC propeller shaft bearings. John McMillan, Technical Director for Beltship Management, managers of Gypsum Transportation vessels, commented "The vessel design was specified to meet the LRS "EP" (Environmental Protection) designation, because Gypsum Transportation wanted have completely to а environmentally friendly vessel. As the vessel's trading route from Nova Scotia, Canada to ports along the US eastern seaboard takes it through environmentally sensitive fishing areas," John noted, "we wanted to eliminate any risk of leaking stern tube oil so we specified water lubricated propeller shaft bearings. The propulsion system supplier, LIPS B.V. of the Netherlands, proposed Thordon COMPAC and we approved their recommendation," said John. Shinshin Engineering, Thordon's distributor in South Korea, worked with the builder. Hyundai Mipo and B&B

cont'd. on page 2

Engineering, Thordon's distributor in the Netherlands worked with LIPS B.V. to provide technical and installation support. John concluded, "To date, we are very happy with the performance of the COMPAC bearings in *Gypsum Centennial*."

Flinter Group of the Netherlands have also specified Thordon

COMPAC propeller shaft bearings for three 8850 Dwt versatile multipurpose dry cargo/ container vessels. *Flintersun*. *Flinterstar* and Flintersky being built at Shipyard Ferus Smit, Leer in the Netherlands. LIPS B.V. supplied the COMPAC bearings as part of their propulsion system. Sales and technical support was provided by B&B Engineering.

The wave of new orders for COMPAC bearing systems continues with orders for new passenger vessels as well. Mitsubishi Heavy Industries (MHI) has ordered Thordon COMPAC for two new cruise ships being built for Princess Cruises at the Nagasaki Shipyard in Japan. These two 110,000+ ton ships will be slightly larger than the "Grand" class ships currently being built by Fincantieri in Italy and are scheduled for delivery in July 2003 and May 2004. Japan Marine Technologies of Tokyo are supplying the bearings and providing sales and technical support. *Star Princess*, delivered by Fincantieri of Italy in January 2002 at the Monfalcone yard has also been fitted with Thordon COMPAC.



Grimaldi Group of Italy launches their new 3,000 passenger ferry, La Superba, equipped with COMPAC

Star Princess follows Grand Princess (1998) and Golden Princess (2001) into service with Thordon COMPAC. A fourth vessel is scheduled for delivery in May 2004. Thordon COMPAC was also specified for the Grimaldi Group of Italy's new 8000 Dwt, 3000 passenger, fast ferry, *La Superba*. Built by Nuovi Cantieri Apuania in Italy, the 67,000 kW (91,000 HP), twin screw *La Superba* recently completed sea trials and will be going into service shortly. The 737mm (29 in.) bearings were supplied through propulsion system

integrator Rolls Royce, Italy. Pedrotec, the authorized Thordon distributor in Italy, provided sales and technical support. Bearings for the second ship in this series were delivered in January 2002.

COMPAC's success story has even extended to Aristotle Onassis' fabulous former yacht,

Christina O, where President John F. Kennedy first met Winston Churchill. Christina O has been refurbished at Victor Lenac Shipyard in Croatia and, as part of the ship's most extensive restoration ever, the 99m (325 ft.) yacht returns to sail into a new millennium in her original grandeur complemented by today's latest technology, including pollution-free COMPAC propeller shaft bearings.

> Built in 1943, the historic yacht Christina O had its most extensive refurbishment ever in 2001, including COMPAC propeller shaft bearings.

# THORDON Newsworks

### ENVIRONMENTALLY FRIENDLY BEARING SOLUTIONS

## THORDON COMPAC INTEGRAL IN NEW, ULTRA-QUIET FISHERIES SURVEY VESSEL (FSV)

Anglers understand the need to run quietly, as to not scare the fish away. That's relatively easy for a small boat with a trolling motor. But what about a mid-sized diesel-electric powered ship with a 4.3 m (14 ft.) diameter propeller? Such was the challenge faced in building the new Fisheries Survey Vessel (FSV) for the U.S. National Oceanic and Atmospheric Administration (NOAA). To ensure that fish populations could be studied effectively, the specifications featured the most advanced noise suppression technologies in the world - including Thordon COMPAC Water Lubricated Propeller Shaft Bearings.

Built by VT Halter Marine of Mississippi, U.S.A., the newly christened *Oscar Dyson* FSV will play a vital role in maintaining the health of the northern Pacific fishing industry. The ship will use a variety of techniques - including hydroaccoustic surveying - to collect the essential data required to establish accurate quotas.

At 64 m x 15 m x 8.5 m (210 ft. x 49 ft. x 28 ft.), a powered ship of this size would normally generate enough background noise to hinder surveying operations. Therefore, achieving a low acoustic signature was a critical design parameter

right from the start. "One of the areas where a lot of noise infiltrates the water is in the propulsion system," says Thordon Bearings distributor, Jim Bright, Sales Manager for Marine Industries Corporation. "So Thordon COMPAC was the obvious choice for the bearing material. In fact, it was written into the vessel specification."

According to the specifications, the stern tube bearing needed to be "of environmentally safe and acoustically inefficient materials". Thordon COMPAC Propeller Shaft Bearing Systems have a proven track record in Naval and Coast Guard applications featuring:

- Pollution free water lubrication (a renewed innovation pioneered by Thordon);
- No use of oil and, therefore, zero risk of oil pollution from the stern tube;
- An expected 10-year bearing wear life or longer; and
- A low coefficient of friction and superior hydrodynamic performance at lower shaft speeds resulting in quiet operation.

In addition to being acoustically stealthy, *Oscar Dyson* is also equipped with a Dynamic Positioning (DP) System to help



the ship hover at a fixed point on the ocean. This allows the vessel to more accurately monitor undersea activity.

"Of course keeping a large ship in one place isn't as easy as coming to a full stop," says Bright. "The DP coordinates the thrusters and main shaft to effect the station keeping duty and hold the vessel in one position. Starts, stops and low shaft speeds are necessary to maintain the vessel at a precise geographical coordinate. When a ship operates in this manner, shaft squeal or "stick slip" as it is colloquially referred to in the industry - is the noise generated when the shaft is operated at slow speeds and is literally trying to stick to the bearing. This noise will radiate from the vessel into the water. Thordon COMPAC's inherent self-lubricating properties and hydrodynamic design keeps breakaway friction low which helps to eliminate stick slip effects. Thordon engineers also did some further customization as Dave Rickman, Chief Mechanical Engineer for VT Halter, points out: "NOAA specified the Thordon bearing because of its experience showing that Thordon has a low acoustic signature. We had Thordon modify the standard offering to allow for sustained hydrodynamic operation at very low shaft RPM."

Delivered in October 2003 and due to be operational in the fall of 2004, *Oscar Dyson* will survey Alaskan waters and the Bering Sea in its mission to protect, restore and manage the use of living marine, coastal and ocean resources through ecosystem-based management. NOAA recently announced plans to exercise its option to build a second NOAA FSV at VT Halter Marine with delivery in 2006.

U.S. NOAA FSV Oscar Dyson equipped with Thordon COMPAC Water Lubricated Propeller Shaft Bearings

# COMPAC Seawater Lubricated Propeller Shaft Bearing References

Commercial Ships

			5			Shaft	Inital
Vessel Name	Vessel Type	Tonnes (DWT)	Vessel Owner	Shipyard	Classification Society	Diameter (mm)	Install Date
John D. Leitch	Bulker	30,640	Algoma Central Corporation	Lakehead Marine	LR (Lloyd's Register)	810	Aug -2013
			Canada	Canada			
Royal Princess	Cruise Ship	10,900	Carnival Corp.	Fincantieri	LR (Lloyd's Register)	758	Apr -2013
			U.S.A.	Italy			
Regal Princess	Cruise Ship	10,900	Carnival Corp.	Fincantieri-Cantieri Navali Italiani	LR (Lloyd's Register)	758	Apr -2014
			U.S.A.	Italy			
La Superba	Ferry	9,750	Grimaldi Group Genoa	Marina di Carrara	RINA (Registro Italiano Navale)	728	Oct -2001
			Italy	Italy			
La Suprema	Ferry	9,750	Grimaldi Group Genoa	Marina di Carrara	RINA (Registro Italiano Navale)	728	Aug -2002
			Italy	Italy			
Gypsum Integrity	Bulker	47,800	United States Gypsum Company IIS A	Estaleiro IIHA SA (EISA) Rrazil	LR (Lloyd's Register)	655	Mar -2009
			U.O.Y.	DIAZII			
Gypsum Centennial	Bulker	50,000	United States Gypsum Company U.S.A.	Hyundai Mipo Shipyard South Korea	LR (Lloyd's Register)	655	Nov -2001
Disney Dream	Cruise Ship	9,800	Disney Cruise Line	Meyer Werft GmbH	LR (Lloyd's Register)	651	Jan -2011
			U.S.A.	Germany			
Disney Fantasy	Cruise Ship	9,800	Disney Cruise Line	Meyer Werft GmbH	LR (Lloyd's Register)	651	Feb -2012
			U.S.A.	Germany			
CSL Acadian	Bulker	74,000	CSL Group Inc	Shanhaiguan Shipbuilding Industry	LR (Lloyd's Register)	645	Feb -2006
			Canada	China			
COSCO Shengshi	Car Carrier	18,500	cosco	COSCO Zhoushan Shipyard Co. Ltd.	NKK (Nipon Kaiji Kyokai)	642	Nov -2009
			China	China			
COSCO Tengfei	Car Carrier	18,500	cosco	COSCO Zhoushan Shipyard Co. Ltd.	NKK (Nipon Kaiji Kyokai)	642	Mar -2010
			China	China			

Page 1 of 31

# COMPAC Seawater Lubricated Propeller Shaft Bearing References

Commercial Shine

			5			Shaft	Inital
Vessel Name	Vessel Type	Tonnes (DWT)	Vessel Owner	Shipyard	Classification Society	Diameter (mm)	Install Date
Grand Princess	Cruise Ship	6,750	Carnival Corp.	Fincantieri	LR (Lloyd's Register)	642	May -1998
			U.S.A.	Italy			
Caribbean Princess	Cruise Ship	6,750	Carnival Corp.	Fincantieri	LR (Lloyd's Register)	642	Mar -2004
			U.S.A.	Italy			
Golden Princess	Cruise Ship	6,800	Carnival Corp.	Fincantieri	LR (Lloyd's Register)	642	Oct -2000
			U.S.A.	Italy			
Star Princess	Cruise Ship	6,800	Carnival Corp.	Fincantieri	LR (Lloyd's Register)	642	Jan -2002
			U.S.A.	Italy			
Ruby Princess	Cruise Ship	8,044	Carnival Corp.	Fincantieri	LR (Lloyd's Register)	642	Aug -2008
			U.S.A.	Italy			
Emerald Princess	Cruise Ship	8,400	Carnival Corp.	Fincantieri	LR (Lloyd's Register)	642	Apr -2007
			U.S.A.	Italy			
Ventura	Cruise Ship	8,400	Carnival Corp.	Fincantieri	LR (Lloyd's Register)	642	Mar -2008
			U.S.A.	Italy			
Crown Princess	Cruise Ship	8,900	Carnival Corp.	Fincantieri	LR (Lloyd's Register)	642	May -2006
			U.S.A.	Italy			
Azura	Cruise Ship	9,000	Carnival Corp.	Fincantieri	LR (Lloyd's Register)	642	Mar -2010
			U.S.A.	Italy			
Diamond Princess	Cruise Ship	7,921	Carnival Corp.	Mitsubishi Heavy Industries	LR (Lloyd's Register)	642	Feb -2004
			U.S.A.	Japan			
Sapphire Princess	Cruise Ship	7,921	Carnival Corp.	Mitsubishi Heavy Industries	LR (Lloyd's Register)	642	May -2004
			U.S.A.	Japan			
Peter R. Cresswell	Bulker	30,735	Algoma Central Corporation	Seaway Marine and Industrial	LR (Lloyd's Register)	638	Mar -2010
			Canada	Canada			

October 15, 2014

Page 2 of 31

# COMPAC Seawater Lubricated Propeller Shaft Bearing References

Commercial Shine

						Choff	letiul
Vessel Name	Vessel Type	Tonnes (DWT)	Vessel Owner	Shipyard	Classification Society	Diameter (mm)	Install Date
Algoma Quebecois	Bulker	27,490	Algoma Central Corporation	Pascol Engineering	LR (Lloyd's Register)	636	Jun -1999
			Canada	Canada			
Algoma Transport	Bulker	34,000	Algoma Central Corporation	Lakehead Marine	LR (Lloyd's Register)	629	Feb -2012
			Canada	Canada			
Marco Polo	Cruise Ship	5,180	Global Cruise Lines	Malta Shipyards Ltd.	DNV (Det Norske Veritas)	620	Mar -2007
			Greece	Malta			
Disney Magic	Cruise Ship	6,000	Disney Cruise Line	Fincantieri	LR (Lloyd's Register)	615	May -1998
			U.S.A.	Italy			
Disney Wonder	Cruise Ship	6,000	Disney Cruise Line	Fincantieri	LR (Lloyd's Register)	615	Jun -1999
			U.S.A.	Italy			
Rt Hon Paul E Martin	Bulker	71,406	CSL Group Inc	Chengxi Shipyard	LR (Lloyd's Register)	614	Sep -2012
			Canada	China			
CSL Tecumseh	Bulker	71,406	CSL Group Inc	Chengxi Shipyard	LR (Lloyd's Register)	614	May -2013
			Canada	China			
Balto	Bulker	71,406	CSL Group Inc	Chengxi Shipyard	LR (Lloyd's Register)	614	Aug -2013
			Canada	China			
Balchen	Bulker	71,406	CSL Group Inc	Chengxi Shipyard	LR (Lloyd's Register)	614	Sep -2013
			Canada	China			
CSL Tacoma	Bulker	71,406	CSL Group Inc	Chengxi Shipyard	LR (Lloyd's Register)	614	Oct -2013
			Canada	China			
Alaskan Navigator	Tanker	193,048	BP Shipping	NASSCO, San Diego Shipyard	ABS (American Bureau of Shipping)	610	Nov -2005
			U.S.A.	U.S.A.			
Alaskan Legend	Tanker	193,048	BP Shipping	NASSCO, San Diego Shipyard	ABS (American Bureau of Shipping)	610	Aug -2006
			United Kingdom	U.S.A.			

October 15, 2014

Page 3 of 31

# COMPAC Seawater Lubricated Propeller Shaft Bearing References

Commercial Shins

						Shaft	Inital
Vessel Name	Vessel Type	Tonnes (DWT)	Vessel Owner	Shipyard	Classification Society	Diameter (mm)	Install Date
Alaskan Frontier	Tanker	193,049	BP Shipping	NASSCO, San Diego Shipyard	ABS (American Bureau of Shipping)	610	Aug -2004
			U.S.A.	U.S.A.	) -		
Alaskan Explorer	Tanker	193,049	BP Shipping	NASSCO, San Diego Shipyard	ABS (American Bureau of Shipping)	610	Mar -2005
			U.S.A.	U.S.A.			
Algoma Olympic	Bulker	33,680	Algoma Central Corporation	Lakehead Marine	LR (Lloyd's Register)	603	Feb -2012
			Canada	Canada			
Mega Express Five	Ferry	5,802	Tourship Group	Genova	RINA (Registro Italiano Navale)	586	Feb -2009
			Italy	Italy	(		
Polar Adventure	Tanker	141,739	Owner Name withheld as per contract	Sembawang Shipyard	ABS (American Bureau of Shipping)	569	Jan -2010
			U.S.A.	Singapore			
Polar Resolution	Tanker	141,739	Owner Name withheld as per contract	Sembawang Shipyard	ABS (American Bureau of Shipping)	569	Jun -2010
			U.S.A.	Singapore			
Polar Discovery	Tanker	141,739	Owner Name withheld as per contract	Sembawang Shipyard	ABS (American Bureau of Shipping)	569	Apr -2011
			U.S.A.	Singapore			
Polar Enterprise	Tanker	141,739	Owner Name withheld as per contract	Sembawang Shipyard	ABS (American Bureau of Shipping)	569	Oct -2011
			U.S.A.	Singapore			
Polar Endeavour	Tanker	141,739	Owner Name withheld as per contract	Sembawang Shipyard	ABS (American Bureau of Shipping)	569	May -2012
Queen of Surrey	Ferry	1.395	U.S.A. BC Ferries	Singapore Vancouver Drydock Co.	LR (Lloyd's Register)	563	Nov -2001
			Canada	Canada			
Queen of Oak Bay	Ferry	1,462	BC Ferries	Vancouver Drydock Co.	LR (Lloyd's Register)	563	Nov -2001
			Canada	Canada			
Queen of Coquitlam	Ferry	1,496	BC Ferries	Vancouver Drydock Co.	LR (Lloyd's Register)	556	Jul -2003
			Canada	Canada			

October 15, 2014

Page 4 of 31

# COMPAC Seawater Lubricated Propeller Shaft Bearing References

Commercial Shine

			0			Shaft	Inital
Vessel Name	Vessel Type	Tonnes (DWT)	Vessel Owner	Shipyard	Classification Society	Diameter (mm)	Install Date
Queen of Cowichan	Ferry	1,496	BC Ferries	Vancouver Drydock Co.	LR (Lloyd's Register)	552	Oct -2003
			Canada	Canada			
Queen of Alberni	Ferry	1,981	BC Ferries	Vancouver Drydock Co.	LR (Lloyd's Register)	552	Oct -2003
			Canada	Canada			
Swift 141	Yacht (Pleasure Vessel)		Royal Family	Abu Dhabi MAR		542	Jun -2009
			U.A.E.	U.A.E.			
CSL Welland	Bulker	36,100	CSL Group Inc	Yangfan Group	LR (Lloyd's Register)	530	Apr -2014
			Canada	China			
CSL Laurent	Bulker	36,100	CSL Group Inc	Yangfan Group	LR (Lloyd's Register)	530	Oct -2014
			Canada	China			
Baie St. Paul	Bulker	37,690	CSL Group Inc	Chengxi Shipyard	LR (Lloyd's Register)	530	Sep -2012
			Canada	China			
Thunder Bay	Bulker	37,690	CSL Group Inc	Chengxi Shipyard	LR (Lloyd's Register)	530	May -2013
			Canada	China			
Whitefish Bay	Bulker	37,690	CSL Group Inc	Chengxi Shipyard	LR (Lloyd's Register)	530	May -2013
			Canada	China			
Baie Comeau	Bulker	37,690	CSL Group Inc	Chengxi Shipyard	LR (Lloyd's Register)	530	Jun -2013
			Canada	China			
Noble	Container/Dry Cargo	4,055	Northern Shipping	Turku Repair Yard	Russian Maritime Register of Shipping	515	Jan -1995
			Russia	Finland			
Dubai	Yacht (Pleasure Vessel)	1,557	Platinum Yacht Management	Dubai Dry-dock	LR (Lloyd's Register)	509	Aug -2011
			U.A.E.	U.A.E.			
Hai Yang Shi You 278	Bulker	53,500	Offshore Oil Engineering Co.	You Lian NanShen district. ShenZheng China	CCS (China Classification Society)	505	Mar -2012
			China	China			

Page 5 of 31

# COMPAC Seawater Lubricated Propeller Shaft Bearing References

Commercial Ships

			5			Shaft	loital
Vessel Name	Vessel Type	Tonnes (DWT)	Vessel Owner	Shipyard	Classification Society	Diameter (mm)	Install Date
Marina	Cruise Ship	6,000	Oceania Cruises	Fincantieri	Bureau Veritas	505	Jan -2011
			U.S.A.	Italy			
Riviera	Cruise Ship	6,000	Oceania Cruises	Fincantieri	Bureau Veritas	505	Jan -2012
			U.S.A.	Italy			
Kennicott	Ferry	1,695	State of Alaska	Halter Marine	ABS (American Bureau of Shipping)	500	Jul -1997
			U.S.A.	U.S.A.			
Xin Hai Tong 1	Bulker	51,000	Fuzhou Haitong Shipping China	Taizhou Sanfu Ship Engineering China	CCS (China Classification Society)	496	Jun -2012
			QIIIIa	CIIIId			
Xin Hai Tong 2	Bulker	51,000	Fuzhou Haitong Shipping China	Taizhou Sanfu Ship Engineering China	CCS (China Classification Society)	496	Aug -2012
Castillo de Plasencia	Tanker	12,219	Empresa Naviera Elcano		NKK (Nipon Kaiji Kyokai)	495	Aug -1993
			Spain	Netherlands			
James R. Barker	Bulker	61,564	Interlake Steamship	Bay Shipbuilding	ABS (American Bureau of Shipping)	492	Jan -2005
			U.S.A.	U.S.A.			
Paul R. Tregurtha	Bulker	69,172	Interlake Steamship	Bay Shipbuilding Co.	ABS (American Bureau of Shipping)	492	Jan -2007
			U.S.A.	U.S.A.			
Jin Guang Ling	Bulker	32,000	COSCO China	CSSC Guangzhou Huangpu Shipbuilding Co., Ltd. China	CCS (China Classification Society)	486	Dec -2008
Jin Yuan Ling	Bulker	32,000	COSCO China	CSSC Guangzhou Huangpu Shipbuilding Co., Ltd. China	CCS (China Classification Society)	486	Jun -2009
Ning An Cheng	Container/Dry Cargo	32,000	Cosco	CSSC Guangzhou Huangpu Shipbuilding Co., Ltd.	CCS (China Classification Society)	486	Jan -2010
			Cnina	China			
Du An Cheng	Bulker	32,000	cosco	CSSC Guangzhou Huangpu Shipbuilding Co., Ltd.	CCS (China Classification Society)	486	May -2011
			China	China			

October 15, 2014

Page 6 of 31

# COMPAC Seawater Lubricated Propeller Shaft Bearing References

Commercial Ships

						Shaft	Inital
		Tonnes			Classification	Diameter	Install
Vessel Name	Vessel Type	(DWT)	Vessel Owner	Shipyard	Society	(mm)	Date
Great Resource	Carrier	18,500	Sinotrans	CSSC Guangzhou Huangpu Shipbuilding Co., Ltd.	NKK (Nipon Kaiji Kyokai)	480	Feb -2009
			China	China			
Jin Xing Ling	Bulker	32,000	cosco	CSSC Guangzhou Huangpu Shipbuilding Co., Ltd.	CCS (China Classification Society)	480	Mar -2010
			China	China			
Jin Wang Ling	Bulker	32,000	cosco	CSSC Guangzhou Huangpu Shipbuilding Co., Ltd.	CCS (China Classification Society)	480	Jun -2010
			China	China			
Trans Friendship I	Bulker	32,000	Sinotrans	CSSC Guangzhou Huangpu Shipbuilding Co., Ltd.	CCS (China Classification Society)	480	May -2010
			China	China			
Trans Friendship II	Bulker	32,000	Sinotrans	CSSC Guangzhou Huangpu Shipbuilding Co., Ltd.	CCS (China Classification Society)	480	Aug -2010
			China	China			
Great Reward	Bulker	32,000	Sinotrans	LongXue, Nansha district, Guangzhou	CCS (China Classification Society)	480	Aug -2010
			China	China			
Rio Utamboni	Bulker	21,461	Glomar Supplies	Istanbul Shipyard	CCS (China Classification Society)	480	Jan -2010
			Panama	Turkey			
Flinterstream	Container/Dry Cargo	9,120	Flinter Groningen BV	Haiphong	Bureau Veritas	475	Sep -2008
			Netherlands	Vietnam			
HC Lara	Container/Dry Cargo	9,120	Flinter Groningen BV	Haiphong	Bureau Veritas	475	Jun -2009
			Netherlands	Vietnam			
HC Melina	Container/Dry Cargo	9,120	Flinter Groningen BV	Haiphong	Bureau Veritas	475	Jun -2009
			Netherlands	Vietnam			
Ben Kien 9200-RSBK-04	Container/Dry Cargo	9,120	Flinter Groningen BV	Haiphong	Bureau Veritas	475	Jun -2013
			Netherlands	Vietnam			
Vectis Eagle	Container/Dry Cargo	8,500	Carisbrooke Shipping Ltd.	Jiangsu Yangzijiang Shipbuilding	Bureau Veritas	470	Dec -2011
			United Kingdom	China			

October 15, 2014

Page 7 of 31

# COMPAC Seawater Lubricated Propeller Shaft Bearing References

Commercial Ships

						Shaft	Inital
		Tonnes			Classification	Diameter	Install
Vessel Name	Vessel Type	(DWT)	Vessel Owner	Shipyard	Society	(mm)	Date
Vectis Osprey	Container/Dry Cargo	8,500	Carisbrooke Shipping Ltd.	Jiangsu Yangzijiang Shipbuilding	Bureau Veritas	470	Jun -2012
			United Kingdom	China			
Vectis Falcon	Container/Dry Cargo	8,500	Carisbrooke Shipping Ltd.	Jiangsu Yangzijiang Shipbuilding	Bureau Veritas	470	Dec -2012
			United Kingdom	China			
Vectis Harrier	Container/Dry Cargo	8,500	Carisbrooke Shipping Ltd.	Jiangsu Yangzijiang Shipbuilding	Germanischer Lloyd	470	Apr -2012
			United Kingdom	China			
Vectis Isle	Container/Dry Cargo	10,199	Carisbrooke Shipping Ltd.	Jiangsu Yangzijiang Shipbuilding	Germanischer Lloyd	470	Dec -2012
			United Kingdom	China			
Vectis Castle	Container/Dry Cargo	10,203	Carisbrooke Shipping Ltd.	Jiangsu Yangzijiang Shipbuilding	Germanischer Lloyd	470	Jan -2013
			United Kingdom	China			
Vectis Pride	Container/Dry Cargo	10,230	Carisbrooke Shipping Ltd.	Jiangsu Yangzijiang Shipbuilding	Germanischer Lloyd	470	Aug -2012
			United Kingdom	China			
Vectis Progress	Container/Dry Cargo	10,260	Carisbrooke Shipping Ltd.	Jiangsu Yangzijiang Shipbuilding	Bureau Veritas	470	Oct -2012
			United Kingdom	China			
COSCO Kunlunshan	Bulker	3,200	cosco	Fujian Mawei Shipbuilding Ltd.	CCS (China Classification Society)	466	May -2010
			China	China			
COSCO Taihangshan	Bulker	32,000	cosco	Fujian Mawei Shipbuilding Ltd.	CCS (China Classification Society)	466	Feb -2010
			China	China			
Wuyishan	Bulker	32,000	cosco	Fujian Mawei Shipbuilding Ltd.	CCS (China Classification Society)	464	Jun -2009
			China	China			
Jinggangshan	Bulker	32,000	cosco	Fujian Mawei Shipbuilding Ltd.	CCS (China Classification Society)	464	Dec -2009
			China	China			
COSCO Taihangshan	Bulker	32,000	cosco	Fujian Mawei Shipbuilding Ltd.	CCS (China Classification Society)	460	Mar -2010
			China	China			

October 15, 2014

Page 8 of 31

# COMPAC Seawater Lubricated Propeller Shaft Bearing References

Commercial Ships

			3			Shaft	Inital
		Tonnes			Classification	Diameter	Install
Vessel Name	Vessel Type	(DWT)	Vessel Owner	Shipyard	Society	(mm)	Date
Kun Lun Shan	Bulker	32,000	cosco	Fujian Mawei Shipbuilding Ltd.	CCS (China Classification Society)	460	May -2010
			China	China			
Flintersky	Container/Dry Cargo	9,120	Flinter Groep	Kiran Shipyard	Bureau Veritas	458	Oct -2013
			Netherlands	Turkey			
Balder	Offshore	59,404	Heerema Engineering Service	Verolme Botlek Shipyard	LR (Lloyd's Register)	456	Apr -2001
			Netherlands	Netherlands			
Hermod	Offshore	59,344	Heerema Engineering Service	Drunen	LR (Lloyd's Register)	455	Jul -2004
			Netherlands	Netherlands			
Citadel	Container/Dry Cargo	6,000	Flinter Groningen BV	Ferus Smit Scheepswerf	Bureau Veritas	452	Oct -2008
			Netherlands	Germany			
Flinterstar	Container/Dry Cargo	9,000	Flinter Groningen BV	Ferus Smit, Leer	Bureau Veritas	452	Jan -2002
			Netherlands	Germany			
Flintersun	Container/Dry Cargo	9,000	Flinter Groningen BV	Ferus Smit, Leer	Bureau Veritas	452	Jul -2002
			Netherlands	Germany			
UAL Aberdeen	Container/Dry Cargo	9,200	Flinter Groningen BV	Ferus Smit, Leer	Bureau Veritas	452	Sep -2002
			Netherlands	Germany			
Newfoundland Pioneer	Fishing Vessel	1,241	Fame Fisheries	Slippurinn Akureyri ehf.	LR (Lloyd's Register)	445	Jun -2011
			Canada	Iceland			
C.E. Laborde Jr.	Anchor Handling Tug Supply (AHTS)	3,297	Tidewater Inc.	Singapore Technologies Marine Ltd.	ABS (American Bureau of Shipping)	441	Oct -2005
			U.S.A.	Singapore			
Seabourn Odyssey	Cruise Ship	3,000	Carnival Corp.	Mariotti SpA	RINA (Registro Italiano Navale)	440	Jun -2009
			U.S.A.	Italy			
Seabourn Sojourn	Cruise Ship	3,000	Carnival Corp.	Mariotti SpA	RINA (Registro Italiano Navale)	440	May -2010
			U.S.A.	Italy			

Page 9 of 31

# COMPAC Seawater Lubricated Propeller Shaft Bearing References

Commercial Ships

			00			Shaft	Inital
:	:	Tonnes			Classification	Diameter	Install
Vessel Name	Vessel Type	(DWT)	Vessel Owner	Shipyard	Society	(mm)	Date
Seabourn Quest	Cruise Ship	3,000	Carnival Corp.	Mariotti SpA	RINA (Registro Italiano Navale)	440	Aug -2011
			U.S.A.	Italy			
William C. O'Malley	Anchor Handling Tug Supply (AHTS)	3,343	Tidewater Inc.	ENAVI Shipyard Niteroi	ABS (American Bureau of Shipping)	437	Jun -2010
			U.S.A.	Brazil	) 		
Alden J Laborde	Anchor Handling Tug Supply (AHTS)	3,343	Tidewater Inc.	ENAVI Shipyard Niteroi	ABS (American Bureau of Shipping)	437	Sep -2010
			U.S.A.	Brazil			
John P. Laborde	Anchor Handling Tug Supply (AHTS)	4,500	Tidewater Inc.	Enavi Shipyard - Niteroi	ABS (American Bureau of Shipping)	437	Aug -2009
			U.S.A.	Brazil			
Richard M. Currence	Anchor Handling Tug Supply (AHTS)	4,500	Tidewater Inc.	ENAVI Shipyard - Niteroi	ABS (American Bureau of Shipping)	437	Sep -2010
			U.S.A.	Brazil			
Dependent	Container/Dry Cargo	4,536	Flinter Groningen BV	Leer	Bureau Veritas	435	Nov -2006
			Netherlands	Germany			
Wave	Container/Dry Cargo	4,500	Flinter Groningen BV	Ferus Smit, Groningen Shipyard	Bureau Veritas	435	Nov -2004
			Netherlands	Netherlands			
Forest	Container/Dry Cargo	4,500	Flinter Groningen BV	Ferus-Smit, Groningen Shipyard	Bureau Veritas	435	Jan -2004
			Netherlands	Netherlands			
Flinterfirst	Container/Dry Cargo	4,500	Flinter Groningen BV	Westerbroek	Bureau Veritas	435	Feb -2008
			Netherlands	Netherlands			
Fortune	Container/Dry Cargo	4,500	Flinter Groningen BV	Westerbroek	Bureau Veritas	435	Jun -2008
			Netherlands	Netherlands			
Sylvia	Container/Dry Cargo	4,500	Flinter Groningen BV	Westerbroek	Bureau Veritas	435	Jun -2008
			Netherlands	Netherlands			
Tasman	Container/Dry Cargo	4,537	Broersma/Brouwer/Pitrans BV	Westerbroek	Bureau Veritas	435	Nov -2007
			Netherlands	Netherlands			

October 15, 2014

Page 10 of 31







ZERO POLLUTION | HIGH PERFORMANCE | BEARING SYSTEMS

3225 Mainway Drive, Burlington, Ontario L7M 1A6 Canada Tel: +1.905.335.1440 Fax: +1.905.335.4033 www.ThordonBearings.com