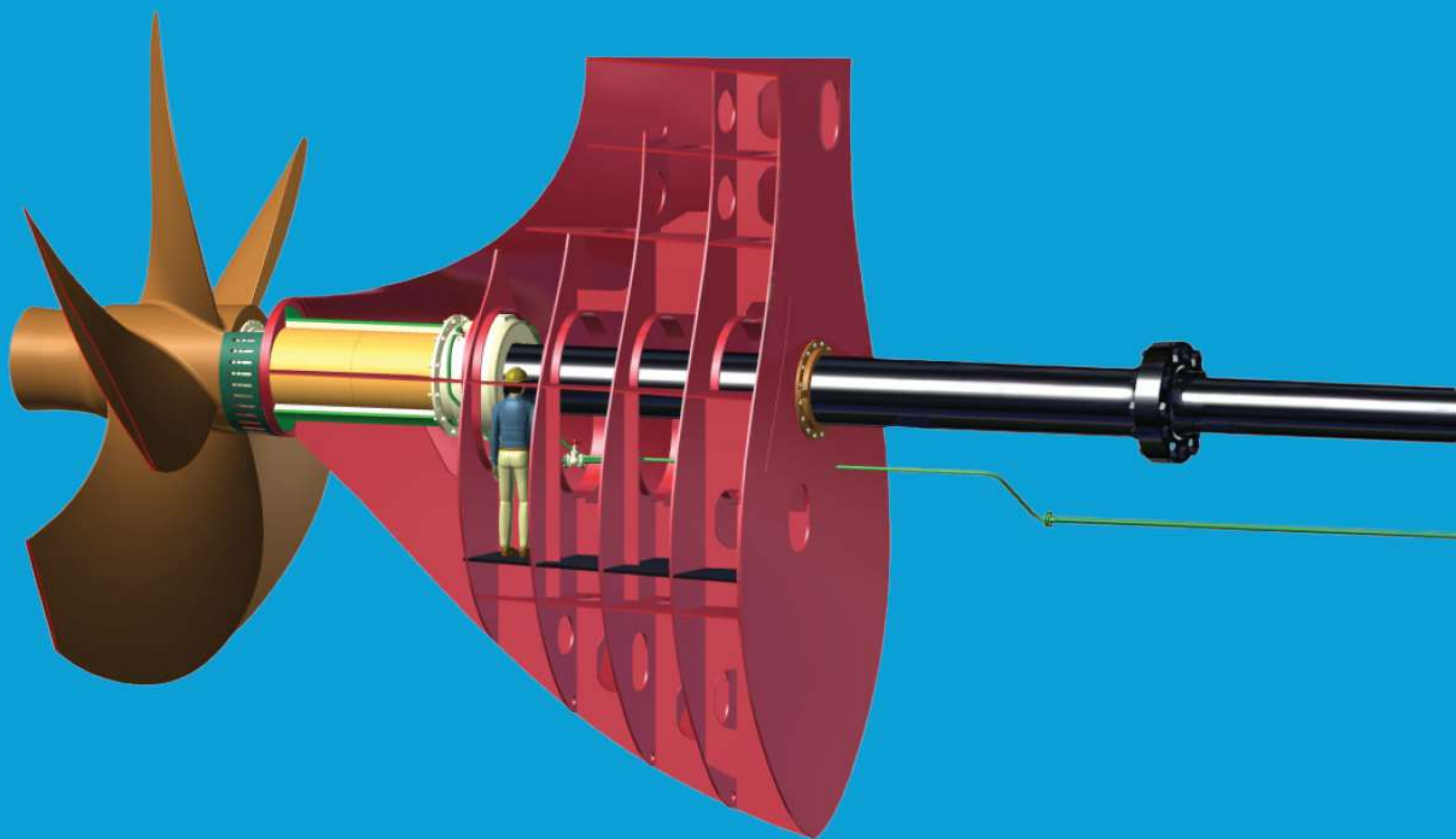


Arrangement for supporting propeller shaft and method of servicing per patents CN109641644(B), EP3475165(B1), KR101979186(B1), under licence from Wärtsilä

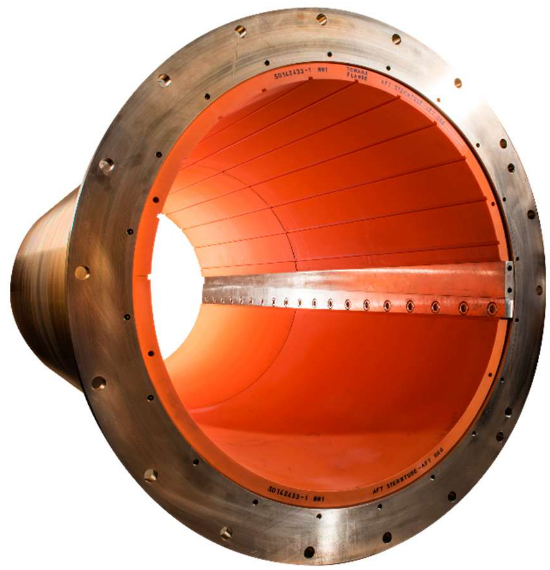
Case Study of a Conventional Sealed Oil-Lubricated Sterntube System *vs.* a T-BOSS® Sterntubeless Seawater-Lubricated Shaftline for a 157,000 DWT Suezmax Crude Oil Tanker Newbuilding - CAPEX Implications

A White Paper Published by Thordon Bearings Inc., January 20, 2026©

Contents

1. Executive Summary

This study evaluates the T-BOSS® sterntubeless shaftline solution compared to the conventional air-sealed, oil-lubricated sterntube system for a newbuilding vessel, using a Suezmax prototype vessel as the case study. The comparison covers all shipbuilding disciplines—seal systems, piping, structural works, shafting, outfitting, painting, electrical systems, testing, and regulatory aspects.



COMPAC Elastomeric Polymer Bearing in Bronze Carrier

Based on current analysis, the two solutions show:

- **the shipbuilding labour and installation costs are lower with a T-BOSS® design**
- **the propeller shaft length is reduced with a T-BOSS® design by 1.7m in this case study.**

Beyond these discipline-level comparisons, T-BOSS® offers distinct design wise, operational and lifetime economic benefits:

Eliminate the Sterntube Forward Bearing:

The designer/builder gains greater flexibility to shorten the shaftline, removing one of the existing constraints and enabling the main engine to be shifted further aft. This can allow for improved cargo space utilization, with a preliminary gain of ~660 m³ estimated for the subject vessel.

Alternatively, the freed space aft of the main engine can be utilized for the installation of a shaft generator, supported by the increased flexibility in arranging the intermediate shaft bearing. This option is particularly valuable given the tighter space constraints of modern, slender hull forms. Shaft generator installations are increasingly adopted in newbuildings, both dual-fuel and conventional, as they eliminate the need to install or retrofit dual-fuel auxiliary generators, thereby reducing costs. Moreover, upcoming Carbon Capture System (CCS) applications will require considerable additional electrical power, further reinforcing the benefits of this arrangement.

Avoid Shaftline Lubricant Costs

The owner can reduce operating costs by approximately US$33,000 in initial CAPEX savings and US$11,500 per year in OPEX savings by eliminating the need of lubricating oil. If the ship owner is using an EAL (Environmentally Acceptable Lubricant), the lubricant costs could be 8-10 times higher than oil.

Simplify Inspection and Replacement:

If necessary, a sterntube bearing replacement can be performed afloat, without shaftline or propeller removal, avoiding drydocking. A typical US$500,000 repair becomes a one-day afloat operation. Under a Shipyard Guarantee, the benefit is also substantial for the builder.

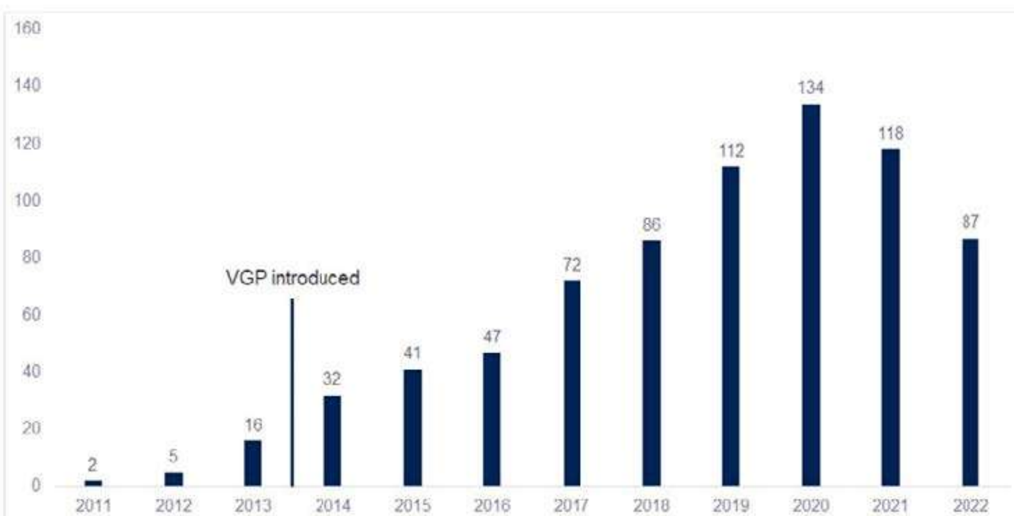
Prevent Environmental Pollution and Seal Damage Risk:

By eliminating the use of lubricating oil in the sterntube, the T-BOSS® design eliminates the risk of oil leakage into the marine environment, ensuring de-risked full compliance with environmental regulations (e.g., MARPOL, U.S. VGP).

Insurer data (e.g., Gard) also confirm a rising trend of sterntube related damages (2023 analysis), highlighting the environmental and operational risks of oil-lubricated systems—risks inherently avoided with T-BOSS®.

A Lloyd's Register Classification Society report noted: "Defect statistics over the last 20 years indicate that the aft stern bush represents 10% of all 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.

In summary, although direct construction cost differences are expected to be marginal, the T-BOSS® sterntubeless solution provides improved design flexibility, increased engine room space, long-term savings, notable repair and maintenance benefits, and reduced environmental pollution risk, making it a valuable contributor to the transition toward greener and safer ship designs.



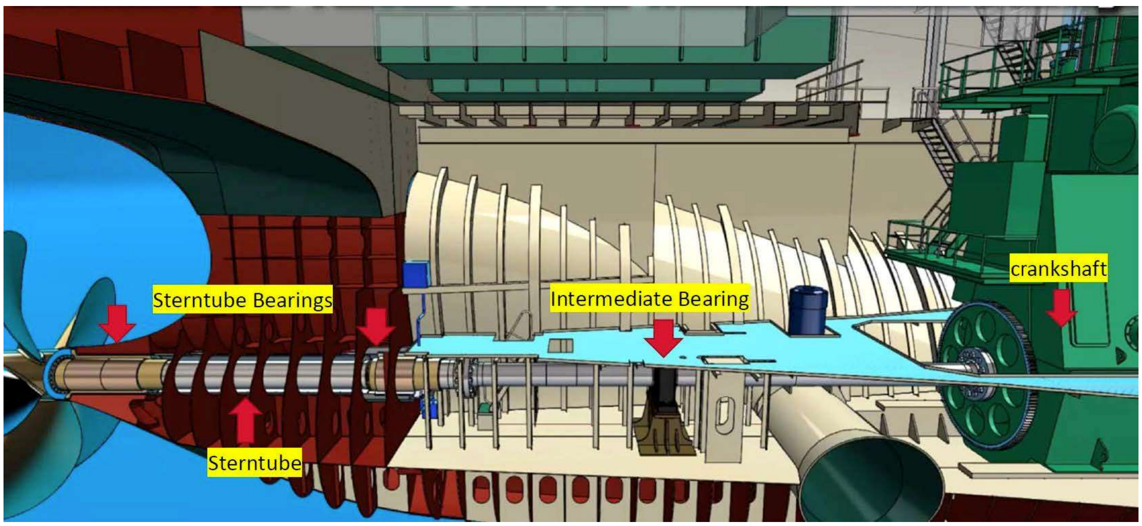
Total Sterntube-related claims in Gard in excess of US$5,000 are reflected

2. T-BOSS® Design

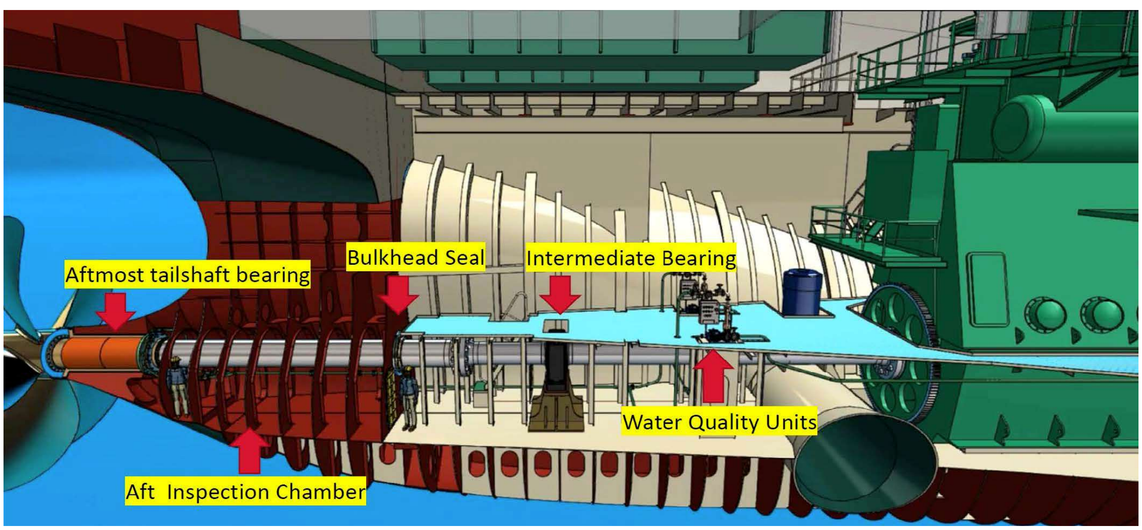
The T-BOSS® (Thordon - Blue Ocean Stern Space) is an innovative sterntubeless shaftline arrangement developed jointly by:

- Thordon Bearings Inc.
- CSSC-Shanghai Merchant Ship Design and Research Institute (SDARI)
- American Bureau of Shipping (ABS)
- Wärtsilä Shaft Line Solutions
- National Technical University of Athens (NTUA)

Unlike conventional oil-lubricated sterntube systems, which require a sterntube, multiple bearings, and a dedicated cooling tank, the T-BOSS design integrates a seawater-lubricated single aft bearing and seal within a dry stern inspection chamber.



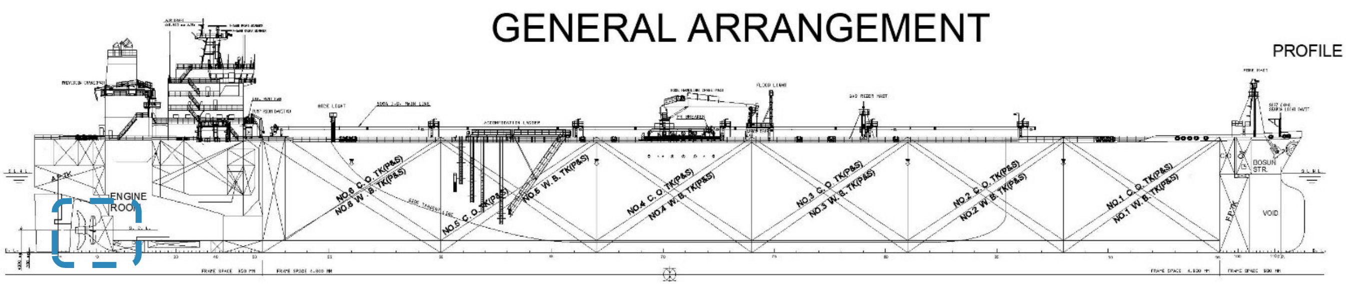
Conventional Shaftline with Sterntube

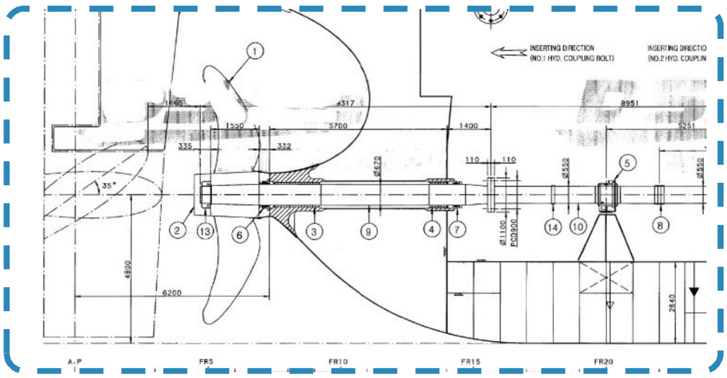


T-BOSS® Solution

Arrangement for supporting propeller shaft and method of servicing per patents CN109641644(B), EP3475165(B1), KR101979186(B1), under licence from Wärtsilä.

3. Prototype Vessel





BILL OF MATERIAL

-Q'TY IS PER SHIP
-WEIGHT IS PER UNIT

DWG NO | SHEET 4 / 12

NO.	DESCRIPTION	MATERIAL	Q'TY W	Q'TY S	WEIGHT (kg)	SUPPLIER
1	F.P. PROPELLER (4 BLADES, DIA 8.35 M)	G-CuAl10Ni F650	1	2/10	42,760	M.M.G
2	PROPELLER CAP	G-CuAl10Ni F650	1	–	860	↓
3	AFT S/T BEARING	CAST IRON WITH WHITE METAL	1	–	1,596	KEMEL
4	FWD S/T BEARING		1	–	588	
5	INTERMEDIATE SHAFT BEARING		1	–	890	
6	AFT S/T SEAL & LINER (AX-710)	VITON CHROME STEEL	1	–	668	
7	FWD S/T SEAL & LINER (AX-710)		1	–	490	↓
8	SHAFT EARTHING DEVICE	SILVER ALLOY	1	–	11	K. C. LTD
9	PROPELLER SHAFT	SILVER ALLOY FORGED STEEL	1	2/10	25,166	DSME
10	INTERMEDIATE SHAFT		1	–	18,237	↓
11	NO.1 HYD. COUPLING BOLT & NUT	ALLOY STEEL	8	1	–	SAMBOO
12	NO.2 HYD. COUPLING BOLT & NUT		10	1	–	↓
13	PROPELLER NUT	SF590	1	–	779	DSME
14	SHAFT HORSE POWER METER	–	1	–	–	KYMA

Shafting Arrangement

Prototype Vessel	
Vessel's type	Crude Oil Tanker
Vessel's size category	Suezmax
Principal Dimensions	
Length overall	274.0 m
Length between perpendiculars	264.0 m
Breadth, moulded	48.0 m
Depth to upper deck, moulded	23.7 m
Scantling draft, moulded	17.0 m
Deadweight	157,430 t
Shafting information	
Propeller Shaft Diameter	⌀ 670 mm

4. Technology Comparison

The purpose of this section is to identify and document the equipment requirements and design modifications that a newbuilding shipyard must consider to incorporate the T-BOSS® sterntubeless solution into an existing vessel design and also provide an assessment of the cost differences that may be involved.

The above assessment is carried out for the prototype vessel.

The shipbuilding disciplines that have been assessed are the following:

1. Sterntube Seal and Bearing System
2. Piping Systems
3. Structural
4. Shafting
5. Outfitting
6. Surface Treatment & Painting
7. Electrical
8. Testing
9. Regulatory aspects

The cost differences (covering material, labor, and installation) have been primarily estimated using information from an established Chinese newbuilding shipyard, supplemented by data from Hydrus Engineering (Greece), JBL Tech Service PTE. Ltd. (Singapore), and Thordon Bearings (Canada).

4.1 Sterntube Seal and Bearing System

The components required for each sterntube seal system are reflected in the herewith table:

	Sealed Oil System with Sterntube and Air Seals		Open Sterntubeless Design with Seawater-Lubricated COMPAC Bearing	
Components Needed	**Required**	**Supplier**	**Required**	**Supplier**
Sealing System				
Sterntube Aft Seal Assembly	✓	Seal Maker	✗	-
Sterntube Aft Bearing Assembly	✓	Seal Maker	✓	Thordon
FWD Seal	✓	Seal Maker	✓	Thordon
FWD Sterntube Bearing	✓	Seal Maker	✗	-
Oil Circulation Unit (Pumps and Small Tanks)	✓	Seal Maker	✗	-
Air Control Unit	✓	Seal Maker	✗	-
Lubricating Oil Drain Configuration (Including Tank)	✓	Seal Maker	✗	-
Sterntube Lubricating Oil Cooler	✓	Shipyard	✗	-
Sterntube Lubricating Oil Pumps (x2) – 2 m^3/h @ 2.5 bar	✓	Shipyard	✗	-
Sterntube Lubricating Oil	✓	Shipyard	✗	-
Bronze Shaft Liner	✗	-	✓	Thordon
Thordon Water Quality Package (x2)	✗	-	✓	Thordon
Bearing Weardown Monitoring	✓ Simple Manual Reading	-	✓ (Remote)	Thordon

4.2 Piping System

The piping categories required for each Sterntube seal system are reflected in the herewith table:

	Sealed Oil System with Sterntube and Air Seals		Open Sterntubeless Design with Seawater-Lubricated COMPAC Bearing	
Components Needed	**Required**	**Supplier**	**Required**	**Supplier**
Piping System				
Sterntube Lubricating Oil Pipes (Sealing System)	✓	Shipyard	✗	-
Control Air Pipes	✓	Shipyard	✗	-
Fresh Water Pipes (CWT) Filling/Discharging)	✓	Shipyard	✗	-
Cooling Fresh Water Pipes (Sterntube Lubricating Oil Cooler)	✓	Shipyard	✗	-
Sterntube System Lubricating Oil Vent Pipes	✓	Shipyard	✗	-
Seawater Supply for the Water-Lubricated Bearing	✗	-	✓	Shipyard

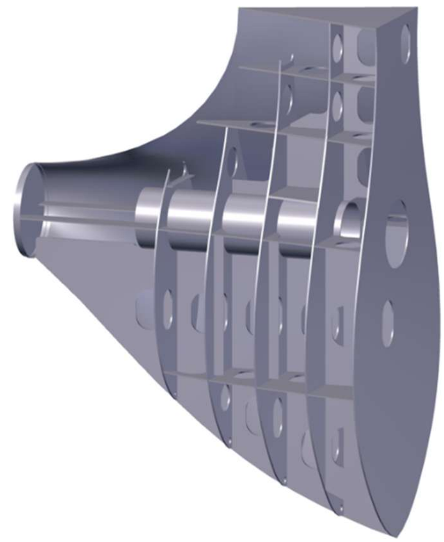
4.3 Structural modifications

Both the existing sterntube cooling tank and the redesignated stern inspection chamber were developed in 3D models to enable a detailed assessment of the resulting structural weight variation.

The outcomes of this analysis are presented below.

Material List & Weight Estimation

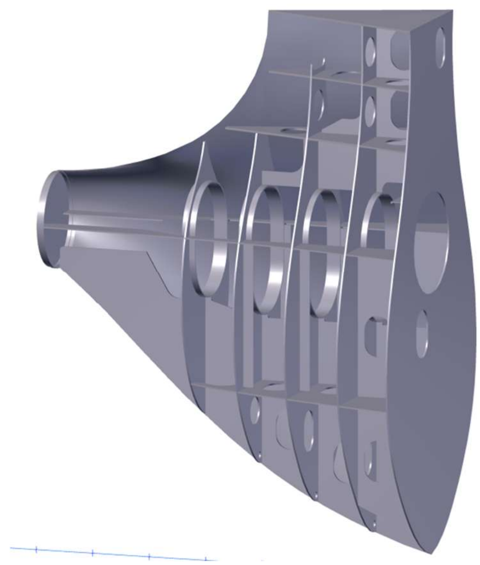
#	Item	Volume (m^3)	Weight (t)
1	FB100 x10	0.0028	0.02
2	FB100 x15	0.0015	0.01
3	FB150 x15	0.0217	0.17
4	FB200 x15	0.0112	0.09
5	Plate 15t	0.0806	0.63
6	Plate 20t	0.3922	1.68
7	Plate 25t B	1.7253	13.54
8	Plate 30t D	0.1994	1.57
	Total	**2.4347 m^3**	**17.71 t**



Existing Sterntube CSW Tank

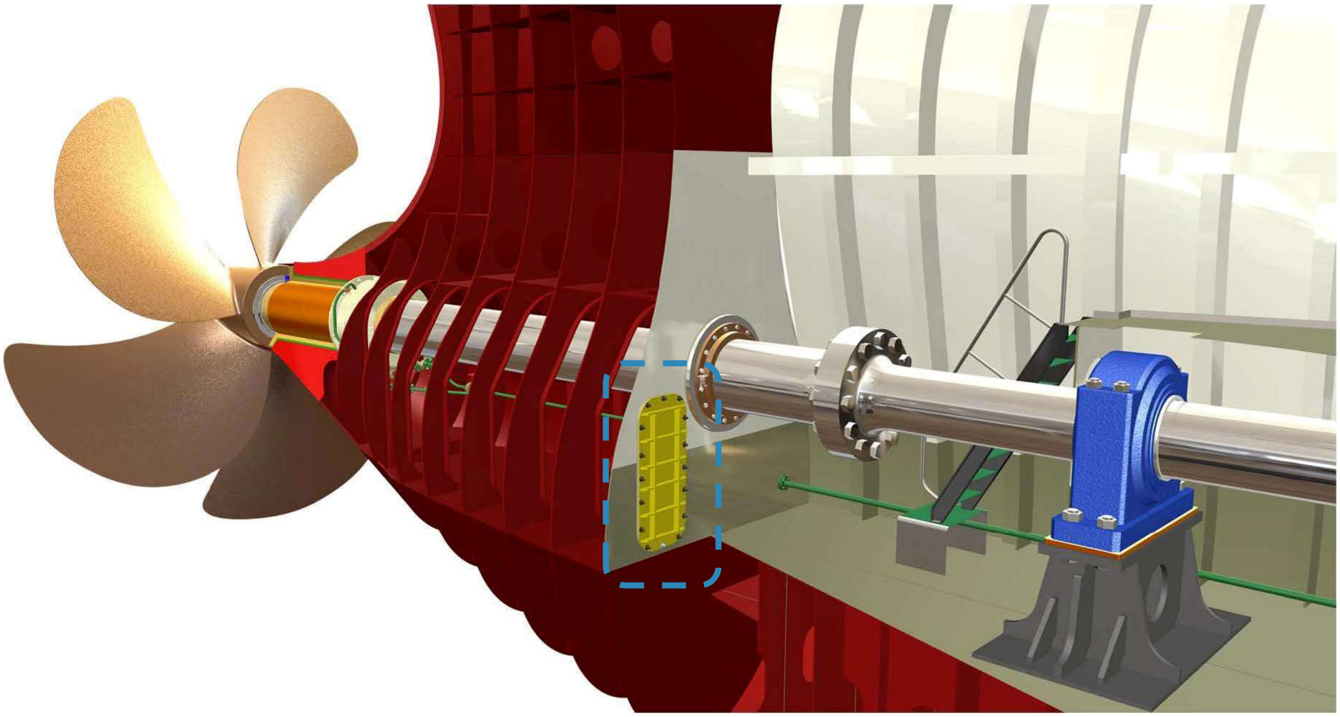
Material List & Weight Estimation

#	Item	Volume (m^3)	Weight (t)
1	HP200 x12	0.0060	0.05
2	FB150 x15	0.0217	0.17
3	FB200 x15	0.0067	0.05
4	Plate 15t	0.0806	0.63
5	Plate 20t	0.2229	1.75
6	Plate 25t B	1.7054	13.35
7	Plate 30t D	0.1227	0.96
	Total	**2.166 m^3**	**16.96 t**



New Stern Inspection Chamber

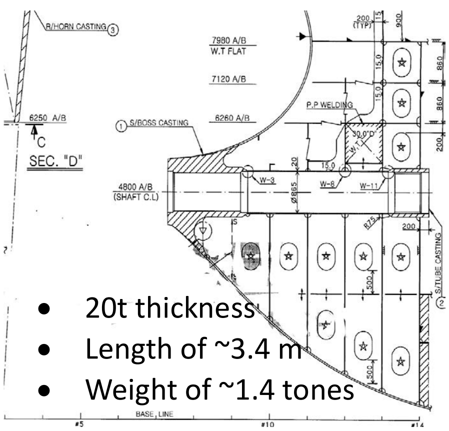
Another structural modification for the T-BOSS® solution is the addition of a new access hatch for the sterntube inspection chamber. This cost has also been considered in the cost comparison.



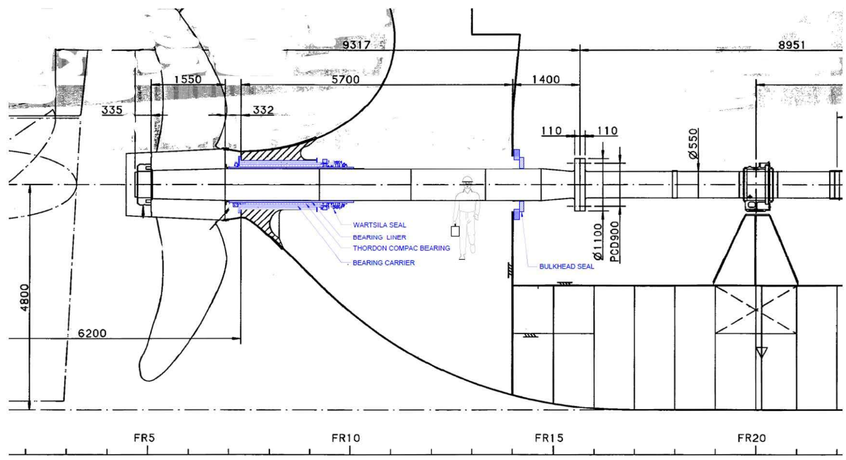
New Access Hatch

4.4 Shafting Modifications

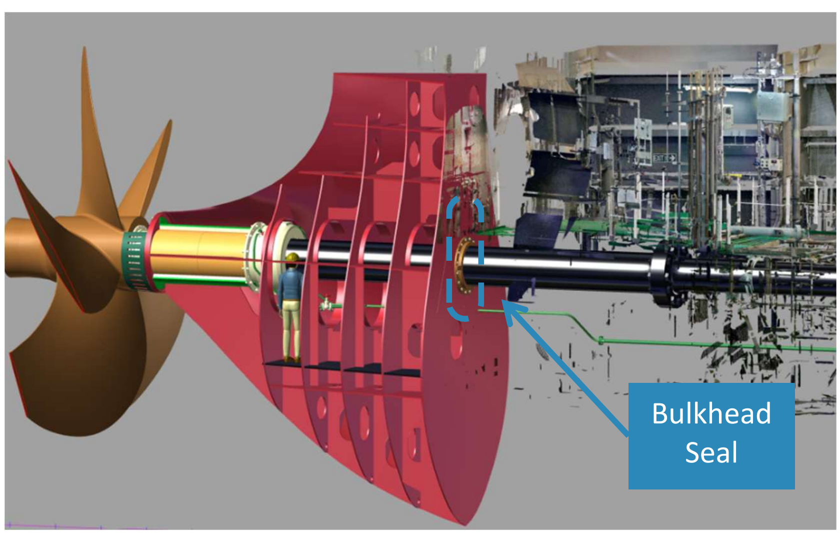
	Sealed Oil System with Sterntube and Air Seals		Open Sterntubeless Design with Seawater-Lubricated COMPAC Bearing	
Components Needed	**Required**	**Supplier**	**Required**	**Supplier**
Piping System				
Sterntube Pipe	✓	Shipyard	✗	
Bulkhead Seal	✗		✓	Shipyard



Sterntube Characteristics



T-BOSS® Shafting Arrangement (Updated)



Bulkhead Seal

4.5 Outfitting Modifications

Based on ABS requirements for sterntubeless vessels with water-lubricated bearings (notation "Sterntubeless-W"), sterntube inspection chamber should be fitted with the following:

- A dedicated bilge well
- Two independent bilge level alarms
- A drip tray for collecting sea water below the inboard bearing seal
- A portable vent duct to supply temporary ventilation while people are inside the stern inspection chamber carrying out maintenance tasks

A typical portable ventilator is reflected below for assisting the cost estimation.

4.6 Surface Treatment & Painting

The cost difference from the surface preparation and painting has been calculated for the purpose of this assessment. The results are included in the herewith figures:

Painting Area	Shop Primer	S/P	Brand Name & Colour Shade of Paint			D.F.T. (μ)	Total D.F.T. (μ)	Remark	Ser. No.
			Coat	Brand Name	Colour				
S.T.C.W. Tank	S	B1	1st	Jotacote Universal 80	Bronze	150	300	(16)	190
			2nd	Jotacote Universal 80	Aluminum	150			

Existing Sterntube CSW Tank Internal Area: ~260 m^2

Painting Area	Shop Primer	S/P	Brand Name & Colour Shade of Paint			D.F.T. (μ)	Total D.F.T. (μ)	Remark	Ser. No.
			Coat	Brand Name	Colour				
S.T.C.W. Tank	S	P3	1st	Jotacote Universal 80	Aluminum	150	150		191

New Stern Inspection Chamber (Dry Space) Internal Area: ~238 m^2

Symbol	**At Block Stage** (Welded, burnt and damaged parts of shopprimed surfaces)	**At P.E. & Hull Stage** (Block joint line and burnt part)
P2	St 2 (QISSP DPt-2)	St 2 (QISSP DPt-2)
P3	St 3 (QISSP DPt-3)	St 3 (QISSP DPt-3)
B1	Sa 2½ (QISSP DGB-2½)	St 3 (QISSP DPt-3)
B4	Sa 2½ (QISSP DGB-2½)	Sa 2½ (QISSP DGB-2½) St 3 (QISSP DPt-3)

Surface Preparation Table from Prototype Vessel

4.7 Electrical modifications

For the electrical modifications, the following categories were assessed:

a) Alarms & Control for the T-BOSS® solution compared to the conventional air seal system
b) Cabling for the Thordon Water Quality Packages (x2) for the T-BOSS® solution (equivalent with the eliminated existing sterntube lubricating oil pumps power cabling)
c) Cabling for the additional Bilge Level Alarms
d) Cabling for the lights in the sterntube inspection chamber
e) Additional lights for the sterntube inspection chamber

For each of the above categories, detailed alarm list and cable list was submitted to the shipyard to facilitate the cost comparison. The results are described below:

Alarms & Control

#	Conventional System Alarms & Control	T-BOSS® System Alarms & Control
1	Sterntube Lubricating Oil Tank High Level	Flow
2	Sterntube Lubricating Oil Tank Low Level	Pressure
3	Sterntube Lubricating Oil Drain Tank High Level	Diff. Pressure (Filter)
4	Sterntube Drain Collection Unit High Level	Bearing Temperature
5	Sterntube FWD Seal Tank Low Level	Wear Down
6	FWD Sterntube Bearing Temp. High	Water Filtration System
7	Aft Sterntube Bearing Temp. High	Pump
8	Air Control Unit Low Pressure	Power Circuit

Cables

#	Description	Length (m)	Type (Indicative)
1	WQP No.1	55	3 × 2.5 mm^2 (TPYCY-2.5)
2	WQP No.2	55	3 × 2.5 mm^2 (TPYCY-2.5)
3	Bilge Level Alarm No.1	10	Shipyard's standard for alarm signals
4	Bilge Level Alarm No.2	10	Shipyard's standard for alarm signals
5	Sterntube Insp. Chamber Light No.1	10	2 × 2.5 mm^2 (DPYCE-2.5)
6	Sterntube Insp. Chamber Light No.2	10	2 × 2.5 mm^2 (DPYCE-2.5)
7	Sterntube Insp. Chamber Light No.3	10	2 × 2.5 mm^2 (DPYCE-2.5)
8	Sterntube Insp. Chamber Light No.4	10	2 × 2.5 mm^2 (DPYCE-2.5)

4.8 Testing/Inspection procedures

With reference to the typical newbuilding Inspection Test Plan, a few tests are required for a conventional sterntube seal system which are not applicable to the T-BOSS® solution:

a) Installation inspection of lubrication oil pipe of sterntube
b) Completeness of installation and tightness test for the sterntube lubricating oil piping system (final test)
c) Hydraulic test of sterntube lubricating oil Pipes
d) Wear-down gauge measurement
e) Fore bearing sterntube press fitting
f) Inspection of sterntube installation and NDT welding
g) Painting inspection of the 2nd coating layer of the cooling water tank (CWT)

According to ABS requirements for the relevant Sterntubeless-W notation, the following tests are only applicable to the T-BOSS® solution:

1. Pressure test of the bulkhead seal to verify its tightness
2. The bearing replacement procedure through the stern inspection chamber while the vessel is afloat is a requirement that is to be demonstrated to the satisfaction of the attending surveyor before sea trials.

Note
Based on the vessel's Inspection Test Plan, several other tests apply to both conventional and T-BOSS® systems. Since these are common to both arrangements, no cost difference is foreseen.

4.9. Regulatory Aspects

For estimating the cost comparison from regulatory point of view, ABS has been officially contacted to advise on any cost difference derived from the following review assessments:

Item 1 – Indicative Review Cost between Conventional Sealed Oil Lubricated System and T-BOSS® Solution

Shaft alignment and sterntube bearing design review cost may differ between a conventional sealed oil system and the T-BOSS® solution considering the different requirements applicable to each case (multi-sloping assessment, ESA notation, etc.).

ABS advised that, "There is no cost difference between the two designs."

Item 2 – Localized Hull Strength Calculations

In line with ABS *Sterntubeless-W* notation Sec.2, par. 2.2, localized hull strength calculations are to be carried out, as applicable, to verify that the new sterntube design (including material selection and structural component sizing) has equivalent strength as the vessel with a conventional cast sterntube arrangement.

ABS advised that "If the design is conventional then there is no cost difference between the two designs. If the design of that part of the hull is irregular, then, as per the notation requirements, FEA modeling should be submitted, and the verification cost could be up to US$1,600."

Item 3 – ABS Surveyors' Cost

Additional or reduced manhours may be required for the T-BOSS® seal system solution compared to the conventional one. ABS advised that, "There is no cost difference between the two designs, from ABS's side."

Cost (USD) Differential Table with a 670mm Shaft Diameter	Sealed Oil Lubricated System with Sterntube and Air Seals		Open Sterntubeless Design with Seawater-Lubricated COMPAC Bearing	
Components Needed	**Labour/ Installation Cost**	**Purchase/ Material Cost**	**Labour/ Installation Cost**	**Purchase/ Material Cost**
1. Sealing & Bearing System	$4,500	$183,000 [1]	$3,400	$449,285
2. Piping System	$1,430	$1,430	$500	$500
3. Structural Modifications			- $600 [2]	- $600 [2]
4. Shafting Modifications			$300	$11,000 (bulkhead seal)
5. Outfitting Modifications			$450	
6. Surface Treatment & Painting			- $300 [2]	- $900 [2]
7. Electrical Modifications			$30	$30
8. Testing / Inspection			$200	
9. Regulatory Aspects			$800	
Total	**$5,930**	**$184,430**	**$4,780**	**$459,315**

[1] *Including cost of sterntube and the initial cost of lubricating oil*

[2] *Compared to the conventional sealed oil system with sterntube, metallic bearings and air seals*

Conclusion

- The implementation of the T-BOSS® design results in an overall reduction in shipbuilding labour and installation costs of ~$1,150.
- From a purchase/material cost standpoint, the main cost differential of $274,885 is attributed to the CAPEX of the T-BOSS system (bronze materials). However, when viewed from a shipbuilding cost perspective, the T-BOSS configuration yields an estimated cost reduction of ~$3,830, reflecting its **simplified arrangement and reduced construction complexity**.
- The T-BOSS design offers a reduction in the propeller shaft length by 1.7m in this case study. The potential cost reduction associated with the shortened shaftline has been intentionally excluded from the cost comparison table. The potential aftward relocation of the main engine, together with the associated opportunity for increased cargo tank capacity—represent a design change and a conceptual design option, intended primarily for application by newbuilding designers. This option serves as a tool to enhance layout flexibility at the early newbuild design stage.

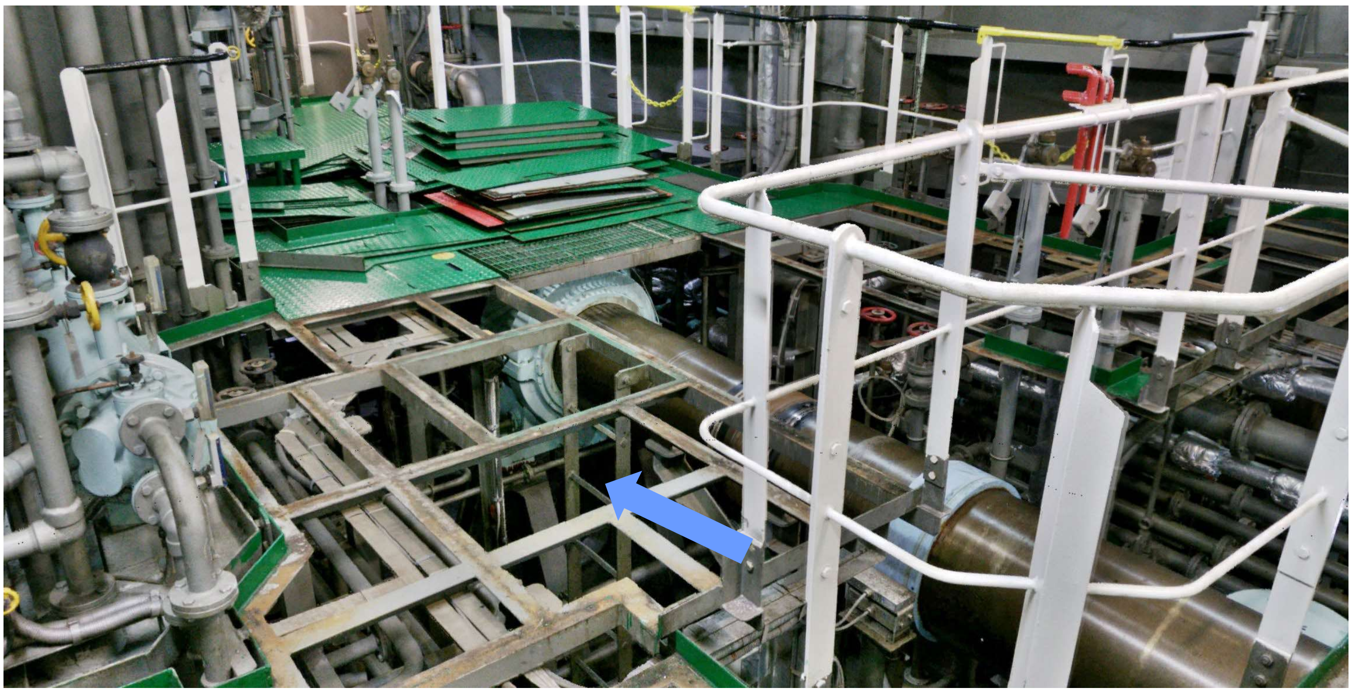
5. Additional Benefits

5.1 Avoided Sterntube Lubricating Oil Cost

A notable cost element is the expense of the sterntube lubricating oil purchase, which is eliminated with the adoption of the T-BOSS® seawater-lubricated solution.

For the prototype vessel, and according to an established sterntube seal OEM, the daily oil consumption is estimated at ~4 L/day for the aft seal and 1 L/day for the forward seal, resulting in a total consumption of 5 L/day or 1.8 m^3/year.

Moreover, the sterntube lubricating oil drain tank of the prototype vessel is 5.2 m^3.



Prototype vessel's sterntube lubricating oil drain tank (5.2m^3)

Assuming a lubricating oil density of 900 kg/m^3 and a market price of $7 USD/kg (eni INTERNATIONAL PRICE LIST n° 43) the avoided cost is estimated as follows:

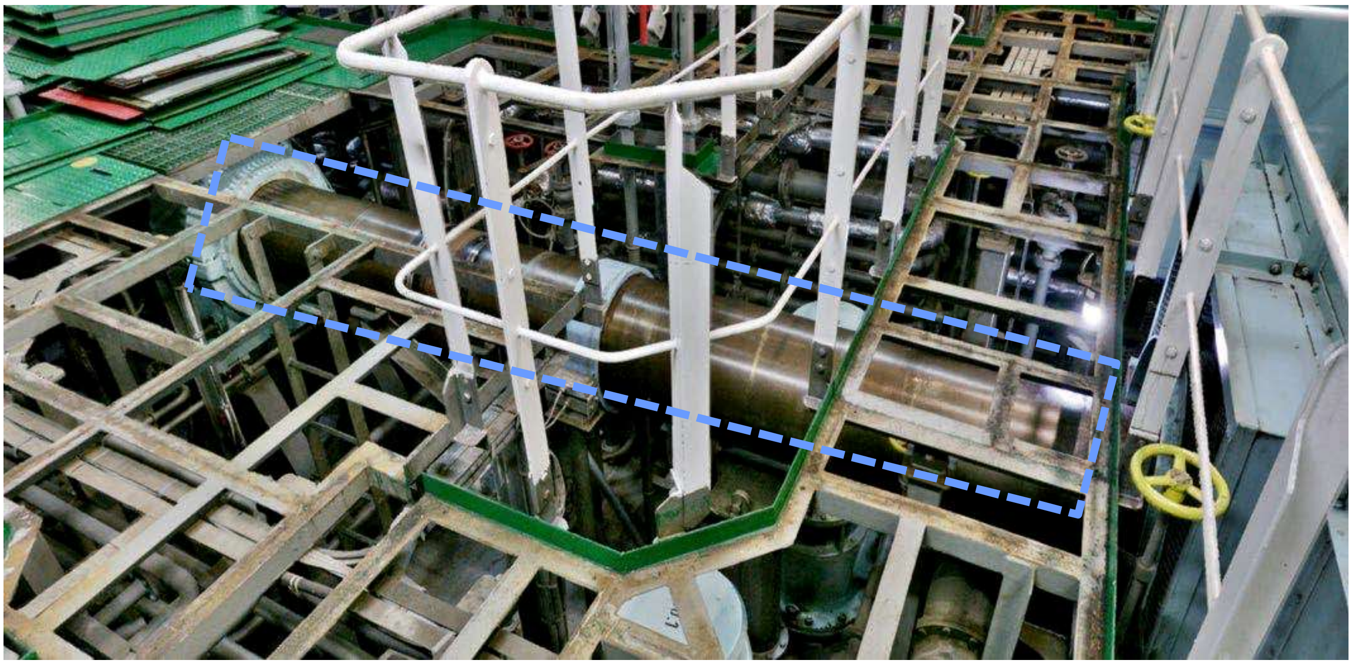
1. Oil initial purchase avoided cost of ~US$33,000
2. Operational avoided cost of ~US$11,500 per year

5.2 Reduced Shaftline Length

The implementation of the T-BOSS® solution eliminates the need for a forward sterntube bearing, thereby allowing the intermediate shaft bearing to be relocated closer to the aft engine room bulkhead.

As a result, the intermediate shaft itself can be designed with a shorter length, creating additional potentially usable space between the main engine and the intermediate shaft. The cost reduction due to the shorter shaft was intentionally excluded in the cost comparison, as the main engine would need to be re-positioned and was outside the scope of the present study.

Moreover, in new designs the T-BOSS® solution provides the capability to shift the aft engine room boundary aftwards, for gaining more flexibility on the arrangements aftwards of the main engine.



Prototype vessel's intermediate shaft and bearing

This newly available space offers two potential design opportunities:

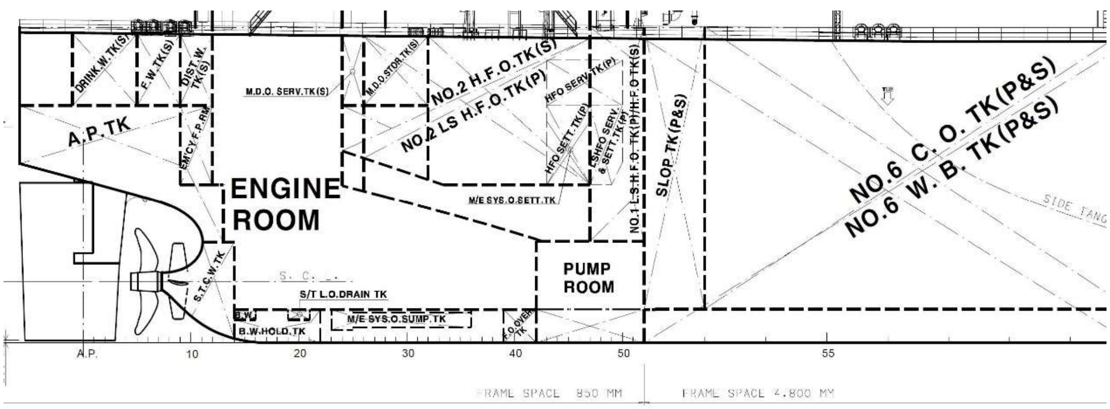
1. Repositioning of the main engine closer to the stern, which could lead to a more compact engine room and free volume that may be reassigned to cargo capacity.
2. Maintaining the main engine in its original position while utilizing the new space for the installation of a shaft generator, which is a justified trend in the modern designs.

5.2.1 Main Engine Repositioning

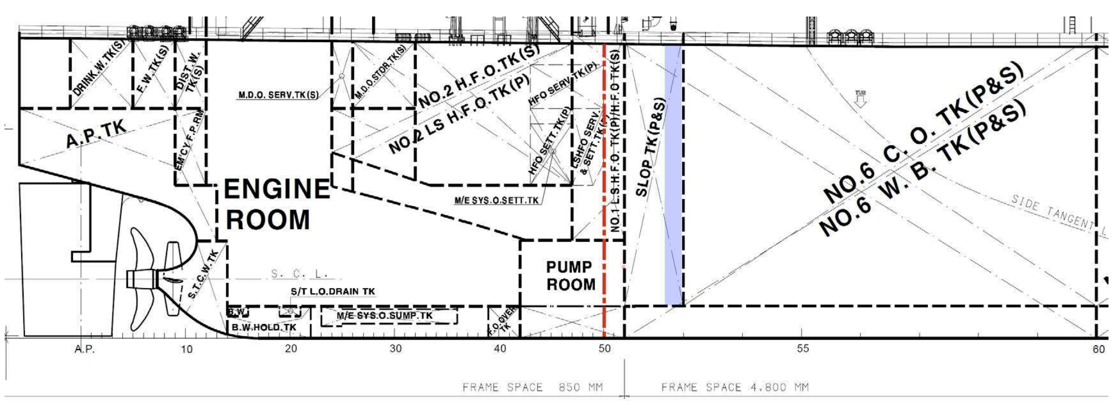
In this option, the possibility of shifting the main engine towards the stern is considered on a conceptual basis. The scope of this assessment is not to depict a firm proposal but to reflect visually the potential that is created via the induced flexibility for adjusting the main engine position. The arrangement of the engine room and adjacent compartments on the prototype vessel has been reviewed, with the following assumptions applied for this assessment:

Assumptions

a) The reduced intermediate shaft length is ~1,700 mm (~2 frames shorter).
b) The main engine can be repositioned aft, subject to the hull line constraints in the relevant area.
c) Remaining equipment and tanks within the engine room decks is practicable to be rearranged and fit within a more compact footprint.
d) The pump room is practicable to be rearranged and fit in the smaller available space.
e) Slop tanks aft and fore boundaries to be shifted aftwards. The resulted capacity decrease (due to the slender hull lines) to be considered being within acceptable level.



Prototype vessel's original boundaries



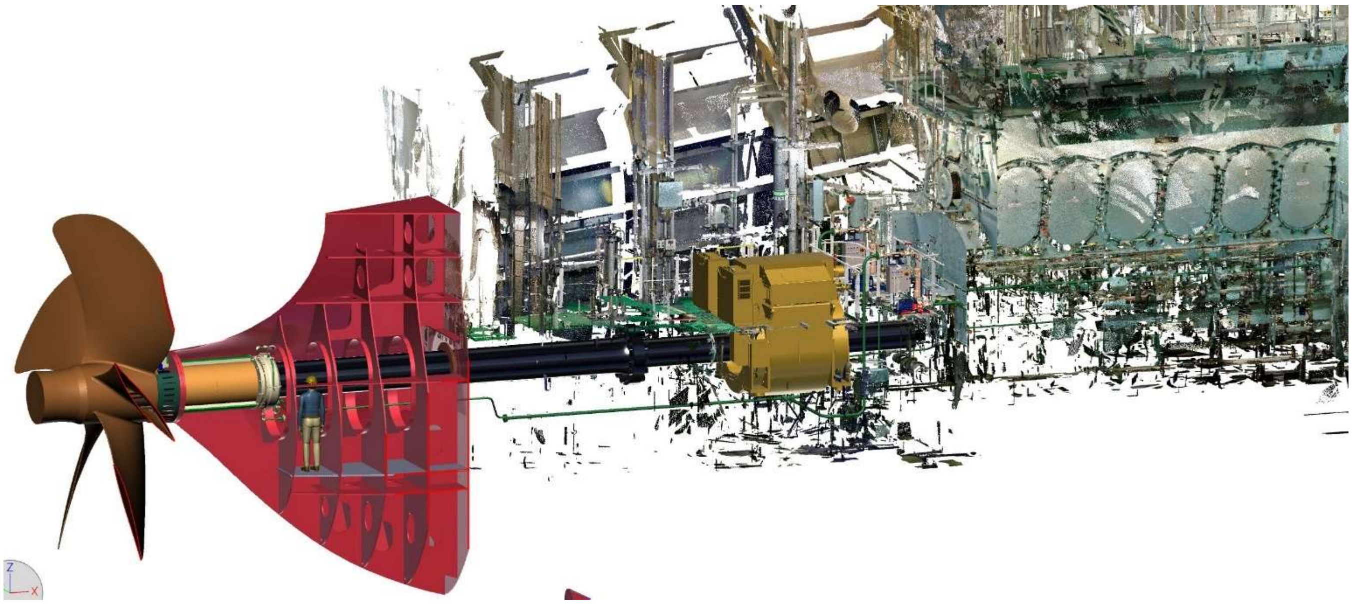
Updated engine room and slop tank boundaries

The outcome of this assessment indicates a **potential cargo volume increase of ~660 m³**.

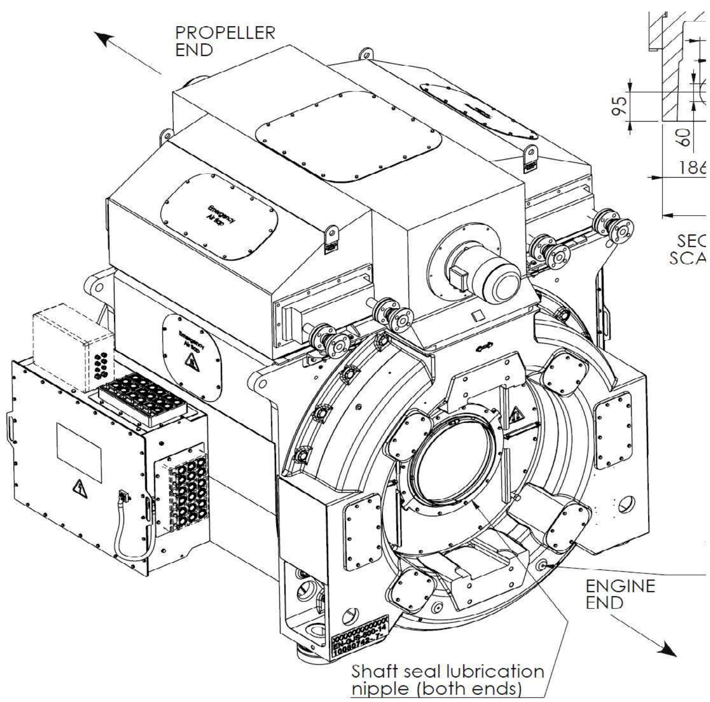
T-BOSS® is an additional "tool" for the newbuild designers for developing designs of higher cargo capacity and improve vessels' carbon footprint per transferred cargo tonne.

5.2.2 Shaft Generator Installation

The increased flexibility in the intermediate shaft bearing arrangement, combined with the potential aftward shift of the engine room aft bulkhead, provides additional design "tools" to facilitate the integration of a shaft generator and optimize the shafting system. This is particularly valuable in modern vessel designs, where sharper aft hull lines make the installation of bulky shaft generators more challenging.



Prototype vessel shaft generator indicative location



Shaft Generator sized for 1,000kWe PTO

The integration of a shaft generator provides substantial advantages for both shipowners and shipyards:

a) **Enhanced Efficiency:**
Improves the efficiency of electric power generation, leading to lower fuel consumption and a reduction in associated regulatory compliance costs (EU ETS, FuelEU Maritime, IMO GHG Framework).

b) **Cost and Emissions Savings in Dual-Fuel Applications:**
Avoids the additional CAPEX and the potential emission slip linked to dual-fuel 4-stroke generators, for dual-fuel newbuildings.

c) **Improved Redundancy:**
Increases power production redundancy, enhancing operational reliability.

d) **Expanded Power Capacity:**
Provides additional electric power capacity to accommodate new loads required by GHG-reduction technologies (e.g., CCS, WAPS, air lubrication), both at the newbuilding stage and during retrofits.

e) **Regulatory Performance:**
Contributes to improved vessel IMO EEDI ratings and contribute to IMO CII compliance.

f) **Safety:**
Enables the optional Power Take-In (PTI) function.

5.3 Fuel Savings Potential

The T-BOSS® sterntubeless design offers a substantial advantage over conventional oil-lubricated sterntube systems. The T-BOSS® sterntubeless design offers fuel saving potential which is calculated based on the losses seen due to the frictional drag of the lubricating oil as compared to a seawater lubricated bearing. Using formulas provided from the paper from Dr. Guojun (Gary) Ren titled: *Hypo-elastohydrodynamic lubrication of journal bearings with deformable surface,* published in **Tribology International 175 (2022),** fuel savings would be approximately US$5100 annually for the vessel in this case study using a single elastomeric COMPAC propeller shaft bearing lubricated with seawater.

5.4 Enhanced Inspection, Maintenance, and Replacement

The T-BOSS® sterntubeless design offers a substantial advantage over conventional oil-lubricated sterntube systems in terms of inspection, maintenance, and replacement of seals and bearings.

The key benefits include:

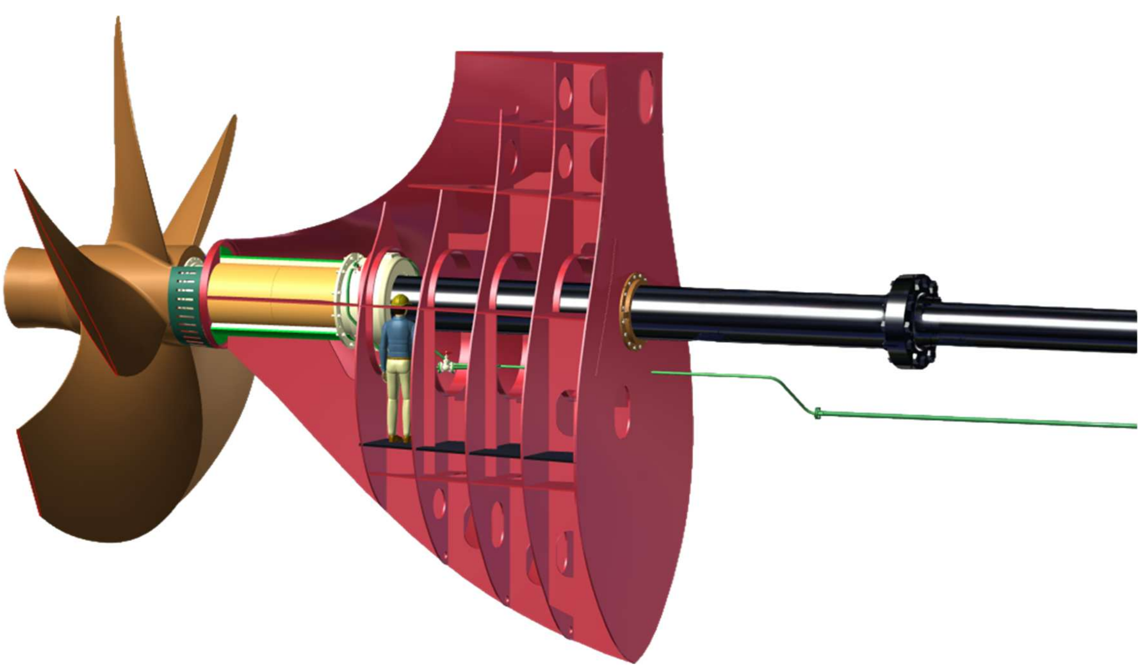
a) **Dry Chamber Arrangement:**
The conventional sterntube cooling tank is replaced with a dry chamber, enabling inspection, maintenance, or replacement of the seawater-lubricated single bearing and seal from inside the vessel.

b) **Afloat Bearing Replacement:**
Depending on vessel type, a bearing replacement can be carried out while the ship is afloat, using forward ballasting to raise the propeller above the waterline.

c) **No Shaftline or Propeller Disassembly:**
The replacement of the aft bearing can be performed without dismantling the shaftline or removing the propeller.

d) **Elimination of Drydocking:**
Shaftline maintenance operations can be executed afloat, avoiding costly and time-consuming drydockings.

e) **Real Time Monitoring:**
A Bearing Condition Monitoring (BCM) provides continuous real-time clearance data, enabling operators to detect and address issues before they escalate.

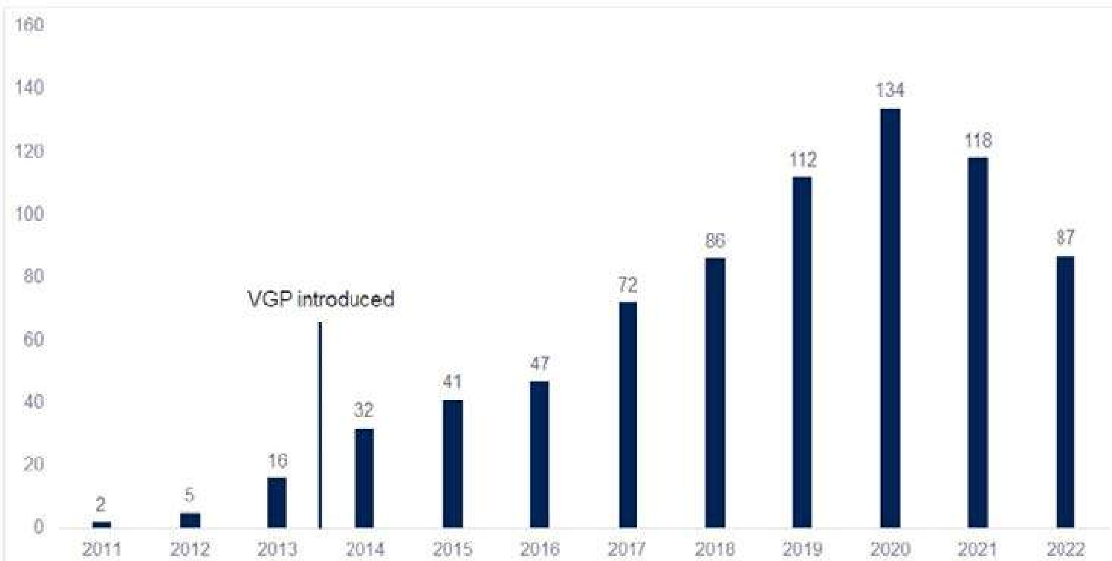


T-BOSS® design application on prototype vessel

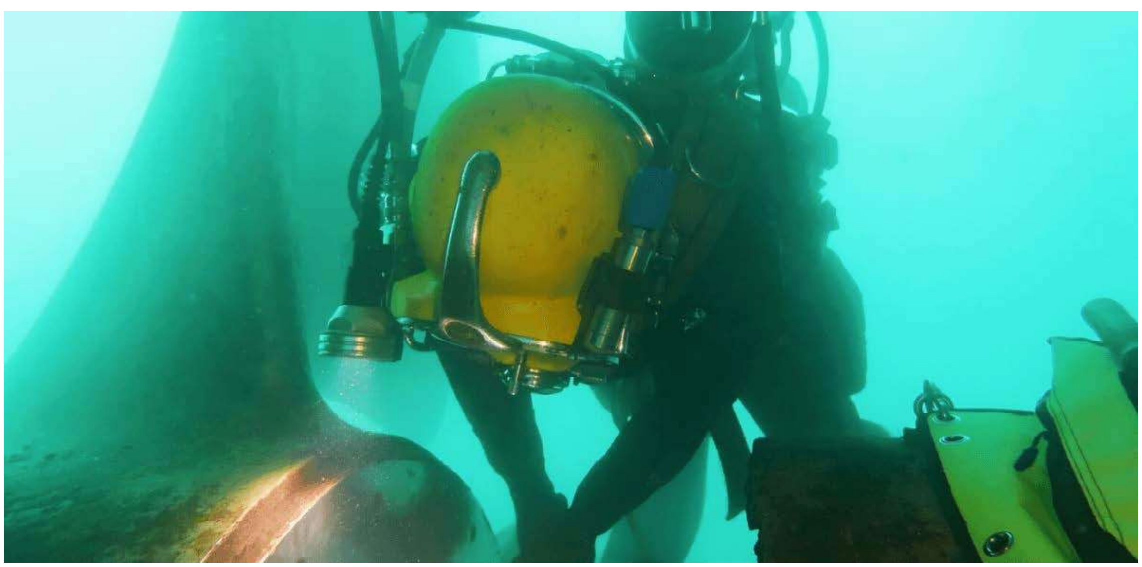
Cost Implications of Conventional Systems

Indicative Drydocking Cost:
According to ship owners, a typical two-week shaft re-alignment job, normally costing around US$500,000 in drydock, can instead be completed in just one day afloat, dispensing entirely with drydocking requirements.

Indicative Diver Repair Team Cost:
Gard, a leading Scandinavian insurer, has reported a notable increase in sterntube damage claims in recent years, many involving costly underwater seal repairs. To illustrate the cost impact, Thordon estimates that a six-hour diving team intervention can cost ~US$18,000 —a cost which is significantly reduced with the adoption of a sweater lubricated T-BOSS® sterntubeless design.



Total sterntube-related claims in Gard in excess of US$5,000 are reflected.



Diving team during repair

Concluding Remarks

In conclusion, the present study has demonstrated the technical feasibility and economic implications of adopting the T-BOSS® sterntubeless solution as an alternative to the conventional sterntube system.

The key findings and takeaways are summarized below:

- The T-BOSS® sterntubeless solution has been successfully benchmarked at technical and economical implications against the conventional oil-lubricated sterntube system using a Suezmax prototype vessel with a 670mm shaft diameter as reference.
- The discipline-by-discipline cost comparison (seal, piping, structural, shafting, outfitting, painting, electrical, testing, and regulatory) indicates that overall construction cost differences are not considerable, and the overall cost difference lies in the CAPEX of the T-BOSS® equipment.
- Design changes from a conventional oil-lubricated sterntube system to a sterntubeless design are estimated to take 40 manhours (based on the prototype vessel as reference).
- T-BOSS offers clear operational and economic advantages by eliminating lubricating oil use, resulting in avoided costs of ~US$33,000 per vessel as an initial CAPEX and ~US$11,500 per year from lubricating oil consumption.
- The induced space flexibility for this case study provides design opportunities: either enabling main engine repositioning with a potential cargo gain of ~660 m^3, or facilitating the installation of a shaft generator, which supports GHG emissions reductions, lowers fuel costs, and unlocks future decarbonization pathways.
- The dry stern inspection chamber simplifies inspection, maintenance, and bearing replacement (if necessary), all of which can be performed afloat without shaftline or propeller disassembly, thus eliminating costly drydockings and diver interventions.
- By eliminating the use of lubricating-oil in the sterntube, the T-BOSS® design removes the risk of oil leakage into the marine environment.
- Elastomeric polymer bearings lubricated with seawater offer a 1% fuel savings based on the lower viscosity/friction compared to metal bearings lubricated by oil when hydrodynamic operation is achieved.
- Industry data highlight the rising frequency of sterntube seal damages, emphasizing the operational vulnerabilities of conventional oil-lubricated systems, which T-BOSS® inherently avoids.

In summary, the T-BOSS® solution delivers higher design flexibility, long-term OPEX savings, enhanced environmental compliance, and greater operational reliability, making it a compelling and future-proof alternative for shipowners and shipyards.

The information contained in this document is based on industry research from an established Chinese newbuilding shipyard, supplemented by data from Hydrus Engineering (Greece), JBL Tech Service PTE. Ltd. (Singapore), and Thordon Bearings (Canada).

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