Requirements for

Sterntubeless Vessels with Water Lubricated Bearings

June 2024

REQUIREMENTS FOR

STERNTUBELESS VESSELS WITH WATER LUBRICATED BEARINGS
JUNE 2024

American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862

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Foreword

This document has been developed to address the requirements for the design of the aftmost part of the vessel's shaftline, specifically for an open-loop, water lubricated bearing type with a stern inspection chamber providing access for inspection and bearing replacement without the need to remove the tail shaft. The **STBLess-W** Notation may be assigned upon verification of compliance with all the requirements in this document to indicate the specific characteristics of the vessel design,

Subject to a satisfactory installation and operational record, the shaft may not require disassembly, or removal for inspection, under the arrangements described in this document.

The main aspects denoting compliance with this Notation from the standard Rule application are:

i) The existence of a stern inspection chamber aft of the vessel's engine room, adequately sized to allow direct access for survey and examination.

ii) The installation of a split type of aftmost water-lubricated bearing and appropriate seal.

iii) The installation of a seawater cooling/conditioning system for lubricant sea-water supply, including appropriate redundancy.

iv) Shaft alignment verification at more than one service condition including conditions of maximum bearing wear for the water lubricated bearing.

v) Compliance with the applicable requirements of the *Guide for Enhanced Shaft Alignment (ESA Guide)*.

vi) Compliance with the requirements of the Class Notation **TCM-W**, as per 4-3-2/15 of the *Rules for Building and Classing Marine Vessels* (*Marine Vessel Rules*).

The Requirements document is to be used in conjunction with other applicable Rules, Guides and Requirements, published by ABS.

This document becomes effective on the first day of the month of publication.

Users are advised to periodically check the ABS website www.eagle.org to verify that this version of this document is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org

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SECTION 1
General

1 Introduction

1.1 STBLess-W Notation

The notation **STBLess-W** is optional, however, the requirements contained in this document are mandatory for vessels with sterntubeless arrangements described here.

This document has been developed to address the requirements for the design arrangement of the aft part of a vessel, where the aftmost bearing of the vessel's shaftline is water lubricated, there is no sterntube cylinder, or a sterntube oil cooling tank and a dry stern inspection chamber is formed in the same area, hereby called a "stern inspection chamber". This document provides criteria for additional calculation requirements, such as design optimization for shaft alignment, as well as more detailed requirements regarding design characteristics, such as the design of a stern inspection chamber and an appropriate cooling sea-water supply and conditioning system.

Subject to verification of satisfactory operational records and surveys required for maintaining the TCM-W notation, as per 7-9-20/7 of the ABS *Rules for Survey After Construction (Part 7)*, the vessels assigned with **STBLess-W** Notation, the tailshaft survey interval required by 7-2-1/13.1.3 may be extended under the arrangements described in this document.

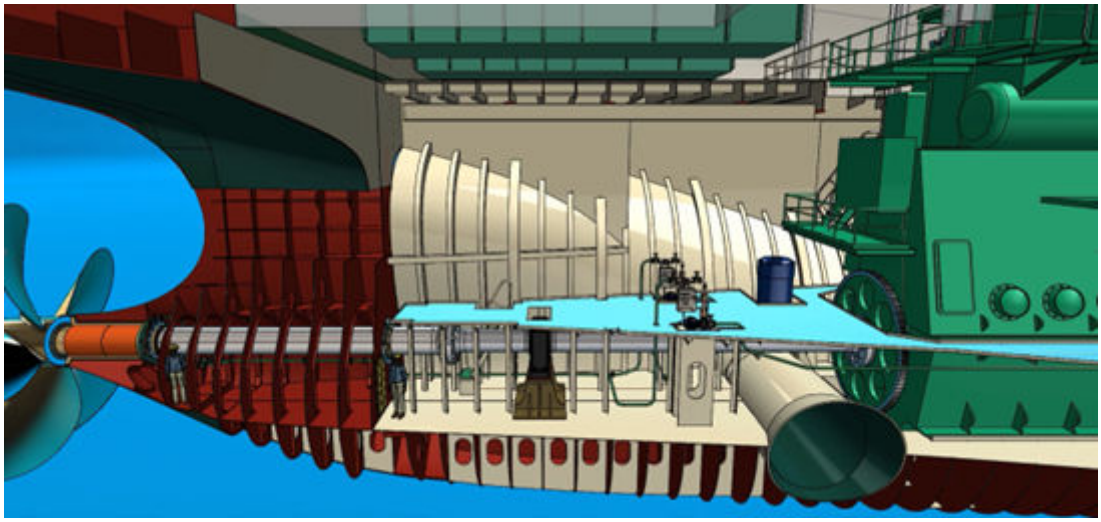
1.1.1 Objective

The goals and functional requirements for the topics covered in this document are included in Section 2.

1.1.2 General Requirements

The design concept for vessels with the **STBLess-W** notation requires that a stern inspection chamber (see 1/Figure 1) is provided aft of the vessel's engine room bulkhead adequately sized for a human to enter and carry out maintenance or repairs (as per 2/2.3). Additionally, drawings and supporting calculations submitted are to provide evidence that the aftmost propeller shaft bearing can be inspected and replaced from within the stern inspection chamber without the removal of the vessel's propeller or shaftline components.

FIGURE 1
3D View of the Sterntubeless Vessels Design Arrangement



1.1.3 ESA Notation

Compliance with the applicable sections of the *Guide for Enhanced Shaft Alignment (ESA Guide)* and pertinent Class Notation **ESA**, is a requirement for obtaining the **STBLess-W** Notation. Compliance with the applicable requirements of the *ESA Guide* mitigates:

i) the risk of accelerated wear-down due to overloading of the aftmost bearing, or due to misalignment is mitigated, through shaft alignment bearing load and slope optimization.

ii) the possibility of whirling vibration resonance due to the potentially increased bearing span between the intermediate bearing and the aftmost bearing.

1.1.4 TCM-W Notation

Compliance with 4-3-2/15 of the *Marine Vessel Rules* for opened loop water lubricated propeller shaft bearing system and pertinent Class Notation **TCM-W** is a requirement for obtaining the **STBLess-W** Notation.

2 Application

2.1 General

2.1.1 Notation Assignment

The Notation **STBLess-W** can be assigned to a vessel incorporating the design features and characteristics in compliance with the requirements of this document.

2.1.2 Other

The Class Notation **STBLess-W** can be assigned to twin-screw vessels.

The Class Notation **STBLess-W** cannot be assigned to:

- Vessels designed with azimuthal thrusters, or nonconventional shaft lines intended for main propulsion, or as otherwise deemed incompatible for the application of this design by ABS. Consideration will be given to vessels and offshore units with thrusters that may be compatible with the requirements of this notation subject to ABS technical assessment and approval.
- Vessels whose size or design is such that the existence of a stern inspection chamber is not practical.

- Shafting arrangements that have a forward propeller shaft bearing, because this necessitates the inclusion of a sterntube casting.
- Vessels with strut bearing arrangement(s).

2.1.3 Applicability Requirements

Class Notation **STBLess-W** may be assigned to vessels designed with open-loop; water lubricated propeller shaft bearings that comply with the following:

i) The existence of a dry inspection chamber aft of the vessel's engine room, with adequate space for inspection, hereby called "stern inspection chamber".

ii) The installation of the aftmost tail shaft water-lubricated bearing with appropriate inboard seal including a bulkhead seal in way of the aft engine room bulkhead shaft penetration.

iii) The installation of a seawater cooling system with conditioning/filtering capability for lubricant sea-water supply, including redundancy, such as the installation of two units allowing one unit to operation while the other is on standby mode.

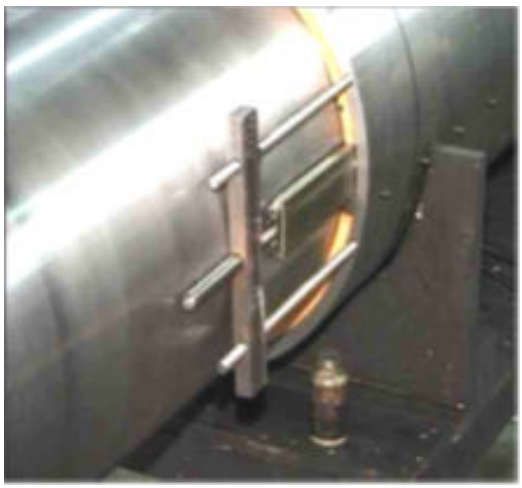
iv) A split type bearing with keyset, which allows bearing replacement without shaft removal. (see 1/Figure 2).

v) Shaft alignment calculation verification at more than one service condition including conditions of maximum bearing wear for the water lubricated bearing.

vi) Compliance with all the applicable requirements of the *ESA Guide*.

vii) Compliance with all the requirements of the Class Notation **TCM-W**, as per 4-3-2/15 of the *Marine Vessel Rules*.

FIGURE 2
Bearing Key removal tools



3 Documentation

The following plans or information are to be submitted:

R: Documents to be reviewed

I: Documentation for information and verification for consistency with related review.

3.1 Documentation to be Submitted for the STBLess-W Notation

3.1.1 Drawings

i) All drawings as required in Subsection 1/5 of the *ESA Guide* **(R)**,

ii) All drawings as required as per 4-3-2/1.5, 4-3-2/3.5 and 4-3-2/7.3 of the *Marine Vessel Rules* **(R)**,

iii) Aftmost seal drawings and drawings of inflatable aftmost outboard seal (See 1/4.8), if provided **(R)**,

iv) Stern inspection chamber arrangement drawing, showing the chamber meets the requirements of Section 3 **(R)**,

v) Tailshaft lifting arrangement drawing, outlining the use and position of either hydraulic jacks from within the stern inspection chamber, or lifting devices mounted to appendages external to the vessel's hull **(I)**.

3.1.2 Data (R)

i) All data as required in Subsection 1/5 of the *ESA Guide*.

ii) All data as required as per 4-3-2/7 of the *Marine Vessel Rules*.

3.1.3 Calculations (R):

i) All calculations required for compliance with the *ESA Guide*,

ii) Shaft alignment calculations analyzed for both initial conditions and conditions of manufacturer's maximum allowable wear down limits for compliance with Class Notation **TCM-W**,

iii) Details of shaft alignment and torsional, lateral, and axial vibration calculations as required by the 4-3-2/7 of the *Marine Vessel Rules*,

a) Shaft Alignment parametric study for a series of water lubricated bearing wear-down values. The calculations are to show that all bearing reaction loads are within acceptable limits, for each given reduction in the water lubricated bearing's thickness, up to a maximum value of wear-down prescribed by the bearing manufacturer,

b) Shaft alignment calculations are to include designated jack support locations and tailshaft lift-off clearance values if jack-up arrangements from inside the stern inspection chamber are required to verify complete shaft lifting within the aftmost bearing clearance and shaft is not resting on the bearing lower half. Refer also to 1/3.1.1(v).

Commentary:

Attention is to be given to the review of torsional vibration calculations, especially for shafts shorter in length than in the equivalent conventional (no aft inspection chamber) design. Where compliance with 4-3-2/7 of the *Marine Vessel Rules* is not achieved, the installation of a torsional vibration damper may be necessary as per 4-3-2/7.5.7 of the *Marine Vessel Rules*.

End of Commentary

3.1.4 Materials

i) Material specifications including mechanical and chemical properties of the shafts and bearings **(I)**,

ii) Material strength and welding properties for stiffeners and other hull girder members present in the stern inspection chamber area that are not of the same properties as the rest of the vessel's structure **(I)**.

3.1.5 Procedures to be Submitted for Review

i) Details of tailshaft lifting procedures, recording the lifting methods used, as well as the force, or pressure required to lift the tailshaft to replace the aft-most bearing **(I)**,

ii) Details of aftmost bearing replacement procedures and the aftmost seal replacement procedures **(I)**,

iii) Details of tailshaft, seal and bearing inspection procedure (e.g. bearing weardown measurement, use of borescope, etc.) as per the applicable requirements for TCM-W under 4-3-2/15 of the *Marine Vessel Rules* **(I)**,

iv) Details of the inspection chamber access and work (replacement or inspection) procedure, highlighting the safety aspects for the persons involved (lighting, ventilation, communication with the engine room, emergency evacuation and accident provisions etc.) **(I)**,

v) Details of the operation of the water-conditioning machinery units (machinery skids), including failure mode and effect analysis (FMEA, or equivalent) **(I)**.

3.1.6 Other Calculations

ABS may require additional calculations, drawings, or documentation, for review as deemed necessary.

ABS may require justification of the theoretical basis of any simplified approach utilized in submitted analysis, as well as the origin and methods used to obtain any empirical data used.

4 Definitions

4.1 Alignment Optimization

Alignment optimization is a condition where a mathematically predicted set of bearing offsets produces a satisfactory bearing load distribution for more than one alignment condition.

The shaft alignment optimization estimates the most possible uniform bearing load distribution for any given vessel loading case. It will produce an optimum set of bearing offsets, which when applied in the dry dock or at the light ship draft, will satisfy the bearing loading conditions in all service drafts of the vessel (e.g. from ballast to the fully laden vessel).

Knowledge of the hull deflections envelope together with the required operating conditions (e.g. fully loaded, hot dynamic, including propeller loads) allows the bearing offsets range to be defined within which a bearing load distribution is found acceptable.

This set of bearing offsets is said to be optimal and the shaftline is said to be optimum for alignment purposes, in accordance with the definition given to the alignment optimization.

4.2 Axial Seal

An axial lip seal with redundancy capability (e.g. a two or more) and low friction sealing ring (see 1/Figure 3).

FIGURE 3
Water Lubricated Face Type Seal

4.3 Bearing Condition Monitoring System

The Bearing Condition Monitoring System (BCMS) allows for regular bearing wear measurements from inside the vessel, monitoring the bearing clearance and detecting if the limits declared by the bearing maker have been exceeded.

4.4 Bearing Inspection

Any process by which the condition of the aft-most water lubricated bearing may be visually inspected without removal, by means of camera, or other scope, insertion along the longitudinal grooves.

4.5 Bearing Replacement Loading Condition

The combination of vessel draft and trim allows for the safe inspection and replacement of the shaftline's aft-most bearing and seal from within the stern inspection chamber. Ideally, the vessel's propulsion shafts are to be above the water during the bearing replacement, as illustrated in Appendix 2/Figure 1.

4.6 Cooling Water Supply and Conditioning system

All pumping, conditioning and piping systems associated with open-loop water lubricated systems as described in 4-3-2/15 of the *Marine Vessel Rules* for the **TCM-W** notation, as well as any other requirements imposed by the maker or supplier of the water lubricated bearing and accompanying system.

4.7 Equivalent Strength Design

Relevant analysis that supports that the design including material selection and structural component sizing has equivalent strength as the vessel with a conventional cast sterntube arrangement.

4.8 Outboard Inflatable Axial Seal

An outboard axial seal fitted on the side of the propeller with the capability of being inflated remotely, for the purpose of inspection and replacement of the inboard axial seal and aft-most water lubricated shaftline bearing (see 1/Figure 4). The existence of such a seal removes the need for the shaftline to be above water level for bearing replacement. The installation of this outboard seal at the aft of the aftmost tailshaft water lubricated bearing can be installed for those vessel types that cannot be forward ballasted for bearing or seal replacement or shaftline inspection purposes in the stern inspection chamber.

FIGURE 4
Inflatable axial seal

4.9 Shaft Alignment

The configuration of the shafts and bearings relative to the centerlines of the bearings from the theoretical straight-line condition to achieve an acceptable bearing load distribution and shaft-bearing misalignment angles.

4.10 Stern Inspection Chamber

A stern inspection chamber, created within the space around the propeller shaft aft bearing/seal and aft of the aft bulkhead of the engine room (See Appendix 1).

4.11 Water Lubricated Bearings

Bearings that support the propeller shaft and lubricated or cooled by water. These are typically made of non-metallic homogeneous elastomeric polymer alloys.

SECTION 2
Design Requirements

1 Objective

1.1 Goals

The shafting/stern arrangements covered in this document are to be designed, constructed, operated, and maintained to:

Goal No.	*Goal*
STRU 1	In the intact condition, have sufficient structural strength to withstand the environmental conditions, loading conditions, and operational loads anticipated during the design life.
STAB 2	Have adequate subdivision and stability to provide survivability to damage or accidental conditions.
STAB 4	Detect accumulated liquids.
STAB 5	Be able to remove accumulated liquids to mitigate the effects of flooding.
AUTO 1	Perform its functions as intended and in a safe manner.
SAFE 2	Provide suitable and readily available illumination.
MGMT 5-1	Facilitate safe access, ease of inspection, survey, and maintenance of the vessel, machinery and electrical systems.

The goals in the cross-referenced Rules and Guides are also to be met.

1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of the vessel's propulsion shafting are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Structure (STRU)	
STRU-FR1	Provide adequate hull support structure to the propulsion shafting to withstand operational and environmental loads.
STRU-FR2	Means of inspection chamber access is to be designed to withstand the flooding condition of the inspection chamber.
STRU-FR3	Provide means to protect stern inspection chamber from overpressure due to piping system damage and bearing seal failure.

Functional Requirement No.	*Functional Requirements*
Stability (STAB)	
STAB-FR1	Provide means to prevent inadvertent flooding of an internal space.
STAB-FR2 (AUTO)	Provide means to control and monitor from manned control stations flooding of the stern inspection chamber due to piping system damage and bearing seal failure.
Safey Management (MGMT)	
MGMT-FR1	Watertight access opening is to be large enough to easily transport parts, tools, and injured personnel.
Safey of Personal (SAFE)	
SAFE-FR1 (MGMT)	Provide sufficient lighting for inspection and maintenance.

The Functional Requirements in the cross-referenced Rules and Guides are also to be met.

1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of Classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved, refer to Part 1D, Chapter 2.

2 Requirements for the Stern Inspection Chamber

2.1 Purpose

A stern inspection chamber (see 2/Figure 1 and 2/Figure 2) allows access to the aft-most bearing of the shafting system from the aft of the engine room. This stern inspection chamber is to comply with the pertinent rule requirements addressed in the *Marine Vessel Rules*.

FIGURE 1
3D View of the Stern Inspection Chamber

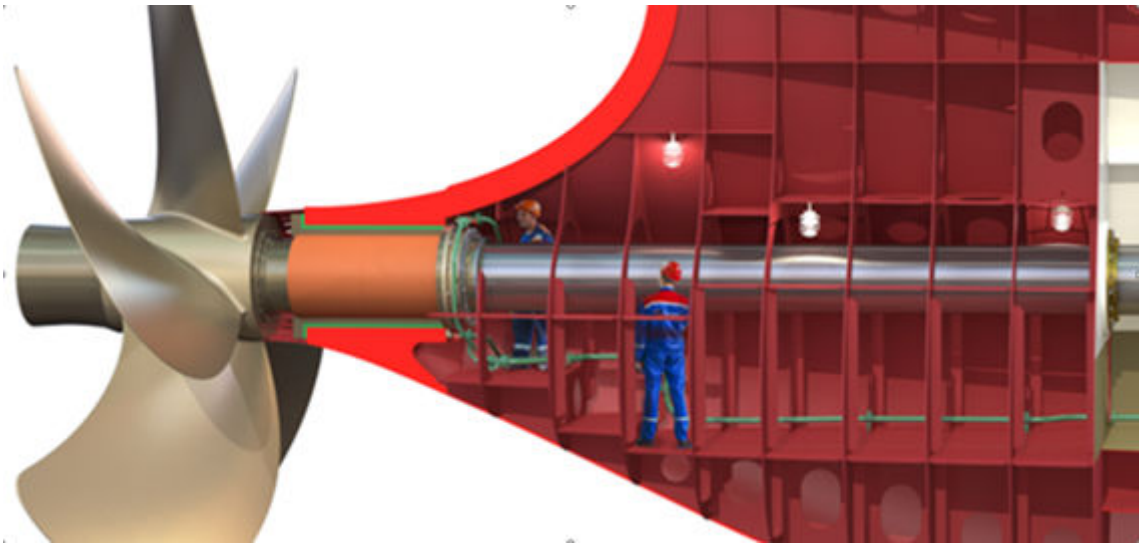
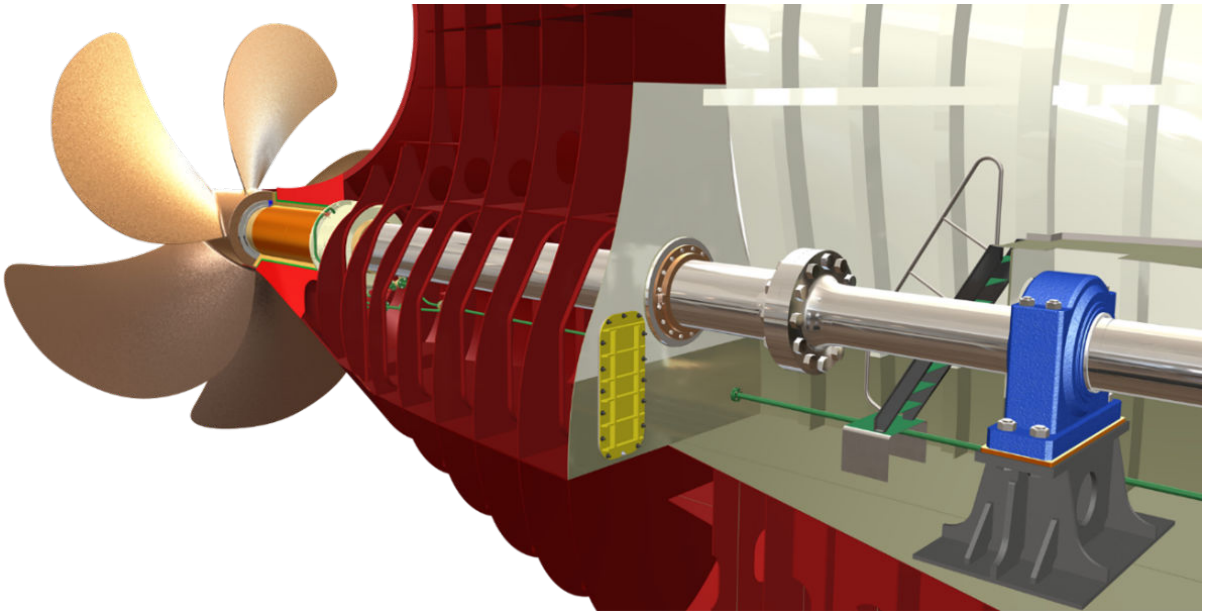


FIGURE 2
Illustration of means of access



2.2 Stern Inspection Chamber Structural Stiffness

In accordance with 3-2-4 of the *Marine Vessel Rules*, specific requirements apply to double bottom sizing including the requirements for center and side girders, brackets, tank-end floors, and floor stiffeners. In addition, localized hull strength calculations are to be carried out, as applicable, to verify that the local stiffness is satisfactory, according to the definition of Equivalent Strength Design in Subsection 1/4, such as comparing:

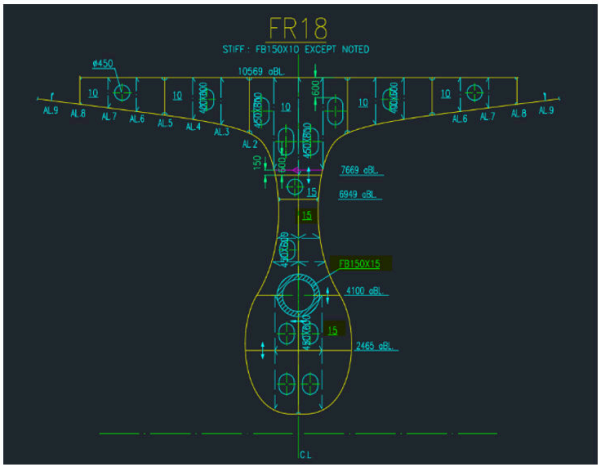
i) A conventional stern tube design that is compliant with the requirements in the *Marine Vessel Rules*,

ii) A design that incorporates the stern inspection chamber arrangement as provided in this document.

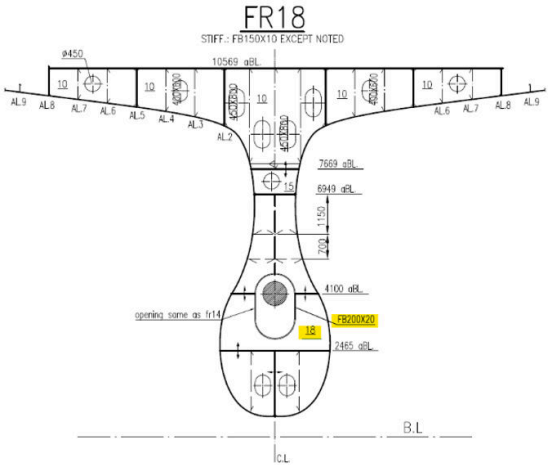
With regard to the section modulus of floors between the edge of the cutout for the inspection chamber and the side shell is to be equal to, or greater than the section modulus of a conventional design that incorporates a sterntube (see 2/Figure 3). Floors are to be fitted at each frame space in the aft peak and carried to a height at least above the stern inspection chamber.

FIGURE 3
Comparison between the two desings in a typical container vessel

Conventional Design



STBLess Design



For designs that are deemed unusual, or beyond the usual level of complexity, a Finite Element Analysis (FEA) may be carried out in this area, complementing the hull strength calculations, to verify that the local vessel hull strength is not affected.

The resulting stiffness of the aft-most bearing's foundation is to be considered for the shaft alignment calculations.

2.3 Stern Inspection Chamber Requirements

The following requirements for the arrangement of the stern inspection chamber as well as the adjacent engine room spaces are to be satisfied:

i) The access to the stern inspection chamber is to be **Normally Closed**. The chamber is to be accessed only for bearing inspection and replacement. Means of access between the engine room and the stern inspection chamber are to be watertight,

ii) The scantlings for the means of access to the inspection chamber are to be sized and designed considering the maximum head pressure from the flooded adjacent chamber, or the maximum hydrostatic pressure considering the maximum vessel draft (whichever is greater). The structural strength of the access is to be equivalent to that of the engine room bulkhead. Calculations are to be submitted in accordance with 3-2-9 of the *Marine Vessel Rules*.

iii) The watertight access openings are to be adequately sized to allow for man entry, movement of bearing components and tools required for bearing replacement to and from the chamber. The access should permit evacuation of an injured person from the space. The height of the lower portion (deck to opening) of the door should be less than 600 mm high. If higher than 600 mm, a step should be provided. The step should be placed midway between the deck and the lower hatch opening.

iv) The stern inspection chamber is to be fitted with a dedicated bilge well and bilge level monitoring as per 4-9-5/15.3 of the *Marine Vessel Rules*. Bilge suction valve is to be located outside the space.

v) The bilge suction is to be connected to the machinery space bilge system and is to be capable of pumping out and draining the stern inspection chamber and its bilge well. The piping arrangements are to be in accordance with 4-6-4/5 of the *Marine Vessel Rules*. The piping penetration to this space is to comply with the requirements in 4-6-2/9.7 of the *Marine Vessel Rules*.

vi) A drip tray for collecting sea water is to be fitted below the inboard bearing seal, with draining arrangements to the stern inspection chamber's bilge well. It is to be constructed so as to collect most of the water leakage while not obstructing the replacement of the bearing and seal. If the drip tray is constructed in a way that may restrict the access to the bearing maintenance, it is to be the bolted type so that it can be unbolted and moved out of the way during maintenance.

vii) The stern inspection chamber is to be provided with venting arrangements, in accordance with the requirements in 4-6-4/9 of the *Marine Vessel Rules*.

viii) Permanent lighting is to be provided enabling inspection and component replacement work (bearing, seal) within the chamber.

ix) Bilge level sensors are to be provided to monitor water ingress into the chamber. A water ingress alarm is to be initiated at the machinery control stations and navigation bridge. The specific criteria for water ingress alarms are to be in accordance with 4-9-5/15.3 of the *Marine Vessel Rules*.

x) In order to facilitate the bearing inspection and replacement works in the stern inspection chamber, supply outlets for service air, electricity and water, are to be located as close to the access openings leading to the chamber, as possible.

xi) An opening in the bulkhead with a bolted cover of at least 12 inch (300 mm dia) providing access for the insertion a portable vent duct to supply temporary ventilation while people are inside the stern inspection chamber carrying out maintenance tasks.

Commentary:

Before entering the stern inspection chamber, the space is to be made gas-free, ventilated, and illuminated to protect the personnel.

End of Commentary

SECTION 3
Survey Requirements

1 Objective

The objective is to verify conformance to the goals and functional requirements outlined in Section 2.

2 Initial Survey

In addition to all the applicable requirements under 4-3-2/11 and 4-3-2/15.9 of the *Marine Vessel Rules*, for Class Notation **TCM-W**, the Surveyor is to inspect the stern inspection chamber for compliance with all requirements of this document as per approved drawings, as well as all watertight access hatches, and doors connecting the chamber to the engine room for compliance with the applicable requirements in the Rules. The bulkhead seal tightness is to be verified by appropriate pressure test.

All systems required by the **STBLess-W** Notation are to be examined in accordance with the approved plans to verify compliance. All testing procedures submitted under Subsection 1/3 are to be verified.

The **STBLess-W** Notation can be granted upon satisfactory trial results as detailed in 3/2.1 (Bearing Replacement Procedure).

2.1 Bearing Replacement Procedure

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. Demonstration by simulation (mock-up) can be considered on a case-by-case basis. This trial can be limited to the first of a series of sister vessels, or similar vessels at the discretion of ABS.

The Surveyor is to attend a trial bearing inspection and replacement activity carried out under the prescribed afloat bearing replacement conditions and verify the following before sea trials:

i) The aftmost bearing and tailshaft/tailshaft liner can be inspected using approved inspection techniques, such as with the use of borescope, or similar, without the withdrawal of the tailshaft.

ii) Demonstration that the aftmost water lubricated bearing can be replaced while the vessel is afloat and from within the stern inspection chamber of the vessel without the need of propeller or shaftline disassembly. This can be done either by the installation and on-demand activation of an outboard inflatable seal to restrict water ingress through the aftmost water lubricated bearing or through forward ballasting the vessel in order for the propeller plane to be above the water surface.

3 Surveys after Construction

To maintain the **STBLess-W** Notation, the survey requirements contained in the ABS *Rules for Survey After Construction (Part 7)* are to be complied with.

Subject to a satisfactory operational record, as per 7-9-20/7 of the ABS *Rules for Survey After Construction (Part 7)*, the vessels assigned with **STBLess-W** Notation, the tailshaft survey interval required by 7-2-1/13.1.3 of the ABS *Rules for Survey After Construction (Part 7)*, can be extended under the arrangements described in this document.

APPENDIX **1**

Visual Examples of a Stern Inspection Chamber

FIGURE 1
3D View of the Stern Inspection Chamber

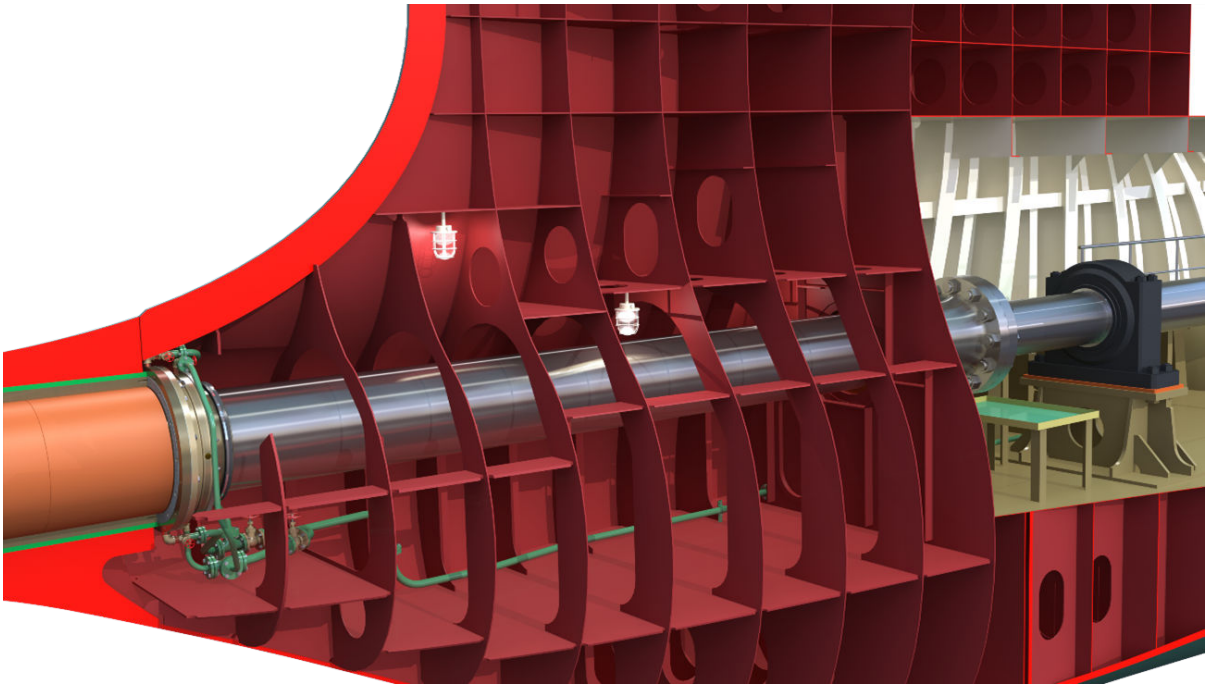


FIGURE 2
3D View of the Stern Inspection Chamber looking at the Engine Room Bulkhead

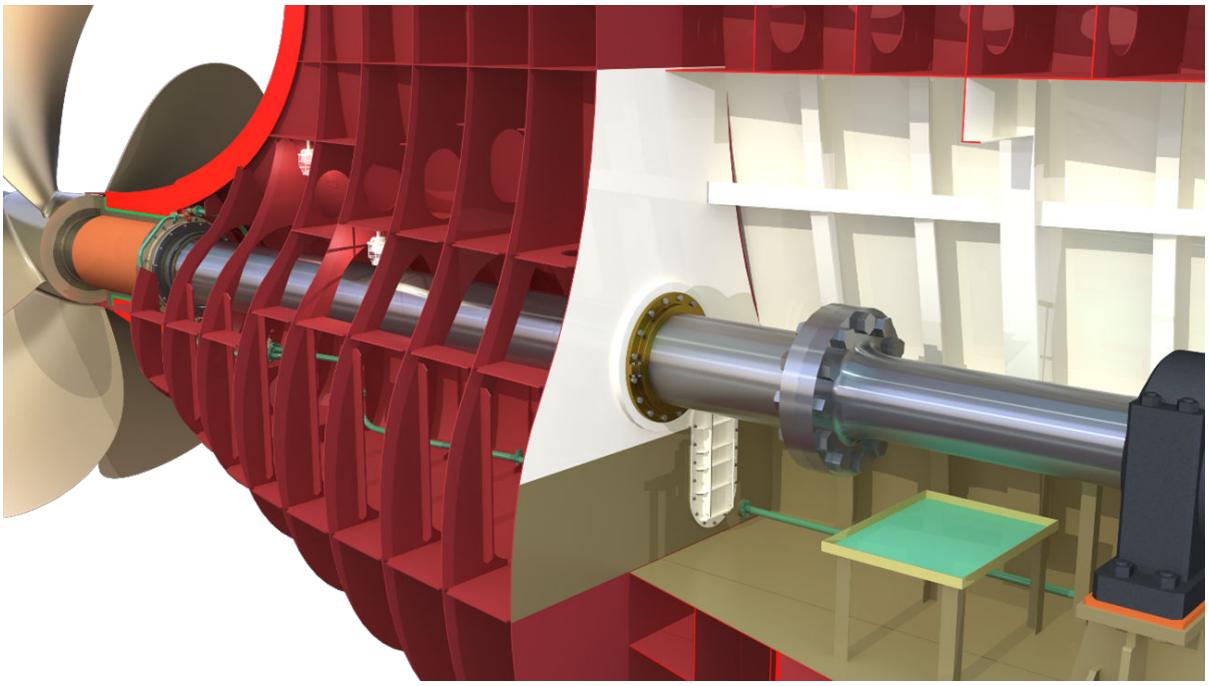


FIGURE 3
3D View inside the Stern Inspection Chamber

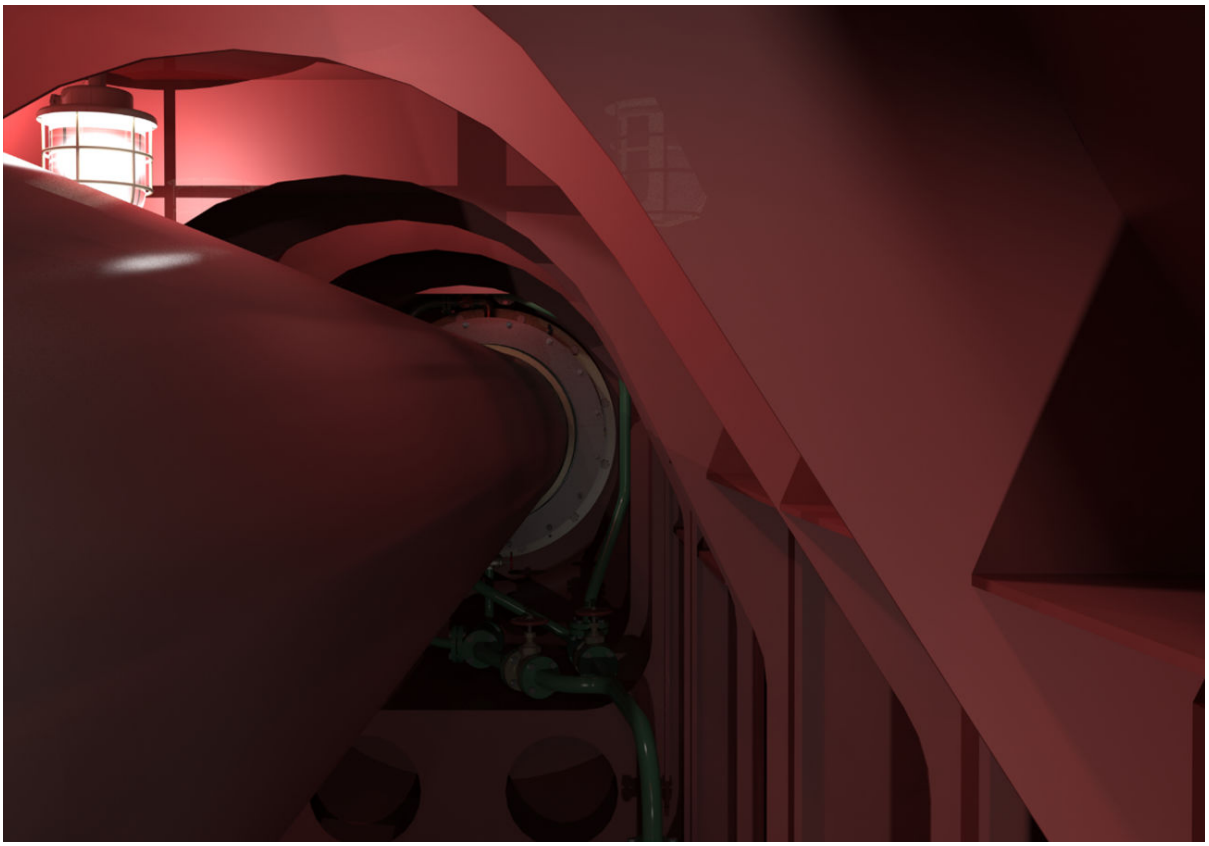


FIGURE 4
3D View of the Stern Inspection Chamber

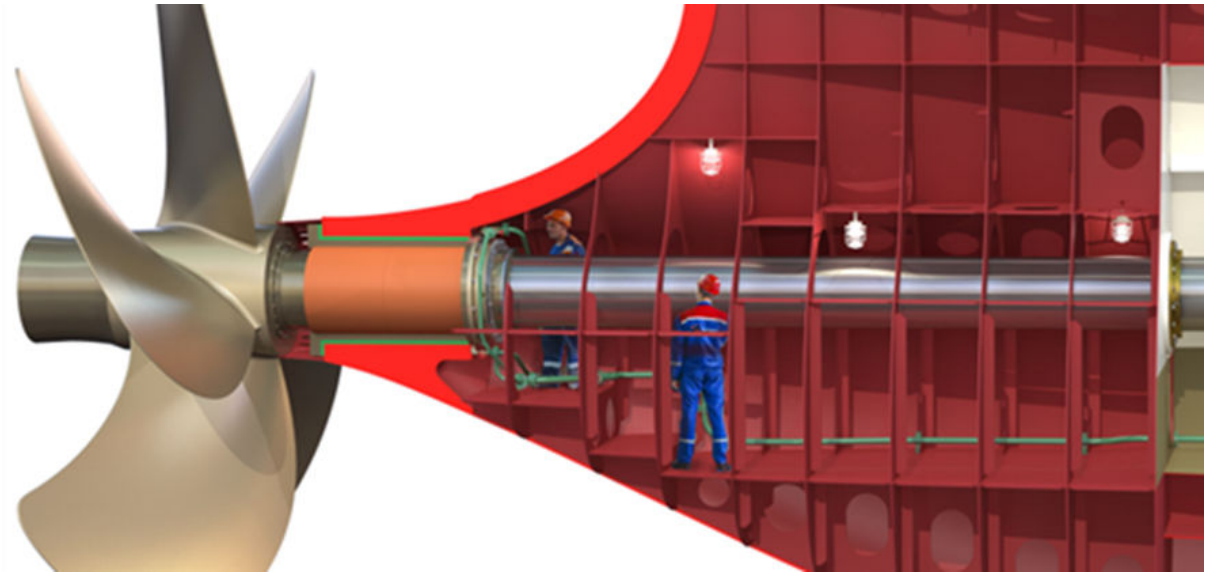
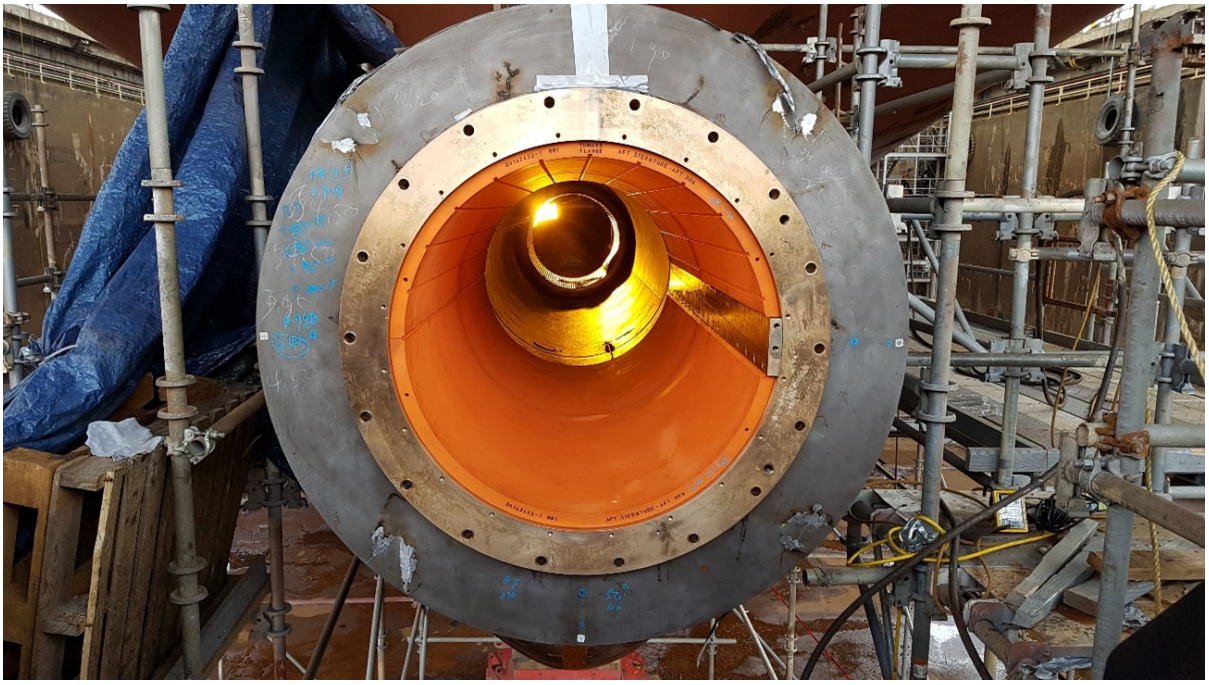


FIGURE 5
Water-Lubricated bearing assembly



APPENDIX **2**

Example of Vessel Forward Ballasting for Conventional Shaft Alignment Purposes

FIGURE 1
Forward Ballasting of a vessel for shafting repairs

APPENDIX **3**

References

1) Rossopoulos, G, O. Vlachos, C Leontopoulos, G. Koutsoumpas, A Hamilton, C Papadopoulos " Design of Stern Tube-less Vessels with Water Lubricated Bearings Effects on Environmental Performance and Shafting Efficiency." SNAME Maritime Convention, SMC 2023, 27-29 September, San Diego, CA.

2) Leontopoulos, C, Sterntubeless Vessels with Water Lubricated Bearings – A Novel Design Concept, The Motorship, Future Fuels Conference, Hamburg, 21-23 Nov, 2023.

3) ABS *Guide for Enhanced shaft Alignment (ESA Guide)*.

4) ABS *Rules for Building and Classing Marine Vessels (Marine Vessel Rules)*.