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COMMISSION STAFF WORKING DOCUMENT

Union submission to the 105th session of the International Maritime Organization's Maritime Safety Committee on reviewing SOLAS chapters II-1 (Part C) and V to address both traditional and non-traditional propulsion and steering systems

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PURPOSE

This Staff Working Document contains a draft Union submission to the International Maritime Organization's (IMO) 105th session of the Maritime Safety Committee (MSC 105). The IMO has scheduled MSC 105 from 20 to 29 April 2022.

The draft submission elaborates on the suggestions in a previous EU submission (MSC 104/15/8). It provides the proposed amendments to SOLAS chapters II 1 (Part C) and V, and related non-mandatory instruments, and underscores the urgency of the matter. The text addresses both traditional and non-traditional propulsion and steering systems.

EU COMPETENCE

The European Union pursues implementing SOLAS through Directive 2009/45/EC on safety rules and standards for passenger ships[1]. Pursuant to Article 6(2)(i) of this Directive, new passenger ships of Class A shall comply entirely with the requirements of the 1974 SOLAS Convention, as amended, and with the specific relevant requirements specified in this Directive.

For those regulations where the SOLAS Convention, as amended, leaves the interpretation to the discretion of States' Administrations, the flag State shall apply them as contained in Annex I to this Directive. Any changes in respective SOLAS regulation(s) would therefore impact EU legislation.

In light of all of the above, the present draft Union submission falls under EU exclusive competence.[2] This Staff Working Document is presented to establish an EU position on the matter and to transmit the document to the IMO prior to the required deadline of 14 January 2021.[3]

[1] Directive 2009/45/EC of the European Parliament and of the Council of 6 May 2009 on safety rules and standards for passenger ships; OJ L 163, 25.6.2009, p. 1–140

[2] An EU position under Article 218(9) TFEU is to be established in due time should the IMO Maritime Safety Committee eventually be called upon to adopt an act having legal effects as regards the subject matter of the said draft Union submission. The concept of '*acts having legal effects*' includes acts that have legal effects by virtue of the rules of international law governing the body in question. It also includes instruments that do not have a binding effect under international law, but that are '*capable of decisively influencing the content of the legislation adopted by the EU legislature*' (Case C-399/12 Germany v Council (OIV), ECLI:EU:C:2014:2258, paragraphs 61-64). The present submission, however, does not produce legal effects and thus the procedure for Article 218(9) TFEU is not applied.

[3] The submission of proposals or information papers to the IMO, on issues falling under external exclusive EU competence, are acts of external representation. Such submissions are to be made by an EU actor who can represent the Union externally under the Treaty, which for non-CFSP (Common Foreign and Security Policy) issues is the Commission or the EU Delegation in accordance with Article 17(1) TEU and Article 221 TFEU. IMO internal rules make such an arrangement absolutely possible as regards existing agenda and work programme items. This way of proceeding is in line with the General Arrangements for EU statements in multilateral organisations endorsed by COREPER on 24 October 2011.

MARITIME SAFETY COMMITTEE
105th session
Agenda item 18

MSC 105/18/X
XX XXXX 2022
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WORK PROGRAMME

Elaboration on the proposal contained in document MSC 104/15/8 for a new output to review SOLAS chapters II-1 (Part C) and V, and related non-mandatory instruments, to address both traditional and non-traditional propulsion and steering systems

Submitted by the European Commission on behalf of the European Union[4], [supported] by the United States, and by IACS

SUMMARY

Executive summary:	This document elaborates on the proposal in document MSC 104/15/8. It provides the suggested amendments to SOLAS chapters II 1 (Part C) and V, and related non-mandatory instruments, and underscores the urgency of the matter. The draft submission addresses both traditional and non-traditional propulsion and steering systems.
Strategic direction, if applicable:	2 and 6
Output:	XX
Action to be taken:	Paragraphs 18 and 19
Related documents:	DE 55/3; SSE 6/12, SSE 6/18 and MSC 104/15/8

Introduction

1 Document MSC 104/15/8, proposing to revise SOLAS chapters II-1 (Part C) and V, and related non-mandatory instruments, to address both traditional and non-traditional propulsion and steering systems, was submitted in accordance with the provisions of the *Organization and method of work of the Maritime Safety Committee and the Marine Environment Protection Committee and their subsidiary bodies* (MSC-MEPC.1/Circ.5/Rev.2) on the submission of proposals for new outputs.

2 The preliminary assessment of this output (document MSC 104/WP.2) resulted in considering it under the post-biennial agenda of SSE, in line with what was originally proposed in paragraph 20 of document MSC 104/15/8. As the Committee could not consider document MSC 104/15/8 at MSC 104 due to lack of time, its adoption, in the best case, may be in 2027, entering into force in 2030, more than a decade after the initial proposals were sent. The objective of this submission is therefore to highlight that a comprehensive and mature set of amendments to SOLAS chapters II-1 (Part C) and V, and related non-mandatory instruments, to address both

[4] The position of the European Union will be confirmed after completion of its internal procedures.

traditional and non-traditional propulsion and steering systems, is already available based on a dedicated study (see paragraph 6).

Background

3 As outlined in document MSC 104/15/8, existing SOLAS requirements for steering and propulsion, mainly based on the traditional system consisting of a single propeller and a single rudder, need to be revised to consider modern systems such as azimuth thrusters, podded propulsors, waterjets, cycloidal propellers, etc. So far, the discrepancy between regulations and current technology has been addressed by unified interpretations.

4 IACS already addressed this issue in document DE 55/3, which contains its Unified Interpretation SC 242 on the arrangements for steering capabilities and function on ships fitted with propulsion and steering systems other than traditional arrangements for a ship's directional control, by providing interpretation of SOLAS regulations II-1/28 and II-1/29. This unified interpretation was agreed at DE 55 and subsequently approved by MSC 90 as *Unified interpretation of SOLAS regulations II-1/28 and II-1/29* (MSC.1/Circ.1416).

5 Based on the experience of the application of MSC.1/Circ.1416 (UI SC 242 respectively) and feedback from the industry, IACS submitted a revised version of UI SC 242 to SSE 6 (SSE 6/12). However, the Sub-Committee, while accepting this latest version as an interim measure (it was further approved as MSC.1/Circ.1416/Rev.1 at MSC 99), decided that a new output proposal encompassing all types of modern propulsion and steering systems would be necessary (SSE 6/18, paragraph 12.42).

Information on a study commissioned by EMSA

6 With a view to addressing this issue, a dedicated study on the subject called "STEERSAFE Steering and Manoeuvrability Study" was commissioned by EMSA and carried out by DNV. The consolidated Final Report on the Study can be found under the following link:
http://emsa.europa.eu/publications/reports/item/4398-steersafe.html

7 The overall objective of the project was to provide sound technical knowledge and proposals to accomplish a complete revision of the SOLAS requirements at stake: regulation II-1/28 on Means of going astern, regulation II-1/29 on Steering gear, regulation II-1/30 on Additional requirements for electric and electrohydraulic steering gear, regulation V/25 on Operation of steering gear and regulation V/26 on Steering gear: testing and drills. Related non-mandatory instruments (resolutions and circulars) referred by footnotes in SOLAS regulations II-1/28 and II-1/29 also need to be considered.

8 In order to achieve the referred objective, a two-stage goal-based approach was followed: firstly, the Tiers I & II of a Goal-Based Standard (GBS) framework for steering and manoeuvrability were developed, i.e. goals, functional requirements and expected performance; secondly, current SOLAS regulations were verified against the developed GBS Tiers I & II.

9 The outputs obtained from the verification (gaps and shortcomings), in conjunction with the accummulated DNV experience in solving practical problems found when implementing the current regulations at stake, served as basis for the key project result: a complete update of SOLAS regulations and associated Resolutions and Circulars. The suggested proposals contained in this document are based on the referred project results.

Urgency

10 The COVID-19 pandemic has caused considerable delays in the normal IMO approval process. MSC 103 only considered proposals for new outputs already submitted to MSC 102. Consequently, proposals for new outputs, i.e. additional to those submitted to MSC 102 (as the output at stake) were to be submitted to MSC 104. Additionally, due to time constraints, MSC 104 was not able to consider the great majority of proposals for new outputs submitted to that session and agreed to postpone their consideration to MSC 105.

11 In view of the aforementioned delays, the mature status of the suggested amendment herewith included and the urgent need to update the obsolet present regulations, the following way forward is proposed to speed the process: notwithstanding paragraph 20 of document MSC 104/15/8, the Committee is invited to include the referred new output in the 2022-2023 biennial agenda of the SSE Sub-Committee and the provisional agenda for SSE 9, with a target to complete the item at SSE 10.

Proposals

12 The suggested revision is included in Annex 2 to this document whereas Annex 1 summarises the main changes proposed. It should be noted that the proposals made are only intended for new builds.

13 The suggested amendments for SOLAS Regulations II-1/28 & 29 incorporate, on top of the updated prescriptive requirements, the associated goals and functional requirements by following a similar model to that of Chapter II-2.

14 Furthermore, in Annex 2 to this document, a suggested proposal for a Circular is put forward to include the associated goals, functional requirements and expected performance criteria. This draft Circular may contribute to the work under the existing output to develop "Safety objectives and functional requirements of the Guidelines on alternative design and arrangements for SOLAS chapter II-1" under the coordination of the Sub-Committee on Ship Design and Construction (SDC).

15 The suggested amendments for SOLAS Regulations V/25 & 26 are mainly dealing with updating the terminology to make it technology neutral for steering type.

16 If the suggested amendments to SOLAS Regulation II-1/28 & 29 were approved, revoking the following two MSC Circulars could be considered as their contents have been incorporated into the regulations:

- MSC.1/Circ.1398 – Unified interpretation of SOLAS Regulation II-1/29 Mechanical, Hydraulic and Electrical Independency and Failure Detection and Response of Steering and Control Systems.
- MSC.1/Circ.1416/Rev.1 – Unified interpretation of SOLAS Regulation II-1/28 and II-1/29 concerning the arrangements for steering capability and function on ships fitted with propulsion and steering systems other than conventional arrangements for a ship's directional control.

17 In addition, revocation of the following Resolutions could be contemplated as they are considered outdated:

- Resolution A.415(XI) – Improved steering gear standards for passenger and cargo ships.
- Resolution A.416(XI) – Examination of steering gear on existing tankers.

Action requested of the Committee

18 The Committee is invited to include the new output on "Revision of SOLAS chapters II-1 (Part C) and V, and related non-mandatory instruments, to address both traditional and non-traditional propulsion and steering systems", proposed in document MSC 104/15/8, in the 2022-2023 biennial agenda of the SSE Sub-Committee and the provisional agenda for SSE 9, with a target to complete the item at SSE 10.

19 The Committee is also invited to consider the proposals in paragraphs 12 to 17 and instruct the SSE Sub-Committee, as appropriate.

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ANNEX 1

SUMMARY OF THE SIGNIFICANT CHANGES CONTAINED IN THE PROPOSAL

General

- Technology neutral requirements.
- Included basic goals and functional requirements in SOLAS regulations II-1/28 & 29, using the same model as that of Chapter II-2
- Proposed an independent new circular with the goals and functional requirements expanded with detailed performance criteria.
- Improved consistency and structure.
- Incorporated some Unified Interpretations in SOLAS regulations.
- Some trial test currently included in MSC.137(76) are proposed to be directly contrued in SOLAS regulations.
- Pilot card, wheelhouse poster and manoeuvring booklet are proposed to be required through SOLAS regulations.
- Added criteria for ship performance in a failure condition/reduced service.

SOLAS Regulation II-1/3 – Definitions

- Improved some definitions to better reflect the proposed regulation text.
- Added definitions found necessary for proposed regulation text, e.g. “steering force unit”, “declared steering limit angles”, etc.

SOLAS Regulation II-1/28 – Means of going astern

- Heading changed to “Means of stopping and going astern”.
- Added goal and functional requirements.
- Added mandatory requirements for ship stopping ability. For ships with multiple propulsion lines, requirements added for failure condition.

SOLAS Regulation II-1/29 – Steering gear

- This regulation has been entirely re-formulated and re-structured.
- Heading changed to “Steering”
- Added goal and functional requirements.
- Although technology neutral, the proposal differentiates on particular solutions where found necessary.
- Incorporated the content of MSC.1/Circ.1416/Rev.1 and MSC.1/Circ.1398.
- Incorporated the content of SOLAS Regulation II-1/30 (Additional requirements for electric and electrohydraulic steering gears).
- Added mandatory requirements for ship course stability and turning ability, also in a failure condition (reduced service).
- Added regulations addressing solutions with multiple steering systems (acceptance of redundancy on ship level as equivalent to redundancy on system level).

SOLAS Regulation II-1/30 – Additional requirements for electric and electrohydraulic steering gears

- Content incorporated in SOLAS Regulation II-1/29.

SOLAS Regulations II-1/42 & 43 – Emergency source of electric power in passenger & cargo ships

- References to SOLAS Regulation II-1/29 have been consequentially updated.

SOLAS Regulation V/25 – Operation of steering gear

- For ships with multiple steering systems, when operating in an area of special caution, a requirement to have more than one system in operation has been added.

SOLAS Regulation V/26 – Steering gear: Testing and drills

- The terminology has been improved to be technology neutral for steering type.
- Ship's manoeuvring characteristics have been added as part of the familiarisation scope.

MSC.1/Circ.1536 – Unified Interpretation of SOLAS Regulations II-1/29.3 and 29.4

- The terminology has been improved to be technology neutral for steering force unit.
- References have been updated.

Resolution A.467(XII) – Guidelines for acceptance of non-duplicated rudder actuators for tankers, chemical tankers and gas carriers of 10,000 tons gross tonnage and above but less than 100,000 tonnes deadweight

- The terminology has been improved to be technology neutral for actuating system.
- References have been updated.

Resolution MSC.137(76) – Standards for Ship Manoeuvrability

- Improved terminology to be technology neutral for steering type.
- Replaced ±35 degrees by "declared steering angle limits".
- Added heading keeping test.
- Added criteria for ship course stability, turning ability and stopping ability in a failure condition/reduced service.
- Excluding the criteria for the initial turning ability and the zig-zag test, the remaining contents of this Resolution becomes mandatory through the proposed amendments to SOLAS Regulations II-1/28 & 29.

MSC/Circ.1053 – Explanatory Notes to the Standards for Ship Manoeuvrability

- Improved terminology to be technology neutral for steering type.
- Modified procedure (heading towards wind changed to head from wind) as this is considered to be more conservative and less possible to exploit during tests.
- Added procedure for tests in failure condition.
- Specified CFD simulation as prediction method.

Resolution A.601(15) – Provision and Display of Manoeuvring Information on board Ships

- Removed obsolete text.

- Changed terminology to be technology neutral for steering type.
- This Resolution becomes mandatory through the proposed amendments to SOLAS Regulations II-1/28 & 29.

Tentative Draft Circular MSC.1/Circ. XXXX – Goals, functional requirements and expected performance criteria for SOLAS Regulations II-1/28 & 29 and V/25 & 26

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- Appendix A contains the goals, functional requirements and expected performance criteria as such.
- Appendix B establishes the cross check of the amended SOLAS regulations II–1/28 & 29 and V/25 & 26 against them.

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ANNEX 2

PROPOSED DRAFT TEXT REVISION[5]

SOLAS Ch. II-1, Part A, regulation 3

Regulation 3 is amended as follows:

Regulation 3 Definitions relating to Parts C, D and E

For the purpose of parts C, D and E, unless expressly provided otherwise:

1 Steering system(s) is the ship's mean(s) of directional control, including steering gear, steering control and monitoring system and steering force unit, as well as all means connecting to power supply.

~~1~~ 2 Steering ~~gear~~ control system is the equipment by which orders are transmitted ~~from the navigating bridge~~ to the steering ~~gear power units.~~ actuating system(s). Steering ~~gear~~ control systems comprise all components from the user input device to the receivers, including transmitters, ~~receivers~~, controllers, piping, cables, software and data networks, hydraulic control pumps and their associated motors, motor controllers~~, piping~~ and ~~cables~~ solenoid valves, as appropriate.

3 Steering control and monitoring system is the steering control system and all monitoring devices, alarms and indicators (remote and local) and software needed to ensure safe, efficient and reliable operation of the steering system.

4 Steering gear is the machinery, actuating system(s) and ancillary equipment to direct the steering force unit for the purpose of steering the ship. The steering gear may include various combinations of steering actuating systems and tiller or equivalent component.

~~2 Main steering gear is the machinery, rudder actuators, steering gear, power units, if any, and ancillary equipment and the means of applying torque to the rudder stock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.~~

~~3~~ 5 Steering gear power unit is:

.1 in the case of electric steering gear, an electric motor and its associated electrical equipment;

.2 in the case of electrohydraulic steering gear, an electric motor and its associated electrical equipment and connected pump; or

.3 in the case of other hydraulic steering gear, a driving engine and connected pump.

[5] Tracked changes are created using "strikeout" for deleted text and "grey shading" to highlight all modifications and new insertions, including deleted text.

~~4 Auxiliary steering gear is the equipment other than any part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.~~

6 Steering actuator is a component which converts energy into mechanical motion to direct the steering force unit (e.g. hydraulic cylinder, piston, etc.).

7 Steering actuating system is the equipment provided for supplying power to direct the steering force unit, i.e. comprising steering gear power unit, steering actuator and the system connecting them (e.g.: transmission or piping system).

8 Steering force unit is the element generating the forces required to control the vessel (e.g. rudder and stock, rudder propeller, thruster, pod, gate rudder, cycloidal propeller), including all parts up to the interface to the steering gear.

9 Declared steering angle limits are the operational limits in terms of maximum steering angle, or equivalent, taking into account the ship's speed or propeller torque/speed or other parameter; set according to both manufacturer's guidelines for safe operation and any ship design limitation.

10 Neutral position is a position of the steering force unit producing none or the lowest possible steering force in straight ahead course.

~~5~~ 11 Normal operational and habitable condition is a condition under which the ship as a whole, the machinery, services, means and aids ensuring propulsion, ability to steer, safe navigation, fire and flooding safety, internal and external communications and signals, means of escape, and emergency boat winches, as well as the designed comfortable conditions of habitability are in working order and functioning normally.

~~6~~ 12 Emergency condition is a condition under which any services needed for normal operational and habitable conditions are not in working order due to failure of the main source of electrical power.

~~7~~ 13 Main source of electrical power is a source intended to supply electrical power to the main switchboard for distribution to all services necessary for maintaining the ship in normal operational and habitable conditions.

~~8~~ 14 Dead ship condition is the condition under which the main propulsion plant, boilers and auxiliaries are not in operation due to the absence of power.

~~9~~ 15 Main generating station is the space in which the main source of electrical power is situated.

~~10~~ 16 Main switchboard is a switchboard which is directly supplied by the main source of electrical power and is intended to distribute electrical energy to the ship' s services.

~~11~~ 17 Emergency switchboard is a switchboard which in the event of failure of the main electrical power supply system is directly supplied by the emergency source of electrical power or the transitional source of emergency power and is intended to distribute electrical energy to the emergency services.

~~12~~ 18 Emergency source of electrical power is a source of electrical power, intended to supply the emergency switchboard in the event of a failure of the supply from the main source of electrical power.

~~13 Power actuating system is the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components (i.e. tiller, quadrant and rudder stock) or components serving the same purpose~~.

~~14~~ 19 Maximum ahead service speed is the greatest speed which the ship is designed to maintain in service at sea at the deepest sea-going draught.

~~15~~ 20 Maximum astern speed is the speed which it is estimated the ship can attain at the designed maximum astern power at the deepest sea-going draught.

~~16~~ 21 Machinery spaces are all machinery spaces of category A and all other spaces containing propelling machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.

~~17~~ 22 Machinery spaces of category A are those spaces and trunks to such spaces which contain:

.1 internal combustion machinery used for main propulsion;

.2 internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or

.3 any oil-fired boiler or oil fuel unit.

~~18~~ 23 Control stations are those spaces in which the ship' s radio or main navigating equipment or the emergency source of power is located or where the fire recording or fire control equipment is centralized.

~~19~~ 24 Chemical tanker is a cargo ship constructed or adapted and used for the carriage in bulk of any liquid product listed in either:

.1 chapter 17 of the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk adopted by the Maritime Safety Committee by resolution MSC.4(48), hereinafter referred to as "the International Bulk Chemical Code", as may be amended by the Organization; or

.2 chapter VI of the Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk adopted by the Assembly of the Organization by resolution A.212(VII), hereinafter referred to as "the Bulk Chemical Code", as has been or may be amended by the Organization,

whichever is applicable.

~~20~~ 25 Gas carrier is a cargo ship constructed or adapted and used for the carriage in bulk of any liquefied gas or other products listed in either:

.1 chapter 19 of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk adopted by the Maritime Safety Committee by resolution MSC.5(48), hereinafter referred to as "the International Gas Carrier Code", as may be amended by the Organization; or

.2 chapter XIX of the Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk adopted by the Organization by resolution A.328(IX), hereinafter referred to as "the Gas Carrier Code", as has been or may be amended by the Organization,

whichever is applicable.

SOLAS Ch. II-1, Part C, regulation 28

Regulation 28 is amended as follows:

Regulation 28 Means of stopping and going astern[6]

1 SCOPE

This regulation is addressing ships astern propulsion and stopping ability.

2 GOAL

The goal of this regulation is to prevent casualties arising from malfunction or insufficient performance of astern propulsion to control the vessel.

3 FUNCTIONAL REQUIREMENTS

In order to achieve the goal in paragraph 0 above, the following functional requirements shall be met:

1. The propulsion system provides adequate astern propulsion performance for ship operation.
2. Proper ship operation is enabled by providing information about ship's stopping characteristics.

4 MEANS OF GOING ASTERN

~~1~~ Sufficient power for going astern shall be provided to secure proper control of the ship in all normal circumstances.

5 STOPPING ABILITY

5.1 Ships under normal operational condition shall have stopping ability meeting the criteria in paragraph 5.3.4.1 of Resolution MSC.137(76).

5.2 Ships provided with multiple propulsion lines shall have stopping ability meeting the criteria in paragraph 5.3.4.2 of Resolution MSC.137(76) while any one of the propulsion systems and its corresponding steering system is out of operation.

5.3 Compliance with stopping ability requirements shall be demonstrated by trials and the results shall be recorded. Trials shall be performed according to procedure and in condition as defined in paragraphs 4, 5.1, 5.2 and 6 of Resolution MSC.137(76).

5.4 For the purpose of this regulation, those paragraphs of Resolution MSC.137(76) referred in the preceding paragraphs 5.1 to 5.3 shall be treated as mandatory.

[6] Refer to ~~the Recommendation on the provision and the display of manoeuvring information on board ships (resolution A.601(15)),~~ *Standards for ship manoeuvrability* (resolution MSC.137(76)) and *Explanatory notes to the standards for ship manoeuvrability* (MSC/Circ.1053), as may be amended.

~~2 The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, and so to bring the ship to rest within a reasonable distance from maximum ahead service speed, shall be demonstrated and recorded.~~

~~3~~ 5.5 The stopping times, ship headings and distances recorded on trials, together with the corresponding stopping procedures ~~results of trials to determine the ability of ships having multiple propellers to navigate and manoeuvre with one or more propellers inoperative~~, shall be readily available on board for the use of the master or designated personnel through the wheelhouse poster and manoeuvring booklet as defined in Resolution A.601(15).

~~4~~ 5.6 Where the ship is provided with supplementary means for manoeuvring or stopping, the effectiveness of such means shall be demonstrated by trials and the results recorded as referred to in paragraph~~s 2 and 3~~ 5.5.

SOLAS Ch. II-1, Part C, regulation 29

The whole Regulation 29 is replaced as follows:

Regulation 29 Steering

1 SCOPE
This regulation is addressing steering function and steering performance of the ship, as well as requirements for the steering system(s) and its power supply.

2 GOAL
The goal of this regulation is to prevent casualties arising from malfunction, insufficient performance or incorrect use of steering system(s).

3 FUNCTIONAL REQUIREMENTS

In order to achieve the goal in paragraph 2 above, the following functional requirements shall be met:

1. The steering system provides adequate steering performance for ship operation.
2. The steering capability is maintained or can be regained in case of malfunction in either the steering control or steering actuating sub-systems or both together.
3. The steering system is designed adequately for operational loads.
4. The steering system is protected from external impacts.
5. The steering system is arranged to minimize impact of erroneous functionality.
6. The steering system is arranged to minimize impact of erroneous operation.
7. Proper ship operation is enabled by providing information about ship’s manoeuvring characteristics.

4 SHIP STEERING PERFORMANCE

4.1 For the purpose of present paragraph 4, a ship with steering system in reduced service is assumed to be as follows:

4.1.1 For ships with single steering system, one steering gear power unit shall be out of operation.

4.1.2 For ships with multiple steering systems, the least favourable steering system shall be out of operation.

4.2 Ships shall, both under normal operational condition and when the steering system is in reduced service, meet the criteria for heading keeping ability in paragraph 5.3.5 of Resolution MSC.137(76).

4.3 Ships under normal operational condition shall meet the criteria for turning ability in paragraph 5.3.1.1 of Resolution MSC.137(76).

4.4 Passenger ships of 70,000 gross tonnage and upwards shall, when the steering system is in reduced service, meet the criteria for turning ability in paragraph 5.3.1.1 of Resolution MSC.137(76).

4.5 Passenger ships of less than 70,000 gross tonnage and any cargo ship shall, when the steering system is in reduced service, meet the criteria for turning ability in paragraph 5.3.1.2 of Resolution MSC.137(76).

4.6 Compliance with ship steering performance requirements shall be demonstrated by trials and the results shall be recorded. Trials shall be performed according to procedure and in condition as defined in paragraphs 4, 5.1, 5.2 and 6 of Resolution MSC.137(76).

4.7 For the purpose of this regulation, those paragraphs of Resolution MSC.137(76) referred in the preceding paragraphs 4.2 to 4.6 shall be treated as mandatory.

5 INFORMATION TO OFFICER IN CHARGE OF NAVIGATIONAL WATCH

To enable proper operation, information about ship's manoeuvring characteristics shall be made readily available for the use of the master or designated personnel in the form of:

.1 Simple operation instruction showing available backup solutions, switchover procedure and responses to alarms to speedily regain steering. Instruction shall be displayed at navigation position(s) and in steering gear compartment(s).

.2 Pilot card, as defined in Resolution A.601(15).

.3 Wheelhouse poster, as defined in Resolution A.601(15).

.4 Manoeuvring booklet, as defined in Resolution A.601(15). Its content shall cover, as a minimum, the standard manoeuvres as listed in Resolution MSC.137(76), based on trial results and/or predictions, as appropriate.

6 DESIGN PRINCIPLES

6.1 All steering system components shall be of sound and reliable construction based on adequate strength assessment for ship operation and specified design life considering:

.1 mechanical, hydraulic and electrical loads;

.2 characteristic loads resulting from operation of the steering system at the ship:
  .1 environmental loads such as but not limited to waves, ice and ship motion;
  .2 loads generated from operation of steering gear within the ships design speed range ahead and astern;
.3 static and fatigue design criteria;
.4 degradation due to operational environment;
.5 degradation by wear and tear and
.6 safety factor(s) for scantling calculations adequately addressing uncertainty in load determination, material properties and component tolerances.

6.2 Special consideration shall be given to the suitability of any essential component which is not duplicated.

6.3 System shall be operable under ship motion and environmental conditions.

6.4 Loads resulting from malfunction of the system itself or external generated loads (excluding grounding), including dynamic effects, shall be limited to the design loads. Load limitation shall be provided by passive means.

6.5 To minimise the impact of erroneous operation or failure, the steering system shall prevent operation outside of declared steering angle limits considering combination of permissible steering angles and ship speed.

6.6 To minimise the impact of erroneous functionality, the failures likely to cause uncontrolled movement of steering force unit shall be identified. Steering gear shall be arranged so that, in the event of such failures, the steering force unit shall stop in the current position or return to midship/neutral without manual intervention.

7 FAILURE TOLERANCE OF STEERING SYSTEM

7.1 General

7.1.1 Every ship shall be provided with steering system(s) arranged so that any of the following single failures does not render the ship without steering capability:
  .1 Steering control system:
    .1 Failure of power supply
    .2 Component/sensor failure
    .3 Loop failure (short circuit, broken connection and earth faults)
    .4 Data communication error
    .5 Programmable system failures (hardware and software failure)
  .2 Steering gear
    .1 Failure of steering gear power unit
    .2 Failure in connection to power supply
    .3 Failure of hydraulic system: leakage and malfunction of valves
    .4 In the case of tankers, chemical tankers and gas carriers of 10,000 gross tonnage and upwards: failure of steering actuator

7.1.2 The following failures do not need to be considered:
  .1 Blockage/damage on tiller/mechanical transmission
  .2 Blockage/seizure of hydraulic actuator
  .3 Blockage/seizure of electric actuator
  .4 Blocking/damage on steering force unit

7.2 Ships with multiple steering systems

A ship with multiple steering systems is considered to be sufficiently fault tolerant as per 7.1, provided the following is complied with:

7.2.1 Each steering system is provided with an independent steering gear capable of meeting the requirements in paragraph 8.1.1.

7.2.2 To minimise the impact of either steering gear power unit or steering actuator failure, means shall be provided for positioning and locking any failed steering system in neutral position.

7.3 Ships with single steering system

A ship with single steering system is considered to be sufficiently fault tolerant as per 7.1, provided the following is complied with:

7.3.1 The steering actuating system shall be so arranged that after a single failure in one of the steering gear power units or, in case of hydraulic power operated, its piping system, the defect can be isolated so that steering capability can be maintained or regained within 15 minutes.

7.3.2 Every tanker, chemical tanker or gas carrier of 10,000 gross tonnage and upwards provided with a single steering system shall comply with the following:

7.3.2.1 The steering actuating system shall be so arranged that after a single failure in one of the steering gear power units, steering actuators or, in case of hydraulic power operated, its piping system; the defect can be isolated so that steering capability as per 8.1.1 can be maintained or automatically regained within 45 seconds.

7.3.2.2 Two identical steering actuating systems shall be arranged. However, tankers, chemical tankers or gas carriers of less than 100,000 tonnes deadweight do not need to have redundant steering actuators provided that an equivalent safety standard is achieved and special consideration is given to the following:

.1 material used;

.2 stress analysis for the design including fatigue analysis and fracture mechanics analysis;

.3 installation of sealing arrangements;

.4 testing and inspection;

.5 provision of effective maintenance.

In consideration of the foregoing, the Administration shall adopt regulations which include the provisions of the Guidelines for acceptance of non-duplicated steering actuators for tankers, chemical tankers and gas carriers of 10,000 tons gross tonnage and above but less than 100,000 tonnes deadweight, adopted by the Organization.[7]

[7] Refer to *Guidelines for acceptance of non-duplicated steering actuators for tankers, chemical tankers and gas carriers of 10,000 tons gross tonnage and above but less than 100,000 tonnes deadweight* (resolution A.467(XII), as may be amended).

8 STEERING GEAR PERFORMANCE

8.1 Each steering gear shall have the following performance:

8.1.1 Ability in normal operational condition, operating at maximum ahead service speed:

.1 Turn each steering force unit between declared steering angles limits;

.2 Turn each steering force unit from declared steering angle limit on one side to 85% of declared steering angle limit on the other in not more than 28 seconds. The steering gear shall be operated by power where necessary to meet this requirement and, in any case:

.1 for rudder based steering systems, when the Administration requires a rudder stock of over 120 mm diameter in way of tiller, excluding strengthening for navigation in ice;

.2 for thruster based steering systems.

8.1.2 For ships with single steering system, ability when one steering gear power unit is out of operation:

.1 Passenger ships of 70,000 gross tonnage and upwards shall meet the requirements in paragraph 8.1.1.

.2 Tankers, chemical tankers and gas carriers of 10,000 gross tonnage and upwards and every other cargo ship of 70,000 gross tonnage and upwards shall be able to turn the steering force unit from declared steering angle limit on one side to 85% of declared steering angle limit on the other in not more than 56 seconds, with the ship running ahead at maximum ahead service speed;

.3 Any other ship not considered in the previous two subparagraphs shall be able to turn the steering force unit from 50% of declared steering angle limit on one side to 50% of declared steering angle limit on the other in not more than 60 seconds, with the ship running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater.

.4 The steering gear shall be operated by power where necessary to meet this requirement and, in any case:

.1 for rudder based steering systems, when the Administration requires a rudder stock of over 230 mm diameter in way of tiller, excluding strengthening for navigation in ice;

.2 for thruster based steering systems, when the propulsion power per thruster unit exceeds 2,500 kW.

8.1.3 For rudder-based steering systems, the declared steering angle limit shall be 35 degrees unless otherwise is substantiated.

8.2 Compliance with steering gear performance requirements shall be demonstrated by trials and the results shall be recorded.

8.3 Trials shall be performed with the ship at its deepest seagoing draught and even keel. Where this cannot be achieved, the procedure in MSC.1/Circ.1536 may be followed to predict full load results based on test results.

9 STEERING CONTROL SYSTEM

9.1 Steering control and monitoring function

9.1.1 Steering control and monitoring systems shall be arranged to ensure safe, efficient and reliable operation of the steering system from the dedicated control positions.

9.1.2 No single failure in steering control system shall cause loss of steering capability.

9.1.3 Availability and performance of steering system shall be continuously monitored and indicated on navigation position.

9.2 Steering control systems

9.2.1 Ships shall be provided with at least two independent steering control systems.

9.2.2 The two independent steering control systems shall, as far as practicable, be arranged with physical segregation.

9.2.3 It shall be possible to operate each independent steering control system both remotely from the navigating bridge and locally from the steering gear compartment(s) as follows:

- .1 Remote control:
  - .1 The navigating bridge is the main command position for remote steering.
  - .2 Means to bring the steering system into operation shall be provided.
  - .3 If multiple steering modes are available, a mode selector function and indication shall be provided.
- .2 Local control:
  - .1 The local control shall not depend on any part of the control system located outside the steering gear compartment.
  - .2 Means shall be provided to disable remote control.

9.2.4 Independent steering control systems may be interfaced to common external systems/units (e.g. autopilot, dynamic positioning or mode selector) if no single failures in the external system/unit can propagate to the independent steering control systems.

9.2.5 A common lever/steering wheel may serve independent steering control systems provided that the electrical transmitters and circuits serving the control systems are independent.

9.3 Alarm and monitoring

9.3.1 Alarm functions for all steering systems may be arranged in a common alarm system.

9.3.2 The most probable failures with the potential of functional loss, reduced or erroneous system performance shall be detected and alarmed. At least, the following failures shall be included:

1. Steering Control and monitoring system failures:
    1. Equipment/component failures
    2. Power supply failure including earth fault
    3. Loop failure in closed loop systems (open loop, short circuit, earth fault)
    4. Sensor failure
    5. Data communication failure
    6. Hardware/Software failure in programmable systems
2. Steering function response failures:
    1. Deviation between steering command and feedback
3. Steering gear failures:
    1. Conflicting operation of two steering actuators in a common steering system that may cause blocking and loss of steering
    2. Steering gear power unit failure
    3. If hydraulically powered: low level alarm in reservoir, hydraulic locking, leakage, malfunction of valves
4. Steering gear power units failures: electric power supply failures: phase failure, overload
5. Converters failures: power supply failure, converter failure, converter trip and earth failure.

9.3.3 Failure conditions shall initiate alarms at the navigating bridge and/or engine-/control room.

9.3.4 Alarms presented at the navigating bridge shall be limited to those requiring attention from bridge personnel, according the following categories:

1. All alarms requiring immediate attention and action from the bridge: Alarm status shall be continuously displayed, readily observable at the steering stand;
2. All other failures and conditions not immediately affecting steering capabilities shall be presented by warnings. Warnings are presented for precautionary reasons and can be displayed individually or in groups

9.3.5 All alarms and warnings shall be given in engine-/control room, including those presented at the navigating bridge.

9.3.6 Alarm acknowledgment shall, in general, be only possible from the location that is responsible to respond. Only alarms that specifically demand attention from the navigation bridge shall be acknowledged from the bridge.

9.3.7 For unattended machinery operations, the engine-/control room alarms shall be presented through the alarm systems.

9.4 Indicators

9.4.1 All necessary indicators for the safe operation of the ship shall be provided at each control position including:

- .1 remotely at the navigating bridge: steering force angle indication for each steering force unit, independent of any remote control system;
- .2 remotely at other control positions, if provided: steering angle indication for each steering force unit;
- .3 locally in the steering gear compartment(s):
  1. steering angle indication for each steering force unit. Indication system shall be independent of the remote control system;
  2. vessel heading.

9.4.2 Steering gear power units

The steering gear power units shall be:

- .1 provided with necessary means for control and indication from the required steering control positions,
- .2 arranged to re-start automatically when power is restored after a power failure.

9.5 Power supply

Each steering control system shall be:

1. fed by a separate circuit from either the circuit of the power units of the associated steering gear from a point within the steering gear compartment, or directly from switchboard busbars supplying the power units of the associated steering gear at a point on the switchboard adjacent to the supply to the power units of the associated steering gear, and

2. the switchboard connection shall be provided with short circuit protection.

9.6 Response to failures

A single failure in a steering control system shall:

1. Not affect the other, independent steering control system

2. Lead to the least critical state of the steering system

3. If leading to loss of control of the associated steering force unit, put the steering force unit to neutral position or freeze it in its present steering angle. In the latter case, it shall be arranged such that the steering force unit can be positioned and locked in neutral position by the means prescribed in paragraph 7.2.2.

4. Not impair the steering systems ability to automatically prevent steering angles beyond the declared limits in any mode of operation

5. Be detected and alarmed

10 HYDRAULIC POWER SUPPLY

10.1 Hydraulic power-operated steering gear shall be provided with the following:

1. arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system;

2. a low-level alarm for each hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage.

3. relief valves shall be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The setting of the relief valves shall not exceed the design pressure. The valves shall be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

4. for ships with single steering system: a fixed storage tank having sufficient capacity to recharge at least one steering actuating system including the reservoir. The storage tank shall be:

   .1 permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering gear compartment; and,

   .2 provided with a contents gauge.

10.2 The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure shall be at least 1.25 times the maximum working pressure to be expected under the operational conditions specified in paragraph 8.1.1, taking into account any pressure which may exist in the low pressure side of the system. At the discretion of the Administration, fatigue criteria shall be applied for the design of piping and components, taking into account pulsating pressures due to dynamic loads.

11 ELECTRIC POWER SUPPLY

11.1 Electric power supply for steering gear shall be arranged such that a single circuit failure shall not render the ship without steering capability.

11.2 In case the ship is provided with multiple steering systems, each steering gear shall be served by at least one exclusive circuit fed directly from the main switchboard. In case of a split switchboard, the circuits shall be taken from separate sides.

11.3 In case the ship is provided with a single steering system, the steering gear shall be served by at least two exclusive circuits fed directly from the main switchboard. In case of a split switchboard, the circuits shall be taken from separate sides; however, one of the circuits may be supplied through the emergency switchboard.

11.3.1 For ships of less than 1,600 gross tonnage, the steering gear complying with paragraph 8.1.1 may be fed by only one electric circuit from the main switchboard when the steering gear complying with paragraph 8.1.2, if different, is required to be operated by power and either:

1. is not electrically powered or,

2. is electrically powered by an electric motor primarily intended for other services. The requirement in paragraphs 11.6 and 11.7 may be waived by the Administration for such a non-exclusive circuit if satisfied with the protection arrangement together with the requirements in paragraphs 9.4.2 and 9.2.3.

11.4 Alternative electric power supply

11.4.1 An alternative electric power supply shall be provided from the emergency source of electrical power or from an independent and dedicated power source located in the steering gear compartment:

1. For rudder based steering systems, when the Administration requires a rudder stock of over 230 mm diameter in way of the tiller, excluding strengthening for navigation in ice.

2. For thruster based steering systems proving certain steering capability due to ship speed also in case propulsion power has failed, when the propulsion power per thruster unit exceeds 2,500 kW.

11.4.2 This alternative electric power supply shall:

1. be provided automatically within 45 seconds;
2. be sufficient to turn the steering force unit from 50% of declared steering angle limit on one side to 50% of declared steering angle limit on the other in not more than 60 seconds, with the ship running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater;
3. be sufficient to power the associated steering control system and the steering angle indicator;
4. for every ship of 10,000 gross tonnage and upwards, have a capacity for at least 30 minutes of continuous operation and in any other ship for at least 10 minutes. The Administration may waive this requirement provided that an equivalent availability of power supply is proven.

11.5 The circuits supplying an electric or electrohydraulic steering gear shall have adequate rating for supplying all motors which can be simultaneously connected to them and may be required to operate simultaneously.

11.6 Short circuit protection and an overload alarm shall be provided for circuits and motors.

11.7 If excess current protection is provided, the release current shall not be less than twice the full load current. Circuits obtaining their power supply via an electronic converter, which are limited to full load current, are exempted from the requirement to only trip upon short circuit.

11.8 Converters shall be provided with alarm for power supply failure, converter failure, converter trip and earth failure.

12 STEERING GEAR COMPARTMENT

12.1 To protect steering system from external impacts, the steering gear compartment(s) shall as far as practicable be separated from other machinery spaces.

12.2 To enable regaining steering by local control, as well as enabling inspection and maintenance, the steering gear compartment(s) shall be:

1. readily accessible;
2. provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements shall include handrails and gratings or other non-slip surfaces;
3. provided with means of two-way communication between the navigating bridge and the steering gear compartment.

SOLAS Ch. II-1, Part C, regulation 30

Regulation 30 is deleted.

Regulation 30 Additional requirements for electric and electrohydraulic steering gear

[content incorporated in Reg.29]

SOLAS Ch. II-1, Part C, regulation 42

Paragraph 2.5 of Regulation 42 is amended as follows:

Regulation 42 Emergency source of electrical power in passenger ships

2.5 For the period of time required by regulation 29.11.4 the steering gear if required to be so supplied by that regulation.

SOLAS Ch. II-1, Part C, regulation 43

Paragraph 2.6.1 of Regulation 43 is amended as follows:

Regulation 43 Emergency source of electrical power in cargo ships

2.6.1 For the period of time required by regulation 29.11.4 the steering gear ~~where it is~~ if required to be so supplied by that regulation.

SOLAS Ch. V, regulation 25

Regulation 25 is amended as follows:

Regulation 25 Operation of steering gear

In areas where navigation demands special caution, ships shall have more than one steering gear power unit in operation when such units are capable of simultaneous operation. Ships with multiple steering systems shall have more than one steering system in operation.

SOLAS Ch. V, regulation 26

Regulation 26 is amended as follows:

Regulation 26 Steering gear: Testing and drills

1 Within 12 hours before departure, the ship's steering gear shall be checked and tested by the ship's crew. The test procedure shall include, where applicable, the operation of the following:

.1 the ~~main~~ steering gear(s);

.2 ~~the auxiliary steering gear;~~ manual isolation arrangements to regain steering

.3 the remote steering gear control systems;

.4 the steering positions located on the navigation bridge;

.5 the emergency power supply;

.6 the ~~rudder~~ steering angle indicators in relation to the actual position of the steering force unit ~~rudder~~;

.7 the remote steering gear control system power failure alarms;

.8 the steering gear power unit failure alarms; and

.9 automatic isolating arrangements and other automatic equipment.

2 The checks and tests shall include:

.1 the full movement of the ~~rudder~~ steering force unit according to the required capabilities of the steering gear;

.2 a visual inspection for the steering gear and its connecting linkage; and

.3 the operation of the means of communication between the navigation bridge and steering gear compartment.

3.1 Simple operating instructions with a block diagram showing the change-over procedures for remote steering gear control systems and steering gear power units shall be permanently displayed on the navigation bridge and in the steering compartment.

3.2 All ships' officers concerned with the operation and/or maintenance of steering gear shall be familiar with the operation of the steering systems fitted on the ship and with the procedures for changing from one system to another, as well as the ship's manoeuvring characteristics.

4 In addition to the routine checks and tests prescribed in paragraphs 1 and 2, emergency steering drills shall take place at least once every three months in order to practise emergency steering procedures. These drills shall include direct control within the steering gear compartment, the communications procedure with the navigation bridge and, where applicable the operation of alternative power supplies.

5 The Administration may waive the requirements to carry out the checks and tests prescribed in paragraphs 1 and 2 for ships which regularly engage on voyages of short duration. Such ships shall carry out these checks and tests at least once every week.

6 The date upon which the checks and tests prescribed in paragraphs 1 and 2 are carried out and the date and details of emergency steering drills carried out under paragraph 4, shall be recorded.

Circular MSC.1/Circ.1536

Annex to MSC.1/Circ.1536 is amended as follows:

ANNEX

UNIFIED INTERPRETATIONS OF SOLAS REGULATION~~S~~ II-1/29.8~~3~~ ~~AND II-1/29.4~~

Regulation II-1/29 – Steering ~~gear~~

1 In order for ships to comply with the performance requirements stated in regulation~~s~~ II-1/29.8.1~~3.2 and 29.4.2~~, they are to have steering gear capable of meeting these performance requirements when at their deepest seagoing draught.

2 In order to demonstrate this ability, the trials may be conducted in accordance with section 6.1.5.1 of the standard ISO 19019:2005 (Sea-going vessels and marine technology – Instructions for planning, carrying out and reporting sea trials).

3 On all occasions when trials are conducted with the vessel not at the deepest seagoing draught, the loading condition can be accepted on the conditions that either:

.1 The ~~rudder~~ steering force unit is fully submerged (at zero speed waterline) and the vessel is in an acceptable trim condition.

.2 For traditional steering systems with rudder: The rudder torque at the trial loading condition has been reliably predicted (based on the system pressure measurement) and extrapolated to the maximum seagoing draught condition using the following method to predict the equivalent torque and actuator pressure at the deepest seagoing draught:

$$Q_F = Q_T \alpha$$

$$\alpha = 1.25\left(\frac{A_F}{A_T}\right)\left(\frac{V_F}{V_T}\right)^2$$

where:

α is the Extrapolation factor.

Q_F is the rudder stock moment (torque in the rudder stock) for the deepest service draught and maximum service speed condition.

Q_T is the rudder stock moment (torque in the rudder stock) for the trial condition.

A_F is the total immersed projected area of the movable part of the rudder in the deepest seagoing condition.

A_T is the total immersed projected area of the movable part of the rudder in the trial condition.

V_F is the contractual design speed of the vessel corresponding to the maximum continuous revolutions of the main engine at the deepest seagoing draught.

V_T is the measured speed of the vessel (considering current) in the trial condition.

Where the rudder actuator system pressure is shown to have a linear relationship to the rudder stock torque the above equation can be taken as:

$$P_F = P_T \alpha$$

where:

P_F is the estimated steering actuator hydraulic pressure in the deepest seagoing draught condition.

P_T is the maximum measured steering actuator hydraulic pressure in the trial condition.

Where constant volume fixed displacement pumps are utilized then the regulations can be deemed satisfied if the estimated steering actuator hydraulic pressure at the deepest draught is less than the specified maximum working pressure of the rudder actuator. Where a variable delivery pump is utilized pump data should be supplied and interpreted to estimate the delivered flow rate corresponds to the deepest seagoing draught in order to calculate the steering time and allow it to be compared to the required time.

Where A_T is greater than $0.95A_F$ there is no need for extrapolation methods to be applied.

.3 Alternatively, the designer or builder may use computational fluid dynamic (CFD) studies or experimental investigations to predict the rudder stock moment at the full seagoing draught condition and service speed. These calculations or experimental investigations should be to the satisfaction of the Administration.

4 ~~In any case for the main steering gear trial, t~~The speed of the ship corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch applies in general for the trial condition, except for testing the performance stated in regulation II-1/29.8.1.2.3, where one half of that speed or 7 knots, whichever is greater, applies.

Resolution A.467(XII)

Annex to Resolution A.467(XII) is amended as follows:

ANNEX

GUIDELINES FOR ACCEPTANCE OF NON-DUPLICATED ~~RUDDER~~STEERING ACTUATORS FOR TANKERS, CHEMICAL TANKERS AND GAS CARRIERS OF 10,000 GROSS TONNAGE AND ABOVE BUT LESS THAN 100,000 TONNES DEADWEIGHT

(References are related to Regulations II-1/29.~~2~~10.1.3 and 29.~~3.2~~8.1.1 of the ~~1981~~2014 amendments to the 1974 SOLAS Convention)

1 MATERIALS

Parts subject to internal hydraulic pressure or transmitting mechanical forces to the ~~rudder stock~~steering force unit should be made of duly tested ductile materials complying with recognized standards. Materials for pressure retaining components should be in accordance with recognized pressure vessel standards. These materials should not have an elongation of less than 12 per cent nor a tensile strength in excess of 650 N/mm².

2 DESIGN

Design pressure

2.1 The design pressure should be assumed to be at least equal to the greater of the following:

> .1 1.25 times the maximum working pressure to be expected under the operating conditions required in regulation 29.~~3.2~~8.1.1;
>
> .2 the relief valves setting.

Analysis

2.2.1 The manufacturers of ~~rudder~~steering actuators should submit detailed calculations showing the suitability of the design for the intended service.

2.2.2 A detailed stress analysis of the pressure retaining parts of the steering actuator should be carried out to determine the stresses at the design pressure.

2.2.3 Where considered necessary because of the design complexity or manufacturing procedures, a fatigue analysis and fracture mechanics analysis may be required. In connexion with these analyses, all foreseen dynamic loads should be taken into account. Experimental stress analysis may be required in addition to, or in lieu of, theoretical calculations depending on the complexity of the design.

Allowable stresses

2.3 For the purpose of determining the general scantlings of parts of ~~rudder~~steering actuators subject to internal hydraulic pressure, the allowable stresses should not exceed:

$$\sigma_m \leq f$$

$$\sigma_\ell \leq 1.5f$$

$$\sigma_b \leq 1.5f$$

$$\sigma_\ell + \sigma_b \leq 1.5f$$

$$\sigma_m + \sigma_b \leq 1.5f$$

where

σ_m = equivalent primary general membrane stress

σ_ℓ = equivalent primary local membrane stress

σ_b = equivalent primary bending stress

f = the lesser of σ_B/A or σ_y/B

σ_B = specified minimum tensile strength of material at ambient temperature

σ_y = specified minimum yield stress or 0.2 per cent proof stress of material at ambient temperature

A and B are as follows:

	Steel	Cast steel	Nodular cast iron
A	4	4.6	5.8
B	2	2.3	3.5

Burst test

2.4.1 Pressure retaining parts not requiring fatigue analysis and fracture mechanics analysis may be accepted on the basis of a certified burst test at the discretion of the Administration and the detailed stress analysis required by 2.2.2 need not be provided.

2.4.2 The minimum bursting pressure should be calculated as follows:

$$P_b = P \cdot A \cdot \sigma_{Ba}/\sigma_B$$

where

P_b= minimum bursting pressure

P = design pressure as defined in 2.1

A = as from table in 2.3

σ_{Ba} = actual tensile strength

σ_B = tensile strength as defined in 2.3

3 CONSTRUCTION DETAILS

General

3.1 The construction should be such as to minimize local concentrations of stress.

Welds

3.2.1 The welding details and welding procedures should be approved.

3.2.2 All welded joints within the pressure boundary of a ~~rudder~~steering actuator or connecting parts transmitting mechanical loads should be full penetration type or of equivalent strength.

Oil seals

3.3.1 Oil seals between non-moving parts, forming part of the external pressure boundary, should be of the metal upon metal type or of an equivalent type.

3.3.2 Oil seals between moving parts, forming part of the external pressure boundary, should be duplicated, so that the failure of one seal does not render the steering actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted at the discretion of the Administration.

Isolating valves

3.4 Isolating valves should be fitted at the connexion of pipes to the steering actuator, and should be directly mounted on the steering actuator.

Relief valves

3.5 Relief valves for protecting the ~~rudder~~steering actuator against over-pressure as required in regulation 29.~~2~~10.1.3 should comply with the following:

> .1 The setting pressure should not be less than 1.25 times the maximum working pressure expected under operating conditions required in regulation 29.~~3.2~~8.1.1.
>
> .2 The minimum discharge capacity of the relief valves should not be less than the total capacity of all pumps which provide power for the steering actuator, increased by 10 per cent. Under such conditions the rise in pressure should not exceed 10 per cent of the setting pressure. In this regard, due consideration should be given to extreme foreseen ambient conditions in respect of oil viscosity.

4 NON-DESTRUCTIVE TESTING

The ~~rudder~~steering actuator should be subjected to suitable and complete non-destructive testing to detect both surface flaws and volumetric flaws. The procedure and acceptance criteria for non-destructive testing should be in accordance with requirements of recognized standards. If found necessary, fracture mechanics analysis may be used for determining maximum allowable flaw size.

5 TESTING

5.1 Tests, including hydrostatic tests, of all pressure parts at 1.5 times the design pressure should be carried out.

5.2 When installed on board the ship, the ~~rudder~~steering actuator should be subjected to a hydrostatic test and a running test.

Resolution MSC.137(76)

Annex to Resolution MSC.137(76) is amended as follows:

ANNEX

STANDARDS FOR SHIP MANOEUVRABILITY

1 Principles

1.1 The Standards for ship manoeuvrability (the Standards) should be used to evaluate the manoeuvring performance of ships and to assist those responsible for the design, construction, repair and operation of ships.

1.2 It should be noted that the Standards were initially developed for ships with traditional propulsion and steering systems (e.g. shaft driven ships with conventional rudders) and have been further updated to also consider other known propulsion/steering systems (azimuthing thrusters, water jets, cycloidals and gate rudders). Therefore, the Standards and methods for establishing compliance may continue to be periodically reviewed and updated by the Organization, as appropriate, taking into account new technologies, research and development, and the results of experience with the present Standards.

2 General

2.1 The Standards contained in this document are based on the understanding that the manoeuvrability of ships can be evaluated from the characteristics of conventional trial manoeuvres. The following two methods can be used to demonstrate compliance with these Standards:

> .1 scale model tests and/or computer predictions using mathematical models can be performed to predict compliance at the design stage. In this case full- scale trials should be conducted to validate these results. The ship should then be considered to meet these Standards regardless of full-scale trial results, except where the Administration determines that the prediction efforts were substandard and/or the ship performance is in substantial disagreement with these Standards; and
>
> .2 the compliance with the Standards can be demonstrated based on the results of the full-scale trials conducted in accordance with the Standards. If a ship is found in substantial disagreement with the Standards, then the Administration should take remedial action, as appropriate.

3 Application

3.1 Notwithstanding the points raised in paragraph 1.2 above, the Standards should be applied to ships of all ~~rudder~~steering and propulsion types, of 100 m in length and over, and tankers, chemical tankers and gas carriers regardless of the length. The criteria contained in paragraphs 5.3.1, 5.3.4 and 5.3.5, any related definition in paragraph 4 as well as the conditions and considerations in paragraphs 5.1, 5.2 & 6, all of them mandatory under Chapter II-1 of the 1974 SOLAS Convention, are also applicable to any ship subject to referred Chapter II-1 of the 1974 SOLAS Convention.

3.2 In the event that the ships referred to in paragraph 3.1 above undergo repairs, alterations or modifications, which, in the opinion of the Administration, may influence their manoeuvrability characteristics, the continued compliance with the Standards should be verified.

3.3 Whenever other ships, originally not subject to the Standards, undergo repairs, alterations or modifications, which, in the opinion of the Administration, are of such an extent that the ship may be considered to be a new ship, then that ship should comply with these Standards. Otherwise, if the repairs, alterations and modifications, in the opinion of the Administration, may influence the manoeuvrability characteristics, it should be demonstrated that these characteristics do not lead to any deterioration of the manoeuvrability of the ship.

3.4 The Standards should not be applied to high-speed craft as defined in the relevant Code.

4 Definitions

4.1 *Geometry of the ship*

4.1.1 *Length* (L) is the length ~~measured between the aft and forward perpendiculars~~as defined in the International Convention on Load Lines in force.

4.1.2 *Midship point* is the point on the centreline of a ship midway between the aft and forward perpendiculars.

4.1.3 *Draught* (T_a) is the draught at the aft perpendicular.

4.1.4 *Draught* (T_f) is the draught at the forward perpendicular.

4.1.5 *Mean draught* (T_m) is defined as $T_m = (T_a + T_f)/2$.

4.1.6 *Trim* (τ) is defined as $\tau = (T_a - T_f)$.

4.1.7 Δ is the full load displacement of the ship (tonnes).

4.2 *Standard manoeuvres and associated terminology*

Standard manoeuvres and associated terminology are as defined below:

.1 The test speed (V) used in the Standards is a speed of at least 90% of the ship's speed corresponding to 85% of the maximum engine output.

.2 Turning circle manoeuvre is the manoeuvre to be performed to both starboard and port with ~~35° rudder angle or the maximum rudder angle permissible~~declared steering angle limit (SOLAS, II-1, 3.9) at the test speed, following a steady approach with zero yaw rate.

.3 Advance is the distance travelled in the direction of the original course by the midship point of a ship from the position at which the steering order is given to the position at which the heading has changed 90° from the original course.

.4 Tactical diameter is the distance travelled by the midship point of a ship from the position at which the steering order is given to the position at which the heading has changed 180° from the original course. It is measured in a direction perpendicular to the original heading of the ship.

.5 Zig-zag test is the manoeuvre where a known amount of helm is applied alternately to either side when a known heading deviation from the original heading is reached.

.6 The 10°/10° zig-zag test is performed by ~~turning the rudder~~steering alternately by ~~10°~~1/3 of the declared steering angle limit to either side following a heading deviation of 10° from the original heading in accordance with the following procedure:

> .1 after a steady approach with zero yaw rate, the ~~rudder~~steering is put over to ~~10°~~1/3 of the declared steering angle limit to starboard or port (first execute);
>
> .2 when the heading has changed to 10° off the original heading, the ~~rudder~~steering is reversed to ~~10°~~1/3 of the declared steering angle limit to port or starboard (second execute); and
>
> .3 after the ~~rudder~~steering has been turned to port/starboard, the ship will continue turning in the original direction with decreasing turning rate. In response to the ~~rudder~~steering, the ship should then turn to port/starboard. When the ship has reached a heading of 10° to port/starboard of the original course the ~~rudder~~steering is again reversed to ~~10°~~1/3 of the declared steering angle limit to starboard/port (third execute).

.7 The first overshoot angle is the additional heading deviation experienced in the zig-zag test following the second execute.

.8 The second overshoot angle is the additional heading deviation experienced in the zig-zag test following the third execute.

.9 The 20°/20° zig-zag test is performed using the procedure given in paragraph 4.2.6 above using ~~20° rudder angles~~2/3 of the declared steering angle limit as steering angle and 20° change of heading, instead of ~~10° rudder angles~~1/3 of the declared steering angle limit and 10° change of heading, respectively.

.10 Full astern stopping test determines the track reach of a ship from the time an order for full astern is given until the ship stops in the water.

.11 Track reach is the distance along the path described by the midship point of a ship measured from the position at which an order for full astern is given to the position at which the ship stops in the water.

.12 The heading keeping test is performed by running straight ahead for 30 minutes. Autopilot may be engaged.

.13 The maximum yaw deviation is the maximum heading deviation from the preset heading.

.14 A ship with steering system in reduced service is assumed to be as follows (SOLAS, II-1, 29.4.1):

> .1 For ships with single steering system, one steering gear power unit shall be out of operation.
>
> .2 For ships with multiple steering systems, the least favourable steering system shall be out of operation.

4.3 Definitions contained in regulation 3 of SOLAS Chapter II-1 are also applicable.

5 Standards

5.1 The standard manoeuvres should be performed without the use of any manoeuvring aids which are not continuously and readily available in normal operation.

5.2 *Conditions at which the standards apply*

In order to evaluate the performance of a ship, manoeuvring trials should be conducted to both port and starboard and at conditions specified below:

.1 deep, unrestricted water;

.2 calm environment;

.3 full load (summer load line draught), even keel condition; and

.4 steady approach at the test speed.

5.3 *Criteria*~~*~~

~~* For ships with non-conventional steering and propulsion systems, the Administration may permit the use of comparative steering angles to the rudder angles specified by this Standard.~~

The manoeuvrability of the ship is considered satisfactory if the following criteria are complied with:

.1 Turning ability

.1 Standard criteria: t~~T~~he advance should not exceed 4.5 ship lengths (L) and the tactical diameter should not exceed 5 ship lengths in the turning circle manoeuvre.

.2 Reduced criteria: the advance should not exceed 5.6 ship lengths (L) and the tactical diameter should not exceed 6.25 ship lengths in the turning circle manoeuvre.

.3 The standard criteria are applicable to (SOLAS, II-1, 29.4.3-4):

a. Ships under normal operational condition.

b. Passenger ships of 70,000 gross tonnage and upwards also when the steering system is in reduced service.

.4 The reduced criteria are applicable to (SOLAS, II-1, 29.4.5):

a. Passenger ships of less than 70,000 gross tonnage and any cargo ship when the steering system is in reduced service.

.2 Initial turning ability

With the application of ~~10° rudder~~1/3 of the declared steering angle limit to port/starboard, the ship should not have travelled more than 2.5 ship lengths by the time the heading has changed by 10° from the original heading.

.3 Yaw-checking and course-keeping abilities

.1 The value of the first overshoot angle in the 10°/10° zig-zag test should not exceed:

.1 10° if L/V is less than 10 s;

.2 20° if L/V is 30 s or more; and

.3 [5 + 1/2(L/V)] degrees if L/V is 10 s or more, but less than 30 s, where L and V are expressed in m and m/s, respectively.

.2 The value of the second overshoot angle in the 10°/10° zig-zag test should not exceed:

.1 25°, if L/V is less than 10 s;

.2 40°, if L/V is 30 s or more; and

.3 [17.5 + 0.75(L/V)]°, if L/V is 10 s or more, but less than 30 s.

.3 The value of the first overshoot angle in the 20°/20° zig-zag test should not exceed 25°.

.4 Stopping ability

.1 Standard criterion: ~~t~~The track reach in the full astern stopping test should not exceed 15 ship lengths. However, this value may be modified by the Administration where ships of large displacement make this criterion impracticable, but should in no case exceed 20 ship lengths.

.2 Reduced criterion: the track reach in the full astern stopping test should not exceed 20 ship lengths.

.3 The standard criterion is applicable to (SOLAS, II-1, 28.5.1):

a. Ships under normal operational condition.

.4 The reduced criterion is applicable to (SOLAS, II-1, 28.5.2):

a. Ships provided with multiple propulsion lines while any one of the propulsion systems and its corresponding steering system is out of operation.

.5 Heading keeping ability

The maximum yaw deviation should not exceed 2 degrees during the heading keeping test both under normal operational condition and when the steering system is in reduced service.

6 Additional considerations

6.1 In case the standard trials are conducted at a condition different from those specified in paragraph 5.2.3, necessary corrections should be made in accordance with the guidelines contained in the Explanatory notes to the Standards for ship manoeuvrability, developed by the Organization*.

6.2 Where standard manoeuvres indicate dynamic instability, alternative tests may be conducted to define the degree of instability. Guidelines for alternative tests such as a spiral test or pull-out manoeuvre are included in the Explanatory notes to the Standards for ship manoeuvrability, referred to in paragraph 6.1 above.

* Refer to MSC/Circ.1053 on *Explanatory notes to the Standards for ship manoeuvrability* as may be amended.

Circular MSC/Circ.1053

Annex to MSC/Circ.1053 is amended as follows:

ANNEX

EXPLANATORY NOTES TO THE STANDARDS FOR SHIP MANOEUVRABILITY

CHAPTER 1 GENERAL PRINCIPLES

1.1 Philosophy and background

1.1.1 The purpose of this section is to provide guidance for the application of the Standards for Ship Manoeuvrability (resolution MSC.137(76)) along with the general philosophy and background for the Standards.

1.1.2 Manoeuvring performance has traditionally received little attention during the design stages of a commercial ship. A primary reason has been the lack of manoeuvring performance standards for the ship designer to design to, and/or regulatory authorities to enforce. Consequently, some ships have been built with very poor manoeuvring qualities that have resulted in marine casualties and pollution. Designers have relied on the shiphandling abilities of human operators to compensate for any deficiencies in inherent manoeuvring qualities of the hull. The implementation of manoeuvring standards will ensure that ships are designed to a uniform standard, so that an undue burden is not imposed on shiphandlers in trying to compensate for deficiencies in inherent ship manoeuvrability.

1.1.3 IMO has been concerned with the safety implications of ships with poor manoeuvring characteristics since the meeting of the Sub-Committee on Ship Design and Equipment (DE) in 1968. MSC/Circ.389 titled "Interim Guidelines for Estimating Manoeuvring Performance in Ship Design", dated 10 January 1985, encourages the integration of manoeuvrability requirements into the ship design process through the collection and systematic evaluation of ship manoeuvring data. Subsequently, the Assembly, at its fifteenth session in November 1987, adopted resolution A.601(15), entitled "Provision and Display of Manoeuvring Information on board Ships". This process culminated at the eighteenth Assembly in November 1993, where "Interim Standards for Ship Manoeuvrability" were adopted by resolution A.751(18).

1.1.4 After the adoption of resolution A.751(18), the Maritime Safety Committee, at its sixty-third session, approved MSC/Circ.644 titled "Explanatory notes to the Interim Standards for ship manoeuvrability", dated 6 June 1994, to provide Administrations with specific guidance so that adequate data could be collected by the Organization on the manoeuvrability of ships with a view to amending the aforementioned Interim Standards. This process culminated at the seventy-sixth session of the Maritime Safety Committee in December 2002, where Standards for ship manoeuvrability were adopted by resolution MSC.137(76).

1.1.5 The Standards were selected so that they are simple, practical and do not require a significant increase in trials time or complexity over that in current trials practice. The Standards are based on the premise that the manoeuvrability of ships can be adequately judged from the results of typical ship trials manoeuvres. It is intended that the manoeuvring performance of a ship be designed to comply with the Standards during the design stage, and that the actual manoeuvring characteristics of the ship be verified for compliance by trials. Alternatively, the compliance with the Standards can be demonstrated based on the results of full-scale trials, although the Administration may require remedial action if the ship is found in substantial disagreement with the Standards. Upon completion of ship trials, the shipbuilder should examine the validity of the manoeuvrability prediction methods used during the design stage.

1.2 Manoeuvring characteristics

The "manoeuvring characteristics" addressed by the IMO Standards for ship manoeuvrability are typical measures of performance quality and handling ability that are of direct nautical interest. Each can be reasonably well predicted at the design stage and measured or evaluated from simple trial-type manoeuvres.

1.2.1 Manoeuvring characteristics: general

1.2.1.1 In the following discussion, the assumption is made that the ship has normal actuators for the control of forward speed and heading positioned close to the stern (i.e., ~~a stern~~ propeller(s) and ~~a stern~~ rudder~~).~~(s), azimuthing thruster(s), water jet(s) or cycloidal(s)). However, most of the definitions and conclusions may also apply to ships with other (novel) types of control actuators.

1.2.1.2 In accepted terminology, questions concerning the manoeuvrability of a ship include the stability of steady-state motion with "fixed controls" as well as the time-dependent responses that result from the control actions used to maintain or modify steady motion, make the ship follow a prescribed path or initiate an emergency manoeuvre, etc. Some of these actions are considered to be especially characteristic of ship manoeuvring performance and therefore should be required to meet a certain minimum standard. A ship operator may choose to ask for a higher standard in some respect, in which case it should be remembered that some requirements may be mutually incompatible within conventional designs. For similar reasons the formulation of the IMO Standards for ship manoeuvrability has involved certain compromises.

1.2.2 Manoeuvring characteristics: some fundamentals (Reference is made to Appendix 1)

1.2.2.1 At a given engine output and ~~rudder~~steering angle δ, the ship may take up a certain steady motion. In general, this will be a turning motion with constant yaw rate $y\cancel{\psi}$, speed V and drift angle β (bow-in). The radius of the turn is then defined by the following relationship, expressed in consistent units:

$$R = V/y\cancel{\psi}.$$

1.2.2.2 This particular ship-~~rudder~~steering angle configuration is said to be "dynamically stable in a turn of radius R". Thus, a straight course may be viewed as part of a very wide circle with an infinite radius, corresponding to zero yaw rate.

1.2.2.3 Most ships, perhaps, are "dynamically stable on a straight course" (usually referred to as simply "dynamically stable") with the ~~rudder~~steering in a neutral position close to midship. In the case of a single screw ship with a right-handed propeller, this neutral helm is typically of the order δ_0 = -1° (i.e., 1° to starboard). Other ships which are dynamically unstable, however, can only maintain a straight course by repeated use of ~~rudder~~steering control. While some instability is fully acceptable, large instabilities should be avoided by suitable design of ship proportions and stern shape.

1.2.2.4 The motion of the ship is governed mainly by the propeller thrust and the hydrodynamic and mass forces acting on the hull. During a manoeuvre, the side force due to ~~the rudder~~steering is often small compared to the other lateral forces. However, the introduced controlling moment is mostly sufficient to balance or overcome the resultant moment of these other forces. In a steady turn there is complete balance between all the forces and moments acting on the hull. Some of these forces seeming to "stabilize" and others to "destabilize" the motion. Thus the damping moment due to yaw, which always resists the turning, is stabilizing and the moment associated with the side force due to sway is destabilizing. Any small disturbance of the equilibrium attitude in the steady turn causes a change of the force and moment balance. If the ship is dynamically stable in the turn (or on a straight course) the net effect of this change will strive to restore the original turning (or straight) motion.

1.2.2.5 The general analytical criterion for dynamic stability may be formulated and evaluated with the appropriate coefficients of the mathematical model that describes the ship' s motion. The criterion for dynamic stability on a straight course includes only four "linear stability derivatives" which together with the centre-of-gravity position, may be used to express the "dynamic stability lever". This lever denotes the longitudinal distance from the centre-of-pressure of the side force due to pure sway (or sideslip) to the position of the resultant side force due to pure turning, including the mass force, for small deviations from the straight-line motion. If this distance is positive (in the direction of positive x, i.e. towards the bow) the ship is stable. Obviously "captive tests" with a ship model in oblique towing and under the rotating arm will furnish results of immediate interest.

1.2.2.6 It is understood that a change of trim will have a marked effect mainly on the location of the centre-of-pressure of the side force resulting from sway. This is easily seen that a ship with a stern trim, a common situation in ballast trial condition, is likely to be much more stable than it would be on an even draught.

1.2.2.7 Figure 1 gives an example of the equilibrium yaw-rate/~~rudder~~steering angle relation for a ship which is inherently dynamically unstable on a straight course. The yaw rate is shown in the non-dimensional form for turn path curvature discussed above. This diagram is often referred to as "the spiral loop curve" because it may be obtained from spiral tests with a ship or model. The dotted part of the curve can only be obtained from some kind of reverse spiral test. Wherever the slope is positive, which is indicated by a tangent sloping down to the right in the diagram, the equilibrium balance is unstable. A ship which is unstable on a straight course will be stable in a turn despite the ~~rudder~~steering being fixed in the midship or neutral position. The curvature of this stable turn is called "the loop height" and may be obtained from the pull-out manoeuvre. Loop height, width and slope at the origin may all be regarded as a measure of the instability.

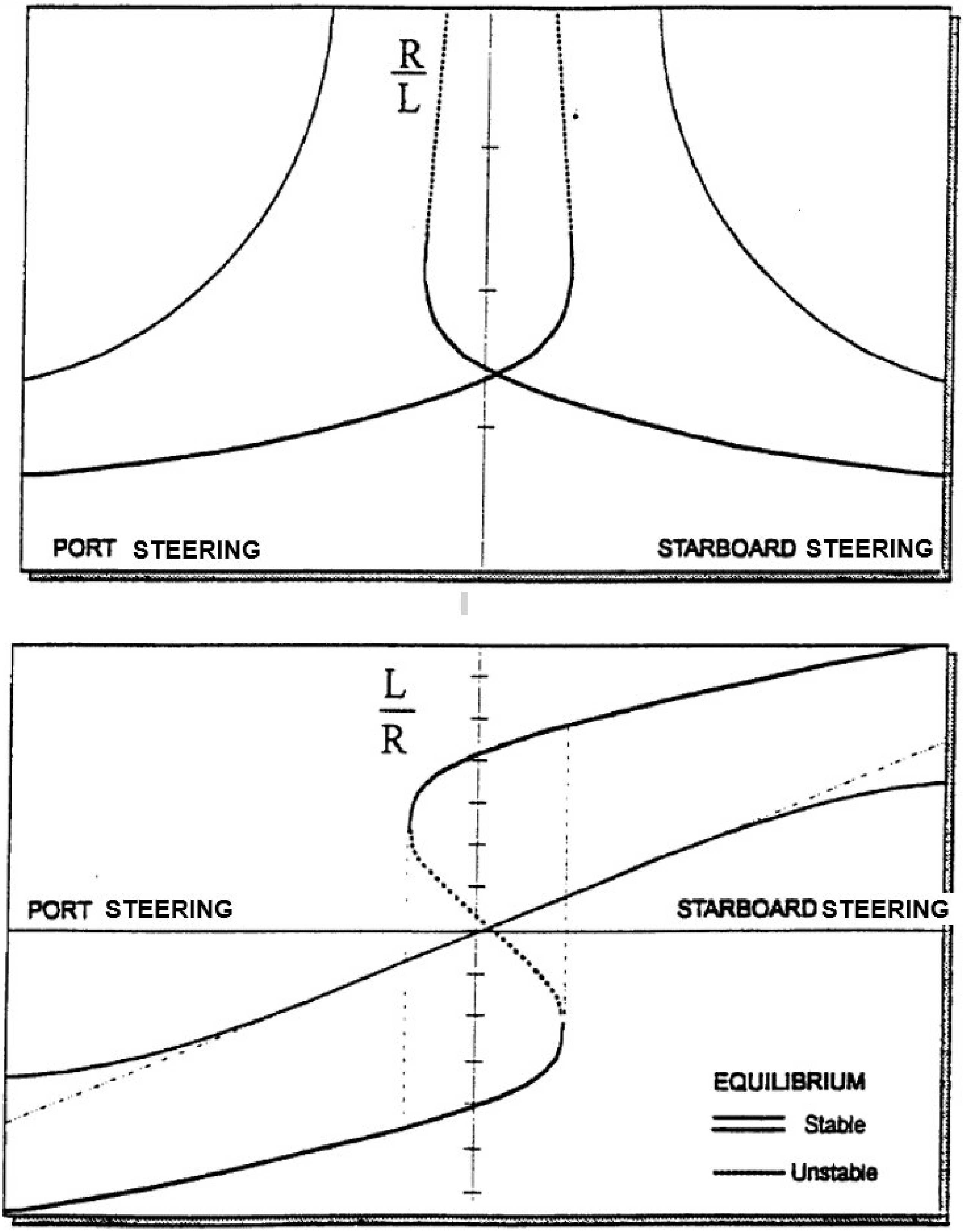


Figure 1 - The equilibrium yaw rate/~~rudder~~steering angle relation

1.2.2.8 If motion is not in an equilibrium turn, which is the general case of motion, there are not only unbalanced damping forces but also hydrodynamic forces associated with the added inertia in the flow of water around the hull. Therefore, if the ~~rudder~~steering is left in a position the ship will search for a new stable equilibrium. If the ~~rudder~~steering is shifted (put over "to the other side") the direction of the ship on the equilibrium turning curve is reversed and the original yaw tendency will be checked. By use of early counter-~~rudder~~steering it is fully possible to control the ship on a straight course with helm angles and yaw rates well within the loop.

1.2.2.9 The course-keeping ability or "directional stability" obviously depends on the performance of the closed loop system including not only the ship and ~~rudder~~steering but also the course error sensor and control system. Therefore, the acceptable amount of inherent dynamic instability decreases as ship speed increases, covering more ship lengths in a given period of time. This results because a human helmsman will face a certain limit of conceptual capacity and response time. This fact is reflected in the IMO Standards for ship manoeuvrability where the criterion for the acceptable first overshoot in a zig-zag test includes a dependence on the ratio L/V, a factor characterizing the ship "time constant" and the time history of the process.

1.2.2.10 In terms of control engineering, the acceptable inherent instability may be expressed by the "phase margin" available in the open loop. If the ~~rudder~~steering is oscillated with a given amplitude, ship heading also oscillates at the same frequency with a certain amplitude. Due to the inertia and damping in the ship dynamics and time delays in the steering engine, this amplitude will be smaller with increasing frequency, meaning the open loop response will lag further and further behind the ~~rudder~~steering input. At some certain frequency, the "unit gain" frequency, the response to the counter-~~rudder~~steering is still large enough to check the heading swing before the oscillation diverges (i.e., the phase lag of the response must then be less than 180°). If a manual helmsman takes over the heading control, closing the steering process loop, a further steering lag could result but, in fact, he will be able to anticipate the swing of the ship and thus introduce a certain "phase advance". Various studies suggest that this phase advance may be of the order of 10° to 20°. At present there is no straightforward method available for evaluating the phase margin from routine trial manoeuvres.

1.2.2.11 Obviously the course-keeping ability will depend not only upon the counter-~~rudder~~steering timing but also on how effectively the ~~rudder~~steering can produce a yaw checking moment large enough to prevent excessive heading error amplitudes. The magnitude of the overshoot angle alone is a poor measure for separating the opposing effects of instability and ~~rudder~~steering effectiveness, additional characteristics should therefore be observed. So, for instance, "time to reach second execute", which is a measure of "initial turning ability", is shortened by both large instability and high ~~rudder~~steering effectiveness.

1.2.2.12 It follows from the above that a large dynamic instability will favour a high "turning ability" whereas the large yaw damping, which contributes to a stable ship, will normally be accompanied by a larger turning radius. This is noted by the thin full-drawn curve for a stable ship included in figure 1.

1.2.2.13 Hard-over turning ability is mainly an asset when manoeuvring at slow speed in confined waters. However, a small advance and tactical diameter will be of value in case emergency collision avoidance manoeuvres at normal service speeds are required.

1.2.2.14 The "crash-stop" or "crash-astern" manoeuvre is mainly a test of engine functioning and ~~propeller~~propulsion reversal. The stopping distance is essentially a function of the ratio of astern power to ship displacement. A test for the stopping distance from full speed has been included in the Standards in order to allow a comparison with hard-over turning results in terms of initial speed drop and lateral deviations.

1.2.3 Manoeuvring characteristics: selected quality measures

The IMO Standards for ship manoeuvrability identify significant qualities for the evaluation of ship manoeuvring characteristics. Each has been discussed above and is briefly defined below:

.1 *Inherent dynamic stability:*

A ship is dynamically stable on a straight course if it, after a small disturbance, soon will settle on a new straight course without any corrective ~~rudder~~steering. The resultant deviation from the original heading will depend on the degree of inherent stability and on the magnitude and duration of the disturbance.

.2 *Course-keeping ability:*

The course-keeping quality is a measure of the ability of the steered ship to maintain a straight path in a predetermined course direction without excessive oscillations of ~~rudder~~steering or heading. In most cases, reasonable course control is still possible where there exists an inherent dynamic instability of limited magnitude.

.3 *Initial turning/course-changing ability:*

The initial turning ability is defined by the change-of-heading response to a moderate helm, in terms of heading deviation per unit distance sailed (the P number) or in terms of the distance covered before realizing a certain heading deviation (such as the "time to second execute" demonstrated when entering the zig-zag manoeuvre).

.4 *Yaw checking ability:*

The yaw checking ability of the ship is a measure of the response to counter-~~rudder~~steering applied in a certain state of turning, such as the heading overshoot reached before the yawing tendency has been cancelled by the counter-~~rudder~~steering in a standard zig-zag manoeuvre.

.5 *Turning ability:*

Turning ability is the measure of the ability to turn the ship using hard-over ~~rudder~~steering. The result being a minimum "advance at 90° change of heading" and "tactical diameter" defined by the "transfer at 180° change of heading". Analysis of the final turning diameter is of additional interest.

.6 *Stopping ability:*

Stopping ability is measured by the "track reach" and "time to dead in water" realized in a stop engine-full astern manoeuvre performed after a steady approach at full test speed. Lateral deviations are also of interest, but they are very sensitive to initial conditions and wind disturbances.

1.3 Tests required by the Standards

1.3.1 Turning tests

A turning circle manoeuvre is to be performed to both starboard and port with ~~35° rudder~~declared steering angle ~~or the maximum design rudder angle permissible~~limit at the test speed. The ~~rudder~~steering angle is executed following a steady approach with zero yaw rate. The essential information to be obtained from this manoeuvre is tactical diameter, advance, and transfer (see figure 2).

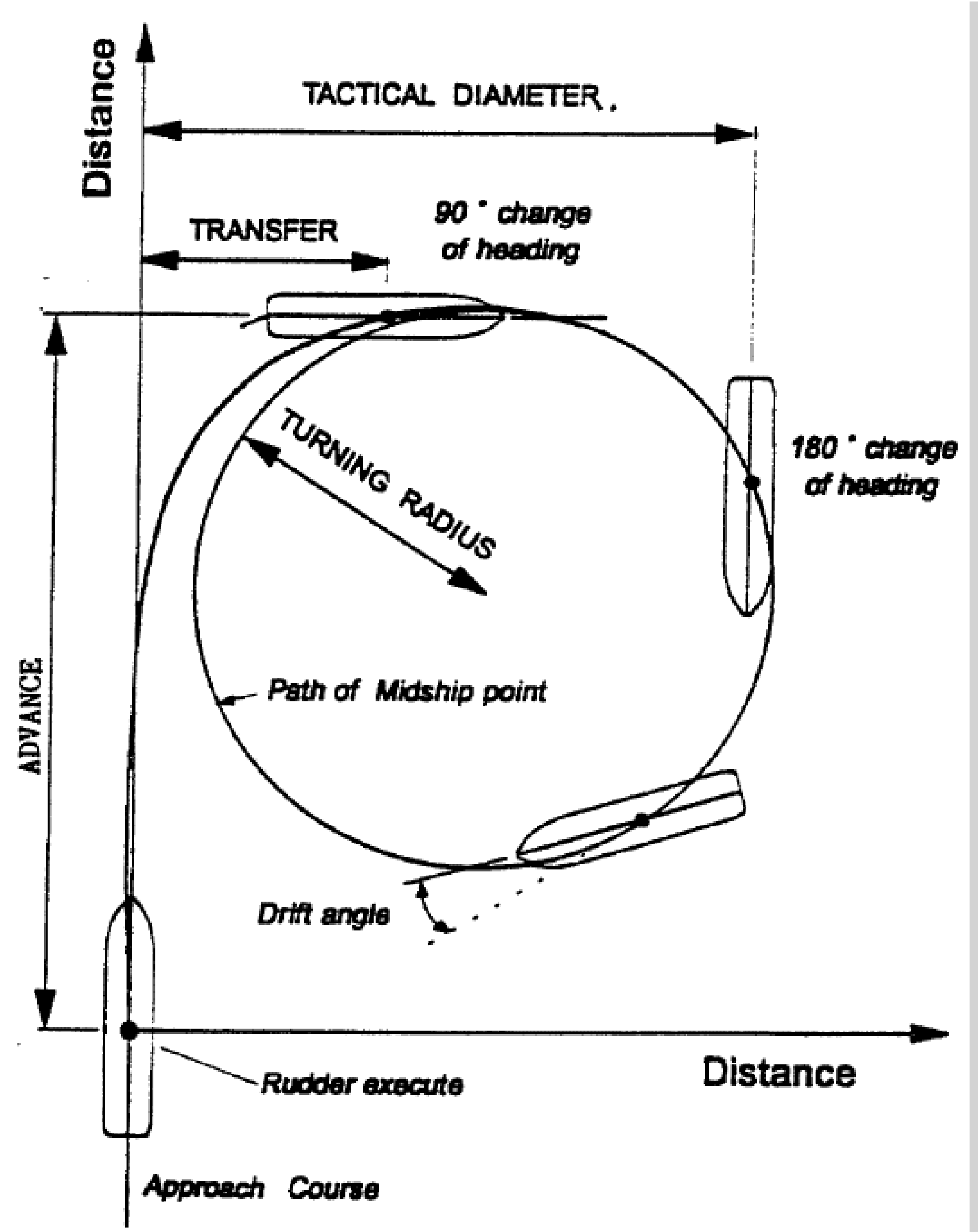
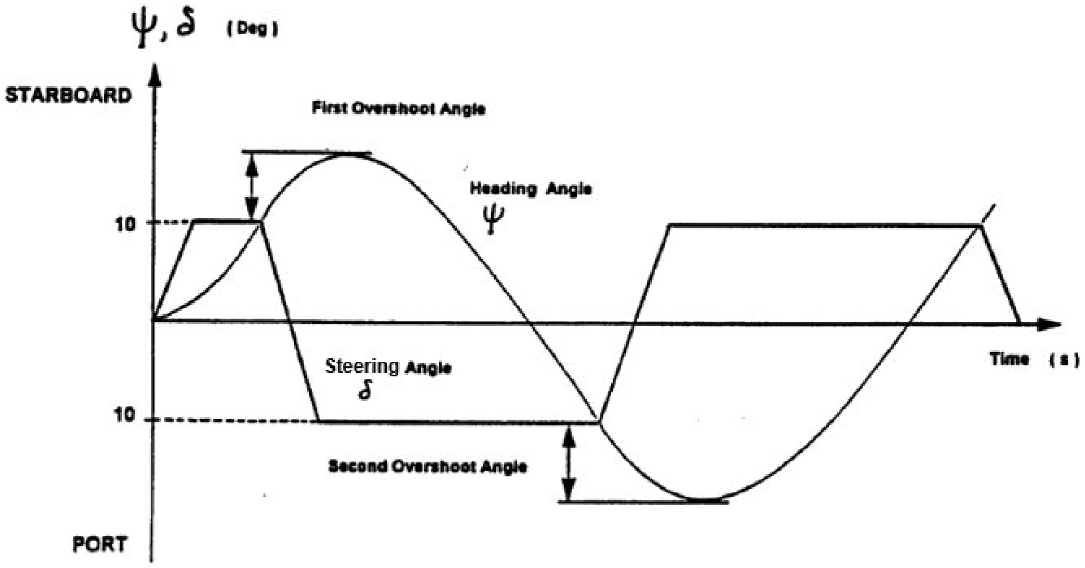


Figure 2 - Definitions used on turning circle test

1.3.2 Zig-zag tests

1.3.2.1 A zig-zag test should be initiated to both starboard and port and begins by applying a specified amount of ~~rudder~~steering angle to an initially straight approach ("first execute"). The ~~rudder~~steering angle is then alternately shifted to either side after a specified deviation from the ship' s original heading is reached ("second execute" and following) (see figure 3).



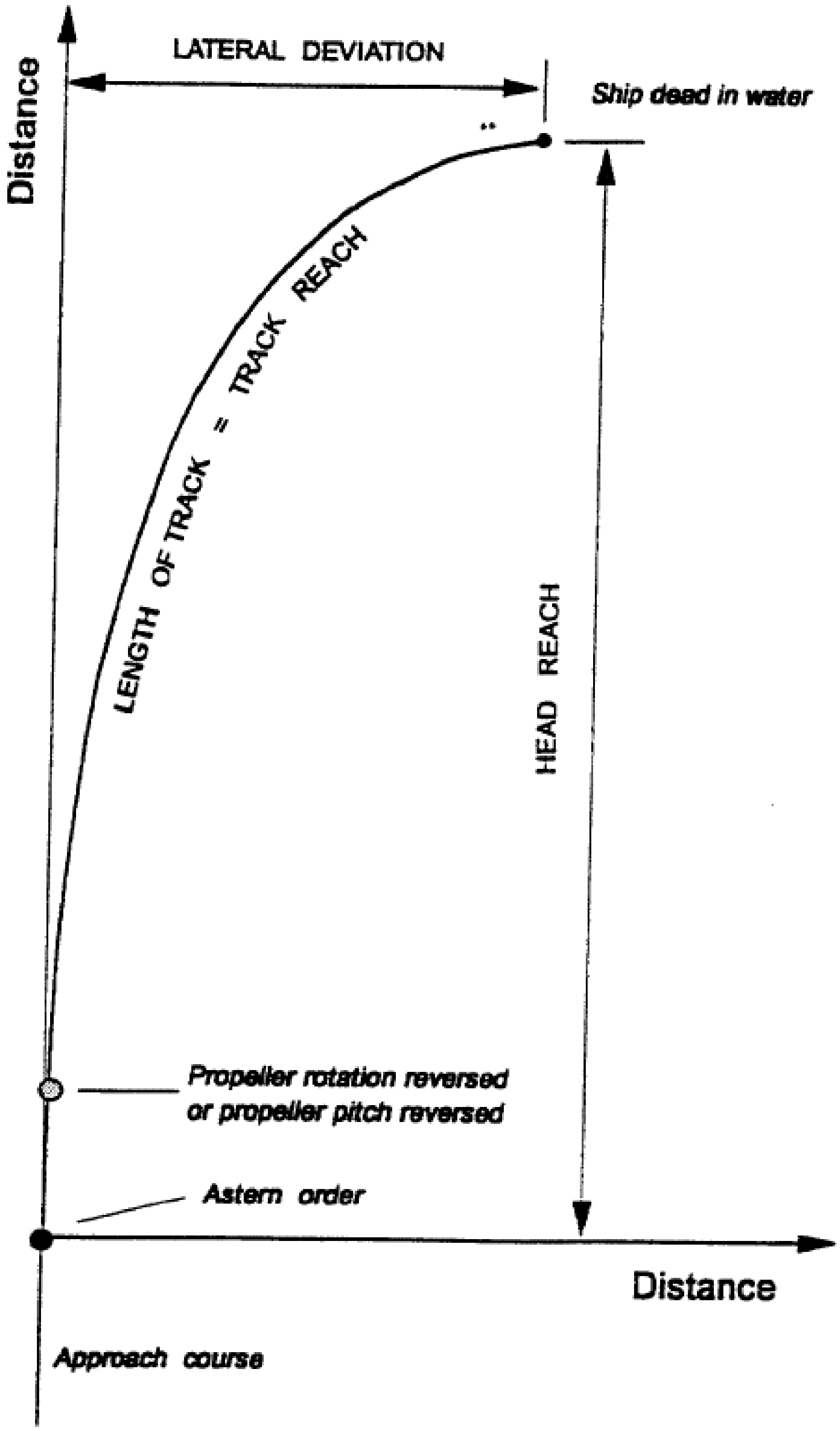
Zig-zag 10°/10° test

Figure 3

1.3.2.2 Two kinds of zig-zag tests are included in the Standards, the 10°/10° and 20°/20° zig-zag tests. The 10°/10° zig-zag test uses ~~rudder~~steering angles of ~~10°~~1/3 of the declared steering angle limit to either side following a heading deviation of 10° from the original course. The 20°/20° zig-zag test uses ~~20° rudder angles~~2/3 of the declared steering angle limit coupled with a 20° change of heading from the original course. The essential information to be obtained from these tests is the overshoot angles, initial turning time to second execute and the time to check yaw.

1.3.3 Stopping tests

A full astern stopping test is used to determine the track reach of a ship from the time an order for full astern is given until the ship is stopped dead in the water (see figure 4).



Definitions used in stopping test

Figure 4

1.3.4 Heading keeping tests

A heading keeping test is used to verify that the ship yaw deviations from a preset heading, when running straight ahead for a minimum period of 30 minutes, do not exceed 2 degrees at any moment. The autopilot may be engaged.

CHAPTER 2

GUIDELINES FOR THE APPLICATION OF THE STANDARDS

2.1 Conditions at which the Standards apply

2.1.1 General

2.1.1.1 Compliance with the manoeuvring criteria should be evaluated under the standard conditions in paragraph 5.2 of the Standards for ship manoeuvrability. The standard conditions provide a uniform and idealized basis against which the inherent manoeuvring performance of all ships may be assessed.

2.1.1.2 The Standards cannot be used to evaluate directly manoeuvring performance under non-standard, but often realistic, conditions. The establishment of manoeuvrability standards for ships under different operating conditions is a complex task that deserves ongoing research.

2.1.2 Deep, unrestricted water

Manoeuvrability of a ship is strongly affected by interaction with the bottom of the waterway, banks and passing ships. Trials should therefore be conducted preferably in deep, unconfined but sheltered waters. The water depth should exceed four times the mean draught of the ship.

2.1.3 Full load and even keel condition

2.1.3.1 The Standards apply to the full load and even keel condition. The term "fully loaded" refers to the situation where the ship is loaded to its summer load line draught (referred to hereafter as "full load draught"). This draught is chosen based on the general understanding that the poorest manoeuvring performance of a ship occurs at this draught. The full load draught, however, is not based on hydrodynamic considerations but rather statutory and classification society requirements for scantlings, freeboard and stability. The result being that the final full load draught might not be known or may be changed as a design develops.

2.1.3.2 Where it is impractical to conduct trials at full load because of ship type, trials should be conducted as close to full load draught and zero trim as possible. Special attention should also be given to ensuring that sufficient propeller immersion exists in the trial condition.

2.1.3.3 Where trials are conducted in conditions other than full load, manoeuvring characteristics should be predicted for trial and full load conditions using a reliable method (i.e. model tests or reliable computer simulation) that ensures satisfactory extrapolation of trial results to the full load condition. It rests with the designer/owner to demonstrate compliance at the final full load condition. Section 3.5 of Chapter 3 provides guidance on the subject.

2.1.4 Metacentric height

The Standards apply to a situation where the ship is loaded to a reasonable and practicable metacentric height for which it is designed at the full load draught.

2.1.5 Calm environment

Trials should be held in the calmest weather conditions possible. Wind, waves and current can significantly affect trial results, having a more pronounced effect on smaller ships. The environmental conditions should be accurately recorded before and after trials so that corrections may be applied. Specific environmental guidelines are outlined in 2.2.1.2.1.

2.1.6 Steady approach at the test speed

The required test speed is defined in paragraph 4.2.1 of the Standards for ship manoeuvrability.

2.2 Guidance for required trials and validation

2.2.1 Test procedures~~*~~

~~* It should be noted that these procedures were developed for ships with conventional steering and propulsion systems.~~

2.2.1.1 General

The test procedures given in the following guidelines were established to support the application of the manoeuvring standards by providing to shipyards and other institutions standard procedures for the testing trials of new ships or for later trials made to supplement data on manoeuvrability. This guidance includes trial procedures that need to be performed in order to provide sufficient data for assessing ship manoeuvring behaviour against the defined criteria.

2.2.1.2 Test conditions

2.2.1.2.1 Environment

Manoeuvring trials should be performed in the calmest possible weather conditions. The geographical position of the trial is preferably in a deep sea, sheltered area where accurate positioning fixing is possible. Trials should be conducted in conditions within the following limits:

.1 Deep unrestricted water: more than 4 times the mean draught.

.2 Wind: not to exceed Beaufort 5.

.3 Waves: not to exceed sea state 4.

.4 Current: uniform only.

~~Correction may need to be applied to the test results following the guidance contained in 3.4.2.~~

2.2.1.2.2 Loading

The ship should preferably be loaded to the full load draught and even keel, however, a 5% deviation from that draught may be allowed.

Alternatively, the ship may be in a ballast condition with a minimum of trim, and sufficient propeller immersion.

2.2.1.2.3 Ship speed

The test speed is defined in paragraph 4.2.1 of the Standards.

2.2.1.2.4 Heading

Preferably head into the wind during the approach run of the zig-zag tests and from the wind during the approach run of turning circle, heading keeping and full astern stopping tests.

2.2.1.2.5 Engine

Engine control setting to be kept constant during the trial if not otherwise stated in following procedures.

2.2.1.2.6 Approach run

The above-mentioned conditions must be fulfilled for at least two minutes preceding the test. The ship is running at test speed down wind (up wind for the zig-zag tests) with minimum ~~rudder~~steering to keep its course.

2.2.1.3 Turning circle manoeuvre

Trials shall be made to port and to starboard using ~~maximum rudder~~declared steering angle limit without changing engine control setting from the initial speed. The following general procedure is recommended:

.1 The ship is brought to a steady course and speed according to the specific approach condition.

.2 The recording of data starts.

.3 The manoeuvre is started by ordering the ~~rudder~~steering to ~~the maximum rudder~~declared steering angle~~. Rudder~~ limit. Steering and engine controls are kept constant during the turn.

.4 The turn continues until 360° change of heading has been completed. It is, however, recommended that in order to fully assess environmental effects a 720° turn be completed (3.~~4~~5.2 refers).

.5 Recording of data is stopped and the manoeuvre is terminated.

When testing a ship with the steering system in reduced service, the procedure shall be repeated in that condition and considering that, for ships provided with multiple steering systems, the least favorable steering system shall be out of operation. Reduction of propulsion on the propulsor associated with the faulty steering may only be done if operational restrictions apply. It is suggested to have the port system out of operation in a starboard turn and vice versa. The inoperative steering system shall be placed in neutral position.

2.2.1.4 Zig-zag manoeuvre

~~The given rudder and change of heading angle for the~~ The following procedure is ~~10°. This value can be replaced~~ for ~~alternative or combined zig-zag manoeuvres by other angles such as 20° for the other required~~the 10°/10° zig-zag test. Same procedure can be applied to other combinations of steering command and heading angle by replacing as appropriate. Trials should be made to both port and starboard. The following general procedure is recommended:

.1 The ship is brought to a steady course and. speed according to the specific approach condition.

.2 The recording of data starts.

.3 The ~~rudder~~steering is ordered to ~~10°~~1/3 of the declared steering angle limit to starboard/port.

.4 When the heading has changed by 10° off the base course, the ~~rudder~~steering is shifted to ~~10°~~1/3 of the declared steering angle limit to port/starboard. The ship's yaw will be checked and a turn in the opposite direction (port/starboard) will begin. The ship will continue in the turn and the original heading will be crossed.

.5 When the heading is 10° port/starboard off the base course, the ~~rudder~~steering is reversed as before.

.6 The procedure is repeated until the ship heading has passed the base course no less than two times.

.7 Recording of data is stopped and the manoeuvre is terminated.

2.2.1.5 Full astern ~~S~~stopping test

~~Full astern is applied and the rudder maintained at midship throughout this test.~~

The following general procedure is recommended:

.1 The ship is brought to a steady course and speed according to the specific approach condition.

.2 The recording of data starts.

.3 The manoeuvre is started by giving a stop order. The full astern ~~engine~~ order is applied.

.4 Data recording stops and the manoeuvre is terminated when the ship is stopped dead in the water.

For rudder-steered ships, the rudder shall be maintained at neutral position throughout the test.

When testing a ship with multiple propulsion lines, the procedure shall be repeated with the following modifications:

.1 The test is performed with one propulsion system and its corresponding steering system out of operation.

.1 The inoperative propeller may be allowed to windmill (depending on manufacturers specification and recommendation).

.2 The steering system corresponding to the inoperative propulsion line shall be placed at neutral position.

.3 The approach speed shall consequently be adjusted based on remaining available propulsion.

.2 For non-rudder-steered ships where the stopping in normal operational condition is done by turning the steering force units, the test in .1 shall be performed with all the propulsion systems active until the stop order is given. Consequently, the approach speed shall be the same as in normal operational condition.

2.2.1.6 Heading keeping test

The following general procedure is recommended:

.1 The ship is brought to a steady course and speed according to the specific approach condition.

.2 The recording of data starts.

.3 Recording of data is stopped and the manoeuvre is terminated.

When testing a ship with the steering system in reduced service, same related considerations as stated in 2.2.1.3 apply.

2.2.2 Recording

For each trial, a summary of the principal manoeuvring information should be provided in order to assess the behaviour of the ship. Continuous recording of data should be either manual or automatic using analogue or digital acquisition units. In case of manual recording, a regular sound/light signal for synchronization is advisable.

2.2.2.1 Ship's particulars

Prior to trials, draughts forward and aft should be read in order to calculate displacement, longitudinal centre of gravity, draughts and metacentric height. In addition the geometry, projected areas and steering particulars should be known. The disposition of the engine, propeller, ~~rudder~~steering, thrusters and other device characteristics should be stated with operating condition.

2.2.2.2 Environment

The following environmental data should be recorded before each trial:

.1 Water depth.

.2 Waves: The sea state should be noted. If there is a swell, note period and direction.

.3 Current: The trials should be conducted in a well surveyed area and the condition of the current noted from relevant hydrographic data. Correlation should be made with the tide.

.4 Weather: Weather conditions, including visibility, should be observed and noted.

2.2.2.3 Trial related data

The following data as applicable for each test should be measured and recorded during each test at appropriate intervals of not more than 20 s:

Position

Heading

Speed

~~Rudder~~Steering angle and rate of movement

Propeller speed of revolution

Propeller pitch

Wind speed

A time signal should be provided for the synchronization of all recordings. Specific events should be timed, such as trial starting-point, engine/helm change, significant changes in any parameter such as crossing ship course, ~~rudder~~steering to zero or engine reversal in operating condition such as ship speed and shaft/propeller direction.

2.2.2.4 Presentation of data

The recordings should be analysed to give plots and values for significant parameters of the trial. Sample recording forms are given in appendix 6. The manoeuvring criteria of the Standards should be evaluated from these values.

CHAPTER 3

PREDICTION GUIDANCE

3.1 General

3.1.1 To be able to assess the manoeuvring performance of a new ship at the design stage, it is necessary to predict the ship manoeuvring behaviour on the basis of main dimensions, lines drawings and other relevant information available at the design stage.

3.1.2 A variety of methods for prediction of manoeuvring behaviour at the design stage exists, varying in the accuracy of the predicted manoeuvres and the cost of performing the prediction. In practice most of the predictions at the design stage have been based on ~~three~~four methods.

3.1.3 The first and simplest method is to base the prediction on experience and existing data, assuming that the manoeuvring characteristics of the new ship will be close to those of similar existing ships.

3.1.4 The second method is to base the prediction on results from model tests. ~~At the time these notes were written, model tests must be considered the most reliable prediction method. However, it~~It may be said that traditionally the requirements with regard to accuracy have been somewhat more lenient in this area than in other areas of ship model testing. The reason for this has simply been the absence of manoeuvring standards. The feedback of full-scale trial results has generally been less regular in this area than in the case of speed trials. Consequently the correlation basis for manoeuvrability is therefore of a somewhat lower standard, particularly for hull forms that may present a problem with regard to steering and manoeuvring characteristics. ~~It is expected that this situation will improve very rapidly when it becomes generally known that a standard for ship manoeuvrability is going to be introduced.~~ Model tests are described in section 3.2.

3.1.5 The third method is to base the prediction on results from calculation/simulation using a mathematical model. Mathematical models are described in section 3.3.

3.1.6 The fourth method is to base the prediction on CFD simulations. CFD simulations could be considered as particular cases of mathematical model but, in view of their specifics, they are described separately in section 3.4.

3.2 Model tests

There are two commonly used model test methods available for prediction of manoeuvring characteristics. One method employs a free-running model moving in response to specified control input (i.e. helm and ~~propeller~~propulsion); the tests duplicate the full-scale trial manoeuvres and so provide direct results for the manoeuvring characteristics. The other method makes use of force measurements on a "captive" model, forced to move in a particular manner with controls fixed; the analysis of the measurements provides the coefficients of a mathematical model, which may be used for the prediction of the ship response to any control input.

3.2.1 Manoeuvring test with free-running model

3.2.1.1 The most direct method of predicting the manoeuvring behaviour of a ship is to perform representative manoeuvres with a scale model. To reduce costs by avoiding the manufacture of a special model for manoeuvring tests, such tests may be carried out with the same model employed for resistance and self-propulsion tests. Generally it means that a relatively large model will be used for the manoeuvring tests, which is also favourable with regard to reducing scale effects of the results.

3.2.1.2 The large offshore, sea-keeping and manoeuvring basins are well suited for manoeuvring tests with free-running models provided they have the necessary acquisition and data processing equipment. In many cases, conventional towing tanks are wide enough to allow the performance of the 10°/10° zig-zag test. Alternatively, tests with a free-running model can be conducted on a lake. In this case measuring equipment must be installed and the tests will be dependent on weather conditions. Both laboratory and open-air tests with free-running models suffer from scale effects, even if these effects to a certain extent will be reduced by using a large model for the tests. Sometimes it has been attempted to compensate for scale effects by means of an air propeller on board the model. Another improvement is to make the drive motor of the ship model simulate the characteristics of the main engine of the ship with regard to propeller loading.

3.2.1.3 Manoeuvres such as turning circle, zig-zag and spiral tests are carried out with the free-running model, and the results can be compared directly with the standard of manoeuvrability. There are however uncertainties in the results due to scale effects.

3.2.1.4 More recently, efforts have been made at deriving the coefficients of mathematical models from tests with free-running models. The mathematical model is then used for predicting the manoeuvring characteristics of the ship. Parameter identification methods have been used and this procedure has been combined with oblique towing and propulsion tests to provide some of the coefficients.

3.2.2 Manoeuvring tests with captive model

3.2.2.1 Captive model tests include oblique-towing tests in long narrow tanks as well as "circling" tests in rotating-arm facilities, but in particular such tests are performed by the use of a Planar Motion Mechanism (PMM) system capable of producing any kind of motion by combining static or oscillatory modes of drift and yaw. Generally, it may be said that captive model tests suffer from scale effects similar to those of the free-running tests, but corrections are more easily introduced in the analysis of the results.

3.2.2.2 In using captive model tests due account of the effect of roll during manoeuvring should be taken.

3.2.2.3 The PMM has its origin in devices operating in the vertical plane and used for submarine testing. The PMM makes it possible to conduct manoeuvring tests in a conventional long and narrow towing tank. The basic principle is to conduct various simpler parts of more complex complete manoeuvres. By analysis of the forces measured on the model the manoeuvring behaviour is broken down into its basic elements, the hydrodynamic coefficients. The hydrodynamic coefficients are entered into a computer based mathematical model and the results of the standard manoeuvres are predicted by means of this mathematical model.

3.2.2.4 A rotating arm facility consists of a circular basin, spanned by an arm from the centre to the circumference. The model is mounted on this arm and moved in a circle, varying the diameter for each test. The hydrodynamic coefficients related to ship turning as well as to the combination of turning and drift will be determined by this method. Additional tests often have to be conducted in a towing tank in order to determine hydrodynamic coefficients related to ship drift. As in the case of the PMM the manoeuvring characteristics of the ship are then predicted by means of a mathematical model using the coefficients derived from the measurements as input.

3.2.3 Model test condition

The Standards are applicable to the full load condition of the ship. The model tests should therefore be performed for this condition. For many ships the delivery trials will be made at a load condition different from full load. It will then be necessary to assess the full load manoeuvring characteristics of the ship on the basis of the results of manoeuvring trials performed at a condition different from full load. To make this assessment as reliable as possible the model tests should also be carried out for the trial condition, meaning that this condition must be specified at the time of performing the model tests. The assumption will be that when there is an acceptable agreement between model test results and ship trial results in the trial condition, the model test results for the loaded condition will then be a reliable basis for assessing the manoeuvring characteristics of the ship.

3.3 Mathematical model

A "mathematical model" is a set of equations which can be used to describe the dynamics of a manoeuvring ship. But it may be possible to predict the manoeuvrability for the conventional ship' s form with certain accuracy from the practical point of view using some mathematical models which have already been published. In this section, the method used to predict the manoeuvring performance of a ship at full load for comparison with the Standards is explained. The following details of the mathematical model are to be indicated:

.1 when and where to use;

.2 how to use;

.3 accuracy level of predicted results; and

.4 description of mathematical model

3.3.1 Application of the mathematical model

3.3.1.1 In general, the manoeuvring performance of the ship must be checked by a sea trial to determine whether it satisfies the manoeuvring standards or not. The Standards are regulated in full load condition from the viewpoints of marine safety. Consequently, it is desired that the sea trial for any ship be carried out in full load condition. This may be a difficult proposition for ships like a dry cargo ship, for which the sea trial is usually carried out in ballast or heavy ballast conditions from the practical point of view.

3.3.1.2 In such cases, it will be required to predict the manoeuvring performance in full load condition by means of some method that uses the results of the sea trial. As an alternative to scale model tests, usually conducted during the ship design phase, a numerical simulation using a mathematical model is a useful method for predicting ship manoeuvring performance in full load condition.

3.4 CFD simulations

A CFD simulation is a solution of the flow around the hull by dividing the fluid into many parts and solving equations for the water motions in these. There exist a large variety of CFD tools. Currently, most tools require the user to set key parameters significantly affecting the results. This particularly includes division into parts (mesh), time step and physical models (equations to be solved). This means that equally important as the accuracy of the tool itself is the choices made by the user. In order to ensure high accuracy, well founded choices need to be made. It is believed that adequately performed CFD simulations exceed the accuracy of model tests.

High accuracy in CFD simulations typically come at a significant computational cost. It is therefore relevant for the user to vary the accuracy depending on the need. This could e.g. be done by the choice of physical models, mesh and time step. A lot of useful information can be extracted from simplified simulations, however, if the simulation is to be used to provide proof of compliance with performance parameters, the needed accuracy is considerably higher. The following gives some general suggestions on what to include in CFD simulations used to document compliance with performance requirements.

3.4.1 Suggested content of CFD simulations for compliance with performance requirements

The following geometries should be modelled:

- .1 Hull
- .2 Propulsion device
- .3 Steering device
- .4 Relevant appendices

The following can normally be excluded, but should be included if they are believed to have a significant effect on the maneuvering performance:

- .1 Bow thrusters including openings
- .2 Bilge keels
- .3 Sea chests
- .4 Pipe openings
- .5 Super structure

The following physics should be included:

- .1 The hull should be self-propelled, self-steered and free floating in 6 degrees of freedom
- .2 The mass properties of the hull in terms of mass, center of gravity and radii of gyration
- .3 The motion (translation and rotation) of the steering device relative to the hull should be modelled.
- .4 The propulsion device should be moving (translation and rotation) relative to the hull as in real life (except for water jets for which a momentum source may be applied inside the duct)
- .5 Shear forces on the geometries should be modelled at least by appropriate wall models
- .6 Pressure forces on the geometries should be modelled
- .7 The free surface waves generated by the geometries should be modelled in the vicinity of the hull
- .8 Simplified engine model including torque and shaft speed

Cavitation should be included if it is believed to have a significant effect on the maneuvering performance.

The mesh should be of appropriate quality to resolve the above geometries and physic. The timestep should be chosen appropriate considering the mesh and fluid velocities.

The quality of CFD simulations used for documenting compliance with performance requirements should be to the satisfaction of the Administration and may need verification by third party.

3.5 Corrections from non-standard trial conditions

3.45.1 Loading condition

3.45.1.1 In the case for predicting manoeuvrability of a ship in full load condition using the mathematical model through the sea trial results in ballast or heavy, ballast condition, the following two methods are used in current practice.

Option 1:

3.~~4~~5.1.2 The manoeuvring performance in full load condition can be obtained from the criteria of measured performance during the sea trial in ballast condition (T) and the interaction factor between the criteria of manoeuvrability in full load condition and in a trial condition (F/B), that is as given below;

$$R = TF/B$$

where,

B: the estimated performance in the condition of sea trial based on the numerical simulation using the mathematical model or CFD simulation or on the model test;

F: the estimated performance in full load condition based on the numerical simulation using the mathematical model or CFD simulation or on the model test;

T: the measured performance during the sea trial; and

R: the performance of the ship in full load condition.

3.~~4~~5.1.3 It should be noted that the method used to derive B and F should be the same.

Option 2:

3.~~4~~5.1.4 The manoeuvring performance in the condition of sea trial such as ballast or heavy ballast are predicted by the method shown in appendix 2, and the predicted results must be checked with the results of the sea trial.

3.~~4~~5.1.5 Afterwards it should be confirmed that both results agree well with each other. ~~The~~In that case, the performance in full load condition may be obtained by means of the same method ~~using the mathematical model~~shown in appendix 2.

3.~~4~~5.2 Environmental conditions

3.~~4~~5.2.1 Ship manoeuvrability can be significantly affected by the immediate environment such as wind, waves, and current. Environmental forces can cause reduced course-keeping stability or complete loss of the ability to maintain a desired course. They can also cause increased resistance to a ship' s forward motion, with consequent demand for additional power to achieve a given speed or reduces the stopping distance.

3.~~4~~5.2.2 When the ratio of wind velocity to ship speed is large, wind has an appreciable effect on ship control. The ship may be unstable in wind from some directions. Waves can also have significant effect on course-keeping and manoeuvring. It has been shown that for large wave heights a ship may behave quite erratically and, in certain situations, can lose course stability.

3.~~4~~5.2.3 Ocean current affects manoeuvrability in a manner somewhat different from that of wind. The effect of current is usually treated by using the relative velocity between the ship and the water. Local surface current velocities in the open ocean are generally modest and close to constant in the horizontal plane.

3.~~4~~5.2.4 Therefore, trials shall be performed in the calmest weather conditions possible. ~~In the case that the minimum weather conditions for the criteria requirements are not applied, the trial results should be corrected.~~

~~3.4.2.5 Generally, it is easy to account for the effect of constant current. The turning circle test results may be used to measure the magnitude and direction of current. The ship' s~~

~~track, heading and the elapsed time should be recorded until at least a 720° change of heading has been completed. The data obtained after ship' s heading change 180° are used to estimate magnitude and direction of the current. Position (x_{li}' y_{li}' t_{li}) and (x_{2i}' y_{2i}' t_{2i}) in figure 5 are the positions of the ship measured after a heading rotation of 360°. By defining the local current velocity V_i for any two corresponding positions as the estimated current velocity can be obtained from the following equation:~~

~~$\underline{v}_i = (x_{2i} - x_{1i}, y_{2i} - y_{1i})/(t_{2i} - t_{1i})$~~

~~the estimated current velocity can be obtained from the following equation:~~

~~$\underline{v}_c = (1/n) \sum \underline{v}_i = (1/n) \sum (x_{2i} - x_{1i}, y_{2i} - y_{1i})/(t_{2i} - t_{1i})$~~

~~3.4.2.6 If the constant time interval, $\delta t = (t_{2i} - t_{1i})$, is used this equation can be simplified and written:~~

~~$\underline{v}_c = (1/n\delta t) \{\sum x_{2i} - \sum x_{1i}, \sum y_{2i} - \sum y_{1i}\}$~~

~~The above vector, $\underline{v}_c$, obtained from a 720° turning test will also include the effect of wind and waves.~~

~~3.4.2.7 The magnitude of the current velocity and the root mean square of the current velocities can be obtained from the equations:~~

~~$v_c = |v_c|$~~

~~$v_c(RMS) = [(1/n) \sum |\underline{v}_i - \underline{v}_c|^2]^{1/2}$~~

~~v_c(RMS) represents the non-uniformity of vi which may be induced from wing, waves, and non uniform current.~~

~~3.4.2.8 All trajectories obtained from the sea trials should be corrected as follows:~~

~~$x'(t) = x(t) - v_c t$~~

~~where~~

~~$x(t)$ is the measured position vector and~~

~~$x'(t)$ is the corrected one of the ship and~~

~~$x'(t) = x(t)$ at $t = 0$.~~

3.~~5~~6 Uncertainties

3.~~5~~6.1 Accuracy of model test results

3.~~5~~6.1.1 The model may turn out to be more stable than the ship due to scale effects. This problem seems to be less serious when employing a large model. Consequently, to reduce this effect model scale ratios comparable to that considered acceptable for resistance and self-propulsion tests should be specified for manoeuvring tests that use a free-running model. Captive model tests can achieve satisfactory results with smaller scale models.

3.~~5~~6.1.2 While the correlation data currently available are insufficient to give reliable values for the accuracy of manoeuvring model test results, it is the intent of the Standards to promote the collection of adequate correlation data.

3.~~5~~6.2 Accuracy of predicted results using the mathematical model

3.~~5~~6.2.1 The mathematical model that can be used for the prediction of the manoeuvring performance depends on the type and amount of prepared data.

3.~~5~~6.2.2 If there is no available data, under assumptions that resistance and self-propulsion factors are known, a set of approximate formulae for estimation of the derivatives and coefficients in the mathematical model will become necessary to predict the ship' s manoeuvrability.

3.~~5~~6.2.3 If there is enough experimental and accumulated data, it is desirable to use a detailed mathematical model based on this data. In most cases, the available data is not sufficient and a mathematical model can be obtained by a proper combination of different parts derived from experimental data and those obtained by the estimated formulae.

3.6.3 Accuracy of CFD simulations

Due to the large number of choices made when preparing a CFD simulation, the accuracy will vary depending on the program used, which geometries are included, how the fluid is subdivided (mesh), the chosen time step and physical models. It is believed that a lot of useful information can be extracted from simplified simulations, however if the simulation is to be used to provide proof of compliance with performance parameters, the simulation shall be performed according to 3.4.1.

APPENDIX 1

NOMENCLATURE AND REFERENCE SYSTEMS

1 The manoeuvres of a surface ship may be seen to take place in the xoyo-plane of a right-handed system of axes Oo(xoyozo) "fixed in space", the zo-axis of which is pointing downwards in the direction of gravity. For the present discussion let the origin of this system coincide with the position at time t = 0 of the midship point O of the ship, and let the xo-axis be pointing in the direction of ship's heading at the same moment, the yo-axis pointing to starboard. The future orientation of the ship in this system is given by its heading angle ψ, its angle of pitch θ, and its angle of roll ϕ (see figure A1-1).

2 In calm conditions with no tide or current ship speed through water (V) equals the speed over the ground, and the progress along the ship track is equal to the time integral

$$\int vdt.$$

3 This distance may conveniently be expressed by the number of ship lengths sailed (i.e. by the non-dimensional time):

$$t' = \int_o^t (V/L)dt.$$

4 In general the ship's heading deviates from the direction of the speed vector by the sideslip or drift angle β. The advance and transfer parallel to and at right angles to the original line of course (and ideal line of approach) are given by the integrals:

$$X_o(t) = \int_o^t V\cos(\psi\text{-}\beta)dt$$

$$Y_o(t) = \int_o^t V\sin(\psi\text{-}\beta)dt.$$

5 Mathematical models of ship dynamics involve expressions for the forces acting on the hull, usually separated in their components along the axes of a system 0(xyz) moving with the body. The full six-degrees-of-freedom motion of the ship may be defined by the three components of linear velocities (u,v,w) along the body axes, and by the three components of angular velocities (p,q,r) around these axes. Again, for the present discussion it is sufficient to consider the surface ship, moving with forward velocity u and sway velocity v in the 0(xy) plane, and turning with yaw velocity r around the z-axis normal to that plane (the yaw rate is also referred as *y* in section 1.2.2 of Chapter 1). On these assumptions the speed $V = (u^2+v^2)^{1/2}$, the drift angle $\beta = -\tan^{-1}(v/u)$ and the yaw rate r is equal to the time rate of change of heading angle *ψ*, i.e. r = d/dt(−*ψ*) = *y*ψ.

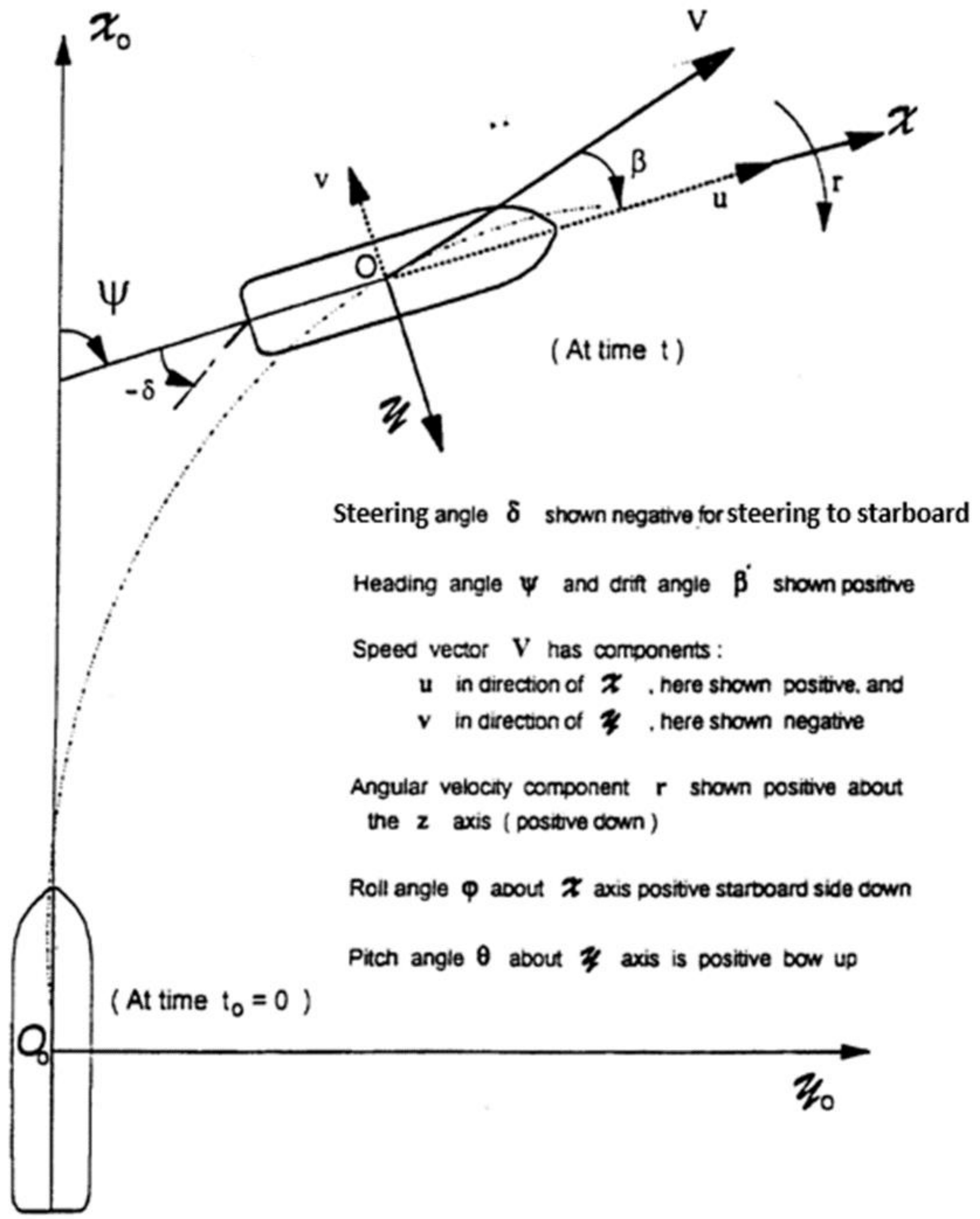
6 The non-dimensional yaw rate in terms of change of heading (in radians) per ship length sailed is

$$r' = d/dt'(-\psi) = y' = (L/V)y$$

which is also seen to be the non-dimensional measure of the instantaneous curvature of the path of this ship L/R.

7 Many ships will experience a substantial rolling velocity and roll angle during a turning manoeuvre, and it is understood that the mathematical model used to predict the manoeuvring characteristics should then include the more stringent expressions as appropriate.

8 Further information can be found in section 4.2 of the Standards for ship manoeuvrability.



Surface ship with body axes O(xyz) manoeuvring within space-fixed inertial frame with axes O_O ($x_o y_o z_o$)

Figure A1-1

APPENDIX 2

GENERAL VIEW OF PREDICTION OF MANOEUVRING PERFORMANCE

1 A mathematical model of the ship manoeuvring motion can be used as one of the effective methods to check whether a ship satisfies the manoeuvrability standards or not, by a performance prediction at the full load condition and from the results of the sea trial in a condition such as ballast.

2 Existing mathematical models of ship manoeuvring motion are classified into two types. One of the models is called a 'response model', which expresses a relationship between input as the control and output as its manoeuvring motion. The other model is called a "hydrodynamic force model", which is based on the hydrodynamic forces that include the mutual interferences. By changing the relevant force derivatives and interference coefficients composed of a hydrodynamic force model, the manoeuvring characteristics due to a change in the ship's form or loading condition can be estimated.

3 Furthermore, a hydrodynamic force model is helpful for understanding the relationship between manoeuvring performance and ship form than a response model from the viewpoint of design. Considering these situations, this Appendix shows the prediction method using a hydrodynamic force model. Certainly, the kind of mathematical model suitable for prediction of the performance depends on the kind of available data. There are many kinds of mathematical models.

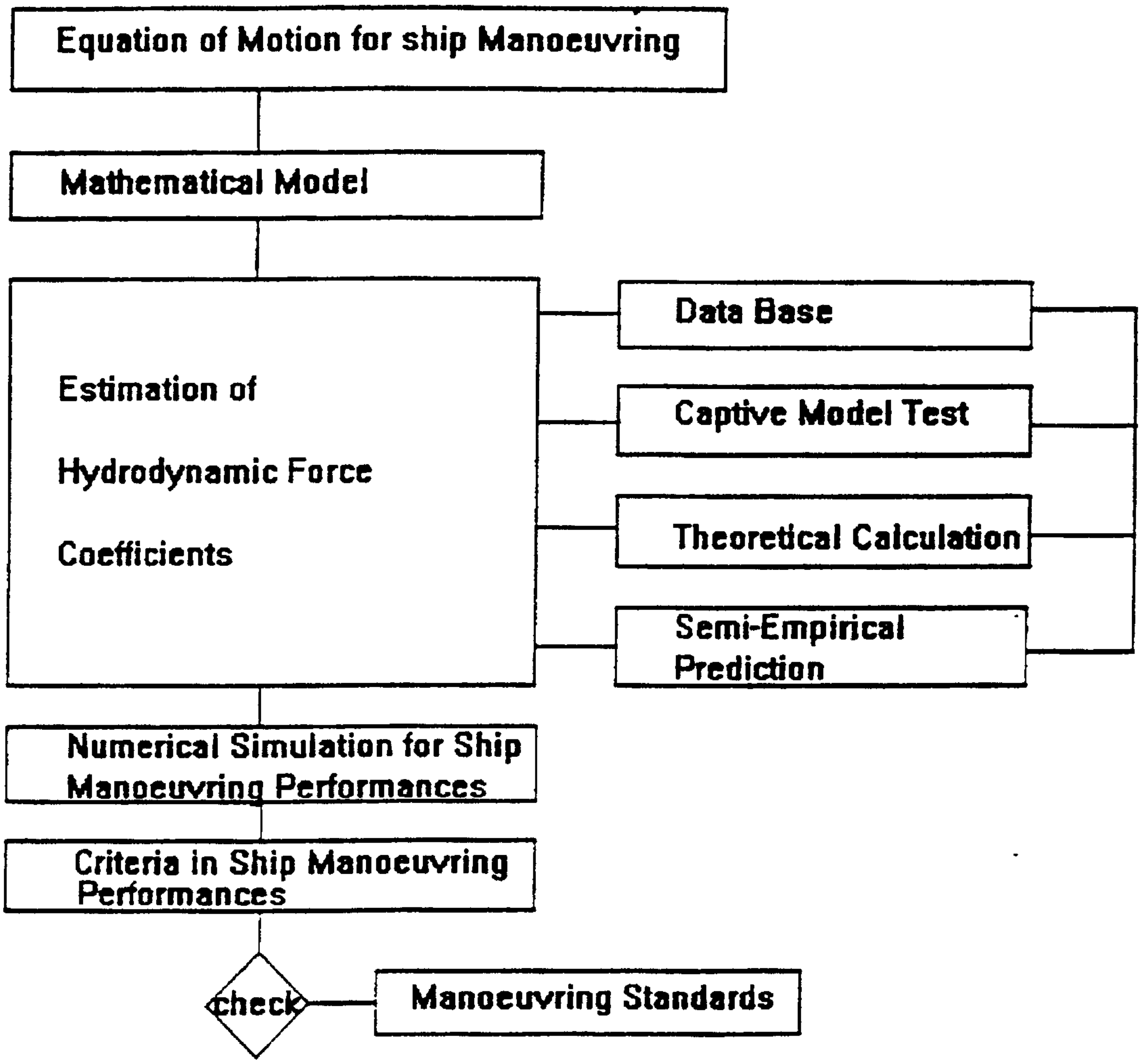
4 In figure A2-1, the flow chart of prediction method of ship manoeuvring performance using a hydrodynamic force model is shown. There are in general various expressions of a hydrodynamic force model in current practice, though their fundamental ideas based on hydrodynamic considerations have little difference. Concerning the hydrodynamic force acting on a ship in manoeuvring motion, they are usually expressed as a polynomial term of motion variables such as the surge, sway and angular yaw velocities.

5 The most important and difficult work in performance prediction is to estimate such derivatives and parameters of these expressions to compose an equation of a ship manoeuvring motion. These hydrodynamic force coefficients and derivatives may usually be estimated by the method shown in figure A2-1.

6 The coefficients and derivatives can be estimated by the model test directly, by data based on the data accumulated in the past, by theoretical calculation~~ and~~, by semi-empirical formulae based on any of these methods and by CFD simulations. There is also an example that uses approximate formulae for estimation derived from a combination of theoretical calculation and empirical formulae based on the accumulated data. The derivatives which are coefficients of hydrodynamic forces acting on a ship's hull, propeller and ~~rudder~~steering are estimated from such parameters as ship length, breadth, mean draught, trim and the block coefficient. Change of derivatives due to a change in the load condition may be easily estimated from the changes in draught and trim.

7 As mentioned above, accuracy of manoeuvring performance predicted by a hydrodynamic force model depends on accuracy of estimated results by hydrodynamic forces which constitutes the equation of a ship manoeuvring motion. Estimating the hydrodynamic derivatives and coefficients will be important to raise accuracy as a whole while keeping consistency of relative accuracy among various hydrodynamic forces.

8 A stage in which theoretical calculations can provide all of the necessary hydrodynamic forces with sufficient accuracy has not yet been reached. Particularly, non-linear hydrodynamic forces and mutual interferences are difficult to estimate with sufficient accuracy by pure theoretical calculations. Thus, empirical formulae and databases are often used, or incorporated into theoretical calculations.



Flow chart for prediction of ship manoeuvring performance

Figure A2-1

APPENDIX 3

STOPPING ABILITY OF VERY LARGE SHIPS

1 It is stated in the Standards for ship manoeuvrability that the track reach in the full astern stopping test may be modified from 15 ship lengths, at the discretion of the Administration, where ship size and form make the criterion impracticable. The following example and information given in tables A3-1, 2 and 3 indicate that the discretion of the Administration is only likely to be required in the case of large tankers.

2 The behaviour of a ship during a stopping manoeuvre is extremely complicated. However, a fairly simple mathematical model can be used to demonstrate the important aspects which affect the stopping ability of a ship. For any ship the longest stopping distance can be assumed to result when the ship travels in a straight line along the original course, after the astern order is given. In reality the ship will either veer off to port or starboard and travel along a curved track, resulting in a shorter track reach, due to increased hull drag.

3 To calculate the stopping distance on a straight path, the following assumptions should be made:

.1 the resistance of the hull is proportional to the square of the ship speed.

.2 the astern thrust is constant throughout the stopping manoeuvre and equal to the astern thrust generated by the propeller when the ship eventually stops dead in the water; and

.3 the propeller is reversed as rapidly as possible after the astern order is given.

4 An expression for the stopping distance along a straight track, in ship lengths, can be written in the form:

$$S = A \log_e (1 + B) + C,$$

where:

S : is the stopping distance, in ship lengths.

A : is a coefficient dependent upon the mass of the ship divided by its resistance coefficient.

B : is a coefficient dependent on the ratio of the ship resistance immediately before the stopping manoeuvre, to the astern thrust when the ship is dead in the water.

C : is a coefficient dependent upon the product of the time taken to achieve the astern thrust and the initial speed of the ship.

5 The value of the coefficient A is entirely due to the type of ship and the shape of its hull. Typical values of A are shown in table A3-1.

6 The value of the coefficient B is controlled by the amount of astern power which is available from the Dower plant. With diesel machinery, the astern power available is usually about 85% of the ahead power, whereas with steam turbine machinery this figure could be as low as 40%.

Table A3-1

Ship type	*Coefficient A*
Cargo ship	5-8
Passenger/car ferry	8-9
Gas carrier	10-11
Products tanker	12-13
VLCC	14-16

7 Accordingly the value of the coefficient B is smaller if a large amount of astern power and hence astern thrust, is available. Typical values of the coefficient B are given in table A3-2.

Table A3-2

Type of machinery	*Percentage power astern*	*Coefficient B*	*Log (1+B)*
Diesel	85%	0.6-1.0	0.5-0.7
Steam turbine	40%	1.0-1.5	0.7-0.9

8 The value of the coefficient C is half the distance travelled, in ship lengths, by the ship, whilst the engine is reversed and full astern thrust is developed. The value of C will be larger for smaller ships and typical values are given in table A3-3.

Table A3-3

Ship length (metres)	*Time to achieve astern thrust (s)*	*Ship speed (knots)*	*Coefficient C*
100	60	15	2.3
200	60	15	1.1
300	60	15	0.8

9 If the time taken to achieve the astern thrust is longer than 60 seconds, as assumed in table A3-3, or if the ship speed is greater than 15 knots, then the values of the coefficient C will increase pro rata.

10 Although all the values given for the coefficients A, B and C may only be considered as typical values for illustrative purposes, they indicate that large ships may have difficulty satisfying the adopted stopping ability criterion of 15 ship lengths.

11 Considering a steam turbine propelled VLCC of 300 metres length, travelling at 15 knots, and assuming that it takes 1 minute to develop full-astern thrust in a stopping manoeuvre, the results using tables A3-1, 2 and 3 are:

$A = 16$,

$B = 1.5$, and

$C = 0.8$

12 Using the formula for the stopping distance S, given above, then:

$S = 16 \log_e (1 + 1.5) + 0.8$

= 15.5 ship lengths,

which exceeds the stopping ability criterion of 15 ship lengths.

13 In all cases the value of A is inherent in the shape of the hull and so cannot be changed unless resistance is significantly increased. The value of B can only be reduced by incorporating more astern power in the engine, an option which is unrealistic for a steam turbine powered ship. The value of C would become larger if more than one minute was taken to reverse the engines, from the astern order to the time when the full-astern thrust is developed.

APPENDIX 4

ADDITIONAL MANOEUVRES

1 Additional methods to assess course keeping ability

1.1 The Standards note that additional testing may be used to further investigate a dynamic stability problem identified by the standard trial manoeuvres. This appendix briefly discusses additional trials that may be used to evaluate a ship's manoeuvring characteristics.

1.2 The Standards are used to evaluate course-keeping ability based on the overshoot angles resulting from the 10°/10° zig-zag manoeuvre. The zig-zag manoeuvre was chosen for reasons of simplicity and expediency in conducting trials. However, where more detailed analysis of dynamic stability is required some form of spiral manoeuvre should be conducted as an additional measure. A direct or reverse spiral manoeuvre may be conducted. The spiral and pull-out manoeuvres have historically been recommended by various trial codes as measures that provide the comprehensive information necessary for reliably evaluating course-keeping ability. The direct spiral manoeuvre is generally time consuming and weather sensitive. The simplified spiral can be used to quickly evaluate key points of the spiral loop curve.

2 Spiral manoeuvres

2.1 Direct spiral manoeuvre

2.1.1 The direct spiral manoeuvre is an orderly sequence of turning circle tests to obtain a steady turning rate versus ~~rudder~~steering angle relation (see figure A4-2).

2.1.2 Should there be reasons to expect the ship to be dynamically unstable, or only marginally stable, a direct spiral test will give additional information. This is a time-consuming test to perform especially for large and slow ships. A significant amount of time is needed for the ship to obtain a steady rate of change of heading after each ~~rudder~~steering angle change. Also, the test is very sensitive to weather conditions.

2.1.3 In the case where dynamic instability is detected with other trials or is expected, a direct spiral test can provide more detailed information about the degree of instability that exists. While this test can be time consuming and sensitive to weather conditions, it yields information about the yaw rate/~~rudder~~steering angle relation that cannot be measured by any other test.

2.1.4 The direct spiral is a turning circle manoeuvre in which various steady state yaw rate/~~rudder~~steering angle values are measured by making incremental ~~rudder~~steering angle changes throughout a circling manoeuvre. Adequate time must be allowed for the ship to reach a steady yaw rate so that false indications of instability are avoided.

2.1.5 In cases where the ship is dynamically unstable it will appear that it is still turning steadily in the original direction although the ~~rudder~~steering is now slightly deflected to the opposite side. At a certain stage the yaw rate will abruptly change to the other side and the yaw rate versus ~~rudder~~steering angle relation will now be defined by a separate curve. Upon completion of the test the results will display the characteristic spiral loop as presented in figure A4-3.

2.1.6 A direct spiral manoeuvre can be conducted using the following general procedure:

.1 the ship is brought to a steady course and speed according to the specific initial condition;

.2 the recording of data starts;

.3 the ~~rudder~~steering is turned about ~~15°~~half the declared steering angle limit and held until the yaw rate remains constant for approximately one minute;

.4 the ~~rudder~~steering angle is then decreased in three approximately ~~5 degree~~equal increments~~.~~ towards zero steering angle. At each increment the ~~rudder~~steering is held fixed until a steady yaw rate is obtained, measured and then decreased again;

.5 this is repeated for different ~~rudder~~steering angles starting from large angles to both port and starboard; and

.6 when a sufficient number of points is defined, data recording stops.

2.2 Reverse spiral manoeuvre

2.2.1 The reverse spiral test may provide a more rapid procedure than the direct spiral test to define the instability loop as well as the unstable branch of the yaw rate versus ~~rudder~~steering angle relationship indicated by the dotted curve as shown in figure A4-2. In the reverse spiral test the ship is steered to obtain a constant yaw rate, the mean ~~rudder~~steering angle required to produce this yaw rate is measured and the yaw rate versus ~~rudder~~steering angle plot is created. Points on the curve of yaw rate versus ~~rudder~~steering angle may be taken in any order.

2.2.2 This trial requires a properly calibrated rate of turn indicator and an accurate ~~rudder~~steering angle indicator. Accuracy can be improved if continuous recording of rate of turn and ~~rudder~~steering angle is available for the analysis. Alternatively the test may be performed using a conventional autopilot. If manual steering is used, the instantaneous rate of turn should be visually displayed to the helmsman.

2.3 Simplified spiral manoeuvre

2.3.1 The simplified spiral reduces the complexity of the spiral manoeuvre. The simplified spiral consists of three points which can be easily measured at the end of the turning circle test. The first point is a measurement of the steady state yaw rate at the ~~maximum rudder~~declared steering angle limit. To measure the second point, the ~~rudder~~steering is returned to the neutral position and the steady state yaw rate is measured. If the ship returns to zero yaw rate the ship is stable and the manoeuvre may be terminated. Alternatively, the third point is reached by placing the ~~rudder~~steering in the direction opposite of the original ~~rudder~~steering angle to an angle equal to half the allowable loop width. The allowable loop width may be defined as:

0°	for	L/V < 9	seconds
~~3 +~~(-1/~~3~~12 + 1/108 (L/V)) of declared steering angle limit	for	9 < L/V < 45	seconds
~~12°~~1/3 of declared steering angle limit	for	45 < L/V	seconds

When the ~~rudder~~steering is placed at half the allowable loop width and the ship continues to turn in the direction opposite to that of the ~~rudder~~steering angle, then the ship is unstable beyond the acceptable limit.

3 Pull-out manoeuvre

After the completion of the turning circle test the ~~rudder~~steering is returned to the midship position and kept there until a steady turning rate is obtained. This test gives a simple indication of a ship's dynamic stability on a straight course. If the ship is stable, the rate of turn will decay to zero for turns to both port and starboard. If the ship is unstable, then the rate of turn will reduce to some residual rate of turn (see figure A4-1). The residual rates of turn to port and starboard indicate the magnitude of instability at the neutral ~~rudder~~steering angle. Normally, pull-out manoeuvres are performed in connection with the turning circle, zig-zag, or initial turning tests, but they may be carried out separately.

4 Very small zig-zag manoeuvre

4.1 The shortcomings of the spiral and 10°/10° zig-zag manoeuvres may be overcome by a variation of the zig-zag manoeuvre that quite closely approximates the behaviour of a ship being steered to maintain a straight course. This zig-zag is referred to as a Very Small Zig Zag (VSZZ), which can be expressed using the usual nomenclature, as 0°/5° zig-zag, where ψ is 0° and δ is ~~5º~~ 1/7 of the declared steering angle limit.

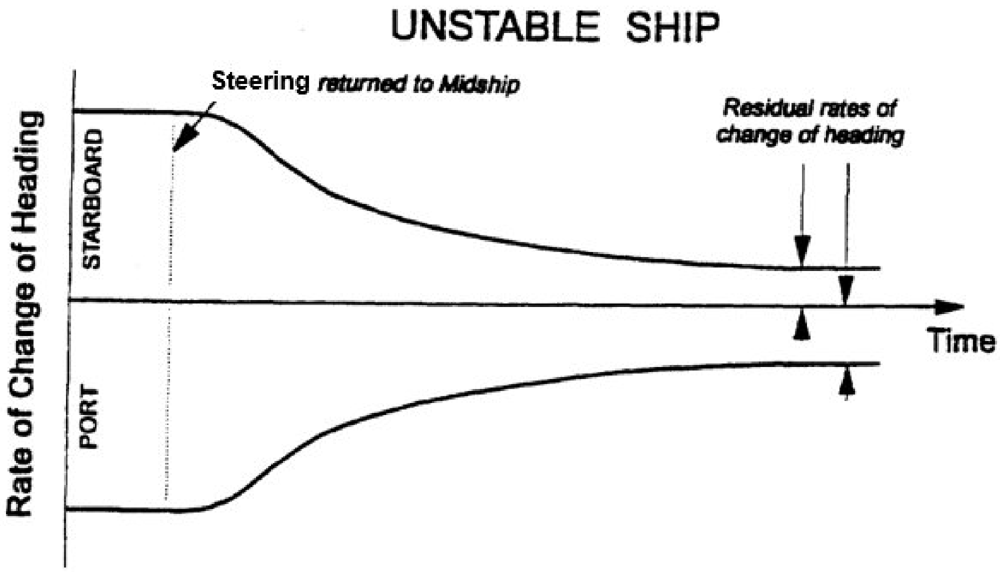
4.2 VSZZs characterized by 0°/5° are believed to be the most useful type, for the following two reasons:

.1 a human helmsman can conduct VSZZs by evaluating the instant at which to move the wheel while sighting over the bow, which he can do more accurately than by watching a conventional compass.

.2 a conventional autopilot could be used to conduct VSZZs by setting a large proportional gain and the differential gain to zero.

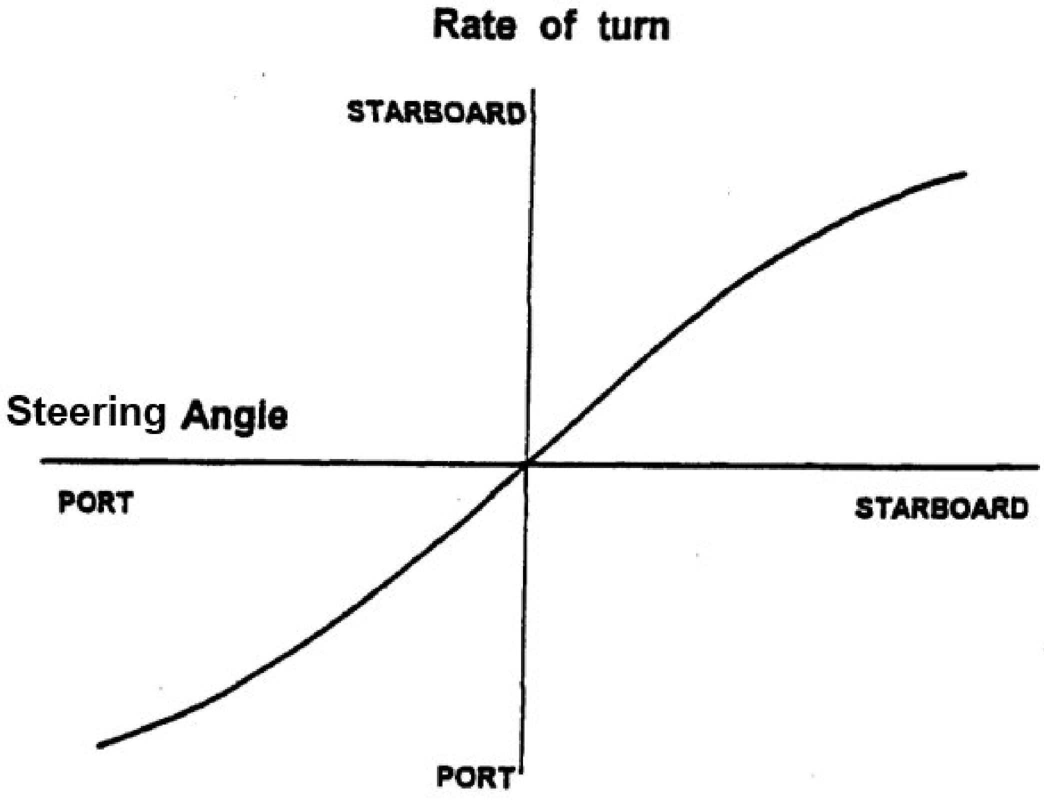
4.3 There is a small but essential difference between 0°/5° VSZZs and more conventional similar zig-zags, such as 1°/5° zig-zag. The 0°/5° zig-zag must be initialised with a non-zero rate-of-turn. In reality, this happens naturally in the case of inherently unstable ships.

4.4 A VSZZ consists of a larger number of cycles than a conventional zig-zag, perhaps 20 overshoots or so, rather than the conventional two or three, and interest focuses on the value of the overshoot in long term. The minimum criterion for course-keeping is expressed in terms of the limit-cycle overshoot angle for 0°/5° VSZZs and is a function of length to speed ratio.



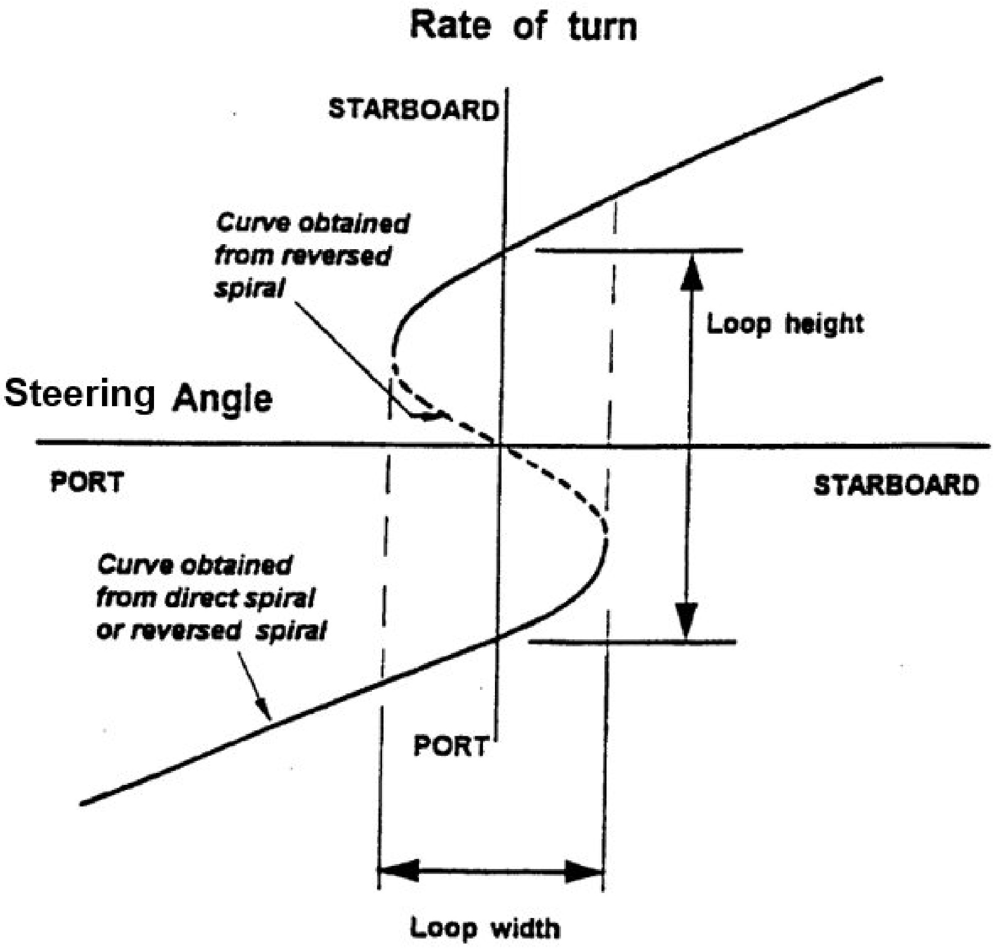
Presentation of pull-out test results

Figure A4-1



Presentation of spiral test results for stable ship

Figure A4-2



Presentation of spiral test results for unstable ship

Figure A4-3

APPENDIX 5

BACKGROUND AND BIBLIOGRAPHY

1 Background data

MSC/Circ.389 and MSC/Circ.644 invited Member Governments to submit ship manoeuvrability data for use in ship design and for establishing manoeuvrability standards. In response, ship trials data and other manoeuvring research and information were submitted to the Sub-Committee on Ship Design and Equipment by Member Governments. This data, along with other available information, were used in the development of the Standards for ship manoeuvrability (resolution MSC.137(76)) and Explanatory notes, as appropriate.

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APPENDIX 6

FORM FOR REPORTING MANOEUVRING DATA TO IMO

Administration: ______________________ **Reference No.***

SHIP DATA: (FULL LOAD CONDITION)

Ship type*			L/V	sec
L/B		B/T	C_B	
~~Rudder~~Steering/ rudder type*			Number of rudders	
Total rudder area/LT			Trim	
Propeller type*				
No. of propellers			Ballast condition	
Engine type*				

TRIALS DATA: (ENVIRONMENTAL CONDITION)

Water depth/trial draught	
Wind: Beaufort number	
Wave: Sea state	

MANOEUVRING DATA:

Loading condition: Tested at Full load ☐ Tested at partial load and corrected ☐

	TEST RESULTS			IMO CRITERIA
Turning circle:	**PORT**	**STBD**		
Advance			Ship lengths	4.5
Tactical diameter			Ship lengths	5
Zig-Zag:				
10 deg/10 deg	**PORT**	**STBD**		
1st overshoot angle			deg	
2nd overshoot angle			deg	
20 deg/20 deg	**PORT**	**STBD**		
1st overshoot angle			deg	25
Initial turning:	**PORT**	**STBD**		
Distance to turn 10 deg with ~~10 deg rudder~~1/3 declared steering angle limit			Ship lengths	2.5
Stopping distance: Track reach			Ship lengths	15 to 20

REMARKS:

* See notes on the reverse of the page.

Form for reporting manoeuvring data to IMO

Notes:

1 Reference no. assigned by the Administration for internal use.

2 Ship type such as container ship, tanker, gas carrier, ro-ro ship, passenger ship, car carrier, bulk carrier, etc.

3 ~~Rudder~~Steering type such as azimuthing, water jet, cycloidal, full spade rudder, semi-spade rudder, high lift rudder, etc.

4 Propeller tune such as fixed pitch, controllable pitch, with/without nozzle, etc.

5 Engine type such as diesel, steam turbine, gas turbine, diesel-electric, etc.

6 IMO criteria for 10°/10° zig-zag test vary with L/V. Refer to paragraphs 5.3.3.1 and 5.3.3.2 of the Standards for ship manoeuvrability (resolution MSC.137(76)).

Resolution A.601(15)

Annex to Resolution A.601(15) is amended as follows:

ANNEX

~~RECOMMENDATION ON THE~~ PROVISION AND ~~THE~~ DISPLAY OF MANOEUVRING INFORMATION ON BOARD SHIPS

1 INTRODUCTION

1.1 In pursuance of the ~~Recommendation on Data Concerning Manoeuvring Capabilities and Stopping Distances of Ships~~Standards for Ship Manoeuvrability, adopted by resolution ~~A.160(ES.IV~~MSC.137(76), and Part 4-1 ~~paragraph 10~~ of Section A-VIII/2 ~~regulation II/1~~ of the ~~International Convention on Standards of Training, Certification and Watchkeeping for Seafarers~~ STCW Code, ~~1978~~ Administrations shall~~are recommended to~~ require that the manoeuvring information given herewith is on board and available to navigators.

1.2 The manoeuvring information ~~should~~shall be presented as follows:

.1 Pilot card

.2 Wheelhouse poster

.3 Manoeuvring booklet.

2 APPLICATION

2.1 The Administration ~~should~~shall require~~recommend~~ that manoeuvring information, in the form of the models contained in the appendices, should be provided ~~as follows:~~for all new ships to which the requirements of the 1974 SOLAS Convention, as amended, apply.

~~.1 for all new ships to which the requirements of the 1974 SOLAS Convention, as amended, apply, the pilot card should be provided;~~

~~.2 for all new ships of 100 metres in length and over, and all new chemical tankers and gas carriers regardless of size, the pilot card, wheelhouse poster and manoeuvring booklet should be provided.~~

2.2 The Administration ~~should~~shall encourage the provision of manoeuvring information on existing ships, and ships that may pose a hazard due to unusual dimensions or characteristics.

2.3 The manoeuvring information ~~should~~shall be amended after modification or conversion of the ship which may alter its manoeuvring characteristics or extreme dimensions.

3 MANOEUVRING INFORMATION

3.1 Pilot card (appendix 1)

The pilot card, to be filled in by the master, is intended to provide information to the pilot on boarding the ship. This information ~~should~~shall describe the current condition of the ship, with regard to its loading, propulsion and manoeuvring equipment, and other relevant equipment. The contents of the pilot card are available for use without the necessity of conducting special manoeuvring trials.

3.2 Wheelhouse poster (appendix 2)

The wheelhouse poster ~~should~~shall be permanently displayed in the wheelhouse. It ~~should~~shall contain general particulars and detailed information describing the manoeuvring characteristics of the ship, and be of such a size to ensure ease of use. The manoeuvring performance of the ship may differ from that shown on the poster due to environmental, hull and loading conditions.

3.3 Manoeuvring booklet (appendix 3)

The manoeuvring booklet ~~should~~shall be available on board and ~~should~~shall contain comprehensive details of the ship's manoeuvring characteristics and other relevant data. The manoeuvring booklet ~~should~~shall include the information shown on the wheelhouse poster together with other available manoeuvring information. Most of the manoeuvring information in the booklet can be estimated but some should be obtained from trials. The information in the booklet may be supplemented in the course of the ship's life.

APPENDIX 1

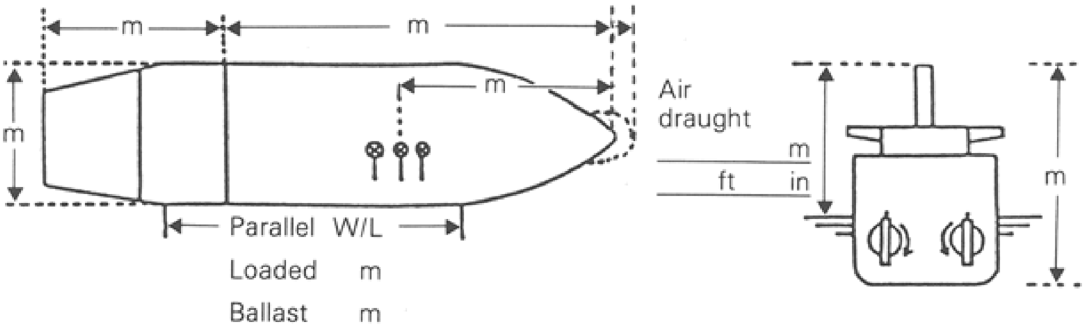
PILOT CARD

Ship's name ______________________ Date ______________

Call sign ____________ Deadweight ____________ tonnes Year built ____________

Draught aft ______m/____ft ____in, Forward ______m/____ft ____in, Displacement ______tonnes

SHIP'S PARTICULARS		
Length overall ______m,	Anchor chain: Port ______shackles,	Starboard ______shackles,
Breadth ______m	Stern ______shackles	
Bulbous bow Yes/No	(1 shackle = ________m/________fathoms)	



Type of engine ________________ Maximum power __________kW (__________HP)

Manoeuvring engine order	Rpm/pitch	Speed (knots) Loaded	Speed (knots) Ballast
Full ahead			
Half ahead			
Slow ahead			
Dead slow ahead			
Dead slow astern		Time limit astern	__________min
Slow astern		Full ahead to full astern	___________s
Half astern		Max. no. of consec. starts	___________
Full astern		Minimum RPM ________	_______ knots
		Astern power	_________% ahead

STEERING PARTICULARS	
Type of steering/ rudder ________	Maximum angle ______________ °
Hard-over to hard-over ______________ s	Declared steering angle limit: ______deg
Steering angle for neutral effect ______________ °	
Thruster: Bow ________ kW (________ HP)	Stern ________ kW (________ HP)

CHECKED IF ABOARD AND READY

Anchors ☐

Whistle ☐

Radar ☐ 3 cm ☐ 10 cm

ARPA ☐

Speed log ☐ Doppler: Yes/No

- Water speed ☐
- Ground speed ☐
- Dual-axis ☐

Engine telegraphs ☐

Steering gear ☐

- Number of power units operating ☐

Indicators:

- Steering ☐
- Rpm/pitch ☐
- Rate of turn ☐

Compass system ☐

Constant gyro error ± _____ °

VHF ☐

Elec. pos. fix. system ☐

Type ____________

OTHER INFORMATION:

APPENDIX 2

WHEELHOUSE POSTER

Ship's name ______________, Call sign __________, Gross tonnage __________, Net tonnage __________

Max. displacement ________tonnes, and Deadweight ________tonnes, and Block coefficient ________ at summer full load draught

Draught at which the manoeuvring data were obtained

Loaded	Ballast
Trial/Estimated	Trial/Estimated
___m forward	___m forward
___m aft	___m aft

STEERING PARTICULARS	
Type of steering/ rudder	____________
Maximum steering angle	________ °
Time hard-over to hard-over	
with one power unit	________ s
with two power units	________ s
Minimum speed to maintain course propeller stopped	____ knots
Steering angle for neutral effect	________ °

ANCHOR CHAIN	No. of shackles	Max. rate of heaving (min/shackle)
Port		
Starboard		
Stern		
(1 shackle = _____m/_____fathoms)		

PROPULSION PARTICULARS

Type of engine ______ ____kW (____HP), Type of propeller ______

Engine order	Rpm/pitch setting	Speed (knots) Loaded	Ballast
Full sea speed			
Full ahead			
Half ahead			
Slow ahead			
Dead slow ahead			
Dead slow astern		Critical revolutions ____rpm Minimum rpm ____ ____knots	
Slow astern		Time limit astern ____min Time limit at min. revs ____min	
Half astern		Emergency full ahead to full astern ____s Stop to full astern ____s	
Full astern		Astern power ____% ahead Max. no. of consecutive starts ____	

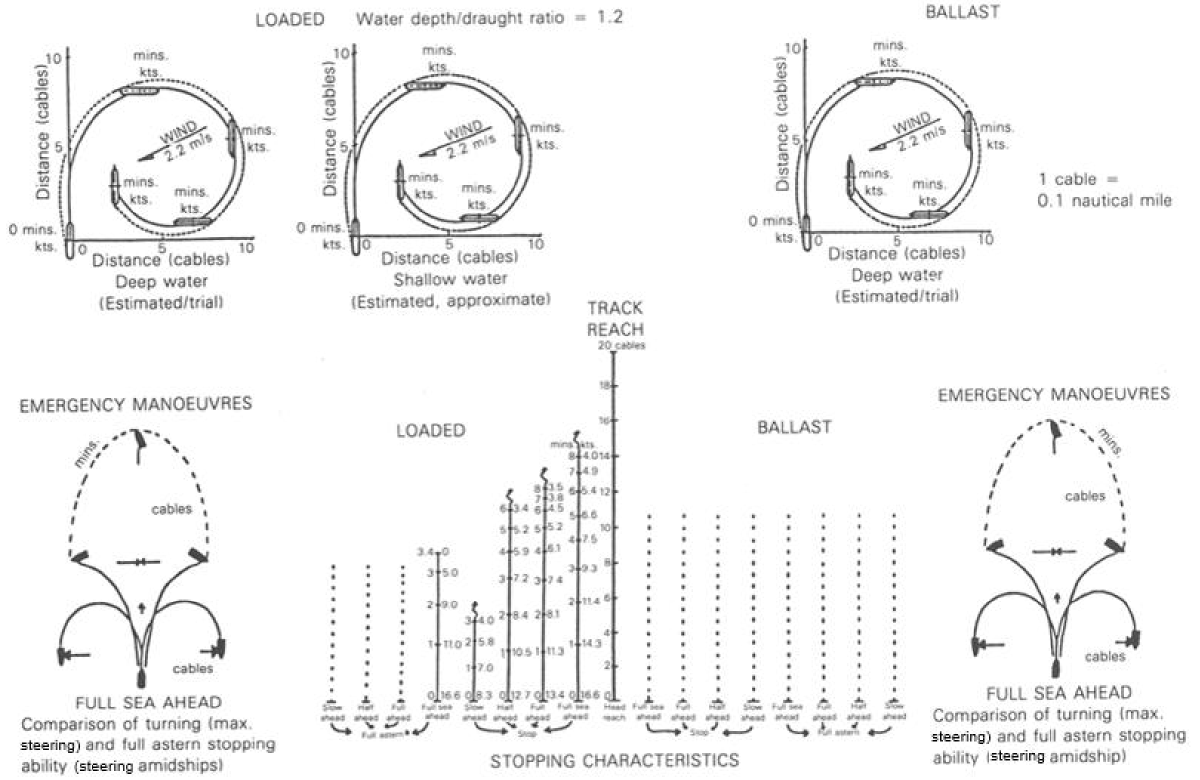
THRUSTER EFFECT at trial conditions

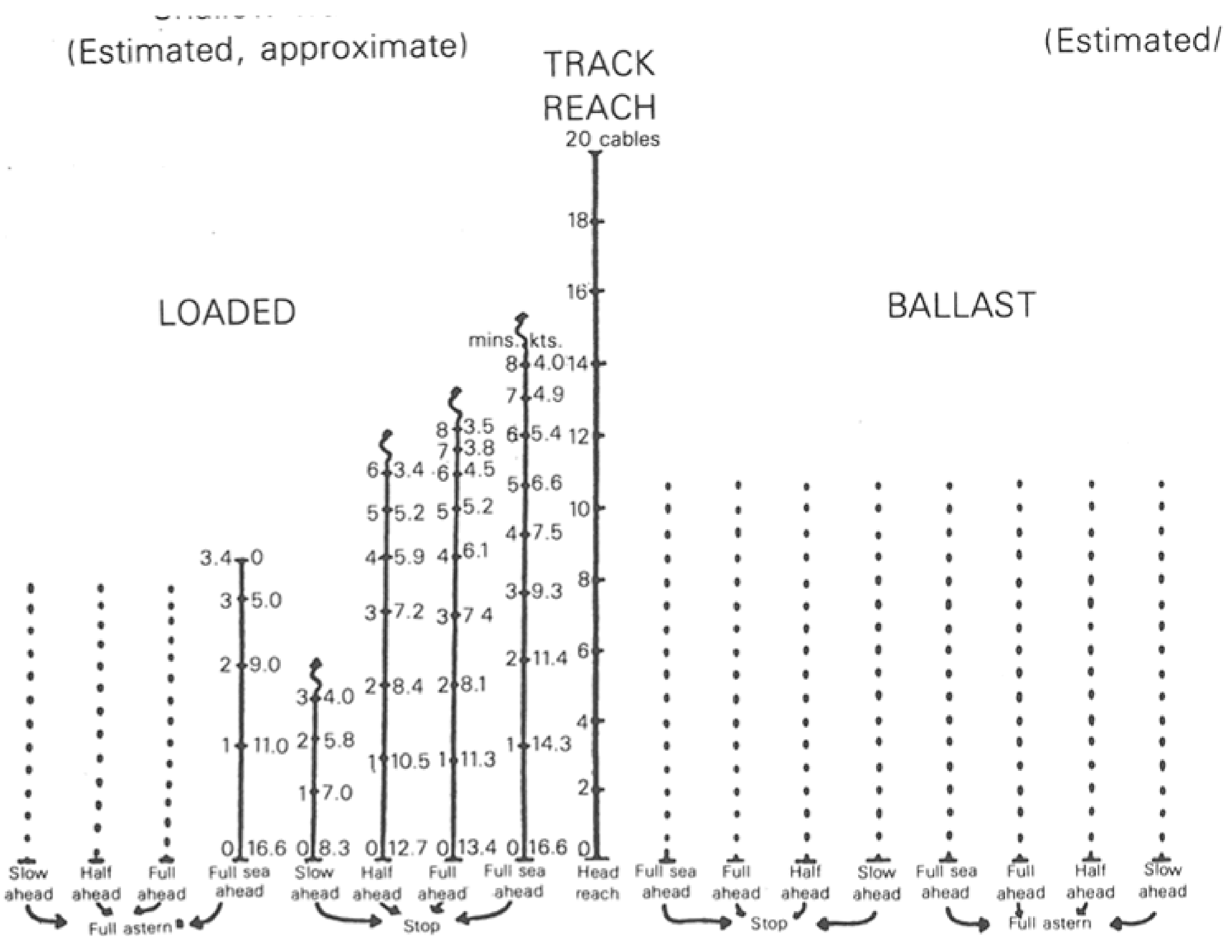
Thruster	kW (HP)	Time delay for full thrust	Turning rate at zero speed	Time delay to reverse full thrust	Not effective above speed
Bow		s	°/min	min s	knots
Stern		s	°/min	min s	knots
Combined		s	°/min	min s	knots

DRAUGHT INCREASE (LOADED)

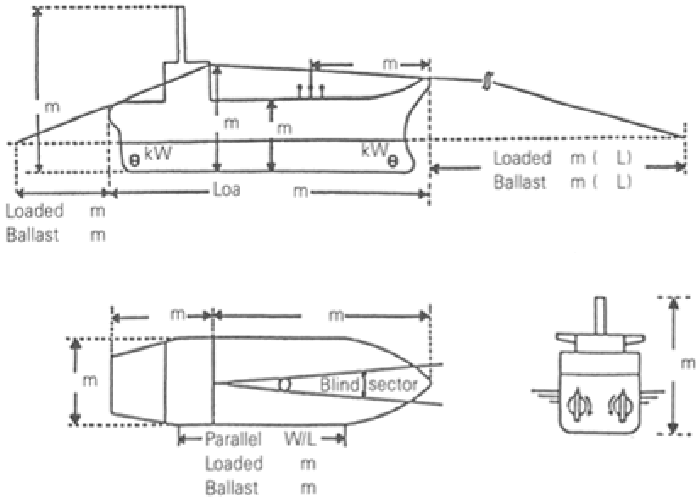
Estimated Squat Effect			Heel Effect	
Under keel clearance	Ship's speed (knots)	Max. bow squat estimated (m)	Heel angle (degree)	Draft increase (m)
			2	
m			4	
			8	
			12	
m			16	

TURNING CIRCLES AT DECLARED STEERING ANGLE LIMIT: ____________deg





STOPPING CHARACTERISTICS



MAN OVERBOARD
RESCUE MANOEUVRE

SEQUENCE OF ACTIONS TO BE TAKEN:

- TO CAST A LIFEBUOY
- TO GIVE THE HELM ORDER
- TO SOUND THE ALARM
- TO KEEP THE LOOK-OUT

Insert a
recommended
turn

Prepared by ______________________

Date ______________________

PERFORMANCE MAY DIFFER FROM THIS RECORD DUE TO
ENVIRONMENTAL, HULL AND LOADING CONDITIONS

APPENDIX 3

RECOMMENDED INFORMATION TO BE INCLUDED IN THE MANOEUVRING BOOKLET

CONTENTS

1 General description
- 1.1 Ship's particulars
- 1.2 Characteristics of main engine

2 Manoeuvring characteristics in deep water
- 2.1 Course change performance
- 2.2 Turning circles in deep water
- 2.3 Heading keeping test in deep water
- 2.4 Accelerating turn
- 2.~~4~~5 Yaw checking tests
- 2.~~5~~6 Man-overboard and parallel course manoeuvres
- 2.~~6~~7 Lateral thruster capabilities

3 Stopping and speed control characteristics in deep water
- 3.1 Stopping ability
- 3.2 Deceleration performance
- 3.3 Acceleration performance

4 Manoeuvring characteristics in shallow water
- 4.1 Turning circle in shallow water
- 4.2 Squat

5 Manoeuvring characteristics in wind
- 5.1 Wind forces and moments
- 5.2 Course-keeping limitations
- 5.3 Drifting under wind influence

6 Manoeuvring characteristics at low speed

7 Additional information

1 General description

1.1 Ship's particulars

1.1.1 General

Ship's name, distinctive number or letters, year of build

1.1.2 Gross tonnage and other information

Gross tonnage, deadweight and displacement (at summer draught)

1.1.3 Principal dimensions and coefficients

Length overall, length between perpendiculars, breadth (moulded), depth (moulded), summer draught, normal ballast draught, hull coefficients at summer load and normal ballast condition

Extreme height of the ship's structure above the keel

1.1.4 Main engine

Type, number of units and power output

1.1.5 ~~Propeller~~Propulsor

Type, number of units, diameter, pitch, direction of rotation, propeller immersion

1.1.6 ~~Rudder~~Steering

Type, number of units, declared steering angle limits (Res. MSC.137(76))

For rudders also: total rudder area, rudder area ratio (full load and normal ballast)

1.1.7 Bow and stern thrusters

Type, number of units, capacities and location

1.1.8 Bow and stern profiles

1.1.9 Forward and after blind zones with dimensions specified (full load and normal ballast)

1.1.10 Other hull particulars

Projected areas of longitudinal and lateral above-water profiles (full load and normal ballast)
Length of parallel middle body for berthing (full load and normal ballast)

1.2 Characteristics of main engine

1.2.1 Manoeuvring speed tables (trial or estimated, at the full load and ballast conditions)

Engine revolutions, ship speed and thrust (at ahead) corresponding to engine orders

1.2.2 Critical revolutions

1.2.3 Time for effecting changes in engine telegraph settings as in 3.1.2 for both routine and emergency conditions

1.2.4 Time limit astern

1.2.5 Minimum operating revolutions (for diesel engines) and corresponding ship speed

1.2.6 Maximum number of consecutive starts (for diesel engines)

2 Manoeuvring characteristics in deep water

2.1 Course change performance

2.1.1 Initial turning test results (trial or estimated, at the full load and ballast conditions), test conditions, diagrams of heading angle versus time and ship's track

2.1.2 Course change test results (trial or estimated, at full load and ballast conditions)

Curves of course change distance and point of initiation of counter rudder for the necessary course change angle (for both full load and ballast conditions)

2.2 Turning circles in deep water (trial or estimated, at the full load and ballast conditions)

2.2.1 Turning circle test results

Test conditions, test results (advance and transfer) and turning track at full sea speed ahead

2.2.1.1 Turning circles in both full load, both in normal operational condition and with the steering system in reduced service, and ballast conditions (stern track should be shown)

2.2.1.2 The data presented should refer to the case of starboard turn only (unless there is significant difference for port turn)

2.2.1.3 The initial speed of the ship should be full sea speed ahead

2.2.1.4 Times and speeds at 90, 180, 270 and 360 degrees turning should be specifically shown together with an outline of the ship

2.2.1.5 The ~~rudder~~steering angle used in the test should be the ~~maximum rudder~~declared steering angle limit

2.3 Heading keeping test in deep water

Heading keeping test at full load, both in normal operational condition and with the steering system in reduced service. The maximum yaw deviation during the heading keeping test is to be reported.

2.~~3~~4 Accelerating turn (trial or estimated)

Data are to be presented for both full load and ballast conditions in the same manner as 2.2 for turning circles. The ship accelerates from rest with the engine full manoeuvring speed ahead and the ~~maximum rudder~~declared steering angle limit

2.~~4~~5 Yaw checking tests (trial or estimated)

2.~~4~~5.1 Results of the zig-zag and pull-out manoeuvre tests at the full load or ballast condition shown as diagrams of the heading changes and ~~rudder~~steering angle

2.~~5~~6 Man-overboard and parallel course manoeuvres

2.~~5~~6.1 Man-overboard manoeuvre (trial)

Diagrams for cases of both starboard and port turns should be shown for both full load and ballast conditions

2.~~5~~6.2 Parallel course manoeuvre (estimated)

Diagrams showing lateral shift to a parallel course using ~~maximum rudder~~declared steering angle limit

2.~~6~~7 Lateral thruster capabilities (trial or estimated)

2.~~6~~7.1 Diagrams of turning performance at zero forward speed in the full load or ballast condition should be shown, for bow and stern thrusters acting separately and in combination

2.~~6~~7.2 Diagrams showing the effect of forward speed on turning performance should be included

2.~~6~~7.3 Information on the effect of wind on turning performance should be given

3 Stopping and speed control characteristics in deep water

3.1 Stopping ability

3.1.1 Stopping test results (trial)

Test conditions, ship's tracks, rpm, speed, track reach, head reach and side reach

Two or more tests should be carried out including a test of full astern from full sea speed ahead and a test of full astern from full ahead speed. For ships provided with multiple propulsion lines, additional tests should be carried out while any one of the propulsion systems and its corresponding steering system is out of operation.

3.1.2 Stopping ability (estimated)

Information and diagrams should be given of the track reach, head reach, side reach, time required and track reach deceleration factor (distance/one knot reduction) of a ship in both full load and ballast conditions covering the following modes of stopping manoeuvres:

– full astern from full sea speed ahead

– full astern from full ahead speed

– full astern from half ahead speed

– full astern from slow ahead speed

– stop engine from full sea speed ahead

– stop engine from full ahead speed

– stop engine from half ahead speed

– stop engine from slow ahead speed

3.2 Deceleration performance (estimated)

3.2.1 Deceleration ability (estimated)

Information and diagrams should be given concerning the track reach, time required and deceleration factor of the ship in both full load and ballast conditions for the following engine orders:

– full sea speed to "stand by engines"

– full ahead to half ahead

– half ahead to slow ahead

– slow ahead to dead slow ahead

3.3 Acceleration performance (estimated)

3.3.1 Information and diagrams should be given for track reach and time for the ship to achieve full sea speed ahead, from zero speed

4 Manoeuvring characteristics in shallow water

4.1 Turning circle in shallow water (estimated)

4.1.1 Turning circle in the full load condition (stern track to be shown)

4.1.2 The initial speed of the ship should be half ahead

4.1.3 Times and speeds at 90°, 180°, 270° and 360° turning should be specifically shown, together with an outline of the ship

4.1.4 The ~~rudder~~steering angle should be the ~~maximum~~declared steering angle limit and the water depth to draught ratio should be 1.2

4.2 Squat (estimated)

4.2.1 Curves should be drawn for shallow water and infinite width of channel, indicating the maximum squat versus ship speed for various water depth/draught ratios

4.2.2 Curves should be drawn for shallow and confined water, indicating the maximum squat versus speed for different blockage factors

5 Manoeuvring characteristics in wind

5.1 Wind forces and moments (estimated)

5.1.1 Information should be given on the wind forces and moments acting on the ship for different relative wind speeds and directions in both full load and ballast conditions, to assist in berthing

5.2 Course-keeping limitation (estimated)

5.2.1 Information should be given for both full load and ballast conditions, showing the effect of wind on the ability of the ship to maintain course

5.3 Drifting under wind influence (estimated)

5.3.1 Information should be given on the drifting behaviour under wind influence with no engine power available

6 Manoeuvring characteristics at low speed (trial or estimated)

6.1 Information on the minimum operating revolutions of the main engine and corresponding ship's speed should be given

6.2 Information on the minimum speed at which the ship can maintain course while still making headway after stopping engines

7 Additional information

7.1 Any other relevant additional information should be added to the contents of the booklet, particularly information concerned with the operation of the bridge manoeuvring controls.

Circular MSC.1/Circ. XXXX: Goals, functional requirements and expected performance criteria for SOLAS Regulations II-1/28 & 29 and V/25 & 26

The following Annex to a tentative draft MSC Circular is proposed:

1. Scope

This circular describes the goals and establish the functional requirements that the rules for the design and construction of ship's steering and propulsion systems should be conform to.

The Appendix A contains the goals, functional requirements and expected performance criteria as such; while Appendix B establishes the cross check between them and the SOLAS regulations II–1/28 & 29 and V/25 & 26 as relevant requirements for ship's steering and propulsion systems.

2. Definitions

For the purpose of this Circular, unless expressly provided otherwise, the terms used have the meanings defined in the following paragraphs. Terms used, but not defined below, are to be interpreted as they are defined in the relevant SOLAS regulations.

Term	**Definition**
Cold redundancy	Cold redundancy is for non-critical processes where time is not a high priority and human intervention is acceptable
Declared steering angle limits	Declared steering angle limits are the operational limits in terms of maximum steering angle, or equivalent, taking into account the ship's speed or propeller torque/speed or other parameter; set according to both manufacturer's guidelines for safe operation and any ship design limitation.
Environmental load	Any kind of load due to weather, wind, wave etc.
Expected performance	Part of functional requirement (MSC.1Circ.1394/Rev.2) providing the criterion for verification of compliance
Fail-safe	A concept which is incorporated into the design of a product such that, in the event of a failure, it enters or remains in a safe state (EN 50129)
Failure	An occurrence in which a part, or parts of a system ceases to perform the required function, i.e. a state of inability to perform a normal function
Failure mode	Inability to perform intended function and manifestation
Functional requirement	Functional requirements provide the criteria to be complied with in order to meet the goals. (MSC.1Circ.1394/Rev.2)
Goal	High-level objectives to be met that addresses the issue(s) of concern and reflect the required level of safety
Hazard	A potential to threaten human life, health, property or the environment

Hot redundancy	Warm & hot redundancy are similar in arrangement, but hot redundancy offers instant process correction when a failure is detected
Insufficient performance	Performance does not meet the expectations for safe steering and manoeuvring
Load	Any kind of load acting in or on a system or component of system such as mechanical, hydraulic or electrical
Malfunctioning/malfunction	System or component blocked, broken down, output deviates from design intent
Mode	Manifestation, form or arrangement of being
Normal service	A system fully functional and provides intended performance
Operational profile	Conditions a vessel operates in, e.g. wind, waves, temperature, loading etc.
Overload	Load outside loads considered for design
Reduced service	Service of system in the event of a failure not causing complete loss, i.e. system delivers limited performance compared to normal service
Redundancy	Ability of a system to maintain its function when one failure has occurred
Steering actuating system	Steering actuating system is the equipment provided for supplying power to turn the steering force unit, i.e. comprising steering gear power unit, actuator and the system connecting them (e.g.: transmission or piping system).
Steering actuator	Steering actuator is a component which converts energy into mechanical motion to turn the steering force unit (e.g. hydraulic cylinder, piston, etc.).
Steering control system	Steering control system is the equipment by which orders are transmitted to the steering actuating system(s). Steering control systems comprise all components from the user input device to the receivers, including transmitters, controllers, piping, cables and data networks, hydraulic control pumps and their associated motors, motor controllers and solenoid valves, as appropriate.
Steering force unit	Steering force unit is the element generating the forces required to control the vessel (i.e. rudder and stock, rudder propeller, thruster, pod), including all parts up to the interface

	to the steering gear.
Steering gear	Steering gear is the machinery, actuating system(s) and ancillary equipment to direct the steering force unit for the purpose of steering the ship. The steering gear may include various combinations of steering actuating systems and tiller or equivalent component.
Steering gear power unit	Steering gear power unit is: .1 in the case of electric steering gear, an electric motor and its associated electrical equipment; .2 in the case of electrohydraulic steering gear, an electric motor and its associated electrical equipment and connected pump; or .3 in the case of other hydraulic steering gear, a driving engine and connected pump.
Steering system	Steering system(s) is the ship's mean(s) of directional control, including steering gear, steering control and monitoring system and steering force unit, as well as all means connecting to power supply
Warm redundancy	When time and response to a failure is more important but not critical, a warm redundancy strategy may suffice if a temporary outage is acceptable. The cycle can tolerate certain minutes of interruption, but the process must be restored quickly and automatically to avoid any integrity issues.

Final goals and functional requirements for steering and manoeuvring

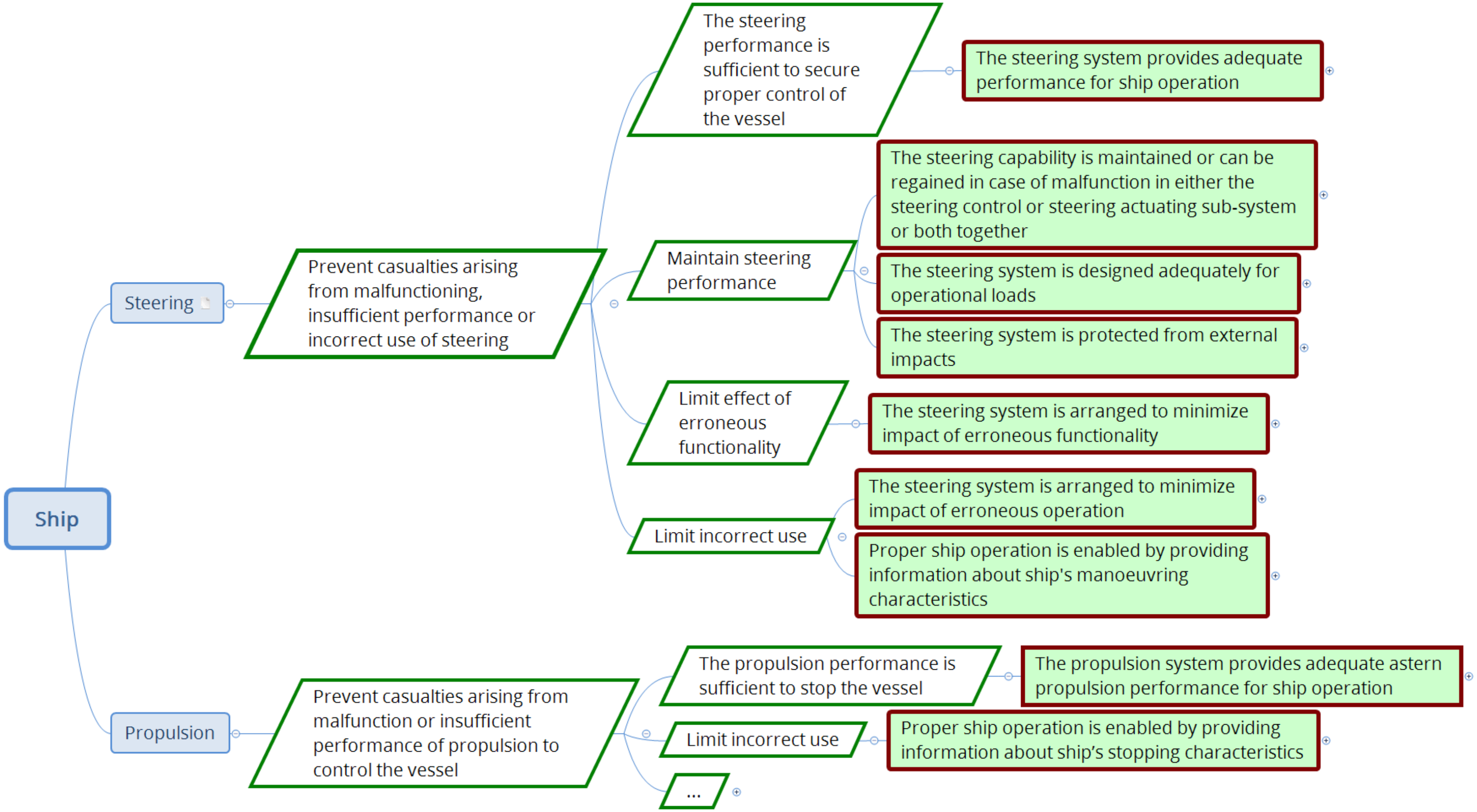


Figure 1 Structure of goals and functional requirements

Top goal and individual goals for steering

Top goal for steering: Prevent casualties arising from malfunctioning, insufficient performance or incorrect use of steering

- Individual goal 1: The steering performance is sufficient to secure proper control of the vessel
- Individual goal 2: Maintain steering performance
- Individual goal 3: Limit effect of erroneous functionality
- Individual goal 4: Limit incorrect use

Top goal and individual goals for propulsion

Top goal for propulsion: Prevent casualties arising from malfunctioning or insufficient performance of astern propulsion to control the vessel

- Individual goal 1: The propulsion performance is sufficient to stop the vessel
- Individual goal 2: Limit incorrect use

Function I: The steering system provides adequate steering performance for ship operation

Expected performance:

- The ship can maintain a straight course with yaw oscillations less than ±2 degrees for 30 minutes. Applicable for both normal and reduced service.
- Ability to turn/change course. Performance during Turning circle manoeuvre:
  - In normal service: advance within 4.5 ship lengths, tactical diameter within 5 ship lengths.
  - In reduced service: advance within 5.6 ship lengths, tactical diameter within 6.25 ship lengths.
- Steering gear performance

  Each steering gear can turn the steering force unit both to port and starboard with the following performance at scantling draft:
  - In Normal service, running ahead at maximum ahead service speed:
    - from declared steering angle limit on one side to declared steering angle limit on the other side
    - from declared steering angle limit on one side to 85% of declared steering angle limit on the other in not more than 28 seconds
  - In Reduced service (only applicable to ships with single steering system):
    - from declared steering angle limit on one side to 85% of declared steering angle limit on the other in not more than 56 seconds, running ahead at maximum ahead service speed
    - For tanker, chemical tanker or gas carrier of less than 10,000 gross tonnage and every other ship of less than 70,000 gross tonnage, the requirement may be reduced to:
      from 50% of declared steering angle limit on one side to 50% of declared steering angle limit on the other in not more than 60 seconds, running

ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater.

Function II: The steering capability is maintained or can be regained in case of malfunction in either the steering control or steering actuating sub-systems or both together

Expected Performance:

- Malfunction of steering gear will not lead to complete loss of steering capability and at least reduced service performance is maintained;
    - For passenger ships of 70,000 gross tonnage and upwards, normal service performance is maintained
    - and for all other ships, at least reduced service performance is maintained
    - For multiple steering-propulsion systems, redundancy can be realized on ship level
- Malfunction of steering control system will not lead to complete loss of steering capability;
    - Reduced service steering capability is maintained.
    - Steering system can be operated from navigation position.
    - Steering force unit angle indicated independent of control system
    - Indication of steering force unit angle in all locations the steering gear can be operated from
- Normal service capability is available without steering remote control system
- Steering capability (either normal or reduced) will be speedily regained;
    - For tanker, chemical tanker and gas carrier of 10,000 gross tonnage and upwards within 45 s (e.g. by warm redundancy)
    - For all other ships within 15 min. (e.g. by cold redundancy)
    - Automatic restart of steering system when electrical power is regained after failure in electrical power supply
- Availability and performance of steering system continuously monitored and indicated on navigation position
- Loss of availability and overload is indicated by an alarm

Function III: The steering system is designed adequately for operational loads

Expected Performance:

- Components have adequate strength for ship operation and specified design life, considering:
    - All mechanical, hydraulic and electrical loads

    - Characteristic loads resulting from operation of steering system considering ship operation and environment (e.g. waves, ice, maximum speed ahead/astern)
    - Safety factor adequate to address uncertainty in load determination and material/component properties
    - Actuating system is protected from overloads resulting from malfunctioning of the system
- Steering system is designed with margins such that normal wear and degradation will have negligible effect on functionality
- System operable under ship motion and environmental conditions
- Steering system availability is not hampered by safety devices
- Inspection concept adequate for steering system design

Function IV: The steering system is protected from external impacts

Expected Performance:

- Steering control system and actuator system are separated from other ship systems, and their electrical power supply arranged as separate circuit
- Electrical power supply maintained after malfunction in electric circuit
- Steering system is protected from external impacts by fire;
    - Separate routing of cabling for power supply and control system
    - No routing through areas of high risk of fire
    - Separate steering gear compartment from other machinery spaces
- Actuating system is protected from overloads, respectively;
    - Overloads due to external forces
    - Overloads resulting from erroneous operation

Additionally, passenger ships of 120 m in length or more or having three or more main vertical zones:

- Fire: reduced service steering capability available after loss of any space of origin
    - up to the nearest A class boundaries protected by fixed fire extinguishing system; or,
    - adjacent spaces up to nearest A class boundaries outside the space of origin
- Flooding: reduced service steering capability available after flooding of any single watertight compartment

Function V: The steering system is arranged to minimize impact of erroneous functionality

Expected Performance:

- Steering system shall be arranged with a fail-safe behaviour in case of failures

- Malfunction in data communication and programmable systems are automatically detected
- Consequences of malfunction in data communication and programmable systems are limited and do not render the system inoperable or with insufficient performance, and at least reduced service performance is maintained
- Earth fault does not render the system inoperable or with insufficient performance, and at least reduced service performance is maintained

Function VI: The steering system is arranged to minimize impact of erroneous operation

Expected Performance:

- Minimize possibilities of steering system operation threatening ship safety:
    - Limit possibility of erroneous input
        - Declare safe operational limits for steering system considering at least speed and stability
    - Limit effect of erroneous input

Function VII: Proper ship operation is enabled by providing information about ship's manoeuvring characteristics

Expected Performance:

- Provide information about ship's manoeuvring characteristics adequate for all persons involved in navigation and available at all navigation positions;
    - Condensed format for easy use summarising main manoeuvring characteristics (pilot card, wheelhouse poster)
    - Comprehensive details of manoeuvring characteristics per MSC.137 shall be readily available to the operator

- Provide familiarisation of ship's manoeuvrability characteristics (drills and training)

Function VIII: The propulsion system provides adequate astern propulsion performance for ship operation

Expected Performance:

- Ship can be brought to rest with stopping distance within 15 ship lengths
- In reduced service, ships provided with multiple propulsion-steering systems can be brought to rest with stopping distance within 20 ship lengths

Function IX: Proper ship operation is enabled by providing information about ship's stopping characteristics

Expected Performance:

Provide information about ship´s stopping characteristics adequate for all persons involved in navigation and available at all navigation positions

Cross reference functions and SOLAS regulation

Steering system

Function	Expected Performance	Reference SOLAS Ch. II-1
I. The steering system provides adequate steering performance for ship operation	• The ship can maintain a straight course with yaw oscillations less than ±2 degrees for 30 minutes. Applicable for both normal and reduced service.	Reg.29.4
	• Ability to turn/change course. Performance during Turning circle manoeuvre: ○ In normal service: advance within 4.5 ship lengths, tactical diameter within 5 ship lengths. ○ In reduced service: advance within 5.6 ship lengths, tactical diameter within 6.25 ship lengths.	Reg.29.4
	• Steering gear performance Each steering gear can turn the steering force unit both to port and starboard with the following performance at scantling draft: ○ In Normal service, running ahead at maximum ahead service speed: ▪ from declared steering angle limit on one side to declared steering angle limit on the other side ▪ from declared steering angle limit on one side to 85% of declared steering angle limit on the other	Reg.29.8

Function	Expected Performance	Reference SOLAS Ch. II-1
	in not more than 28 seconds o In Reduced service (only applicable to ships with single steering system): ▪ from declared steering angle limit on one side to 85% of declared steering angle limit on the other in not more than 56 seconds, running ahead at maximum ahead service speed ▪ For tanker, chemical tanker or gas carrier of less than 10,000 gross tonnage and every other ship of less than 70,000 gross tonnage, the requirement may be reduced to: from 50% of declared steering angle limit on one side to 50% of declared steering angle limit on the other in not more than 60 seconds, running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater.	

Function	Expected Performance	Reference SOLAS Ch. II-1
II. The steering capability is maintained or can be regained in case of malfunction in either the steering control or steering actuating or both together	• Malfunction of steering gear will not lead to complete loss of steering capability and at least reduced service performance is maintained; ○ For passenger ships of 70,000 gross tonnage and upwards, normal service performance is maintained ○ and for all other ships, at least reduced service performance is maintained ○ For multiple steering-propulsion systems, redundancy can be realized on ship level	Ch.V Reg.25 Reg.29.4, Reg.29.7, Reg.29.10.1 4)
	• Malfunction of steering control system will not lead to complete loss of steering capability; ○ Reduced service steering capability is maintained. ○ Steering system can be operated from navigation position. ○ Steering force unit angle indicated independent of control system ○ Indication of steering force unit angle in all locations the steering gear can be operated from	Reg.29.7 Reg.29.9 Reg.29.9.2.3 Reg.29.9.4.1
	• Normal service capability is available without steering	

Function	Expected Performance	Reference SOLAS Ch. II-1
	remote control system	Reg.29.9.2.3
	• Steering capability (either normal or reduced) will be speedily regained; o For tanker, chemical tanker and gas carrier of 10,000 gross tonnage and upwards within 45 s (e.g. by warm redundancy) o For all other ships within 15 min. (e.g. by cold redundancy) o Automatic restart of steering system when electrical power is regained after failure in electrical power supply	Reg.29.4.4 Reg. 29.7.3.2 Reg.29.4.5 Reg.29.7.3.1 Reg.29.9.4.2
	• Availability and performance of steering system continuously monitored and indicated on navigation position	Reg.29.9.3
	• Loss of availability and overload is indicated by an alarm	Reg.29.9.3.3 Reg.29.10.1 2)
III. The steering system is	• Components have adequate strength for ship operation and	

Function	Expected Performance	Reference SOLAS Ch. II-1
designed adequately for operational loads	specified design life, considering: ○ All mechanical, hydraulic and electrical loads ○ Characteristic loads resulting from operation of steering system considering ship operation and environment (e.g. waves, ice, maximum speed ahead/astern) ○ Safety factor adequate to address uncertainty in load determination and material/component properties ○ Actuating system is protected from overloads resulting from malfunctioning of the system	Reg.29.6 Reg.29.10.2 Reg.29.10.1 3)
	• Steering system is designed with margins such that normal wear and degradation will have negligible effect on functionality	Reg.29.6.1
	• System operable under ship motion and environmental conditions	Reg.29.6.1
	• Steering system availability is not hampered by safety devices	Reg.29.11.7
	• Inspection concept adequate for steering system design	Reg.29.12.2 Ch.V Reg.26

Function	Expected Performance	Reference SOLAS Ch. II-1
IV. The steering system is protected from external impacts	• Steering control system and actuator system are separated from other ship systems, and their electrical power supply arranged as separate circuit	Reg.29.9.2.4, Reg.29.9.5, Reg.29.11
	• Electrical power supply maintained after malfunction in electric circuit	Reg.29.9.5, Reg.29.11

	• Steering system is protected from external impacts by fire;
	    ○ Separate routing of cabling for power supply and control system
	    ○ No routing through areas of high risk of fire
	    ○ Separate steering gear compartment from other machinery spaces
		Reg.29.11
		Reg.29.9.2.2
		Reg.29.12.1

Function	Expected Performance	Reference SOLAS Ch. II-1

	• Actuating system is protected from overloads, respectively;
	  ○ Overloads due to external forces
	  ○ Overloads resulting from erroneous operation
		Reg.29.6.4,
		Reg.29.6.5,
		Reg.29.6.6
		Reg.29.10.1 3)

For Pax of 120 m in length or more or having three or more main vertical zones: Steering capability available after loss of any A-bounded space	• Fire: reduced service steering capability available after loss of any space of origin
	  ○ up to the nearest A class boundaries protected by fixed fire extinguishing system; or,
	  ○ adjacent spaces up to nearest A class boundaries outside the space of origin
		II-2/21, II-1/8-1.3

	• Flooding: reduced service steering capability available after flooding of any single watertight compartment	
V. The steering system is arranged to minimize impact of erroneous functionality	• Steering system shall be arranged with a fail-safe behaviour in case of failures	Reg.29.7, Reg.29.9.3.2,
	• Malfunction in data communication and programmable systems are automatically detected	Reg.29.7, Reg.29.9.3.2,

Function	Expected Performance	Reference SOLAS Ch. II-1
	• Consequences of malfunction in data communication and programmable systems are limited and do not render the system inoperable or with insufficient performance, and at least reduced service performance is maintained	Reg.29.9.3.2, Reg.29.9.6
	• Earth fault does not render the system inoperable or with insufficient performance, and at least reduced service performance is maintained	Reg.29.9.3.2

VI. The steering system is arranged to minimize impact of erroneous operation	• Minimize possibilities of steering system operation threatening ship safety:
	    ○ Limit possibility of erroneous input
	        ▪ Declare safe operational limits for steering system considering at least speed and stability
	    ○ Limit effect of erroneous input
		Reg.29.9.3.2, Reg.29.9.6

VII. Proper ship operation is enabled by providing information about ship's manoeuvring characteristics	• Provide information about ship's manoeuvring characteristics adequate for all persons involved in navigation and available at all navigation positions;
	    ○ Condensed format for easy use summarising main manoeuvring characteristics (pilot card, wheelhouse poster)
	    ○ Comprehensive details of manoeuvring characteristics per MSC.137 shall be readily available to the operator
		Reg.29.5

	• Provide familiarisation of ship's manoeuvrability characteristics (drills and training)	Ch. V Reg. 26

Propulsion system

Function	Expected Performance	Reference SOLAS Ch.II-1
VIII**.** The propulsion system provides adequate astern propulsion performance for ship operation	• Ship can be brought to rest with stopping distance within 15 ship lengths	Reg.28.5.1
	• In reduced service, ships provided with multiple propulsion-steering systems can be brought to rest with stopping distance within 20 ship lengths	Reg.28.5.2
IX: Proper ship operation is enabled by providing information about ship's manoeuvring characteristics	• Provide information about ship's stopping characteristics adequate for all persons involved in navigation and available at all navigation positions	Reg.28.5.5

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