

GUIDE FOR

VESSEL MANEUVERABILITY MARCH 2006

Guide to Color Coding Used in Online Version of the Rules

The following summarizes the colors corresponding to Rule Changes, Corrigenda items and editorial changes in the Rules files which are available for download.

Rule Changes:

NOTICE NO. 1 – February 2017 (effective 15 February 2017)

Corrigenda:

CORRIGENDA/EDITORIALS – 5 June 2006

CORRIGENDA/EDITORIALS – 1 March 2016

Editorials:

Editorial Changes



GUIDE FOR

VESSEL MANEUVERABILITY

MARCH 2006 (Updated February 2017 – see next page)

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

**© 2006 American Bureau of Shipping. All rights reserved.
ABS Plaza
16855 Northchase Drive
Houston, TX 77060 USA**

Updates

February 2017 consolidation includes:

- March 2016 version plus Notice No. 1

March 2016 consolidation includes:

- June 2006 version plus Corrigenda/Editorials

June 2006 consolidation includes:

- March 2006 version plus Corrigenda/Editorials

Foreword

This Guide is intended to assist users in applying IMO maneuvering standards and to allow the Owner, designer and builder to rate the vessel's maneuvering performance relative to statistical data of vessel maneuvering characteristics. The Guide summarizes the procedures to be used in assessing a vessel's maneuvering performance.

ABS welcomes comments and suggestions for improvement of this Guide. *Comments or suggestions can be sent electronically to rsd@eagle.org.*



GUIDE FOR VESSEL MANEUVERABILITY

CONTENTS

SECTION 1	Introduction	1
1	General Description	1
2	Description and Requirements of Optional Class Notations.....	3
3	Submittals, Surveys and Maintenance of Optional Class Notation	4
4	General Definitions and Nomenclature	5
5	Waiver of Full Scale Tests for Sister Vessels	7
TABLE 1	Requirements for Optional Class Notations.....	4
FIGURE 1	General Sequence of Maneuverability Assessment	2
FIGURE 2	Definitions of Rudder and Bow Profile Dimensions	6
FIGURE 3	Types of Stern Profiles.....	6
SECTION 2	Standards and Criteria	8
1	Overview of Standards and Criteria	8
2	Turning Ability	9
2.1	Definitions	9
2.2	Advance and Tactical Diameter Criteria	10
3	Initial Turning/Course Changing and Yaw Checking Ability	11
3.1	Definitions	11
3.2	The First Overshoot Angle in the 10/10 Zig-zag Maneuver Criteria	11
3.3	The Second Overshoot Angle in the 10/10 Zig-zag Maneuver Criteria	12
3.4	The First Overshoot Angle in the 20/20 Zig-zag Maneuver Criteria	13
3.5	Resulting Overshoot Angle Rating.....	13
3.6	Initial Turning Ability Criterion	13
4	Stopping Ability	14
4.1	Definitions	14
4.2	Track Reach Criterion	14
4.3	Head Reach Criterion	14

5	Straight-line Stability and Course Keeping Ability	16
5.1	Definitions.....	16
5.2	The Pull-out Test	17
5.3	Tests for Straight-line Unstable Vessels.....	18
5.4	Maximum Width of Unstable Loop.....	18
TABLE 1	Overview of Standards and Criteria.....	8
FIGURE 1	Turning Circle Test.....	9
FIGURE 2	Rating of Turning Ability	10
FIGURE 3	10/10 Zig-zag Maneuver Test.....	11
FIGURE 4	Stopping Ability Test	15
FIGURE 5	Relation between Rudder Angle and Yaw (Turn) Rate for Straight-line Unstable Vessel.....	16
FIGURE 6	Pull-out Test.....	17
FIGURE 7	Maximum Width of Unstable Loop.....	18
SECTION 3	Prediction of Maneuverability	19
1	General	19
2	Comparative Prediction.....	19
3	Numerical Simulation	19
3.1	General.....	19
3.2	Data Sources for Hydrodynamic Coefficients	19
3.3	Model Test as a Source of Data for Hydrodynamic Coefficients.....	20
3.4	Maneuvering Simulation.....	21
4	Scale Model Test	21
5	Validation of Prediction of Maneuverability.....	22
FIGURE 1	Scheme of Planar Motion Mechanism with Three Degrees of Freedom.....	20
SECTION 4	Sea Trials	23
1	Required and Recommended Maneuvers	23
2	Conditions of Trials	23
3	Guidelines on Test Procedures	24
3.1	Turning Circle Maneuver	24
3.2	Zig-zag Maneuver	24
3.3	Stopping Test (Crash Stop)	25
3.4	Pull-out Test	25
3.5	Spiral Maneuver	26
4	Data Acquisition Instrumentation	26
5	Information to Submit.....	26
FIGURE 1	Elements of 10/10 Zig-zag Maneuver.....	25

SECTION 5	Onboard Information.....	27
1	General	27
2	Wheelhouse Poster.....	27
3	Pilot Card	28
APPENDIX 1	Example.....	29
1	General Ship Data	29
2	Prediction of Maneuverability in Early Design Stage	30
2.1	Prediction and Evaluation of Elements of Turning Circle	30
2.2	Prediction and Evaluation of Stopping Ability	30
3	Maneuvering Simulation	30
3.1	Hydrodynamic Coefficients	30
3.2	Mathematical Model.....	31
3.3	Simulation of Turning Circle.....	34
3.4	Simulation of 10/10 Zig-zag Test	36
3.5	Simulation of the 20/20 Zig-zag Test	39
3.6	Simulation of the Pull-out Test.....	41
3.7	Simulation of Direct Spiral Maneuver.....	43
3.8	Simulation of Stopping.....	47
3.9	Evaluation of Maneuverability Based on Simulation	50
TABLE 1	General Data for Sample Ship	29
TABLE 2	Prediction of Turning Circle in Early Design Stage	30
TABLE 3	Prediction of Stopping Ability in Early Design Stage	30
TABLE 4	Hydrodynamic Coefficients	31
TABLE 5	Parameters of Turning Circle	36
TABLE 6	Parameters of 10/10 Zig-zag Maneuver	38
TABLE 7	Parameters of 20/20 Zig-zag Maneuver	41
TABLE 8	Parameters of Pull-out Maneuver	43
TABLE 9	Parameters of Direct Spiral Maneuver.....	47
TABLE 10	Parameters of Stopping Maneuver	50
TABLE 11	Evaluation of Maneuverability	51
FIGURE 1	Turning Circle: Axial Velocity	34
FIGURE 2	Turning Circle: Sway Velocity	34
FIGURE 3	Turning Circle: Yaw Rate	34
FIGURE 4	Turning Circle: Yaw Angle	35
FIGURE 5	Turning Circle: Trajectory.....	36
FIGURE 6	10/10 Zig-zag Maneuver: Axial Velocity.....	37
FIGURE 7	10/10 Zig-zag Maneuver: Sway Velocity.....	37
FIGURE 8	10/10 Zig-zag Maneuver: Yaw Rate	37
FIGURE 9	10/10 Zig-zag Maneuver: Yaw and Rudder Angles	37
FIGURE 10	10/10 Zig-zag Maneuver: Trajectory.....	38
FIGURE 11	20/20 Zig-zag Maneuver: Axial Velocity.....	39
FIGURE 12	20/20 Zig-zag Maneuver: Sway Velocity.....	39

FIGURE 13	20/20 Zig-zag Maneuver: Yaw Rate	39
FIGURE 14	20/20 Zig-zag Maneuver: Yaw and Rudder Angles	40
FIGURE 15	20/20 Zig-zag Maneuver: Trajectory	40
FIGURE 16	Pull-out Maneuver: Axial Velocity	41
FIGURE 17	Pull-out Maneuver: Sway Velocity	41
FIGURE 18	Pull-out Maneuver: Yaw Rate	42
FIGURE 19	Pull-out Maneuver: Yaw and Rudder Angles	42
FIGURE 20	Pull-out Maneuver: Trajectory	42
FIGURE 21	Direct Spiral Maneuver, Starboard: Axial Velocity	43
FIGURE 22	Direct Spiral Maneuver, Starboard: Sway Velocity	43
FIGURE 23	Direct Spiral Maneuver, Starboard: Yaw Rate	44
FIGURE 24	Direct Spiral Maneuver, Port: Axial Velocity	44
FIGURE 25	Direct Spiral Maneuver, Port: Sway Velocity	44
FIGURE 26	Direct Spiral Maneuver, Port: Yaw Rate	44
FIGURE 27	Direct Spiral Maneuver, Starboard: Yaw and Rudder Angles	45
FIGURE 28	Direct Spiral Maneuver, Port: Yaw and Rudder Angles	45
FIGURE 29	Direct Spiral Maneuver, Starboard: Trajectory	46
FIGURE 30	Direct Spiral Maneuver, Port: Trajectory	46
FIGURE 31	Relation between Rudder Angle and Yaw (Turn) Rate	47
FIGURE 32	Time History of Engine RPM during Stopping Maneuver	48
FIGURE 33	Time History of Commanded Speed during Stopping Maneuver	48
FIGURE 34	Stopping Maneuver: Axial Velocity	48
FIGURE 35	Stopping Maneuver: Sway Velocity	49
FIGURE 36	Stopping Maneuver: Yaw Rate	49
FIGURE 37	Stopping Maneuver: Yaw Angle	49
FIGURE 38	Stopping Maneuver: Trajectory	50

APPENDIX 2 Definitions and Nomenclature for Maneuvering Simulation 52

APPENDIX 3 Theoretical Background 57

1	Forces Acting on Vessel in Horizontal Plane	57
1.1	Straight Forward Sailing with Constant Speed	57
1.2	Rudder Forces	57
1.3	Hydrodynamic Forces on Hull	58
1.4	Other Forces Acting on Vessel During a Maneuver	59
2	Equations of Motions in Horizontal Plane	59
2.1	Accepted System of Coordinates and General Equations of Motions	59
2.2	Expressions for the Hull Forces in Linear Formulation	60
2.3	Taylor Series Expansion of Hull Forces	61
2.4	Concept of Hydrodynamic Derivatives	62
2.5	Expressions for Rudder Forces	62
2.6	Linear Equations of Motion	63
2.7	Equations of Motions in Standard (Cauchy) Form	64

2.8	Solution of Linear Equations of Motions	66
2.9	Steady Turning	67
3	Directional Stability	68
3.1	Vessel Behavior in Horizontal Plane and Steady Turning.....	68
3.2	Stability of Motion	69
3.3	Evaluation of Straight-line Stability	69
3.4	Measure of Straight-line Instability.....	71
4	Nonlinear Equations of Motion.....	72
4.1	General.....	72
4.2	Surging Equation	73
4.3	Swaying Equation.....	75
4.4	Yawing Equation.....	76
FIGURE 1	Straight Ahead Sailing with Constant Forward Speed.....	57
FIGURE 2	Geometry and Forces on Rudder	58
FIGURE 3	On the Moment of Rudder Lift Force	58
FIGURE 4	Hydrodynamic Forces on the Hull.....	58
FIGURE 5	Vessel Hull as Lifting Surface	58
FIGURE 6	Earth and Ship-fixed Coordinate Systems (IMO, 2002b).....	60
FIGURE 7	Reaction on Small Perturbation if Eigenvalues are Negative	68
FIGURE 8	Stability of Equilibrium.....	69
FIGURE 9	Relation between Rudder Angle and Yaw (Turn) Rate for Straight-line Stable Vessel.....	71
FIGURE 10	Relation between Rudder Angle and Yaw (Turn) Rate for Straight-line Unstable Vessel.....	72
FIGURE 11	Model for Thrust/Resistance Balance	74
APPENDIX 4	Empirical Methods of Prediction of Maneuverability	78
1	Empirical Prediction	78
1.1	Advantages and Applicability of Empirical Prediction Methods.....	78
1.2	Prediction of Elements of Turning Circle.....	78
1.3	Empirical Formulae for the Stopping Track Reach	80
TABLE 1	Limitations of Empirical Technique for Prediction of Turning Circle	78
TABLE 2	Numerical Values for Boundaries of the Coefficient A	80
TABLE 3	Numerical Values for Boundaries of the Coefficient B	81
APPENDIX 5	Forms	82
1	Form for Reporting Maneuvering Data by Surveyor	83
2	Form for Reporting Maneuvering Data to ABS by Shipyard.....	84
APPENDIX 6	Environmental Correction of Results of Sea Trials	85
FIGURE 1	Correction of Trajectory for Current, Wind and Waves (IMO, 2002b)	86

APPENDIX 7	Sample Wheelhouse Poster and Pilot Card	87
PART 1	Drafts and Propulsion	88
PART 2	Ship's Particulars, Steering and Loading Conditions.....	89
PART 3	Man Overboard Rescue Maneuver.....	90
PART 4	Anchor Chain	91
PART 5	Turning Circles at Maximum Rudder Angle	91
PART 6	Emergency Stopping in Loaded Conditions.....	92
PART 7	Emergency Stopping in Ballast Conditions.....	93
PART 8	Stopping Characteristics	94
PART 9	Visibility Characteristics	95
FIGURE 1	Layout of the Wheelhouse Poster.....	87
FIGURE 2	Sample of One Sided Pilot Card	96
FIGURE 3	Sample of Double Sided Pilot Card	97
APPENDIX 8	Human Element (Factor) Considerations.....	99
1	General	99
2	ABS Guidance Notes on the Application of Ergonomics to Marine Systems	99
3	ABS Guidance Notes on Ergonomic Design of Navigation Bridges	100
4	ABS Guide for Crew Habitability on Ships.....	100
5	Bridge Resource Management Practices	100
APPENDIX 9	References.....	101

This Page Intentionally Left Blank



SECTION 1 Introduction

1 General Description

The International Maritime Organization (IMO) approved Standards for Ship Maneuverability [IMO 2002a and IMO 2002b] and encouraged the application of these standards for vessels constructed after 2004. The IMO standards specify the type of standard maneuvers and associated criteria. Some port and flag states already have adopted some of IMO standards as their national requirements. An International Standard also exists for planning, conducting and reporting sea trials [ISO 2005].

ABS provides this Guide to help its clients prepare for implementation of the IMO standards and application of the relevant procedures. Minimum requirements given in this Guide are consistent with IMO standards. An optional class notation, **MAN**, offered for compliant vessels could be used as evidence of adherence to the IMO standards (see Section 1, Table 1).

ABS may assign another optional class notation, **MAN-A**, as defined in Section 1, Table 1. This optional class notation is in compliance with IMO Standards and signifies demonstration of maneuvering performance superior to IMO Standards.

Maneuvering performance of a vessel is judged based on maneuvering criteria which are characteristic of several maneuvers. These maneuvers and their criteria, as well as the required numerical values, are described in Section 2 of this Guide.

This Guide summarizes the procedures to be used in assessing a vessel's maneuvering performance with an explanation of requirements in Subsection 1/2. Criteria of the maneuvering performance are described in Section 2.

There are two ways to assess maneuvering performance and demonstrate compliance with IMO Standards. See Section 1, Figure 1.

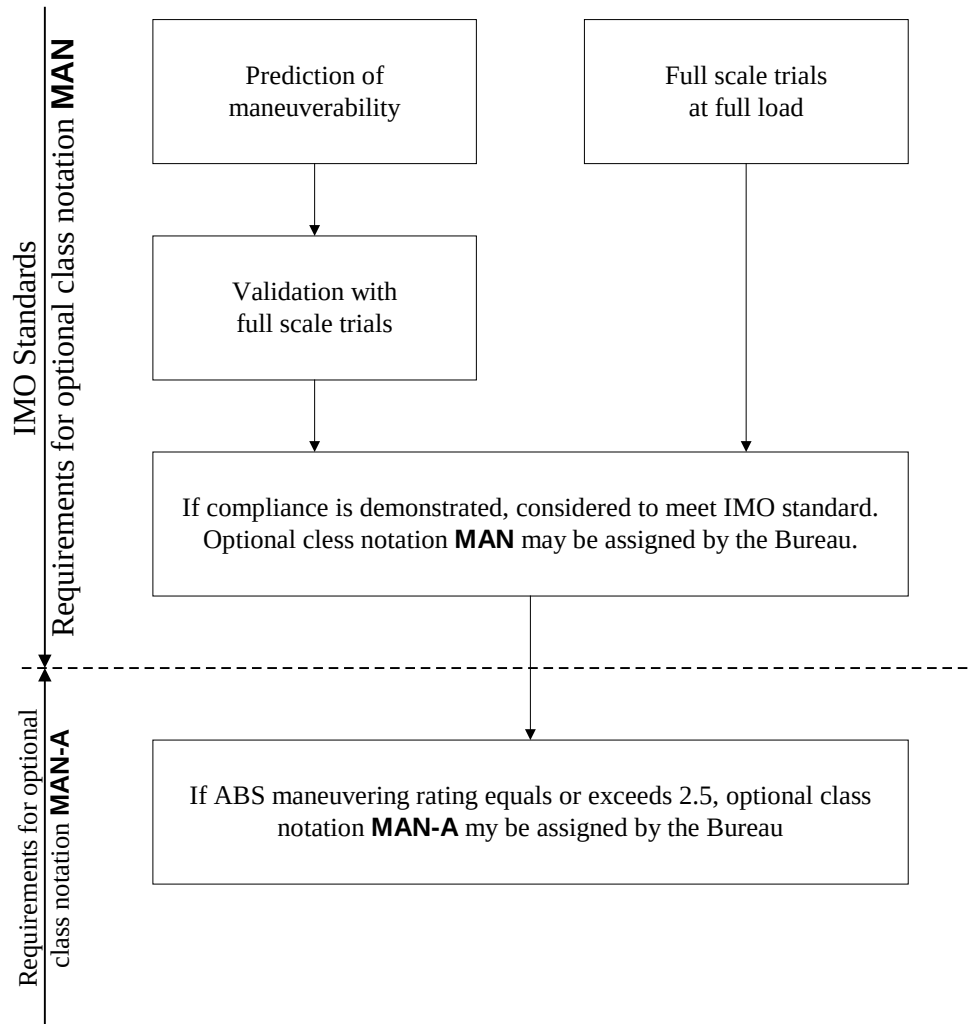
Full scale sea trials in full load conditions could be used for the demonstration of compliance with IMO standards. The requirements for the sea trials are described in Section 4. Appendix 5 contains forms for the results of sea trials and Appendix 6 describes a procedure of environmental correction for sea trials.

Prediction of maneuverability validated by full scale sea trials could be used for the demonstration of compliance with IMO standards. Prediction of maneuverability performance in the design stage enables a designer to take appropriate measures in good time to achieve compliance with IMO standards. The prediction of the maneuvering could be carried out with the following methods: using existing data, or scaled model test, or numerical simulation or any combination of the three listed methods. See Section 3 for details. The prediction method is to be validated with the full scale trials. If full scale sea trials are used for the validation of maneuvering prediction methods, the trials do not have to be carried out in full load conditions. Once the prediction method is validated it may be used to demonstrate compliance with IMO standard for a vessel in full load conditions.

Results of maneuvering prediction and sea trials are also used for the wheelhouse poster recommended by IMO Resolution A.601(16) [IMO 1987]. Contents and source of maneuverability data needed for the wheelhouse poster and pilot card are described in Section 5. A sample of the wheelhouse poster and pilot card is given in Appendix 7.

The Guide also contains a large amount of reference material along with practical recommendations and samples.

FIGURE 1
General Sequence of Maneuverability Assessment



Appendix 1 contains a detailed sample of the numerical simulation with all the necessary equations of motion, data on hydrodynamic forces and intermediate results. Appendix 3 reviews the background information on physical phenomena behind vessel maneuvering. Appendix 2 is a detailed nomenclature for the mathematical model used in Appendices 1 and 3.

The Guide contains some sample methods for *Empirical assessment of turning and stopping ability in the early design stage*. Their advantage is to indicate possible problems with maneuvering performance as soon as principal dimensions, hull form coefficients, speed, power and type of engine are known. Methods of empirical assessment are based on statistical processing of model test and past sea trials data. Application of the empirical methods is limited to the range of parameters of the vessel included in the statistics. The empirical methods provide simple formulae and therefore do not require detailed calculations. The procedure for empirical assessment of turning and stopping ability in the early design stage is described in Appendix 4.

Appendix 8 provides a review of the Human Factors aspect of maneuverability. Finally, the references are found in Appendix 9

The maneuverability standards included in this Guide are applicable to vessels equipped with all types of steering and propulsion devices of 100 m in length and over and chemical and gas carriers regardless of length. These standards are not applicable for high-speed craft as defined in the relevant Code.

2 Description and Requirements of Optional Class Notations

In recognition of demonstrated compliance with the requirement of the Guide, ABS may assign an optional class notation, **MAN** or **MAN-A**.

These optional class notations can be used to certify that maneuverability of the vessel complies with IMO Standards for Ship Maneuverability, Resolution MSC.137(76) [IMO 2002a]. The general sequence of these procedures is shown in the form of a flowchart in Section 1, Figure 1

The optional class notations may be assigned based on the results of full scale sea trials or maneuvering prediction.

Loading conditions during the full scale sea trials are further referred to as “full load” if they correspond to full load at summer load line draft and at even keel. Any other loading conditions during the sea trials are referred to as “trial load”.

If full scale sea trials are performed in “full load”, the optional class notations may be assigned solely based on the results of such trials.

Upon successful validation, the optional class notations may be assigned based on the results of prediction of maneuvering in full load conditions. Validation of prediction is to be done by performing full scale sea trials and comparing the results of these trials with the results of maneuvering prediction performed for “trial load” condition. Full scale sea trials carried out for validation purposes only do not have to be performed in full load conditions. However, all other requirements of Section 4 are applicable. To demonstrate compliance, the prediction of maneuvering is to be done for a vessel in full load conditions. See Section 3 for details.

The optional class notations are assigned based on a Maneuverability Rating that consists of the rating levels one to five of all the rated maneuverability criteria, as described in Section 2. Minimum rating equal to one indicates adherence to the IMO standards. Any rating above one shows that maneuverability performance exceeds the IMO standards [IMO 2002a].

- *Rtd* – tactical diameter rating
- *Rtα* – rating for the first overshoot angle
- *Rti* – initial turning ability rating
- *Rts* – stopping ability rating

The overall rating is an average of the above ratings:

$$Rt = 0.25 \cdot (Rtd + Rt\alpha + Rti + Rts) \dots \dots \dots (1.1)$$

The other criteria in Section 2 are not rated. They are essentially a “pass-fail” type:

- Advance
- Second overshoot angle in the 10/10 zig-zag maneuver
- Track reach
- Width of unstable loop (applicable only for straight-line unstable vessels; recommended, not mandatory)

Requirements for optional class notations include development of maneuverability information and pilot cards that must be available onboard as recommended by [IMO 1987].

The optional class notation **MAN** may be assigned if all non-rated criteria are satisfied and rating of all the rated criteria is 1 or more.

The optional class notation **MAN-A** may be assigned if all non-rated criteria are satisfied and rating of all the rated criteria is 1 or more and the overall rating is 2.5 or more

The requirements for the optional class notations are described in Section 1, Table 1.

Although prediction of maneuverability is not required for assigning optional class notations if sea trials are carried out in full load conditions, it is recommended that it be performed during the design stage to check for compliance with IMO standards.

TABLE 1
Requirements for Optional Class Notations

Optional Class Notation	Description	Requirements	
		<i>Maneuvering assessment is based on sea trials in full load conditions</i>	<i>Maneuvering assessment is based on prediction</i>
MAN	Demonstrated Maneuverability performance in compliance with IMO standards	1. Sea trials are performed in full load conditions, as required in Section 4. 2. Based on sea trials, maneuverability rating is not less than 1 for each of rated criteria as required in Section 2. 3. Based on sea trials, all mandatory non-rated maneuverability criteria are satisfied as required in Section 2. 4. Maneuverability information is posted on the navigation bridge and pilot card is available onboard as described in Section 5.	1. Maneuvering prediction is performed for full load conditions as required in Section 3 2. Based on maneuvering prediction in full load conditions, maneuverability rating is not less than 1 for each of rated criteria as required in Section 2 3. Based on maneuvering prediction in full load conditions, all mandatory non-rated maneuverability criteria are satisfied as required in Section 2. 4. Sea trials are performed in trial load conditions; all other requirements of Section 4 are met. 5. Maneuvering prediction is performed for trial load conditions as required in Section 3. 6. Method used for maneuvering prediction is successfully validated using data of sea trials in trial load conditions as required in Section 3 7. Maneuverability information is posted on the navigation bridge and pilot card is available onboard as described in Section 5.
MAN-A	Demonstrated Maneuverability Performance Superior to IMO standards	In addition to the requirement above, maneuverability rating is 2.5 or more.	In addition to the requirement above, maneuverability rating is 2.5 or more.

3 Submittals, Surveys and Maintenance of Optional Class Notation

The following information is to be submitted in case an optional class notation is requested on the basis of full load sea trials:

- General ship data, including information on propulsion and steering devices. Exact set of data is to be determined by ABS on a case-by-case basis
- Report on sea trials in full load as required in Section 4
- Assessment of maneuvering based on trials as described in Section 2
- Copy of wheelhouse poster and pilot card as required in Section 5

The following information is to be submitted in case an optional class notation is requested on the basis of maneuvering prediction:

- General ship data, including information on propulsion and steering devices. Exact set of data is to be determined by ABS on a case-by-case basis
- Description of prediction method and results of prediction of maneuvering in full load as required in Section 3
- Assessment of maneuvering based on prediction for the vessels in full load conditions as described in Section 2
- Report on full scale sea trials in trial load as required in Section 4.

- Results of maneuvering prediction in trial load as required in Section 3
- Report on validation of maneuvering prediction method using results of prediction and sea trials in trial conditions as required in Section 3
- Copy of wheelhouse poster and pilot card as required in Section 5

Optional class notation **MAN** or **MAN-A** may be assigned upon the completion of the survey after construction. During the survey after construction, the Surveyor will verify that

- Wheelhouse poster is displayed in the wheelhouse
- Copies of pilot card are available on-board
- Information included in wheelhouse poster and pilot card is consistent with submittals approved by ABS.

Maintenance of the optional class notation shall be assured by Annual Surveys.

In general, a modification that will alter the vessel's maneuverability performance includes, but is not limited to: any change in hull form length or shape, change in appendages (such as changing the rudder or installation of anti-rolling fins, increasing/decreasing the size of bilge keels or changing the vessel speed), replacing or modifying the main engine, propeller, the steering machinery (e.g., changing the operating pressure), etc. If any such modification has been made, the optional class notation is to be reviewed.

During the Annual Survey, the Surveyor verifies that

- Modifications that may affect the vessel maneuverability performance have not been made to the vessel
- Wheelhouse poster is displayed in the wheelhouse
- Pilot card are available onboard

4 General Definitions and Nomenclature

The following contains nomenclature and definitions for most of the values used in this Guide. For the user's convenience, they are subdivided into several groups. This Subsection does not include the definitions and nomenclature for values only related to numerical simulation and equations of motion, which are given separately in Appendix 2.

- *Test Speed or Approach Speed.* The test speed or the approach speed is defined as a speed at the moment when the maneuver begins. The test speed or the approach speed for all criteria and corresponding test maneuvers either at early stage design prediction, numerical simulation, or sea trials must be within 90-100% of the speed corresponding to 85% of maximum continuous rating (MCR) of the engine.
- *Full Load Conditions.* Full load conditions correspond to full load at summer load line draft and at even keel. Deviation of draft within 5% is allowed.
- *Trial Load Conditions.* Trial loading conditions are loading conditions during sea trials other than operational loading conditions.
- The following symbols are used for vessel dimensions and other general values:

L	=	length of the vessel, in m, measured between perpendiculars
B	=	molded breadth, in m
T	=	design draft (summer) at full load, in m
C_B	=	block coefficient
V	=	test speed, in m/s
V_S	=	test speed, in knots
$Trim$	=	static trim, in m, positive when trimmed by stern
A_B	=	submerged bow profile area, in m^2 , considered positive when projecting forward of the fore perpendicular, see Section 1, Figure 2

T_L	=	draft, in m, at which the turning circle is estimated
δ_R	=	rudder angle, in degrees (positive to starboard)
Sp	=	span of rudder, in m
Ch	=	chord of rudder, in m, defined as mean chord (average of root and tip chords), see Section 1, Figure 2
ST	=	stern profile type (1 = Closed 2 = Open, see Section 1, Figure 3)
NR	=	number of rudders
STD	=	steady turning diameter, in m
TD	=	tactical diameter, in m
Ad	=	advance, in m
Tr	=	transfer, in m
V_T	=	velocity in a turn, in knots
HR	=	head reach, in m
TR	=	track reach, in m
α_U	=	width of instability loop, in degrees

FIGURE 2
Definitions of Rudder and Bow Profile Dimensions

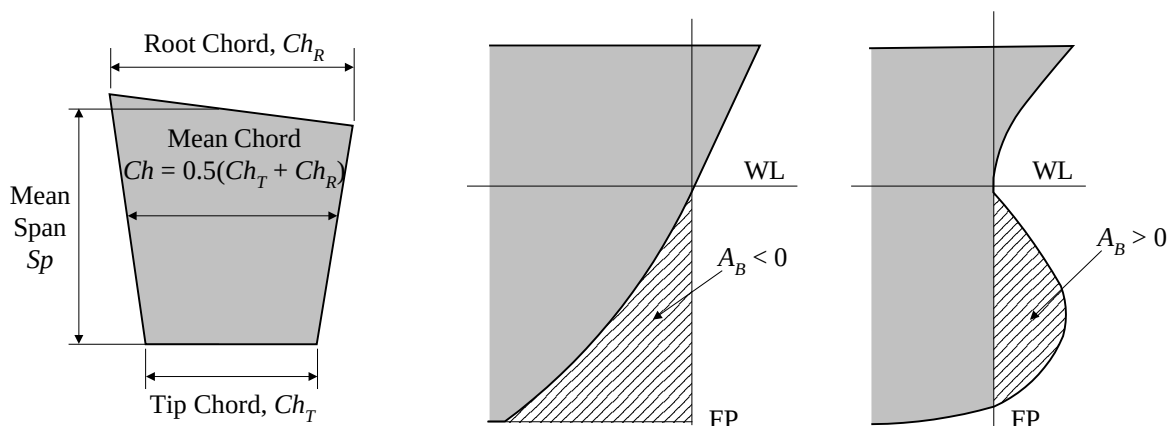
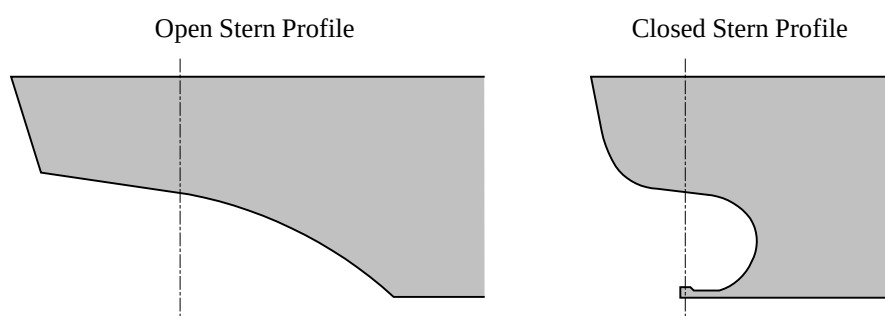


FIGURE 3
Types of Stern Profiles



5 Waiver of Full Scale Tests for Sister Vessels (15 February 2017)

For vessels seeking **MAN** notation, full scale maneuvering tests required for the notation may be waived for sister vessels in the same series. For this the vessel for which tests were carried out and sister vessels should have identical:

- Hull form
- Design draft and speed
- Steering/propulsion systems (rudder, propeller, steering gear)
- Main engine (make, model, power output)
- Energy saving devices and other appendages that may influence the inflow to propeller and rudder, if applied

Tests may be waived for sister vessels under the conditions given above and if the attained overall rating for the tested vessel is 3.0 or higher. However, an initial turning test is required even for the sister vessel seeking **MAN** or **MAN-A** notation.

Flag Administration requirements are to be checked concerning maneuvering tests for vessels in a series.



SECTION 2 Standards and Criteria

1 Overview of Standards and Criteria

An overview of standards and criteria is given in Section 2, Table 1. All the maneuvers, except stopping, are to be executed on both port and starboard and averaged values are to be used for rated and non-rated criteria.

TABLE 1
Overview of Standards and Criteria

Measure of Maneuverability	Criteria and Standard	Maneuver	IMO Standard	ABS Guide Requirement
Required for Optional Class Notation				
Turning Ability	Tactical Diameter	Turning Circle	$TD < 5L$	Rated $Rtd \geq 1$
	Advance		$Ad < 4.5L$	Not rated $Ad < 4.5L$
Course Changing and Yaw Checking Ability	First Overshoot Angle	10/10 Zig-zag test	$\alpha_{10_1} \leq f_{10_1}(L/V)$	Rated $Rt\alpha_{10} \geq 1$
	Second Overshoot Angle		$\alpha_{10_2} < f_{10_2}(L/V)$	Not rated $\alpha_{10_2} < f_{10_2}(L/V)$
	First Overshoot Angle	20/20 Zig-zag test	$\alpha_{20_1} \leq 25$	Rated $Rt\alpha_{20} \geq 1$
Initial Turning Ability	Distance traveled before 10-degrees course change	10/10 Zig-zag test	$\ell_{10} \leq 2.5L$	Rated $Rti \geq 1$
Stopping Ability	Track Reach	Crash stop	$TR < 15L^{(1)}$	Not rated $TR < 15L^{(1)}$
	Head Reach		None	Rated $Rts \geq 1$
Recommended, Not Required for Optional Class Notation				
Straight-line Stability and Course Keeping Ability	Residual turning rate	Pull-out test	$r \neq 0$	Not rated $r \neq 0$
	Width of instability ⁽²⁾ loop	Simplified spiral	$\alpha_U \leq f_U(L/V)$	Not rated $\alpha_U \leq f_U(L/V)$

Notes:

- 1 For large, low powered vessels, $TR < 20L$.
- 2 Applicable only for path-unstable vessels.

2 Turning Ability

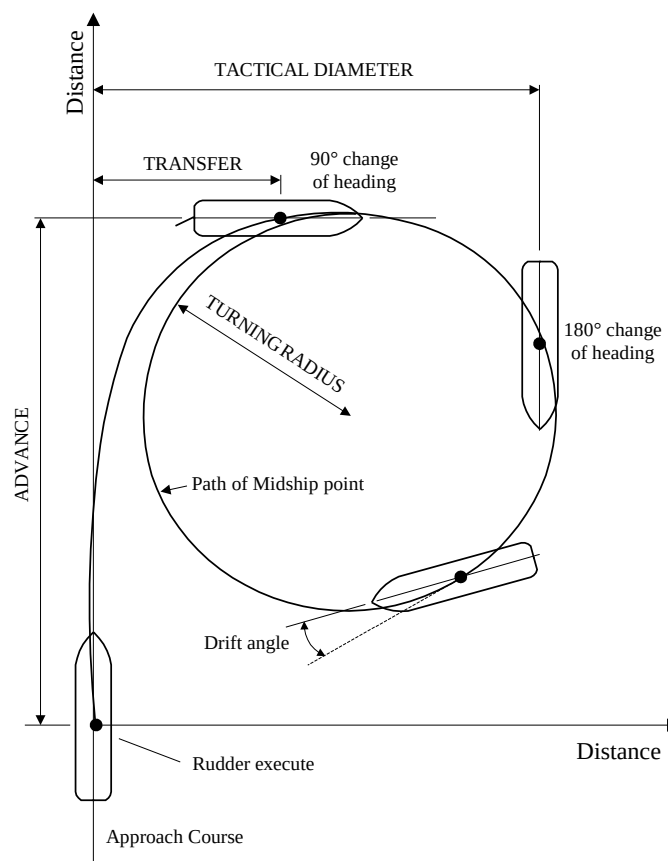
2.1 Definitions

Turning ability is the measure of the ability to turn the vessel using hard-over rudder (or other primary mean of directional control), the result being a minimum “advance at 90° change of heading” and “tactical diameter” defined by the “transfer at 180° change of heading”.

A turning circle maneuver is to be performed to both starboard and port. The rudder angle must be the maximum design rudder angle permissible at the test speed, but is not required to be more than 35 degrees (applicable only to a vessel equipped with conventional rudder as a primary mean of directional control).

The rudder angle is executed following a steady approach with zero yaw rate. The essential information to be obtained from this maneuver is tactical diameter, advance and transfer (see Section 2, Figure 1). In addition, the speed lost in a turn and maximum roll angle, as well as the peak and final yaw rates, should be recorded.

FIGURE 1
Turning Circle Test



2.2 Advance and Tactical Diameter Criteria

Tactical diameter and advance are to be determined from the turning circle test, as defined in Section 2, Figure 1.

IMO requires that the tactical diameter is to be less than 5 ship lengths and the advance is to be less than 4.5 ship lengths [IMO 2002a]:

$$Ad \leq 4.5L \dots\dots\dots (2.1)$$

Provided that condition (2.1) is satisfied, the rating of turning ability is found from the following formulae or from Section 2, Figure 2.

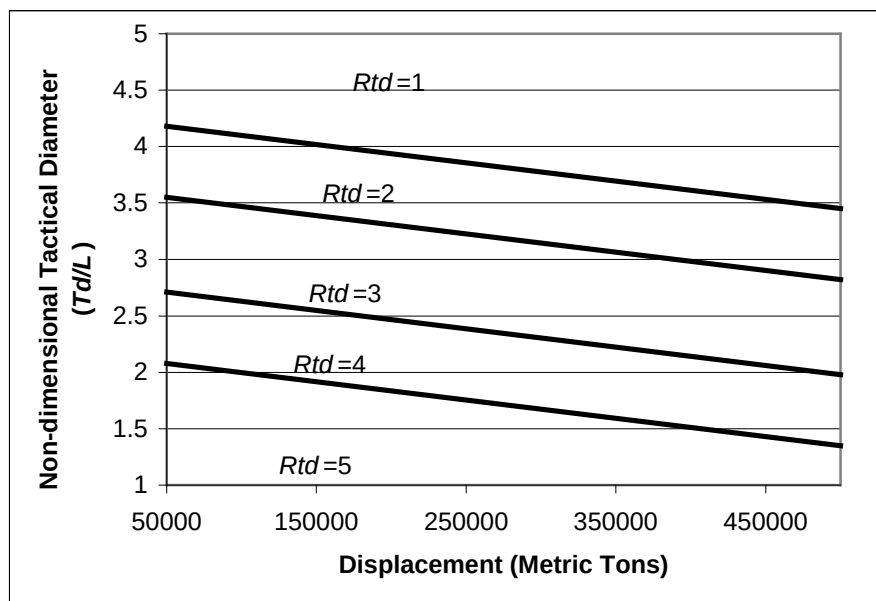
if $(4.26 - 1.62 \cdot 10^{-6} \Delta) \cdot L < TD \leq 5 \cdot L$	then $Rtd = 1$
if $(3.63 - 1.62 \cdot 10^{-6} \Delta) \cdot L < TD \leq (4.26 - 1.62 \cdot 10^{-6} \Delta) \cdot L$	then $Rtd = 2$
if $(2.79 - 1.62 \cdot 10^{-6} \Delta) \cdot L < TD \leq (3.63 - 1.62 \cdot 10^{-6} \Delta) \cdot L$	then $Rtd = 3$
if $(2.16 - 1.62 \cdot 10^{-6} \Delta) \cdot L < TD \leq (2.79 - 1.62 \cdot 10^{-6} \Delta) \cdot L$	then $Rtd = 4$
if $(2.16 - 1.62 \cdot 10^{-6} \Delta) \cdot L > TD$	then $Rtd = 5 \dots\dots\dots (2.2)$

where

TD = tactical diameter, in meters
 L = vessel length, in meters
 Δ = vessel displacement, in metric tons
 Rtd = rating of turning ability

The above rating is based on statistics of sea trials [Barr, *et al* 1981].

FIGURE 2
Rating of Turning Ability



3 Initial Turning/Course Changing and Yaw Checking Ability

3.1 Definitions

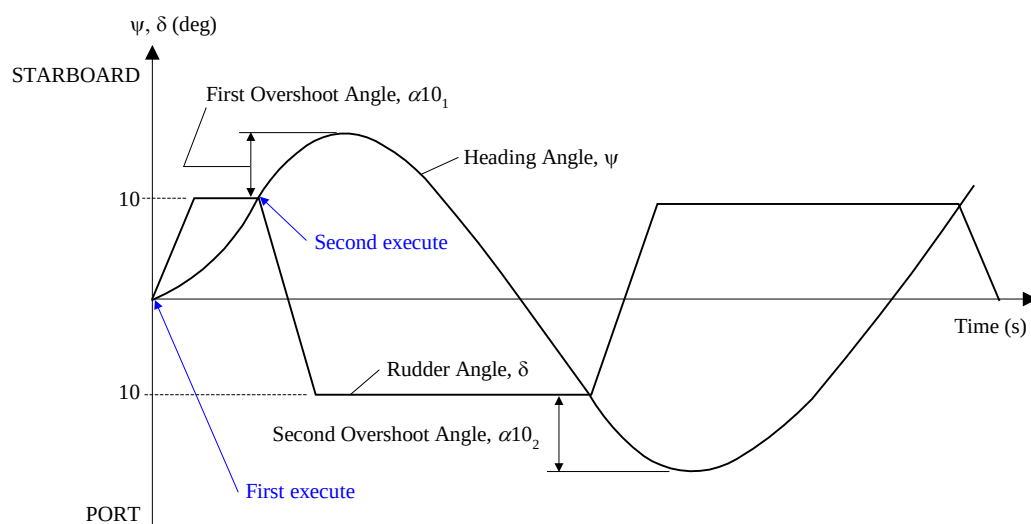
The initial turning ability is defined by the change-of-heading response to a moderate helm, in terms of heading deviation per unit distance sailed or in terms of the distance covered before realizing a certain heading deviation (such as the “time to second execute” demonstrated when entering the zig-zag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

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

A zig-zag test should be initiated to both starboard and port and begins by applying a specified amount of rudder angle to an initially straight approach (“first execute”). The rudder angle is then alternately shifted to either side after a specified deviation from the vessel’s original heading is reached (“second execute” and following) (see Section 2, Figure 3).

Two kinds of zig-zag tests are included in the Standards [IMO 2002a], the 10/10 and 20/20 zig-zag tests. The 10/10 zig-zag test uses rudder angles of 10 degrees to either side following a heading deviation of 10 degrees from the original course. The 20/20 zig-zag test uses 20-degree rudder angles coupled with a 20-degree 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.

FIGURE 3
10/10 Zig-zag Maneuver Test



3.2 The First Overshoot Angle in the 10/10 Zig-zag Maneuver Criteria

The first overshoot angle in the zig-zag test is a measure of the vessel’s course checking ability. It is defined in Section 2, Figure 3. The requirements below are the result of harmonization of the IMO standards [IMO 2002a] rating system based on statistics of sea trials [Barr, et al 1981].

As measured in the 10/10 zig-zag test, the first overshoot angle, α_{10_1} , is to be evaluated with the following auxiliary function:

$$f_{101}(L/V) = \begin{cases} 10.0 & \text{if } L/V \leq 10 \text{ sec.} \\ 5 + 0.5 \cdot (L/V) & \text{if } 10 \text{ s} < L/V < 30 \text{ sec.} \\ 20.0 & \text{if } L/V \geq 30 \text{ sec.} \end{cases} \quad (2.3)$$

where

L = vessel length, in meters

V = vessel speed, in m/s

The first overshoot angle in the 10/10 zig-zag test is to be rated as follows.

The rating for the first overshoot angle in the 10/10 zig-zag test, $Rt\alpha_{10} = 1$, can be assigned only if:

$$10.04 + 2.22C_b < f_{101}(L/V) \dots \dots \dots (2.4)$$

where

C_b = block coefficient

L = vessel length, in meters

V = test speed, in m/s

Provided that condition (2.4) is satisfied:

$$\text{if } 10.04 + 2.22C_b < \alpha_{101} \leq f_{101}(L/V) \quad \text{then } Rt\alpha_{10} = 1 \dots \dots \dots (2.5)$$

Provided that condition (2.4) is satisfied:

$$\text{if } 7.42 + 2.22C_b < \alpha_{101} \leq 10.04 + 2.22C_b \quad \text{then } Rt\alpha_{10} = 2 \dots \dots \dots (2.6)$$

If condition (2.4) is not satisfied:

$$\text{if } 7.42 + 2.22C_b < \alpha_{101} \leq f_{101}(L/V) \quad \text{then } Rt\alpha_{10} = 2 \dots \dots \dots (2.7)$$

Assignment of other ratings does not depend on condition (2.4) and is to be done according to the following formulae.

$$\text{if } 3.92 + 2.22C_b < \alpha_{101} \leq 7.42 + 2.22C_b \quad \text{then } Rt\alpha_{10} = 3$$

$$\text{if } 1.29 + 2.22C_b < \alpha_{101} \leq 3.92 + 2.22C_b \quad \text{then } Rt\alpha_{10} = 4$$

$$\text{if } \alpha_{101} \leq 1.29 + 2.22C_b \quad \text{then } Rt\alpha_{10} = 5 \dots \dots \dots (2.8)$$

where

C_b = block coefficient

$Rt\alpha_{10}$ = rating for the first overshoot angle in the 10/10 zig-zag test

3.3 The Second Overshoot Angle in the 10/10 Zig-zag Maneuver Criteria

The second overshoot angle in the 10/10 zig-zag test, α_{102} , as required by IMO standards [IMO 2002a], is to be evaluated with the following function:

$$f_{102}(L/V) = \begin{cases} 25.0 & \text{if } L/V \leq 10 \text{ s} \\ 17.5 + 0.75 \cdot (L/V) & \text{if } 10 \text{ s} < L/V < 30 \text{ s} \\ 40.0 & \text{if } L/V \geq 30 \text{ s} \end{cases} \dots \dots \dots (2.9)$$

Based on IMO standards [IMO 2002a], the second overshoot angle in the 10/10 zig-zag test should meet the following requirement:

$$\alpha_{102} < f_{102}(L/V) \dots \dots \dots (2.10)$$

where

L = vessel length, in meters

V = test speed in m/s

3.4 The First Overshoot Angle in the 20/20 Zig-zag Maneuver Criteria

The requirements below are the result of harmonization of the IMO standards [IMO 2002a] rating system based on the statistics of the sea trials [Barr, et al 1981]. As measured in the 20/20 zig-zag test, the first overshoot angle, α_{20_1} , is to be rated as follows.

if $20.09 + 4.44C_b < \alpha_{20_1} \leq 25$	then $Rt\alpha_{20} = 1$
if $14.84 + 4.44C_b < \alpha_{20_1} \leq 20.09 + 4.44C_b$	then $Rt\alpha_{20} = 2$
if $7.84 + 4.44C_b < \alpha_{20_1} \leq 14.84 + 4.44C_b$	then $Rt\alpha_{20} = 3$
if $2.59 + 4.44C_b < \alpha_{20_1} \leq 7.84 + 4.44C_b$	then $Rt\alpha_{20} = 4$
if $\alpha_{20_1} \leq 2.59 + 4.44C_b$	then $Rt\alpha_{20} = 5$ (2.11)

where

L = vessel length, in meters

$Rt\alpha_{20}$ = rating for the first overshoot angle in the 20/20 zig-zag test.

3.5 Resulting Overshoot Angle Rating

Provided both ratings $Rt\alpha_{10}$ and $Rt\alpha_{20}$ are one or more, the resulting overshoot angle rating is to be calculated as:

$$Rt\alpha = 0.5(Rt\alpha_{10} + Rt\alpha_{20}) \dots\dots\dots (2.12)$$

3.6 Initial Turning Ability Criterion

The initial part of the zig-zag test is used to judge the vessel's initial turning ability. Specifically, with the application of a 10-degree rudder angle, the vessel must not travel more than 2.5 ship lengths before the vessel's heading has changed 10 degrees.

The requirements below are the result of harmonization of the IMO standards [IMO 2002a] rating system based on statistics of the sea trials [Barr, et al 1981]. Assignment of the initial turning ability rating is to be done as follows:

if $2.24L < \ell_{10} \leq 2.50L$	then $Rti = 1$
if $2.07L < \ell_{10} \leq 2.24L$	then $Rti = 2$
if $1.89L < \ell_{10} \leq 2.07L$	then $Rti = 3$
if $1.63L < \ell_{10} \leq 1.89L$	then $Rti = 4$
if $\ell_{10} \leq 1.63L$	then $Rti = 5$ (2.13)

where

L = vessel length between perpendiculars, in meters

ℓ_{10} = distance that the vessel travels from the moment of the first execute until the course angle reaches 10 degrees in the 10/10 zig-zag maneuver

Rti = rating for the initial turning ability

4 Stopping Ability

4.1 Definitions

Stopping ability is measured by the “track reach” and “head reach” realized in a stop engine-full astern maneuver performed after a steady approach at the test speed until ahead speed in ship coordinates changes sign (i.e., vessel starts going backward).

- *Track Reach* is defined as a distance along the vessel’s track that the vessel covers from the moment that the “full astern” command is given until ahead speed changes sign. See Section 2, Figure 4.
- *Head Reach* is defined as a distance along the direction of the course at the moment when the “full astern” command was given. The distance is measured from the moment when the “full astern” command is given until the vessel is stopped dead in the water. See Section 2, Figure 4.

4.2 Track Reach Criterion

The stopping ability of the vessel is judged using a full astern crash stop maneuver. Based on IMO requirements [IMO, 2002a], the track reach (see Section 2, Figure 4) should generally not exceed 15 ship lengths (measured along the path).

However, in the case of low-powered large displacement vessels, this value may be modified, but in no case should exceed 20 ship lengths, subject to special consideration and approval by ABS. Determination of whether a vessel falls into the category of “low powered large displacement vessels” also will be done by ABS.

4.3 Head Reach Criterion

Head reach criterion in a form of rating is based on statistics of sea trials [Barr, et al 1981].

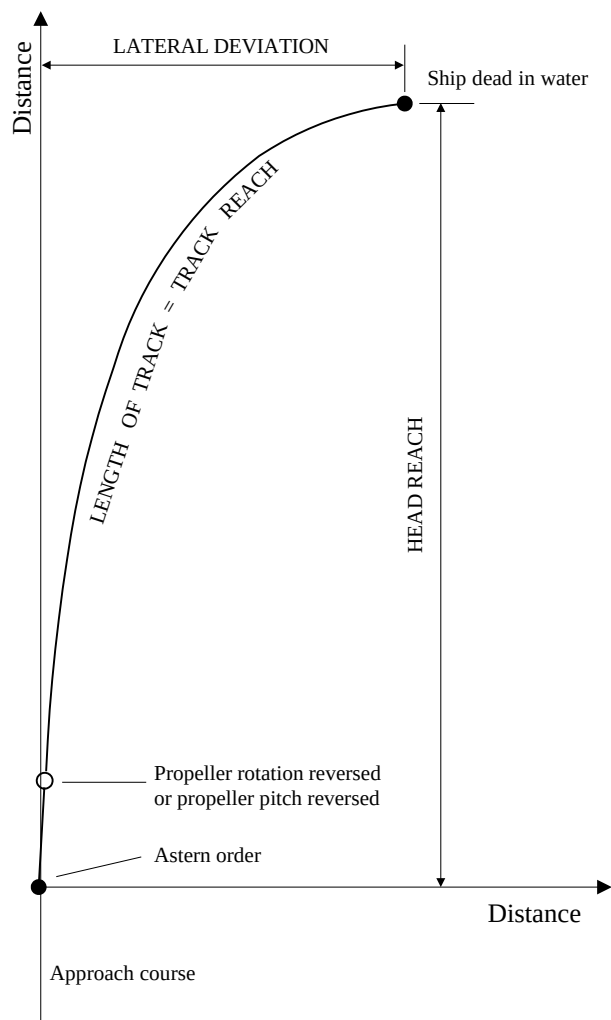
Stopping ability rating only if:

$$\begin{array}{ll} TR < 20L & \text{only for low-powered large displacement vessel} \\ TR < 15L & \text{in all other cases} \dots\dots\dots (2.14) \end{array}$$

where

$$\begin{array}{ll} TR & = \text{track reach, in meters, as defined in 2/4.1 (see Section 2, Figure 4)} \\ L & = \text{vessel length, in meters} \end{array}$$

FIGURE 4
Stopping Ability Test



Defintions Used in Stopping Test

Provided that condition (2.14) is satisfied, the head reach is to be rated as follows:

$$\text{if } Fn(69.4 + 0.000139 \cdot \Delta) < HR/L \quad \text{then } R_{ts} = 1 \dots\dots\dots (2.15)$$

where

- HR = non-dimensional head reach, measured in ship lengths, as defined in 2/4.1 (see Section 2, Figure 4)
- L = vessel length, in meters
- Δ = displacement, in metric tons
- Fn = Froude Number, $\frac{V}{\sqrt{gL}}$ (2.16)
- g = gravity acceleration (9.807 m/s²)
- L = vessel length, in meters
- V = test speed in, m/s

Provided that condition (2.14) is satisfied, assignment of other ratings is to be done according to the following formulae:

$$\begin{aligned}
 &\text{if } Fn(56.2 + 0.000139 \cdot \Delta) < HR/L \leq Fn(64.9 + 0.000139 \cdot \Delta) && \text{then } Rts = 2 \\
 &\text{if } Fn(29.8 + 0.000139 \cdot \Delta) < HR/L \leq Fn(56.2 + 0.000139 \cdot \Delta) && \text{then } Rts = 3 \\
 &\text{if } Fn(16.6 + 0.000139 \cdot \Delta) < HR/L \leq Fn(29.8 + 0.000139 \cdot \Delta) && \text{then } Rts = 4 \\
 &\text{if } HR/L \leq Fn(16.6 + 0.000139 \cdot \Delta) && \text{then } Rts = 5 \dots \dots \dots (2.17)
 \end{aligned}$$

where

HR = non-dimensional head reach, measured in ship lengths, (see Section 2, Figure 4)
 Δ = displacement, in metric tons
 Fn = Froude Number
 Rts = rating for stopping ability

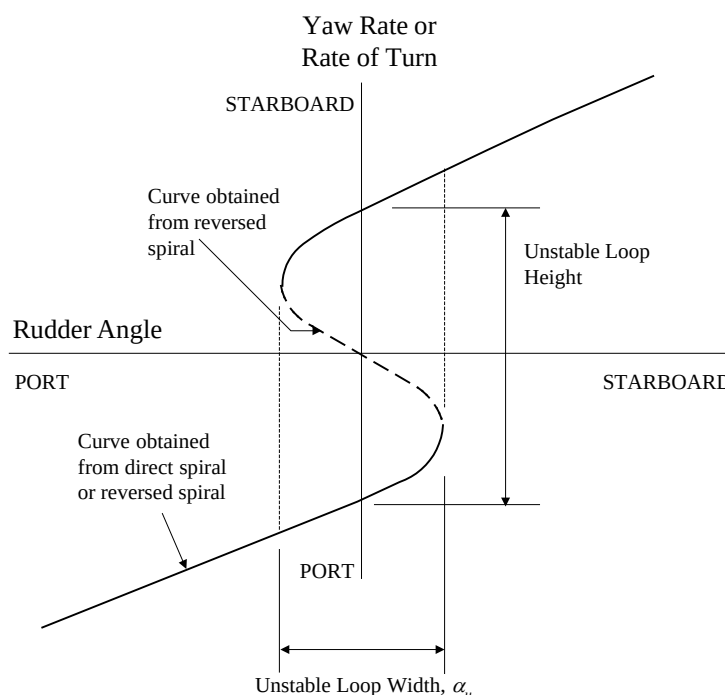
5 Straight-line Stability and Course Keeping Ability

5.1 Definitions

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

The course-keeping quality is a measure of the ability of the steered vessel to maintain a straight path in a predetermined course direction without excessive oscillations of rudder or heading. In most cases, reasonable course control is possible where there is small straight-line instability. The relationship between rudder angle and yaw rate is used to quantify a magnitude of straight-line instability, in particular with unstable loop, α_u , as recommended by IMO standards [IMO 2002a], see Section 2, Figure 5.

FIGURE 5
Relation between Rudder Angle and Yaw (Turn) Rate
for Straight-line Unstable Vessel

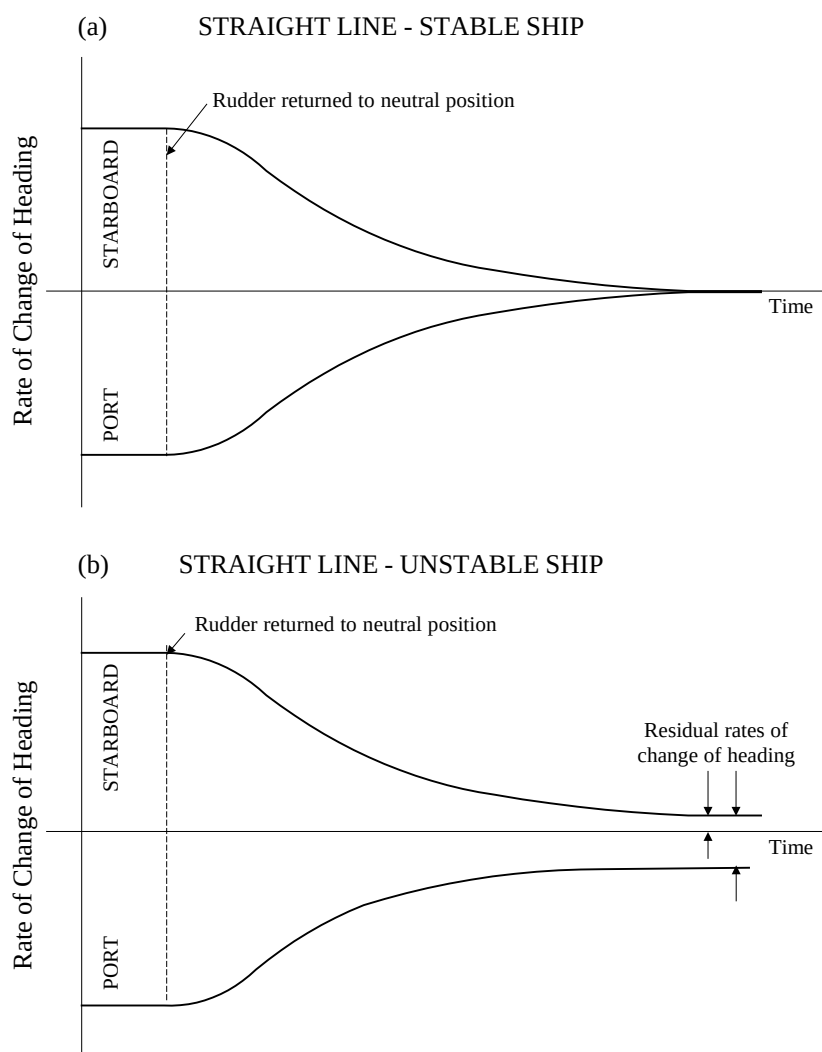


5.2 The Pull-out Test

The pull-out test allows for the determination of whether a vessel is dynamically stable and able to keep the course.

After the completion of the turning circle test, the rudder is returned to neutral position, (zero for twin screw vessels, may not equal to zero for single screw vessels) and kept there until a steady turning rate is obtained. This test gives a simple indication of a vessel's dynamic stability on a straight course. If the vessel is stable, the rate of turn will decay to zero (within accuracy of vessel equipment) for turns to both port and starboard (see Section 2, Figure 6a). If the vessel is unstable, then the rate of turn will reduce to some residual rate of turn (see Section 2, Figure 6b). The residual rates of turn to port and starboard indicate the magnitude of instability at the neutral rudder angle. Normally, pull-out maneuvers are performed in connection with the turning circle, zig-zag, or initial turning tests, but they may be carried out separately. (*Note: This test should only be used to identify course instability.*)

FIGURE 6
Pull-out Test



5.3 Tests for Straight-line Unstable Vessels

If the vessel is found to be straight-line unstable by the pull-out test, one of spiral tests may also be performed:

- The direct spiral maneuver (Dieudonné Spiral) is an orderly sequence of turning circle tests to obtain a steady turning rate versus rudder angle relation. The maneuver requires a very long time and therefore is not recommended for sea trial.
- The reverse spiral (Bech Spiral) test may provide a more rapid procedure than the direct spiral test in developing the spiral curve and enables obtaining the dashed or unstable portion of the yaw rate versus rudder angle relationship in Section 2, Figure 5 which is not obtainable from the Dieudonné test. In the reverse spiral test, the vessel is steered to obtain a constant yaw rate, the mean rudder angle required to produce this yaw rate is measured and the yaw rate versus rudder angle plot is created. Points on the curve of yaw rate versus rudder angle may be taken in any order. A more detailed description of the reverse spiral is given in 4/3.5.

5.4 Maximum Width of Unstable Loop

If the vessel is found to be straight-line unstable (there is a residual turn rate after the rudder was returned to the neutral position), the magnitude of the instability loop (see Appendix 3, Figure 11) should be assessed in order to determine if an average helmsman can control the vessel. In order to assure this capability, the following maximum value of the width of the instability loop, α_U , is specified by the following formulae (see also Section 2, Figure 7):

$$\alpha_U \leq f_U(L/V)$$

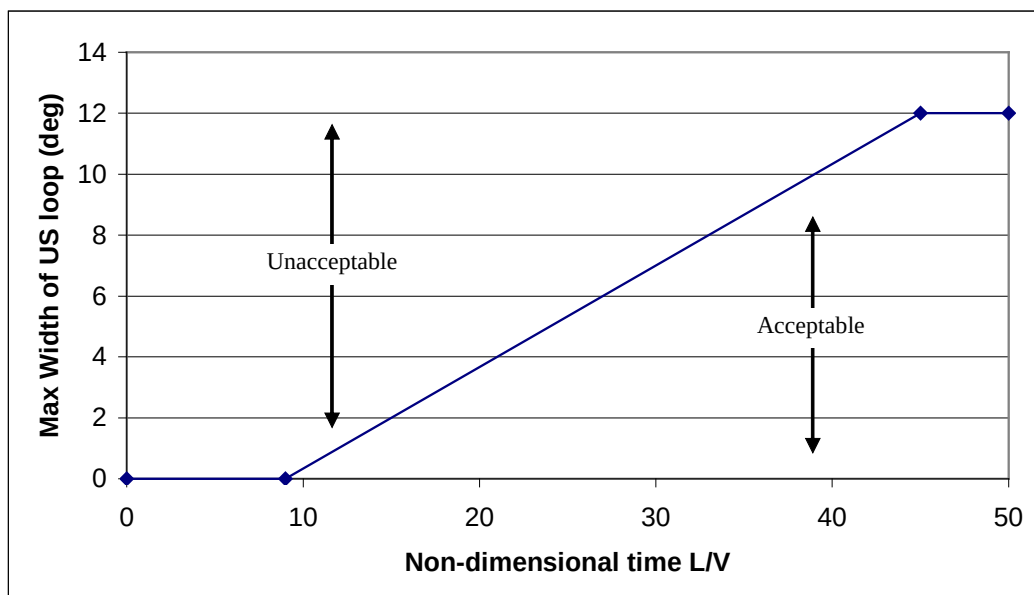
$$f_U(L/V) = \begin{cases} 0 & \text{if } L/V < 9 \text{ s} \\ \left(\frac{1}{3} \frac{L}{V} - 3\right) & \text{if } 9 \leq L/V < 45 \text{ s} \\ 12 & \text{if } L/V \geq 45 \text{ s} \end{cases} \quad (2.18)$$

where

L = vessel length, in meters
 V = test speed measured, in m/s

No rating is assigned in relation to the width of the instability loop.

FIGURE 7
Maximum Width of Unstable Loop





SECTION 3 Prediction of Maneuverability

1 General

An optional class notation may be requested on the basis of maneuvering prediction, which can be performed using one of three methods:

- Comparative prediction, see Subsection 3/2
- Numerical simulation, see Subsection 3/3
- Scaled model test, see Subsection 3/4

2 Comparative Prediction

Comparative prediction of maneuvering could be performed based on maneuvering information available from a similar vessel.

Choice of a similar vessel is to be justified with the previous positive experience. Considerations of similarity are to be included in the submittal.

3 Numerical Simulation

3.1 General

Numerical simulation based on model test data is a recommended prediction tool.

This numerical simulation is to be performed for a vessel in full load conditions (see definition in Subsection 1/4). The mathematical model (definition – see below) used for numerical simulation is to be validated with sea trial results for a vessel in trial load conditions.

Numerical simulation is the integration of differential equations describing ship motions in a horizontal plane. A sample of these equations (also called the “mathematical model”) is considered in detail in Appendix 1, their brief theoretical background is reviewed in Appendix 3 and the derivation of these equations is given in Appendix 4. These Appendices are included for convenient reference.

The most important input data required by the mathematical model are hydrodynamic forces and moments acting on the submerged part of the hull and usually presented in non-dimensional form commonly known as “hydrodynamic coefficients”, “maneuvering coefficients” or “maneuvering derivatives”.

The only reliable source of hydrodynamic coefficients is a model test. These coefficients, however, are reusable for a vessel with similar underwater hull geometry. See 3/3.2.

3.2 Data Sources for Hydrodynamic Coefficients

Determining hydrodynamic forces and moments is the most difficult problem for maneuverability prediction. If data on hydrodynamic forces and moments is available for a similar existing vessel, it may be possible to use them for a vessel being designed.

If hydrodynamic coefficients from similar vessels are used, the justification of similarity is to be included in the submittal.

If enough information on hydrodynamic forces and moments (including nonlinear components) is available for the similar hull, these forces and moments can be used in a mathematical model to simulate maneuvers described in Section 2. Requirements for a mathematical model are listed in 3/3.4. The theoretical background of such a model is given in Appendix 3.

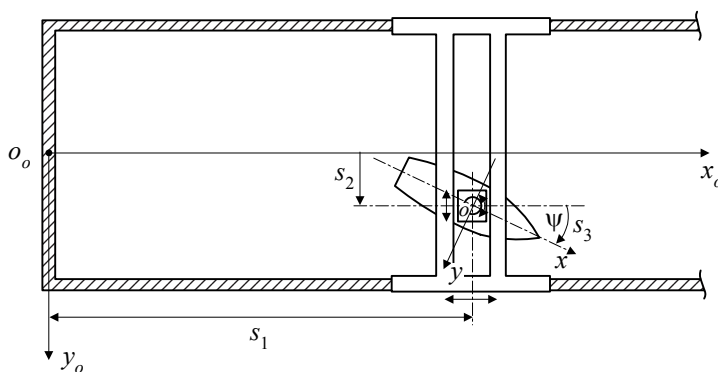
If data on hydrodynamic forces and moments are not available, the forces and moments should be acquired through a model test, as described in 3/3.3, and then used for numerical simulation with the mathematical model.

3.3 Model Test as a Source of Data for Hydrodynamic Coefficients

If a model test is to be carried out to obtain hydrodynamic coefficients, the Planar Motion Mechanism (PMM) Technique is the preferred method. PMM testing is preferable to self-propelled model tests since the PMM tests can be run at the correct vessel (not model) self-propulsion point giving the correct flow over the rudder.

The PMM is a horizontal oscillator used in a traditional long towing tank. The PMM is capable of forcing a ship model to oscillate in pure sway (s_2) or yaw (s_3) or a combination of the two. Most PMM's consist of two rams that oscillate the model horizontally. See Section 3, Figure 1 below.

FIGURE 1
Scheme of Planar Motion Mechanism
with Three Degrees of Freedom



The phasing of these rams determines if the model is oscillated in pure sway or pure yaw. The tests are used to determine the hydrodynamic forces and moments acting upon a model as a result of these motions. The results of the tests are used to derive a linear or nonlinear hydrodynamics model describing the vessel maneuvering capability. The model is towed at the design speed and the amplitude of the sway and yaw motion is varied.

The maneuvering forces and moments are assumed to be low frequency values and independent of frequency. The PMM model test must be conducted according to ITTC-Recommended Procedure 7.5-02-06-02 "Testing and Extrapolation Methods Maneuverability Captive Model Test Procedure".

Experimental results, obtained with Rotating Arm could also be used as a source of data for hydrodynamic coefficients. Self-propelled model test results are admissible only by special consideration by ABS on a case-by-case basis.

The following are the requirements for the model test:

- The model test is to be performed for both operational and trial loading conditions.
- The model test is to be carried out by an ABS-recognized facility, which is usually a member of the International Towing Tank Conference (ITTC).
- The model test must be conducted both for full load and ballast conditions
- A copy of the model test report and measured data in electronic format should be submitted to ABS. The report should contain a brief description of the method used (PMM, Rotating Arm, etc.), detailed description of the model, analysis of uncertainties and errors, detailed description of data processing and definitions and values for linear and nonlinear hydrodynamic derivatives and other coefficients. Electronic data are to be presented as an ASCII file with detailed description of the layout of the data.

All the model test data will be treated by ABS as confidential information.

3.4 Maneuvering Simulation

Once hydrodynamic derivatives and other coefficients have been determined either from similar vessels or through model test, the numerical simulation of maneuvers described in Section 2 has to be performed in order to predict maneuverability of a vessel being designed.

Numerical simulation of maneuvers is numerical integration of a system of ordinary differential equations describing ship motion in a horizontal plane. Such a system is also called a “mathematical model”. Numerical integration of a system of ordinary differential equations is a standard mathematical procedure; relevant software is available and is a part of most engineering and mathematical packages.

The following are requirements for a mathematical model to be used for maneuvering simulation:

- The mathematical model is to be capable of simulating tight maneuvers for both straight-line stable and straight-line unstable vessels.
- The mathematical model is to account for forward speed loss during maneuvers.
- The mathematical model is to account for forces and moments caused by asymmetric flow around propeller.
- The mathematical model is to account for interaction of propeller and rudder.
- The mathematical model is to be capable of taking into account rudder deflection rate.
- The mathematical model is to be capable of simulating control actions such as deflection of the rudder and changing speed for “full ahead” to “crash astern” during a time interval typical for a vessel being designed.
- All the simulations are to be carried out for full load and ballast conditions at test speed.
- Slow speed (within the range 6-8 knots) maneuvering simulation is recommended in addition to the test speed maneuvering simulation. If such simulation is performed, it is recommended that the results are made available for the Owner/operator.
- It is recommended that for twin screw vessels, the model is to account for the interaction of the two systems.
- It is recommended to include roll into the mathematical model for fast vessels, especially for container carriers and vessels with small value of GM.

The following information is to be submitted to ABS:

- Formulation for system of differential equations
- Definition for each coefficient and its numerical value
- Straight-line stability analysis
- Time history of control inputs (commanded speed and rudder deflection angle) for each maneuver required in Section 2
- Time histories of vessel response: motions surge, sway, yaw and respective velocities obtained during simulation of maneuvers required in Section 2
- Value of maneuverability criteria as described in Section 2 with the rating figure for each of them

4 Scale Model Test

Self-propelled model test results are admissible only by special consideration by ABS on a case-by-case basis.

5 Validation of Prediction of Maneuverability

If an optional class notation is requested on the basis of maneuvering prediction, the prediction is to be validated with full scale sea trials.

Validation includes carrying out maneuvering prediction for a vessel in trial load condition exactly in the same way as it is done for the vessel in full load conditions. The results of this prediction are to include all criteria and standard values of the required maneuvers from Section 2, Table 1.

The results of this prediction are to be compared with the results of full scale sea trials. The allowable difference between prediction and trials is to be determined by ABS.

If numerical simulation is used as a method of maneuvering prediction, the validation may be done following the ITTC-recommended Procedure 7.5-02-06-03 "Testing and Extrapolation Methods Maneuverability Validation of Maneuvering Simulation Models"

If proprietary data are used, ABS will treat such data as confidential.



SECTION 4 Sea Trials

1 Required and Recommended Maneuvers

Sea trials are the final confirmation of a vessel's maneuvering qualities and its maneuverability prior to its delivery. The required maneuvers are:

- *Turning test.* For initial turning and steady turning ability
- *10/10 zig-zag test.* For yaw checking ability, course-keeping ability and initial turning/course changing ability
- *20/20 zig-zag test.* For yaw checking ability and course-keeping ability
- *Stopping test (Crash Stop).* For emergency stopping ability

The recommended maneuvers are:

- *Pull-out test.* For inherent straight-line stability
- *One of the spiral tests.* For inherent straight-line stability if the pull-out test indicated that the vessel is directionally unstable. (Recommended – not mandatory)

Additional guidance on conducting of sea trials is also available from [SNAME 1987], [IMO 2002b] and [ISO 2005].

2 Conditions of Trials

Maneuverability of a vessel may be significantly influenced by hydrodynamic interaction with the sea bottom, banks and other vessels passing nearby. In addition, winds, waves, currents and tides also affect maneuverability. In order to get credible results, sea trials are to be carried out in the following conditions:

- *Deep and unrestricted waters.* Water depth at the trial site is to be more than four times of vessel draft at midship. The site should be free from other traffic and far enough from banks that any maneuver would not make any bank closer than two ship lengths.
- *Winds and waves.* The trials are not to be conducted if sea state is greater than 4. Wind is not to exceed Beaufort 5. It is not recommended to conduct the trials if the sea state is greater than 2 and wind greater than Beaufort 3.
- *Tides and currents.* It is recommended to avoid places with strong current and/or tidal influence when choosing a trial site. If current cannot be avoided, it should be uniform and the tests should be performed both for initial following and initial ahead current.

Vessel loading conditions also can affect measurements of maneuverability. The following are the requirements for loading conditions:

- If the decision is made to perform sea trials in full load conditions (definition, see Subsection 1/2), a vessel is to be loaded within 5% of full load draft, without trim and on even keel [IMO 2002b].
- If the decision is made to perform sea trials in trial load conditions (definition, see Subsection 1/2), there should be minimal possible trim and the propeller is to be immersed sufficiently