BS ISO 13643-3:2017

BSI Standards Publication

Ships and marine technology — Manoeuvring of ships

Part 3: Yaw stability and steering

National foreword

This British Standard is the UK implementation of ISO 13643-3:2017. It supersedes BS ISO 13643-3:2013 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EPL/80, Maritime navigation and radiocommunication equipment and systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Published by BSI Standards Limited 2017

ISBN 978 0 580 94633 2

ICS 47.020.70

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 28 February 2017.

Amendments/corrigenda issued since publication

Date	Text affected

INTERNATIONAL STANDARD

ISO 13643-3

Second edition
2017-02

Ships and marine technology — Manoeuvring of ships —

Part 3:
Yaw stability and steering

Navires et technologie maritime — Manoeuvres des navires —

Partie 3: Stabilité en lacet et pilotage

Reference number
ISO 13643-3:2017(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 8, *Ships and marine technology*, Subcommittee SC 6, *Navigation and ship operations*.

This second edition cancels and replaces the first edition (ISO 13643-3:2013), of which it constitutes a minor revision with the following changes:

— the numbering has changed;

— in Clause 4, Table 1, the SI-Unit in first line was changed from "rad $^{s-1}$" to "rad s^{-1}";

— in the second line of 9.4, "δ_{Ri} = 10° (10)" was changed to "δ_{Ri} = −10° (10)".

A list of all parts in the ISO 13643- series can be found on the ISO website.

Ships and marine technology — Manoeuvring of ships —

Part 3: Yaw stability and steering

1 Scope

This document defines symbols and terms and provides guidelines for the conduct of tests to give evidence about the yaw stability and steering of surface ships, submarines, and models. It is meant to be read in conjunction with ISO 13643-1.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13643-1:2017, *Ships and marine technology — Manoeuvring of ships — Part 1: General concepts, quantities and test conditions*

ISO 13643-5:2017, *Ships and marine technology — Manoeuvring of ships — Part 5: Submarine specials*

ISO 80000-1, *Quantities and units — Part 1: General*

ISO 80000-3, *Quantities and units — Part 3: Space and time*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp/

3.1
astern test
manoeuvring test to determine the ship's ability to maintain course while making way astern

3.2
astern zig-zag test
manoeuvring test to determine the ship's ability to maintain course while making way astern by assessing manoeuvring devices efficiency from a zig-zag test

3.3
direct astern test
manoeuvring test to determine the ship's ability to maintain course when making way astern using its manoeuvring devices and tunnel thrusters as available

3.4
direct spiral test (according to Dieudonné)
manoeuvring test to determine the yaw stability and turning ability when using constant manoeuvring device settings

3.5
manoeuvring device
rudder, azimuthing thruster, hydroplane, cycloidal propeller, or equivalent system used to manoeuvre a vessel

3.6
pull-out test
manoeuvring test for quick determination of a ship's yaw stability related to its speed through the water

3.7
reverse spiral test (according to Bech)
manoeuvring test to determine the yaw stability and turning ability when using constant yaw rates of turn

3.8
sine test
manoeuvring test to determine the ship's turning and yaw-checking ability in relation to initial speed and manoeuvring device settings for the purpose of setting up auto pilots

3.9
weave test
manoeuvring test to determine the extent of a ship's potential yaw instability

4 Test-related physical quantities

Test-related physical quantities are listed in Table 1. The more general quantities and concepts concerning the manoeuvring of ships are set out in ISO 13643-1.

For quantities and their units, ISO 80000-1 and ISO 80000-3 shall be used.

Table 1 — Test-related physical quantities

Symbol	CC-Code	SI-Unit	Concept	
			Term	Definition or explanation
$\frac{\mathrm{d}\dot{\psi}_C}{\mathrm{d}\delta_{Ri}}$	GRDNTD	s^{-1}	Gradient of the $\dot{\psi}_C(\delta_{Ri})$ curve at δ_0	—
$\frac{\mathrm{d}\dot{\psi}_i}{\mathrm{d}\delta_R}$	GRDNTB	s^{-1}	Gradient of the $\dot{\psi}_i(\delta_R)$ curve at δ_0	—
L	L	m	Length	Reference length of a ship (see ISO 13643-1)
l_δ	LWRD	rad[a]	Loop width	For a ship with yaw instability: measured between the two extremes of the curve $\delta_R(\dot{\psi})$
$l\dot{\psi}$	LHRD	rad s^{-1} [b]	Loop height	For a ship with yaw instability: measured between the intersections of the $\dot{\psi}(\delta_R)$ curve with the axis $\delta_R = 0$
n_i	NI	s^{-1}	Test propeller speed	—
P/D	PDR	1	Pitch ratio	—
P_i	PITCHI	m	Test propeller pitch	Propeller pitch given relative to the pitch for zero thrust at zero speed

a For angles, the unit ° (degree) may be used.

b For rate of turn, the unit °/s (degree per second) may be used.

c The unit kn, common in navigation, may be used.

Table 1 *(continued)*

Symbol	CC-Code	SI-Unit	Concept	
			Term	**Definition or explanation**
T	TIP	s	Period of manoeuvring device oscillation	Specified time to move the manoeuvring device, e.g. from the specified amplitude to starboard (S) to the same amplitude to port (P) and back to the specified amplitude to starboard (S)
t_{C1}	TIC1	s	First time to check yaw	Elapsed time from initiating 1st application of manoeuvring devices in the opposite direction until maximum change of heading is reached
t_{C2}	TIC2	s	Second time to check yaw	Elapsed time from initiating 2nd application of manoeuvring devices in the opposite direction until maximum change of heading is reached
t_F	TIF	s	Course keeping time	Time during which the ship maintains course in accordance with 10.2.1
V_F	VF	m s^{-1} [c]	Final speed	Speed at the end of test (run)
V_i	VI	m s^{-1} [c]	Target speed	Speed corresponding to propeller speed/pitch setting on straight track
V_0	V0	m s^{-1} [c]	Initial speed	(See ISO 13643-1)
x_0	X0	m	—	Coordinate in the direction of the initial heading of the earth-fixed axis system moving with the water, the origin of which coincides with that of ship-fixed axis system at $t = 0$ (see also ISO 13643-1)
x_{0F}	X0F	m	Sternboard	x_0-component (astern) of the ship's track at t_F
y_0	Y0	m	Transverse axis	Coordinate of the earth-fixed axis system in water surface perpendicular to x_0, analogous definition (see also ISO 13643-1)
y_{0F}	Y0F	m	Transfer at end of test (run)	y_0-component of the ship's track at t_F
z_0	Z0	m	Vertical axis	Coordinate of the earth-fixed axis system orthogonal to x_0 and y_0, vertically down, analogous definition (see also ISO 13643-1)
Δz_{0F}	DZ0F	m	Change of dived depth	z_0-component of the ship's track at t_F, relative to the value at the commencement of a test (run)
$\Delta\delta_{Ri}$	DANRUI	rad[a]	Manoeuvring device angle step	—
$\Delta\psi$	DPSIH	rad[a]	Change of heading	$\psi - \psi_0$
$\Delta\psi_E$	DPSIHE	rad[a]	Execute change of heading	Specified absolute amount of change of heading for applying the manoeuvring devices into the opposite direction
$\Delta\psi_F$	DPSIHF	rad[a]	Change of heading at end of test	$\psi_F - \psi_0$
$\Delta\psi_{MAX}$	DPSIHM	rad[a]	Maximum change of heading	—
$\Delta\dot{\psi}_C$	DYARTC	rad s^{-1} [b]	Difference between final asymptotic rates of turn	Resulting from S and P turns at the same V_0
δ_{Ra}	ANRUA	rad[a]	Manoeuvring device angle amplitude	If necessary, an equivalent manoeuvring device amplitude shall be given, e.g. for submarines with X-planes: ¼ ($\delta_{Aa2} + \delta_{Aa3} - \delta_{Aa1} - \delta_{Aa4}$).

a For angles, the unit ° (degree) may be used.

b For rate of turn, the unit °/s (degree per second) may be used.

c The unit kn, common in navigation, may be used.

Table 1 *(continued)*

Symbol	CC-Code	SI-Unit	Concept	
			Term	**Definition or explanation**
δ_{Ri}	ANRUI	rad[a]	Test manoeuvring device setting	Relative to δ_0 If necessary, an equivalent test setting shall be given, e.g. for submarines with X-planes: ¼ ($\delta_{Ai2} + \delta_{Ai3} - \delta_{Ai1} - \delta_{Ai4}$).
δ_{Ri1}	ANRUI1	rad[a]	First test manoeuvring device setting	Relative to δ_0 To which the manoeuvring devices are put at the commencement of the test. If necessary, an equivalent test setting shall be given, e.g. for submarines with X-planes: ¼ ($\delta_{A2} + \delta_{A3} - \delta_{A1} - \delta_{A4}$).
δ_{Ri2}	ANRUI2	rad[a]	Second test manoeuvring device setting	Relative to δ_0 To which the manoeuvring devices are put at 1st counter setting. If necessary, an equivalent test setting shall be given as for δ_{Ri1}.
δ_{Ri3}	ANRUI3	rad[a]	Third test manoeuvring device angle	Relative to δ_0 To which the manoeuvring devices are put at 2nd counter setting. If necessary, an equivalent test setting shall be given as for δ_{Ri1}.
δ_0	ANRU0	rad[a]	Neutral manoeuvring device angle	(See ISO 13643-1)
$\bar{\delta}_R$	ANRUM	rad[a]	Mean manoeuvring device angle	Determined in each stage of the test during a period of sufficiently constant ship's speed through the water and rate of turn
ε	EPH	rad[a]	Phase shift	Between heading and manoeuvring device angle
θ_{SF}	TRIMSF	rad[a]	Trim angle at end of test	—
θ_{SMAX}	TRIMSM	rad[a]	Maximum trim angle	—
θ_{S0}	TRIMS0	rad[a]	Initial trim angle	—
ψ	PSIH	rad[a]	Heading	(See ISO 13643-1)
ψ_{E1}	PSIHE1	rad[a]	Heading for first execute	$\psi_0 + \Delta\psi_E$ Heading when the manoeuvring devices are applied in the opposite direction (turn to P)
ψ_{E2}	PSIHE2	rad[a]	Heading for second execute	$\psi_0 - \Delta\psi_E$ Heading when the manoeuvring devices are applied back in the original direction (turn to S)
ψ_F	PSIHF	rad[a]	Final heading	Heading at the end of a test (run)
ψ_{S1}	PSIS1	rad[a]	First overshoot angle	During the turn, angle between the heading at which the manoeuvring devices are applied in the opposite direction and the heading at which the vessel ceases to turn in the current direction
ψ_{S2}	PSIS2	rad[a]	Second overshoot angle	During the turn, angle between the heading at which the manoeuvring devices are applied back in the original direction and the heading at which the vessel ceases to turn in the current direction

[a] For angles, the unit ° (degree) may be used.

[b] For rate of turn, the unit °/s (degree per second) may be used.

[c] The unit kn, common in navigation, may be used.

Table 1 *(continued)*

Symbol	CC-Code	SI-Unit	Concept	
			Term	Definition or explanation
ψ_a	PSIHA	rad[a]	Amplitude of heading	Amplitude of the heading resulting from the sinusoidal oscillation of the manoeuvring devices
ψ_0	PSIH0	rad[a]	Initial heading	Heading of a vessel at the commencement of a test (run)
$\dot{\psi}$	YART	rad s^{-1} [b]	Rate of turn	—
$\dot{\psi}_a$	YARTA	rad s^{-1} [b]	Amplitude of rate of turn	Amplitude of the rate of turn resulting from the sinusoidal oscillation of the manoeuvring devices
$\dot{\psi}_C$	YARTC	rad s^{-1} [b]	Constant rate of turn	Mean value of the rate when the ship has reached steady conditions after each change of manoeuvring device setting
$\dot{\psi}_{CP}$	YARTCP	rad s^{-1} [b]	Asymptotic rate of turn (for P turn)	To which the ship pulls out in P turn
$\dot{\psi}_{CS}$	YARTCS	rad s^{-1} [b]	Asymptotic rate of turn (for S turn)	To which the ship pulls out in S turn
$\dot{\psi}_i$	YARTI	rad s^{-1} [b]	Test turning rate	Required rate of turn for a stage of the test
ω	OMF	rad s^{-1} [b]	Angular frequency	$2\pi/T$

[a] For angles, the unit ° (degree) may be used.

[b] For rate of turn, the unit °/s (degree per second) may be used.

[c] The unit kn, common in navigation, may be used.

5 General test conditions

The general test conditions in ISO 13643-1:2017, Clause 8 shall be observed.

When operating submerged, submarines shall be trimmed according to the results of the neutral level flight test in ISO 13643-5:2017, Clause 8. During the test, the dived depth shall be kept as constant as possible. The dived depth and the plane angles are to be recorded continuously. If the submarine is equipped with planes acting into the horizontal as well as into the vertical direction at the same time (e.g. X-planes), these planes should be controlled in such a way that the dived depth is maintained with priority.

During the test, including the approach phase, each successive position of the ship is to be recorded — e.g. using an onboard navigation system during surface operations — at suitable time intervals (usually every second).

The reference point on the vessel from where its track is measured should be defined in advance (e.g. location of a positioning system antenna). This point is not necessarily identical with the origin of the ship-fixed axis system for which the vessel's track is given (see ISO 13643-1). Data which are to be recorded continuously include (but need not be limited to) manoeuvring device angle of operation, power setting, speed through the water, heading, rate of turn, angle of heel, propeller shaft speed/torque, propeller pitch, true wind velocity and direction, and relative wind velocity and direction.

6 Test 3.1 — Pull-out test

6.1 General

In addition to the general test conditions outlined in ISO 13643-1 and Clause 5, the following conditions shall be complied with.

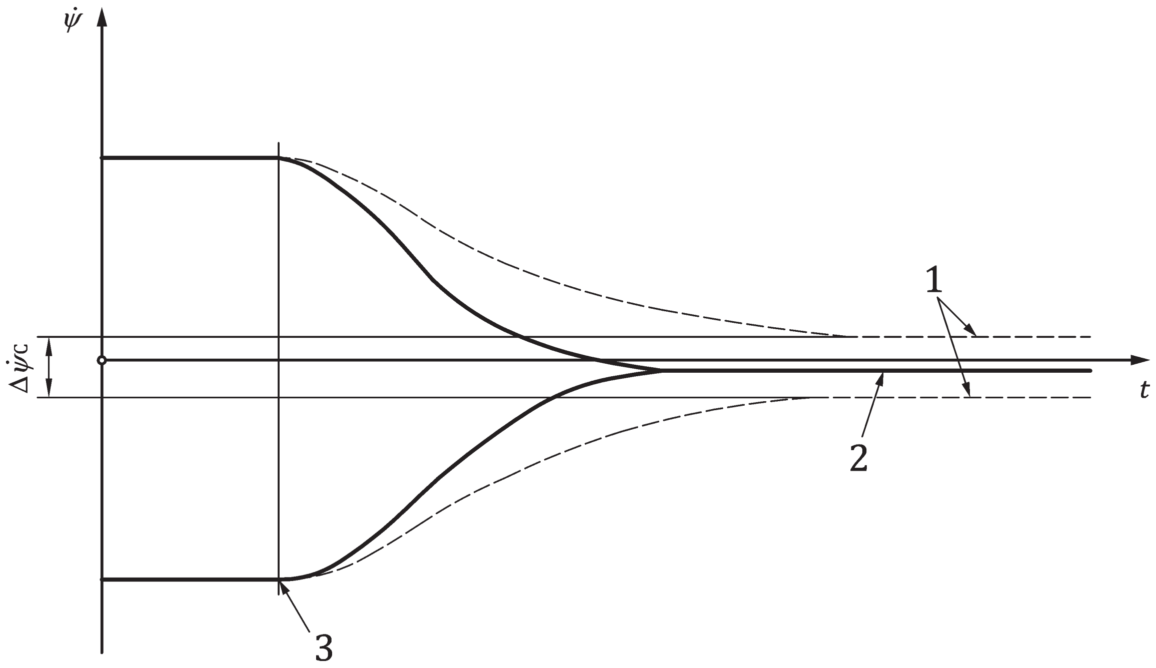
— The ship shall approach on a steady heading and at a constant speed, V_0, before commencing the test. During the test, the propulsion plant settings shall remain unaltered.

— The ship is put into a steady turn, which is outside the expected range of yaw instability, e.g. with a test manoeuvring device setting δ_{Ri} of at least 20° to either P or S. The description is for a turn to S.

— When the rate of turn and the speed of the ship have become constant, the manoeuvring device is returned to amidships (zero-position) and held there until the rate of turn again reaches a sufficiently steady final asymptotic value, $\dot{\psi}_{\mathrm{CS}}$. Heading, manoeuvring device setting, and propeller speed/pitch are to be recorded continuously. The test comprises a second run turning in the opposite direction.

If the ship is stable in yaw, the rates of turn for alterations to both P and S will decrease to the same residual rate of turn (not necessarily zero); if the ship is unstable, the residual rates of turn will differ.

The individual runs of the test may be conducted after corresponding turning circle tests (see ISO 13643-2:2016, Clause 6).



Key

1 ship unstable in yaw

2 ship stable in yaw

3 manoeuvring device back to zero

Figure 1 — Pull-out test

6.2 Analysis and presentation of results of a pull-out test

The following data are obtained from the test:

— difference between asymptotic rates of turn $\Delta\dot{\psi}_C$

— asymptotic rate of turn (for starboard turn) $\dot{\psi}_{CS}$

— asymptotic rate of turn (for port turn) $\dot{\psi}_{CP}$

The time histories of the rates of turn for a pair of S and P turns with identical initial speeds are plotted in the same diagram. The difference between the final asymptotic rates of turn, $\Delta\dot{\psi}_C$, indicates the degree of yaw instability.

If the assessment of the range given by the residual values for the S and P rates of turn proves the ship to be unstable, consideration should be given to conducting either a weave test (see Clause 9) or a reverse spiral test (see Clause 8), taking into account the residual values for the S and P rates of turn.

6.3 Designation of a pull-out test

Designation of a pull-out test according to ISO 13643-3, (3), Test 1 (1), carried out with an initial speed of V_0 = 18 kn (18) and a test manoeuvring device setting δ_{Ri} = 20° (20):

Pull-out test ISO 13643 – 3.1 × 18/20

7 Test 3.2 — Direct spiral test (according to Dieudonné)

7.1 General

In addition to the general test conditions outlined in ISO 13643-1 and Clause 5, the following conditions shall be complied with.

— The direct spiral test consists of several steps performed in succession. The individual steps are performed using different manoeuvring device settings which shall be kept constant during each step.

— To minimize the time needed for the test, the results of the turning circle tests (see ISO 13643-2) should be considered in advance in order to avoid repetition of tests at specific manoeuvring device settings and rates of turn.

7.2 Description

The ship shall approach on a steady heading and at the specified speed, V_0, before commencing the test. During the test, the setting of the propulsion plant remains unaltered.

The manoeuvring devices are put to starboard (S) at a test manoeuvring device equivalent δ_{Ri} = −20° and held in this position until rate of turn and speed are constant.

The manoeuvring device setting, δ_{Ri}, is then successively decreased to −15° (S), −10° (S) and again held at each setting until constant speeds and rates of turn are obtained.

In the range δ_{Ri} = −10° (S) to +10° (P), the test manoeuvring device setting should be decreased in steps of, e.g. $\Delta\delta_{Ri}$ = 2°. When moderate yaw instability is expected, the test manoeuvring device setting, δ_{Ri}, should be decreased in steps of $\Delta\delta_{Ri}$ = 1°, in the range δ_{Ri} = −5° (S) to +5° (P). Beyond δ_{Ri} = +5°, steps should be increased again.

Manoeuvring device setting, rate of turn, heading, ship speed through the water, and/or propeller speed/pitch shall be recorded continuously.

After the test manoeuvring device setting δ_{Ri} = 20° (P) has been reached, an initial evaluation of the test results is made. When yaw instability (see 7.3) is observed, the test shall be continued by reversing the process from a manoeuvring device setting δ_{Ri} = +20° (P) to −20° (S).

If the test procedure is interrupted, it is important to recommence it using a manoeuvring device angle inducing the same direction of turn as before the interruption.

7.3 Analysis and presentation of results of a direct spiral test (according to Dieudonné)

The following data are obtained from the test:

— gradient of the $\dot{\psi}(\delta_R)$ curve at δ_0 $\frac{d\dot{\psi}_C}{d\delta_{Ri}}$

— loop width l_δ

— loop height $l_{\dot{\psi}}$

— neutral manoeuvring device angle δ_0

The mean constant turning rates, $\dot{\psi}_C$, during the constant phase of each step are plotted against the test manoeuvring device setting, δ_{Ri}.

The tendency of the measured rates of turn, particularly for small manoeuvring device angles, indicates the ship's yaw stability. The ship is stable in yaw if the results indicate a continuous curve and the gradient of the rate of turn, $\dot{\psi}_C(\delta_{Ri})$, at the intersection with the δ_{Ri}-axis is negative (see Figure 2) or, in the limit, infinite. If the trend of the results indicates the existence of two separate "branches" of the curve (see Figure 3), then the ship is unstable in yaw. The extent of the region of yaw instability (loop) defined by the height and the width of the discontinuity is a measure for the yaw instability.

For ships stable in yaw, the test yields the neutral manoeuvring device angle, δ_0.

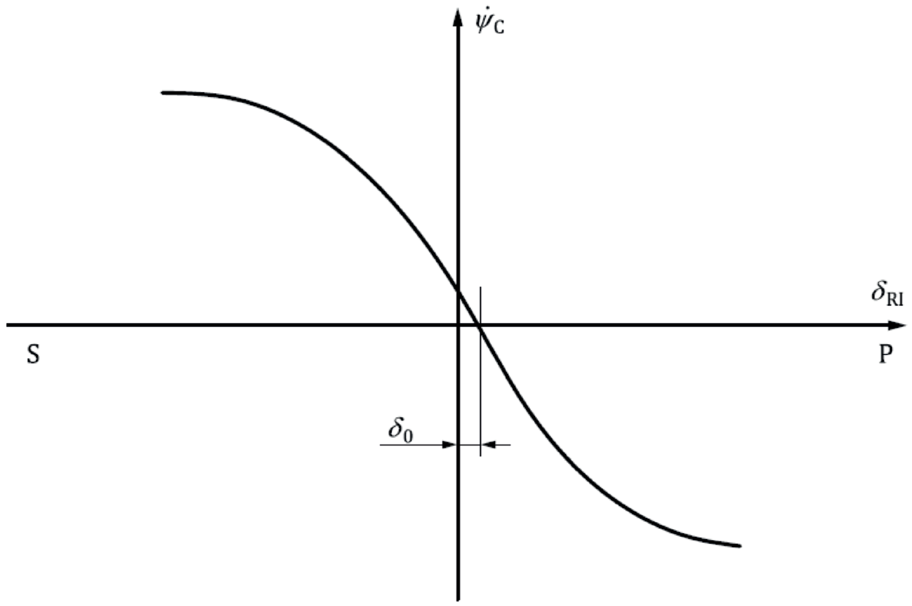
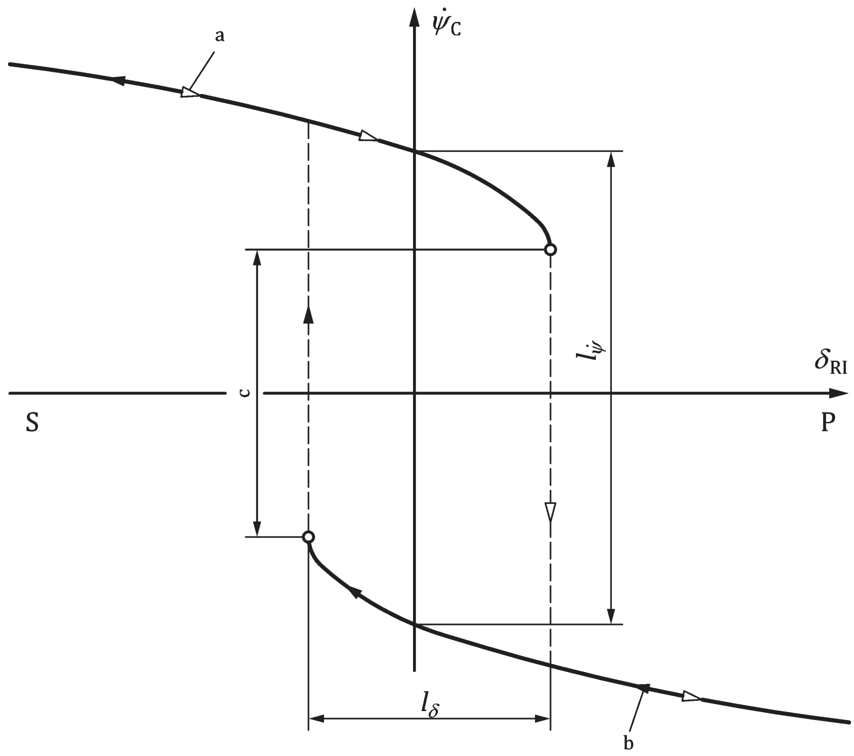


Figure 2 — Ship stable in yaw



Key

a Change of manoeuvring device angle from S to P.

b Change of manoeuvring device from P to S.

c In this test, the function can only be determined outside this range (solid line).

Figure 3 — Ship unstable in yaw

7.4 Designation of a direct spiral test (according to Dieudonné)

Designation of a direct spiral test according to ISO 13643-3, (3), Test 2 (2), carried out with an initial speed of V_0 = 18 kn (18) and a maximum test manoeuvring device setting δ_{Ri} = 20° (20):

Direct spiral test (according to Dieudonné) ISO 13643 – 3.2 × 18/20

8 Test 3.3 — Reverse spiral test (according to Bech)

8.1 General

In addition to the general test conditions outlined in ISO 13643-1 and Clause 5, the following conditions shall be complied with.

— The reverse spiral test consists of several steps performed in succession. The individual steps are performed at different turning rates which shall be kept constant during each step. The individual rates of turn may be taken in any order.

— To minimize the time needed for the test, the results of the turning circle test (see ISO 13643-2) should be considered in advance in order to avoid repetition of tests at specific manoeuvring device settings and rates of turn.

— The test may be performed using an autopilot provided that the latter can be made to control the rate of turn to a set value. If manual steering is used, the rate of turn shall be visually displayed for the helmsman, by means of a rate gyro.

— In contrast to the direct spiral test (according to Dieudonné) (see Clause 7), the ship is steered for the reverse spiral test by maintaining set, constant rates of turn and the necessary manoeuvring device settings are recorded.

8.2 Description

The ship shall approach on a steady heading and at the specified speed, V_0, before commencing the test. During the test, the setting of the propulsion plant remains unaltered.

A turn is initiated by applying the manoeuvring device, usually to starboard (S) first, until the given constant rate of turn and speed can be held constant for at least 60 s with minimal changes of manoeuvring device setting. For each of these periods, the mean values of turning rate and manoeuvring device setting are determined.

It is common practice to start at a maximum turning rate equivalent to starboard manoeuvring device angle of 20°. Additional lesser rates of turn shall be selected such that, after four runs, the rate of turn $\dot{\psi}_\mathrm{i} = 0$. If yaw instability is apparent, additional runs with small rates of turn are necessary. Thereafter, the test is continued to port (P) using the same rates of turn.

Manoeuvring device setting, rate of turn, heading, speed through the water, and/or propeller speed/pitch shall be recorded continuously.

Because of the difficulty of maintaining the low turning rates at small manoeuvring device settings, the test is particularly susceptible to external influences. Ideally, therefore, the test should be carried out when wind velocity and sea state are low.

8.3 Analysis and presentation of results of a reverse spiral test (according to Bech)

The following data are obtained from the test:

— gradient of the $\dot{\psi}(\delta_\mathrm{R})$ curve at δ_0 $\dfrac{\mathrm{d}\dot{\psi}_\mathrm{i}}{\mathrm{d}\delta_\mathrm{R}}$

— loop width l_δ

— loop height $l_{\dot{\psi}}$

— neutral manoeuvring device angle δ_0

The test turning rates, $\dot{\psi}_\mathrm{i}$, are plotted against the mean manoeuvring device angles, $\bar{\delta}_\mathrm{R}$, needed to achieve a steady turn in each step.

The tendency of the measured turning rates, particularly for small manoeuvring device angles, serves to assess the ship's yaw stability.

The ship is stable in yaw if the gradient $\dfrac{\mathrm{d}\dot{\psi}_\mathrm{i}}{\mathrm{d}\delta_\mathrm{R}}$ of curve $\dot{\psi}_\mathrm{i}(\bar{\delta}_\mathrm{R})$, at the intersection with the $\bar{\delta}_\mathrm{R}$ axis, is negative (see Figure 4) or, in the limit, infinite. If this gradient is positive, the ship is unstable in yaw; the gradient is a measure of the yaw instability, also the height, $l_{\dot{\psi}}$, and the width, l_δ, of the loop characterize the instability (see Figure 5).

The test also yields the neutral manoeuvring device angle, δ_0.

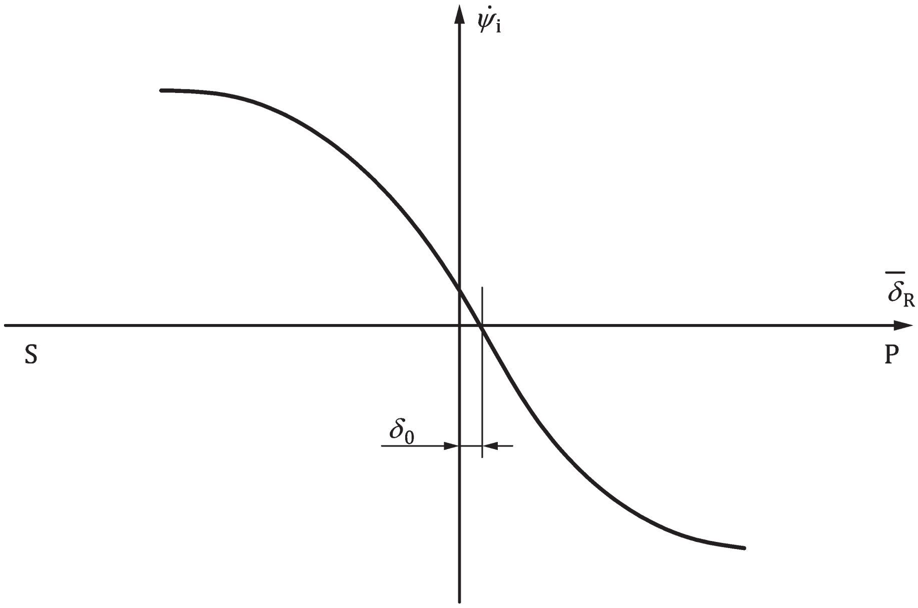


Figure 4 — Ship stable in yaw

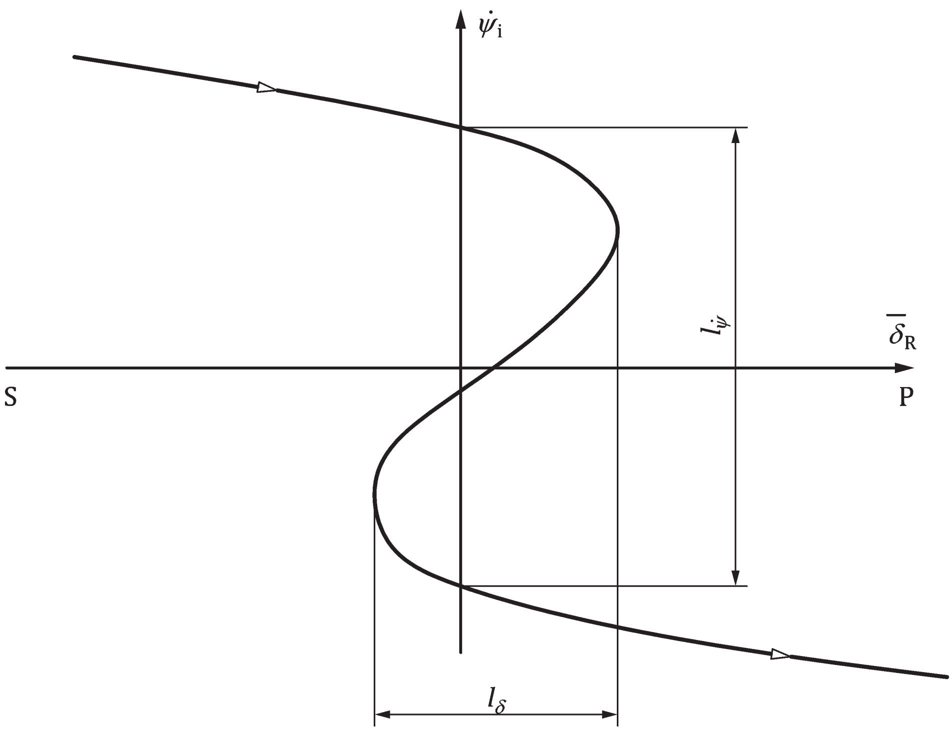


Figure 5 — Ship unstable in yaw

8.4 Designation of a reverse spiral test (according to Bech)

Designation of a reverse spiral test according to ISO 13643-3, (3), Test 3 (3), carried out with an initial speed of V_0 = 18 kn (18) and a maximum turning rate equivalent to a manoeuvring device angle of 20° (20):

Reverse spiral test (according to Bech) ISO 13643 – 3.3 × 18/20

9 Test 3.4 — Weave test

9.1 General

In addition to the general test conditions outlined in ISO 13643-1 and Clause 5, the following conditions shall be complied with.

— The ship shall approach on a steady heading and at a constant speed, V_0, before commencing the test. During the test, the propulsion plant settings shall remain unaltered.

— The weave test consists of several similar stages performed in succession. The individual parts are performed by using pairs of identical manoeuvring device settings to starboard (S) and port (P) which shall be held constant during each stage.

9.2 Description

To commence the test, the manoeuvring devices are put over to a given test manoeuvring device setting, δ_{Ri}, (in this example to S), and held until the speed through the water and the rate of turn have reached constant values (Point 1 in Figure 6). This setting should be chosen such that it is outside the likely range of yaw instability. For most ships, $\delta_{Ri} = 10°$ will be sufficient.

Thereafter, the manoeuvring devices are put to the same angle, δ_{Ri}, on the opposite side (e.g. now to P) and held there until the speed through the water and the rate of turn have reached constant values. If the ship follows the helm, i.e. it changes its direction of turn, this means the ship is stable in yaw for that manoeuvring device setting (Point 2 in Figure 6), and the test is continued as described below. If not, the test can be terminated.

If yaw stability was identified, the test manoeuvring device setting is reduced appropriately [e.g. by 2°, i.e. to $\delta_{Ri} = +8°$(P)]. Waiting for constant speed through the water and rate of turn begins again (Point 3 in Figure 6). Thereafter, the manoeuvring devices are put to the same setting, δ_{Ri}, on the opposite side [$\delta_{Ri} = \sim 8°$(S)] and held there until speed and rate of turn are constant again. If the ship follows the helm, i.e. it changes its direction of turn, then the ship is stable in yaw for that manoeuvring device setting (Point 4 in Figure 6).

The procedure is continued by further reducing the manoeuvring device angle at the same interval (Point 5 in Figure 6) [manoeuvring device setting $\delta_{Ri} = -6°$(S)]. The manoeuvring devices are held until a steady speed and rate of turn are achieved. At this point, a potential yaw instability cannot be determined. Thereafter, the manoeuvring devices are put to the same angle on the opposite side [$\delta_{Ri} = 6°$(P)]. If the ship follows the helm, then, again, the ship is stable in yaw at this manoeuvring device setting. In Figure 6, the ship no longer follows the helm (Point 6). If symmetrical turning ability is assumed, the limit of the range of yaw instability would be between Points 4 and 5. As an approximation, the limit is shown halfway between Points 4 and 5.

Since the limit of the range of yaw instability may be different when changing the manoeuvring device setting from S (direction of turn to S) to the manoeuvring device setting P (direction of turn to P), following the first indication of yaw instability, the mirror image pair of manoeuvres should be tested. For that purpose, it shall first be confirmed that the ship follows the helm.

The weave test is considered complete either when yaw instability has been identified or the test has proven that the ship follows the helm down to manoeuvring device settings of, e.g. $\delta_{Ri} = 2°$.

Manoeuvring device setting, heading, rate of turn, speed through the water, and/or propeller speed/pitch shall be recorded continuously.

9.3 Analysis and presentation of results of a weave test

The following data are obtained from the test:

— loop width l_δ

— loop height $l_{\dot{\psi}}$

The constant rates of turn, $\dot{\psi}_C$, determined for the single stages are plotted in a diagram against the corresponding test manoeuvring device settings, δ_{Ri} (see example in Figure 6).

This diagram showing the approximate width, l_δ, and height, $l_{\dot{\psi}}$, extrapolated from the measured points is the basis for assessing the degree of yaw stability.

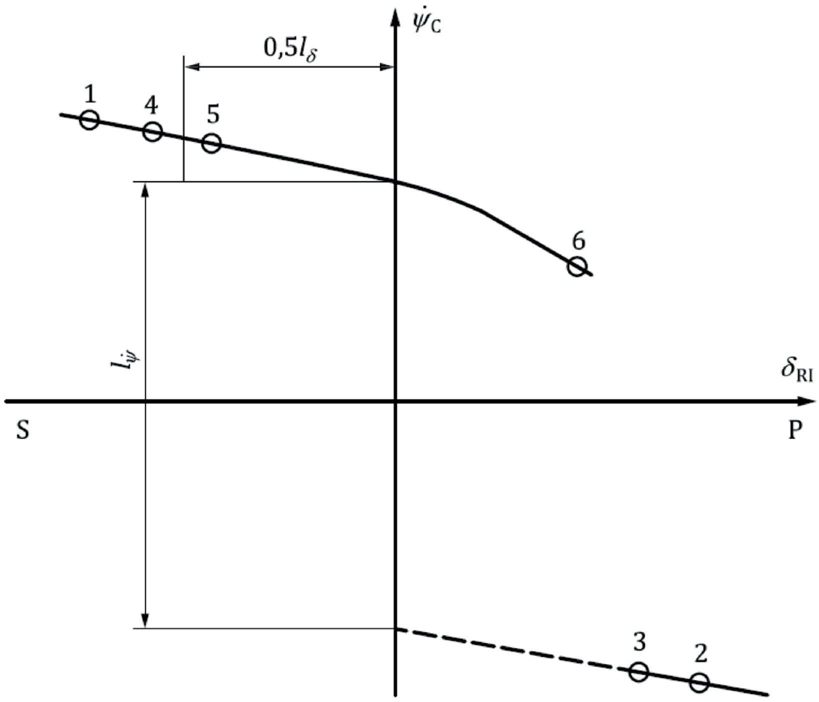


Figure 6 — Analysis (ship unstable in yaw)

9.4 Designation of a weave test

Designation of a weave test, according to ISO 13643-3, (3), Test 4 (4), carried out with an initial speed V_0 = 20 kn (20) and an initial manoeuvring device setting δ_{Ri} = –10° (10):

Weave test ISO 13643 – 3.4 × 20/10

10 Test 3.5 — Astern test

10.1 General

In addition to the general test conditions outlined in ISO 13643-1 and Clause 5, the following conditions shall be complied with.

— The test is performed with a propulsion setting corresponding to a target speed of preferably not more than 50 % of the designed maximum astern speed.

The astern test may be carried out by one of two different methods, i.e.

— as a direct astern test, the result of which may to a certain degree be affected by the helmsman, or

— as an astern zig-zag test.

The two test methods are described in 10.2.1 and 10.2.2. The above general requirements refer to both test methods.

The astern test need only be performed in ships which require astern manoeuvrability. In ships with a symmetrical arrangement of propulsors, the astern zig-zag test need be performed to one side only.

10.2 Description

10.2.1 Description of the direct astern test

The ship starts to make way astern with a propulsion setting in accordance with 10.1 and the manoeuvring devices held amidships initially. The helmsman keeps the ship on its initial heading for as long as possible using the manoeuvring devices and, if available, bow thrusters.

The test is complete when the absolute change of heading, $|\Delta\psi|$, exceeds 15° or when the ship has made a sternboard, x_{0F}, of five ship lengths astern (see Figure 7). For submarines in submerged operation, the test is also complete when the absolute change of dived depth, $|\Delta z_{0F}|$, exceeds one ship length or the absolute trim angle exceeds 15°.

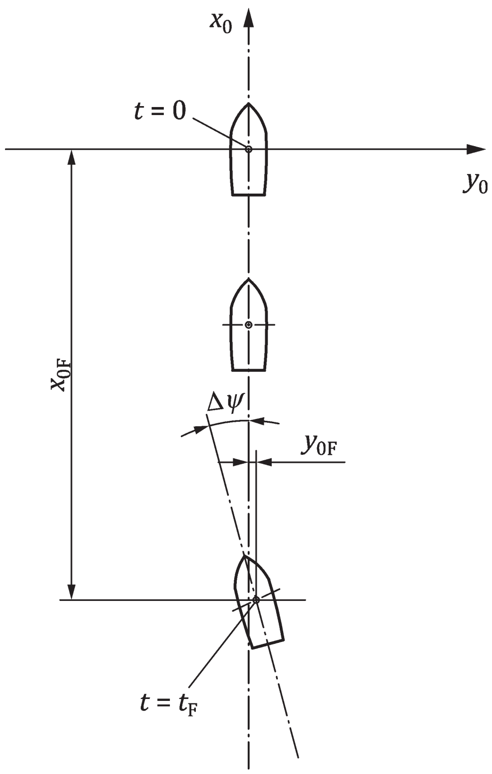


Figure 7 — Direct astern test

10.2.2 Description of the astern zig-zag test

The ship starts to make way astern from zero speed with a propulsion setting in accordance with 10.1. At the same time, the manoeuvring devices are put over to 15° (preferably to starboard), i.e. to δ_{Ri1} = −15°(S). The manoeuvring devices are held at this setting until the ship's heading has changed from the initial heading, ψ_0, by the specified execute change of heading, $\Delta\psi_E$ (it is preferable that

$|\Delta\psi_E| = 10°$), to the heading ψ_{E1}. At this point, the manoeuvring devices are put over as fast as possible to the same setting in the opposite direction [δ_{Ri2} = +15° (P)] and held there. The ship continues to turn in the initial direction. If the turning decays completely and the ship starts to turn in the opposite direction with increasing rate of turn, wait until the heading has changed from the original heading by $\Delta\psi_E$ to the opposite side of the initial heading to heading ψ_{E2}. At this point, the manoeuvring devices are reversed again to the manoeuvring device setting $\delta_{Ri3} = \delta_{Ri1}$. The test run is complete when the turning is not stopped after the first or second counter application of the manoeuvring devices or when, after the second counter application, the heading reaches the initial heading.

For submarines operating submerged, the test is also complete when the absolute change of dived depth, $|\Delta z_{0F}|$, exceeds one ship length or the absolute trim angle exceeds 15°.

If the ship does not stop turning after the first or the second counter application of the manoeuvring device, the test run shall be repeated with the same first manoeuvring device setting, δ_{Ri1} = −15° (S), and the same execute change of heading, $\Delta\psi_E$, but with δ_{Ri2} and δ_{Ri3} corresponding to full rudder.

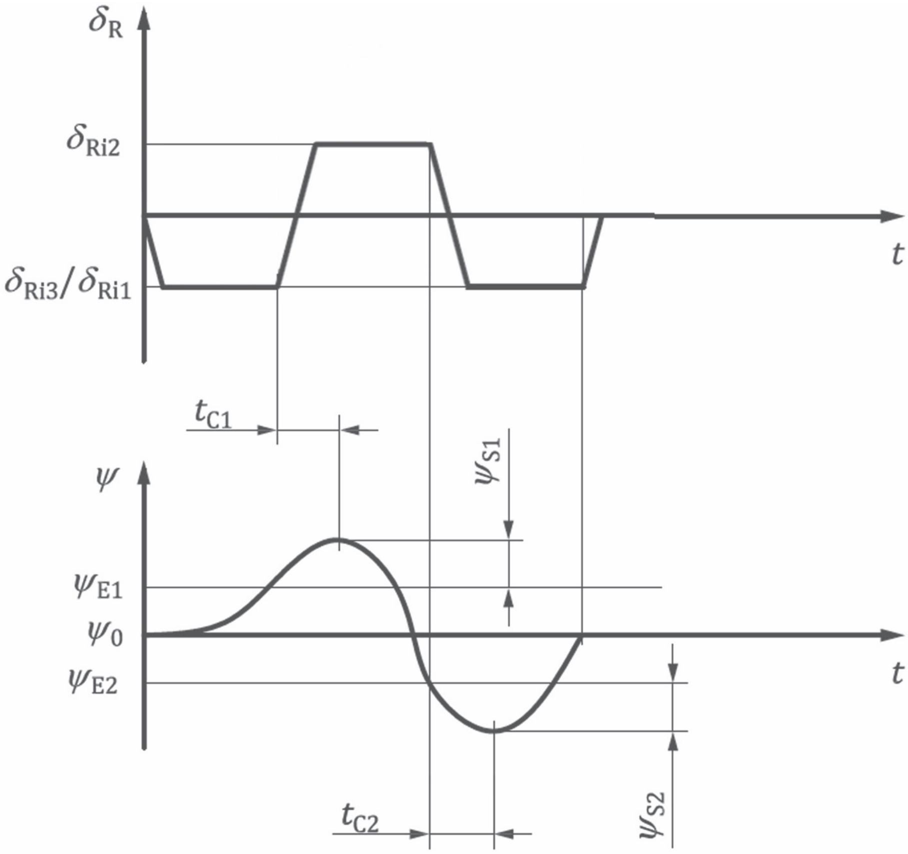


Figure 8 — Time history of an astern zig-zag test

10.3 Analysis and presentation of results of an astern test

10.3.1 Analysis of a direct astern test

The following data are obtained from the test:

— course keeping time	t_F	— change of dived depth	Δz_{0F}
— final speed	V_F	— trim angle at end of test	θ_{SF}
— sternboard	x_{0F}	— maximum change of heading	$\Delta\psi_{MAX}$
— change of heading at end of test	$\Delta\psi_F$	— maximum trim angle	θ_{SMAX}

In particular, the course keeping time, t_F, provides an indication of the course keeping ability while going astern, with reference to the specified parameters. Important, also, is a result which shows that the ship only experienced changes of heading of not more than 15° over full five ship lengths.

10.3.2 Analysis of an astern zig-zag test

The following data are obtained from the test:

— first time to check yaw	t_{C1}	— second overshoot angle	ψ_{S2}
— second time to check yaw	t_{C2}	— change of dived depth	Δz_{0F}
— sternboard	x_{0F}	— trim angle at end of test	θ_{SF}
— transfer	y_{0F}	— maximum trim angle	θ_{SMAX}
— first overshoot angle	ψ_{S1}		

In particular, the two overshoot angles, ψ_{S1} and ψ_{S2}, and the times to check yaw, t_{C1} and t_{C2}, are, in combination with the speed V_i, indicators of the ability to keep course when sternway. Further criteria can be the termination of the test due to uncontrollable overshoot and the necessity of larger angles δ_{Ri2} and δ_{Ri3}.

10.4 Designation of an astern test

10.4.1 Designation of a direct astern test

Designation of a direct astern test according to ISO 13643-3, (3), Test 5 (5), carried out with a target speed of V_i = 10 kn (10):

Direct astern test ISO 13643 – 3.5 × 10

10.4.2 Designation of an astern zig-zag test

Designation of an astern zig-zag test according to ISO 13643-3, (3), Test 5 (5), carried out with a target speed of V_i = 10 kn (10):

Astern zig-zag test ISO 13643 – 3.5 × 10

11 Test 3.6 — Sine test

11.1 General

In addition to the general test conditions outlined in ISO 13643-1 and Clause 5, the following conditions shall be complied with.

— The ship approaches at a constant speed, V_0. During the test, the setting of the propulsion plant remains unaltered.

— The sinusoidal change of the manoeuvring device angle may be based on commands by the test personnel using a table of manoeuvring device settings listed as a function of time and a stop watch, or achieved by a suitable device.

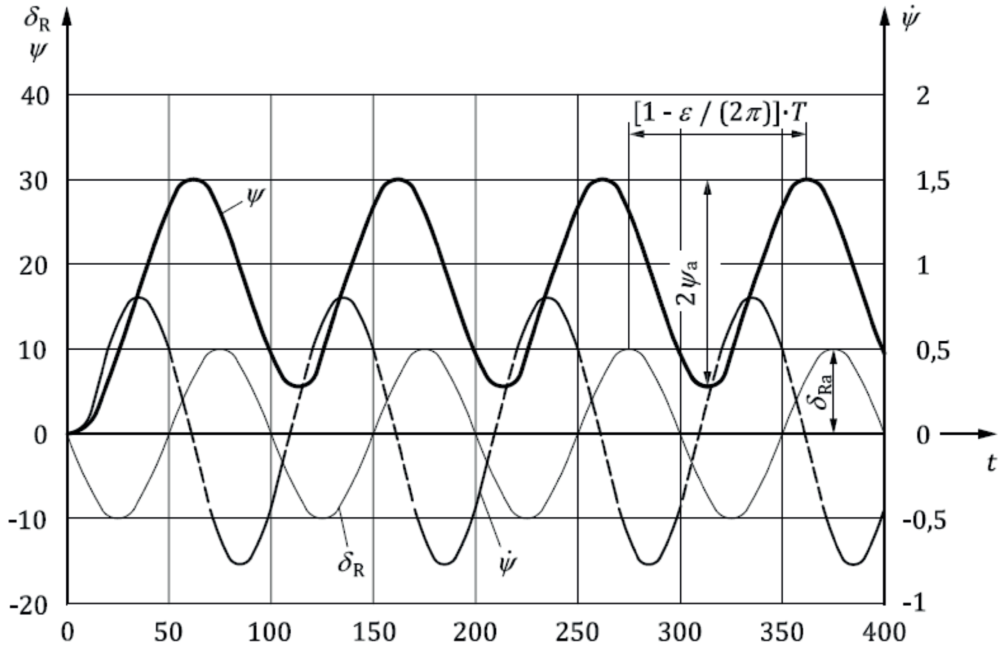
11.2 Description

During the test, the manoeuvring device setting is changed in a sinusoidal manner with a given amplitude, δ_{Ra}, and a given period of oscillation, T. At least four full cycles shall be completed. A series of test runs shall be performed using suitable combinations of manoeuvring device amplitudes δ_{Ra} = 5°, 10°, and 20°, and periods of oscillation between $T = 5\ L/V_0$ and $25\ L/V_0$.

An example of results of a test run is shown in Figure 9.

NOTE 1 The sine test yields useful results only for ships stable in yaw.

NOTE 2 For submarines operating submerged, tracking of ship's path is not required.



Key

δ_R, ψ in °

t in s

$\dot{\psi}$ in rad/s

Figure 9 — Manoeuvring device angle, heading, and rate of turn

11.3 Analysis and presentation of results of a sine test

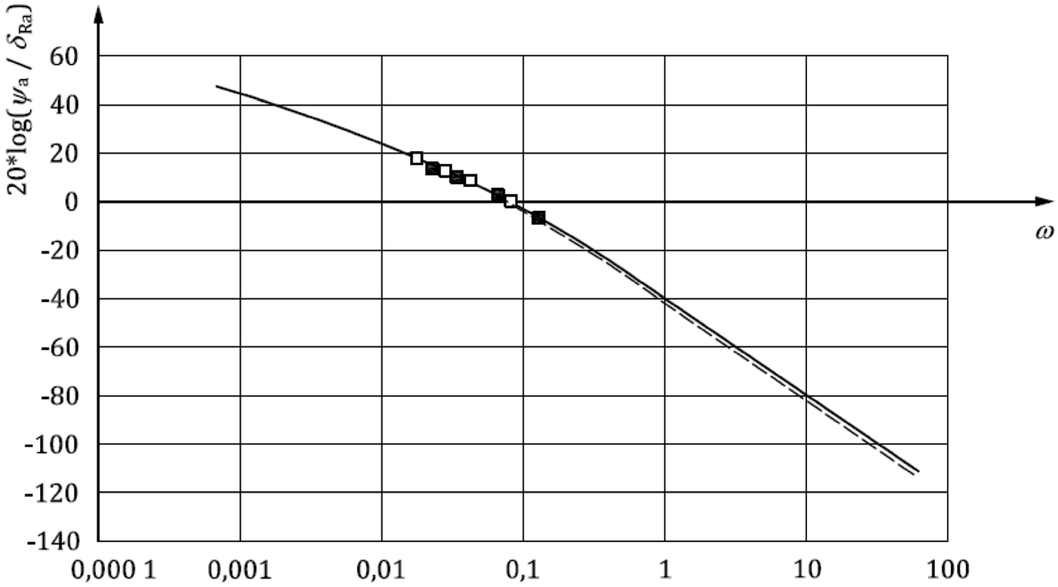
The following data are obtained from the test:

— ratio of amplitude of heading, ψ_a, and manoeuvring device angle amplitude, δ_{Ra}, which is $\frac{\psi_a}{\delta_{Ra}}$;

— ratio between non-dimensional amplitude of rate of turn, $\frac{\dot{\psi}_a L}{V_0}$, and the amplitude δ_{Ra}, which is $\frac{\dot{\psi}_a L}{V_0 \delta_{Ra}}$;

— phase shift between heading and manoeuvring device angle, ε.

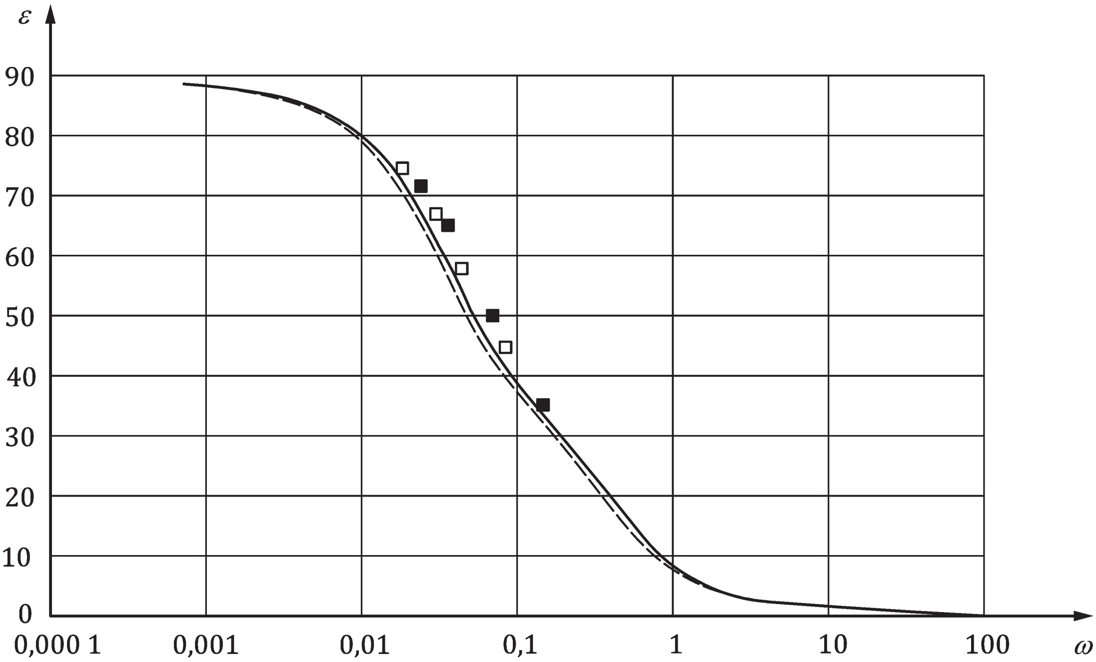
The results may be presented as Bode diagrams (see Figure 10 and Figure 11).



Key

———	linear coefficients (V_0 = 10 kn)
— — —	linear coefficients (V_0 = 9 kn)
□	test (δ_{Ra} = 5°, V_0 = 10 kn)
■	test (δ_{Ra} = 10°, V_0 = 10 kn)
ω	in rad/s

Figure 10 — Bode diagram



Key

———	linear coefficients (V_0 = 10 kn)
— — —	linear coefficients (V_0 = 9 kn)
□	test (δ_{Ra} = 5°, V_0 = 10 kn)
■	test (δ_{Ra} = 10°, V_0 = 10 kn)
ε	in °
ω	in rad/s

Figure 11 — Bode phase diagram

11.4 Designation of a sine test

Designation of an individual sine test according to ISO 13643-3, (3), Test 6 (6), carried out with an initial speed V_0 = 15 kn (15), a manoeuvring device angle amplitude δ_{Ra} = 20° (20), and a period of manoeuvring device oscillation T = 100 s (100):

Sine test ISO 13643 – 3.6 × 15/20/100

Bibliography

[1] ISO 13643-2:2017, *Ships and marine technology — Manoeuvring of ships — Part 2: Turning and yaw checking*

ICS 47.020.70

Price based on 20 pages

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Copyright in BSI publications

All the content in BSI publications, including British Standards, is the property of and copyrighted by BSI or some person or entity that owns copyright in the information used (such as the international standardization bodies) and has formally licensed such information to BSI for commercial publication and use.

Save for the provisions below, you may not transfer, share or disseminate any portion of the standard to any other person. You may not adapt, distribute, commercially exploit, or publicly display the standard or any portion thereof in any manner whatsoever without BSI's prior written consent.

Storing and using standards

Standards purchased in soft copy format:

- A British Standard purchased in soft copy format is licensed to a sole named user for personal or internal company use only.
- The standard may be stored on more than 1 device provided that it is accessible by the sole named user only and that only 1 copy is accessed at any one time.
- A single paper copy may be printed for personal or internal company use only.

Standards purchased in hard copy format:

- A British Standard purchased in hard copy format is for personal or internal company use only.
- It may not be further reproduced – in any format – to create an additional copy. This includes scanning of the document.

If you need more than 1 copy of the document, or if you wish to share the document on an internal network, you can save money by choosing a subscription product (see 'Subscriptions').

Reproducing extracts

For permission to reproduce content from BSI publications contact the BSI Copyright & Licensing team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email subscriptions@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Useful Contacts

Customer Services
Tel: +44 345 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 345 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK