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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

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Foreword

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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. www.iso.org/directives

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

ISO 13643 consists of the following parts, under the general title *Ships and marine technology — Manoeuvring of ships*:

— *Part 1: General concepts, quantities and test conditions*

— *Part 2: Turning and yaw checking*

— *Part 3: Yaw stability and steering*

— *Part 4: Stopping, acceleration, traversing*

— *Part 5: Submarine specials*

— *Part 6: Model test specials*

Ships and marine technology — Manoeuvring of ships —

Part 3:
Yaw stability and steering

1 Scope

This part of ISO 13643 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, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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, *Ships and marine technology — Manoeuvring of ships — Part 1: General concepts, quantities and test conditions*

ISO 13643-5, *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.

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
$\frac{d\dot{\psi}_C}{d\delta_{Ri}}$	GRDNTD	s^{-1}	Gradient of the $\dot{\psi}_C(\delta_{Ri})$ curve at δ_0	
$\frac{d\dot{\psi}_i}{d\bar{\delta}_R}$	GRDNTB	s^{-1}	Gradient of the $\dot{\psi}_i(\bar{\delta}_R)$ 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
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

[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_{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-1c	Final speed	Speed at the end of test (run)
V_i	VI	m s-1c	Target speed	Speed corresponding to propeller speed/pitch setting on straight track
V_0	V0	m s-1c	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-1b	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 ($\delta_{Aa2} + \delta_{Aa3} - \delta_{Aa1} - \delta_{Aa4}$).
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 ($\delta_{Ai2} + \delta_{Ai3} - \delta_{Ai1} - \delta_{Ai4}$).

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_{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
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	—

[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
$\dot{\psi}_a$	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 Clause 8 of ISO 13643-1 shall be observed.

When operating submerged, submarines shall be trimmed according to the results of the neutral level flight test in Clause 8 of ISO 13643-5. During the test, the dived depth must 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 on board 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:

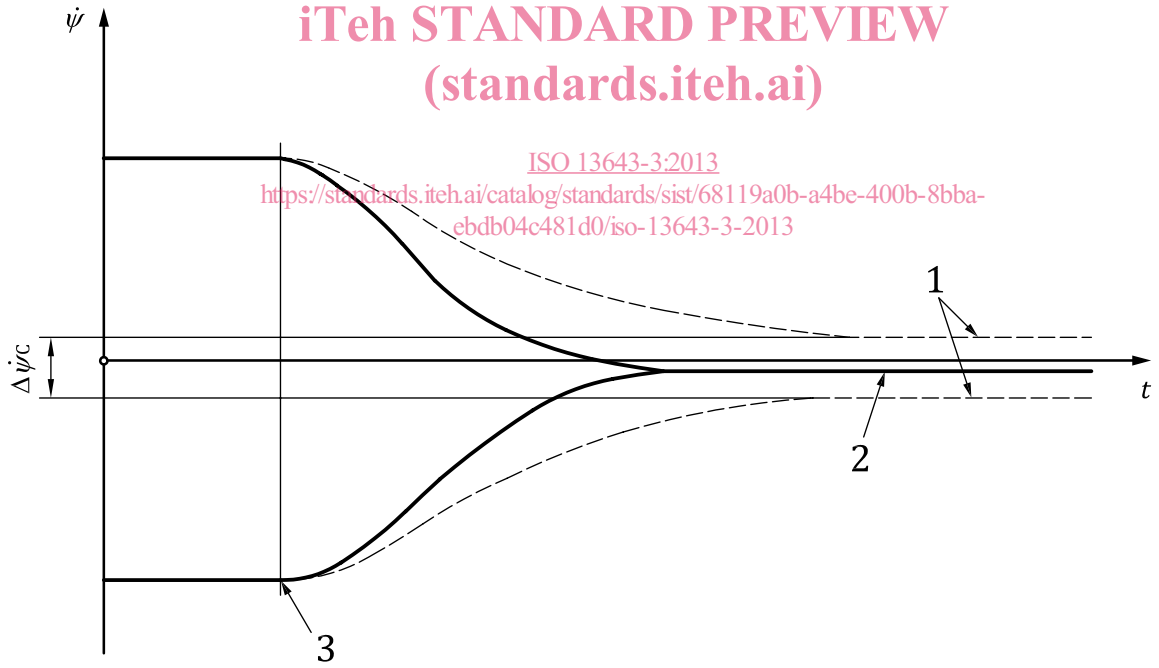
— The ship shall approach on a steady heading and at a constant speed, V_0, before commencing the test. During the test, the propulsion plant settings must remain unaltered.

— The ship is put into a steady turn, which is outside the expected range of yaw instability, e.g. with a test manoeuvring device angle 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, ψ_{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 Clause 6 of ISO 13643-2).



Key

1 ship unstable in yaw
2 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 Part 3 (3) Test 1 (1), carried out with an initial speed of V_0 = 18 kn (18) and a test manoeuvring device angle 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 must 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 settings 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 angle, δ_{Ri}, is then successively decreased to −15° (S), −10° (S) and again held at each angle 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 angle, 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.