INTERNATIONAL STANDARD

ISO 13643-2

Second edition
2017-02

Ships and marine technology — Manoeuvring of ships —

Part 2: Turning and yaw checking

Navires et technologie maritime — Manoeuvres des navires —

Partie 2: Giration et contrôle de lacet

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Reference number
ISO 13643-2:2017(E)

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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).

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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*.

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This second edition cancels and replaces the first edition (ISO 13643-2:2013), of which it constitutes a minor revision with the following changes:

— Formula (3) has been changed from "$w = w_A + x_A p - y_A p$" to "$w = w_A + x_A q - y_A p$";

— in 12.2, Paragraph 3, $(\Delta\psi_E > 60°)$ has been changed to $(\Delta\psi_E < 60°)$ and $(\Delta\psi_E < 60°)$ to $(\Delta\psi_E > 60°)$;

— in 12.3, Paragraph 3, $(\Delta\psi_E > 240°)$ has been changed to $(\Delta\psi_E < 240°)$ and $(\Delta\psi_E < 240°)$ to $(\Delta\psi_E > 240°)$.

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

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Ships and marine technology — Manoeuvring of ships —

Part 2:
Turning and yaw checking

1 Scope

This document defines symbols and terms and provides guidelines for the conduct of tests to give evidences about the turning ability and the yaw containment of surface ships, submarines, and models. It is intended that it 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*

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

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

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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 http://www.iso.org/obp

3.1
turning circle test
manoeuvring test to determine the ship's turning characteristics due to application of manoeuvring devices during the period of transient motion and the ensuing steady turn depending on initial speed, manoeuvring device angle or equivalent, and direction of turn

3.2
accelerating turn test
manoeuvring test to determine the ship's behaviour when accelerating from stand-still and simultaneously applying the manoeuvring devices hard over

3.3
thruster turning test
manoeuvring test to determine the capability to turn a ship at zero speed by using its thrusters and to determine the limiting speed at which no more turning effect from bow thrusters can be obtained

Note 1 to entry: This test is relevant to all types and arrangements of tunnel or azimuth thrusters. However, dynamic positioning or traversing tests are beyond the scope of this document.

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3.4
zig-zag test
manoeuvring test to determine the ship's turning and yaw checking ability depending upon initial speed, the amount of manoeuvring devices effect applied, and execute change of heading at which the manoeuvring device is applied in the opposite direction (execute change of heading)

3.5
course change test
manoeuvring test to determine the ship's capability to change heading by a given angle by use of the manoeuvring devices

3.6
parallel track test
manoeuvring test to determine the behaviour of the ship steering to a parallel track by applying manoeuvring devices and subsequently applying the manoeuvring devices in the opposite sense

3.7
person overboard test
manoeuvring test to determine the change of heading at which the ship is steered back to the reciprocal of its initial track by applying manoeuvring devices hard over

3.8
manoeuvring device
rudder, azimuthing thruster, hydroplane, cycloidal propeller, or equivalent system used to manoeuvre a vessel

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3.9
hard over
application of the manoeuvring devices to their maximum designed effect

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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
D_c	DC	m	Steady turning diameter	Diameter of ship's track relative to the water once a steady turn is established
P			Port (side)	—
P_{EX}	EXP	—	Extreme point	Point of the after part of the vessel which, during the steady turn, describes the path with the greatest diameter relative to the water
p	OMX	rad s^{-1} [a]	Roll velocity	(See ISO 13643-1)
q	OMY	rad s^{-1} [a]	Angular velocity about y-axis	(See ISO 13643-1)
r	OMZ	rad s^{-1} [a]	Angular velocity about z-axis	(See ISO 13643-1)
S			Starboard (side)	—
s_{10}	SP10	m	Track reach for 10° change of heading	Distance along the ship's track at $\Delta\psi$ = 10° (usually only for δ_{Ri} = 10°)
T	TIP	s	Time of complete cycle	See Figure 5

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Table 1 *(continued)*

Symbol	CC-code	SI-unit	Concept	
			Term	Definition or explanation
t_E	TIE	s	Execute time	From t = 0 to applying the manoeuvring devices in the opposite direction
t_F	TIF	s	Time to complete test (run)	For course change test: from start of heading change to $\dot{\psi}$ = 0 For parallel track test: from t = 0 to again reaching the initial heading ψ_0 For person overboard test: from t = 0 to reaching reciprocal heading ($\Delta\psi$ = 180°) after applying the manoeuvring devices in the opposite direction
t_S	TIS	s	Time to reach maximum change of heading	—
t_a	TIA	s	Initial turning time	Until ψ_{E1} is reached
t_{c1}	TIC1	s	First time to check yaw	From initiating application of manoeuvring devices in the opposite direction until maximum change of heading is reached (indices 1, 3, etc. for overshoot to S)
t_{c2}	TIC2	s	Second time to check yaw	From initiating application of manoeuvring devices in the opposite direction until maximum change of heading is reached (indices 2, 4, etc. for overshoot to P)
t_r	TIR	s	Reach time	Time taken to complete the first half cycle
t_{0R}	TI0R	s	Time to return to 0°	Time taken to return to the initial heading
t_{10}	TI10	s	Time to turn 10°	To turn through $\Delta\psi$ = 10°
t_{15}	TI15	s	Time to turn 15°	To turn through $\Delta\psi$ = 15°
t_{180}	TI180	s	Time to turn 180°	To turn through $\Delta\psi$ = 180°
t_{270}	TI270	s	Time to turn 270°	To turn through $\Delta\psi$ = 270°
t_{30}	TI30	s	Time to turn 30°	To turn through $\Delta\psi$ = 30°
t_{30R}	TI30R	s	Time to return to 30°	To turn back to reach again $\Delta\psi$ = 30°
t_{360}	TI360	s	Time to turn 360°	To turn through $\Delta\psi$ = 360°
t_{60}	TI60	s	Time to turn 60°	To turn through $\Delta\psi$ = 60°
t_{60R}	TI60R	s	Time to return to 60°	To turn back to reach again $\Delta\psi$ = 60°
t_{90}	TI90	s	Time to turn 90°	To turn through $\Delta\psi$ = 90°
u	VX	$m\ s^{-1}$ [b]	Longitudinal velocity	(See ISO 13643-1)
u_A	VXA	$m\ s^{-1}$ [b]	Longitudinal velocity at antenna	(See ISO 13643-1)
u_d	VXD	$m\ s^{-1}$ [b]	Mean steady longitudinal velocity	—
V	V	$m\ s^{-1}$ [b]	Ship's speed through the water	(See ISO 13643-1)
V_c	VC	$m\ s^{-1}$ [b]	Speed during steady turn	If the wind influence is significant, a speed which would be valid under still conditions shall be derived by averaging.
V_F	VF	$m\ s^{-1}$ [b]	Final speed	Speed at end of test (run)
V_L	VL	$m\ s^{-1}$ [b]	Threshold speed	Speed ahead at which no more turning effect by the bow thrusters can be observed
V_0	V0	$m\ s^{-1}$ [b]	Initial speed	(See ISO 13643-1)

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Table 1 *(continued)*

Symbol	CC-code	SI-unit	Concept	
			Term	Definition or explanation
V_{180}	V180	m s^{-1} b	Speed at 180° change of heading	V at $\Delta\psi$ = 180°
V_{270}	V270	m s^{-1} b	Speed at 270° change of heading	V at $\Delta\psi$ = 270°
V_{360}	V360	m s^{-1} b	Speed at 360° change of heading	V at $\Delta\psi$ = 360°
V_{90}	V90	m s^{-1} b	Speed at 90° change of heading	V at $\Delta\psi$ = 90°
v	VY	m s^{-1} b	Lateral velocity	(See ISO 13643-1)
v_A	VYA	m s^{-1} b	Lateral velocity at antenna	(See ISO 13643-1)
v_c	VYC	m s^{-1}b	Lateral velocity in steady turn	—
v_d	VYD	m s^{-1} b	Mean steady lateral (drift) velocity	—
w	VZ	m s^{-1} b	Normal velocity	(See ISO 13643-1)
w_A	VZA	m s^{-1} b	Normal velocity at antenna	(See ISO 13643-1)
x_A	XA	m	Longitudinal position of antenna	In ship-fixed axis system
x_x	XX	m	Longitudinal position of pivoting point	Coordinate of the point on the centreline plane at which the speed is tangential to that plane $\frac{v}{\dot{\theta}\sin\phi - \dot{\psi}\cos\phi\cos\theta}$
x_{xc}	XXC	m	Longitudinal position of pivoting point during steady turn	$-\frac{v_c}{\dot{\psi}_C\cos\phi_C\cos\theta_C}$
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 the ship-fixed axis system at t = 0 (See also ISO 13643-1)
x_{0F}	X0F	m	Advance at end of test (run)	x_0-component of ship's track at t_F
x_{0MAX}	X0MAX	m	Maximum advance	Largest x_0-component of ship's track
x_{0V}	X0V	m	Virtual advance	x_0 at intersection of initial track and tangent to the track at t_F
x_{090}	X090	m	Advance	x_0-component of ship's track at $\Delta\psi$ = 90°
$\dot{x}_0$	X0T	m s^{-1} b	Rate of change of global coordinates	In x_0-direction
y_A	YA	m	Lateral position of antenna	In ship-fixed axis system
y_0	Y0	m	Transverse axis	Coordinate in the 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 ship's track at t_F

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Table 1 *(continued)*

Symbol	CC-code	SI-unit	Concept	
			Term	Definition or explanation
y_{0MAX}	Y0MAX	m	Maximum transfer	For turning circle, accelerating turn and person overboard test: largest y_0-component of ship's track
				For zig-zag test: during first half cycle to S
y_{0OPP}	Y0OPP	m	Maximum opposite transfer	Largest y_0-component of the ship's track opposite to the direction of turn
y_{0180}	Y0180	m	Tactical diameter	y_0-component of ship's track at $\Delta\psi$ = 180°
y_{090}	Y090	m	Transfer	y_0-component of ship's track at $\Delta\psi$ = 90°
$\dot{y}_0$	Y0T	$m\ s^{-1}$ [b]	Rate of change of global coordinates	In y_0-direction
z_A	ZA	m	Normal position of antenna	In ship-fixed axis system
α	ALPHA	rad[c]	Maximum slope angle of heading curve	—
β_c	BETC	rad[c]	Drift angle during steady turn	See ISO 13643-1 for definition of drift angle β
Δt_s	DTIS	s	Overshoot time	$t_s - t_{60}$
$\Delta\psi$	DPSIH	rad[c]	Change of heading	$\psi - \psi_0$
$\Delta\psi_E$	DPSIHE	rad[c]	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[c]	Change of heading at end of test	$\psi_F - \psi_0$
$\Delta\psi_s$	DPSIHS	rad[c]	Overshoot angle	Angle by which the change of heading of 60° is exceeded before the vessels start turning in the opposite direction
δ_{Ri}	ANRUI	rad[c]	Test manoeuvring device angle	For turning circle and accelerating turn test: relative to δ_0; if necessary, an equivalent test manoeuvring device setting shall be given, e.g. for submarines with X-planes: $\frac{1}{4}(\delta_{Ai2} + \delta_{Ai3} - \delta_{Ai1} - \delta_{Ai4})$
				For zig-zag and course change test: absolute value relative to δ_0; if necessary, an equivalent test manoeuvring device setting shall be given, e.g. for submarines with X-planes: $\left\vert \frac{1}{4}(\delta_{Ai2} + \delta_{Ai3} - \delta_{Ai1} - \delta_{Ai4}) \right\vert$
				For parallel track test: for which maximum manoeuvring device efficiency can be expected
δ_0	ANRU0	rad[c]	Neutral manoeuvring device angle	(See ISO 13643-1)
θ_c	TRIMSC	rad[c]	Trim angle during steady turn	See ISO 13643-1 for definition of trim angle
ϕ_c	HELANC	rad[c]	Heel angle during steady turn	If the wind influence is significant, a heel angle which would be valid in still conditions shall be derived by averaging.
ϕ_{MAX}	HELANM	rad[c]	Maximum heel angle	During initial phase
ψ	PSIH	rad[c]	Heading	(See ISO 13643-1)

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Table 1 *(continued)*

Symbol	CC-code	SI-unit	Concept	
			Term	Definition or explanation
ψ_{E1}	PSIHE1	rad[c]	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[c]	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[c]	Final heading	Heading at end of test (run)
ψ_s	PSIS	rad[c]	Heading at which the turn becomes steady	—
ψ_{s1}	PSIS1	rad[c]	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. Index 1 identifies the first overshoot angle to S, and subsequent overshoots to S are identified by indices 3, 5, and so on.
ψ_{s2}	PSIS2	rad[c]	Second overshoot angle	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. Index 2 identifies the first overshoot angle to P, and subsequent overshoots to P are identified by indices 4, 6, and so on.
ψ_0	PSIH0	rad[c]	Initial heading	Heading of a vessel at the commencement of a test run (sometimes also known as the approach heading)
$\dot{\psi}_C$	YARTC	rad s^{-1} [a]	Rate of turn during steady turn	Rate of change of heading during steady turn. If the wind influence is significant, a rate which would be valid in still conditions shall be derived by averaging.
$\dot{\psi}_{MAX}$	YARTM	rad s^{-1} [a]	Maximum rate of turn	Shortly after first, second, etc. application of the manoeuvring devices in the opposite direction $\frac{m_t}{m_\psi}\tan\alpha$, with m_t for the scale of the t-axis in m/s and m_ψ for the scale of the ψ-axis in m/rad[b]

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

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

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

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5 General test conditions

— The general test conditions in ISO 13643-1:2013, Clause 8 shall be observed.

— When operating submerged, submarines shall be trimmed according to the results of the neutral level flight test (see ISO 13643-5:2013, 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.

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— 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 ship relative to which its track is measured should be defined in advance (e.g. location of the antenna). This point is not necessarily identical with the origin of the ship-fixed axis system for which the ship's track shall be given (see ISO 13643-1). If the location of the antenna has the coordinates x_A, y_A, and z_A in the ship-fixed axis system and the velocity components measured at this location are u_A, v_A, and w_A, the velocity components at origin of the ship-fixed axis system are given by:

$$u = u_A + y_A r - z_A q \tag{1}$$

$$v = v_A + x_A r + z_A p \tag{2}$$

$$w = w_A + x_A q - y_A p \tag{3}$$

— Data which shall 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, heel angle, propeller shaft speed/torque, propeller pitch, true wind velocity and direction, and relative wind velocity and direction.

— Test descriptions are valid for ships. Tests with models are carried out analogously.

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6 Test 2.1 — Turning circle test

6.1 General

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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 be at a steady speed V_0 before commencing the test. During the test, the propulsion plant settings shall remain unaltered.

— During the approach, the ship is going straight ahead at a steady speed without significant application of a manoeuvring device for at least 2 min. For ships unstable in yaw, realistic minimum manoeuvring device angles should be used during the approach. It is important that during the approach, the ship has as little yaw velocity as possible. To start the test, the manoeuvring devices are applied as required by the specific test as fast as possible in the required direction of the turn and are maintained at that setting during the rest of the test (beginning of the application at $t = 0$). Following a transient phase, the turn will become steady, i.e. the rate of turn, ship's speed, heel, and drift angle will then all be constant. The steady turn may be disturbed by external influences.

— Applying the manoeuvring devices equally to port (P) or starboard (S) may result in differing responses of the vessels (e.g. dissimilar turning diameters). Consequently, the direction of turn for which the data were measured shall be recorded. The conduct of port and starboard turning circles using the same settings of the manoeuvring devices should be attempted consecutively from the same initial heading, preferably into wind.

— The test is completed after a change of heading of at least 360° (see Figure 1).

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If the submarine's track cannot be determined by means of an inertia platform onboard, the measured speeds V or u have to be used. Generally, it is sufficient to assume $u \approx V$ and to calculate the rate of change of the global coordinates $\dot{x}_0$ and $\dot{y}_0$ by the formulae:

$$\begin{aligned} \dot{x}_0 &\approx u\cos\psi \\ \dot{y}_0 &\approx u\sin\psi \end{aligned} \tag{4}$$

Time integration gives the coordinates x_0 and y_0 as functions of time.

Average steady drift velocities u_d and v_d in global x_0- and y_0-directions can be determined by:

$$\frac{1}{2\pi}\int_{\psi_s}^{\psi_s+2\pi} \dot{x}_0 \, d\psi = u_d \tag{5}$$

$$\frac{1}{2\pi}\int_{\psi_s}^{\psi_s+2\pi} \dot{y}_0 \, d\psi = v_d \tag{6}$$

where ψ_S is the heading at which the turn is expected to become steady. Subtracting u_d and v_d from the measured velocities $\dot{x}_0$ and $\dot{y}_0$ and integrating to get the track coordinates x_0 and y_0 might be a reasonable method to reduce the effect of external influences. Also, the measured speed, V, shall be corrected accordingly, where

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$$V = \sqrt{\left(\dot{x}_0 - u_d\right)^2 + \left(\dot{y}_0 - v_d\right)^2} \tag{7}$$

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