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Ships and marine technology — Manoeuvring of ships —

Part 5: Submarine specials

Navires et technologie maritime — Manoeuvres des navires —

Partie 5: Spécificités des sous-marins

Reference number
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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).

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 13643-5:2013), of which it constitutes a minor revision with the following changes:

— the numbering has been changed;

— in Figure 1, key 2 has been changed from "boat dynamically unstable" to "boat dynamically stable";

— in Figure 1, key 5 has been changed from "dynamically unstable" to "dynamically stable".

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 5: Submarine specials

1 Scope

This document defines symbols and terms and provides guidelines for the conduct of tests to give evidence about the manoeuvring ability in the vertical plane of submarines and models. It is intended 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*

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
meander test
manoeuvring test to establish a submarine's manoeuvring characteristics and to verify the submarine's dynamic stability in the vertical plane

3.2
vertical overshoot test
manoeuvring test to determine the effectiveness of the stern planes when initiating and terminating changes of depth

3.3
neutral level flight test
manoeuvring test to determine the trim angle and the hydroplane angles at which the submarine maintains a constant dived depth at any given speed during submerged operation

Note 1 to entry: Neutral level flight is obtained

— for submarines with retracted bow planes by using a definite trim angle and a definite angle of stern planes, and

— for submarines with non-retractable bow planes, by using definite angles of the bow and stern planes for arbitrary trim angles (preferably $\theta_S = 0°$).

3.4
critical speed test
manoeuvring test to determine the speed at which the effect of the hydroplanes is reversed during submerged operation

4 Test-related physical quantities

Test-related physical quantities are according to Table 1; general quantities and concepts are according to ISO 13643-1.

Table 1 — Test-related physical quantities

Symbol	CC-code	SI unit	Concept	
			Term	Definition or explanation
a_1	—	rad m^2 s^{-2} [a]	Coefficient	For regression approximation
a_2	—	m^2 s^{-2}	Coefficient	For regression approximation
b_1	—	rad m^2 s^{-2} [a]	Coefficient	For regression approximation
b_2	—	m^2 s^{-2}	Coefficient	For regression approximation
C_c	CCR	1	Damping ratio	Ratio between damping constant $\ln 2/t_{½}$ and eigenfrequency $2\pi/T_0$ of the undamped oscillation
c_1	—	rad m^2 s^{-2} [a]	Coefficient	For regression approximation
d_1	—	rad m^2 s^{-2} [a]	Coefficient	For regression approximation
F_V	FVC	N	Vertical force	—
MA	MAX	—	Main axis	(See ISO 13643-1)
M_T	MYT	Nm	Trim moment	—
T	TIP	s	Period of oscillation	Period of the damped oscillation, average of times $[t_{A(i+1)} - t_{Ai}]$
T_0	TIP0	s	Period of oscillation	Period of the undamped oscillation
t_A	TIA	s	Response time	For meander test: Times to achieve the trim amplitudes, θ_{Ai}, i = 1, 2, 3, ...
				For vertical overshoot test: Time to change trim angle by $\Delta\theta_E$
t_C	TIC	s	Overshoot time	Time from putting the stern planes into the opposite direction until reaching maximum trim angle
t_t	TIT	s	Levelling-off time	Time from putting the stern planes into the opposite direction until reaching maximum depth change
$t_{½}$	TI05	s	Time to half-value	Time elapsed before the envelope of time-dependent trim variation has decreased by half
V_{CR}	VCR	m s^{-1} [b]	Critical speed	Speed at which the effect of the hydroplanes is reversed
V_F	VF	m s^{-1} [b]	Final speed	Speed at the end of test (run)
V_0	V0	m s^{-1} [b]	Initial speed	(See ISO 13643-1)
V_{0i}	V0I	m s^{-1} [b]	Initial speed	For neutral level flight and vertical overshoot test: For individual runs of the test
V_{0m}	V0M	m s^{-1} [b]	Mean test speed	—
z_0	Z0	m	Dived depth	Vertical coordinate in the earth-fixed axis system of the origin of the submarine (see ISO 13643-1:2017, Table 2) at any given time

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

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

Table 1 *(continued)*

Symbol	CC-code	SI unit	Concept	
			Term	**Definition or explanation**
z_{00}	Z00	m	Initial dived depth	At the commencement of the test (run)
$\dot{z}_{0F}$	DZDTF	m s^{-1} [b]	Rate of depth change	When constant trim angle, θ_F, has been reached
Δz_{0E}	DZ0E	m	Response depth change	Change of depth relative to z_{00} when trim angle is changed by $\Delta\theta_E$
Δz_{0F}	DZ0F	m	Final change of dived depth	Under steady final conditions, only defined for a dynamically stable boat
Δz_{0M}	DZ0M	m	Levelling-off depth change	Maximum change of depth, relative to $z_{00} + \Delta z_{0E}$
$\Delta\delta_{Si}$	DANSI	rad[a]	Test stern plane angle	Relative to δ_{S0}; if necessary, an equivalent stern plane angle shall be given, e.g. for submarines with X-planes: ¼ ($\Delta\delta_{Ai1} + \Delta\delta_{Ai2} + \Delta\delta_{Ai3} + \Delta\delta_{Ai4}$).
$\Delta\theta_E$	DTETPE	rad[a]	Execute change of trim angle	For meander test: $\theta_E - \theta_{S0}$ Specified change of trim angle relative to θ_{S0} at which the stern planes are returned to their initial settings δ_{S0}
				For vertical overshoot test: $\theta_E - \theta_{S0}$ Specified change of trim angle relative to θ_{S0} at which the stern planes are applied in the opposite direction (δ_{Si})
δ_B	ANB	rad[a]	Bow plane angle	(See ISO 13643-1)
δ_{B0}	ANB0	rad[a]	Initial bow plane angle	For meander, vertical overshoot, and critical speed tests: Bow plane angle at the commencement of the test (valid for neutral level flight)
			Bow plane angle for neutral level flight	Result of neutral level flight test
δ_S	ANS	rad[a]	Stern plane angle	(See ISO 13643-1)
δ_{SX}	ANSX	rad[a]	Angle of stabilising fin or of the fixed post of a stern plane	Relative to the horizontal plane in MA, positive when leading edge tilts upwards
δ_{SX0}	ANSX0	rad [a]	Angle of stabilising fin or of the fixed post of a stern plane, for neutral level flight	—
δ_{Si}	ANSI	rad[a]	Test stern plane angle	Relative to δ_{S0}; if necessary, an equivalent stern plane angle shall be given, e.g. for submarines with X-planes: ¼ ($\delta_{Ai1} + \delta_{Ai2} + \delta_{Ai3} + \delta_{Ai4}$).
δ_{S0}	ANS0	rad[a]	Initial stern plane angle	For meander, vertical overshoot and critical speed tests: Stern plane angle at the commencement of the test (valid for neutral level flight)
			Stern plane angle for neutral level flight	Result of neutral level flight test: If necessary, an equivalent stern plane angle shall be given, e.g. for submarines with X-planes: ¼ ($\delta_{A01} + \delta_{A02} + \delta_{A03} + \delta_{A04}$).

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

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

Table 1 *(continued)*

Symbol	CC-code	SI unit	Concept	
			Term	Definition or explanation
θ_A	TRIMSA	rad[a]	Trim amplitude	Absolute value of the respective extreme θ_{Ai}, i = 1, 2, 3, ... of the change of trim with reference to θ_0
θ_E	TRIMSE	rad[a]	Execute trim angle	$\theta_{S0} + \Delta\theta_E$
θ_F	TRIMSF	rad[a]	Trim angle at the end of run	Constant trim angle for the respective hydroplane settings
θ_S	TRIMS	rad[a]	Trim angle	(See ISO 13643-1)
θ_{SS}	TRIMSS	rad[a]	Overshoot angle	In the vertical plane after applying the stern planes in the opposite direction
θ_{S0}	TRIMS0	rad[a]	Initial trim angle	For meander, vertical overshoot, and critical speed tests: Trim angle at the commencement of the test (valid for neutral level flight)
			Trim angle for neutral level flight	Result of neutral level flight test: Trim angle at which the submarine maintains a constant dived depth

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

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

5 General test conditions

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

— During the test, including the approach phase, each successive position of the ship shall be recorded at suitable time intervals (usually every second).

— The submarine shall be trimmed according to the results of the neutral level flight test (see Clause 8).

— Dived depth and water depth shall be sufficient (a clearance of at least one boat's length to the surface and to the bottom shall be maintained). For model tests, surface and bottom effects shall be excluded by the use of suitable measures.

— The bow plane angle shall remain unaltered.

— There shall be no relocation of mass (e.g. due to movements of the crew) during the conduct of any test. Unavoidable shifts of mass are to be compensated and recorded.

6 Test 5.1 — Meander test

6.1 Description

A series of tests for different initial speeds shall be conducted since damping and time constants of the motion of the submarine are speed-dependent, and a boat that proves to be stable at low speeds may become unstable at higher speeds.

For safety reasons, the series of tests shall be commenced with a low initial speed, V_0.

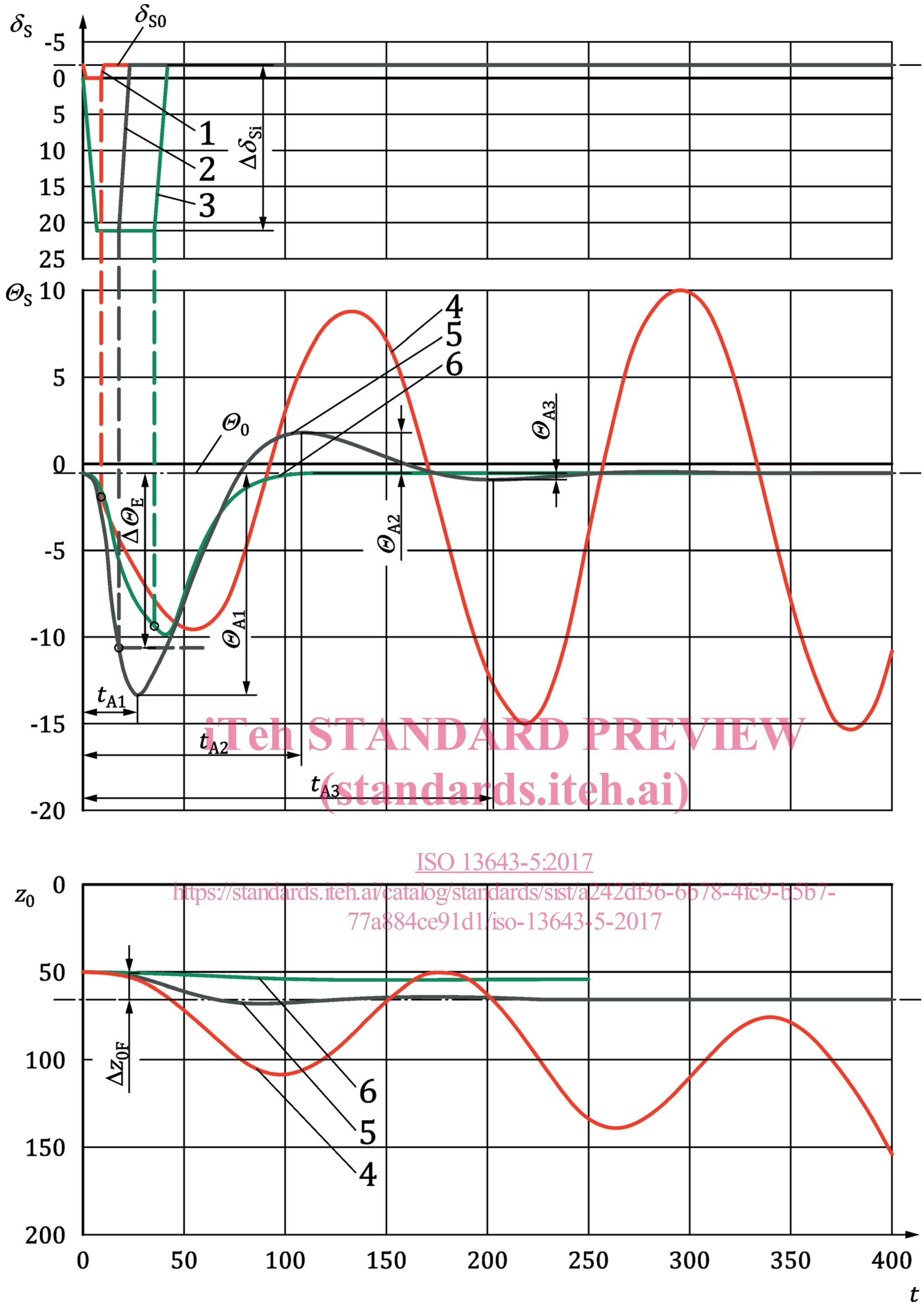
The submarine shall approach on a steady speed, V_0, before commencing the test. During the test, the propulsion plant settings shall remain unaltered and the heading kept as constant as possible. Heading and rudder movements shall be recorded throughout the test (ideally, at intervals of 1 s). If the submarine is equipped with planes acting simultaneously in the horizontal and the vertical directions (e.g. X-planes), these planes should be controlled in such a way that a steady heading is maintained as a matter of priority.

After the submarine has been moving ahead for at least 2 min without significant movements of rudder and planes, the stern planes are set to the specified test stern plane angle, $\Delta\delta_{Si}$, as fast as possible and shall be held there until the trim angle has deviated from the initial trim angle, θ_{S0}, by the specified execute change of trim angle, $\Delta\theta_E$. At this point, the stern planes are reversed to the initial position and held until the test is completed.

The stern plane impetus moves the submarine from its equilibrium condition. Test stern plane angle, $\Delta\delta_{Si}$, and execute change of trim angle, $\Delta\theta_E$, shall be selected in such a way that the stern plane impetus acts as quickly and powerfully as possible, and the submarine has at least three measurable trim amplitudes, θ_A, in the case of a subsequent oscillation. Only data after completion of the stimulation are to be evaluated.

Because of the stern plane impetus, the submarine turns about its transverse axis and, in doing so, changes its trim and dived depth in the direction in which the planes were acting. Submarines with high damping approach a different dived depth without oscillation about the transverse axis. If the damping is less, the submarine starts to oscillate about the transverse axis. As long as the oscillation is damped, the submarine is stable and approaches a different constant dived depth. On the other hand, if the trim amplitude, θ_A, increases, the submarine is dynamically unstable. The mean dived depth may alter also (see Figure 1).

If the submarine demonstrates pronounced instability, the test is to be stopped immediately for safety reasons.



Key

1 V_0 = 14,0 kn, $\Delta\delta_{Si}$ = 2°, $\Delta\theta_E$ = 2° (boat dynamically unstable)

2 V_0 = 6,0 kn, $\Delta\delta_{Si}$ = 23°, $\Delta\theta_E$ = 10° (boat dynamically stable)

3 V_0 = 3,9 kn, $\Delta\delta_{Si}$ = 23°, $\Delta\theta_E$ = 9° (boat supercritically damped)

4 dynamically unstable

5 dynamically stable

6 supercritically damped

δ_S, Θ_S in °

t in s

z_0 in m

Figure 1 — Time history

6.2 Analysis and presentation of results of a meander test

6.2.1 Evaluation for subcritical damping

The following data are obtained from the test:

— mean test speed V_{0m}

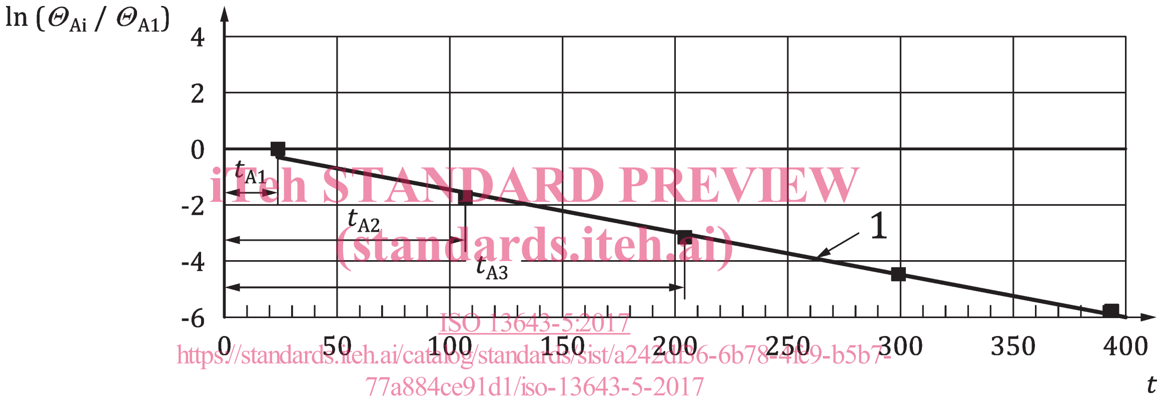
— trim amplitudes θ_{Ai}, i = 1, 2, 3,...

— response times to reach the trim amplitudes, θ_{Ai} t_{Ai}, i = 1, 2, 3,...

— period of oscillation T

— time to half-value $t_{1/2}$

— final change of dived depth Δz_{0F}



Key

■ test with V_0 = 6 kn

▬ linear least square fit for V_0 = 6 kn

1 slope = $-(\ln 2)/t_{1/2}$

t in s

Figure 2 — Evaluation

6.2.2 Damping ratio

The damping ratios shall be plotted against the mean test speed, V_{0m}, as shown in Figure 3.

$$C_c = \frac{1}{\sqrt{\left(\frac{2\pi t_{1/2}}{T \ln 2}\right)^2 + 1}} \quad (1)$$