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Ships and marine technology — Specifications for the assessment of speed and power performance by analysis of speed trial data

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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 document 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).

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For an explanation of the voluntary nature of standards, 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 6, *Navigation and ship operations*.

This third edition cancels and replaces the second edition (ISO 15016:2015), which has been technically revised.

The main changes are as follows:

— the status of Annex K has been changed to normative;

— the requirements for the wind sensor have been updated;

— the wind limits have been made more specific;

— new wind coefficient reference data has been added;

— wave correction methods have been updated (SNNM method has been added; “STAWAVE-2” and “Theoretical method with simplified tank tests in short waves” have been deleted);

— the application of wave correction methods has been clearly defined;

— with regard to shallow water correction, the Lackenby method has been replaced by the modern Raven method.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document concerns the procedure of analysing the results obtained from ship speed-power trials.

The primary purpose of speed and power trials is to determine a ship's performance in terms of its speed, power and propeller shaft speed under the ship's prescribed conditions, and thereby verify the satisfactory attainment of a ship speed stipulated by the Energy Efficiency Design Index (EEDI) regulations and the shipbuilding contract. To determine the contracted ship speed and the ship speed for EEDI, the same procedure is followed. The EEDI forms an integral part of the sea trial conduct and analysis.

The contracted ship speed and the ship speed for EEDI are determined at specific draughts (either contract draught or EEDI draught, or both). For EEDI, the environmental conditions are: no wind, no waves, no current and deep water of 15 °C.

Normally, such stipulated conditions are unlikely to be experienced in part or in full during the actual trials. In practice, certain corrections for the environmental conditions such as water depth, surface wind, waves, current [1][2] and deviating ship draught, should be considered. For this reason, during the speed and power trials, not only shaft power and ship speed are measured, but also relevant ship data and environmental conditions.

The purpose of this document is to define the basic requirements for the performance of speed trials and to provide methods for the evaluation and correction of speed trial data, covering all influences which can be relevant to the individual trial runs based on sound scientific grounds, thereby enabling owners and others to have confidence in the validity of the final results.

This document is intended to help the interested parties to achieve the desired target accuracy of within 2 % in shaft power and 0,1 knot[1)] in speed.[1]

The procedure specified in this document has been developed largely based on published data on speed trials and on ship's performance, including the International Towing Tank Conference (ITTC) documents listed in Clause 2.

The basic development of sea trial procedures using the Direct Power Method has been initiated by the STA-Group and later by ITTC. This document takes into account the work of the STA-Group[3] and the guidelines of ITTC which are approved by the Maritime Environmental Protection Committee (MEPC) MEPC 65 for EEDI.[1]

In 2002, the first edition of this document was published. ISO 15016:2002 was based on the evaluation of resistance increase and propeller characteristics.

The second edition (ISO 15016:2015) enabled this document to be used for EEDI regulations as well as for the shipbuilding contract. This new procedure was based on the direct power method. The "mean of means" and the "iterative" method were selected for the correction of current effects. For wave correction, several methods were offered as options in combination with observed wave conditions.

This third edition takes into account methods for the correction of wind, waves and shallow water which have been recently developed and validated. The application of these methods has been made consistent and ambiguities are avoided. This document includes modern accurate measurement methods of wind and waves. It has been updated to achieve the specified target accuracy of speed and power.

This document generally applies to ships for which survey and certification of EEDI and Energy Efficiency Existing Ship Index (EEXI) is required under the International Maritime Organization Resolutions.[4][7][8] For other ships, to which the above International Maritime Organization (IMO) resolutions are not applicable, the terms or phrases of this document are deemed to be replaced as necessary (e.g. "agreement between the shipbuilder, the owner and the verifier" can be read as "agreement between the shipbuilder and the owner" etc.)

In this document, the unit used to express the amount of an angle is "rad" (radian) and the unit of speed is "m/s" (metres per second). Nevertheless, "degree" as a unit for an angle and "knots" as a unit for speed

1) 1 kn = 1 852/3 600 m/s.

are used wherever indicated. Moreover, for the convenience of the users of this document, numerical values using the units of degree and knots are stated together, where appropriate.

Ships and marine technology — Specifications for the assessment of speed and power performance by analysis of speed trial data

1 Scope

This document specifies requirements for the preparation, execution and reporting of speed trials of ships of the displacement type with a length between perpendiculars (L_{pp}) from 50 metres to 500 metres. It provides a procedure for the analysis, evaluation and correction of the gathered speed trial data covering all influences that can be relevant to the individual trial runs reporting on speed trials for ships, including effects that can influence the speed, power and propeller shaft speed relationship.

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.

ITTC 7.5-02-03-01.4, *ITTC Recommended Procedures and Guidelines, 1978 ITTC Performance Prediction Method*

ITTC 7.5-02-07-02.2, *ITTC Recommended Procedures and Guidelines, Prediction of Power Increase in Irregular Waves from Model Tests.*

3 Terms and definitions

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

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

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

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

3.1
brake power
power, in watts, delivered by the output coupling of the propulsion machinery before passing through any speed-reducing and transmission devices

3.2
contract power
brake power (3.1) or *shaft power* (3.20), in watts, that is stipulated in the new build or conversion contract between the *shipbuilder* (3.21) and the *owner* (3.14)

3.3
contract speed
ship speed (3.23) to be achieved as agreed within the terms of the new build/conversion contract

3.4
direct power method
procedure where the measured power is directly corrected by the power increase due to added resistance in the trial conditions

3.5
double run
two consecutive *speed runs* (3.27) at the same *power setting* (3.16) on reciprocal *headings* (3.8)

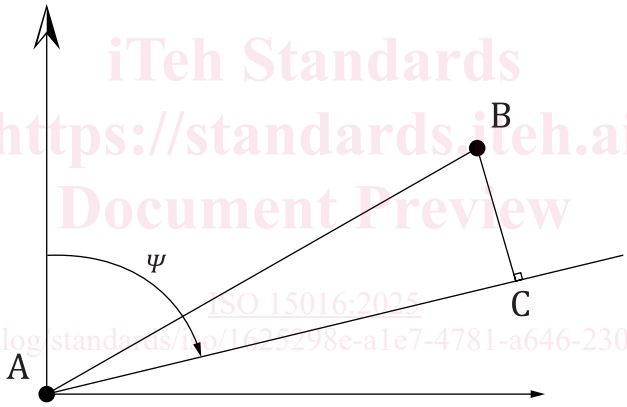
3.6
Energy Efficiency Design Index power
EEDI power
brake power (3.1), in watts, that is stipulated by the Energy Efficiency Design Index (EEDI) regulations

3.7
Energy Efficiency Design Index speed
EEDI speed
ship speed (3.23) achieved under the conditions specified by the IMO Resolution MEPC.245(66) (as amended)

3.8
heading
compass direction (based on true North) in which the vessel's bow is pointed, measured over the centreline of the vessel

3.9
headway distance
length travelled during the *speed run* (3.27) in the direction of the compass *heading* (3.8) (based on true North)

Note 1 to entry: The compass direction (based on true North) shall be the one at the start of the *speed run* (3.27); see also Figure 1.



Key

ψ	the ship compass *heading* (3.8) (based on true north)
A	the Global Navigation Satellite System (GNSS) position at start of the *speed run* (3.27)
B	the GNSS position at end of the speed run
AC	the headway distance between start and end position of the *speed run*, expressed in metres

Figure 1 — Determination of headway distance

3.10
ideal conditions
trial situation without wind, without waves, without current, in deep water, with a water temperature of 15 °C, a specific water density of 1 026,0 kg/m^3, an air temperature of 15 °C and an air specific density of 1,225 kg/m^3 (unless specified otherwise in the shipbuilding contract)

3.11
load variation test
procedure conducted during tank-testing to find out the variation of performance (in terms of efficiency, revolutions, torque and thrust) according to the variation of load on the ship resistance

3.12
maximum continuous rating
maximum power output that the prime mover(s) can produce while running continuously at safe limits and conditions as specified on the nameplate and in the technical file of the prime mover(s)

Note 1 to entry: In case a prime mover power limitation (EPL) or a shaft power limitation (Shapoli) system is installed, the limited installed power is as specified in the Energy Efficiency Existing Ship Index (EEXI) Technical File.

3.13
measured ship speed
vessel velocity during a *speed run* (3.27) derived from the *headway distance* (3.9) between the start and end position and the elapsed time of the *speed run* (3.27)

3.14
owner
party that signed the new building or conversion contract with the *shipbuilder* (3.21)

3.15
owner's master
person in command after delivery of the vessel

3.16
power setting
selection of the throttle of the prime mover(s) and the propeller shaft speed and, in case of controllable pitch propellers (CPP), the selection of the *pitch angle* (3.19)

3.17
propeller
driving screw propulsor or alternative propulsion system of the ship

3.18
propeller pitch
design pitch at 0,7 R for a fixed pitch propeller

3.19
pitch angle
operating blade angle of a controllable pitch propeller (CPP)

3.20
shaft power
net power, in watts, supplied by the machinery of the prime mover(s) to the propulsion shafting after passing through all speed-reducing and other devices, and after power for all attached auxiliaries has been taken off, and accounting for losses in the shaft between the *propeller* (3.17) and the location of power measurement at the shaft

3.21
shipbuilder
shipbuilding company that signed the new building or conversion contract with the *owner* (3.14)

3.22
shipyard
shipbuilding production facility where the subject ship is constructed

3.23
ship speed
forward velocity of the ship that is realised under the stipulated conditions

Note 1 to entry: See also, *contract speed* (3.3), *Energy Efficiency Design Index speed* (3.7) and *measured ship speed* (3.13).

3.24
sister ship
ship with identical main dimensions, body lines, appendages and propulsion system built in a series by the same *shipyard* (3.22)

3.25
S/P trial
speed and power trial
trial to establish the relationship between power and speed for a particular ship

3.26
S/P trial agenda
speed and power trial agenda
document outlining the scope of a particular *S/P trial* (3.25)

3.27
speed run
track of the ship with specified *heading* (3.8), distance and duration for which the *measured ship speed* (3.13) and *shaft power* (3.20) of the ship are calculated

3.28
tank test
model basin measurement for the prediction of the speed-power relation for the stipulated conditions

3.29
trial leader
duly authorized person [representative of the *shipbuilder* (3.21)] responsible for the execution of all phases of the *speed and power (S/P) trials* (3.25) including the pre-trial preparation

3.30
trial log
data recorded before, during and after the *speed and power (S/P) trial* (3.25)

3.31
trial team
team that consists of the *trial leader* (3.29), the owner's representative, the appointed persons responsible for the *speed and power trial (S/P)* (3.25) measurements and, if the ship requires the Energy Efficiency Design Index, the *verifier* (3.32)

3.32
verifier
third party responsible for verification of the Energy Efficiency Design Index

3.33
zero pitch
blade angle of a controllable pitch propeller (CPP) at which the propeller generates zero thrust

4 Symbols and abbreviated terms

4.1 Symbols

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

$1+k$	the ship form factor
A	the direction of the bow for SNNM method
A_{LV}	the lateral projected area above the waterline including superstructures
A_M	the midship section area under water
A_{OD}	the lateral projected area of superstructures above upper deck

A_W	the water plane area at the trial draught
A_{XV}	the transverse projected area above the waterline including superstructures
B	the moulded ship breadth
C_{AA}	the wind resistance coefficient; $C_{AA}(0)$ means the wind resistance coefficient in head wind
C_B	the block coefficient
C_{Fact}	the flat plate viscous resistance coefficient for the actual water temperature and water density
C_{Fref}	the flat plate viscous resistance coefficient for the reference water temperature and water density
C_{MC}	the horizontal distance from midship section to centre of lateral projected area A_{LV}, where + means forward from midship
C_V'	the viscous resistance coefficient in deep water
$d_{(sinkage)}$	the increase of the ship dynamic sinkage in shallow water
E	the directional spectrum
E_1	the angle of entrance on the waterline
E_2	the angle of the run on the waterline
F_D	the skin friction correction force, which is the same as in the normal self-propulsion tests
Fr	the Froude number
Fr_h	the Froude number based on water depth
Fr_{hd}	the Froude number based on a water depth of 0,3 L_{PP}
Fr_{rel}	the relative Froude number
F_X	the external tow force measured during load variation test
g	the acceleration of gravity
h	the water depth at S/P run
$H_{1/3}$	the total significant wave height
H_{BR}	the height of top of superstructure (bridge etc.)
H_C	the height from waterline to centre of lateral projected area A_{LV}
$H_{S1/3}$	the significant height of local swell
$H_{W1/3}$	the significant height of local wind driven waves
(i)	the run number
k_s	the hull roughness
k_{yy}	the non-dimensional radius of gyration in the lateral direction (k_{yy}/L_{pp})
L_{BWL}	the distance of the bow to 95 % of maximum breadth on the waterline
L_E	the length of entrance of the waterline
L_{OA}	the overall length of the ship
L_{PP}	the length of the ship between perpendiculars
L_R	the length of run of the waterline
n_{id}	the corrected propeller shaft speed
n_{ms}	the measured propeller shaft speed
n_{MCR}	the shaft speed at Maximum Continuous Rating (MCR) power of the main prime mover(s)
n_{NCR}	the shaft speed at Normal Continuous Rating (NCR) power of the main prime mover(s)
$n_{Contract}$	the contracted shaft speed at $P_{SContract}$
p_A	the air pressure at S/P run
P_{act}	the power after all corrections on power have been applied, corresponding to the moulded actual displacement volume
P_{Bms}	the measured brake power in the trial condition

P_{Did}	the delivered power in the ideal condition
P_{Dim}	the initial power values for the iterative method
P_{Ddeep}	the power to propel the vessel in deep water after shallow water correction
P_{Dms}	the delivered power in the trial condition
P_{Dmsc}	the delivered power in trial condition after correction of wind, waves and water temperature and water density
$P_{\mathrm{Model\text{-}1}}$	the power at the trial condition at V_{S1} predicted by the tank tests
$P_{\mathrm{Model\text{-}2}}$	the power at the trial condition at V_{S2} predicted by the tank tests
$P_{\mathrm{Model\text{-}3}}$	the power at the trial condition at V_{S3} predicted by the tank tests
P_{ref}	the power corresponding to the moulded reference displacement volume used in the tank tests
P_{Sid}	the shaft power in ideal condition predicted by the tank tests
P_{Sms}	the measured shaft power in the in the trial condition
P_{SMCR}	the shaft power at MCR power setting of the prime mover(s)
P_{SNCR}	the shaft power at Normal Continuous Rating (NCR) power setting of the prime mover(s)
$P_{\mathrm{SContract}}$	the contracted shaft power of the prime movers(s)
$P_{\mathrm{Trial\text{-}1}}$	the power at the first power setting in trial condition obtained by the S/P trials
$P_{\mathrm{Trial\text{-}2}}$	the power at the second power setting in trial condition obtained by the S/P trials
$P_{\mathrm{Trial\text{-}3}}$	the power at the third power setting in trial condition obtained by the S/P trials
$P_{\mathrm{Trial,P}}$	the brake power at the trial condition predicted by the tank tests at V_{s}
r_{sink}	the sinkage displacement effect
R_{AA}	the resistance increase due to relative wind
R_{AS}	the resistance increase due to deviation of water temperature and water density
R_{AW}	the mean resistance increase in short crested irregular waves
R_{AWL}	the mean resistance increase in long crested irregular waves, as substitute for R_{AW}
R_{AWM}	the motion induced wave resistance
R_{AWR}	the wave resistance resulting from wave reflection
Re	the Reynolds number for the subject water temperature and water density
R_{Fact}	the frictional resistance for the actual water temperature and water density
R_{Fref}	the frictional resistance for the reference water temperature and water density
R_{id}	the full-scale resistance in the ideal condition
R_{SHV}	the increase of viscous resistance in shallow water
R_{Tref}	the total resistance for the reference water temperature and water density
R_{Vdeep}	the ship viscous resistance of the ship in deep water
R_{wave}	the mean resistance increase in regular waves
S	the wetted surface area at zero speed condition
S_{η}	the frequency spectrum
t	the mid time of the steady recording for each run
t_{e}	the elapsed time of the S/P run
t_{A}	the air temperature
t_{s}	the start time of the first speed run of a power setting
t_{W}	the temperature of the subject water
T_{01}	the mean centroid wave period in seconds
T_{A}	the moulded draught at the aft perpendicular
$T_{\mathrm{A\text{-}Tanktest}}$	the moulded draught at the aft perpendicular during tank test