



**International
Standard**

ISO 15016

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

**Third edition
2025-02**

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Published in Switzerland

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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 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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

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 knot¹⁾ 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.

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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.

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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

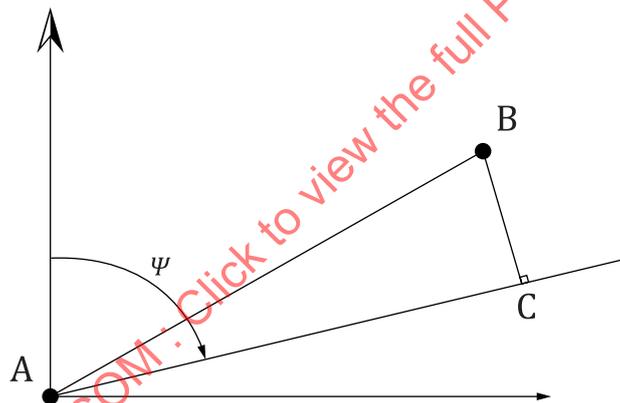
compass direction (based on true North) in which the vessel's bow is pointed, measured over the centreline of the vessel

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/m³, an air temperature of 15 °C and an air specific density of 1,225 kg/m³ (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

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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

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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
$P_{Model-1}$	the power at the trial condition at V_{S1} predicted by the tank tests
$P_{Model-2}$	the power at the trial condition at V_{S2} predicted by the tank tests
$P_{Model-3}$	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)
$P_{SContract}$	the contracted shaft power of the prime movers(s)
$P_{Trial-1}$	the power at the first power setting in trial condition obtained by the S/P trials
$P_{Trial-2}$	the power at the second power setting in trial condition obtained by the S/P trials
$P_{Trial-3}$	the power at the third power setting in trial condition obtained by the S/P trials
$P_{Trial,P}$	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
$T_{A-Tanktest}$	the moulded draught at the aft perpendicular during tank test

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T_{AE}	the draught at the aft perpendicular (extreme)
T_C	the period of variation of current speed
T_E	the average draught (extreme)
T_F	the moulded draught at the forward perpendicular
$T_{F-Tanktest}$	the moulded draught at the forward perpendicular during tank test
T_{FE}	the draught at the forward perpendicular (extreme)
T_{deep}	the deepest moulded draught for a trimmed condition
T_M	the moulded draught at midships
T_{ME}	the draught at midships (extreme)
T_Z	the mean observed wave period in seconds
V'_{WR}	the corrected relative wind velocity at anemometer height
V'_{WT}	the averaged true wind velocity at anemometer height
V_C	the current speed
V_G	the measured ship speed over ground
V_{G1}	the measured ship speed over ground on the first of four runs
V_{G2}	the measured ship speed over ground on the second of four runs
V_{G3}	the measured ship speed over ground on the third of four runs
V_{G4}	the measured ship speed over ground on the fourth of four runs
V_{group}	the group velocity of the incident wave
V_S	the ship speed through the water
V_{S1}	the speed through the water at the first power setting in trial condition at the S/P
V_{S2}	the speed through the water at the second power setting in trial condition at the S/P
V_{S3}	the speed through the water at the third power setting in trial condition at the S/P
$V_{S,service\ Contract}$	the service speed in contract condition at $P_{SContract}$ and $n_{Contract}$
V_{WR}	the mean value of the measured relative wind velocity at anemometer height
V_{WRref}	the relative wind velocity at the reference height
V_{WT}	the true wind velocity at anemometer height
V_{WTref}	the true wind velocity at the reference height
Z_a	the vertical position of the anemometer
Z_{ref}	the reference height for the wind resistance coefficients
δV	the ship additional displacement volume due to sinkage as fraction of the total displacement
α	the relative wave or wind direction, relative to the bow in degrees. Zero (0) degrees on the bow and positive to starboard (clockwise)
α_p	the power factor
α_{p1}	the power factor at the first power setting
α_{p2}	the power factor at the second power setting
α_{p3}	the power factor at the third power setting
ΔC_{Fact}	the roughness allowance associated with Reynolds number for the actual water temperature and water density with a minimum of 0,00
ΔC_{Fref}	the roughness allowance associated with Reynolds number for the reference water temperature and water density with a minimum of 0,00
Δn	the required correction for propeller shaft speed
ΔP	the required correction for power
ΔP_{SH}	the power increase caused by shallow water effects
ΔR	the total resistance increase

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Δt	half of the elapsed time between two successive runs
γ	the compass bearing of the incoming waves in degrees
ζ_A	the wave amplitude
η_{Did}	the propulsive efficiency coefficient in ideal condition predicted by the tank tests
η_{Dms}	the propulsive efficiency coefficient in trial condition
η_T	the transmission efficiency
η_S	the shaft efficiency
λ	the scale factor
μ	the smoothing range
ξ_n	the load variation coefficient of the shaft speed
ξ_P	the load variation coefficient of the delivered power
ρ_A	the mass density of air
ρ_{act}	the water density of the actual water temperature and salt content
ρ_M	the water density in the tank tests
ρ_{ref}	the water density of the reference water temperature and salt content
ψ	the compass heading of the ship
ψ'_{WR}	the corrected relative wind direction at anemometer height
ψ'_{WT}	the averaged true wind direction at anemometer height
ψ_{WR}	the mean value of the relative wind direction at anemometer height; 0 means head winds
ψ_{WRref}	the relative wind direction at the reference height
ψ_{WT}	the true wind direction at anemometer height in Earth system
ν	the kinematic viscosity at the subject water temperature and water density
ω	the circular frequency of regular waves
∇_{act}	the actual moulded displacement volume during the S/P trial
∇_{ref}	the reference moulded displacement volume used in the tank tests

4.2 Abbreviated terms

COMEX	Point of starting data collection (US Navy abbreviation)
CFD	computational fluid dynamics
CPP	controllable pitch propeller
EEDI	Energy Efficiency Design Index
EEXI	Energy Efficiency Existing ships Index
FINEX	Point of ending data collection (US Navy abbreviation)
FPP	fixed pitch propeller
GNSS	Global Navigation Satellite System
IMO	International Maritime Organization
ITTC	International Towing Tank Conference
kDWT	1 000 deadweight tons
k-m ³	1 000 m ³
LC	loading condition
LIDAR	light detection and ranging
LNG	liquified natural gas
ms	midship as shown in Figure C.19
MCR	maximum continuous rating

M/E	main engine
MEPC	Marine Environmental Protection Committee in IMO
NCR	normal continuous rating
o	the centre of gravity of A_{LV} in Figure C.19
rpm	revolutions per minute
SOLAS	Safety of Life at Sea (IMO International Convention)
SNAME	The Society of Naval Architects and Marine Engineers
S/P	speed/power
STA-Group	The international group of owners, shipbuilders, research institutes, classification societies and universities studying and improving sea trial procedures and Sea Trial Analyses (STA)
TEU	Twenty-foot equivalent unit
ud	Upperdeck shown in Figure C.19
UTC	Coordinated Universal Time

5 Responsibilities

5.1 Shipbuilder's responsibilities

The shipbuilder is responsible for the planning, conduct and evaluation of the S/P trials. The shipbuilder shall ensure that:

- an appropriately authorized trial leader is appointed to oversee all aspects of the S/P trial;
- all permits and certificates required for the ship to go to sea are provided;
- all qualified personnel necessary for operating the ship and all systems and equipment required during the sea trials are on board;
- all regulatory bodies have been informed, and are available and are on board when required;

NOTE Regulatory bodies include the Classification Society, the owner, ship agents, suppliers, subcontractors, harbour facilities, departments organizing the supply of provisions, fuel, water, towage, etc. necessary for conducting these trials.

- all safety measures have been checked;
- all fixed, portable and individual material (for crew, trial personnel and guests) is on board and operative;
- all warning and safety systems for conducting safe S/P trials have been checked in accordance with the regulatory requirements;
- an inclining test has been performed, or at least an approved preliminary stability booklet, including the S/P trials condition; see Safety of Life at Sea (SOLAS)^[21] Convention;
- all ship data relevant for the S/P trials preparation, conduct, analysis and reporting are made available to the trial team prior to the S/P trials. These data shall include the information requested in [Annex A](#) as well as the results of the tank tests for this ship at trial draught and trim, EEDI draught and trim, and contract draught and trim.

Speed and power measurements and analysis shall be conducted by persons acknowledged as competent to perform those tasks, as agreed between the shipbuilder, the owner and the verifier (where applicable).

The shipbuilder shall arrange for divers to inspect the ship's hull and propeller(s), if necessary.

The shipbuilder is responsible for the overall trial coordination. A pre-trial meeting between the trial team and the ship's crew shall be held to discuss the various trial events and to resolve any outstanding issues.

The trial leader shall maintain contact with the trial team regarding the preparation, execution and results of the S/P trials.

5.2 Trial team

The trial team is responsible for correct measurements and reporting of the S/P trials according to this document. They are also responsible for the analysis of the measured data to derive the ship speed and power at the stipulated conditions.

The trial team is responsible for the following:

- conducting an inspection of the ship, including the condition of the hull and propeller(s), prior to the commencement of the S/P trial;
- the provision, installation, operation and removal of all necessary trial instrumentation and temporary cabling;
- providing the owner's master and the owner's representative with the measurement data package, the full S/P analysis and the S/P results before disembarking;
- delivering a final report upon completion of the full analysis of the measurements taken during the trial.

If it is physically impossible to meet the conditions described in this document, a practical treatment is allowed based on a documented mutual agreement between the owner, the verifier and the shipbuilder. This documented mutual agreement shall be included in the trial report.

6 Trial preparations

6.1 General

The success of the S/P trials largely depends on the preparations. The important steps are summarized in [6.2](#) and [6.3](#).

6.2 Step 1: Installation and calibration

Assemble all the trial instrumentation in the configuration that shall be used on the ship. Test the instrumentation system for any malfunctioning or other complications.

The availability and the proper functioning of the following equipment shall be confirmed prior to the S/P trials:

- a) gyrocompasses;
- b) anemometer;
- c) barometer;
- d) speed log system of the ship (ready for calibration);
- e) propeller pitch angle indicating system (of each controllable pitch propeller);
- f) draught measurement system of the ship including the longitudinal and vertical offsets against a proper draught reading (if available);
- g) water temperature sensors;
- h) water depth measuring system;
- i) shaft torque and shaft speed measurement system;
- j) draught marks of the ship;
- k) GNSS system.

After the trial instrumentation is installed, carefully check that all shipboard input signals that shall be recorded during the S/P trials are functioning (see [Clause 9](#)).

As part of the pre-trial check for a ship equipped with controllable pitch propellers, the method shall be as follows:

- l) prior to dock-out, the oil distribution mechanism showing the propeller pitch angle shall be checked for zero pitch;
- m) check the zero pitch angle reading in the measurement system against the mechanical reading in the oil distribution box;
- n) determine the design pitch angle, maximum ahead pitch angle and maximum astern pitch angle, then adjust the ship indicators to reflect the measurements. Establish the corrections necessary to account for changes in pitch angle due to shaft compression as thrust increase and temperature affects the propeller pitch control rod.

At this stage, an important deliverable to be provided by the shipbuilder to the trial team is a document describing the test set-up, including evidence of the checks and (factory) calibrations that have been carried out.

It is important to note that there are two stages to consider in performing instrumentation checks: the pre-trial check and the post-trial check for the torque meter to verify the calibration results.

The shaft material properties, i.e. the G-Modulus, shall be fully described and documented by the shipbuilder. If no certificate based on an actual shaft torsional test is available, the G-Modulus equal to 82 400 N/mm² shall be used. The shaft diameter used in the power calculation shall be derived from the shaft circumference measured at the location of the torsion meter. In case a controllable pitch propeller(s) is used, it is necessary to consider the drilling diameter using the relevant data supplied by the shipbuilder.

6.3 Step 2: S/P trial agenda and pre-trial meeting

Before departure, a pre-trial meeting shall be held to fix the S/P trial agenda. During this meeting two items shall be addressed:

- approval by the trial team of the S/P trial agenda;
- approval by the trial team of the procedures and the consequential analysis methods to be used to calculate the trial speed and to deliver the speed trial report, i.e. [Clauses 11](#) to [13](#).

The S/P trial agenda is a document prepared by the shipbuilder, outlining the scope of a particular speed and power trial, among other elements. This document contains the procedure on how to conduct the trial and table(s) portraying the runs which shall be conducted. It outlines the responsibilities of the trial team members and ship's crew. The scope and the trial execution shall be in line with [Clauses 7, 8, 9, 10](#) and [11](#).

The trial agenda shall contain the agreements between the trial team members including the limits of wind speeds, the limits for wave heights, the wave directions and the water depths up to which the trials shall be performed. Furthermore, the wind correction method and the wave correction method shall be mentioned in the S/P trial agenda. The measured data, the analysis process and the results shall be transparent and open to all the members of the trial team. If changes from the pre-agreed agenda are necessary, those changes require consensus among the trial team members. The changes shall be documented.

7 Ship conditions

7.1 Trim

The trim shall be maintained within very narrow limits. For the even keel condition, the trim shall be less than 0,1 % of the length between perpendiculars. For the trimmed trial condition, the forward draught shall be within $\pm 0,1$ m of the ship condition for which tank tests results are available.

7.2 Displacement volume

The difference between the ship's actual moulded displacement volume during the S/P trials and the required moulded displacement volume shall be less than 2 % of the required moulded displacement volume. If tank tests results are used for the analysis of the S/P trials, the deviation of the actual moulded displacement volume during the S/P trials shall be within 2 % of the displacement volume used during the tank tests.

The moulded displacement volume is determined as follows:

- a) Immediately prior to the S/P trials in the S/P trial area, the vessel will be stopped.
- b) The ship's draught at the draught sensor positions is obtained by recording the draught sensor values every 3 s over a period of 3 min per sensor. This sampling interval is irrespective of the sampling interval of the draught measuring system.
- c) Determine the draught at sensor position by averaging the recorded values per sensor.
- d) Convert the average of the sensor readings towards draught at the perpendiculars and midship, taking into consideration trim, longitudinal and vertical offsets.
- e) Average the port and starboard draughts.
- f) Calculate the average draught of the ship with the [Formula \(1\)](#):

$$T_E = (T_{AE} + 6 T_{ME} + T_{FE}) / 8 \quad (1)$$

where

T_E is ship's average draught (extreme), expressed in metres;

T_{AE} is draught at the aft perpendicular (extreme), expressed in metres;

T_{ME} is draught at midships (extreme), expressed in metres;

T_{FE} is draught at the forward perpendicular (extreme), expressed in metres.

- g) Deduct keel thickness to arrive at the average moulded draught of the ship.
- h) Calculate moulded displacement volume in cubic metres by interpolating in the hydrostatic tables using the average moulded draught and trim.
- i) If the deviation between actual displacement volume and the required displacement volume is more than 2 %, or the trim deviation is more than the trim limits as mentioned in [7.1](#), then adjust the ballast situation and repeat steps a) to g).

Alternatively, draught readings may be carried out by boat or with the aid of a drone.

7.3 Hull, propeller, and shaft

The ship shall have a clean hull and propeller(s) for the sea trial. Hull roughness and marine growth can increase the resistance of the ship significantly^[9] but are not corrected for in S/P trials. Therefore, it is recommended that the hull and propeller(s) be carefully inspected before the sea trial and cleaned as needed and as per coating-manufacturer's recommendation. The dates of last docking and hull and propeller cleaning shall be recorded in the S/P trials report by the shipyard.

Shaft torque shall be measured by means of a calibrated permanent torque sensor or strain gauges on the propeller shaft. The measurement system shall be certified for power measurements with a bias error smaller than 1 % so that an overall bias error smaller than 2 % (on board the ship undergoing trials) can be achieved.

Alternative shaft torque measurement devices with a certified accuracy equal to or better than the above figures are acceptable.

When shaft torque measurement is not possible, an alternative power measurement method recommended by the manufacturer of the prime mover(s) and approved by the owner and the verifier is acceptable.

8 Trial boundary conditions

8.1 General

During the S/P trial, conditions can occur that deviate from the contract/EEDI condition. The objective during the S/P trial is to minimize the number of influencing factors.

Although there are analysis methods for certain deviations from the contract condition, these methods are only valid up to certain limits.

To arrive at reliable S/P trial results, the trial conditions shall be as ideal as physically possible, and the boundary conditions shall not exceed the values given in the [8.2](#), [8.3](#), [8.4](#), [8.5](#) and [8.6](#).

During the execution of the S/P trials, second order effects such as wind drift, roll motions and rudder movements shall be avoided, as those second order effects reduce the vessels' speed during the execution of the S/P trials. This means that the speed runs shall be carried out by heading into and following the dominant wave or wind direction, depending on which effects the ship speed most.

8.2 Location

High wind and sea state in combination with a heading deviating from head waves and following waves can require the use of excessive rudder angles to maintain the heading, which cause excessive fluctuations in propeller shaft torque, propeller shaft speed and the measured ship speed.

The S/P trials shall be conducted in a location where the environmental conditions are expected to be constant and have only the smallest possible impact on the ship to avoid unexpected environmental effects in the S/P trial results.

This means that the S/P trial range shall be located in a sheltered area (i.e. limited wind, waves and current). Ideally, the area shall be free from hindrance by small boats and commercial traffic.

8.3 Wind

In case the wind velocity is measured with a remote sensor e.g. a light detection and ranging (LIDAR) capable of measuring the wind just outside the region where airflow is distorted by the vessel (in accordance with [9.3.3](#)) or a 3D ultrasonic sensor (in accordance with [9.3.3](#)), the wind velocity at reference height (10-min average in [m/s]) during the S/P trial shall not be higher than calculated with [Formula \(2\)](#):

$$V_{WT,ref} = 10,7 + 0,23\sqrt{(L_{PP} - 50)} \quad (2)$$

for ships with a length restriction of

$$| 50 \text{ m} < L_{PP} < 500 \text{ m} |$$

where

$V_{WT,ref}$ is the true wind velocity at the reference height, expressed in metres per second (m/s);

L_{PP} is the ship's length between perpendiculars, expressed in metres (m).

The result of [Formula \(2\)](#) is illustrated in [Figure 2](#).

In case the wind velocity is measured with a conventional anemometer (e.g. cup/vane anemometer) in accordance 9.3.3, the wind velocity at reference height (10-min average in [m/s]) during the S/P trial shall not be higher than calculated with Formula (3):

$$V_{WTref} = 9,7 + 0,23\sqrt{(L_{PP} - 50)} \quad (3)$$

for ships with a length restriction of

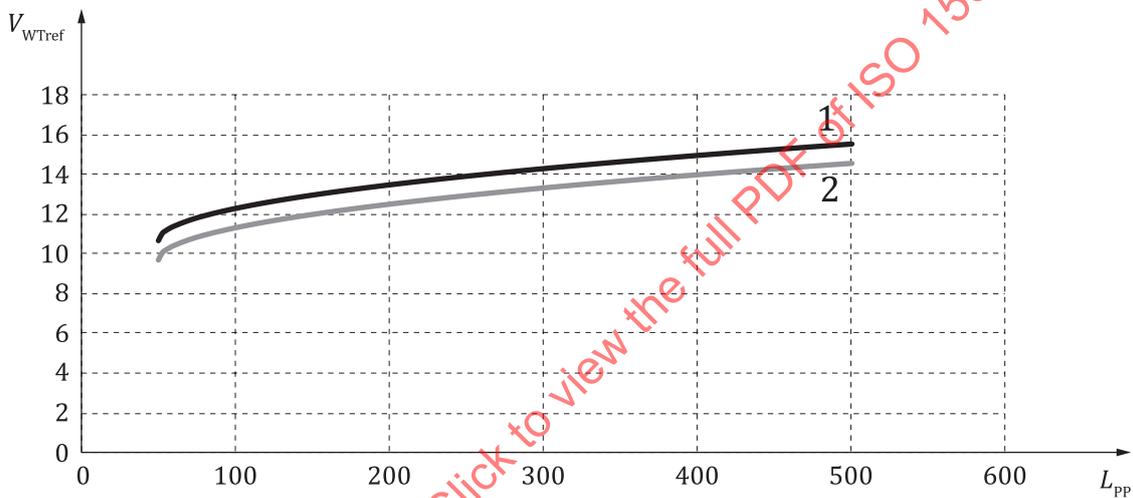
$$| 50 \text{ m} < L_{PP} < 500 \text{ m} |$$

where

V_{WTref} is the true wind velocity at the reference height, expressed in metres per second;

L_{PP} is the ship's length between perpendiculars, expressed in metres.

The result of Formula (3) is illustrated in Figure 2.



Key

- 1 max permissible wind velocity with 3D ultrasonic/remote sensor, expressed in m/s [see Formula (2)]
- 2 the max permissible wind velocity with conventional sensor (e.g. cup/vane sensor); expressed in m/s [see Formula (3)]
- V_{WTref} the true wind velocity at the reference height, expressed in m/s
- L_{PP} ship's length between perpendiculars, expressed in m

Figure 2 — Limits for permissible wind velocity

The compliance with the wind limits shall be shown before starting the S/P trial, in accordance with 10.2. If the true wind speed (which is the mean value of the true wind speed of both legs of each double run at reference height) exceeds the limit value during the execution of the S/P trials, the maximum true wind speed that may be used in trial evaluation in this case is the relevant wind speed limit value +10 %.

Wind conditions are described in Table B.1

8.4 Sea state

The total significant wave height, $H_{1/3}$, is derived from the significant wave heights of local wind driven seas $H_{W1/3}$ and swells $H_{S1/3}$ by the [Formula \(4\)](#):

$$H_{1/3} = \sqrt{H_{W1/3}^2 + H_{S1/3}^2} \quad (4)$$

For all analysis methods related to waves, the following empirical criteria shall be applied in relation to the ship's length in order to determine the maximum allowable correction for resistance increases due to waves:

when the wave spectrum encountered during the S/P trials is measured:

$$H_{1/3} \leq 0,225\sqrt{L_{PP}} \quad (5)$$

or, when the wave height is derived from visual observations:

$$H_{1/3} \leq 0,15\sqrt{L_{PP}} \quad (6)$$

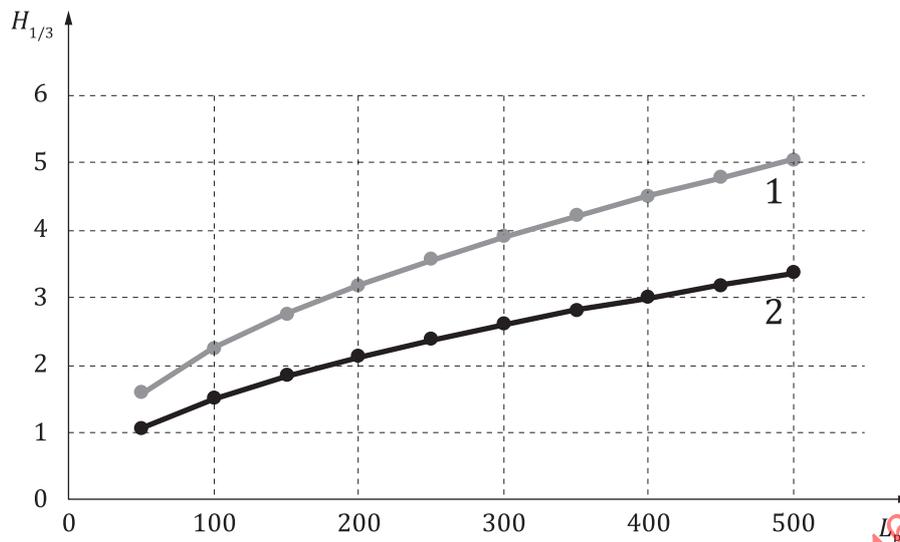
where

- L_{PP} is the ship's length between perpendiculars, expressed in metres;
- $H_{1/3}$ is the total significant wave height, expressed in metres;
- $H_{W1/3}$ is the significant height of local wind driven waves, expressed in metres;
- $H_{S1/3}$ is the significant height of local swell, expressed in metres.

The above limits are illustrated in [Figure 3](#).

See [9.3.5](#) for the definition of observations respectively measured in this context.

The directions of the waves and swells may be derived from visual observations in all cases.



Key

- 1 the limit of permissible wave height for measured wave spectrum expressed in metres [see [Formula \(5\)](#)]
- 2 the limit of permissible wave height for observed wave height expressed in metres [see [Formula \(6\)](#)]
- H_{1/3} the significant height, expressed in metres
- L_{PP} ship's length between perpendiculars, expressed in metres

Figure 3 — Limits for permissible wave height

The compliance with the wave limits shall be shown before starting the S/P trial, in accordance [10.2](#). If the permissible wave height is exceeded, either the S/P trial shall be repeated at accepted wave height conditions or the wave height from [Formulae \(5\)](#) or [\(6\)](#), depending on the observation method required for the trial evaluation.

Sea state conditions are described in [Table B.1](#) and [Table B.2](#)

8.5 Water depth

There is an analysis method that compensates for shallow water effects (see [Annex G](#)). However, it is preferable to reduce these corrections by selecting a suitable S/P trial location. Sea trials shall not be conducted in waters with a water depth lower than the outcome of [Formula \(7\)](#):

$$|MAX| \left(h = 2,5T_M, h = 2,4 \frac{V_S^2}{g} \right) \tag{7}$$

where

- |MAX| is the absolute value of the maximum of the two terms;
- h is the water depth at the S/P run, expressed in metres;
- T_M is the ship's moulded draught at midships, expressed in metres;
- V_S is the measured ship speed through the water, expressed in metres per second;
- g is the acceleration of gravity, expressed in metres per second squared.

Whenever the water depth is more than defined in [Formula \(7\)](#), [Annex G](#) shall be applied.

Furthermore, areas with significant variations in the bottom contours shall be avoided. The actual water depth during each speed run shall be read from the ship's instruments or the sea chart and recorded in the trial log.

8.6 Current

Ideally, S/P trials shall be conducted in a location where the current speed and direction are essentially uniform throughout the trial area.

After finalising the S/P trials, the current curve shall be analysed.

In cases where the time history of the current deviates from the assumed parabolic/sinusoidal trend and the change of the current speed within the timespan of one double run is more than 0,5 knots, neither of the analysis methods in [Annex F](#) are applicable. Areas where this may occur shall be avoided for S/P trials.

9 Trial procedure

9.1 General

This Clause gives an overview of the parameters that influence the trial speed. All these parameters shall be measured and recorded as accurately as possible.

For this purpose, a distinction has been made between parameters measured at the speed trial site and parameters measured during each speed run. [Table 1](#) and [Table 2](#) list the acceptable measurement methods and units for each parameter.

All relevant data shall be recorded in accordance with [Annex A](#) and shared among the members of the trial team.

[Table 1](#) lists the parameters that shall be measured at the speed trial site, and the accepted measurement devices and units.

Table 1 — Parameters measured at the speed trial site

Parameter	Acceptable measurement device	Unit
Weather condition		
Water density	Hydrometer	kg/m ³
Water temperature	Thermometer	°C
Air temperature	Thermometer	°C
Air pressure	Barometer	hPa, mb
Torsion meter	Torsion meter with calibrated torque sensor or strain gauges	kNm
Trial area	Geographical position (Lat-Long) by GNSS	ddd-mm
Vertical position of anemometer above waterline	General arrangement plan of the ship	m
Draughts	Physical observation and/or calibrated draught gauges	m
Trim	Calculated from draughts	m
Displacement volume	Calculated from draughts	m ³
Wind area	Transverse projected area above the waterline including superstructures calculated from the general arrangement plan of the ship and the measured draughts	m ²
Superstructure wind area for C.3.5 (Fujiwara)	Lateral projected area of superstructures above upper deck + height of superstructure, measured from the general arrangement plan of the ship and measured draughts	m ²
Total lateral wind area for C.3.5 (Fujiwara)	Lateral projected area above the waterline including superstructures and position of centre of gravity, measured from general arrangement plan and measured draughts	m ²

Table 2 lists the parameters that shall be measured during each run and the accepted measurement devices and units.

Table 2 — Parameters measured during each run

Parameter	Acceptable measurement devices	Unit
Date	Calendar	dd-mmm-yyyy
Ship's position	GNSS	Lat., Lon., °
Speed over ground	GNSS (for information purpose only)	knots
Shaft torque or shaft power	Torsion meter with calibrated torque sensor or strain gauges Power calculated from propeller shaft torque and propeller shaft speed	kNm kW
Propeller shaft speed	Pick-up, optical sensor, ship's revolutions counter	min ⁻¹
Propeller pitch (CPP)	Bridge replicator, indicator on shaft	° or mm
Time	GNSS Time or UTC	hh:mm:ss
Time elapsed over the speed run	GNSS Time	hh:mm:ss
Water depth	Ship echo sounder and nautical charts	m
Ship's heading	Gyro compass, or GNSS-compass	°
Relative wind velocity and direction	Lidar, 3D ultrasonic anemometer, if not available, a conventional anemometer	m/s, °
Wave height, mean period and compass direction of wind driven waves Swell height, mean period, and compass direction of swell	Wave measuring device such as wave buoy, wave radar, or LIDAR. Observation by multiple mariners. The average observed wave height derived from observations by multiple mariners is assumed to be equal to the significant wave height over the run length.	m, s, °

9.2 Tank test information

The quality and accuracy of tank tests play a large role in the outcome of full-scale S/P trials. For some ship types, sea trials are normally carried out in ballast condition, whereas the contractual condition is normally defined as the design loaded condition. For the conversion from ballast trial results to loaded condition, the difference between the ballast and loaded tank tests curves is used. Therefore, accurate tank tests and a validated consistent method for extrapolation to full scale are required.

The tank tests shall be conducted in accordance with the following criteria.

- a) Tank tests shall be conducted at the moulded contract draught and trim and the moulded EEDI draught and trim, as well as the moulded trial draught and trim.
- b) Tank tests shall be conducted in accordance with ITTC 7.5-02-03-01.4, *ITTC Recommended Procedures and Guidelines, 1978 ITTC Performance Prediction Method*.
- c) For all draughts and trims, the same methods, procedures, and empirical coefficients shall be used to extrapolate the model scale values to full scale. Where different empirical coefficients for the different draughts are used, full details shall be documented in the tank test report, including justification by means of full-scale S/P trial data for the specific ship type, size, loading condition, tank test facility and evaluation method.
- d) All relevant tank test information shall be provided by the shipbuilder to the trial team members. This information shall be transparent and give sufficient information to enable the trial team to check the tank test results related to the sea trial analysis. This means that the tank test information shall include the measured data, the predicted full-scale data and detailed description of the applied extrapolation method and appropriate coefficients.

9.3 Scope and conduct of the measurements

9.3.1 Ship track and speed over ground

The ship's position and speed shall be measured by a global positioning system such as a GNSS. The positioning system shall be operated in the differential mode to ensure sufficient accuracy. Position and speed shall be monitored and stored continuously.

9.3.2 Torque

The calibration of the torque measurement system shall not be altered during the S/P trials. Torque and rate of revolution measurements shall be monitored and stored continuously.

9.3.3 Wind

The wind measured on trials should be as close as possible to a measurement of the undisturbed wind speed encountered by the ship. To this end, it is encouraged to use technology capable of measuring wind speed outside the region where airflow is distorted by the ship.

To measure the wind velocity and direction, the following ship born sensor systems shall be used in the given priority sequence:

- a) Remote sensor capable of measuring the wind just outside the region where airflow is distorted by the vessel (e.g. LIDAR).
- b) 3D ultrasonic sensor mounted close to the upwind leading edge of the superstructures and as high above them as possible. Mounting on a foremast away from superstructure is preferable.
- c) Conventional anemometer (e.g. cup- or vane anemometer) mounted close to the upwind leading edge of the superstructures and as high above them as possible. Mounting on a foremast away from superstructure is preferable.

Any anemometer of type b) and c) should be mounted away from the mast at a distance more than 3 times the mast diameter to avoid disturbances by that mast.

9.3.4 Water depth

Water depth can be determined by examining a sea chart of the trial area or measured by the ship's echo sounder during the runs. It is important that the echo sounder is calibrated before the speed runs and that the ship's draught (the transducer depth) is considered. Calibration shall be combined with a comparison of indicated depth against the water depth given on the chart in the trial area. Continuous recording of water depth is recommended.

9.3.5 Waves

The wave spectrum and the direction can be derived either by measurements or observations.

For the methods as specified in [D.3](#) and [D.4](#) the directional or uni-directional spectrum of waves induced by local wind and swell originating from remote wind shall be measured during the S/P trials. For this purpose, wave buoys in the S/P trial area or shipborne equipment such as a wave radar can be used. The wave direction shall be included in these measurements. The wave measurement equipment shall be calibrated, and the accuracy shall be validated and documented.

As an alternative for continuous wave measurements during all speed runs, the wave conditions may be measured immediately prior to the S/P runs and immediately after the S/P runs with the vessel stopped in the water. The wave condition shall be measured and analysed over a minimum duration of 20 minutes each time. In case the wave spectra prior to and after the S/P runs are different, linear interpolation in time may be applied for each individual speed-power run.

In case the wave spectrum encountered during the S/P trials is not measured, the wave height, the mean period and compass direction of the waves shall be derived from visual observations by multiple experienced mariners during each S/P run. In addition to the wave observations, wave now- or hind- cast data provided by an experienced and independent weather office may be used, subject to agreement with the trial team.

9.3.6 Water and air properties

Upon arrival at the S/P trial area, when the ship is stopped for draught reading and torsion meter zero setting, the local water temperature and water density shall be recorded to enable the calculation of the power corrections regarding sea water viscosity. The local water temperature shall be taken at water inlet level. The local water density shall be measured with a hydrometer in a bucket of water or with a dedicated sensor, if available.

Air temperature and air pressure shall be measured using a calibrated thermometer and barometer, respectively.

9.3.7 Current

The speed of the current shall be determined as part of the evaluation of each run. See [Annex F](#) for further details.

10 Conduct of the trial

10.1 General

Upon arrival at the S/P trial area, the trial team meets to confirm the procedures. Based on the actual wave condition, the wave correction method may be changed. See [Annex D](#) for the relationship between ship motions, wave directions and the wave correction method.

On the day of and during the S/P trial, several pre-requisites shall be met to arrive at reliable trial results. This Clause gives an overview of the minimum requirements.

10.2 Initiation

Prior to the S/P trials, the weather forecast shall be studied.

Prior to the S/P trials, the following actions shall be taken at zero speed through the water:

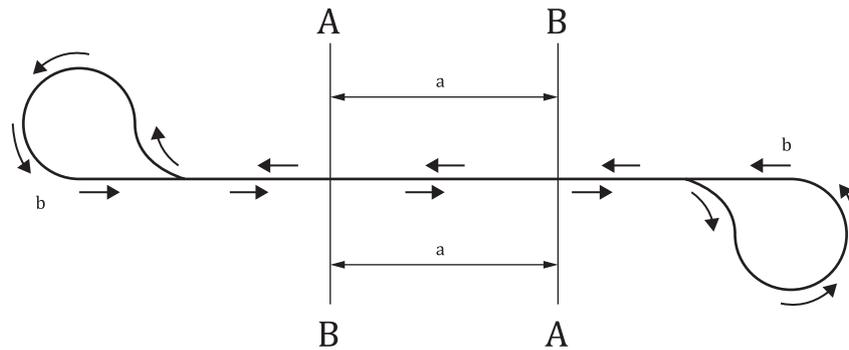
- a) the torsion meter's zero setting shall be carried out in accordance with the maker's instructions. The zero-torque value is determined while the ship is at rest by turning the shaft ahead and astern, and taking the mean of these two readings as the zero value (refer to the ITTC procedures^[19]);
- b) draught reading and calculation of displacement volume as described in [7.2](#);
- c) determination of water temperature and density as described in [9.3.6](#);
- d) check compliance with the wind and wave limits as described in [8.3](#) and [8.4](#).

The runs at EEDI power shall be conducted in daylight to enable a clear visual observation of the wave conditions. For trials in which the encountered wave spectrum and the wave direction (both wind waves and swells) are derived by measurements, these runs may also be conducted without daylight.

The propulsion plant configuration during the S/P trial shall be consistent with the normal ship operation at sea.

10.3 Trajectory of ship during trial

The S/P trial runs shall be conducted over the same ground area. For each base heading, each speed run shall be commenced (COMEX) and completed (FINEX) at the same place as indicated in [Figure 4](#).



Key

- A position where each speed run shall be completed (FINEX)
- B position where each speed run shall commence (COMEX)
- a The time between COMEX and FINEX for each speed run (minimum 10 minutes).
- b The approach path towards the speedrun.

Figure 4 — Path of ship during double run (in ideal condition)

Modified Williamson turns as illustrated in [Figure 4](#) or a similar type of manoeuvre shall be executed between each run to return the ship to the reciprocal heading, taking into consideration that the midpoint of each run is within two (2) ship lengths away from the midpoint of the first run in the direction perpendicular to the heading. This method shall be used to avoid different sea states, wind or current conditions. Propulsion plant throttles, revolutions per minute (rpm) setting(s) or pitch setting(s) shall not be altered during this period. The rudder angles used in this manoeuvre shall be such that the ship speed loss in the turn is minimized.

Second order effects such as wind drift, roll motions and rudder movements shall be avoided as these reduce the speed of the vessel during the execution of the S/P trials. This means that the speed runs shall be carried out by heading into and following the dominant wave or wind direction, depending on which effects the ship speed most.

10.4 Run duration and timing

The S/P trial duration shall be long enough to accommodate a reliable speed-power measurement within the required accuracy. The run duration shall be the same for all speed runs with a minimum of ten (10) minutes. The speed runs for the same power setting shall be evenly distributed in time.

In view of the correction for current, the total duration of the S/P trials programme shall be kept to a minimum.

10.5 Trial direction

The choice of heading during the S/P trial is very important. Cross winds will create wind drift and consequently rudder movements. Cross wave/swell conditions will cause ships to roll. Both phenomena will create additional resistance and negatively influence the ship speed. To minimize those effects, the ship's heading during the S/P runs should be determined carefully.

The speed runs shall be carried out by heading into and following the dominant wave or wind direction, depending on which affects the ship speed most.

Consequently, once the heading for the speed run and the reciprocal heading for the return run are fixed, the selected tracks shall be maintained very precisely throughout the S/P trial. However, if the “mean of means” method is used for current analysis, the trial direction can be changed between each power setting according to change of weather (wind or waves) condition.

Extremely tight control shall be exercised during the execution of the S/P trials to minimize as many variables as possible that can unduly influence the speed-power relationship.

10.6 Steering

An experienced helmsman or adaptive autopilot is required to maintain the heading during each speed run. Minimum rudder angles shall be used while maintaining a steady heading.

During the speed run, the maximum single amplitude of rudder angles shall be not more than 5 degrees.

10.7 Approach

The S/P trial approach shall be long enough to ensure a steady-state ship's condition prior to commencement (COMEX) of each speed run. During the approach run, the ship shall be kept on compass heading with minimum rudder angles.

No fixed approach distance can be given. To verify that the ship reached the steady ship's condition, the measured values of the propeller shaft speed, propeller shaft torque and ship speed at the control position shall be monitored. When all three values are stable, the ship condition shall be deemed "steady".

10.8 Power settings

A minimum of three (3) different power settings is required. These shall be adequately distributed within the power range of 65 % MCR and 100 % MCR. The speed-power runs should start with the lowest power setting and progressively run to the highest power setting. For slow steaming purposes, additional power settings can be trialled, but these will not be included in the analysis of EEDI and contract power.

10.9 Number of speed runs

10.9.1 General

All S/P trials shall be carried out using double runs, i.e. each run shall be followed by a return run in exactly the opposite direction (see also [10.3](#)) and at the same propulsion plant settings.

The number of speed runs required depends on the current analysis method to be applied as described in [Annex F](#). These methods are:

- a) the "iterative" method;
- b) the "mean of means" method.

10.9.2 "Iterative" method

To determine the speed-power curve using the "iterative" current analysis method, a minimum of four (4) double runs at three (3) different power settings is required:

- one (1) double run below EEDI/ contract power;
- two (2) double runs (at the same power setting) around EEDI/ contract power;
- one (1) double run above EEDI/ contract power.

The EEDI/contract power runs shall be conducted neither as the first nor the last power setting in the trial sequence.

10.9.3 "Mean of means" method

To determine the speed-power curve using the "mean of means" current analysis method, a minimum of six (6) double runs at three (3) different power settings is required:

- two (2) double runs below EEDI/ contract power;
- two (2) double runs around EEDI/ contract power;

- two (2) double runs above EEDI/ contract power.

Two (2) double runs compensate for the effect of current and second order current variations^{[11],[12]}. To obtain sufficient accuracy, the time intervals between each run at the same power setting shall be more or less the same (time interval deviation of 25 % is allowed).

10.9.4 Sister ships

If the results of the S/P trials of the first ship of a series are acceptable, sister ships may be subjected to a reduced speed trial programme. For sister ships, it is sufficient to conduct three (3) double runs at three (3) different power settings.

These power settings shall be adequately distributed within the power range of 65 % MCR and 100 % MCR and comprise at least:

- one (1) double run below EEDI/contract power;
- one (1) double run around EEDI/contract power;
- one (1) double run above EEDI/contract power.

For “mean of means” method, if after evaluation the vessel speed deviates more than 0,3 knots (0,154 33 m/s) compared to the first ship, then the same procedure as the first ship should be followed.

10.9.5 Power settings in case of non-availability of tank test data

For an existing vessel for which no speed-relevant power data from tank tests are available (e.g. EEXI), one double run at an additional power setting is required for the post processing of the data. The four power settings shall be selected between 50 % and 100 % of MCR in such a way that the power settings covering this MCR range are adequately distributed.

10.9.6 Additional runs due to limiting wave height

For the first ship of a series or for a sister ship at any power setting, when the wave height is close to the limiting conditions and significant wave-induced ship motions are observed, then one (1) additional double run at that power setting shall be conducted.

10.10 S/P Trial test sequence

- a) The shipbuilder shall make trial preparations as described in [Clause 5](#);
- b) The ship will be prepared as stated in [Clause 6](#);
- c) A pre-trial meeting will be held before departure of the ship (see [5.1](#) and [6.3](#));
- d) The ship proceeds to the S/P trial area;
- e) Confirm that the ship condition is in accordance with [Clause 7](#);
- f) Confirm that the S/P trial environmental conditions are within the boundaries as stated in [Clause 8](#);
- g) Fix the speed run heading, taking into consideration the dominant wave or wind direction;
- h) Navigate through the approach distance on a direct heading;
- i) Prepare all measurements to start;
- j) Start speed run when torque, rpm and heading are stable. Propulsion plant control levers shall remain unchanged, maximum rudder angle shall not be more than 5 degrees port and 5 degrees starboard. After agreed duration (minimum of 10 minutes) stop speed run;
- k) Determine the achieved speed and power;

- l) During S/P trial run, make environmental observations;
- m) Navigate the ship with small rudder angles to the counter run, taking into consideration that the mid-point of the run will be within two (2) ship lengths from the mid-point of the first run;
- n) Repeat steps h) to m).

11 Data acquisition

11.1 General

During the S/P trial, accurate recording of the speed and power relationship is of great importance.

Apart from this, an accurate quantification of the boundary conditions is necessary since the ship speed and power characteristics are extremely sensitive to factors such as hull and propeller condition, ship displacement volume, shallow water effects, sea state and wind velocity. Consequently, these factors shall be monitored and documented to the greatest possible extent.

During the S/P trials, two types of data acquisition shall be used:

- automated acquisition by means of a data acquisition system (measurement computer);
- the manual recording of information by means of a log sheet.

The objective shall always be to record as many parameters as possible, by means of the measurement computer to increase the level of accuracy of the S/P trials.

11.2 Acquisition system

11.2.1 General

At the end of each run, the data acquisition system shall be able to present all recorded time histories of all recorded parameters to evaluate the quality and consistency of the acquired trial data and be stored for subsequent graphical presentation.

11.2.2 System requirements

The data acquisition system shall:

- a) record all available parameters simultaneously;
- b) perform a time trace recording with a sampling rate of at least 1 Hz;
- c) calculate statistics (mean value, min, max and standard deviation).

Furthermore, the acquisition system shall present the following values for each of the measured data:

- d) trial start time;
- e) number of samples taken;
- f) maximum value;
- g) minimum value;
- h) average value;
- i) standard deviation;
- j) trial end time.

Filtering of the run data is recommended to avoid “spikes” in the recorded time histories. Chauvenet’s criterion, which provides a ratio of maximum acceptable deviation to the precision index as a function of the number of readings (N), shall be used. Readings are automatically rejected from use in the data analysis when they fall outside the selected mean value bandwidth.

11.2.3 Location

The data acquisition system shall be located on the bridge.

11.3 Manual data collection

For parameters that cannot be measured and recorded automatically by means of the data acquisition system, manual data collection is required using a log sheet (see example in [Annex A](#)).

The log sheet is important from two purposes:

- a) to complete the data set, and
- b) to provide a backup for the automated measurements and give a written overview of the measurements.

The parameters that vary with time shall be recorded at least every minute so that the average can be determined over the run period.

11.4 Sign convention

The sign conventions that shall be used for wind and wave direction are presented in [Figure 5](#), [Figure 6](#) and [Figure 7](#).

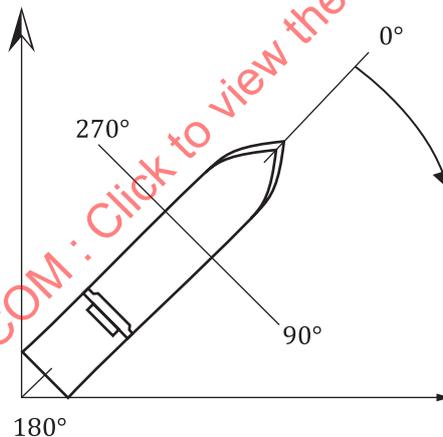
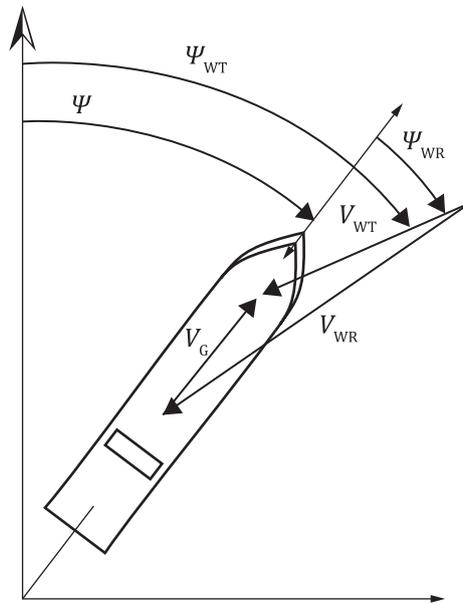


Figure 5 — Sign conventions for the coordinate system of a ship



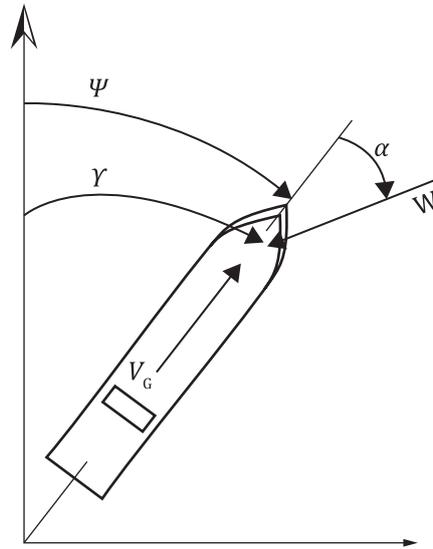
Key

- ψ the ship's compass heading, expressed in degrees
- ψ_{WR} the mean value of the relative wind direction relative to the bow, expressed in degrees
- V_{WR} the mean value of the measured relative wind velocity at anemometer height, expressed in metres per second
- V_G the measured ship speed over ground, expressed in metres per second
- ψ_{WT} the true wind direction at anemometer height in earth system, expressed in degrees
- V_{WT} the true wind velocity at anemometer height, expressed in metres per second

Figure 6 — Sign convention for wind directions

The wind direction is defined as angle between the ship's heading and the direction from which the wind is coming. Zero (0) degrees refers to the wind incoming on the bow and a positive angle refers to wind coming in from starboard (see [Figure 5](#)).

The input parameters and the computed parameters for the wind correction are given in [Figure 6](#).



Key

- ψ the ship's compass heading, expressed in degrees
- α the relative wave direction, relative to the bow, expressed in degrees
- V_G the measured ship speed over ground, expressed in metres per second
- γ the compass bearing of the incoming waves, expressed in degrees
- W direction of the waves

Figure 7 — Sign convention for wave direction

The wave direction is defined as the angle between the ship's heading and the direction from which the wave fronts are approaching. Zero (0) degrees refers to the waves incoming on the bow and a positive angle refers to waves coming in from starboard.

The input parameters for the wave correction are given in [Figure 7](#).

12 Analysis procedure

12.1 General

This Clause describes the procedure used to analyse the results of S/P trials which are conducted according to [Clauses 5](#) to [11](#).

The analysis procedure includes methods to determine corrections to power and speed for environmental influences during S/P trials.

This document offers different analysis methods, details of which are described in the [Annexes C, D, E, F, G, H, I, J](#) and [K](#).

The methods used depend on the situation and the available data. A flow chart is presented in [Figure 8](#).

12.2 Description of the analysis procedure

12.2.1 General

The analysis of S/P trials shall consist of:

- a) evaluation of the acquired data;
- b) analysis of the resistance increase due to the wind (see [Annex C](#));

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- c) analysis of the resistance increase due to the waves (see [Annex D](#));
- d) analysis of the power increase due to water temperature and water density (see [Annex E](#));
- e) calculation of the power effect as a result of additional resistance with the direct power method (see [Annex K](#));
- f) analysis of the speed at each run taking into consideration the current effects (see [Annex F](#));
- g) re-analysis of the resistance increase with current corrected speed (see [Annexes D, E](#));
- h) calculation of the power effect as a result of additional resistance due to the revised speed with the direct power method (see [Annex K](#));
- i) analysis of the power increase due to shallow water effects (see [Annex G](#));
- j) analysis of the power effect for the displacement of volume difference (see [Annex H](#));
- k) presentation of the intermediate analyses and the final results.

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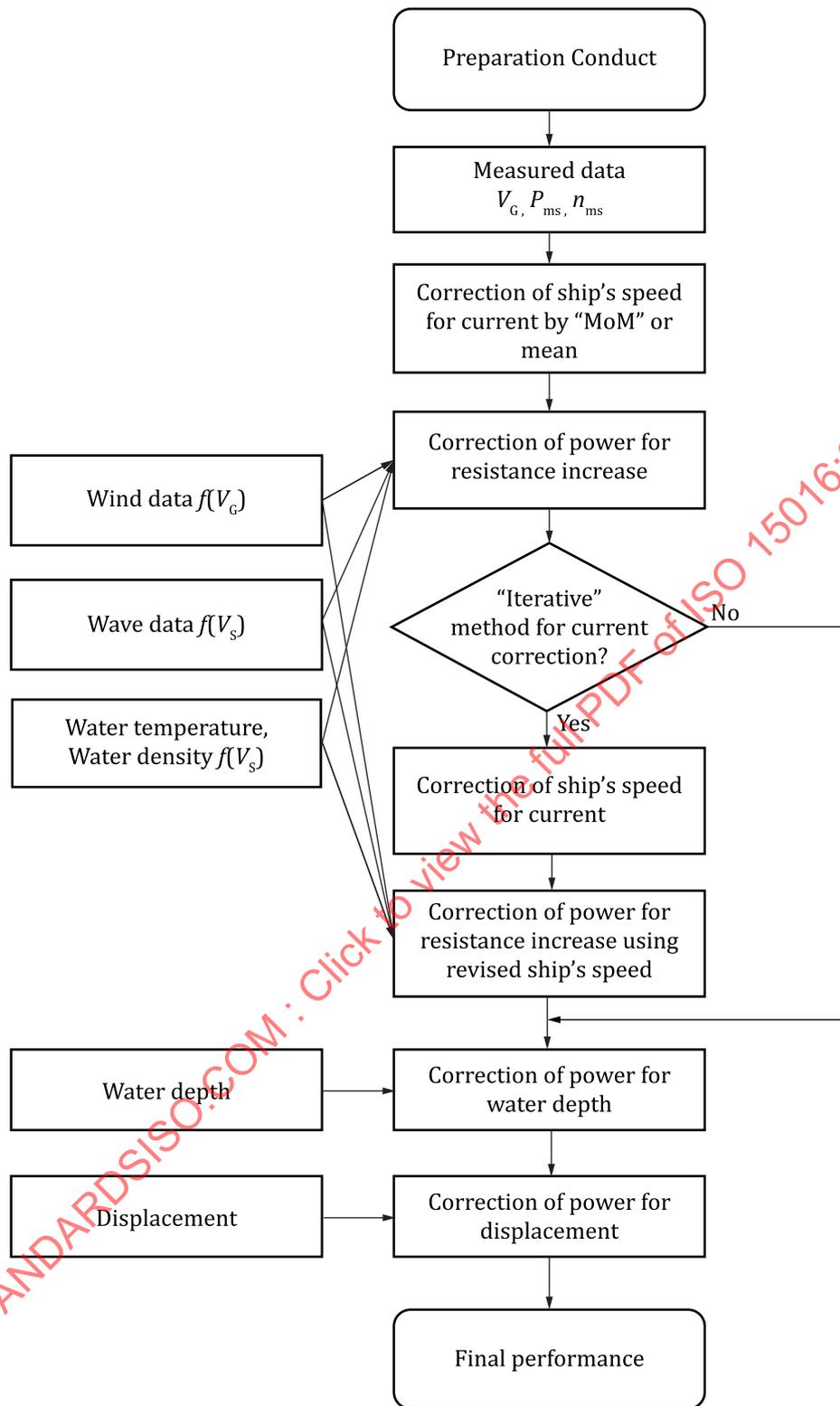


Figure 8 — Flow chart of analysis

12.2.2 Resistance data derived from the acquired data

The resistance values of each run shall be corrected for environmental influences by estimating the resistance increase ΔR as shown in [Formula \(8\)](#):

$$\Delta R = R_{AA} + R_{AW} + R_{AS} \tag{8}$$

where

ΔR is the total resistance increase, expressed in newtons;

R_{AA} is the resistance increase due to relative wind, expressed in newtons (see [Annex C](#));

R_{AW} is the mean resistance increase in short crested irregular waves, expressed in newtons (see [Annex D](#));

R_{AS} is the resistance increase due to deviation of water temperature and water density, expressed in newtons (see [Annex E](#)).

12.2.3 Evaluation of the acquired resistance data

The evaluation of the acquired resistance data consists of calculating the resistance value associated with the measured power value separately for each single run of the speed trials.

The reason that the associated resistance/power shall be calculated for each single run is that a careful evaluation shall consider the effects of varying hydrodynamic coefficients with varying propeller loads.

12.2.4 Evaluation of resistance data based on direct power method

To derive the speed-power performance of the ship from the measured speed over the ground V_G , the measured break power, P_{Sms} and the measured propeller shaft speed, n_{ms} , the direct power method shall be used in accordance with [Annex K](#).

12.2.5 Analysis of the measured ship speed due to the effect of current

The current effect is corrected by subtracting the current speed, V_C , from the measured ship speed over the ground, V_G , at each run as in [Formula \(9\)](#):

$$V_S = V_G - V_C \quad (9)$$

where

V_S is the ship speed through the water, expressed in knots;

V_G is the measured ship speed over ground, expressed in knots;

V_C is the current speed, expressed in knots.

The current correction can be applied by either one of two different methods: the “mean of means” method or the “iterative” method.

The details of the “iterative” method and the “mean of means” method are given in [Annex F](#).

12.2.6 Analysis of the power curve from trial condition to full load/stipulated condition

For dry cargo ships, it is difficult to conduct S/P trials at full load condition. For such cases, S/P trials at ballast condition are performed and the speed-power curve is converted to that of the full load/stipulated condition using the power curves based on the tank tests for these conditions.

The conversion method from the trial condition to full load/stipulated condition is shown in [Annex I](#).

13 Processing of the results

After completion of the S/P trials, the measured data shall be processed in the following sequence.

- a) Derive the average values of each measured parameter for each speed run. The ship speed during a speed run is derived from the headway distance between the start and the end position and the elapsed time of the speed run.
- b) Derive the true wind speed and direction at reference height for each double run using the method described in [Annex C](#).
- c) The maximum allowable true windspeed shall be treated in accordance with [8.3](#).
- d) Calculate the resistance increase due to wind with single run value V_G in accordance with [Annex C](#).
- e) Calculate the current corrected speed, V_s , with the “mean of means” method in case of two double runs, or the mean speed in case of one double run in accordance with [Annex F](#).
- f) Evaluate wave heights and relative wave direction for each run and normalize towards the maximum wave height and allowable direction in accordance with [8.4](#).
- g) Calculate the resistance increase originating from waves for each run based on the current corrected speed in accordance with [Annex D](#).
- h) Calculate the resistance increase originating from water temperature and water density for each run based on the current corrected speed in accordance with [Annex E](#).
- i) Correct the measured power per run for the total resistance increase with the direct power method (wind resistance based on V_G ; waves, water temperature and water density based on V_s) in accordance with [Annex K](#).
- j) If the “mean of means” method is used for current correction, continue with step q) below.
- k) If the “iterative” method is used, apply the speeds as calculated in step e) (using the “mean of means” method) as initial speed values for the “iterative” method.
- l) Calculate the initial power values for each run as the mean power value of step i) in case of one double run or the “mean of means” power value of step i) in case of two double runs.
- m) Apply the regression analysis as stated in [F.1](#) to determine a new current corrected speed, V_s .
- n) Calculate the resistance increase due to waves based on the new current corrected speed, V_s , in accordance with [Annex D](#).
- o) Calculate the resistance increase originating from water temperature and water density for each run based on the new current corrected speed, V_s , in accordance with [Annex E](#).
- p) Correct the measured power per run as a result of total resistance increase with the direct power method (wind resistance based on V_G ; waves, water temperature and water density, based on new V_s) in accordance with [Annex K](#).
- q) Determine for each run the increase of power due to shallow water in accordance with [Annex G](#).
- r) Determine the correction of power for the difference of displacement volume from the stipulated contractual and EEDI conditions in accordance with [Annex H](#).
- s) Determine the correction of propeller revolutions in accordance with [Annex J](#).
- t) Verify the shape of the current curve as described in [8.6](#). In cases where the current time history deviates from the assumed parabolic/ sinusoidal trend and the change of the current speed within the timespan of one double run is more than 0,5 knots, neither of the analysis methods in [Annex F](#) are applicable. In that case, the S/P trials shall be repeated in another area.

- u) The results of the S/P measurements are known in this stage. If speed-power data are available from tank tests, the final speed-power relationship shall be determined in accordance with [Annex I](#).
- v) If no relevant speed-power data from tank tests are available, a speed-power curve shall be obtained by conducting S/P trials for a minimum of four (4) power settings (see description in [10.9.5](#)). The S/P curve is determined by using a spline fitting over the four (4) measured S/P points.
- w) Apply corrections for the contractual weather conditions if these deviate from the ideal conditions.

An example calculation of the complete trial analysis procedure is presented in [Figure 9](#) (input) and [Figure 10](#) (analysis).

14 Reporting

In the trial report, an overview shall be given of the trial conditions and all corrections that have been applied to arrive at the speed achieved in ideal conditions with the contract power setting and the EEDI speed.

The trial report shall contain all relevant information to carry out the data analysis. It shall be written in such a way that all results can be reproduced.

The trial report shall contain the following sections:

- a) Trial report summary comprising details of:
 - 1) ship particulars (including trial draughts and displacement volume),
 - 2) propeller details,
 - 3) propulsion plant data,
 - 4) details of hull appendages and rudder(s);
- b) Contract conditions including contract speed, power, and displacement volume;
- c) EEDI conditions including EEDI speed, power, and displacement volume;
- d) A description of the instrumentation, describing instrument set-up, calibration methods, data acquisition interfacing details, location of sensors (e.g. torsion sensors on shaft, anemometer type/maker), etc.
- e) Description of the trial site. This gives information on geography, distance from land, water depth, etc.
- f) Environmental parameters. This shall list the measured/observed environmental conditions at the site during the S/P trials such as: wave height and period, compass direction of waves, air pressure, relative wind direction, wind velocity, air temperature, water temperature and water density.
- g) S/P trial agenda. This shall give a complete and chronological order of the trial programme (both planned and actual) with specification of the duties of the different recording/monitoring stations on board.
- h) Trial results of each speed run:
 - 1) date and time at start of speed run;
 - 2) run number;
 - 3) ship's positions;
 - 4) ship's heading;
 - 5) run duration;
 - 6) mean value of measured ship speed over ground;
 - 7) mean value and standard deviation of torque (per shaft);

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- 8) mean value and standard deviation of shaft rpm (per shaft);
 - 9) mean value and standard deviation of shaft power (per shaft);
 - 10) relative wind velocity and direction;
 - 11) significant wave height, mean period, and direction;
 - 12) water depth.
- i) Analysis methods. The analysis and correction of the measured trial data shall be conducted in accordance with [Clause 12](#).
 - j) Conclusions: speed and power as contractually specified, as well as on the EEDI condition, derived from the S/P trial analysis, shall be reported.
 - k) The documented mutual agreement (if any) regarding environmental conditions during the trial as described in [5.2](#).
 - l) Recommendations.

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15 Example of speed trial data analysis

GENERAL INFORMATION		
Ship name	MV, Test	
IMO Nr	111111111	
Shipbuilder	X	
Yard number	X	
Shipowner	X	
Trial Team Leader	X	
Verifier	X	
L _{pp}	266,00	[m]
B _{MOULDED}	42,00	[m]
MCR M/E	25 220	[kW]
n _{MCR}	97,0	[RPM]
PS _{NCR}	21 437	[kW]
Shaft efficiency ETAS	0,99	[-]
Shaft diameter (inside)	0	[m]
Shaft diameter (outside)	0,700	[m]
G Modulus (Default =82400)	82 400	[N/mm ²]
Propeller(s)		
Number of propellers	1	[-]
Type of propellers (FPP / CPP)	FPP	[-]
Diameter	X	[m]
Design pitch (FPP)	X	[m]
Direction of rotation	R	R/L
Number of blades	4	[-]
Propelle(s) polished on	01-01-30	[dd-mm-yy]

TRIAL CONDITION AS DESCRIBED IN THE CONTRACT			
Draught condition at trial		BALLAST	
Hull	T _{F-Tank test}	7,90	[m]
	T _A	9,25	[m]
	∇ _{ref}	73 500	[m ³]

HULL CONDITION AT S/P TRIAL AREA			
Draught	PS	SB	Aver,
T _{FORE} moulded at FPP			7,94 [m]
T _{MID} moulded			8,58 [m]
T _{AFT} moulded at APP			9,23 [m]
Moulded displacement volume			73 826 [m ³]
Waterline area A _{w on trial}			8 937 [m ²]
Block coefficient C _{B on trial}			0,7702 [-]
k _{yy} /L _{PP on trial}			0,25 [-]
Midship section A _{M on trial}			358,0 [m ²]
Bow length for STAWAVE - 1			52,00 (-)
Total wetted surface			12 410 [m ²]
Transverse projected wind area			1 764 [m ²]
Vertical position of anemometer above water			46,0 [m]
Last day of hull cleaning			01-12-30 [m ²]

CONTRACT LOADING CONDITION		
Draught condition at contract	FULL	
T _F	11,80	[m]
T _A	11,80	[m]
∇ _{ref}	102 500	[m ³]
Transv, wind area		[m ²]
Sea margin	15	[%]
PS _{Contract}	21 437	[kW]
n _{Contr}	84,0	[-]
V _{S service Contract}	17,8	[kn]
PS _{MCR}	25 200	[kW]
n _{NCR}	91,9	[-]
True wind speed	0	[m/s]
Wave height	0	[m]
Wave period	0	[s]
AIR	Z _{ref}	10 [m]
	Air temp _{,ref}	15 [°C]
	Air press _{,ref}	1 013,25 [mBar]
WATER	T _{w-ref}	15 [°C]
	ρ _{s-ref}	1 025,8 [kg/m ³]

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DATA AT S/P TRIAL AREA		
Weather condition	Fair	Visual
Latitude	46-28 N	[dd-mm]
Longitude	006-27 E	[ddd-mm]
Sea trial Site	Lac Lemman	
Beaufort number	2	[-]
Torsion meter zero setting	Y	Y / N
T _{AIR}	25	[°C]
T _{WATER}	17	[°C]
RHO _{WATER}	1 025,0	[kg/m ³]
Atmospheric pressure	1 012,0	[hPa, mbar]

WIND DATA	
Vessel number from database (windcalculation)	4

WAVE DATA		
HBR for STAWAVE -1	52,00	[m]
Wave observation method	Visual observations	
Heave or pitch motions during trials	No	

LOAD VARIATION TEST	
Overload factors as presented by Model basin	
ξ _p Propulsion (ksi-p)	ξ _n Revolutions (ksi-n)
-0,1000	0,2000

TANK TEST PREDICTIONS

BALLAST DRAUGHT (Non EEDI), Tank test predictions (Speed, power, efficiency)

		16,00	17,00	18,00	19,00	20,00	21,00			
V _s	(knots)	16,00	17,00	18,00	19,00	20,00	21,00			
PS _{id}	(kW)	12 147	14 205	16 350	18 959	22 211	26 367			
n _{id}	[RPM]	74,0	77,8	81,6	85,6	90,0	94,9			
ETA _{Did}	[-]	0,7360	0,7380	0,7410	0,7460	0,7500	0,7510			

FULL DRAUGHT (Non EEDI), Tank test predictions (Speed, power, efficiency)

		16,00	17,00	18,00	19,00	20,00	21,00			
V _s	(knots)	16,00	17,00	18,00	19,00	20,00	21,00			
PS _{id}	(kW)	13 901	16 206	18 609	21 531	25 173	29 828			
n _{id}	[RPM]	80,4	84,2	88,0	92,0	96,4	101,3			
ETA _{Did}	[-]	0,7070	0,7090	0,7120	0,7170	0,7210	0,7220			

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DATA AT S/P TRIAL AREA		
Weather condition	Fair	Visual
Latitude	46-28 N	[dd-mm]
Longitude	006-27 E	[ddd-mm]
Sea trial Site	Lac Lemman	
Beaufort number	2	[-]
Torsion meter zero setting	Y	Y / N
T _{AIR}	25	[°C]
T _{WATER}	17	[°C]
RHO _{WATER}	1 025,0	[kg/m ³]
Atmospheric pressure	1 012,0	[hPa, mbar]

WIND DATA	
Vessel number from database (windcalculation)	4

WAVE DATA		
HBR for STAWAVE -1	52,00	[m]
Wave observation method	Visual observations	
Heave or pitch motions during trials	No	

LOAD VARIATION TEST	
Overload factors as presented by Model basin	
ξ _p Propulsion (ksi-p)	ξ _n Revolutions (ksi-n)
-0,1000	0,2000

TANK TEST PREDICTIONS

BALLAST DRAUGHT (Non EEDI), Tank test predictions (Speed, power, efficiency)

Vs	(knots)	16,00	17,00	18,00	19,00	20,00	21,00			
PS _{id}	(kW)	12 147	14 205	16 350	18 959	22 211	26 367			
n _{id}	[RPM]	74,0	77,8	81,6	85,6	90,0	94,9			
ETA _{Did}	[-]	0,7360	0,7380	0,7410	0,7460	0,7500	0,7510			

FULL DRAUGHT (Non EEDI), Tank test predictions (Speed, power, efficiency)

Vs	(knots)	16,00	17,00	18,00	19,00	20,00	21,00			
PS _{id}	(kW)	13 901	16 206	18 609	21 531	25 173	29 828			
n _{id}	[RPM]	80,4	84,2	88,0	92,0	96,4	101,3			
ETA _{Did}	[-]	0,7070	0,7090	0,7120	0,7170	0,7210	0,7220			

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MEASURED AND OBSERVED DATA ON TRIAL

Run number		1	2	3	4	5	6	
Power setting	% MCR	70%	70%	70%	70%	80%	80%	
Date	dd-mmm-yyyy	2030-12-30	2030-12-30	2030-12-30	2030-12-30	2030-12-30	2030-12-30	
Start time of run	hh:mm:ss	7:00	7:45	8:30	9:15	10:00	10:45	
Run duration	mm:ss	10	10	10	10	10	10	
Run direction based on dominant	[Wave/Wind]	Waves	Waves	Waves	Waves	Waves	Waves	
Run direction	Against/Follow	against	with	against	with	against	with	
Ship's heading during run	[°]	304,0	124,0	303,0	124,0	303,0	124,0	
Ship's speed over the ground	[knots]	18,38	18,10	18,68	18,28	19,18	20,28	
Relative wind at anemometer height	Velocity	[m/s]	15,10	5,60	15,50	5,70	15,90	6,80
	Direction	[°]	-1,0	7,0	-3,0	14,0	-6,0	19,0
Wind waves	Height	[m]	1,50	1,50	1,50	1,50	1,50	1,50
	Direction	[°]	300,0	300,0	300,0	300,0	300,0	300,0
	Period	[s]	5,0	5,0	5,0	5,0	5,0	5,0
Swell	Height	[m]	2,00	2,00	2,00	2,00	2,00	2,00
	Direction	[°]	330,0	330,0	330,0	330,0	330,0	330,0
	Period	[s]	8,0	8,0	8,0	8,0	8,0	8,0
Propeller	Brake power	[kW]	18 200	17 900	18 220	17 920	21 350	20 600
	Shaft speed	[rpm]	85,30	85,30	85,30	85,30	90,20	90,20
	Pitch of CPP	[°]						
Water depth	[m]	60,0	60,0	60,0	60,0	60,0	60,0	

Run number		7	8	9	10	11	12	
Power setting	% MCR	80%	80%	100%	100%	100%	100%	
Date	dd-mmm-yyyy	2030-12-30	2030-12-30	2030-12-30	2030-12-30	2030-12-30	2030-12-30	
Start time of run	hh:mm:ss	11:30	12:15	13:00	13:45	14:30	15:15	
Run duration	mm:ss	10	10	10	10	10	10	
Run direction based on dominant	[Wave/Wind]	Waves	Waves	Waves	Waves	Waves	Waves	
Run direction	Against/Follow	against	with	against	with	against	with	
Ship's heading during run	[°]	304,0	124,0	304,0	124,0	304,0	124,0	
Ship's speed over the ground	[knots]	18,23	21,08	18,38	22,03	18,48	21,58	
Relative wind at anemometer height	Velocity	[m/s]	15,60	7,10	16,00	7,00	16,50	6,30
	Direction	[°]	-10,0	20,0	-9,0	18,0	-7,0	18,0
Wind waves	Height	[m]	1,50	1,50	1,50	1,50	1,50	1,50
	Direction	[°]	300,0	300,0	300,0	300,0	300,0	300,0
	Period	[s]	5,0	5,0	5,0	5,0	5,0	5,0
Swell	Height	[m]	2,00	2,00	2,00	2,00	2,00	2,00
	Direction	[°]	330,0	330,0	330,0	330,0	330,0	330,0
	Period	[s]	8,0	8,0	8,0	8,0	8,0	8,0
Propeller	Brake power	[kW]	21 320	20 750	24 450	23 500	24 480	23 520
	Shaft speed	[rpm]	90,20	90,20	94,90	94,90	94,90	94,90
	Pitch of CPP	[°]						
Water depth	[m]	60,0	60,0	60,0	60,0	60,0	60,0	

Figure 9 — Example of input data from speed trial analysis

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1 2 3 4 5 6

run number			1	2	3	4	5	6
main engine output setting			70%	70%	70%	70%	80%	80%
start time of each run	Input	(seconds)	25 200	27 900	30 600	33 300	36 000	38 700
time elapsed for the speed run	Input	(seconds)	600	600	600	600	600	600
mid time of each run	Input	(hh:mm)	25 500	28 200	30 900	33 600	36 300	39 000
mid time of each run	Input	(hh:mm)	7:05	7:50	8:35	9:20	10:05	10:50
ship's heading during run	Input	(deg)	304	124	303	124	303	124
ship's speed over the ground	Input	(knots)	18,38	18,10	18,68	18,28	19,18	20,28
propeller shaft speed	Input	(rpm)	85,3	85,3	85,3	85,3	90,2	90,2
brake power	Input	(kW)	18 200	17 900	18 220	17 920	21 350	20 600
relative wind velocity at anemometer height	Input	(m/s)	15,10	5,60	15,50	5,70	15,90	6,80
relative wind direction at anemometer height	Input	(deg)	-1	7	-3	14	-6	19
mean wave period (Wind waves)	Input	(hh:mm)	5	5	5	5	5	5
significant wave height (Wind waves)	Input	(hh:mm)	1,50	1,50	1,50	1,50	1,50	1,50
incident angle of wave (Wind waves)	Input	(deg)	300	300	300	300	300	300
mean wave period (Swell)	Input	(seconds)	8	8	8	8	8	8
significant wave height (Swell)	Input	(m)	2,00	2,00	2,00	2,00	2,00	2,00
incident angle of wave (Swell)	Input	(deg)	330	330	330	330	330	330
water depth	Input	(m)	60,0	60,0	60,0	60,0	60,0	60,0

power setting	Input		70%	70%	70%	70%	80%	80%
delivered power in trial condition	Input	(kW)	18 018	17 721	18 038	17 741	21 137	20 394
measured propeller shaft speed	Input	(rpm)	85,30	85,30	85,30	85,30	90,20	90,20
average ship's speed over the ground per double run		(knots)	18,24		18,48		19,73	

7 8 9 10 11 12

run number			7	8	9	10	11	12
main engine output setting			80%	80%	100%	100%	100%	100%
start time of each run	Input	(seconds)	41 400	44 100	46 800	49 500	52 200	54 900
time elapsed for the speed run	Input	(seconds)	600	600	600	600	600	600
mid time of each run	Input	(hh:mm)	41 700	44 400	47 100	49 800	52 500	55 200
mid time of each run	Input	(hh:mm)	11:35	12:20	13:05	13:50	14:35	15:20
ship's heading during run	Input	(deg)	304	124	304	124	304	124
ship's speed over the ground	Input	(knots)	18,23	21,08	18,38	22,03	18,48	21,58
propeller shaft speed	Input	(rpm)	90,2	90,2	94,9	94,9	94,9	94,9
brake power	Input	(kW)	21 320	20 750	24 450	23 500	24 480	23 520
relative wind velocity at anemometer height	Input	(m/s)	15,60	7,10	16,00	7,00	16,50	6,30
relative wind direction at anemometer height	Input	(deg)	-10	20	-9	18	-7	18
mean wave period (Wind waves)	Input	(hh:mm)	5	5	5	5	5	5
significant wave height (Wind waves)	Input	(hh:mm)	1,50	1,50	1,50	1,50	1,50	1,50
incident angle of wave (Wind waves)	Input	(deg)	300	300	300	300	300	300
mean wave period (Swell)	Input	(seconds)	8	8	8	8	8	8
significant wave height (Swell)	Input	(m)	2,00	2,00	2,00	2,00	2,00	2,00
incident angle of wave (Swell)	Input	(deg)	330	330	330	330	330	330
water depth	Input	(m)	60,0	60,0	60,0	60,0	60,0	60,0

power setting	Input		80%	80%	100%	100%	100%	100%
delivered power in trial condition	Input	(kW)	21 107	20 543	24 206	23 265	24 235	23 285
measured propeller shaft speed	Input	(rpm)	90,20	90,20	94,90	94,90	94,90	94,90
average ship's speed over the ground per double run		(knots)	19,66		20,21		20,03	

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1 2 3 4 5 6

WIND EVALUATION BASED ON GROUND SPEED V_G								
run number			1	2	3	4	5	6
the measured ship's speed over ground	Input	(knots)	18,38	18,10	18,68	18,28	19,18	20,28
the measured ship's speed over ground	Input	(m/s)	9,46	9,31	9,61	9,40	9,87	10,43
the ship's heading	Input	(deg)	304	124	303	124	303	124
the ship's heading	Input	(radians)	5,31	2,16	5,29	2,16	5,29	2,16
relative wind velocity at anemometer	Input	(m/s)	15,10	5,60	15,50	5,70	15,90	6,80
relative wind direction at anemometer	Input	(deg)	-1	7	-3	14	-6	19
relative wind direction at anemometer	Input	(radians)	-0,02	0,12	-0,05	0,24	-0,10	0,33
true wind velocity at anemometer	C.3	(m/s)	5,65	3,81	5,92	4,11	6,17	4,57
true wind direction at the anemometer	C.4	(deg)	-58,7	-66,3	-64,9	-75,6	-72,6	-84,9
true wind velocity at anemometer	C.3	(m/s)	5,65	3,81	5,92	4,11	6,17	4,57
true wind velocity at anemometer	C.4	(radians)	-1,02	-1,16	-1,13	-1,32	-1,27	-1,48
averaged true wind velocity at the anemometer	C.5	(m/s)	4,72		5,00		5,34	
averaged true wind direction at the anemometer	C.6	(deg)	-61,7		-69,3		-77,9	
averaged true wind velocity at the anemometer height	C.5	(m/s)	4,72		5,00		5,34	
averaged true wind direction at the anemometer height	C.6	(radians)	-1,08		-1,21		-1,36	
measured ship's speed over ground	Input	(m/s)	9,46	9,31	9,61	9,40	9,87	10,43
the ship's heading	Input	(radians)	5,31	2,16	5,29	2,16	5,29	2,16
corrected rel, wind velocity at the anemometer height	C.7	(m/s)	14,16	4,64	14,53	4,68	14,98	5,82
corrected rel, wind direction at the the anemometer height	C.8	(deg)	-1,9	5,9	-4,2	14,2	-7,3	20,0
averaged true windspeed at the anemometer height	C.5	(m/s)	4,72		5,00		5,34	
anemometer height above sealevel	Input	(m)	46,00	46,00	46,00	46,00	46,00	46,00
reference height windtunnel measurements	Input	(m)	10,00	10,00	10,00	10,00	10,00	10,00
true wind velocity at the reference height	C.9	(m/s)	3,99		4,22		4,51	
true wind direction at the reference height	C.6	(deg)	-61,7		-69,3		-77,9	
maximum allowable true wind speed	2	(m/s)	14,08		14,08		14,08	
true wind speed within limits?		(Y/N)	Y		Y		Y	
normalized wind to max wind allowed	C.9	(m/s)	3,99		4,22		4,51	
true wind velocity at the reference height	C.9	(m/s)	3,99		4,22		4,51	
the measured ship's speed over ground	Input	(m/s)	9,46	9,31	9,61	9,40	9,87	10,43
averaged true wind direction at the anemometer	C.6	(radians)	-1,08		-1,21		-1,36	
the ship's heading	Input	(radians)	5,31	2,16	5,29	2,16	5,29	2,16
relative wind velocity at the reference height	C.10	(m/s)	13,43	5,36	13,76	5,39	14,17	6,47
relative wind direction at the reference height	C.11	(deg)	-1,7	4,3	-3,7	10,3	-6,5	15,0

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WIND EVALUATION BASED ON GROUND SPEED V_G								
run number			7	8	9	10	11	12
the measured ship's speed over ground	Input	(knots)	18,23	21,08	18,38	22,03	18,48	21,58
the measured ship's speed over ground	Input	(m/s)	9,38	10,84	9,46	11,33	9,51	11,10
relative wind velocity at anemometer	Input	(m/s)	15,60	7,10	16,00	7,00	16,50	6,30
relative wind direction at anemometer	Input	(deg)	-10	20	-9	18	-7	18
relative wind direction at anemometer	Input	(radians)	-0,17	0,35	-0,16	0,31	-0,12	0,31
true wind velocity at anemometer	C.3	(m/s)	6,57	4,83	6,82	5,15	7,16	5,47
true wind direction at the anemometer	C.4	(deg)	-80,4	-86,2	-77,5	-80,8	-72,3	-76,9
true wind velocity at anemometer	C.3	(m/s)	6,57	4,83	6,82	5,15	7,16	5,47
true wind velocity at anemometer	C.4	(radians)	-1,40	-1,50	-1,35	-1,41	-1,26	-1,34
averaged true wind velocity at the anemometer	C.5	(m/s)	5,69		5,99		6,31	
averaged true wind direction at the anemometer	C.6	(deg)	-82,8		-78,9		-74,3	
averaged true wind velocity at the anemometer height	C.5	(m/s)	5,69		5,99		6,31	
averaged true wind direction at the anemometer height	C.6	(radians)	-1,45		-1,38		-1,30	
measured ship's speed over ground	Input	(m/s)	9,38	10,84	9,46	11,33	9,51	11,10
the ship's heading	Input	(radians)	5,31	2,16	5,31	2,16	5,31	2,16
corrected rel. wind velocity at the anemometer height	C.7	(m/s)	14,683	6,312	15,148	6,272	15,623	5,481
corrected rel. wind direction at the the anemometer height	C.8	(deg)	-10,1	24,0	-8,9	21,8	-7,3	21,2
averaged true windspeed at the anemometer height	C.5	(m/s)	5,69		5,99		6,31	
anemometer height above seale	Input	(m)	46,00	46,00	46,00	46,00	46,00	46,00
reference height windtunnel measurements	Input	(m)	10,00	10,00	10,00	10,00	10,00	10,00
true wind velocity at the reference height	C.9	(m/s)	4,80		5,05		5,32	
true wind direction at the reference height	C.6	(deg)	-82,8		-78,9		-74,3	
maximum allowable true wind speed	2	(m/s)	14,08		14,08		14,08	
true wind speed within limits?		(Y/N)	Y		Y		Y	
normalized wind to max wind allowed	C.9	(m/s)	4,80		5,05		5,32	
true wind velocity at the reference height	C.9	(m/s)	4,80		5,05		5,32	
the measured ship's speed over ground	Input	(m/s)	9,38	10,84	9,46	11,33	9,51	11,10
averaged true wind direction at the anemometer	C.6	(radians)	-1,45		-1,38		-1,30	
the ship's heading	Input	(radians)	5,31	2,16	5,31	2,16	5,31	2,16
relative wind velocity at the reference height	C.10	(m/s)	13,84	6,91	14,24	6,97	14,66	6,27
relative wind direction at the reference height	C.11	(deg)	-9,0	18,3	-7,9	16,4	-6,5	15,4

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Wind analyse method			STAWIND	STAWIND	STAWIND	STAWIND	STAWIND	STAWIND
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WIND RESISTANCE WITH STAWIND								
run number			1	2	3	4	5	6
mass density of air on trial	C.2	(kg/m ³)	1,1827	1,1827	1,1827	1,1827	1,1827	1,1827
relative wind velocity at the reference height	C.10	(m/s)	13,43	5,36	13,76	5,39	14,17	6,47
relative wind direction at the reference height	C.11	(deg)	1,7	4,3	3,7	10,3	6,5	15,0
transverse section exposed to wind	Input	(m ²)	1 764	1 764	1 764	1 764	1 764	1 764
wind resistance coefficient at speed run	Table C.2	(-)	1,0159	1,0093	1,0108	0,9885	1,0028	0,9640
wind resistance at speed run	C.1	(kN)	191,03	30,26	199,64	29,92	210,12	42,08
Steamed wind								
mass density of air on trial	C.2	(kg/m ³)	1,1827	1,1827	1,1827	1,1827	1,1827	1,1827
relative wind velocity at the reference height	input	(m/s)	9,46	9,31	9,61	9,40	9,87	10,43
relative wind direction at the reference height	input	(deg)	0,0	0,0	0,0	0,0	0,0	0,0
transverse section exposed to wind	input	(m ²)	1 764	1 764	1 764	1 764	1 764	1 764
wind resistance coefficient for headwind	Table C.2	(-)	1,0200	1,0200	1,0200	1,0200	1,0200	1,0200
wind resistance	C.1	(kN)	95,13	92,25	98,26	94,09	103,59	115,81
ADDITIONAL RESISTANCE BY STAWIND		(kN)	95,91	-61,99	101,38	-64,18	106,54	-73,73

TOTAL WIND RESISTANCE	(kN)	95,91	-61,99	101,38	-64,18	106,54	-73,73
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Current correction method with MoM			Mean of Means					
powersetting	input		70%	70%	70%	70%	80%	80%
ship's speed over the ground	input	(knots)	18,38	18,10	18,68	18,28	19,18	20,28
ship's speed through the water based on MoM	F.7	(knots)	18,38	18,38	18,38	18,38	19,47	19,47
ship's speed through the water based on MoM	F.7	(m/s)	9,45	9,45	9,45	9,45	10,02	10,02

SPEED TROUGH WATER	F.7	(knots)	18,38	18,38	18,38	18,38	19,47	19,47
SPEED TROUGH WATER	F.7	(m/s)	9,45	9,45	9,45	9,45	10,02	10,02

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Wind analyse method			STAWIND	STAWIND	STAWIND	STAWIND	STAWIND	STAWIND
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WIND RESISTANCE WITH STAWIND								
run number			7	8	9	10	11	12
mass density of air on trial	C.2	(kg/m ³)	1,1827	1,1827	1,1827	1,1827	1,1827	1,1827
relative wind velocity at the reference height	C.10	(m/s)	13,84	6,91	14,24	6,97	14,66	6,27
relative wind direction at the reference height	C.11	(deg)	9,0	18,3	7,9	16,4	6,5	15,4
transverse section exposed to wind	Input	(m ²)	1 764	1 764	1 764	1 764	1 764	1 764
wind resistance coefficient at speed run	Table C.2	(-)	0,9940	0,9426	0,9980	0,9554	1,0027	0,9616
wind resistance at speed run	C.1	(kN)	198,48	46,91	211,22	48,35	224,73	39,46
Steamed wind								
mass density of air on trial	C.2	(kg/m ³)	1,1827	1,1827	1,1827	1,1827	1,1827	1,1827
relative wind velocity at the reference height	input	(m/s)	9,38	10,84	9,46	11,33	9,51	11,10
relative wind direction at the reference height	input	(deg)	0,0	0,0	0,0	0,0	0,0	0,0
transverse section exposed to wind	input	(m ²)	1 764	1 764	1 764	1 764	1 764	1 764
wind resistance coefficient for headwind	Table C.2	(-)	1,0200	1,0200	1,0200	1,0200	1,0200	1,0200
wind resistance	C.1	(kN)	93,58	125,13	95,13	136,66	96,16	131,13
ADDITIONAL RESISTANCE BY STAWIND		(kN)	104,90	-78,22	116,09	-88,31	128,56	-91,67

TOTAL WIND RESISTANCE	(kN)	104,90	-78,22	116,09	-88,31	128,56	-91,67
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Current correction method with MoM			Mean of Means					
power setting	input		80%	80%	100%	100%	100%	100%
ship's speed over the ground	input	(knots)	18,23	21,08	18,38	22,03	18,48	21,58
ship's speed through the water based on MoM	F.7	(knots)	19,47	19,47	20,19	20,19	20,19	20,19
ship's speed through the water based on MoM	F.7	(m/s)	10,02	10,02	10,38	10,38	10,38	10,38

SPEED TROUGH WATER Mo	F.7	(knots)	19,47	19,47	20,19	20,19	20,19	20,19
SPEED TROUGH WATER Mo	F.7	(m/s)	10,02	10,02	10,38	10,38	10,38	10,38

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WAVE EVALUATION								
run number			1	2	3	4	5	6
significant wave height (Wind waves)	input	(m)	1,5	1,5	1,5	1,5	1,5	1,5
significant wave height (Swell)	input	(m)	2	2	2	2	2	2
total significant wave height (Wind and Swell)	4	(m)	2,50	2,50	2,50	2,50	2,50	2,50
max, allowable significant wave height for correction on S/P trials	6	(m)	2,45	2,45	2,45	2,45	2,45	2,45
actual wave height within limits		(Y / N)	N	N	N	N	N	N
significant wave height used in calculation (Wind waves)	13.f	(m)	1,46	1,46	1,46	1,46	1,46	1,46
significant wave height used in calculation (Swell)	13.f	(m)	1,95	1,95	1,95	1,95	1,95	1,95
mean wave period (Wind waves)	input	(seconds)	5	5	5	5	5	5
mean wave period (Swell)	input	(seconds)	8	8	8	8	8	8
ships heading	input	(deg)	304	124	303	124	303	124
incident angle of wave (Wind waves)	input	(deg)	300	300	300	300	300	300
relative direction of incoming waves (Wind waves)		(deg)	-4	176	-3	176	-3	176
acceptable incident angle of waves (Wind waves)			-45 ---> 45	-45 ---> 45	-45 ---> 45	-45 ---> 45	-45 ---> 45	-45 ---> 45
will wave correction (Wind waves) be calculated		(Y / N)	Y	N	Y	N	Y	N
ships heading	input	(deg)	304	124	303	124	303	124
incident angle of wave (Swell)	input	(deg)	330	330	330	330	330	330
relative direction of incoming waves (Swell)		(deg)	26	-154	27	-154	27	-154
acceptable incident angle of waves (Swell)			-45 ---> 45	-45 ---> 45	-45 ---> 45	-45 ---> 45	-45 ---> 45	-45 ---> 45
will wave correction (Swell) be calculated		(Y / N)	Y	N	Y	N	Y	N
WAVE RESISTANCE WITH STAWAVE-1								
significant wave height (Wind waves)	13.f	(m)	1,46	1,46	1,46	1,46	1,46	1,46
wave period (Wind waves)	Input	(seconds)	5	5	5	5	5	5
wave direction (Wind waves)	Input	(deg)	300	300	300	300	300	300
seawater density at trial	Input	(kg/m ³)	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0
distance of the bow to 95 % of maximum breadth	Input	(m)	52,0	52,0	52,0	52,0	52,0	52,0
ship's breadth	Input	(m)	42,0	42,0	42,0	42,0	42,0	42,0
ADD, RESISTANCE BY STAWAVE-1 wave	D.31	(kN)	50,72	0,00	50,72	0,00	50,72	0,00
significant swell height	13.f	(m)	1,95	1,95	1,95	1,95	1,95	1,95
swell period	input	(seconds)	8	8	8	8	8	8
swell direction	input	(deg)	330	330	330	330	330	330
seawater density at trial	input	(kg/m ³)	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0
distance of the bow to 95 % of maximum breadth	input	(m)	52,0	52,0	52,0	52,0	52,0	52,0
ship's breadth	input	(m)	42,0	42,0	42,0	42,0	42,0	42,0
ADD, RESISTANCE BY STAWAVE-1 Swell	D.31	(kN)	90,17	0,00	90,17	0,00	90,17	0,00
TOTAL WAVE RESISTANCE		(kN)	50,72	0,00	50,72	0,00	50,72	0,00
TOTAL SWELL RESISTANCE		(kN)	90,17	0,00	90,17	0,00	90,17	0,00

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WAVE EVALUATION			7	8	9	10	11	12
run number								
significant wave height (Wind waves)	input	(m)	1,5	1,5	1,5	1,5	1,5	1,5
significant wave height (Swell)	input	(m)	2	2	2	2	2	2
total significant wave height (Wind and Swell)	4	(m)	2,50	2,50	2,50	2,50	2,50	2,50
max. allowable significant wave height for correction on S/P trials	6	(m)	2,45	2,45	2,45	2,45	2,45	2,45
actual wave height within limits		(Y /N)	N	N	N	N	N	N
significant wave height used in calculation (Wind waves)	13.f	(m)	1,46	1,46	1,46	1,46	1,46	1,46
significant wave height used in calculation (Swell)	13.f	(m)	1,95	1,95	1,95	1,95	1,95	1,95
mean wave period (Wind waves)	input	(seconds)	5	5	5	5	5	5
mean wave period (Swell)	input	(seconds)	8	8	8	8	8	8
ships heading	input	(deg)	304	124	304	124	304	124
incident angle of wave (Wind waves)	input	(deg)	300	300	300	300	300	300
relative direction of incoming waves (Wind waves)		(deg)	-4	176	-4	176	-4	176
acceptable incident angle of waves (Wind waves)			-45 ---> 45	-45 ---> 45	-45 ---> 45	-45 ---> 45	-45 ---> 45	-45 ---> 45
will wave correction (Wind waves) be calculated		(Y /N)	Y	N	Y	N	Y	N
ships heading	input	(deg)	304	124	304	124	304	124
incident angle of wave (Swell)	input	(deg)	330	330	330	330	330	330
relative direction of incoming waves (Swell)		(deg)	26	-154	26	-154	26	-154
acceptable incident angle of waves (Swell)			-45 ---> 45	-45 ---> 45	-45 ---> 45	-45 ---> 45	-45 ---> 45	-45 ---> 45
will wave correction (Swell) be calculated		(Y /N)	Y	N	Y	N	Y	N

WAVE RESISTANCE WITH STAWAVE-1			7	8	9	10	11	12
significant wave height (Wind waves)	13.f	(m)	1,46	1,46	1,46	1,46	1,46	1,46
wave period (Wind waves)	Input	(seconds)	5	5	5	5	5	5
wave direction (Wind waves)	Input	(deg)	300	300	300	300	300	300
seawater density at trial	Input	(kg/m ³)	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0
distance of the bow to 95 % of maximum breadth	Input	(m)	52,0	52,0	52,0	52,0	52,0	52,0
ship's breadth	Input	(m)	42,0	42,0	42,0	42,0	42,0	42,0
ADD, RESISTANCE BY STAWAVE-1 wave	D.31	(kN)	50,72	0,00	50,72	0,00	50,72	0,00
significant swell height	13.f	(m)	1,95	1,95	1,95	1,95	1,95	1,95
swell period	input	(seconds)	8	8	8	8	8	8
swell direction	input	(deg)	330	330	330	330	330	330
seawater density at trial	input	(kg/m ³)	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0
distance of the bow to 95 % of maximum breadth	input	(m)	52,0	52,0	52,0	52,0	52,0	52,0
ship's breadth	input	(m)	42,0	42,0	42,0	42,0	42,0	42,0
ADD, RESISTANCE BY STAWAVE-1 Swell	D.31	(kN)	90,17	0,00	90,17	0,00	90,17	0,00

TOTAL WAVE RESISTANCE	(kN)	50,72	0,00	50,72	0,00	50,72	0,00
TOTAL SWELL RESISTANCE	(kN)	90,17	0,00	90,17	0,00	90,17	0,00

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RESISTANCE BY TEMP & DENSITY								
run number			1	2	3	4	5	6
actual sea water temperature	Input	(°C)	17	17	17	17	17	17
reference sea water temperature	Input	(°C)	15	15	15	15	15	15
actual sea water density	Input	(kg/m ³)	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0
reference sea water density	Input	(kg/m ³)	1 025,8	1 025,8	1 025,8	1 025,8	1 025,8	1 025,8
length between perpendiculars	Input	(m)	266	266	266	266	266	266
total wetted surface	Input	(m ²)	12 410	12 410	12 410	12 410	12 410	12 410
hull roughness in microns	Input	(m ⁻⁶)	150	150	150	150	150	150
Vs after current iteration	F.7	(knots)	18,38	18,38	18,38	18,38	19,47	19,47
Vs after current iteration	F.7	(m/s)	9,45	9,45	9,45	9,45	10,02	10,02
kinematic viscosity actual seawater	E.8	kg/m ²	1,1313E-06	1,1313E-06	1,1313E-06	1,1313E-06	1,1313E-06	1,1313E-06
Reynolds number, actual seawater	E.6	(-)	2,2226E+09	2,2226E+09	2,2226E+09	2,2226E+09	2,3555E+09	2,3555E+09
frictional resistance coefficient for the actual water	E.5	(-)	1,3895E-03	1,3895E-03	1,3895E-03	1,3895E-03	1,3800E-03	1,3800E-03
roughness allowance associated to actual water	E.6	(-)	0,00015	0,00015	0,00015	0,00015	0,00016	0,00016
kinematic viscosity, reference seawater	E.8	kg/m ²	1,1900E-06	1,1900E-06	1,1900E-06	1,1900E-06	1,1900E-06	1,1900E-06
Reynolds number, reference seawater	E.6	(-)	2,1130E+09	2,1130E+09	2,1130E+09	2,1130E+09	2,2394E+09	2,2394E+09
frictional resistance coefficient for the reference water	E.5	(-)	1,3978E-03	1,3978E-03	1,3978E-03	1,3978E-03	1,3883E-03	1,3883E-03
roughness allowance associated to reference water	E.5	(-)	1,4563E-04	1,4563E-04	1,4563E-04	1,4563E-04	1,5220E-04	1,5220E-04
frictional resistance in the actual sea water	E.1	(kN)	876	876	876	876	982	982
frictional resistance in the reference sea water	E.1	(kN)	878	878	878	878	984	984
total resistance for the reference water	E.1	(kN)	1343	1343	1343	1343	1508	1508
ADD, RESISTANCE BY TEMP & DENSITY	E.2	(kN)	-2,53	-2,53	-2,53	-2,53	-2,86	-2,86

ADD, RESISTANCE BY WIND	(kN)	95,91	-61,99	101,38	-64,18	106,54	-73,73	
ADD, RESISTANCE BY WAVE	(kN)	50,72	0,00	50,72	0,00	50,72	0,00	
ADD, RESISTANCE BY SWELL	(kN)	90,17	0,00	90,17	0,00	90,17	0,00	
ADD, RESISTANCE BY TEMP & DENSITY	(kN)	-2,53	-2,53	-2,53	-2,53	-2,86	-2,86	
TOTAL RESISTANCE INCREASE	8	(kN)	234,27	-64,52	239,74	-66,71	244,57	-76,59

DIRECT POWER METHOD							
trialcondition	input		BALLAST	BALLAST	BALLAST	BALLAST	BALLAST
Vs after current iteration	input	(knots)	18,38	18,38	18,38	18,38	19,47
Vs after current iteration	input	(m/s)	9,45	9,45	9,45	9,45	10,02
delivered power in trial condition	input	(kW)	18 018	17 721	18 038	17 741	21 137
propulsive efficiency coefficient in the ideal condition	input	(-)	0,7427	0,7427	0,7427	0,7427	0,7482
parameter derived from the load variation test	input	ξp (ksi-p)	-0,1000	-0,1000	-0,1000	-0,1000	-0,1000
total resistance increase on trial by environmental cond.		(kN)	234,3	-64,5	239,7	-66,7	244,6
total power used to overcome add, resistance during trial	K.4	(kW)	3 348	-899	3 428	-930	3 671
Delivered power in the ideal condition	K.8	(kW)	14 670	18 620	14 609	18 670	21 516

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RESISTANCE BY TEMP & DENSITY								
run number			7	8	9	10	11	12
actual sea water temperature	Input	(°C)	17	17	17	17	17	17
reference sea water temperature	Input	(°C)	15	15	15	15	15	15
actual sea water density	Input	(kg/m ³)	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0
reference sea water density	Input	(kg/m ³)	1 025,8	1 025,8	1 025,8	1 025,8	1 025,8	1 025,8
length between perpendiculars	Input	(m)	266	266	266	266	266	266
total wetted surface	Input	(m ²)	12 410	12 410	12 410	12 410	12 410	12 410
hull roughness in microns	Input	(m ⁻⁶)	150	150	150	150	150	150
Vs after current iteration	F.7	(knots)	19,47	19,47	20,19	20,19	20,19	20,19
Vs after current iteration	F.7	(m/s)	10,02	10,02	10,38	10,38	10,38	10,38
kinematic viscosity actual seawater	E.8	kg/m ²	1,1313E-06	1,1313E-06	1,1313E-06	1,1313E-06	1,1313E-06	1,1313E-06
Reynolds number, actual seawater	E.6	(-)	2,3555E+09	2,3555E+09	2,4416E+09	2,4416E+09	2,4416E+09	2,4416E+09
frictional resistance coefficient for the actual water	E.5	(-)	1,3800E-03	1,3800E-03	1,3742E-03	1,3742E-03	1,3742E-03	1,3742E-03
roughness allowance associated to actual water	E.6	(-)	0,00016	0,00016	0,00016	0,00016	0,00016	0,00016
kinematic viscosity, reference seawater	E.8	kg/m ²	1,1900E-06	1,1900E-06	1,1900E-06	1,1900E-06	1,1900E-06	1,1900E-06
Reynolds number, reference seawater	E.6	(-)	2,2394E+09	2,2394E+09	2,3213E+09	2,3213E+09	2,3213E+09	2,3213E+09
frictional resistance coefficient for the reference water	E.5	(-)	1,3883E-03	1,3883E-03	1,3824E-03	1,3824E-03	1,3824E-03	1,3824E-03
roughness allowance associated to reference water	E.5	(-)	1,5220E-04	1,5220E-04	1,5621E-04	1,5621E-04	1,5621E-04	1,5621E-04
frictional resistance in the actual sea water	E.1	(kN)	982	982	1053	1053	1053	1053
frictional resistance in the reference sea water	E.1	(kN)	984	984	1056	1056	1056	1056
total resistance for the reference water	E.1	(kN)	1508	1508	1640	1640	1640	1640
ADD, RESISTANCE BY TEMP & DENSITY	E.2	(kN)	-2,86	-2,86	-3,10	-3,10	-3,10	-3,10

ADD, RESISTANCE BY WIND	(kN)	104,90	-78,22	116,09	-88,31	128,56	-91,67	
ADD, RESISTANCE BY WAVE	(kN)	50,72	0,00	50,72	0,00	50,72	0,00	
ADD, RESISTANCE BY SWELL	(kN)	90,17	0,00	90,17	0,00	90,17	0,00	
ADD, RESISTANCE BY TEMP & DENSITY	(kN)	-2,86	-2,86	-3,10	-3,10	-3,10	-3,10	
TOTAL RESISTANCE INCREASE	8	(kN)	242,94	-81,08	253,89	-91,41	266,36	-94,77

DIRECT POWER METHOD							
trialcondition	input		BALLAST	BALLAST	BALLAST	BALLAST	BALLAST
Vs after current iteration	input	(knots)	19,47	19,47	20,19	20,19	20,19
Vs after current iteration	input	(m/s)	10,02	10,02	10,38	10,38	10,38
delivered power in trial condition	input	(kW)	21 107	20 543	24 206	23 265	24 235
propulsive efficiency coefficient in the ideal condition	input	(-)	0,7482	0,7482	0,7504	0,7504	0,7504
parameter derived from the load variation test	input	x _p (ksi-p)	-0,1000	-0,1000	-0,1000	-0,1000	-0,1000
total resistance increase on trial by environmental cond,		(kN)	242,9	-81,1	253,9	-91,4	266,4
total power used to overcome add, resistance during trial	K.4	(kW)	3 646	-1 188	3 933	-1 384	4 131
Delivered power in the ideal condition	K.8	(kW)	17 460	21 730	20 272	24 649	20 104

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SHALLOW WATER		1	2	3	4	5	6
run number							
draught at midship	input	(m)	8,58	8,58	8,58	8,58	8,58
ship's speed through the water	input	(knots)	18,38	18,38	18,38	18,38	19,47
ship's speed through the water	input	(m/s)	9,45	9,45	9,45	9,45	10,02
gravitational acceleration	input	(m/s ²)	9,81	9,81	9,81	9,81	9,81
h1	7	(m)	21,45	21,45	21,45	21,45	21,45
h2	7	(m)	21,87	21,87	21,87	21,87	24,56
Max (h1,h2)	7	(m)	21,87	21,87	21,87	21,87	24,56
water depth at S/P trial run	input	(m)	60,00	60,00	60,00	60,00	60,00
Seatrial allowed		(Y/N)	Y	Y	Y	Y	Y
block coefficient	Input	(-)	0,77	0,77	0,77	0,77	0,77
ship's breadth	Input	(m)	42,00	42,00	42,00	42,00	42,00
length of the ship between perpendiculars	Input	(m)	266,00	266,00	266,00	266,00	266,00
draught at midships	Input	(m)	8,58	8,58	8,58	8,58	8,58
ship's form factor (1+k)	G.9		1,191	1,191	1,191	1,191	1,191
water temperature actual water	Input	(°C)	17,00	17,00	17,00	17,00	17,00
water density for the actual water	Input	(kg/m ³)	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0
length of the ship between perpendiculars	Input	(m)	266,00	266,00	266,00	266,00	266,00
hull roughness in microns	Input	(m ⁻⁶)	150	150	150	150	150
kinematic viscosity for the actual water	E.8	kg/m ²	1,1313E-06	1,1313E-06	1,1313E-06	1,1313E-06	1,1313E-06
Reynolds number for the actual water	G.7	(-)	2,2226E+09	2,2226E+09	2,2226E+09	2,2226E+09	2,3555E+09
flat plate viscous resistance coeff, for the actual water	G.6	(-)	1,3895E-03	1,3895E-03	1,3895E-03	1,3895E-03	1,3800E-03
roughness allowance with Reynolds Nr,for actual water	G.8	(-)	0,00015	0,00015	0,00015	0,00015	0,00016
viscous resistance coefficient in deep water	G.5	(-)	0,0019	0,0019	0,0019	0,0019	1,8994E-03
water density for the actual water	Input	(kg/m ³)	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0
ship's speed through water	input	(m/s)	9,45	9,45	9,45	9,45	10,02
the wetted surface at zero speed condition	input	(m ²)	12 410	12 410	12 410	12 410	12 410
ship's viscous resistance in deep water	G.4	(kN)	1 082,61	1 082,61	1 082,61	1 082,61	1 212,43
increase of viscous resistance in shallow water	G.3	(kN)	18,98	18,98	18,98	18,98	21,26
water depth at S/P trial run	input	(m)	60,00	60,00	60,00	60,00	60,00
length of the ship between perpendiculars	input	(m)	266,00	266,00	266,00	266,00	266,00
Froude number based on a water depth of 0,3 LPP	G.13	Frhd	0,3379	0,3379	0,3379	0,3379	0,3581
Froude number based on water depth	G.13	Frh	0,3897	0,3897	0,3897	0,3897	0,4130
moulded displaced volume of the vessel at trial draught	input	(m ³)	73 826	73 826	73 826	73 826	73 826
water plane area at the trial draught	input	(m ²)	8 937	8 937	8 937	8 937	8 937
ship's increase of the dynamic sinkage	G.12	(m)	0,0664	0,0664	0,0664	0,0664	0,0761
ship's additional displacement volume due to sinkage	G.11	(%)	0,80	0,80	0,80	0,80	0,92
ship's additional displacement volume due to sinkage		(%)	0,80	0,80	0,80	0,80	0,92
sinkage displacement effect	G.10	(-)	1,0054	1,0054	1,0054	1,0054	1,0061
delivered trial power after wind, wave and TD corr			14 670	18 620	14 609	18 670	17 465
increase of viscous resistance in shallow water	G.3	(kN)	18,98	18,98	18,98	18,98	21,26
validity check viscous resistance			OK	OK	OK	OK	OK
ship's speed through the water	input	(m/s)	9,45	9,45	9,45	9,45	10,02
propulsive efficiency coefficient	input	(-)	0,7427	0,7427	0,7427	0,7427	0,7482
power correction because of shallow water		(kW)	320	341	319	341	391
CORRECTED POWER AFTER SHALLOW WATER	G.1	(kW)	14 351	18 280	14 290	18 329	17 075

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SHALLOW WATER		7	8	9	10	11	12	
run number		7	8	9	10	11	12	
draught at midship	input	(m)	8,58	8,58	8,58	8,58	8,58	
ship's speed through the water	input	(knots)	19,47	19,47	20,19	20,19	20,19	
ship's speed through the water	input	(m/s)	10,02	10,02	10,38	10,38	10,38	
gravitational acceleration	input	(m/s ²)	9,81	9,81	9,81	9,81	9,81	
h1	7	(m)	21,45	21,45	21,45	21,45	21,45	
h2	7	(m)	24,56	24,56	26,39	26,39	26,39	
Max (h1,h2)	7	(m)	24,56	24,56	26,39	26,39	26,39	
water depth at S/P trial run	input	(m)	60,00	60,00	60,00	60,00	60,00	
Seatrial allowed		(Y/N)	Y	Y	Y	Y	Y	
block coefficient	Input	(-)	0,77	0,77	0,77	0,77	0,77	
ship's breadth	Input	(m)	42,00	42,00	42,00	42,00	42,00	
length of the ship between perpendiculars	Input	(m)	266,00	266,00	266,00	266,00	266,00	
draught at midships	Input	(m)	8,58	8,58	8,58	8,58	8,58	
ship's form factor (1+k)	G.9		1,191	1,191	1,191	1,191	1,191	
water temperature actual water	Input	(°C)	17,00	17,00	17,00	17,00	17,00	
water density for the actual water	Input	(kg/m ³)	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0	
length of the ship between perpendiculars	Input	(m)	266,00	266,00	266,00	266,00	266,00	
hull roughness in microns	Input	(m ⁻⁶)	150	150	150	150	150	
kinematic viscosity for the actual water	E.8	kg/m ²	1,1313E-06	1,1313E-06	1,1313E-06	1,1313E-06	1,1313E-06	
Reynolds number for the actual water	G.7	(-)	2,3555E+09	2,3555E+09	2,4416E+09	2,4416E+09	2,4416E+09	
flat plate viscous resistance coeff, for the actual water	G.6	(-)	1,3800E-03	1,3800E-03	1,3742E-03	1,3742E-03	1,3742E-03	
roughness allowance with Reynolds Nr,for actual water	G.8	(-)	0,00016	0,00016	0,00016	0,00016	0,00016	
viscous resistance coefficient in deep water	G.5	(-)	1,8994E-03	1,8994E-03	1,8960E-03	1,8960E-03	1,8960E-03	
water density for the actual water	Input	(kg/m ³)	1 025,0	1 025,0	1 025,0	1 025,0	1 025,0	
ship's speed through water	input	(m/s)	10,02	10,02	10,38	10,38	10,38	
the wetted surface at zero speed condition	input	(m ²)	12 410	12 410	12 410	12 410	12 410	
ship's viscous resistance in deep water	G.4	(kN)	1 212,43	1 212,43	1 300,44	1 300,44	1 300,44	
increase of viscous resistance in shallow water	G.3	(kN)	21,26	21,26	22,80	22,80	22,80	
water depth at S/P trial run	input	(m)	60,00	60,00	60,00	60,00	60,00	
length of the ship between perpendiculars	input	(m)	266,00	266,00	266,00	266,00	266,00	
Froude number based on a water depth of 0,3 LPP	G.13	Frhd	0,3581	0,3581	0,3712	0,3712	0,3712	
Froude number based on water depth	G.13	Frh	0,4130	0,4130	0,4281	0,4281	0,4281	
moulded displaced volume of the vessel at trial draught	input	(m ³)	73 826	73 826	73 826	73 826	73 826	
water plane area at the trial draught	input	(m ²)	8 937	8 937	8 937	8 937	8 937	
ship's increase of the dynamic sinkage	G.12	(m)	0,0761	0,0761	0,0829	0,0829	0,0829	
ship's additional displacement volume due to sinkage	G.11	(%)	0,92	0,92	1,00	1,00	1,00	
ship's additional displacement volume due to sinkage		(%)	0,92	0,92	1,00	1,00	1,00	
sinkage displacement effect	G.10	(-)	1,0061	1,0061	1,0067	1,0067	1,0067	
delivered trial power after wind, wave and TD corr			17 460	21 730	20 272	24 649	20 104	24 719
increase of viscous resistance in shallow water	G.3	(kN)	21,26	21,26	22,80	22,80	22,80	22,80
validity check viscous resistance			OK	OK	OK	OK	OK	
ship's speed through the water	input	(m/s)	10,02	10,02	10,38	10,38	10,38	
propulsive efficiency coefficient	input	(-)	0,7482	0,7482	0,7504	0,7504	0,7504	
power correction because of shallow water		(kW)	391	417	450	479	449	480
CORRECTED POWER AFTER SHALLOW WATER	G.1	(kW)	17 070	21 314	19 822	24 170	19 656	24 240

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1 2 3 4 5 6

DISPLACEMENT CORRECTION								
run number			1	2	3	4	5	6
displacement volume during the trial	Input	(m ³)	73 826	73 826	73 826	73 826	73 826	73 826
displacement volume during tank tests		(m ³)	73 500	73 500	73 500	73 500	73 500	73 500
displacement factor	H.1	(-)	0,9971	0,9971	0,9971	0,9971	0,9971	0,9971
power after shallow water correction		(kW)	14 351	18 280	14 290	18 329	17 075	21 101
additional power for displacement correction		(kW)	-42	-54	-42	-54	-50	-62
CORRECTED POWER AFTER DISPLACEMENT CORR	H.1	(kW)	14 308	18 226	14 248	18 275	17 024	21 039

CALCULATING PROPELLER REVOLUTIONS								
measured Propeller shaft speed in trial condition	input	(rpm)	85,3	85,3	85,3	85,3	90,2	90,2
delivered power in ideal condition		(kW)	14 308	18 226	14 248	18 275	17 024	21 039
delivered power imeasured in trial condition	input	(kW)	18 018	17 721	18 038	17 741	21 137	20 394
parameter derived from the load variation test	Input	ξ _n (ksi-n)	0,2000	0,2000	0,2000	0,2000	0,2000	0,2000
Corrected propeller rpm in ideal condition	K.11	(rpm)	81,1	85,8	81,0	85,8	86,0	90,8

Final results S/P trials MoM speed	(knots)	18,38	18,38	18,38	18,38	19,47	19,47
Final results S/P trials MoM speed	(m/s)	9,45	9,45	9,45	9,45	10,02	10,02
Final results S/P trials Engine power	(kW)	16 251	16 251	16 251	16 251	19 056	19 056
Final results S/P trials rpm	(rpm)	83,4	83,4	83,4	83,4	88,4	88,4

DETERMINE POWERFACTORS FOR SHIFTING TANKCURVE							
Trial MoM Speed	(knots)	18,38	18,38	18,38	18,38	19,47	19,47
Trial Power at MoM speed	(kW)	16 251	16 251	16 251	16 251	19 056	19 056
Trial shaft power at MoM speed	(kW)	16 415	16 415	16 415	16 415	19 249	19 249
Tank shaft power at MoM speed	(kW)	17 265	17 265	17 265	17 265	20 392	20 392
Power factor (P _{trial} /P _{tank})	(-)	0,9413	0,9413	0,9413	0,9413	0,9345	0,9345
Weighted power factor	(-)	0,9433	0,9433	0,9433	0,9433	0,9433	0,9433

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7 8 9 10 11 12

DISPLACEMENT CORRECTION								
run number			7	8	9	10	11	12
displacement volume during the trial	Input	(m ³)	73 826	73 826	73 826	73 826	73 826	73 826
displacement volume during tank tests		(m ³)	73 500	73 500	73 500	73 500	73 500	73 500
displacement factor		(-)	0,9971	0,9971	0,9971	0,9971	0,9971	0,9971
power after shallow water correction	H.1	(kW)	17 070	21 314	19 822	24 170	19 656	24 240
additional power for displacement correction		(kW)	-50	-63	-58	-71	-58	-71
CORRECTED POWER AFTER DISPLACEMENT CORR	H.1	(kW)	17 020	21 251	19 764	24 099	19 598	24 169

CALCULATING PROPELLER REVOLUTIONS								
measured Propeller shaft speed in trial condition	input	(rpm)	90,2	90,2	94,9	94,9	94,9	94,9
delivered power in idelal condition		(kW)	17 020	21 251	19 764	24 099	19 598	24 169
delivered power imeasured in trial condition	input	(kW)	21 107	20 543	24 206	23 265	24 235	23 285
parameter derived from the load variation test	Input	(-)	0,2000	0,2000	0,2000	0,2000	0,2000	0,2000
Corrected propeller rpm in ideal condition	K.1.1	(rpm)	86,1	90,8	90,8	95,6	90,6	95,6

Final results S/P trials MoM speed	(knots)	19,47	19,47	20,19	20,19	20,19	20,19
Final results S/P trials MoM speed	(m/s)	10,02	10,02	10,38	10,38	10,38	10,38
Final results S/P trials Engine power	(kW)	19 056	19 056	21 878	21 878	21 878	21 878
Final results S/P trials rpm	(rpm)	88,4	88,4	93,1	93,1	93,1	93,1

DETERMINE POWERFACTORS FOR SHIFTING TANKCURVE								
Trial MoM Speed	(knots)	19,47	19,47	20,19	20,19	20,19	20,19	
Trial Power at MoM speed	(kW)	19 056	19 056	21 878	21 878	21 878	21 878	
Trial shaft power at MoM speed	(kW)	19 249	19 249	22 099	22 099	22 099	22 099	
Tank shaft power at MoM speed	(kW)	20 392	20 392	22 929	22 929	22 929	22 929	
Power factor (P _{trial} /P _{tank})	(-)	0,9345	0,9345	0,9542	0,9542	0,9542	0,9542	
Weighted power factor	(-)	0,9433	0,9433	0,9433	0,9433	0,9433	0,9433	

Tank speeds	(knots)	16	17	18	19	20	21
Tank shaft power in contract condition	(kW)	13 901	16 206	18 609	21 531	25 173	29 828
Tank shaft power corrected with power factor	(kW)	13 113	15 287	17 554	20 311	23 746	28 137
Service shaft power corrected	(kW)	15 080	17 581	20 187	23 357	27 308	32 358

Contract service power	Input	(kW)	21 437
Contract service speed	Input	(knots)	17,80
Propeller rpm at service speed	Input	(rpm)	84,0
Achieved service speed at contract power		(knots)	18,42

Figure 10 — Example calculation of speed trial data analysis

Annex A
(normative)

Trial log sheet

GENERAL INFORMATION		
Ship name		
IMO No.		
Shipbuilder		
Yard number		
Shipowner		
Trial Team Leader		
Verifier		
L_{PP}		[m]
B (moulded)		[m]
P_{SMCR}		[kW]
n_{MCR}		[rpm]
P_{SNCR}		[kW]
n_{NCR}		[rpm]
(η_S) Shaft efficiency		[-]
Shaft diameter (inside)		[m]
Shaft diameter (outside)		[m]
G Modulus shaft (Default 82 400)		[N/mm ²]
Number of propellers		[-]
Type of propellers		[FPP or CPP]
Diameter propeller(s)		[m]
Design pitch (FPP)		[m]
Direction of rotation		R/L
Number of blades		[-]
Propeller(s) polished		[dd-mm-yy]

CONTRACT LOADING CONDITION		
	Draught condition at contract	
T_F	Draught fore	[m]
T_A	Draught aft	[m]
	Displacement moulded	[m ³]
	Transverse projected wind area	[m ²]
	Sea margin	[%]
	$P_{SContract}$	[kW]
	$n_{Contract}$	[-]
	V_S service, contract	[kn]
	True wind speed	[m/s]
	Significant wave height	[m]
	Wave period	[s]
AIR	Z_{ref}	[m]
	Air temperature	[°C]
	Air pressure	[mBar]
WATER	Sea water temperature	[°C]
	Sea water density	[kg/m ³]

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TRIAL CONDITION AS DESCRIBED IN THE CONTRACT			
Draught condition at trial			
Hull	$T_{F-Tanktest}$		[m]
	$T_{A-Tanktest}$		[m]
	V_{ref}		[m ³]

EEDI LOADING CONDITION		
T_F moulded at forward perpendicular		[m]
T_A moulded at aft perpendicular		[m]
Displacement moulded		[m ³]
M/E shaft power at EEDI condition		[kW]

HULL CONDITION AT S/P TRIAL AREA				
Draught	PS	SB	Aver.	
T_F moulded at forward perpendicular				[m]
T_M moulded				[m]
T_A moulded at aft perpendicular				[m]
Moulded displacement volume (V_{act})				[m ³]
Waterplane area (A_W)				[m ²]
Block coefficient (C_B)				[-]
k_{yy}/L_{PP}				[-]
Midship section area under water (A_M)				[m ²]
Total wetted surface (S)				[m ²]
Transverse projected wind area (A_{XV})				[m ²]
Vertical position of anemometer above waterline (Z_a)				[m]
Last day of hull cleaning				[dd-mm-yyyy]

DATA AT S/P TRIAL AREA		
Weather condition		Visual
Latitude		[dd-mm]
Longitude		[ddd-mm]
Sea trial Site		
Beaufort number		[-]
Wave height		
Swell height		
Torsion meter zero setting		Y / N
t_A Air temperature		[°C]
t_W Water temperature		[°C]
ρ_{act} Water density		[kg/m ³]
Atmospheric pressure		[hPa, mBar]

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WIND DATA		
Lateral projected wind area above waterline (Fujiwara)		[m ²]
Lateral projected wind area of the superstructures above (Fujiwara)		[m ²]
C_{MC} (Fujiwara)		[m]
H_C (Fujiwara)		[m]
Number of reference vessel in the database		[-]
WAVE DATA		
Bow length for STAWAVE 1 (L_{BWL})		[m]
Heave or pitch motions during trials		
Wave observation method		
LOAD VARIATION TEST		
Overload factors provided by Tank tests		
ξ_p Propulsion (ksi-p)	ξ_n Revolutions (ksi-n)	

TANK TEST PREDICTIONS

BALLAST DRAUGHT (Non EEDI). Tank test predictions (Speed, power, efficiency)

V_s	(knots)																		
P_{Sid}	(kW)																		
n_{id}	[rpm]																		
η_{Did}	[-]																		

FULL DRAUGHT (Non EEDI). Tank test predictions (Speed, power, efficiency)

V_s	(knots)																		
P_{Sid}	(kW)																		
n_{id}	[rpm]																		
η_{Did}	[-]																		

EEDI DRAUGHT. Tank test predictions (Speed, power, efficiency)

V_s	(knots)																		
P_{Sid}	(kW)																		
n_{id}	[rpm]																		
η_{Did}	[-]																		

WIND PROFILE from wind tunnel test at trial condition

(degrees)																			
C_{AA}																			

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WIND PROFILE from wind tunnel test at contract condition

(degrees)														
C_{AA}														

MEASURED AND OBSERVED DATA ON TRIAL

Run number		1	2	3	4	5	6	7	8	9	10	11	12
Power setting	% MCR												
Date	dd-mmm-yyyy												
Start time of run	hh:mm:ss												
Run duration	mm:ss												
Run direction. based on dominant [Wave / Wind]													
Run direction [Against /Follow]													
Ship's heading during run	[°]												
Ship speed over the ground	[knots]												
Relative wind at anemometer height	Velocity	[m/s]											
	Direction	[°]											
Wind waves	Height	[m]											
	Direction	[°]											
	Period	[s]											
Swell	Height	[m]											
	Direction	[°]											
	Period	[s]											
Propeller	Brake power	[kW]											
	Shaft speed	[rpm]											
	Pitch of CPP	[°]											
Water depth	[m]												

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Annex B
(informative)

Beaufort scale for wind velocity and Sea state scale

Tables B.1 and B.2 are intended as a guide to roughly show what can be expected in the open sea, remote from land. These tables shall never be used in the reverse way, i.e. for logging or reporting the state of the sea. In enclosed waters, or when near land, with an offshore wind, wave heights will be smaller and the waves steeper. Figures in brackets indicate the probable maximum height of waves.^[13]

Table B.1 — Beaufort Scale

a	Descriptive term	Velocity equivalent at a standard height of 10 m above open flat ground				Specifications			Probable wave height	
		Mean velocity in knots	m s ⁻¹	km h ⁻¹	m.p.h.	Land	Sea	Coast	m	ft
0	Calm	<1	0-0,2	<1	<1	Calm: smoke rises vertically	Sea like a mirror	Calm	-	-
1	Light air	1-3	0,3-1,5	1-5	1-3	Direction of wind shown by smoke drift but not by wind vanes	Ripples with the appearance of scales are formed, but without foam crests	Fishing smack just has steerage way	0,1 (0,1)	0,25 (0,25)
2	Light breeze	4-6	1,6-3,3	6-11	4-7	Wind felt on face; leaves rustle; ordinary vanes moved by wind	Small wavelets, still short but more pronounced; crests have a glassy appearance and do not break	Of smacks which then travel at about 1-2 kn	0,2 (0,3)	0,5 (1)
3	Gentle breeze	7-10	3,4-5,4	12-19	8-12	Leaves and small twigs in constant motion; wind extends light flag	Large wavelets; crests begin to break; foam of glassy appearance; perhaps scattered white horses	Smacks begin to careen and travel about 3 kn-4 kn	0,6 (1)	2 (3)
4	Moderate breeze	11-16	5,5-7,9	20-28	13-18	Raises dust and loose paper; small branches are moved	Small waves, becoming longer; fairly frequent white horses	Good working breeze, smacks carry all canvas with good list	1 (1,5)	3,5 (5)
5	Fresh breeze	17-21	8,0-10,7	29-38	19-24	Small trees in leaf begin to sway; crested wavelets form on inland waters	Moderate waves, taking a more pronounced long form; many white horses are formed (chance of some spray)	Smacks shorten sail	2 (2,5)	6 (8,5)
6	Strong breeze	22-27	10,8-13,8	39-49	25-31	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty	Large waves begin to form; the white foam crests are more extensive everywhere (probably some spray)	Smacks have double reef in mainsail; care required when fishing	3 (4)	9,5 (13)
7	Near gale	28-33	13,9-17,1	50-61	32-38	Whole trees in motion; inconvenience felt when walking against wind	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind	Smacks remain in harbour and those at sea lie to	4 (5,5)	13,5 (19)

^a Beaufort number.

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Table B.1 (continued)

a	Descriptive term	Velocity equivalent at a standard height of 10 m above open flat ground				Specifications			Probable wave height	
		Mean velocity in knots	m s ⁻¹	km h ⁻¹	m.p.h.	Land	Sea	Coast	m	ft
8	Gale	34–40	17,2–20,7	62–74	39–46	Breaks twigs off trees; generally impedes progress	Moderately high waves of greater length; edges of crests begin to break into the spindrift; the foam is blown in well-marked streaks along the direction of the wind	All smacks make for harbour, if near	5,5 (7,5)	18 (25)
9	Strong gale	41–47	20,8–24,4	75–88	47–54	Slight structural damage occurs (chimney pots and slates removed)	High waves; dense streaks of foam along the direction of the wind; crests of waves begin to topple, tumble and roll over; spray may affect visibility	-	7 (10)	23 (32)
10	Storm	48–55	24,5–28,4	89–102	55–63	Seldom experienced inland; trees uprooted; considerable structural damage occurs	Very high waves with long over-hanging crests; the resulting foam, in great patches, is blown in dense white streaks along the direction of the wind; overall, the surface of the sea takes on a white appearance; the tumbling of the sea becomes heavy and shock-like; visibility affected	-	9 (12,5)	29 (41)
11	Violent storm	55–63	28,5–32,6	103–117	64–72	Very rarely experienced; accompanied by wide-spread damage	Exceptionally high waves (small and medium-sized ships might be for a time lost to view behind the waves); the sea is completely covered with long white patches of foam lying along the direction of the wind; everywhere the edges of the wave crests are blown into froth; visibility affected	-	11,5 (16)	37 (52)
12	Hurricane	64 and over	32,7 and over	118 and over	73 and over	-	The air is filled with foam and spray; sea completely white with driving spray; visibility very seriously affected	-	14 (-)	45 (-)

a Beaufort number.

Table B.2 — State of the Sea

Code	Descriptive terms	Wave heights ^a		
		m		
0	Calm (glassy)	0	—	—
1	Calm (rippled)	0	—	0,1
2	Smooth (wavelets)	0,1	—	0,5
3	Slight	0,5	—	1,25
4	Moderate	1,25	—	2,5
5	Rough	2,5	—	4
6	Very rough	4	—	6
7	High	6	—	9
8	Very high	9	—	14
9	Phenomenal	Over	—	14

^a These values refer to well-developed wind waves of the open sea. While priority shall be given to the descriptive terms, these height values may be used for guidance by the observer when reporting the total state of agitation of the sea resulting from various factors such as wind, swell, currents, angle between swell and wind, etc.

The bound of the wave height shall be assigned for the lower code figure, e.g. a height of 4 m is coded as 5.

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Annex C (normative)

Correction for wind

C.1 General

The resistance increase due to wind is calculated by [Formula \(C.1\)](#):

$$R_{AA} = 0,5 \rho_A \cdot C_{AA}(\psi_{WRef}) \cdot A_{XV} \cdot V_{WRef}^2 - 0,5 \rho_A \cdot C_{AA}(0) \cdot A_{XV} \cdot V_G^2 \quad (C.1)$$

where

- R_{AA} is the resistance increase due to relative wind, expressed in newtons;
- A_{XV} is the transverse projected area above the waterline including superstructures, expressed in square metres;
- C_{AA} is the wind resistance coefficient; $C_{AA}(0)$ means the wind resistance coefficient in head wind;
- V_G is the measured ship speed over ground, expressed in metres per second;
- V_{WRef} is the relative wind velocity at the reference height, expressed in metres per second;
- ρ_A is the mass density of air, expressed in kilograms per cubic metre;
- ψ_{WRef} is the relative wind direction at the reference height, expressed in degrees.

NOTE Zero (0) degrees refers to the wind incoming on the bow and a positive angle refers to wind coming in from starboard

The evaluation of wind data is explained in detail in [C.2](#).

The mass density of air can be calculated using [Formula \(C.2\)](#):

$$\rho_A = p_A / [2,870 5 (t_A + 273,15)] \quad (C.2)$$

where

- ρ_A is the mass density of air, expressed in kilograms per cubic metre;
- p_A is the air pressure at S/P trial run, expressed in hPa (or millibar);
- t_A is the air temperature at S/P trial run, expressed in degrees Celsius.

The wind resistance coefficient is based on the data derived from model tests in a wind tunnel. In cases where a database is available covering ships of similar type, such data may be used instead of carrying out wind tunnel model tests. Alternatively, statistical regression formulae concerning wind resistance coefficients of various ship types have been developed.

C.2 Evaluation of wind data

C.2.1 General

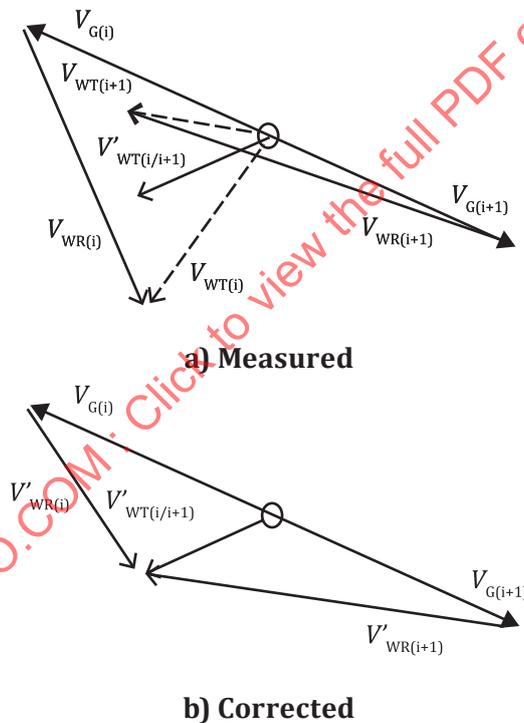
By nature, wind velocity and direction vary in time and therefore they are defined by their mean value over a selected period.

For S/P trials, it is assumed that the wind condition is steady, i.e. that velocity and direction are reasonably constant over the duration of each run. The mean values of direction and velocity recorded during every run are then used as the values for that run.

C.2.2 Averaging process for the true wind velocity and direction

During each S/P run, the relative wind velocity and direction shall be measured as described in 9.3.3.

The true wind vector for each speed run is found from certified measuring instruments that can measure the wind ahead of the vessel and outside the area where airflow is distorted (e.g. LIDAR) or from the relative wind velocity measured and relative wind direction measured at the ship's mast considering the heading and speed over ground. In the latter case, the true wind vector for the run-set is found by averaging the true wind vectors over both speed runs of the double run (see Figure C.1). This run-set averaged true wind vector shall be used to recalculate the relative wind vector for each speed run of the set.



Key

- V_G measured ship speed over ground, expressed in metres per second
- V_{WR} mean value of the measured relative wind velocity at anemometer height, expressed in metres per second
- V_{WT} true wind velocity at anemometer height, expressed in metres per second
- V'_{WT} averaged true wind velocity at anemometer height, expressed in metres per second
- V'_{WR} corrected relative wind velocity at anemometer height, expressed in metres per second
- ψ_{WT} true wind direction at anemometer height in Earth system, expressed in degrees

Figure C.1 — True wind vectors and relative wind vectors

The true wind velocity and direction at the vertical position of the anemometer are calculated by using [Formulae \(C.3\)](#) and [\(C.4\)](#):

$$V_{WT} = \left[V_{WR}^2 + V_G^2 - 2V_{WR}V_G \cos\psi_{WR} \right] \quad (C.3)$$

$$\psi_{WT} = \text{atan} \left[\frac{V_{WR} \sin(\psi_{WR} + \psi) - V_G \sin(\psi)}{V_{WR} \cos(\psi_{WR} + \psi) - V_G \cos(\psi)} \right] \text{ for } V_{WR} \cos(\psi_{WR} + \psi) - V_G \cos(\psi) \geq 0,$$

$$\psi_{WT} = \text{atan} \left[\frac{V_{WR} \sin(\psi_{WR} + \psi) - V_G \sin(\psi)}{V_{WR} \cos(\psi_{WR} + \psi) - V_G \cos(\psi)} \right] + 180$$

$$\text{for } V_{WR} \cos(\psi_{WR} + \psi) - V_G \cos(\psi) < 0 \quad (C.4)$$

where

V_G is the measured ship speed over ground, expressed in metres per second;

V_{WR} is the mean value of the measured relative wind velocity at anemometer height, expressed in metres per second;

V_{WT} is the true wind velocity at anemometer height, expressed in metres per second;

ψ is the ship's compass heading, expressed in degrees;

ψ_{WR} is the mean value of the relative wind direction at anemometer height, expressed in degrees;

NOTE Zero (0) degrees refers to the wind incoming on the bow and a positive angle refers to wind coming in from starboard.

ψ_{WT} is the true wind direction at anemometer height in Earth system, expressed in degrees.

The true wind velocity and direction are corrected by an averaging process over both runs of the double run using [Formulae \(C.5\)](#), [\(C.6\)](#), [\(C.7\)](#) and [\(C.8\)](#):

$$V'_{WT(i/i+1)} = \sqrt{\left[\frac{V_{WT(i)} \cos\psi_{WT(i)} + V_{WT(i+1)} \cos\psi_{WT(i+1)}}{2} \right]^2 + \left[\frac{V_{WT(i)} \sin\psi_{WT(i)} + V_{WT(i+1)} \sin\psi_{WT(i+1)}}{2} \right]^2} \quad (C.5)$$

$$\psi'_{WT(i/i+1)} = \text{atan} \left[\frac{V_{WT(i)} \sin\psi_{WT(i)} + V_{WT(i+1)} \sin\psi_{WT(i+1)}}{V_{WT(i)} \cos\psi_{WT(i)} + V_{WT(i+1)} \cos\psi_{WT(i+1)}} \right]$$

$$\text{for } V_{WT(i)} \cos\psi_{WT(i)} + V_{WT(i+1)} \cos\psi_{WT(i+1)} \geq 0,$$

$$\psi'_{WT(i/i+1)} = \text{atan} \left[\frac{V_{WT(i)} \sin\psi_{WT(i)} + V_{WT(i+1)} \sin\psi_{WT(i+1)}}{V_{WT(i)} \cos\psi_{WT(i)} + V_{WT(i+1)} \cos\psi_{WT(i+1)}} \right] + 180$$

$$\text{for } V_{WT(i)} \cos\psi_{WT(i)} + V_{WT(i+1)} \cos\psi_{WT(i+1)} < 0 \quad (C.6)$$

$$V'_{WR(i)} = \sqrt{V'^2_{WT(i)} + V_{G(i)}^2 + 2V'_{WT(i)}V_{G(i)} \cos[\psi'_{WT(i)} - \psi(i)]} \quad (C.7)$$

$$\psi'_{WR(i)} = \text{atan} \left\{ \frac{V'_{WT(i)} \sin[\psi'_{WT(i)} - \psi(i)]}{V_{G(i)} + V'_{WT(i)} \cos[\psi'_{WT(i)} - \psi(i)]} \right\}$$

$$\text{for } V_{G(i)} + V'_{WT(i)} \cos[\psi'_{WT(i)} - \psi(i)] \geq 0,$$

$$\psi'_{WR(i)} = \text{atan} \left\{ \frac{V'_{WT(i)} \sin[\psi'_{WT(i)} - \psi(i)]}{V_{G(i)} + V'_{WT(i)} \cos[\psi'_{WT(i)} - \psi(i)]} \right\} + 180 \text{ for } V_{G(i)} + V'_{WT(i)} \cos[\psi'_{WT(i)} - \psi(i)] < 0 \quad (\text{C.8})$$

where

V_G is the measured ship speed over ground, expressed in metres per second;

V_{WT} is the true wind velocity at anemometer height, expressed in metres per second;

V'_{WT} is the averaged true wind velocity at anemometer height, expressed in metres per second;

V'_{WR} is the corrected relative wind velocity at anemometer height, expressed in metres per second;

ψ is the ship's compass heading, expressed in degrees;

ψ_{WT} is the true wind direction at anemometer height in Earth system, expressed in degrees;

ψ'_{WT} is the averaged true wind direction at anemometer height, expressed in degrees;

ψ'_{WR} is the corrected relative wind direction at anemometer height, expressed in degrees;

NOTE Zero (0) degrees refers to the wind incoming on the bow and a positive angle refers to wind coming in from starboard.

(i) is the run number.

And then true wind velocity $V_{WT(i)}$, true wind direction $\psi_{WT(i)}$, relative wind velocity $V_{WR(i)}$ and relative wind direction $\psi_{WR(i)}$ are replaced by $V'_{WT(i)}$, $\psi'_{WT(i)}$, $V'_{WR(i)}$ and $\psi'_{WR(i)}$.

The true wind velocity and directions shall be checked by taking the following into consideration:

- the consistency of the curves of true wind velocity and direction with time during each run;
- the consistency of the curves of air temperature and atmospheric pressure with time during each run;
- publicly available weather information.

C.2.3 Correction for the vertical position of the anemometer

The wind effect on the ship consists of two components: shear flow and uniform flow. Shear flow is the natural wind. Uniform flow is the relative speed between still air and the ship's own motion.

To calculate the wind resistance, use the wind velocity and direction at the reference height of the wind tunnel tests, on which the wind resistance coefficients are based. Therefore, the wind velocity and direction at the vertical position of the anemometer shall be corrected to those at the reference height.

The reference height for the wind coefficients is 10 m above sea level.

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The difference between the vertical position of the anemometer and the reference height for the wind resistance shall be corrected by means of the wind velocity profile given by [Formula \(C.9\)](#):

$$V_{WTref} = V_{WT} \left(\frac{Z_{ref}}{Z_a} \right)^{\frac{1}{9}} \quad (C.9)$$

where

V_{WTref} is the true wind velocity at the reference height, expressed in metres per second;

V_{WT} is the true wind velocity at anemometer height, expressed in metres per second;

Z_{ref} is the reference height for the wind resistance coefficients, expressed in metres;

Z_a is the vertical position of the anemometer, expressed in metres.

The reference height for the wind resistance coefficients, Z_{ref} , is selected as the corresponding height for the wind resistance coefficient from wind tunnel tests.

The evaluation of the maximum allowable calculated true wind velocity, V_{WTref} , [[Formula \(C.9\)](#)] shall be done in accordance with [8.3](#).

The relative wind velocity at the reference height is calculated by [Formula \(C.10\)](#):

$$V_{WRref} = \sqrt{V_{WTref}^2 + V_G^2 + 2V_{WTref}V_G \cos(\psi_{WT} - \psi)} \quad (C.10)$$

The relative wind direction at the reference height is calculated by [Formula \(C.11\)](#):

$$\psi_{WRref} = \text{atan} \left[\frac{V_{WTref} \sin(\psi_{WT} - \psi)}{V_G + V_{WTref} \cos(\psi_{WT} - \psi)} \right] \text{ for } V_G + V_{WTref} \cos(\psi_{WT} - \psi) \geq 0,$$

$$\psi_{WRref} = \text{atan} \left[\frac{V_{WTref} \sin(\psi_{WT} - \psi)}{V_G + V_{WTref} \cos(\psi_{WT} - \psi)} \right] + 180 \text{ for } V_G + V_{WTref} \cos(\psi_{WT} - \psi) < 0 \quad (C.11)$$

where

V_G is the measured ship speed over ground, expressed in metres per second;

V_{WRref} is the relative wind velocity at the reference height, expressed in metres per second;

V_{WTref} is the true wind velocity at the reference height, expressed in metres per second;

ψ is the ship's compass heading, expressed in degrees;

ψ_{WRref} is the relative wind direction at the reference height, expressed in degrees;

NOTE Zero (0) degrees refers to the wind incoming on the bow and a positive angle refers to wind coming in from starboard.

ψ_{WT} is the true wind direction at anemometer height in Earth system, expressed in degrees.

C.3 Wind resistance coefficients

C.3.1 General

The wind resistance coefficients C_{AA} determined by the methods in [C.3.2](#), [C.3.3](#), [C.3.4](#) and [C.3.5](#) shall be used.

C.3.2 Wind tunnel test

If wind tunnel test results are available, the wind resistance coefficients evaluated by these tests shall be used.

C.3.3 Wind resistance coefficients by CFD

Wind resistance coefficients derived from a computational fluid dynamics (CFD) viscous flow solver are acceptable provided that the CFD code and the user have demonstrated verification and validation against qualified wind tunnel results for similar ships.

C.3.4 Data set on the wind resistance coefficient

A data set of wind resistance coefficients, C_{AA} , has been prepared by STA-JIP^[12] and others. Data are available for: tankers, LNG carriers, container ships, car carriers, ferry/cruise ships, bulkers and general cargo ships as shown in [Table C.1](#). The wind resistance coefficients, C_{AA} , for ships in the data set, are shown in [Tables C.2](#) to [C.18](#). Graphs of these coefficients as a function of the angle of attack are presented in [Figures C.2](#) to [C.18](#).

Before making use of these coefficients, the ship type, shape and outfitting shall be carefully evaluated and compared with the geometry of the ship for which the data set has been prepared. The images of these ships are presented in [Figures C.2](#) to [C.18](#).

The data provided is limited to common ship types at the time of publication of this document. The database is not suitable for special ships such as tugs, offshore supply vessels, fishery vessels and fast craft, all of which have very individual geometries.

Table C.1 — Ship types included in the data set

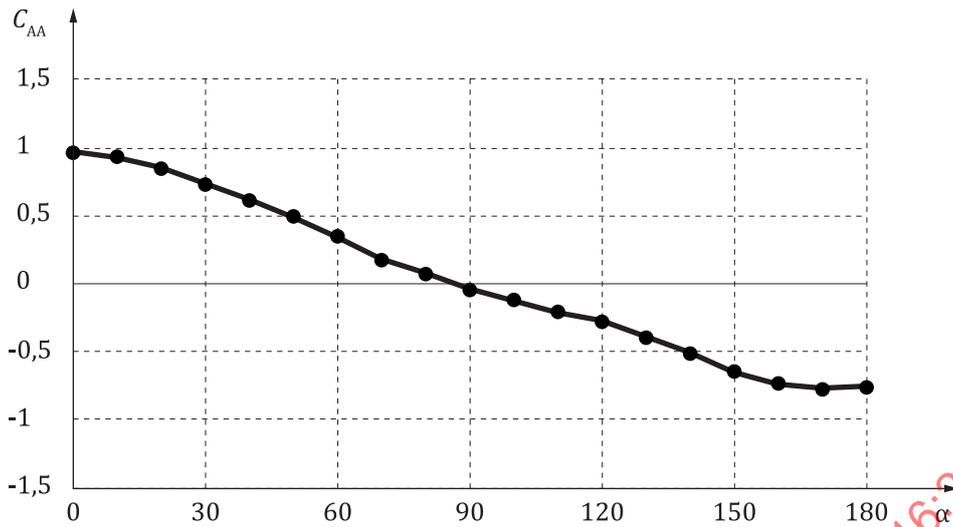
Table	Figure	Ship type	LC	Superstructure	Vessel	Reference
C.2	C.2	Tanker conventional bow	Laden	Normal	280 kDWT	Wind tunnel [3]
C.2	C.2	Tanker conventional bow	Ballast	Normal	280 kDWT	Wind tunnel [3]
C.3	C.3	Tanker cylindrical bow	Ballast	Normal	280 kDWT	Wind tunnel [3]
C.4	C.4	LNG carrier		Prismatic integrated	125 k-m ³	CFD [3]
C.5	C.5	LNG carrier		Prismatic extended deck	138 k-m ³	CFD [3]
C.6	C.6	LNG carrier		Spherical	125 k-m ³	CFD [3]
C.7	C.7	Container ship	Laden draught	Without containers, with lashing bridges	6 800 TEU	Wind tunnel [3]
C.7	C.7	Container ship	Ballast	Without containers, with lashing bridges	6 800 TEU	Wind tunnel [3]
C.8	C.8	Container ship	Laden	With containers	6 800 TEU	Wind tunnel [3]
C.8	C.8	Container ship	Ballast	Without containers	6 800 TEU	Wind tunnel [3]
C.9	C.9	Car carrier		Normal	Autosky	CFD [3]
C.10	C.10	Ferry/cruise ship		Normal		Wind tunnel [3]
C.11	C.11	General Cargo ship		Normal		Wind tunnel [3]
C.12	C.12	Handy size bulk carrier	Heavy Ballast	No cranes		Wind tunnel [1]
C.12	C.12	Handy size bulk carrier	Ballast	No cranes		Wind tunnel [1]

Table C.1 (continued)

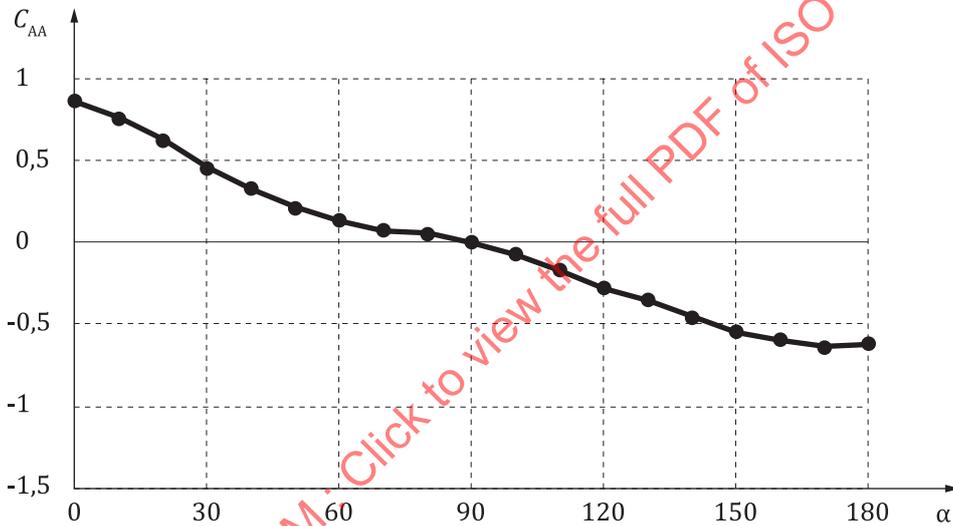
Table	Figure	Ship type	LC	Superstructure	Vessel	Reference
C.13	C.13	Handy size bulk carrier	Heavy Ballast	Cranes		Wind tunnel [1]
C.13	C.13	Handy size bulk carrier	Ballast	Cranes		Wind tunnel [1]
C.14	C.14	Multi-purpose carrier	Laden	With partly containers	19 000 DWT carrier	Wind tunnel [1]
C.14	C.14	Multi-purpose carrier	Ballast	With containers	19 000 DWT carrier	Wind tunnel [1]
C.15	C.15	Cruise ship				Wind tunnel [1]
C.16	C.16	Twin island container vessel	Ballast	No containers		Wind tunnel [3]
C.16	C.16	Twin island container vessel	Laden	With containers		Wind tunnel [3]
C.17	C.17	Cape size bulk carrier	Laden	No cranes		Wind tunnel [3]
C.18	C.18	Cape size bulk carrier	Ballast	No cranes		Wind tunnel [3]

Table C.2 — C_{AA} values for a 280 KDWT tanker with a conventional bow

Angle of attack α (°)	C_{AA}	
	Laden	Ballast
0	0,965 5	0,869 0
10	0,931 0	0,765 5
20	0,855 0	0,627 9
30	0,737 9	0,459 3
40	0,620 7	0,331 0
50	0,496 6	0,213 8
60	0,344 8	0,137 9
70	0,179 3	0,075 9
80	0,075 9	0,055 2
90	-0,041 0	0,000 0
100	-0,124 1	-0,069 0
110	-0,206 9	-0,165 5
120	-0,275 9	-0,275 9
130	-0,389 0	-0,351 7
140	-0,510 3	-0,452 4
150	-0,648 3	-0,544 8
160	-0,733 8	-0,593 1
170	-0,772 4	-0,634 5
180	-0,758 6	-0,618 0



a) C_{AA} values for a laden condition



b) C_{AA} values for a ballasted condition



c) Images

Key

C_{AA} wind resistance coefficient

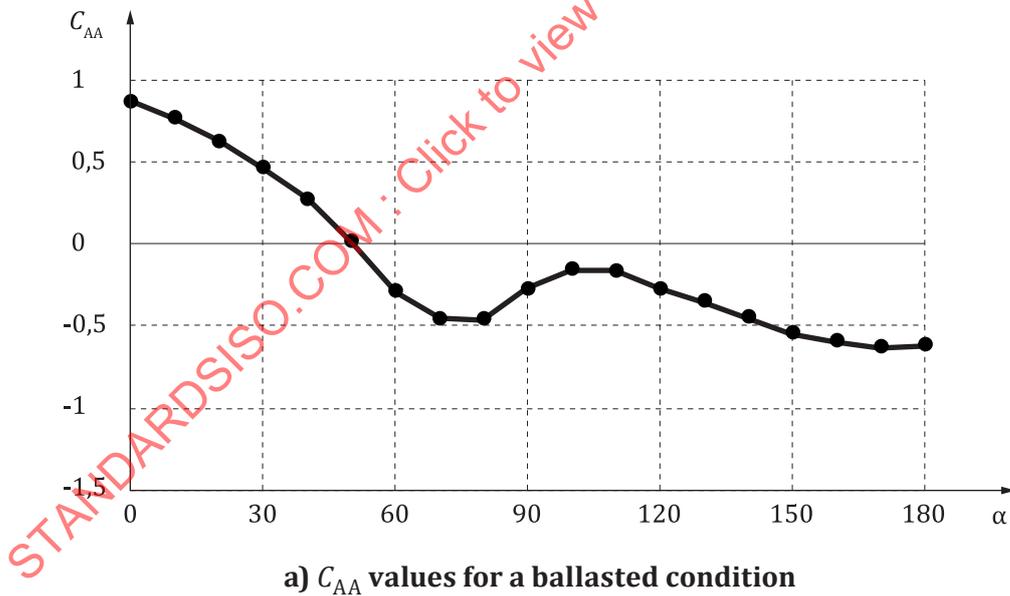
α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

Figure C.2 — Graphics of a 280 KDWT tanker with a conventional bow

Table C.3 — C_{AA} values for a 280 KDWT tanker with a cylindrical bow

Angle of attack α (°)	C_{AA}
	Ballast
0	0,869 0
10	0,765 5
20	0,627 9
30	0,459 3
40	0,275 9
50	0,014 0
60	-0,289 7
70	-0,455 2
80	-0,460 0
90	-0,275 9
100	-0,160 0
110	-0,165 5
120	-0,275 9
130	-0,351 7
140	-0,452 4
150	-0,544 8
160	-0,593 1
170	-0,634 5
180	-0,618 0





b) Image

Key

C_{AA} wind resistance coefficient

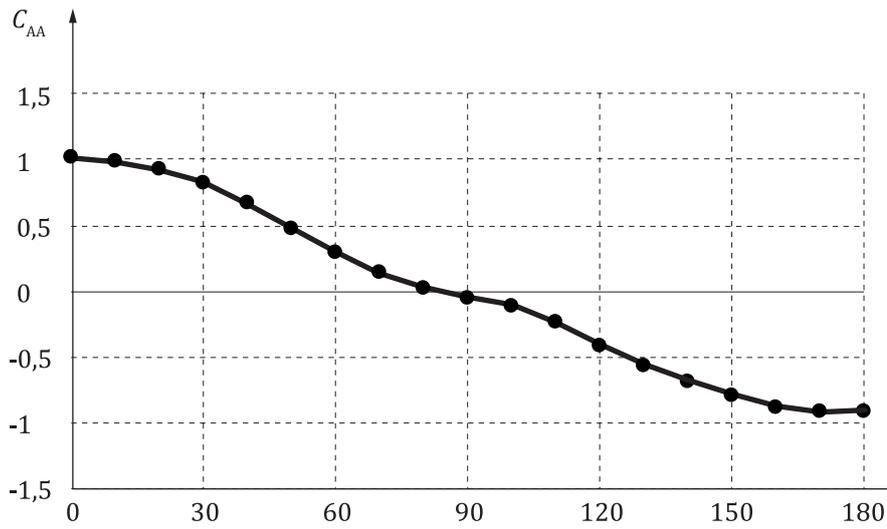
α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

Figure C.3 — Graphics of 280 KDWT tanker with a cylindrical bow

Table C.4 — C_{AA} values for an LNG carrier (prismatic integrated)

Angle of attack α (°)	C_{AA}
0	1,02
10	0,99
20	0,93
30	0,83
40	0,67
50	0,48
60	0,3
70	0,14
80	0,03
90	-0,05
100	-0,11
110	-0,24
120	-0,41
130	-0,56
140	-0,68
150	-0,79
160	-0,88
170	-0,92
180	-0,91



a) C_{AA} values



b) Image

Key

C_{AA} wind resistance coefficient

α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

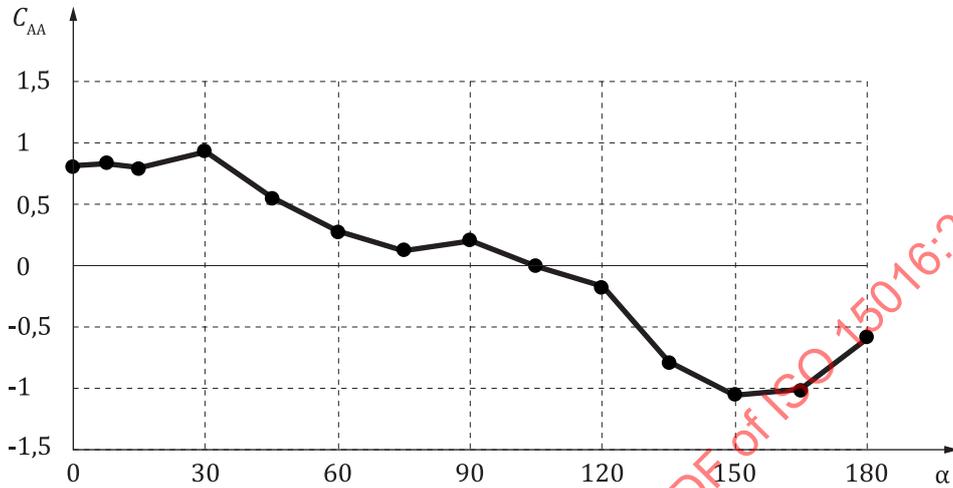
Figure C.4 — Graphics of an LNG carrier (prismatic integrated)

Table C.5 — C_{AA} values for an LNG carrier (Prismatic extended deck)

Angle of attack α (°)	C_{AA}
0	0,815
7,5	0,839
15	0,797
30	0,936
45	0,555
60	0,278
75	0,127
90	0,207
105	0,000
120	-0,173
135	-0,784

Table C.5 (continued)

Angle of attack α (°)	C_{AA}
150	-1,057
165	-1,018
180	-0,582



a) C_{AA} values



b) Image

Key

- C_{AA} wind resistance coefficient
- α relative wind direction, relative to the bow in degrees
- α is zero (0) degrees on the bow and positive to starboard (clockwise)

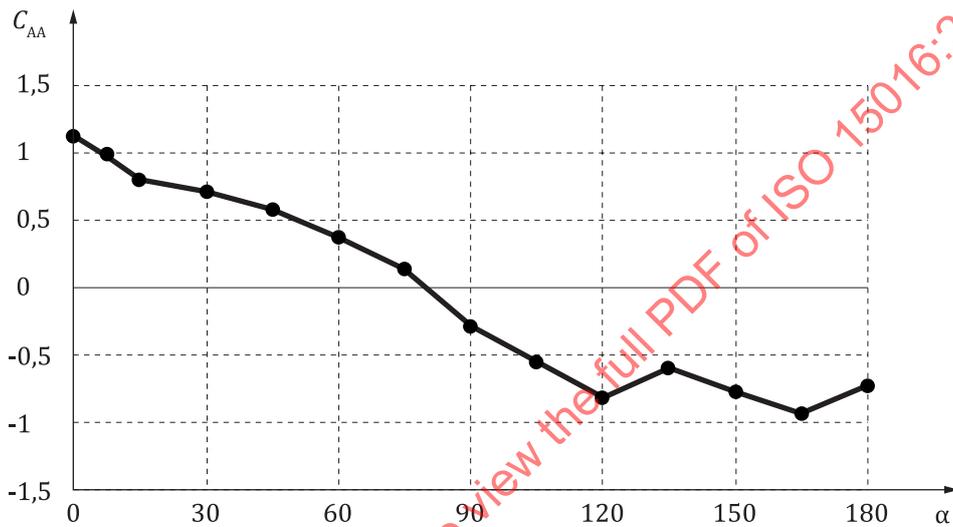
Figure C.5 — Graphics of an LNG carrier (prismatic extended deck)

Table C.6 — C_{AA} values for an LNG carrier (Spherical tanks)

Angle of attack α (°)	C_{AA}
0	1,117
7,5	0,975
15	0,792
30	0,708
45	0,571
60	0,367

Table C.6 (continued)

Angle of attack α (°)	C_{AA}
75	0,132
90	-0,291
105	-0,561
120	-0,821
135	-0,6
150	-0,781
165	-0,942
180	-0,731



a) C_{AA} values



b) Image

Key

C_{AA} wind resistance coefficient

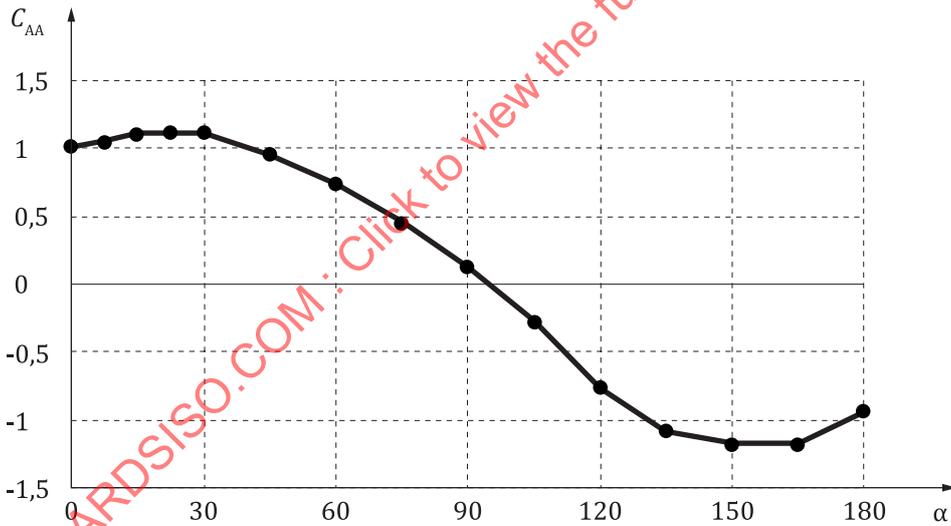
α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

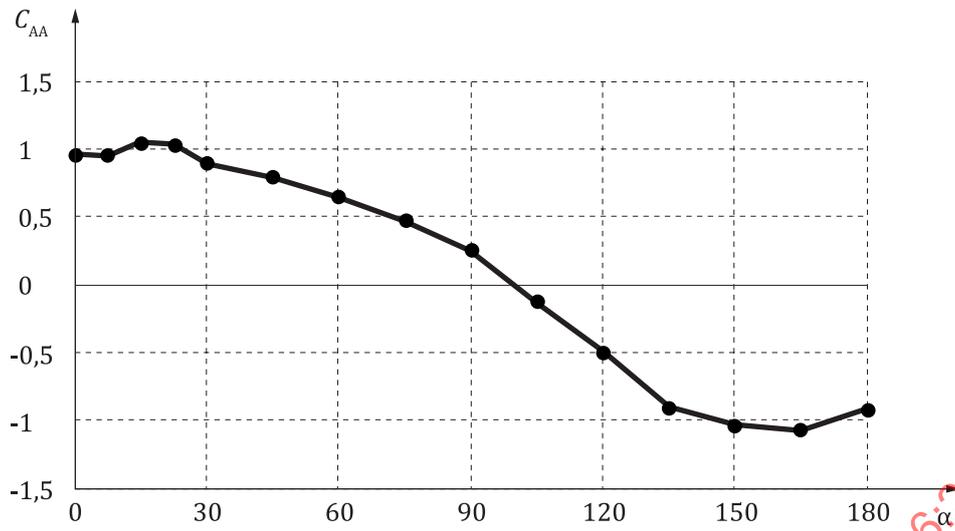
Figure C.6 — Graphics of an LNG carrier (spherical tanks)

Table C.7 — C_{AA} values for a 6,800 TEU container ship

Angle of attack α (°)	C_{AA}	
	Without containers with lashing bridges	
	Laden draught	Ballast
0	1,012 3	0,960 1
7,5	1,050 0	0,956 1
15	1,112 8	1,048 6
22,5	1,116 7	1,034 6
30	1,117 0	0,894 5
45	0,957 9	0,791 4
60	0,738 2	0,644 6
75	0,451 8	0,472 3
90	0,130 9	0,252 0
105	-0,273 4	-0,126 3
120	-0,759 5	-0,497 8
135	-1,080 7	-0,905 0
150	-1,172 9	-1,039 7
165	-1,171 4	-1,070 5
180	-0,931 4	-0,917 8



a) C_{AA} values, laden draught



b) C_{AA} values, ballast draught



c) Image

Key

C_{AA} wind resistance coefficient

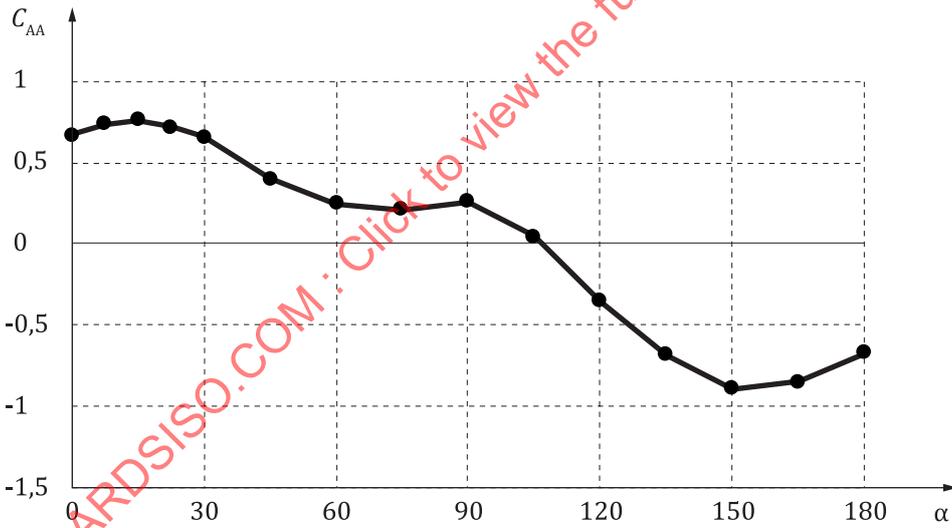
α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

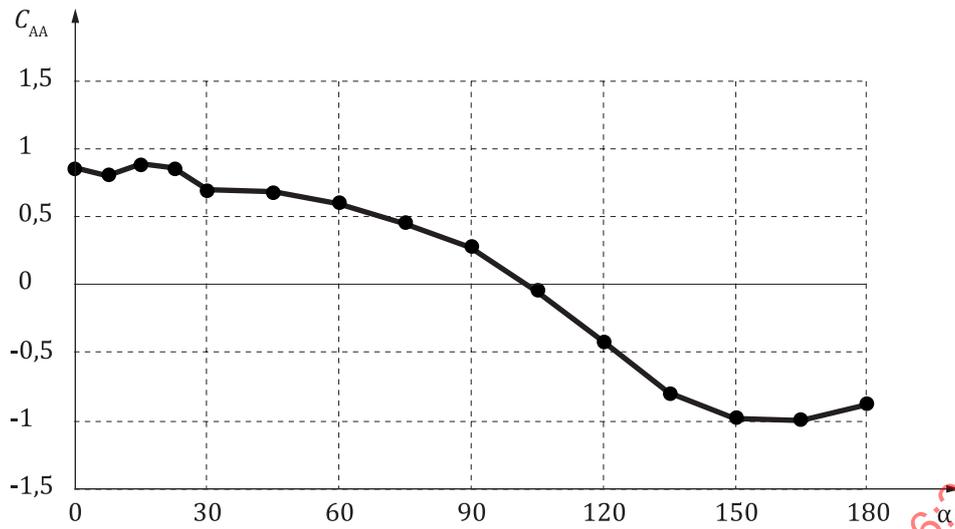
Figure C.7 — Graphics of a 6,800 TEU container ship, with lashing bridges, no containers

Table C.8 — C_{AA} values for a 6,800 TEU container ship

Angle of attack α (°)	C_{AA}	
	Laden with containers	Ballast without lashing bridge
0	0,666 9	0,863 1
7,5	0,735 7	0,811 1
15	0,759 8	0,888 6
22,5	0,720 9	0,859 6
30	0,655 8	0,699 5
45	0,401 4	0,681 4
60	0,248 2	0,604 6
75	0,213 5	0,460 3
90	0,260 8	0,282
105	0,043 0	-0,04
120	-0,353 9	-0,416
135	-0,682 3	-0,8
150	-0,892 8	-0,98
165	-0,846 4	-0,996
180	-0,670 7	-0,88



a) C_{AA} values for a laden condition



b) C_{AA} values for a ballast condition



c) Image

Key

C_{AA} wind resistance coefficient

α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

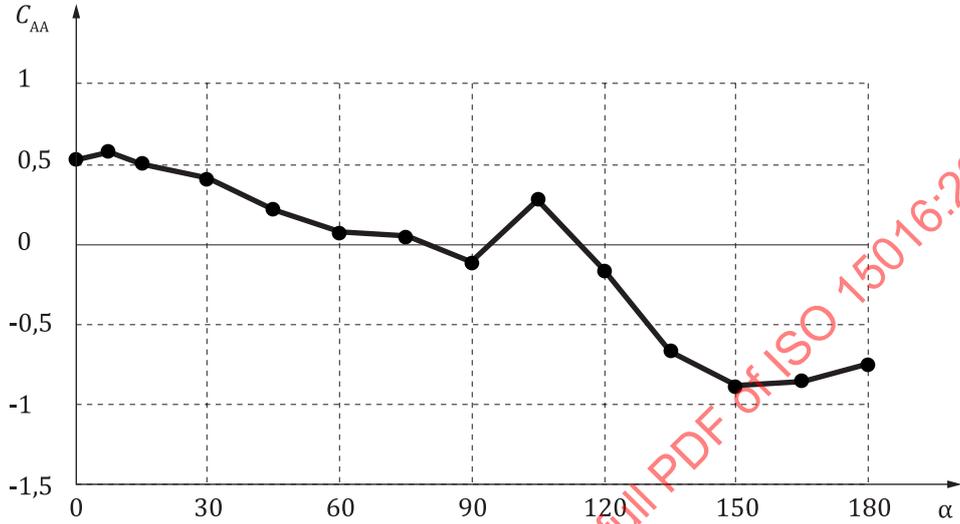
Figure C.8 — Graphics of a 6,800 TEU container ship without lashing bridges

Table C.9 — C_{AA} values for a car carrier

Angle of attack α (°)	C_{AA}
0	0,529
7,5	0,578
15	0,501
30	0,412
45	0,215
60	0,076
75	0,049
90	-0,112
105	0,283
120	-0,162

Table C.9 (continued)

Angle of attack α (°)	C_{AA}
135	-0,668
150	-0,883
165	-0,855
180	-0,75



a) C_{AA} values



b) Image

Key

C_{AA} wind resistance coefficient

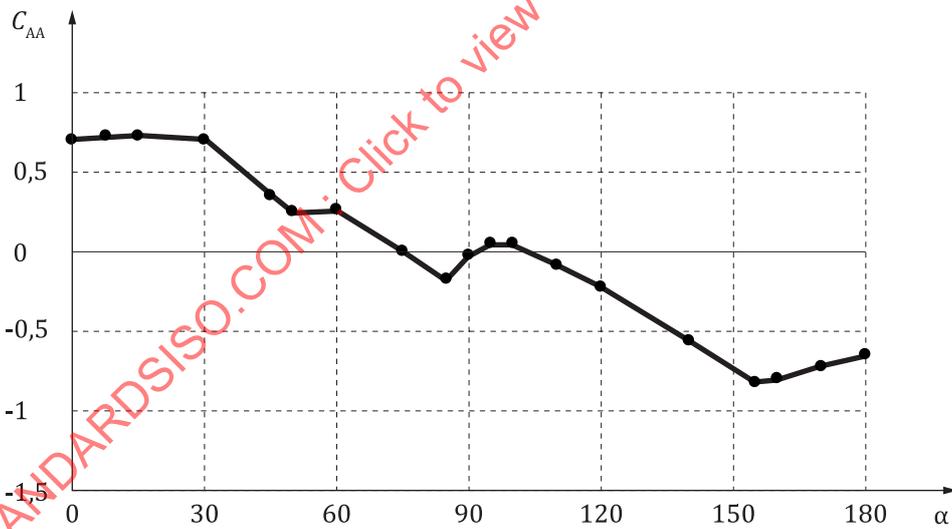
α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

Figure C.9 — Graphics of a car carrier

Table C.10 — C_{AA} values for a cruise ferry

Angle of attack α (°)	C_{AA}
0	0,700
7,5	0,720
15	0,730
30	0,700
45	0,350
50	0,250
60	0,260
75	0,005
85	-0,180
90	-0,025
95	0,050
100	0,050
110	-0,086
120	-0,220
140	-0,555
155	-0,820
160	-0,800
170	-0,720
180	-0,650



a) C_{AA} values



b) Image

Key

C_{AA} wind resistance coefficient

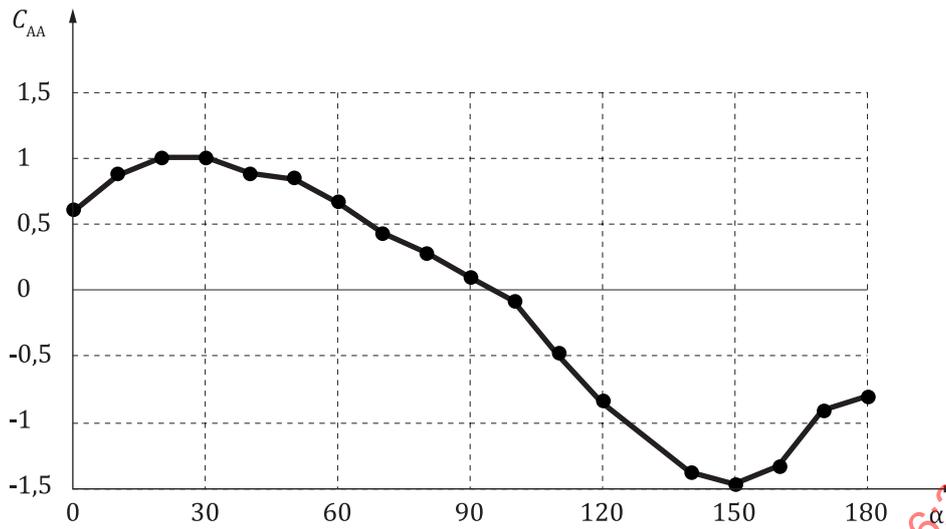
α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

Figure C.10 — Graphics of cruise ferry

Table C.11 — C_{AA} values for a general cargo ship

Angle of attack α (°)	C_{AA}
0	0,600
10	0,876
20	1,003
30	1,001
40	0,880
50	0,845
60	0,660
70	0,430
80	0,280
90	0,100
100	-0,080
110	-0,480
120	-0,840
140	-1,380
150	-1,470
160	-1,330
170	-0,913
180	-0,806



a) C_{AA} values



b) Image

Key

C_{AA} wind resistance coefficient

α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

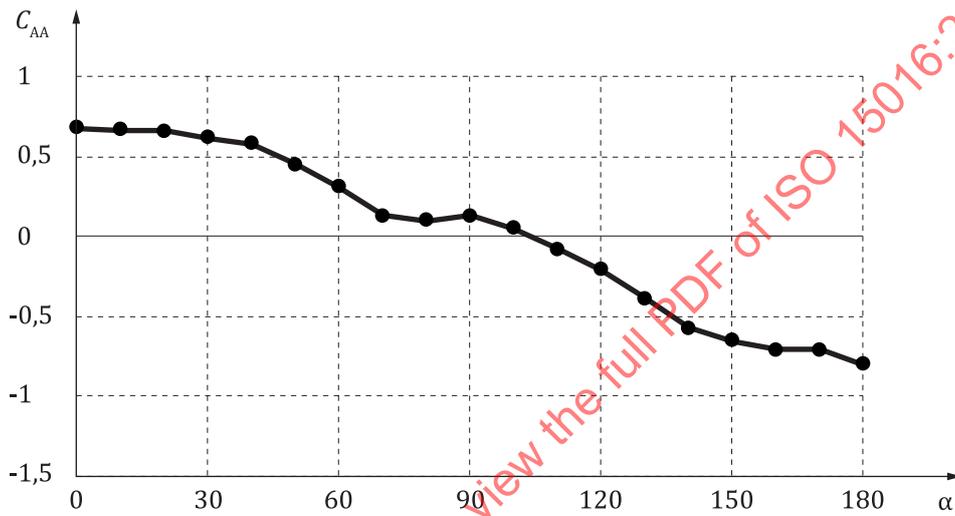
Figure C.11 — Graphics of a General cargo ship

Table C.12 — C_{AA} values for handy size bulk carrier without cranes

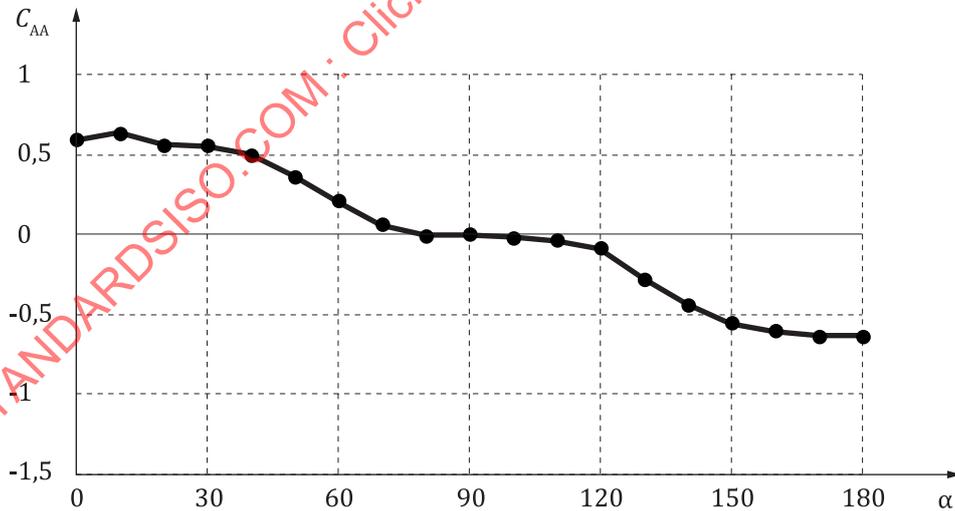
Angle of attack α (°)	C_{AA}	
	Heavy Ballast	Ballast
0	0,68	0,59
10	0,67	0,63
20	0,66	0,56
30	0,62	0,55
40	0,58	0,50
50	0,45	0,36
60	0,31	0,21
70	0,13	0,06
80	0,10	-0,01
90	0,13	0,00
100	0,05	-0,02

Table C.12 (continued)

Angle of attack α (°)	C_{AA}	
	Heavy Ballast	Ballast
110	-0,08	-0,04
120	-0,21	-0,09
130	-0,39	-0,28
140	-0,57	-0,44
150	-0,65	-0,56
160	-0,71	-0,61
170	-0,71	-0,64
180	-0,80	-0,64



a) C_{AA} values for a heavy ballast condition



b) C_{AA} values for a ballast condition



c) Image

Key

C_{AA} wind resistance coefficient

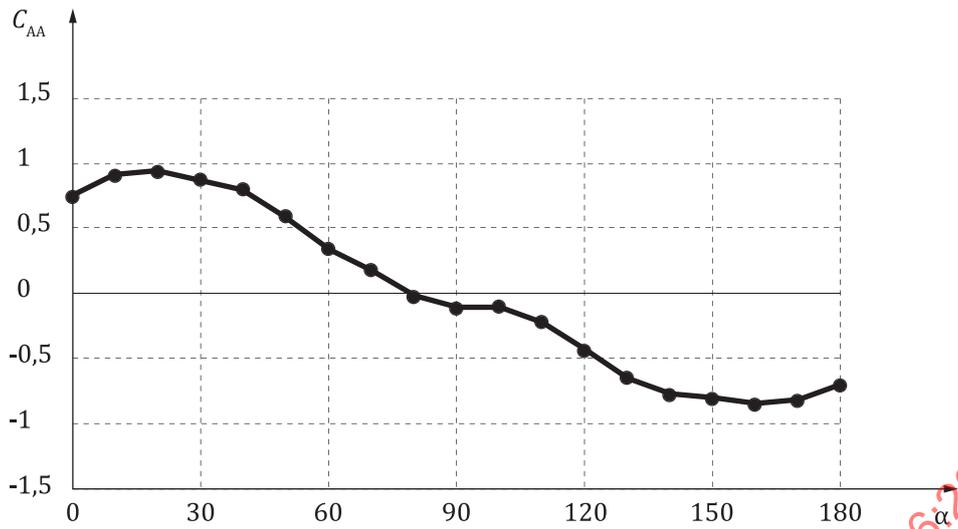
α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

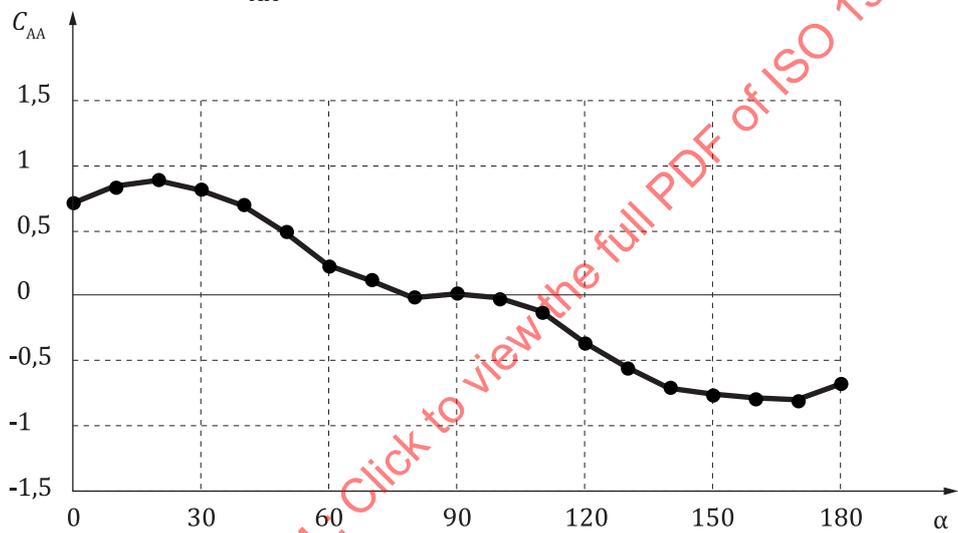
Figure C.12 — Graphics of a handy size bulk carrier without cranes

Table C.13 — C_{AA} values for handy size bulk carrier with cranes

Angle of attack α (°)	C_{AA}	
	Heavy ballast	Ballast
0	0,75	0,71
10	0,91	0,84
20	0,94	0,89
30	0,87	0,82
40	0,80	0,70
50	0,59	0,49
60	0,34	0,23
70	0,18	0,12
80	-0,02	-0,01
90	-0,11	0,02
100	-0,10	-0,02
110	-0,22	-0,12
120	-0,44	-0,36
130	-0,65	-0,55
140	-0,78	-0,71
150	-0,81	-0,76
160	-0,85	-0,79
170	-0,82	-0,80
180	-0,70	-0,68



a) C_{AA} values for a heavy ballast condition



b) C_{AA} values for a ballast condition



c) Image

Key

C_{AA} wind resistance coefficient

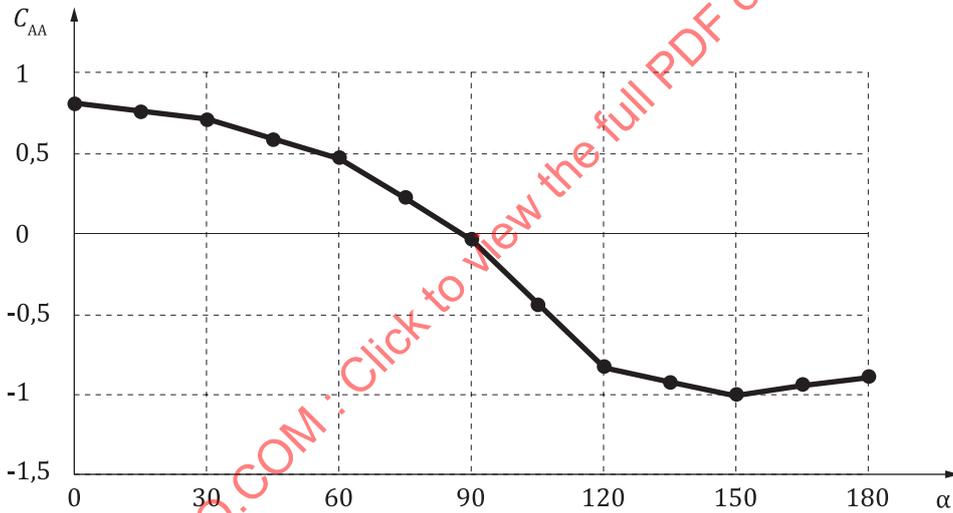
α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

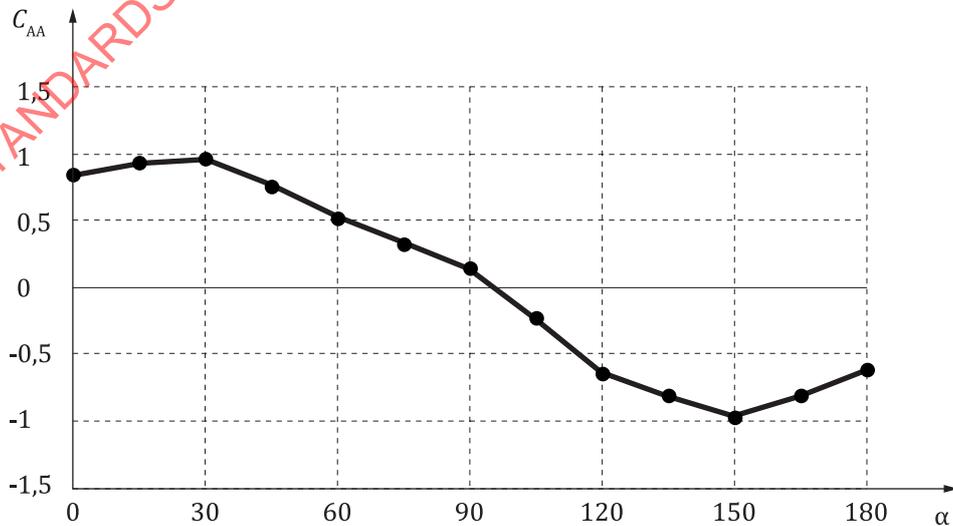
Figure C.13 — Graphics of a handy size bulk carrier with cranes

Table C.14 — C_{AA} values for a multi-purpose carrier

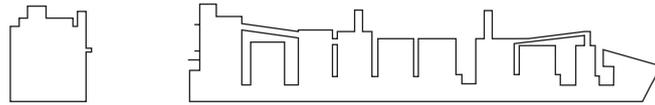
Angle of attack α (°)	C_{AA}	
	With partly containers	With containers
0	0,81	0,84
15	0,76	0,93
30	0,71	0,96
45	0,59	0,76
60	0,47	0,52
75	0,22	0,33
90	-0,04	0,14
105	-0,44	-0,23
120	-0,83	-0,64
135	-0,92	-0,81
150	-1,00	-0,97
165	-0,94	-0,81
180	-0,89	-0,62



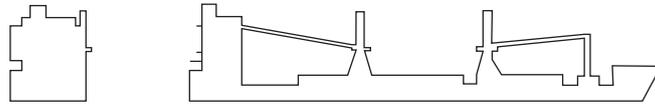
a) C_{AA} values for a loading condition partly with containers



b) C_{AA} values for a loading condition with containers



c) Multi-purpose carrier, with containers



d) Multi-purpose carrier, partly with containers

Key

C_{AA} wind resistance coefficient

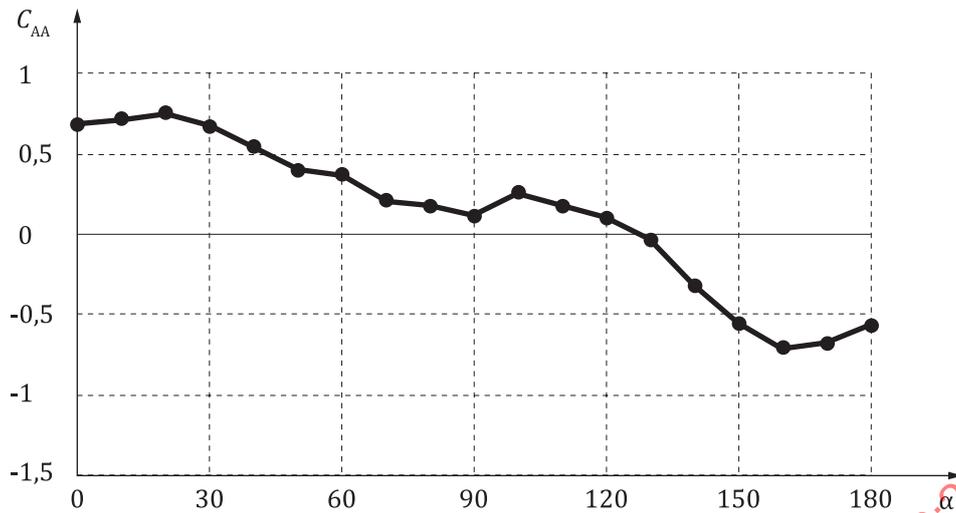
α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

Figure C.14 — Graphics of a multi-purpose carrier

Table C.15 — C_{AA} values for a cruise ship (average)

Angle of attack α (°)	C_{AA}
0	0,684
10	0,719
20	0,753
30	0,676
40	0,544
50	0,403
60	0,367
70	0,211
80	0,177
90	0,113
100	0,26
110	0,179
120	0,101
130	-0,033
140	-0,32
150	-0,552
160	-0,708
170	-0,675
180	-0,568



a) C_{AA} values for average loading condition



b) Image

Key

C_{AA} wind resistance coefficient

α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

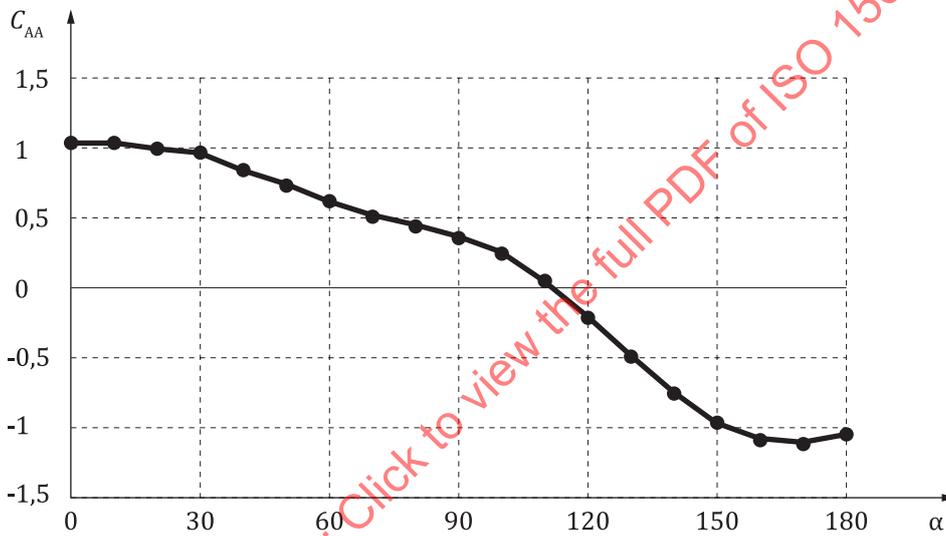
Figure C.15 — Graphics of a cruise vessel

Table C.16 — C_{AA} values for a “twin-island” container vessel

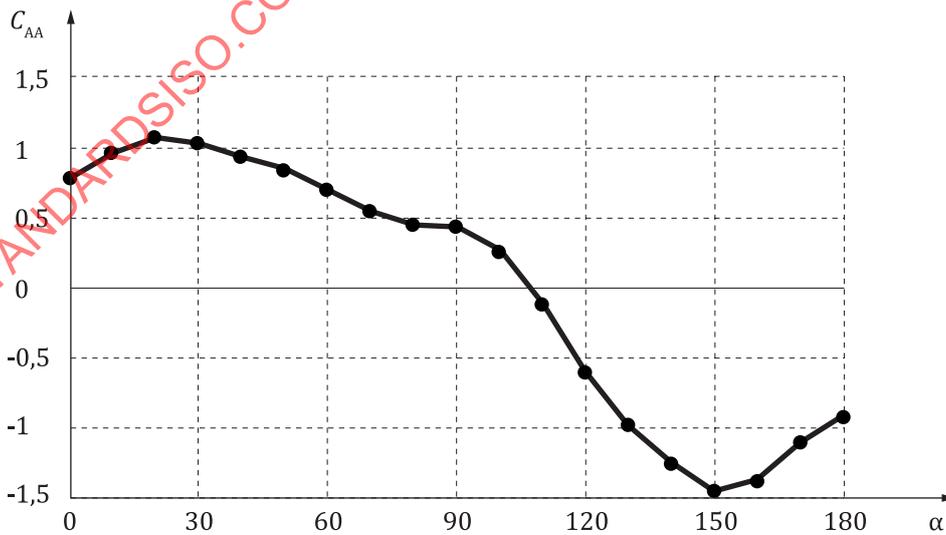
Angle of attack α (°)	C_{AA}	
	Ballast without containers	Laden with containers
0	1,032	0,783
10	1,036	0,964
20	0,99	1,076
30	0,961	1,029
40	0,841	0,933
50	0,733	0,842
60	0,618	0,697
70	0,513	0,545
80	0,446	0,454

Table C.16 (continued)

Angle of attack α (°)	C_{AA}	
	Ballast without containers	Laden with containers
90	0,358	0,438
100	0,25	0,263
110	0,05	-0,114
120	-0,206	-0,595
130	-0,481	-0,974
140	-0,745	-1,247
150	-0,96	-1,447
160	-1,083	-1,374
170	-1,109	-1,102
180	-1,045	-0,914



a) C_{AA} values for ballast condition with no containers on deck



b) C_{AA} values for a loaded condition



c) Image

Key

C_{AA} wind resistance coefficient

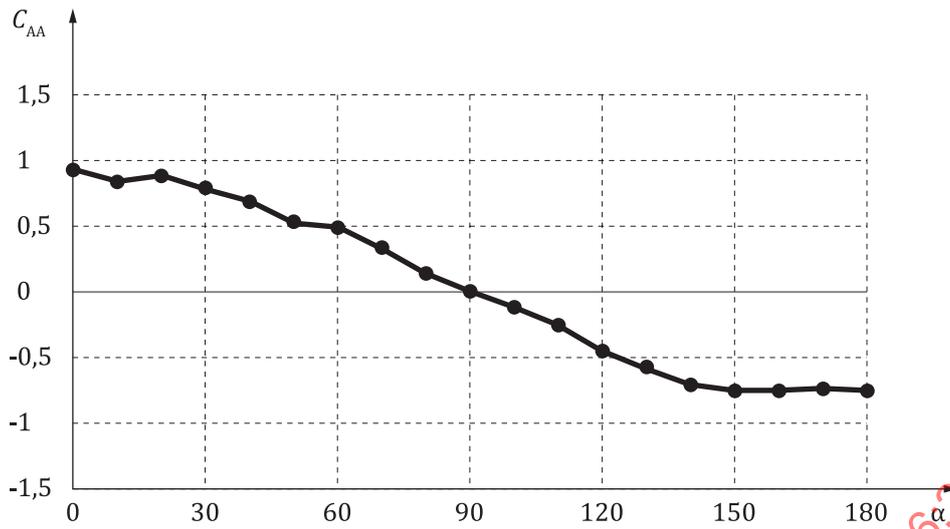
α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

Figure C.16 — Graphics of a twin island container vessel

Table C.17 — C_{AA} values for a cape size bulk carrier

Angle of attack α (°)	C_{AA}
	Laden
0	0,927
10	0,832
20	0,878
30	0,780
40	0,683
50	0,525
60	0,486
70	0,329
80	0,138
90	0,003
100	-0,117
110	-0,253
120	-0,447
130	-0,577
140	-0,708
150	-0,751
160	-0,752
170	-0,739
180	-0,750



a) C_{AA} values for a loaded condition



b) Image

Key

C_{AA} wind resistance coefficient

α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

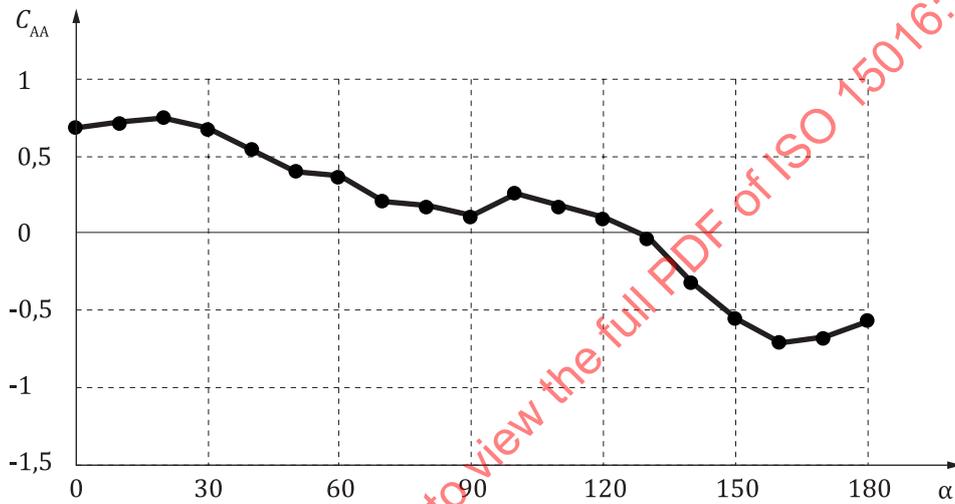
Figure C.17 — Graphics of a cape size bulk carrier (laden)

Table C.18 — C_{AA} values for a cape size bulk carrier

Angle of Attack α (°)	C_{AA}
	Ballast
0	0,684
10	0,719
20	0,753
30	0,676
40	0,544
50	0,403
60	0,367
70	0,211
80	0,177
90	0,113

Table C.18 (continued)

Angle of Attack α (°)	C_{AA}
	Ballast
100	0,26
110	0,179
120	0,101
130	-0,033
140	-0,32
150	-0,552
160	-0,708
170	-0,675
180	-0,568



a) C_{AA} values for a ballast condition



b) Image

Key

C_{AA} wind resistance coefficient

α relative wind direction, relative to the bow in degrees

α is zero (0) degrees on the bow and positive to starboard (clockwise)

Figure C.18 — Graphics of a cape size bulk carrier (ballast)

C.3.5 Regression formula

The regression formulae based on wind tunnel tests developed by Fujiwara et al. [14] are shown in Formulae (C.12) to (C.19):

$$C_{AA}(\psi_{WR}) = C_{LF} \cos \psi_{WR} + C_{XLI} \left(\sin \psi_{WR} - \frac{1}{2} \sin \psi_{WR} \cos^2 \psi_{WR} \right) \sin \psi_{WR} \cos \psi_{WR} + C_{ALF} \sin \psi_{WR} \cos^3 \psi_{WR} \quad (C.12)$$

with:

for $0 \leq \psi_{WR} < 90$ (deg)

$$C_{LF} = \beta_{10} + \beta_{11} \frac{A_{LV}}{L_{OA} B} + \beta_{12} \frac{C_{MC}}{L_{OA}} \quad (C.13)$$

$$C_{XLI} = \delta_{10} + \delta_{11} \frac{A_{LV}}{L_{OA} H_{BR}} + \delta_{12} \frac{A_{XV}}{B H_{BR}} \quad (C.14)$$

$$C_{ALF} = \varepsilon_{10} + \varepsilon_{11} \frac{A_{OD}}{A_{LV}} + \varepsilon_{12} \frac{B}{L_{OA}} \quad (C.15)$$

for $90 < \psi_{WR} \leq 180$ (deg)

$$C_{LF} = \beta_{20} + \beta_{21} \frac{B}{L_{OA}} + \beta_{22} \frac{H_C}{L_{OA}} + \beta_{23} \frac{A_{OD}}{L_{OA}^2} + \beta_{24} \frac{A_{XV}}{B^2} \quad (C.16)$$

$$C_{XLI} = \delta_{20} + \delta_{21} \frac{A_{LV}}{L_{OA} H_{BR}} + \delta_{22} \frac{A_{XV}}{A_{LV}} + \delta_{23} \frac{B}{L_{OA}} + \delta_{24} \frac{A_{XV}}{B H_{BR}} \quad (C.17)$$

$$C_{ALF} = \varepsilon_{20} + \varepsilon_{21} \frac{A_{OD}}{A_{LV}} \quad (C.18)$$

for $\psi_{WR} = 90$ (deg)

$$C_{AA}(90) = \frac{1}{2} [C_{AA}(90 - \mu) + C_{AA}(90 + \mu)] \quad (C.19)$$

where

$C_{AA}(\psi_{WR})$ is the wind resistance coefficient; $C_{AA}(0)$ means the wind resistance coefficient, in head wind;

ψ_{WR} is the mean value of the relative wind direction at anemometer height, expressed in degrees;

NOTE Zero (0) degrees refers to the winds incoming on the bow and a positive angle refers to wind coming in from starboard.

L_{OA} is the ship's length overall, expressed in metres;

B is the moulded ship's breadth, expressed in metres;

A_{OD} is the lateral projected area of superstructures above upper deck, expressed in square metres;

A_{XV} is the transverse projected area above the waterline including superstructures, expressed in square metres;

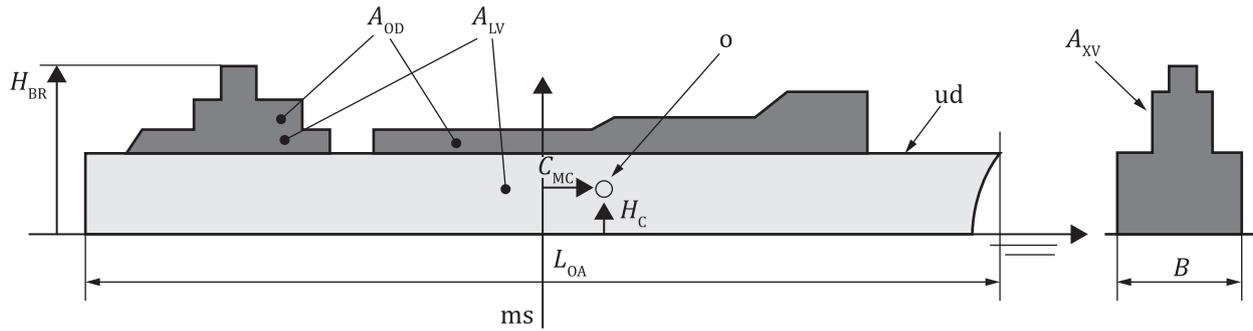
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- A_{LV} is the lateral projected area above the waterline including superstructures, expressed in square metres;
- C_{MC} is the horizontal distance from midship section to the centre of lateral projected area A_{LV} , where + means forward from midship, expressed in metres;
- H_{BR} is the height of top of superstructure (bridge etc.), expressed in metres;
- H_C is the height from waterline to centre of lateral projected area A_{LV} , expressed in metres;
- μ is the smoothing range, expressed in degrees, normally 10 (degrees).

The non-dimensional parameters β_{ij} , δ_{ij} and ε_{ij} used in the formulae are shown in [Table C.19](#), the coordinate system is shown in [Figure C.19](#) and the sign conventions are shown in [Figure 5](#).

Table C.19 — Non-dimensional parameters for Fujiwara method

	i	j				
		0	1	2	3	4
β_{ij}	1	0,922	-0,507	-1,162	-	-
	2	-0,018	5,091	-10,367	3,011	0,341
δ_{ij}	1	-0,458	-3,245	2,313	-	-
	2	1,901	-12,727	-24,407	40,310	5,481
ε_{ij}	1	0,585	0,906	-3,239	-	-
	2	0,314	1,117	-	-	-
Key						
β_{ij} , δ_{ij} , ε_{ij} the non-dimensional parameters in the Formulae (C.13) to (C.18)						



Key

- L_{OA} the ship's length overall, expressed in metres
- B the moulded ship's breadth, expressed in metres
- A_{OD} lateral projected area of superstructures above upper deck, expressed in square metres
- A_{XV} transverse projected area above the waterline including superstructures, expressed in square metres
- A_{LV} lateral projected area above the waterline including superstructures, expressed in square metres
- o centre of A_{LV}
- ms midship
- ud upper deck
- C_{MC} horizontal distance from midship section to the centre of lateral projected area A_{LV} , where + means forward from midship, expressed in metres
- H_{BR} height of top of superstructure (bridge etc.), expressed in metres
- H_C height from waterline to centre of lateral projected area A_{LV} , expressed in metres

Figure C.19 — Input parameters for regression formula

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Annex D (normative)

Resistance increase due to waves

D.1 General

Irregular waves are represented as a linear superposition of the components of regular waves. Therefore, the mean resistance increase in short crested irregular waves, R_{AW} , is calculated by linear superposition of the directional wave spectrum, E , and the response function of the mean resistance increase in regular waves, R_{wave} , as shown in [Formula \(D.1\)](#).

$$R_{AW} = 2 \int_0^{2\pi} \int_0^{\infty} \frac{R_{wave}(\omega, \alpha, V_S)}{\zeta_A^2} E(\omega, \alpha) d\omega d\alpha \quad (D.1)$$

where

R_{AW} is the mean resistance increase in irregular waves, expressed in newtons;

R_{wave} is the mean resistance increase in regular waves, expressed in newtons;

NOTE For the unit wave amplitude of 1 m, R_{wave} corresponds to the value of the transfer function for added wave resistance.

ζ_A is the wave amplitude, expressed in metres;

ω is the circular frequency of regular waves, expressed in radians per second;

α is the relative wave direction, relative to the bow, expressed in degrees;

NOTE Zero (0) degrees refers to the winds incoming on the bow and a positive angle refers to wind coming in from starboard.

V_S is the ship speed through the water, expressed in metres per second;

E is the directional wave spectrum, expressed in square metre seconds.

The theoretical directional wave spectrum is defined by the following relationship as expressed in [Formula \(D.2\)](#):

$$E = S_{\eta}(\omega) G(\alpha) \quad (D.2)$$

where

S_{η} is the spectrum, expressed in square metre seconds, as described in [Formula \(D.8\)](#);

G is the angular distribution function.

During trials the (uni) directional wave spectrum is measured, therefore no use is made of theoretical or empirical angular distribution functions.

The wave spectrum is defined by [Formula \(D.3\)](#):

$$S_{\eta}(\omega) d\omega = 1/2 \zeta_A^2(\omega) \quad (D.3)$$

where

$S_{\eta}(\omega)$ is the spectrum, expressed in square metre seconds, as described in [Formula \(D.8\)](#);

ζ_A is the wave amplitude, expressed in metres;

ω is the circular wave frequency, expressed in rad/s.

The variance of the water surface elevation is found from the total area under the wave spectrum curve as expressed in [Formula \(D.4\)](#):

$$m_o = \int_0^{\infty} S_{\eta}(\omega) d\omega \quad (D.4)$$

where

m_o is the area under the wave spectrum, expressed in square metres;

S_{η} is the spectrum, expressed in square metre seconds, as described in [Formula \(D.8\)](#);

ω is the circular frequency of regular waves, expressed in radians per second.

The significant wave amplitude is derived from [Formula \(D.5\)](#):

$$\zeta_{A1/3} = 2\sqrt{m_o} \quad (D.5)$$

where

m_o is the area under the wave spectrum, expressed in square metres;

$\zeta_{A1/3}$ is the significant wave amplitude, expressed in metres.

The statistical value of the significant wave height is defined as the average (centroid) of the highest 1/3 of the waves in the wave elevation record. There is a good correlation between the wave height visually observed by experienced mariners and the significant wave height. The significant wave height can also directly be found from the wave spectral area as expressed in [Formula \(D.6\)](#):

$$H_{1/3} = 4\sqrt{m_o} \quad (D.6)$$

where

$H_{1/3}$ is the total significant wave height, expressed in metres;

m_o is the area under the wave spectrum, expressed in square metres.

Generally on a sea trial, the direction of the incoming waves is measured on the compass. Buoys also measure the wave direction with an in-built gyro compass. However, wave correction methods are based on relative wave directions. To calculate the angle between the ship's heading and the wave direction of the incoming waves, [Formula \(D.7\)](#) shall be used:

$$\alpha = \text{atan2} [\cos(\gamma - \psi), \sin(\gamma - \psi)] \quad (D.7)$$

where

α is the relative wave direction, relative to the bow in degrees;

NOTE Zero (0) degrees refers to the waves incoming on the bow and a positive angle refers to waves coming in from starboard.

ψ is the ship's compass heading in degrees;

γ is the compass bearing of the incoming waves in degrees.

D.2 Wave correction method to be used

In calculating resistance increase due to waves, one of following methods shall be used in the given priority sequence:

- Use transfer functions derived from seakeeping tank tests in combination with the in situ measured wave spectrum (see [D.3](#));
- Use the semi-empirical SNNM method in combination with the in situ measured wave spectrum. The SNNM method has been developed to approximate the transfer function of the mean resistance increase. This method has been validated with tank tests with measured wave conditions (see [D.4](#));
- Use the dedicated method STAWAVE-1 (see Reference [\[3\]](#)) to estimate the added resistance in waves for speed trial conditions in combination with visual wave height observations, small heave and pitch motions and for waves in the bow sector (less than ± 45 degrees off the bow). See [D.5](#);
- In case pitch and heave obstruct the use of STAWAVE-1 and the absence of a measured wave spectrum obstructs the use of SNNM as described in b) above, the SNNM method may be used for uni-directional waves with the modified Pierson-Moskowitz spectrum (ITTC 1978)^[10] based on observed wave height and period as described in [Formulae \(D.8\)](#) to [\(D.11\)](#).

$$S_{\eta}(\omega) = \frac{A_{fw}}{\omega^5} \exp\left(-\frac{B_{fw}}{\omega^4}\right) \quad (D.8)$$

$$A_{fw} = 173 \frac{H_{1/3}^2}{T_{01}^4} \quad (D.9)$$

$$B_{fw} = \frac{691}{T_{01}^4} \quad (D.10)$$

The significant wave height $H_{1/3}$ is equal to the wave height visually observed by experienced mariners.

The mean centroid wave period T_{01} is derived from the "mean zero up-crossing wave period" referred to as T_z . The value of T_z closely relates to the observed mean wave period. The value of T_{01} from [Formula \(D.11\)](#) shall be used in [Formula \(D.9\)](#) and [Formula \(D.10\)](#) to derive the modified PM spectrum:

$$T_{01} = 1,086 T_z \quad (D.11)$$

where

T_{01} is the mean centroid wave period, expressed in seconds;

T_z is the mean observed wave period, expressed in seconds.

D.3 Seakeeping tank tests

Transfer functions of the resistance increase in waves (R_{wave} for 1 m wave amplitude) may be derived from the tank tests in regular waves of constant height but different wavelengths and different wave directions. The tank tests shall be conducted for the specific ship geometry at the trial draughts and trim, and at contractual draughts if required. A minimum of two different ship speeds (V_S) covering the speed range tested in the speed-power trials shall be tank tested.

If the trials are not conducted in head seas and following seas, the tank tests shall not only comprise head and following waves but also the relevant oblique wave conditions. A maximum interval of incident wave angle shall be 30° for head to beam seas (0° to 90°) but may be larger for beam to following seas (90° to 180°).

These tests shall be performed for a combination of circular frequency of regular waves (ω), angle between ship heading and incident regular waves (α) and ship speed through the water (V_S) based on the following: a minimum of 5 wavelengths in the range of $0,5 L_{PP}$ and less than $2,0 L_{PP}$. The test set-up and procedure shall follow ITTC 7.5-02-07-02.2, *ITTC Recommended Procedures and Guidelines, Prediction of Power Increase in Irregular Waves from Model Tests*.

D.4 SNNM Semi-empirical method for predicting the added resistance in waves

The semi-empirical SNNM method has been developed to approximate the transfer function of the mean resistance increase in regular waves with the use of some additional input parameters. The method includes the effect of wave reflection and ship motions and has been developed based on regression of tank test data for a population of various ship types.^[15] As S/P trials are conducted heading into the dominant wave or wind direction, the prime purpose of SNNM is to correct for these dominant waves. As the method includes approximations for arbitrary wave directions, it can also be used to correct for following seas and for secondary wave systems from other directions. The SNNM method has been validated against tank test results by ITTC.^[20]

The mean added resistance in regular waves, R_{wave} , is calculated as the sum of the motion-induced component, R_{AWM} , and the wave reflection induced component, R_{AWR} , as expressed in [Formula \(D.12\)](#):

$$R_{\text{wave}}(\omega, \alpha, V_S) = R_{\text{AWM}} + R_{\text{AWR}} \quad (\text{D.12})$$

where

R_{WAVE} is the mean resistance increase in irregular waves, expressed in newtons;

NOTE For the unit wave amplitude of 1 m, this value corresponds with the value of the transfer function for added wave resistance.

R_{AWM} is the motion induced wave resistance, expressed in newtons;

R_{AWR} is the wave resistance resulting from wave reflection, expressed in newtons.

The expression of R_{AWM} is given by [Formulae \(D.13\)](#) to [\(D.21\)](#):

$$R_{\text{AWM}} = 3859,2 \rho_{\text{act}} g \zeta_A^2 \frac{B^2}{L_{PP}} C_B^{1,34} k_{yy}^2 a_1 a_2 a_3 \bar{\omega}^{b_1} e^{d_1 (1 - \bar{\omega}^{d_1})} \quad (\text{D.13})$$

where

$$\bar{\omega} = 2,142 \sqrt[3]{k_{yy}} \sqrt{\frac{L_{PP}}{2\pi g}} \left(\frac{C_B}{0,65} \right)^{0,17} \left[1 - \frac{0,111}{C_B} \left(\ln \frac{B}{T_{\text{deep}}} - \ln 2,75 \right) \right] \left[(-1,377 Fr^2 + 1,157 Fr) |\cos \alpha| + \frac{0,618(13 + \cos 2\alpha)}{14} \right] \omega \quad (\text{D.14})$$

$$a_1 \left(0 \leq \alpha \leq \frac{\pi}{2} \right) = \left(\frac{0,87}{C_B} \right)^{(1+Fr)\cos\alpha} \left(\ln \frac{B}{T_{\text{deep}}} \right)^{-1} \frac{(1+2\cos\alpha)}{3} \quad (\text{D.15})$$

$$a_1 (\alpha = \pi) = \begin{cases} \left(\frac{0,87}{C_B} \right)^{1+Fr_{\text{rel}}} \left(\ln \frac{B}{T_{\text{deep}}} \right)^{-1} & \text{for } V_S > V_{\text{group}} \text{ and } Fr_{\text{rel}} \geq 0,12 \\ \left(\frac{0,87}{C_B} \right) \left(\ln \frac{B}{T_{\text{deep}}} \right)^{-1} & \text{elsewhere} \end{cases} \quad (\text{D.16})$$

$$a_2 \left(0 \leq \alpha \leq \frac{\pi}{2} \right) = \begin{cases} 0,0072 + 0,1676Fr & \text{for } Fr < 0,12 \\ Fr^{1,5} e^{-3,5Fr} & \text{for } Fr \geq 0,12 \end{cases} \quad (\text{D.17})$$

$$a_2 (\alpha = \pi) = \begin{cases} 0,0072(2V_S / V_{\text{group}} - 1) & \text{for } V_S \leq V_{\text{group}} \\ 0,0072 + 0,1676Fr_{\text{rel}} & \text{for } V_S > V_{\text{group}} \text{ and } Fr_{\text{rel}} < 0,12 \\ Fr_{\text{rel}}^{1,5} e^{-3,5Fr_{\text{rel}}} & \text{for } V_S > V_{\text{group}} \text{ and } Fr_{\text{rel}} \geq 0,12 \end{cases} \quad (\text{D.18})$$

$$a_3 = 1,0 + 28,7 \text{atan} \frac{|T_A - T_F|}{L_{\text{pp}}} \quad (\text{D.19})$$

$$b_1 = \begin{cases} 11,0 & \text{for } \bar{\omega} < 1 \\ -8,5 & \text{elsewhere} \end{cases} \quad (\text{D.20})$$

$$d_1 = \begin{cases} 566 \left(\frac{L_{\text{pp}} C_B}{B} \right)^{-2,66} & \text{for } \bar{\omega} < 1 \\ -566 \left(\frac{L_{\text{pp}}}{B} \right)^{-2,66} \left(4 - 125 \text{atan} \frac{|T_A - T_F|}{L_{\text{pp}}} \right) & \text{elsewhere} \end{cases} \quad (\text{D.21})$$

where

- ρ_{act} is the water density for the actual water temperature and salt content, expressed in kilograms per cubic metre;
 - g is the acceleration of gravity, expressed in metres per second squared;
 - ζ_A is the wave amplitude, expressed metres;
 - B is the moulded ship's breadth, expressed in metres;
 - L_{pp} is the ship's length between perpendiculars, expressed in metres;
 - C_B is the block coefficient;
 - k_{yy} is the non-dimensional pitch radius of gyration as fraction of L_{pp} ;
 - T_{deep} for a trimmed condition T_{deep} is the deepest moulded draught, expressed in metres;
 - Fr is the Froude number;
 - α is the relative wave direction, relative to the bow in degrees;
- NOTE Zero (0) degrees refers to the waves incoming on the bow and a positive angle refers to waves coming in from starboard.
- ω is the circular frequency of regular waves, expressed in radians per second;

V_S is the ship speed through the water, expressed in metres per second;

V_{group} is the group velocity of the incident wave, $V_{\text{group}} = \frac{g}{2\omega}$, expressed in metres per second;

$Fr_{\text{rel}} = (V_S - V_{\text{group}} / 2) / \sqrt{gL_{\text{pp}}}$;

T_A is the moulded draught at aft perpendicular, expressed in metres;

T_F is the moulded draught at the forward perpendicular, expressed in metres.

R_{AWM} in stern oblique waves, i.e. for $\frac{\pi}{2} \leq \alpha \leq \pi$, is found by linear interpolation between the

values of $R_{\text{AWM}} (\alpha = \frac{\pi}{2})$ in beam waves and $R_{\text{AWM}} (\alpha = \pi)$ in following waves.

The expression of the added resistance due to reflection effect, R_{AWR} , is calculated with [Formulae \(D.22\)](#) to [\(D.30\)](#):

$$R_{\text{AWR}} = \sum_{i=1}^4 R_{\text{AWR},i} \quad (\text{D.22})$$

where

$$R_{\text{AWR},1} = \frac{2,25}{4} \rho_{\text{act}} g B \zeta_A^2 \alpha_{T^*} \left\{ \sin^2 (E_1 + \alpha) + \frac{2\omega V_S}{g} [\cos \alpha - \cos E_1 \cos (E_1 + \alpha)] \right\} \left(\frac{0,87}{C_B} \right)^{(1+4\sqrt{Fr})} f(\alpha) \quad (\text{D.23})$$

for $0 \leq \alpha \leq \pi - E_1$

$$R_{\text{AWR},2} = \frac{2,25}{4} \rho_{\text{act}} g B \zeta_A^2 \alpha_{T^*} \left\{ \sin^2 (E_1 - \alpha) + \frac{2\omega V_S}{g} [\cos \alpha - \cos E_1 \cos (E_1 - \alpha)] \right\} \left(\frac{0,87}{C_B} \right)^{(1+4\sqrt{Fr})} f(\alpha) \quad (\text{D.24})$$

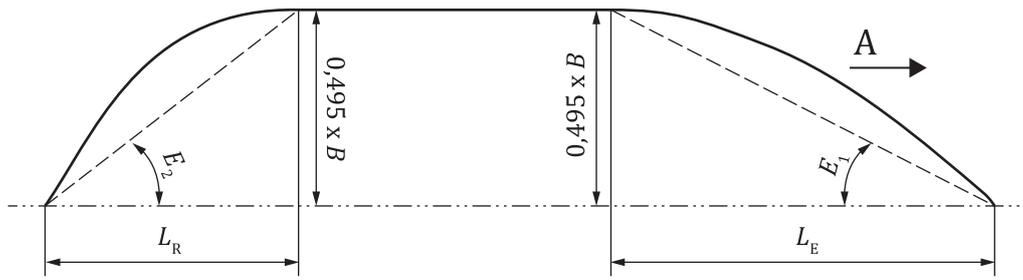
for $0 \leq \alpha \leq E_1$

$$R_{\text{AWR},3} = -\frac{2,25}{4} \rho_{\text{act}} g B \zeta_A^2 \alpha_{T^*} \left\{ \sin^2 (E_2 - \alpha) + \frac{2\omega V_S}{g} [\cos \alpha - \cos E_2 \cos (E_2 - \alpha)] \right\} \quad (\text{D.25})$$

for $E_2 \leq \alpha \leq \pi$

$$R_{\text{AWR},4} = -\frac{2,25}{4} \rho_{\text{act}} g B \zeta_A^2 \alpha_{T^*} \left\{ \sin^2 (E_2 + \alpha) + \frac{2\omega V_S}{g} [\cos \alpha - \cos E_2 \cos (E_2 + \alpha)] \right\} \quad (\text{D.26})$$

for $\pi - E_2 \leq \alpha \leq \pi$



Key

- L_R the length of run of the waterline, expressed in metres
- L_E the length of entrance of the waterline, expressed in metres
- E_1 the angle of entrance on the waterline, expressed in radians
- E_2 the angle of the run on the waterline, expressed in radians
- A the direction of the bow
- B the moulded ship's breadth, expressed in metres

Figure D.1 — Sketch of the half waterline of a ship and related definitions

$$f(\alpha) = \begin{cases} \cos \alpha & 0 \leq \alpha \leq E_1 \\ 0 & \alpha > E_1 \end{cases} \quad (D.27)$$

α_{T^*} is the draught coefficient, calculated as:

$$\alpha_{T^*} = \begin{cases} 1 - e^{-4\pi \left(\frac{T^*}{2\pi g / \omega^2} \frac{T^*}{2,5 L_{PP}} \right)} \frac{2\pi g}{\omega^2 L_{PP}} \leq 2,5 \\ 0 & \frac{2\pi g}{\omega^2 L_{PP}} > 2,5 \end{cases} \quad (D.28)$$

for $R_{AWR,1}$ and $R_{AWR,2}$

$$T^* = T_{\text{deep}} \quad (D.29)$$

and for $R_{AWR,3}$ and $R_{AWR,4}$

$$T^* = \begin{cases} T_{\text{deep}} (4 + \sqrt{|\cos \alpha|}) / 5 & C_B \leq 0,75 \\ T_{\text{deep}} (2 + \sqrt{|\cos \alpha|}) / 3 & C_B > 0,75 \end{cases} \quad (D.30)$$

where

- ρ_{act} is the water density for the actual water temperature and salt content, expressed in kilograms per cubic metre;
- g is the acceleration of gravity, expressed in metres per second squared;
- B is the moulded ship's breadth, expressed in metres;
- ζ_A is the wave amplitude, expressed in metres;
- E_1 is the angle of entrance on the waterline, expressed in radians, as shown in [Figure D.1](#);
- L_E is the length of entrance of the waterline, expressed in metres, shown in [Figure D.1](#);

α	is the relative wave direction, relative to the bow in degrees;
NOTE	Zero (0) degrees refers to the waves incoming on the bow and a positive angle refers to waves coming in from starboard.
ω	is the circular frequency of regular waves, expressed in radians per second;
V_S	is the ship speed through the water, expressed in metres per second;
C_B	is the block coefficient;
Fr	is the Froude number;
E_2	is the angle of the run on the waterline, expressed in radians, as shown in Figure D.1 ;
L_R	is the length of run of the waterline, expressed in metres, shown in Figure D.1 ;
L_{pp}	is the ship's length between perpendiculars, expressed in metres;
T_{deep}	for a trimmed condition T_{deep} is the deepest moulded draught, expressed in metres.

The SNNM method has the following restrictions:

$$75 \text{ m} \leq L_{pp} \leq 400 \text{ m};$$

$$5,0 \leq L_{pp}/B \leq 8,0;$$

$$2,0 \leq B/T \leq 8,0;$$

$$0,52 \leq C_B \leq 0,88;$$

$$0,09 \leq Fr \leq 0,30.$$

D.5 STAWAVE-1: wave analysis method

STAWAVE-1 is a dedicated method to estimate the added resistance in waves for speed trial conditions. This method has been developed and verified by STA-JIP [3] and validated by ITTC 2014.[5] STAWAVE-1 only requires the input of the vessel beam, the length of the bow section and the significant wave height.

Speed trials are conducted in low to mild sea states with restricted wave heights. In head waves, the encounter frequency of the waves is high. In these conditions, the effect of wave induced motions can be neglected and the added resistance is dominated by the wave reflection of the hull on the waterline. The water line geometry is approximated based on the ship beam and the length of the bow section on the water line (see [Figure D.2](#)).

[Formula \(D.31\)](#) estimates the resistance increase in head waves if heave and pitch are small. The application is restricted to waves in the bow sector (less than ± 45 degrees off the bow). For wave directions outside this sector, no wave correction is applied.

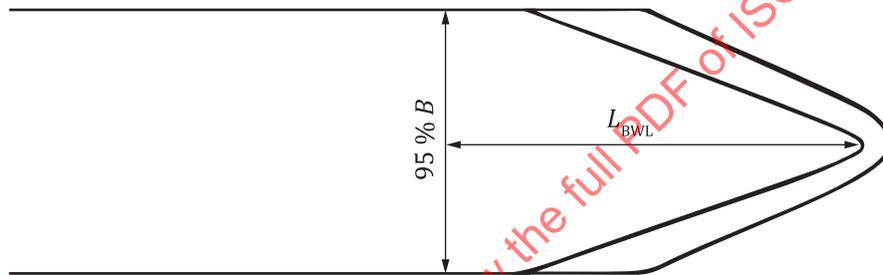
$$R_{AW} = \frac{1}{16} \rho_{act} g H_{1/3}^2 B \sqrt{\frac{B}{L_{BWL}}} \quad (D.31)$$

where

- R_{AW} is the mean resistance increase in irregular waves, expressed in newtons;
- ρ_{act} is the water density for the actual water temperature and salt content, expressed in kilograms per cubic metre;
- g is the acceleration of gravity, expressed in metres per second squared;
- B is the moulded ship's breadth, expressed in metres;
- $H_{1/3}$ is the significant wave height, expressed in metres;
- L_{BWL} is the distance of the bow to 95 % of maximum breadth on the waterline, expressed in metres, shown in [Figure D.2](#).

The STAWAVE-1 method can be used under the following restrictions:

- a) heave and pitch during speed and power trial are small;
- b) wave direction is in the bow sector [head waves ± 45 ($^{\circ}$)].



Key

- B the moulded ship's breadth, expressed in metres
- L_{BWL} the distance of the bow to 95 % of maximum breadth on the waterline, expressed in metres

Figure D.2 — Distance of the bow to 95 % of maximum beam on the waterline