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

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National foreword

This British Standard is the UK implementation of ISO 15016:2015. It supersedes BS ISO 15016:2002 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EPL/80, Maritime navigation and radiocommunication equipment and systems.

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

*Navires et technologie maritime — Lignes directrices pour
l'évaluation des performances de vitesse et de puissance par analyse
des données d'essais de vitesse*



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Contents

Page

Foreword	v
Introduction	vi
1 Scope	1
2 Normative references	2
3 Terms and definitions	2
4 Symbols and abbreviated terms	4
4.1 Symbols	4
4.2 Abbreviated terms	8
5 Responsibilities	8
5.1 Ship builders' responsibilities	8
5.2 The Trial Team	9
6 Trial preparations	9
6.1 Step 1: Installation and Calibration	9
6.2 Step 2: S/P trial agenda and pre-trial meeting	10
7 Ship's condition	11
7.1 Displacement	11
7.2 Trim	11
7.3 Hull and propeller	11
8 Trial boundary conditions	11
8.1 Location	12
8.2 Wind	12
8.3 Sea state	12
8.4 Water depth	13
8.5 Current	14
9 Trial procedures	14
9.1 Parameters that shall be recorded	14
9.2 Parameters measured during each run	14
9.3 Parameters measured at the speed trial site	15
9.4 General information	15
9.5 Tank test information	15
9.6 Scope and conduct of the measurements	16
9.6.1 Ship track and speed over ground	16
9.6.2 Torque	16
9.6.3 Wind	16
9.6.4 Water depth	16
9.6.5 Waves	16
9.6.6 Temperature and density	17
9.6.7 Current	17
10 Conduct of the trial	17
10.1 Initiation	17
10.2 Ship's track during trial	17
10.3 Run duration and timing	18
10.4 Trial direction	18
10.5 Steering	18
10.6 Approach	18
10.7 Number of speed runs	18
10.7.1 'Iterative' method	18
10.7.2 'Mean of means' method	19
11 Data acquisition	19
11.1 General data	19

11.2	Data on each run.....	20
11.3	Acquisition system.....	21
11.3.1	Minimum data.....	21
11.3.2	System requirements.....	21
11.3.3	Location.....	22
11.4	Manual data collection.....	22
12	Analysis procedure.....	24
12.1	General remarks.....	24
12.2	Description of the analysis procedure.....	24
12.2.1	Resistance data derived from the acquired data.....	25
12.2.2	Evaluation of the acquired data.....	25
12.2.3	Evaluation based on Direct Power Method.....	26
12.2.4	Correction of the measured ship's speed due to the effect of current.....	29
12.2.5	Correction of the ship's speed due to the effects of shallow water.....	30
12.2.6	Correction of the ship's performance due to the effects of displacement.....	30
12.2.7	Conversion of power curve from trial condition to full load/ stipulated condition.....	30
13	Processing of the results.....	30
14	Reporting.....	31
15	Example of speed trial data analysis.....	32
	Annex A (normative) General information and trial log sheet.....	34
	Annex B (normative) Beaufort scale for wind velocity.....	35
	Annex C (normative) Resistance increase due to wind.....	38
	Annex D (normative) Resistance increase due to waves.....	48
	Annex E (normative) Effect of water temperature and water density.....	61
	Annex F (normative) Effect of current.....	62
	Annex G (normative) Effect of shallow water.....	66
	Annex H (normative) Effect of displacement.....	67
	Annex I (normative) Conversion from trial condition to other stipulated load conditions.....	68
	Annex J (normative) Derivation of load variation coefficients.....	70
	Annex K (informative) Analysis of direct power method.....	75
	Bibliography.....	85

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

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

This second edition cancels and replaces the first edition (ISO 15016:2002), which has been technically revised.

[Annexes A, B, C, D, E, F, G, H, I and J](#) form a normative part of this International Standard, whereas [Annex K](#) is informative.

Introduction

This International Standard concerns the method of analysing the results obtained from speed trials.

The primary purpose of speed and power trials is to determine a ship's performance in terms of ship's speed, power and propeller shaft speed under prescribed ship's conditions and thereby verify the satisfactory attainment of a ship's speed stipulated by Energy Efficiency Design Index (EEDI) regulations and/or contract. Ship's speed is that realized under conditions stipulated by contract and/or EEDI regulations, which are usually; smooth hull and propeller surfaces, no wind, no waves, no current and deep water of 15°C.

In general it cannot be expected that all such stipulated conditions will be met during the actual trials. In practice, certain corrections for the environmental conditions have to be considered, such as for water depth, wind, waves and current [1][2].

The purpose of this International Standard is to define the basic requirements for the performance of speed trials, and provide procedures for evaluation and correction of speed trial data, covering all influences which may 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 International Standard is intended to help the interested parties achieve the desired target accuracy of, within 2 % in shaft power and 0,1 kn in speed.

The procedure specified in this International Standard has been developed largely on the basis of published data on speed trials and on ship's performance, the more important among them being listed in [Clause 2](#).

ISO has invited the International Towing Tank Conference (ITTC) to co-operate on the development of a new standard for speed/power trials taking into account the new guidelines issued by ITTC and approved by MEPC65 for EEDI. The contribution of the STA-group and the ITTC is highly appreciated.

Substitution of terms clause

This International Standard is generally applied to those ships for which survey and certification of EEDI is required under International Maritime Organization (IMO) Resolution MEPC.214(63) [as amended by MEPC.234(65)]. In the case of other ships, to which the above IMO resolutions are not applicable, the terms or phrases of this International Standard are deemed to be replaced as necessary (e.g. "agreement between the Shipbuilder, the Owner and the Verifier" shall be read as "agreement between the Shipbuilder and the Owner" etc.)

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

1 Scope

The primary purpose of speed and power trials is to determine a ship's performance in terms of ship's speed, power and propeller shaft speed under prescribed ship's conditions and thereby verify the satisfactory attainment of a ship's speed stipulated by EEDI regulations and/or contract.

This International Standard defines and specifies the following procedures to be applied in the preparation, execution, analysis and reporting of speed trials for ships, with reference to the effects which may have an influence upon the speed, power and propeller shaft speed relationship:

- the responsibility of each party involved,
- the trial preparations,
- the ship's condition,
- the limiting weather and sea conditions,
- the trial procedure,
- the execution of the trial,
- the measurements required,
- the data acquisition and recording,
- the procedures for the evaluation and correction,
- the processing of the results.

The contracted ship's speed and the ship's speed for EEDI are determined for stipulated conditions and at specific draughts (contract draught and/or EEDI draught). 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 and deviating ship draught, have to be considered. For this purpose, during the speed and power trials, not only are shaft power and ship's speed measured, but also relevant ship data and environmental conditions.

The applicability of this International Standard is limited to ships of the displacement type.

In this International Standard, it was decided that the unit to express the amount of an angle should be "rad" (radian) and that the unit of speed should be "m/s" (metres per second). Nevertheless, "°" (degree) as a unit for an angle and "knots" as a unit for speed may be used. However, the units for the angles and speeds which appear in calculation formulas are to be "rad" and "m/s" without exception. Moreover, for the convenience of the users of this International Standard, numerical values using the units of degree and knots are stated jointly at appropriate places.

If it is physically impossible to meet the conditions in this International Standard, a practical treatment is allowed based on the documented mutual agreement among the Owner, the Verifier and the Shipbuilder.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ITTC 7.5-04-01-01.4:2002, *ITTC Recommended Procedures and Guidelines, Speed and Power Trials, Part 4: Instrumentation Installation and Calibration*

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

3 Terms and definitions

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

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

**3.2
contract power**
brake power or shaft power that is stipulated in the new build or conversion contract between the Shipbuilder and the Owner

**3.3
contract speed**
ship's speed to be achieved as agreed within the terms of the new build/conversion contract

**3.4
Double Run**
two consecutive speed runs at the same power setting on reciprocal headings

Note 1 to entry: See [3.16](#) for speed runs.

**3.5
EEDI**
Energy Efficiency Design Index as formulated by IMO

**3.6
EEDI power**
brake power that is stipulated by the Energy Efficiency Design Index (EEDI) regulations

**3.7
EEDI Speed**
ship's speed achieved under the conditions specified by the IMO Resolution MEPC.245(66) (as amended)

**3.8
ideal conditions**
ideal weather and sea conditions: no wind, no waves, no current and deep water of 15°C

**3.9
measured ship's speed**
ship's speed during a speed run derived from the headway distance between start and end position and the elapsed time of the speed run

**3.10
Owner**
party that signed the new building or conversion contract with the Shipbuilder

3.11

power setting

setting of engine throttle and propeller shaft speed for fixed pitch propellers and setting of the pitch angle for controllable pitch propellers

3.12

propeller pitch

design pitch for a fixed pitch propeller

3.13

pitch angle

operating pitch angle of a Controllable Pitch Propeller (CPP)

3.14

shaft power

net power supplied by the propulsion machinery 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 shaft between propeller and the location of power measurement at the shaft

3.15

Shipbuilder

shipyard that signed the new building or conversion contract with the Owner

3.16

ship's speed

speed of the ship that is realised under the stipulated conditions

Note 1 to entry: See also measured ship's speed, contract speed and EEDI speed.

3.17

sister ships

ships with identical main dimensions, body lines, appendages and propulsion system built in a series by the same Shipyard

3.18

S/P trials

speed and power trials to establish the relationship between power and speed for a particular ship

3.19

S/P trial agenda

document outlining the scope of a particular S/P trial

3.20

speed run

ship's track with specified heading, distance and duration for which the measured ship's speed and shaft power are calculated

Note 1 to entry: This International Standard contains the procedures on how to conduct the trial and table(s) portraying the runs to be conducted.

3.21

tank tests

model tank tests for the prediction of the speed power relation for the stipulated conditions

3.22

trial baseline

the track of the first S/P run

3.23

Trial Leader

duly authorised (Shipbuilder's representative) person responsible for the execution of all phases of the S/P trials including the pre-trial preparation

3.24

trial log

all the data recorded before, during and after the S/P trial

3.25

Trial Team

team that consists of the Trial Leader, the Owner's representative, the appointed persons responsible for the S/P trial measurements and, if the ship requires EEDI, the Verifier

3.26

Verifier

third party responsible for verification of the EEDI

3.27

zero pitch

Controllable Pitch Propeller (CPP) blade angle at which the pitch angle at the representative radius is equivalent to zero

4 Symbols and abbreviated terms

4.1 Symbols

A_{LV}	is the lateral projected area above the waterline including superstructures
A_M	is the midship section area under water
A_{OD}	is the lateral projected area of superstructures above upper deck
a_Q, b_Q, c_Q	are the factors for the torque coefficient curve
a_T, b_T, c_T	are the factors for the thrust coefficient curve
A_{XV}	is the transverse projected area above the waterline including superstructures in square metres
B	is the ship's breadth
$B(x)$	is the sectional breadth
B_f	is the bluntness coefficient
C_{AA}	is the wind resistance coefficient; $C_{AA}(0)$ means the wind resistance coefficient in head wind
C_B	is the block coefficient
C_F	is the frictional resistance coefficient for the actual water temperature and water density
C_{F0}	is the frictional resistance coefficient for the reference water temperature and water density
C_{MC}	is the horizontal distance from midship section to centre of lateral projected area A_{LV} , where + means forward from midship
C_{Pv}	is the vertical prismatic coefficient
C_{T0}	is the total resistance coefficient for the reference water temperature and water density
C_U	is the coefficient of advance speed
D	is the propeller diameter
E	is the directional spectrum
e_i	is the scale correlation factor of the wake fraction
F_D	is the skin friction correction force same as in the normal self-propulsion tests
Fr	is the Froude number

F_X	is the external tow force measured during load variation test
g	is the acceleration of gravity
G	is the angular distribution function
h	is the water depth
$H_1(m)$	is the function to be determined by the distribution of singularities $\sigma(x)$ which represents a periodical disturbance by the ship
$H_{1/3}$	is the significant wave height
H_{BR}	is the height of top of superstructure (bridge etc.)
H_C	is the height from waterline to centre of lateral projected area A_{LV}
$H_{S1/3}$	is the significant height of local swell
$H_{W1/3}$	is the significant height of local wind driven waves
(i)	is the run number
I_1	is the modified Bessel function of the first kind of order 1
J	is the propeller advance coefficient
J_{id}	is the propeller advance coefficient in the ideal condition
J_{ms}	is the propeller advance coefficient in the trial condition
k	is the wave number
K_1	is the modified Bessel function of the second kind of order 1
K_Q	is the torque coefficient
K_{Qid}	is the torque coefficient in the ideal condition
K_{Qms}	is the torque coefficient in the trial condition
K_T	is the thrust coefficient
K_{Tid}	is the thrust coefficient in the ideal condition
K_{Tms}	is the thrust coefficient in the trial condition
k_{yy}	is the non-dimensional radius of gyration in the lateral direction
L_{BWL}	is the distance of the bow to 95 % of maximum breadth on the waterline
L_{OA}	is the ship's length overall
L_{PP}	is the ship's length between perpendiculars
MCR	is the Maximum Continuous Rating
m_n	is the n^{th} moment of frequency spectrum
n_{id}	is the corrected propeller shaft speed
n_{ms}	is the measured propeller shaft speed
P_1	is the power corresponding to displacement volume ∇_1 during the S/P trial
P_2	is the power corresponding to displacement volume ∇_2 used in the tank test
P_{Bms}	is the measured brake power
P_{Did}	is the delivered power in the ideal condition
P_{Dms}	is the delivered power in the trial condition
$P_{Full,P}$	is the power at full load/stipulated condition predicted by the tank tests
$P_{Full,S}$	is the power at full load/stipulated condition obtained by the S/P trials
P_{Sms}	is the measured shaft power
$P_{Trial,P}$	is the power at the trial condition predicted by the tank tests
$P_{Trial,S}$	is the power at the trial condition obtained by the S/P trials

R_{AA}	is the resistance increase due to relative wind
R_{AS}	is the resistance increase due to deviation of water temperature and water density
R_{AW}	is the resistance increase due to waves
R_{AWL}	is the mean resistance increase in long crested irregular waves, as substitute for R_{AW}
R_{AWM}	is the mean resistance increase in regular waves based on Maruo's theory, which is calculated from the radiation and diffraction components
R_{AWR}	is the correction term of R_{AWM}
R_F	is the frictional resistance for the actual water temperature and water density
R_{F0}	is the frictional resistance for the reference water temperature and water density
R_{id}	is the resistance in the ideal condition
R_{ms}	is the resistance in the trial condition
R_{T0}	is the total resistance for the reference water temperature and water density
R_{wave}	is the mean resistance increase in regular waves
R_{wave}^{EXP}	is the mean resistance increase in regular waves measured in the tank tests
s	is the directional spreading parameter
S	is the wetted surface area
S_S	is the full scale wetted surface, the same value as used in the normal self-propulsion test
S_η	is the frequency spectrum
t	is the thrust deduction factor
T_C	is the period of variation of current speed
T_{deep}	is the draught; for a trim condition T_{deep} is the deepest draught
t_{id}	is the thrust deduction factor in the ideal condition
T_M	is the draught at midships
t_{ms}	is the thrust deduction factor in the trial condition
V'_{WR}	is the corrected relative wind velocity at the vertical position of the anemometer
V'_{WT}	is the averaged true wind velocity at the vertical position of the anemometer
V_A	is the speed of flow into propeller
V_C	is the current speed
V_G	is the measured ship's speed over ground
V_{G1}	is the measured ship's speed over the ground on the first of four runs
V_{G2}	is the measured ship's speed over the ground on the second of four runs
V_{G3}	is the measured ship's speed over the ground on the third of four runs
V_{G4}	is the measured ship's speed over the ground on the fourth of four runs
V_S	is the ship's speed through the water
V_{WR}	is the relative wind velocity
V_{WRref}	is the relative wind velocity at the reference height
V_{WT}	is the true wind velocity
V_{WTref}	is the true wind velocity at the reference height
w_M	is the model wake fraction
w_{Mid}	is the model wake fraction in the ideal condition
w_{Mms}	is the model wake fraction in the trial condition
w_S	is the full-scale wake fraction

w_{Sid}	is the full-scale wake fraction in the ideal condition
w_{Sms}	is the full-scale wake fraction in the trial condition
x	is the longitudinal coordinate
Z_a	is the vertical position of the anemometer
Z_{ref}	is the reference height for the wind resistance coefficients
Z_{Γ}	is the vertical displacement relative to waves in steady motion
α_P	is the power ratio
α_T	is the effect of draught and encounter frequency
α	is the angle between ship's heading and component waves; 0 means head waves
β_W	is the slope of the line element dl along the water line
Γ	is the Gamma function
ΔP	is the required correction for power
ΔR	is the total resistance increase
Δt	is the deviation of the thrust deduction factor
ΔV	is the decrease of ship's speed due to shallow water
Δw_M	is the deviation of the wake fraction
$\Delta \eta_R$	is the deviation of the relative rotative efficiency
ζ_A	is the wave amplitude
η_D	is the propulsive efficiency coefficient
η_{Did}	is the propulsive efficiency coefficient in ideal condition
η_{Dms}	is the propulsive efficiency coefficient in trial condition
η_M	is the transmission efficiency
η_O	is the propeller open water efficiency
η_{Oms}	is the propeller efficiency in the ideal condition
η_R	is the relative rotative efficiency
η_{Rid}	is the relative rotative efficiency in the ideal condition
η_{Rms}	is the relative rotative efficiency in the trial condition
η_S	is the shaft efficiency
θ_m	is the angle between ship's heading and wave direction relative to the bow; 0 means head waves
λ	is the scale factor
μ	is the smoothing range
ξ_n, ξ_V	are derived considering the load variation effect as described in Annex I
ξ_P	is derived considering the load variation effect as described in Annex I
ρ_A	is the mass density of air
ρ_M	is the water density in the model test
ρ_S	is the water density for the actual water temperature and salt content
ρ_{S0}	is the water density for the reference water temperature and salt content
τ_P	is the load factor equal to K_T / J^2
τ_{Pid}	is the load factor in the ideal condition
τ_{Pms}	is the load factor in the trial condition
ψ	is the ship's heading
ψ'_{WR}	is the corrected relative wind direction at the vertical position of the anemometer
ψ'_{WT}	is the averaged true wind direction at the vertical position of the anemometer

ψ_{WR}	is the relative wind direction; 0 means head winds
ψ_{WRref}	is the relative wind direction at the reference height
ψ_{WT}	is the true wind direction in Earth system
ω	is the circular frequency of regular waves
ω_E	is the circular wave frequency of encounter
∇_1	is the displacement volume during the S/P trial
∇_2	is the displacement volume used in the tank test

4.2 Abbreviated terms

CPP	Controllable Pitch Propeller
IMO	International Maritime Organization
ITTC	International Towing Tank Conference
JASNAOE	The Japan Society of Naval Architects and Ocean Engineers
JONSWAP	Joint North Sea Wave Project
MEPC	Marine Environmental Protection Committee in IMO
SNAJ	The Society of Naval Architects of Japan
SNAME	The Society of Naval Architects and Marine Engineers, USA
STA-Group	An international group of owners, shipyards, research institutes, classification societies and universities studying and improving sea trial procedures and Sea Trial Analyses (STA)

5 Responsibilities

5.1 Ship builders' 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 engines, systems and equipment required during the sea trials, are on board,
- all regulatory bodies: 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; have been informed, are available and on board when required,
- all safety measures have been checked,
- all fixed, portable and individual material (for crew, trial personnel and guests) is on board and operative,
- any safety systems for conducting safe S/P trials have been checked in accordance with the administrative requirements,
- an inclining test has been performed and/or at least a preliminary stability booklet including the S/P trials condition has been approved, in accordance with the SOLAS 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. This 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 (where applicable) Verifier.

The Shipbuilder shall arrange for divers to inspect the ship's hull and propulsor(s) if necessary.

The Shipbuilder is responsible for the overall trial co-ordination. 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 on the preparation, execution and results of the S/P trials.

5.2 The Trial Team

The Trial Team is responsible for correct measurements and reporting of the S/P trials according to this International Standard and for the analysis of the measured data to derive the ship's 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)/propulsor(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 ship's Master and the Owner's representative with a preliminary data package and initial analysis before disembarking,
- delivering a final report on completion of full analysis of the measurements taken during the trial.

6 Trial preparations

The success of the S/P trials largely depends on the preparations. In this Clause the most important steps are summarized.

6.1 Step 1: Installation and Calibration

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

Apart from the obvious inputs such as; shaft torque, propeller shaft speed and DGPS, it is important to check:

- a) gyrocompasses,
- b) anemometer system,
- c) propeller pitch (of each propeller),
- d) ship's draught measurement system (if available),
- e) water depth measuring system.

After the trial instrumentation is installed, all shipboard input signals to be recorded during the S/P trials shall be calibrated prior to the trials. For this purpose the sensors shall be cycled throughout the full operating range of the system.

This is accomplished by:

- slewing the gyrocompasses,
- changing the propeller pitch.

Prior to departure for S/P trials and with the ship in a steady loading condition, all draught marks, water temperature and specific density, and ship's draught measuring system (if available) shall be measured and recorded. If no ship's draught measuring system is available, all tank sounding data shall be recorded.

The shaft power shall be derived from torque and propeller shaft speed.

Shaft torque shall be measured by means of a calibrated permanent torque sensor or strain gauges on the 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.

As part of the S/P trial preparation, the torsion meter's zero torque readings shall be determined since there is a residual torque in the shaft, which is resting on the line shaft bearings. The torsion meter zero setting is to be carried out in accordance with its maker's instructions. If not specified otherwise, the zero torque value is determined with the ship at rest by turning the shaft ahead and astern and taking the mean of these two readings as the zero value (refer to ITTC 7.5-04-01-01.4 2002).

The shaft material properties, e.g. 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 of 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 the case of controllable pitch propeller(s) there might be a drilling diameter to be taken into account (to be supplied by Shipbuilder).

When shaft torque measurement is not possible, an alternative power measurement method recommended by the engine manufacturer and approved by the Owner and the Verifier is acceptable.

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

- Prior to dock-out the oil distribution mechanism showing the propeller pitch shall be checked for zero pitch;
- Check zero pitch reading in the measurement system against the mechanical reading in the oil distribution box;
- Determine the design pitch, maximum ahead pitch and maximum astern pitch, then adjust the ship indicators to reflect the measurements. Establish the corrections necessary to account for changes in pitch due to shaft compression as thrust increases and temperature effects on the propeller pitch control rod.

An important deliverable of this stage will be a document describing the test set-up, including evidence of the 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 procedures and the post-trial check to verify the calibration results.

6.2 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 of the S/P trial agenda,

- Approval of the procedures and the consequential correction methods to be used to calculate the trial speed and to deliver the speed trial report, i.e. [Clauses 11](#) to [13](#).

7 Ship's condition

The condition of a ship undergoing an S/P trial shall be as follows:

7.1 Displacement

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

The ship's draught, trim and displacement shall be obtained immediately prior to the S/P trials by averaging the ship draught mark readings at the perpendiculars and midships port and starboard.

In the event that reading the draught marks will be unsafe or provide an inaccurate result, displacement determination shall be conducted either by reading the internal draught measurement system or by evaluating all tank soundings.

Displacement shall be derived from the Bonjean data or using quadratic equations with hydrostatic data, taking into consideration the hog/sag using the draught data (forward, aft and at half length) and the density of the water.

The ship shall be brought into a loading condition that is as close as possible to contract condition and/or the condition at which tank tests have been carried out. The loading condition shall be confirmed at zero ship's speed.

7.2 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 fore draught shall be within $\pm 0,1$ m of the ship's condition for which tank test results are available.

7.3 Hull and propeller

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 [\[3\]](#) 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.

8 Trial boundary conditions

During the S/P trial, there may be many conditions that deviate from the contract condition. The objective during the S/P trial is to minimize the number of influencing factors.

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

In order to arrive at reliable S/P trial results the boundary conditions shall not exceed the values given in this Clause.

8.1 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 deflections to maintain heading which cause excessive fluctuations in shaft torque, propeller shaft speed and measured ship's 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 in order 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.

8.2 Wind

The wind velocity during the S/P trial shall not be higher than:

Beaufort number¹⁾ 6, for ships with

$$L_{PP} > 100 \text{ m}$$

or

Beaufort number 5, for ships with

$$L_{PP} \leq 100 \text{ m}$$

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

8.3 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:

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

For all correction methods related to waves, the following empirical criteria shall be applied in relation to 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:

$$H_{1/3} \leq 2,25 \sqrt{L_{PP} / 100} \quad (2)$$

when the wave height is derived from visual observations:

$$H_{1/3} \leq 1,50 \sqrt{L_{PP} / 100} \quad (3)$$

The above limits are illustrated in [Figure 1](#).

1) The Beaufort Scale is given in [Annex B](#).

When use is made of transfer functions of added resistance from dedicated model tests the wave spectrum encountered during the S/P trials shall be measured unless the wave height is less than:

$$H_{1/3} \leq 0,50 \sqrt{L_{PP} / 100} \quad (4)$$

where, in each case:

L_{PP} is the ship's length between perpendiculars in metres;

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

$H_{W1/3}$ is the significant height of local wind driven waves in metres;

$H_{S1/3}$ is the significant height of local swell in metres.

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

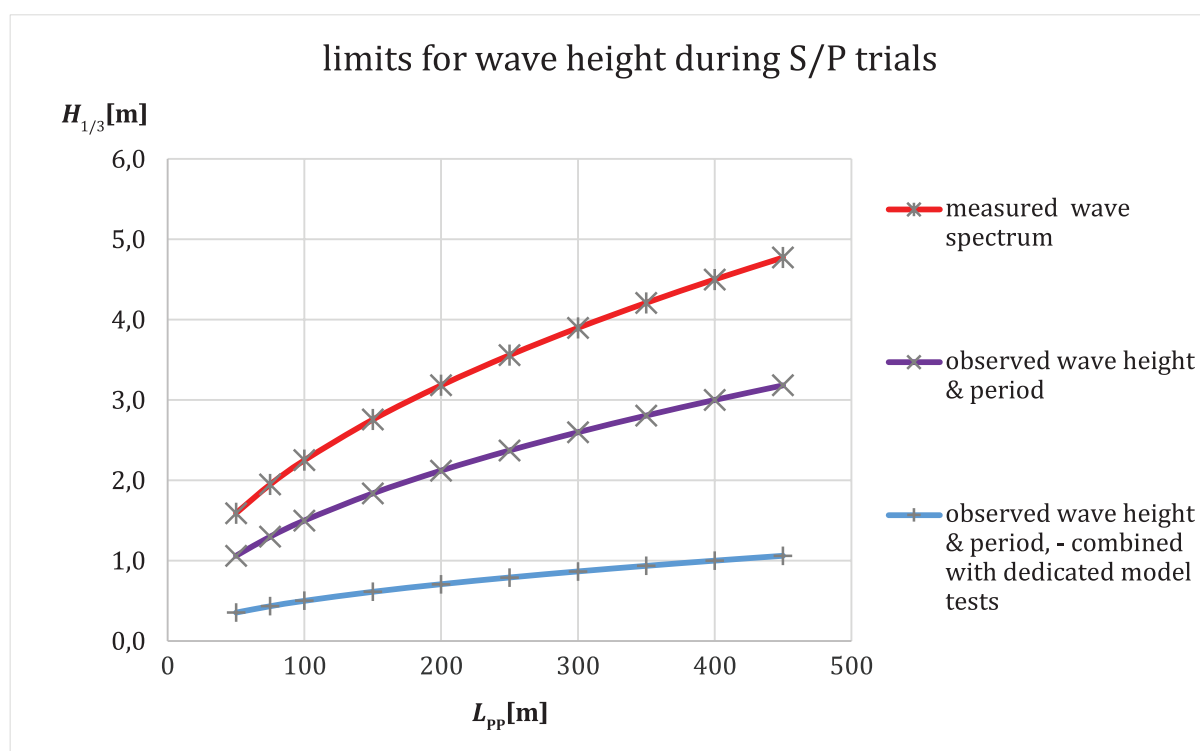


Figure 1 — Limits for allowable wave height

8.4 Water depth

There are correction methods that compensate for shallow water effects (see [Annex G](#)). However, it is preferable to avoid the corrections by selecting a suitable S/P trial location. If the water depth in the S/P

trial area is less than the larger of the values obtained from the following two formulae, shallow water correction may be applied [6],[16] :

$$h = 3\sqrt{B \cdot T_M} \text{ and } h = 2,75 \frac{V_S^2}{g} \quad (5)$$

The value of water depth to be used for correction shall not be less than the larger value obtained from the following two formulae [6] :

$$h = 2\sqrt{B \cdot T_M} \text{ and } h = 2 \frac{V_S^2}{g} \quad (6)$$

where:

h is the water depth in metres;

B is the ship's breadth in metres;

T_M is the ship's draught at midships in metres;

V_S is the measured ship's speed in metres per second;

g is the acceleration of gravity in metres per second squared.

Furthermore, 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.

8.5 Current

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

In cases of current time history deviating 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 correction methods in [Annex F](#) are applicable. Areas where this may occur shall be avoided for S/P trials.

9 Trial procedures

9.1 Parameters that shall be recorded

In this Clause an overview is given of the parameters that influence the trial speed. All these parameters shall be measured and recorded as accurately as possible.

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

9.2 Parameters measured during each run

The accepted measurement devices are given in [Table 1](#).

Table 1 — Parameters measured during each run

	Acceptable measurement devices	Unit
Ship's position	DGPS	Lat., Lon., °
Speed over ground	DGPS (for information purpose only)	knots
Shaft torque	Torsion meter with calibrated torque sensor or strain gauges	kNm
or Shaft power	Power calculated from torque and propeller shaft speed	kW
Propeller shaft speed	Pick-up, optical sensor, ship's revolutions counter	min ⁻¹
Propeller pitch	Bridge replicator, indicator on shaft	° or mm
Time	GPS Time	hh:mm:ss or UTC
Water depth	Ship echo sounder and nautical charts	m
Ship's heading	Gyro compass, or compass- DGPS	°
Relative wind velocity and direction	Ship's anemometer, however if not available, a dedicated trial anemometer	m/s, °
Wave height, period and direction Swell height, period, and direction	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, °
Bow acceleration (STAWAVE-1)	Acceleration meter	m/s ²
Date	Calendar	yyyy-mm-dd

9.3 Parameters measured at the speed trial site

The accepted measurement devices are given in [Table 2](#).

Table 2 — Parameters measured at the speed trial site

Water density	Salinity sensor, Conductivity Density Temperature (CDT) sensor	kg/m ³
Water temperature	Thermometer, CDT sensor	°C
Air temperature	Thermometer	°C
Air pressure	Barometer	hPa, mb
Torsion meter zero setting	Torsion meter with calibrated torque sensor or strain gauges	kNm
Trial area	Geographical position (Lat-Long) by DGPS	dddd-mm
Vertical position of anemometer	General arrangement plan of the ship	m
Draughts	Physical observation and / or calibrated draught gauges	m

9.4 General information

Prior to the trial, the relevant data in [Annex A](#) shall be recorded, and shared among the Shipyard, the Owner and (where applicable) the Verifier.

The S/P Run Data as specified in [Annex A](#) will be recorded during the trials.

9.5 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 test curves is used. Therefore, an accurate tank test and a validated consistent method for extrapolation to full scale are required.

The tank tests shall be conducted according to the following criteria:

- a) Tank tests shall be conducted at the contract draught and trim and the EEDI draught and trim, as well as the trial draught and trim.
- b) Tank tests following the scheme of ITTC Recommended Procedures for Resistance and Propulsion Tank tests [5], including load variation tests shall be conducted.
- c) The same methods, procedures and empirical coefficients shall be used to extrapolate the model scale values to full scale for all draughts and trims. Where different empirical coefficients for the different draughts are used, full details shall be recorded 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) The tank test report shall be transparent and give sufficient information to enable the Verifier to check the tank test results related to the sea trial analysis.

9.6 Scope and conduct of the measurements

9.6.1 Ship track and speed over ground

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

9.6.2 Torque

The calibration of the torque measurement shall not be altered during the S/P trials.

9.6.3 Wind

The ship's own anemometer shall be used. However, if not available, a dedicated trial anemometer is to be used. The anemometer shall be as clear as possible from the superstructure.

9.6.4 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 taken into account. Calibration shall be combined with a comparison of indicated depth against the water depth given on the chart in the trial area.

9.6.5 Waves

Preferably, the wave height, wave period and direction 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 instruments on-board the ship such as wave radar, lidar or wave scanner may be used. The wave measurement equipment shall be calibrated and the accuracy shall be validated and documented.

If, for the wave correction, use is made of transfer functions of added resistance in waves derived from model tests for the subject ship, the wave spectrum encountered during the S/P trials shall be measured unless the wave height satisfies: $H_{1/3} \leq 0,50\sqrt{L_{PP}} / 100$ (see 8.3).

If use is made of the empirical wave correction methods described in Annex D (without specific model tests), and if the wave heights satisfy: $H_{1/3} \leq 1,50\sqrt{L_{PP}} / 100$ (see 8.3), the encountered wave heights, periods and directions of both wind waves and swells may be determined from observations by multiple experienced

mariners, including the Owner's representative and the Verifier. In addition to the wave observations wave data provided by an experienced and independent meteorological office may be used as well.

9.6.6 Temperature and density

The local water temperature and density shall be recorded to enable the calculation of the ship's displacement and corrections with regard to viscosity. The temperature shall be taken at water inlet level. Air temperature and pressure shall be measured using a calibrated thermometer and barometer, respectively.

9.6.7 Current

Current speed shall be determined as part of the evaluation of each run.

When using the 'Mean of means' method, after the two (2) Double Runs with the same power setting, the current speed is calculated from the measured speed at each run and the 'Mean of means' value of those two (2) Double Runs (see [E.2](#)).

Alternatively the 'Iterative' method may be utilized to establish the current speed (see [E.1](#)).

10 Conduct of the trial

On the day of and during the S/P trial, a number of pre-requisites shall be met in order to arrive at reliable trial results. In this Clause an overview is given of the minimum requirements.

10.1 Initiation

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

Where wave height, period or wave directions are derived from visual observation, the schedule for the S/P Trials shall be arranged such that all speed runs around EEDI power are conducted by daylight.

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

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

- draught reading as described in [7.1](#) and calculation of displacement,
- zero setting of shaft torque meter,
- measuring water temperature and density.

10.2 Ship's track during trial

The S/P trial runs shall be conducted over the same ground area. For each base course, each speed run shall be commenced (COMEX) and completed (FINEX) at the same place.

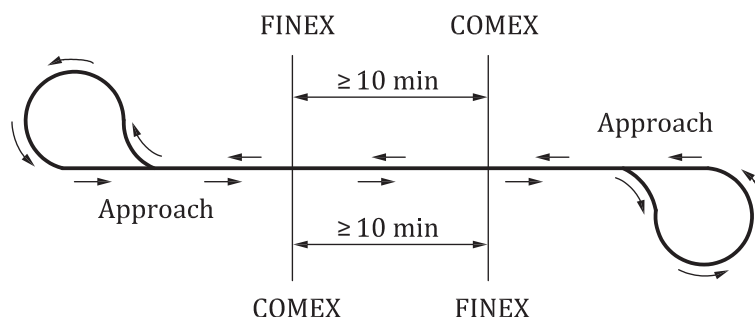


Figure 2 — Path of ship during Double Run

Modified Williamson turns or similar types of manoeuvre shall be executed between each run to return the ship to the reciprocal heading on, or parallel to, the trial baseline. Parallel means within one ship's length of the trial baseline (see also [10.6](#)). This procedure shall be used to avoid different sea states, wind or current conditions. Engine throttles, rpm setting(s) or pitch setting(s) shall not be altered during this period. The rudder angle used in this manoeuvre shall be such that the ship's speed loss in the turn is minimised.

10.3 Run duration and timing

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

10.4 Trial direction

The speed runs shall be carried out by heading into and following the dominant wave direction.

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. It is imperative that extremely tight control is exercised during the execution of the S/P trials to minimize as many variables as possible that could unduly influence the speed/power relationship.

10.5 Steering

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

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

10.6 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 course with minimum rudder angles.

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

10.7 Number of speed runs

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 [10.2](#)) and at the same engine settings.

The number of speed runs required depends on the current correction method to be applied (see [Annex F](#)).

- a) 'Iterative' method;
- b) 'Mean of means' method.

Whenever possible, 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.

10.7.1 'Iterative' method

To determine the speed/power curve for the first ship of a ship series, a minimum of four (4) Double Runs at three (3) different power settings are required.

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

- Two (2) Double Runs for the first ship and one (1) Double Run (at the same power setting) for sister ships around EEDI / Contract power,
- One (1) Double Run below EEDI / Contract power,
- One (1) Double Run above EEDI / Contract power.

If the wave height is around the limiting conditions and significant ship motions are observed, one (1) additional Double Run at that power setting shall be conducted.

10.7.2 'Mean of means' method

To determine the speed/power curve for the first ship of a ship series, a minimum of six (6) Double Runs at three (3) different power settings are required.

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

- Two(2) Double Runs around EEDI / Contract power,
- Two(2) Double Runs below 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 [4],[6]. In order 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).

If the results of the S/P trials of the first ship of a series are acceptable, the second and following sister ships may be subjected to a reduced speed trial program. For such 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 around EEDI / Contract power,
- One(1) Double Run below EEDI / Contract power,
- One(1) Double Run above EEDI / Contract power.

If the wave height is around the limiting conditions and significant ship motions are observed, and/or current variations of above 0.2 knots are encountered, one (1) additional Double Run at that power setting shall be conducted.

11 Data acquisition

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's speed and power characteristics are extremely sensitive to factors such as hull and propeller condition, ship displacement, 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, by means of a data acquisition system (measurement computer), and 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 in order to increase the level of accuracy of the S/P trials.

In general, data to be acquired maybe divided into general data which are applicable to all speed runs and specific data that are varying throughout every run.

11.1 General data

Prior to the trial, the data specified below shall be recorded, based on measurements where relevant:

- Area of trial (in Latitude/Longitude coordinates);
- Weather condition;
- Water temperature and density;
- Air temperature;
- Vertical position of the anemometer above waterline;
- Fore, midships and aft draughts;
- Displacement calculated from the draughts;
- Trim calculated from the draughts;
- Transverse projected area above the waterline including superstructures;
- Lateral projected area of superstructures above upper deck (Fujiwara) + height of superstructure;
- Lateral projected area above the waterline including superstructures (Fujiwara) + position of centre of gravity;
- Bow acceleration (STAWAVE-1).

In order to verify the wind data measured during the S/P trials, it is recommended to record the absolute wind velocity and direction at shore based station(s) or as measured directly prior to and after finalising the speed trials while the ship is stopped.

11.2 Data on each run

- Date;
- Clock time at commencement;
- Time elapsed over the speed run;
- Ship's heading;
- Measured ship's speed over ground calculated from start and end position of the run and the elapsed time of the speed run;
- Propeller shaft speed;
- Propeller shaft torque and/or power;
- Propeller pitch in case of CPP;
- Relative wind velocity and direction by anemometer;
- Mean wave period, significant wave height and direction of wind driven seas;
- Mean swell period, significant swell height and direction of local swell waves;
- Mean water depth.

11.3 Acquisition system

The acquisition system shall record time histories of the measurements described in [11.3.1](#) in order to ensure quality control and to provide information that will allow for the development of uncertainty analysis.

11.3.1 Minimum data

The following parameters, as a minimum, shall be continuously recorded during each speed run:

- Time;
- Propeller shaft torque or power;
- Propeller shaft speed;
- Pitch of CPP;
- Ship's position;
- Ship's heading;
- Measured ship's speed over ground;
- Relative wind direction;
- Relative wind velocity.

11.3.2 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) Display time traces of the trial parameters specified in [11.3.1](#).
- d) Calculate statistics (mean min, max, standard deviation).

At the end of each run the data acquisition system shall display all recorded time histories to facilitate evaluation of the quality and consistency of the acquired trial data and store the readings for subsequent graphical presentation.

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

- e) Trial start time.
- f) Number of samples taken.
- g) Maximum value.
- h) Minimum value.
- i) Average value.
- j) Standard deviation.

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