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Preparation and Conduct of Speed/Power Trials

1. PURPOSE

The primary purpose of speed-power trials is to determine ship performance in terms of speed, power and propeller revolutions under prescribed ship conditions, and thereby verifying the satisfactory attainment of the contractually stipulated Ship Speed and to provide the Ship Speed for the calculation of the Energy Efficiency Design Index (EEDI) as required by IMO.

The present Recommended Procedure concerns the preparation and execution of speed-power trials and has been defined by the 27th ITTC Specialist Committee on the Performance of Ships in Service. In this work the Committee took into account:

- Recommendations 23rd ITTC 2002; Ref [1],
- ISO 19019, 2002; Ref [2],
- ISO 15016, 2002; Ref [3],
- STA-JIP, 2006; Ref [4],[8].

For the analysis and reporting of speed-power trials, reference is made to Part 2 of this Recommended Procedure. The purpose of this document, Part 1, which is applicable to commercial ships of displacement type, is to define and specify:

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

The contracted ship speed and the speed for EEDI shall be determined for stipulated conditions which are defined at specific draughts (contract draught and EEDI draught) and usually for ideal environmental conditions i.e. no wind, no waves, no current, deep water.

Normally, such stipulated conditions are not experienced during the actual trials. In practice, certain corrections for the environmental conditions, as for water depth, wind, waves and deviating ship draught have to be considered. For this purpose, not only the Shaft Power and Ship Speed are measured, but also relevant ship data and environmental conditions during the speed-power trials.

In case it is physically impossible to meet the conditions in these Guidelines, a practical approach mutually agreed by Owner, Verifier and Shipbuilder can be allowed.

All trial procedures and measurements shall be conducted in such a way that the speed at Contract power and the speed at EEDI Power are derived within 0.1 knots and the Shaft Power within 2%.

2. DEFINITIONS

- **Brake Power**: power delivered by the output coupling of the propulsion machinery.
- **Contract Power**: Shaft Power that is stipulated in the newbuilding or conversion contract between Shipbuilder and Owner.

- **Docking Report**: report that documents the condition of the ship hull and propulsors (available from the most recent dry-docking).
- **Double Run**: two consecutive Speed Runs at the same power setting on reciprocal heading.
- **EEDI**: Energy Efficiency Design Index as formulated by IMO.
- **EEDI Power**: Shaft Power that is stipulated by the EEDI regulations.
- **Ideal Conditions**: ideal weather and sea condition; deep water, no wind, no waves and no current.
- **Owner**: party that signed the newbuilding or conversion contract with the Shipbuilder.
- **Propeller Pitch**: the design pitch, also for controllable pitch propellers.
- **Running Pitch**: the operating pitch of a CPP.
- **Shaft Power**: net power supplied by the propulsion machinery to the propulsion shafting after passing through all speed-reducing and other transmission devices and after power for all attached auxiliaries has been taken off.
- **Shipbuilder**: ship yard that signed the newbuilding or conversion contract with the Owner.
- **Ship Speed**: speed that is realised under the stipulated conditions. "Contract Speed" refers to the contractual conditions agreed. "EEDI Speed" refers to the conditions specified by IMO. The ship's speed during a Speed Run is derived from the headway distance between start and end position and the elapsed time of the Speed Run.
- **Sister Ships**: ships with identical main dimensions, body lines and propulsor system built in a series by the same Shipbuilder.
- **S/P Trials**: speed-power trials to establish the Speed-Power relation of the vessel.
- **Speed Run**: ship track with specified heading, distance and duration over which Ship Speed and Shaft Power are measured.
- **S/P Trial Agenda**: document outlining the scope of a particular S/P Trial. This document contains the procedures on how to conduct the trial and table(s) portraying the runs to be conducted.
- **Trial Log**: for each Speed Run, the log contains the run number, the times when the Speed Run starts and stops, and the data as described in Section 9.4 and Appendix C of Part I of these Guidelines.
- The **Trial Leader** is the duly authorised (Shipbuilder's representative) person responsible for the execution of all phases of the S/P Trials including the pre-trial preparation.
- The **Trial Team** consists of the Trial Leader, the Owner's representative, the appointed persons responsible for the S/P Trial measurements and the Verifier.
- **Verifier**: third party responsible for verification of the EEDI.

3. RESPONSIBILITIES

3.1 Shipbuilders' responsibilities

The Shipbuilder is responsible for planning, conducting and evaluating the S/P Trials:

- Speed and Shaft 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,
- The Shipbuilder has to provide all permits and certificates needed to go to sea,
- The Shipbuilder is responsible for ensuring that all qualified personnel, needed for operating the ship, all engines, all systems

and equipment during the sea trials are on board,

- The Shipbuilder is responsible for ensuring that all regulatory bodies, Classification Society, Owner, ship agents, suppliers, subcontractors, harbour facilities, departments organising the delivery of provisions, fuel, water, towing, etc., needed for conducting the sea trials, have been informed and are available and on board, when required,
- It is the Shipbuilder's responsibility that all safety measures have been checked and that all fixed, portable and individual material (for crew, trial personnel and guests) is on board and operative,
- It is the Shipbuilder's responsibility that dock trials of all systems have been executed and all alarms, warning and safety systems have been checked,
- It is the Shipbuilder's responsibility that an inclining test has been performed and/or at least a preliminary stability booklet including S/P Trials condition has been approved, in accordance with the SOLAS Convention,
- It is the Shipbuilders responsibility that 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 Appendix A as well as the results of the model tests for this ship at trial draught and trim, EEDI draught and trim and Contract draught and trim.

The Shipbuilder is responsible for the overall trial coordination between the ship's crew and Trial Team. 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 Shipbuilder has to arrange for divers to inspect the ship's hull and propulsor if necessary.

The Trial Leader maintains contact with the Trial Team on the preparation, execution and results of the S/P Trials.

3.2 The Trial Team

The Trial Team is responsible for correct measurements and reporting of the S/P Trials according to this document and for the analysis of the measured data to derive the ship's speed and power at the stipulated conditions. This analysis shall be conducted in compliance with Part 2 of this Recommended Procedure.

The Trial Team is responsible for the following:

- conducting inspection of ship including hull and propeller condition,
- providing, installing and operating all required trial instrumentation and temporary cabling,
- providing the ship master and Owner's representative with a preliminary data package and preliminary analysis before debarking,
- providing a final report after completion of the trials in accordance with Chapter 10.

4. TRIAL PREPARATIONS

The success of the S/P Trials largely depends on the preparations. In this chapter, the most important steps are summarised.

4.1 Installation & Calibration

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

Apart from the obvious signals such as shaft torque, rpm and DGPS, it is important to check:

1. Gyrocompasses
2. Anemometer system
3. Speed log system
4. Propeller Pitch (of each propeller)
5. Ship's draught measurement system (if available)
6. Water depth measuring system

All shipboard signals that will be recorded during the S/P Trials shall be calibrated after the instrumentation is installed prior to the S/P 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 on S/P Trials, the ship's draught measurement system (if available) needs to be verified by directly reading all draught marks, seawater temperature, specific density and the internal draught system at the same time.

The Shaft Power will be derived from torque and rpm.

Shaft torque shall be measured by means of permanent torque sensor or strain gauges on the shaft. The measurement system shall be certified for power measurements on a test shaft with a bias error smaller than 1% so that an overall bias error smaller than 2% (on board of the actual ship) 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 done according to its maker's instructions.

The shaft material properties, i.e. the G-Modulus, as specified and documented by the shaft supplier shall be provided by the Shipbuilder. The shaft diameter used in the power calculation shall be derived from the shaft circumference in-situ measured at the location of the torque measurement. In case of variable pitch propeller there might be a drilling diameter to be taken into account (to be supplied by Shipbuilder).

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

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

1. Prior to dock-out the oil distribution mechanism showing the Propeller Pitch shall be checked for zero pitch;
2. Check zero pitch reading in the measurement system against the mechanical reading in the oil distribution box;
3. Determine the maximum ahead pitch, design pitch, and maximum astern pitch and then adjust the ship indicators to reflect the measurement. Determine the corrections to account for changes in pitch due to shaft compression as thrust increases and temperature effects on the Propeller Pitch control rod.
4. Verify the weight of the propulsor and hub from the manufacturer's specifications for making thrust measurement corrections.

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

4.2 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 that will be used to calculate the trial speed and to deliver the speed trial report i.e. Part 2 of this Recommended Procedure.

The S/P Trial Agenda is a document prepared by the Shipbuilder, outlining amongst others the scope of a particular Speed/Power trial. This document contains the procedures on how to conduct the trial and table(s) portraying the runs to be conducted. It outlines the particular responsibilities of the Trial Leader, Trial Team, ship's crew/ Shipbuilder, and the Owner's representative. The scope of the S/P Trials shall be in line with this document.

5. SHIP CONDITION

5.1 Displacement

The ship's displacement shall be within 2% difference of the actual required displacement. If model test results are used for the analysis of the S/P Trials, the displacement used in the model tests shall be within 2% of the displacement during the S/P Trials.

Draught at the perpendiculars, trim and displacement of the S/P Trials are obtained by averaging the ship draught mark readings. The ship shall be brought into a loading condition that is as close as possible to contract condition and/or the condition at which model tests have been carried out.

The loading condition shall be confirmed at zero Ship Speed. Draught at the perpendiculars, trim and displacement shall be obtained at the beginning of the trial.

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.

5.2 Trim

The trim shall be maintained within very narrow limits. For the even keel condition the trim shall be less than 1.0% of the mid-ships draught. For trimmed trial conditions, the immergence of the bulbous bow shall be within ± 0.1 m read at the forward draught marks, of the ship condition for which model test results are available.

In case draught and trim requirements cannot be met at the same time, the above immergence requirement of the bulbous bow supersedes.

5.3 Hull & propeller

The ship shall have clean hull and propeller for the sea trial. Hull roughness and marine growth can increase the resistance of the ship significantly but are not corrected for in S/P Trials. Therefore, it is recommended that the hull

and propeller(s) are cleaned just prior to the sea trials. The date of last docking and hull and propeller cleaning are to be documented in the S/P Trials report.

6. TRIAL BOUNDARY CONDITIONS

During the S/P Trial, there are many conditions that deviate from the contract condition. The objective during the S/P Trial is to keep the number of influencing factors as limited as possible.

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 chapter.

6.1 Location

High wind and sea state in combination with a heading deviating from head waves and following waves, can force the use of excessive rudder deflections to maintain heading, and thus cause excessive fluctuations in shaft torque, shaft speed and Ship Speed.

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

This means that the speed trial range shall be located in a sheltered area (i.e. limited wind, waves and current). Furthermore, the area shall be free from hindering small boats and commercial traffic.

6.2 Wind

During the S/P Trial the wind speeds shall not be higher than:

- Beaufort number 6 [1], for vessels with L_{PP} >100 m, or
- Beaufort number 5, for vessel with L_{PP} ≤100 m

where :

L_{PP} : Length between perpendiculars [m].

6.3 Sea state

The total wave height H, derived from the significant wave heights of local wind driven seas $H_{W1/3}$ and swells $H_{S1/3}$, by

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

shall satisfy the following criteria:

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

$$H \leq 2.25\sqrt{L_{pp}/100} \quad (2)$$

In case the wave height is derived from visual observations:

$$H \leq 1.50\sqrt{L_{pp}/100} \quad (3)$$

where:

L_{PP}: Length between perpendiculars [m]

The above limits are illustrated in Figure 1.

[1] The Beaufort scale is given in Appendix B

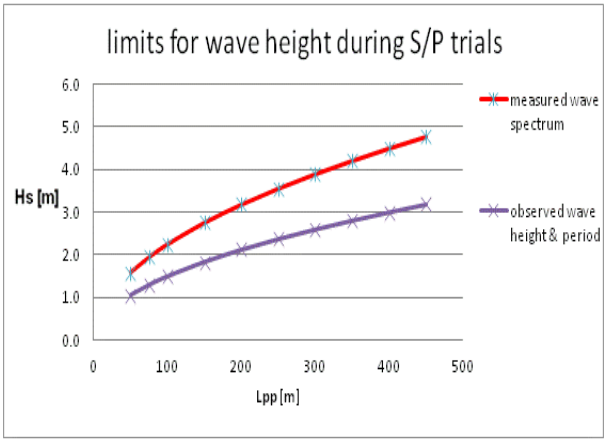

Figure 1; Limits for allowable wave height

In case 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 satisfies equation 4:

$$H \leq 0.50\sqrt{L_{pp}/100} \qquad (4)$$

In case the wave spectrum encountered during the S/P trials is not measured, the wave height and wave period shall be derived from visual observations (see 7.6.5). The directions of the waves and swells may be derived from visual observations in all cases.

6.4 Water depth

There are correction methods that compensate for shallow water (see Part 2). However, it is better to avoid the corrections by a proper choice of the S/P Trial location. The minimum water depth at which no correction for shallow water is needed can be calculated using the larger of the values obtained from the two equations (ref. [1], [4]):

$$h = 3\sqrt{B \cdot T} \quad \text{and} \quad h = 2.75\frac{V_S^2}{g} \qquad (5)$$

The minimum water depth in the S/P Trial area shall satisfy the larger value obtained from the following equations (ref.[4]):

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

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 and documented in the Trial Log.

6.5 Current

Areas with known large current variations in time or space shall be avoided.

7. TRIAL PROCEDURES

7.1 Parameters that shall be logged

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

For this purpose, a split has been made between primary and secondary parameters. For each of the parameters the preferable measurement methods are given.

7.2 Primary parameters

The primary parameters to be measured and the accepted measurement devices are given in Table 1.

	Acceptable measurement devices	Unit
Ship Track	DGPS	[Latitude, Longitude] or [m]
Speed over Ground	DGPS	[Knots]
Shaft Torque or Shaft Power	Torsion meter with calibrated permanent torque sensor or strain gauges. Power calculated from torque and RPM	[kNm], [kW]
Shaft RPM	Pick-up, optical sensor, ship revs counter	[RPM]
Propeller Pitch	Bridge replicator	
Time	GPS Time, Stopwatch	[s]
Water depth	Ship echo sounder + nautical charts	[m]
Ship heading	Gyro compass, or compass- DGPS	[deg]
Relative wind, speed and direction	Ship anemometer, dedicated trial anemometer	[m/s], [knots], [deg]
Wave height, period and direction	Wave measuring device such as wave buoy, radar, or lidar. Observation by multiple Marinners.	[m], [sec], [deg]
Draughts	Physical observation and / or calibrated draught gauges	[m]

Table 1 Primary parameters

7.3 Secondary parameters

Seawater density	Salinity sensor, Conductivity Density Temperature (CDT) sensor	[kg/m^3]
Seawater temperature	Thermometer, CDT sensor	[ºC]
Air temperature	Thermometer	[ºC]
Air pressure	Barometer	[hPa], [mBar]

Table 2 Secondary parameters

The parameters listed in table 2 shall be measured at the trial site.

7.4 General information

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

Hull condition	
Last date of cleaning hull	
Hull appendages and Rudder	
Geometry	
Type	
Rate of Movement during speed trials	
Wind fetch	
Height of wind meter above waterline	
Frontal wind area	
Propeller(s)	
Type (FPP/CPP)	
Pitch (FPP)	
Direction of rotation	
Number of blades	
Shaft(s)	
G modulus Diameter (inside) Diameter (outside)	

Table 3 General information

The shaft material properties i.e. the G-Modulus should be substantially specified and documented by the Shipbuilder. The shaft diameter used in the power calculation should be derived from the shaft circumference in-situ measured at the location of the torque measurement. In case of variable pitch propeller there might be a drilling diameter to be taken into account (to be supplied by Shipbuilder). In case the G-modulus is not provided a default value of 82,649 N/mm2 shall be used for regular shaft steel.

7.5 Model test information

The quality and accuracy of model 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 normally is defined in loaded design condition. For the conversion from bal-

last trial results to loaded condition, the difference between the ballast and loaded model test curves is used. Therefore, an accurate model test and validated consistent extrapolation method to full scale is required.

For the analysis of the S/P Trials, i.e. to include the effect of the propeller loading in non-ideal conditions on the propulsion efficiency and rpm, it is required that the model tests data include the results of propeller load variation measurements as defined in Part 2.

Based on ITTC recommendations, the model tests shall be conducted according to the following criteria:

Model tests shall be conducted at the contract draught & trim, the EEDI draught & trim as well as the trial draught & trim.

Model tests shall be conducted according to the ITTC Recommended Procedures for Resistance and Propulsion Model Tests, including load variation tests. Ref [5].

For all draughts and trims, the same methods, procedures and empirical coefficients shall be used to extrapolate the model scale values to full scale. In case different methods, procedures or empirical coefficients are used for the different draughts, these shall be documented in full detail and documentation must include justification by means of full scale S/P Trial data for the specific ship type, size, loading condition, model test facility and evaluation method.

The model test report shall be transparent and give sufficient information to enable the EEDI Verifier to check the model test results. This means that in the model test report, the measured data, the predicted full scale data and a detailed description of the extrapolation method and the coefficients used have to be given.

7.6 Scope and conduct of the measurements

7.6.1 Ship track and Speed over Ground

The speed is to be measured by a global positioning system such as GPS. The GPS system shall operate in the Differential mode to ensure sufficient accuracy. The position and speed shall be monitored and stored continuously.

7.6.2 Torque

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

7.6.3 Wind

The ship's own sensor or a dedicated trial anemometer can be used. The anemometer shall be as clear as possible from the superstructure.

7.6.4 Water depth

Measuring the water depth can be done by using the ship echo sounder. It is important that the echo sounder is calibrated before the Speed Run in combination with the check of the water depth given on the charts and that the vessel draught is taken into account. Continuous recording of water depth is recommended.

7.6.5 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, use can be made of wave buoys in the speed trial area or from ship born equipment such as wave radar or lidar. 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 Speed Runs shall be measured unless the wave height satisfies: $H \leq 0.50\sqrt{L_{pp}/100}$ (see 6.3). Use can be made of wave buoys or instruments on-board the ship such as wave radar and wave scanner.

If use is made of the empirical wave correction methods described in Part 2 (without specific model tests) and provided that Double Runs are conducted in head and following seas, and if the wave heights satisfies: $H \leq 1.50\sqrt{L_{pp}/100}$) (see 6.3), the encountered wave heights, periods and directions of both seas 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 hind cast data provided by an experienced and independent weather office may be used.

7.6.6 Density and temperature

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

7.6.7 Current

Speed and direction of current shall be derived as part of the evaluation of each run. For each Speed Run in a set of Double Run(s), this current follows from the "mean of means" value derived from all Speed Runs at the same power setting and the measured value for the specific Speed Run after corrections. (See Section 10).

8. TRIAL EXECUTION

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

8.1 Initiation

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

In case wave height, period or wave direction 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.

It is important to check that the engine plant line up during the S/P Trial is consistent with normal ship operations.

Before the actual start of the S/P Trials, the following actions shall be taken when the vessel is stopped in the water (within the schedule of the trials):

1. draught reading as described in section 5.1 and calculation of displacement,
2. measurement of wind speed and direction,
3. zero setting of shaft torque meter,
4. measurement of water temperature and density.

8.2 Trial trajectory

The S/P Trial Runs need to be conducted over the same ground area. For each base course, each Trial Run will be commenced (COMEX) at the same place (within reason).

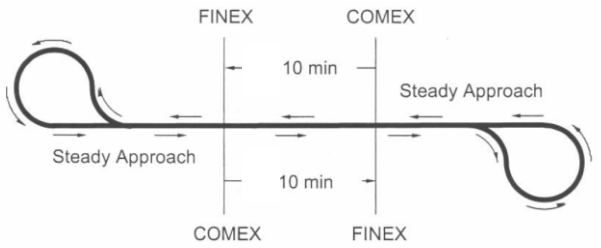

Figure 2 Path of ship during Double Run

Modified Williamson turns will be executed between each run to return the ship to the reciprocal baseline and to the same ground area in which the previous run was conducted. This procedure is used to avoid different sea states or different wind conditions. Engine throttles shall not be moved during this period. The rudder angle used in this manoeuvre shall be such that Ship Speed and time loss are minimised.

8.3 Run duration & 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 ten (10) minutes. The Speed Runs for the same power setting shall be evenly distributed in time.

8.4 Trial direction

The Speed Runs shall be headed 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 minimise as many variables as possible that could unduly influence the speed-power relation.

In case the Double Run cannot be executed in head waves and following waves, the approach to be followed is: runs with headings deviating less than 45 degrees from head waves will be treated as head waves according to methods D2 and D3 (Part 2). For other wave directions no corrections will be applied.

If transfer functions of added resistance in waves for the applied headings for this specific ship are available from model tests at the trials draught and provided that the actual encountered wave spectrum is measured during the trials (see 6.3), these transfer functions can be accepted for the wave correction described in Part 2.

8.5 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 single amplitude of rudder angles shall be within five (5) degrees.

8.6 Approach

The S/P Trial approach shall be long enough to ensure a steady state ship condition prior to commencement (COMEX) of each Speed Run. During the approach run, the ship shall be kept on course with minimum rudder.

No fixed approach distance can be given. To verify that the vessel reached the steady ship condition the measured values of shaft rotation rate, shaft torque and Ship Speed in the control position shall be monitored. The condition is considered “Steady” when the ordered shaft revolutions, shaft torque and the ship speed are steady.

Table 4 provides an indication of approach lengths and corresponding times for various ship speeds and sizes.

Size of ship [DWT]	Approach distance [nm]	Approach time [min]		
		15 knots	20 knots	25 knots
50,000	4 – 5	20	15	12
100,000	5 – 7	26	20	16
250,000	8 – 10	40	30	24
500,000	12 – 15	60	45	36

Table 4 Indication of required approach length and time

8.7 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 the exact opposite direction performed with the same engine settings.

To determine the speed-power curve for the first vessel of a ship series, a minimum number of five (5) Double Runs at three (3) different power settings are required.

These runs comprise:

- Two (2) Double Runs (at the same power setting) around the Contract Power,
- Two (2) Double Runs (at the same power setting) around EEDI Power (i.e. 75% MCR),
- Double Run for at least one other power setting between 65% and 100% MCR.

Two (2) Double Runs around Contract Power and two (2) Double Runs around EEDI Power are required to compensate for tidal currents with sufficient accuracy.

The runs at EEDI-power shall be conducted by daylight to enable a clear visual observation of the wave conditions. In case the encountered wave spectrum and the wave direction (both seas and swells) are derived by measurements, these runs may also be conducted without daylight.

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 program. For such Sister Ships it is sufficient to conduct three (3) Double Runs at three (3) different power settings:

- Double Run (at the same power setting) around the Contract Power,
- Double Run (at the same power setting) around EEDI Power (75% MCR),
- Double Run at one other power setting between 65% and 100% MCR.

In case for the first of a series or a Sister Ship at any power setting:

- strong variations in current within a Double Run (i.e. above 0.3 knots) have been derived from the analysed results (7.6.7), or
- wave height is around the limiting conditions and significant wave-induced ship motions are observed,

one (1) additional Double Run at that power setting shall be conducted.

Test Sequence

Fixing of Speed Run heading against direction of the dominant wave system;

1. Navigating through the approach distance on direct course;
2. Prepare all measurements to start;
3. Start Speed Run. Control levers shall remain unchanged, maximum rudder angle shall not be more than 3 deg. port and

starboard. After agreed duration (minimum of 10 minutes) stop Speed Run. Determine the achieved speed and power;

4. During S/P Trial Run make environmental observations;
5. Turn ship with small rudder angles to navigate the counter run covering the same geographical track as the first run;
6. Repeat steps 2 to 6.

9. DATA ACQUISITION

During the speed/power 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 powering characteristics are extremely sensitive to conditions such as ship 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 acquisition by means of a data acquisition system (measurement computer), and information that is noted down 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 can be divided into general data which is applicable to all Speed Runs and specific data that is varying throughout every run.

9.1 General data

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

- Date
- Area of trial (in Latitude/Longitude co-ordinates)
- Weather
- Water temperature and density
- Air temperature
- Height of anemometer above waterline
- Fore, amidships and aft draughts
- Displacement

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

9.2 Data on each run

- Clock time at commencement (UTC)
- Start and end position in Latitude/Longitude coordinates
- Time elapsed over the measured distance
- Ship's heading
- Ship's speed over ground
- Ship's course over ground
- Propeller rate of revolutions
- 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 wave period, significant wave height and direction of swell waves
- Mean water depth.

9.3 Acquisition system

The acquisition system shall be able to record time histories of the measurements described in chapter 9.3.1 in order to assure quality control and to provide information that will allow for the development of uncertainty analysis.

9.3.1 Minimum data

An overview of minimum parameters that shall be recorded continuously during each Speed Run is given below:

- Time
- Propeller shaft torque or power
- Propeller shaft rpm
- Pitch of CPP
- Ship positional data
- Ship heading
- Ship's speed over ground
- Relative wind direction
- Relative wind speed

9.3.2 System requirements

The data acquisition system shall be able to:

- Record all available parameters simultaneously
- Perform a time trace recording with a sampling rate of at least 1 Hz
- Display time traces of the trial parameters specified in 9.3.1
- Calculating statistics (mean min, max, standard deviation).

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

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

1. Trial start time
2. Number of samples taken
3. Maximum value
4. Minimum value
5. Average value
6. Standard deviation

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

9.3.3 Location

The data acquisition system shall be located on the bridge.

9.4 Manual data collection

For those parameters that cannot be measured and recorded automatically by means of the data acquisition system, manual data collection is required with the use of a log sheet (see Table 5 and Appendix C)

The log sheet is important for two aspects:

1. First of all to complete the dataset
2. Secondly to provide a backup for the automated measurements and give a written overview of the measurements.

It is important that the parameters that are varying in time will be recorded every few

minutes so that the average can be determined over the run period.

An example of a log sheet that can be used is shown in Table 5 and given in further detail in Appendix C. The sign conventions to be used for wave and wind direction are presented in Figures 3, 4 and 5.

Speed - Power Trials Log Form																							
Ship name:					Date:																		
Ship			**Environment**			**Propeller shaft**			**Measurement location:**														
T_{fwd}		m	T_{air}		°C	outer dia D1		mm	Lat														
T_{aft}		m	T_{water}		°C	inner dia D2		mm	Lon														
Displacement		tons	ρ_{water}		kg/m³	steel type		N/mm²	Description														
Height of anemometer above water line:					m																		

						Relative wind		Wind driven waves			Swell			Propeller PS			Propeller SB		
Run No.	Time	Forward / Return	Heading	Speed (SOG)	UKC	Speed	Direction	Height	Direction	Period	Height	Direction	Period	Torque	Power	Revs	Torque	Power	Revs
[-]	[-]	[F / R]	[deg]	[kn]	[m]	[kn]	[m/s] [deg]	[m]	[deg]	[s]	[m]	[deg]	[s]	[kNm]	[kW]	[RPM]	[kNm]	[kW]	[RPM]

Table 5 Example of a log form

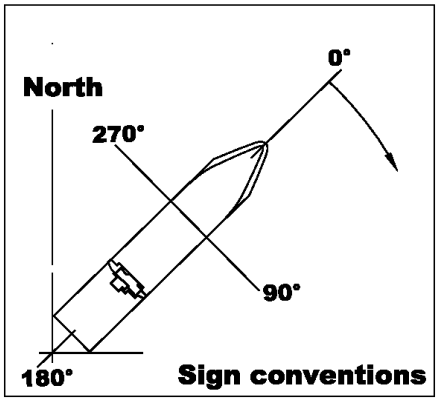

Figure 3 Sign conventions

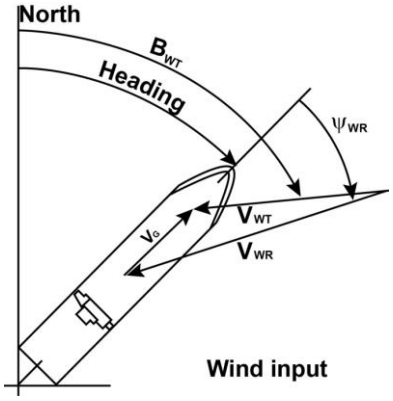

Figure 4 Sign convention for wind directions

The wind direction is defined as the direction where the wind is coming from. Zero (0) degrees on the bow and positive to starboard (clockwise).

Input parameters:

Heading: Heading of the ship [deg]

V_{WR}: Relative wind speed [knots]

ψ_{WR}: Relative wind direction relative to the bow, ship fixed; 0 means heading winds [deg]

V_G: Ship Speed over ground [knots]

Computed parameters:

B_{WT}: True wind angle in earth system [deg]

V_{WT}: True wind speed [knots]

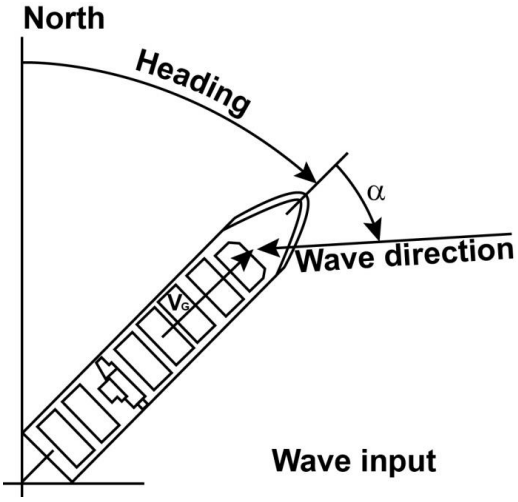

Figure 5 Sign convention for wave directions

The wave direction is defined as the direction where the waves are coming from. Zero (0) degrees on the bow and positive to starboard (clockwise).

Input parameters:

Heading: Heading of the ship [deg]

$H_{1/3}$: Significant wave height (wind driven or swell) [m],

α: Angle between ship heading and wave direction relative to the bow; 0 means head waves [deg]

V_G: Ship Speed over ground [knots]

10. REPORTING

In the trial report, an overview is given of the trial conditions and all corrections that have been applied to arrive at the Contract Speed 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 reprocessed.

The trial report shall contain the following sections:

Trial Report Summary comprising details of

(aa) Ship particulars (including trial draughts and displacement)

(ab) Propeller Details

(ac) Engine Data

(ad) Details of Appendages and Rudder

Contract conditions including contract speed, power, and displacement.

EEDI conditions including EEDI speed, power and displacement.

Description of Instrumentation describing the instrument set-up, calibration procedure, data acquisition interfacing details, location of sensors (e.g. wind meter), etc.

Description of Trial Site. This will give information on geography, distance from land, water depth etc.

Environment Parameters. This will list out the measured/observed environmental conditions at site during S/P Trials such as wave height and -period, wave direction, air pressure, wind direction, wind velocity, air temperature, water temperature, water density etc.

S/P Trial Agenda. This will give a complete and chronological order of the trial programme (both planned and actual) with specification of duties of different recording/monitoring stations on board.

- Trial Results of each Speed Run
- Date and Time at start of Speed Run
- Run number
- Ship’s position

- Ship's heading
- Run duration
- Average Ship Speed
- Average and standard deviation of torque (per shaft)
- Average and standard deviation of shaft rpm (per shaft)
- Average and standard deviation of Shaft Power (per shaft)
- Average and standard deviation of rudder angle
- Relative wind speed and direction
- Significant wave height, period and direction
- Water depth

Analysis and Correction methods. The analysis and correction of the measured trial data shall be conducted in compliance with Part 2 of these Guidelines.

Conclusions. The Contract Speed and the EEDI Speed derived from the S/P Trials analysis have to be reported.

11. REFERENCES

[1] ITTC 7.5-04-01-01.2; "Recommended Procedures and Guidelines for Speed/Power Trials", 23rd ITTC 2002.

[2] ISO 19019; "Guide for Planning, Carrying out and Reporting Sea Trials", 2002.

[3] ISO 15016;"Guidelines for the assessment of speed and power performance by analysis of speed trial data", 2002.

[4] Sea Trial Analysis JIP; "Recommended Practice for Speed Trials", 2006, Public document from www.marin.nl.

[5] ITTC "Recommendations and Guidelines for Resistance & Propulsion Model Tests", 23rd ITTC, 2002.

[6] Principles of Naval Architecture, Volume II, Section II, Ship Standardization Trials; published by SNAME 1988.

[7]World Meteorological Organization: Manual on Codes, International Codes, Volume I.1, Part A-Alphanumeric Codes, WMO-No. 306 (1995 edition).

[8] Boom, H.van den, H. Huisman and F. Mennen: "New Guidelines for Speed/Power Trials", SWZ/Maritime, Jan/Feb 2013.

[9]]Hansa Int. Maritiem Journal 150th Year, No. 4, April 2013, Hansa-online.de/STA-JIP.pdf.

APPENDIX A: GENERAL SHIP AND TRIAL DATA

Ship hull	
Draught	
Trim	
Displacement	
Hull appendages and rudder	
Geometry, deviation, roughness	
Type	
Rate of movement	
Propeller(s)	
Geometry, deviations, roughness	
Pitch	
Direction of rotation	
Number of blades	
Trial site	
Water depth	
Water temperature	
Air temperature	
Sea state	
Specific gravity of water	
Environmental conditions	
Wind	
Waves	
Current	
Atmospheric pressure	

APPENDIX B: BEAUFORT SCALE OF WIND

Beafort number	Descriptive term	Velocity equivalent at a standard height of 10 metres above open flat ground				Specifications			Probable wave height* in metres	Probable wave height* in feet
		Mean velocity in knots	m s-1	km h-1	m.p.h.	Land	Sea	Coast		
0	Calm	<1	0-0.2	<1	<1	Calm; smoke rises vertcally	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)	¼ (¼)
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 knots	0.2 (0.3)	½ (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 3–4 knots	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)	3½ (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 (8½)
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)	9½ (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)	13½ (19)
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 overhanging crests; the resulting foam, in great patches, is blown in dense white streaks along the direction of the wind; on the whole, 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 widespread 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 (-)

* This table is only intended as a guide to show roughly what may be expected in the open sea, remote from land. It 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 off-shore wind, wave heights will be smaller and the waves steeper. Figures in brackets indicate the probable maximum height of waves. (ref[7])

State of the sea

Code figure	Descriptive terms	Height* in metres
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

Notes:

(1) * 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.

(2) The exact bounding height shall be assigned for the lower code figure; e.g. a height of 4 m is coded as 5.

APPENDIX C: Format S/P Trial Log Sheet

Speed - Power Trials Log Form					
Ship name:		Date:			

Ship			**Environment**		
T_{fwd}		m	T_{air}		^{o} C
T_{aft}		m	T_{water}		^{o} C
Displacement		tons	ρ_{water}		kg/m^3
Height of anemometer above water line:					m

Propeller shaft		
outer dia D1		mm
inner dia D2		mm
steel type		N/mm^2

Measurement location:	
Lat	
Lon	
Description	

						Relative wind		Wind driven waves			Swell			Propeller PS			Propeller SB		
Run No.	Time	Forward / Return	Heading	Speed (SOG)	UKC	Speed	Direction	Height	Direction	Period	Height	Direction	Period	Torque	Power	Revs	Torque	Power	Revs
[-]	[-]	[F / R]	[deg]	[kn]	[m]	[kn] [m/s]	[deg]	[m]	[deg]	[s]	[m]	[deg]	[s]	[kNm]	[kW]	[RPM]	[kNm]	[kW]	[RPM]