The Specialist Committee on Trials and Monitoring

Final Report and Recommendations to the 22nd ITTC

TRIALS & MONITORING SPECIALIST COMMITTEE

FINAL REPORT

1. MEMBERSHIP AND MEETINGS

The 21st ITTC appointed the Trials & Monitoring Specialist Committee with the following members:

Dr. Giorgio Lauro - Chairman - Cetena (IT)
Mr. Everett Woo - Secretary - DTMB (USA)
Mr. Pierre Perdon - DCE/BA (FR)
Dr. Alfred Kracht - VWS (D)
Dr. Lech Murawski - CTO (PL)
Mr. Ryosuke Fujino - IHI (JPN)
Mr. J. Thomas - Hamworthy (UK)
(Mr. Thomas resigned in 1997)

Technical Committee meetings were held as follows:
Cetena - Genova (IT) - January 1997
DCE/BA - Paris (FR) - August 1997
IHI – Yokohama (JPN) - May 1998
CDNSWC-DTMB - Bethesda (Md - USA) – September 1998
Cetena - Genova (IT)- January 1999

2. TASKS OF THE SPECIALIST COMMITTEE

Tasks of the 22nd ITTC Technical Committees were given in Appendix 2 of the 21st ITTC Proceedings and are as follows:

1. Recommend updated procedures for conducting full scale trials and long term performance monitoring and data analyses. Consideration will be given to powering, maneuvering and seakeeping trials.
2. Evaluate the use of onboard performance monitoring systems and the Global Positioning System.
3. The Committee should contribute to the work of ISO on standards for speed trials' evaluation.

3. INTRODUCTION

Following the task assignment of the 21st ITTC, the Specialist Committee (SC) defined, at their first meeting, the following three tasks to develop guidelines based on sound scientific and engineering procedures for conducting full scale trials, developing trial programs, measuring techniques, analyzing and correcting trial data, and assessing measurement uncertainty:

Task 1 - Speed/Power Trials and Analysis
Task 2 - Maneuvering Trials and Analysis
Task 3 - Seakeeping Trials and Analysis

Two additional tasks were assigned to evaluate the use of onboard monitoring systems and to evaluate the use of GPS during sea trials:

Task 4 - Performance Monitoring System
Task 5 - Global Positioning System

Task 1 provides guidelines to ITTC members in developing a procedure that demonstrates ISO 9000 compliance.

The specialist committee is composed of experts in sea trials from different areas of the world. Each specialist provided contributions to the various tasks. All contributions were discussed and compared for advantages and disadvantages. Common actions were identified and are discussed below.

The guidelines developed in the past years within the Powering Performance Committee, were the starting point of reference for the SC in formulating a common strategy for conducting trials. The suggested conduct of the trials is predicated upon sound scientific basis and direct practice gained by SC members' experience in sea trials.

There are some sea trial practices still in use that are no longer considered acceptable to the members of the SC. There is a clear distinction between the shipyard practice (mainly devoted to delivering the ship within budget limitations and ship-owner requirements) and the scientific purpose of sea trials.

These guidelines were developed in an attempt to fulfil, where possible, both contractual and scientific needs and concerns.

4. TASK 1: SPEED/POWER TRIALS AND ANALYSIS

At the moment, there is no internationally recognized standard (such as ISO or IMO) for speed/power trials conduct, although in the past 30 years many attempts have been made to provide a common methodology for all to follow. Many shipyards developed their own procedures driven by their experience and by following recommendations or guidelines given in the scientific literature. Taniguchi (1963), ITTC Guide for Measured-Mile Trials, 12th ITTC (1969), and the Powering Committee Report – Appendix I, 21st ITTC (1996) are representative of the efforts made by the International Towing Tank Conference (ITTC) since 1963, with the intention of presenting guidance that balances research and development requirements with commercial and financial constraints. The ultimate objective is to obtain a reliable set of full scale data to be used for ship-model correlation or validation of prediction methods by staying within the boundaries of commercially conducted acceptance trials. Within the last years, the most recent guidance in the conduct of ship trials has been concentrated in the area of newly available measuring techniques and in providing guidelines to ITTC members in developing a procedure that demonstrates compliance to ISO 9000 International Standards for Quality Management (1993).

The Society of Naval Architect and Marine Engineers (SNAME) has also dedicated significant effort in providing guidelines and procedures to be followed in the conduct of surface ship sea trials, by producing a Code for Sea Trials, SNAME (1973). This was later superseded by a Guide for Sea Trials, SNAME (1989) (Chapter 4.0 addresses the speed/power trials, known as "Standardization Trials"). The purpose of the Guide was "... to provide ship-owners, designers, operators and builders with definitive information on ship trials to form a basis for contractual agreement". Additional guidelines can be found in the Japan Ship Research Association

(JSRA) Sea Trial Code for Giant Ships (1972) and BSRA Standard Method of Speed Trial Analysis (1978).

As a result of the philosophy of ITTC, SNAME, and JSRA the current practice for the speed/power trials result from the ship-owner/shipyard contractual agreement, in which a section is devoted to the procedure in determining ship's speed and power. Often the scientific purpose is replaced by the interests of these two parties.

As far as the Committee knows, at the national level, only the Norwegian Standard Organization has issued a document Testing of New Ship, Norsk Standard (1985) pertaining to the testing of new ships. Speed/power trials conduct and analysis of measurement are addressed, together with accuracy criteria.

As a result of the activity developed within Task 1, the SC has developed recommendations on how to conduct speed/power trials, addressing both the practical and scientific aspects. This should allow the maximum exploitation of sea trial data. When possible, all recommendations based on sound scientific basis and referred to in previous ITTC documentation were included. In this section the rationale for each considered item is given.

4.1. Preliminary Controls

1. Hull conditions must be reported to allow an evaluation of the trial results for scientific purposes. No correction of trial results is expected based on the condition of the hull. However, the trial report must clearly state the hull conditions. Hull cleaning, if necessary, is negotiated between the shipyard and the shipowner. It is desirable that quantitative information on the fouled and roughness conditions be documented.

   The information that is required to be reported is as follows:

   a. For a clean hull, documentation indicating manufacturer and kind of paint used, paint layer thickness and, if available, roughness measurements (average, standard deviation, and distribution along the hull) should be provided.
   b. For a dirty hull, documentation indicating visual observations of any fouling, and date of last dry-docking should be provided.

2. Propeller conditions must be reported to allow an evaluation of the trial results for scientific purposes. No correction of trial results is expected based on the condition of the propeller(s). However, the trial report must clearly state the propeller conditions. Propeller cleaning, if necessary is negotiated between the shipyard and the shipowner.

   The following information should be reported:

   a. Last date of cleaning
   b. Means of cleaning
   c. Roughness measurements, if available:

      1. Average
      2. Standard deviation
      3. Distribution along the blades
      4. Physical damage, if any

3. Draft, trim and displacement of the trials must be obtained by averaging the hull draft mark readings before the start of the trials. Draft at the end of the trial must be acquired. This may be accomplished using a loading computer or by taking a second draft reading. Displacement must be derived from the hydrostatic curves by utilizing the draft data and the density of the water. When dealing with Froude numbers higher than 0.5 (e.g. a Fast Ferry with 100 m

length and speed over 30 kn) intermediate ship loading conditions must be documented. This is better accomplished through tank soundings. However, draft, trim and displacement should be as close as possible to the contract condition and/or the condition by which model tests have been carried out. This will allow for the correction of the displacement and trim with respect to the trials that were conducted and will be applicable to the suggestions outlined in section 4.11.

Table 1.- Ship Trial Information by Task

Quantity	Task 1	Task 2	Task 3
Ship Hull			
Draft	√	√	√
Trim	√	√	√
Displacement and Load	√	√	√
Hull Condition			
Roughness of shell and bottom paint	√		
height of welding beads	√		
waviness of hull	√		
size, number and position of zinc anodes	√		
size, number and position of openings of sea water inlets and outlets	√		
paint system	√		
Hull appendages and rudder			
Geometry, deviations, roughness	√	√	√
Type	√	√	√
Rate of movement		√	√
Propellers			
Geometry, deviations, roughness	√	√	√
Pitch	√		
Direction of rotation	√		
Number of blades	√		
Propeller shaft			
Geometry	√		
Material	√		
Trial Site			
Water depth	√	√	√
Water Temperature	√	√	√
Environmental Conditions			
Wind	√	√	√
Waves	√	√	√
Current	√	√	√

The information to be reported is compiled in Table 1.

4.2 Trial Site Criteria

The trial site should be located in waters of adequate depth with as small a current variation and tidal influence as possible. The site will be of adequate size to allow room for ample maneuvering and to preclude the impact of traffic on the trials. The minimum depth of water acceptable, in accordance with the 12th ITTC, may be estimated by the largest value of the following two equations:

$$h > 3(BT)^{0.5} \quad \text{and} \quad h > 2.75\, V^2/g \qquad (1)$$

h = depth in appropriate length units
B = beam in appropriate length units
T = draft in appropriate length units
V = speed in system of units consistent with the above dimensions

In case trials are performed with a reduced water depth with respect to the above criteria, a correction for shallow water should be applied according to the references noted in section 4.10.

4.3 Trial Environmental Conditions

1. Wind
   Wind speed and direction should be determined with a calibrated anemometer mounted in order to avoid interference caused by the ship. Trials should not be conducted with a true wind speed greater than Beaufort 6. Correction for wind is in accordance with the references noted in section 4.10.

2. Waves
   Sea state, swell and wave height should be determined visually and if possible by the use of a wave rider buoy and/or radar. For sea states less than or equal to 5, corrections may be applied in accordance with the references noted in section 4.10. For sea states greater than 5, corrections are no longer reliable from a scientific standpoint.

3. Water Temperature
   Sea water temperature and density should be determined by taking water samples at the trial site and at the site where draft readings are recorded. Measurements will be made using a calibrated thermometer and hydrometer. Corrections are made in accordance with the references noted in section 4.10.

4. Current
   Current speed and direction should be determined in the test area by prognostic analysis. When current speed is suspected to be varying and direction is unknown, the ship's global drift (also including wind effect) should be determined by a 360° turning test conducted at low ahead speed to magnify any environmental effect. Test runs should be conducted against and with global drift. To ensure that tests are performed in comparable conditions, the deviation between reciprocal runs should be checked (a maximum of 0.05 nm may be used as an approximate figure). Individual speed runs conducted in the same conditions should be averaged with their reciprocal runs to take into account global drift.

5. Air temperature and Atmospheric Pressure
   Air temperature and atmospheric pressure should be measured at the trial location using a calibrated thermometer and barometer.

4.4. Selection of Tests

When developing the trial agenda, consideration should be given to the purpose of the trial. In many cases, speed/power trials are conducted in order to fulfil contractual requirements. Others trials are conducted to define the speed/power characteristics of the ship at a given displacement, propeller pitch condition, or operating condition, e.g., locked shaft and trailed shaft tests. Their complexity and extent is dictated by the purpose, contractual or scientific.

1. Displacement Speed/Power Trials

The purpose of these trials is to determine the effect of displacement on the ship's speed/power characteristics. Tests should normally be conducted at design displacement. Follow-up tests are conducted using the same rpm/engine load settings used at the design displacement but at displacements at least 10% different than design. Data are also utilized in conjunction with fuel economy studies.

2. Propeller Pitch Trials (mainly for naval ships)

The purpose of these tests is to determine the effect of changing propeller pitch on the ship's speed/power characteristics. Tests are normally conducted at design pitch. Follow-up tests are conducted using the same engine load settings used during the design pitch tests but at pitches at least 10% higher and lower than design. Unless the ship is equipped with an in-hub propeller pitch sensor, the pitch measurement is extremely difficult to obtain due to temperature contraction and expansion of the control rod(s).

3. Trailed Shaft Trials (mainly for naval ships)

The purpose of these tests is to predict the ship's speed/powering capabilities in the event of a casualty, which requires the trailing of a propeller shaft. Trailed shaft tests are also useful in obtaining fuel rate data (if the ship is equipped with fuel meters) when different combinations of propeller shafts are driving the ship.

4. Locked Shaft Trials (mainly for naval ships)

The purpose of these tests is to predict the ship's speed/powering capabilities in the event of a casualty, which requires the locking of a propeller shaft.

4.5 Measurement Taken During Speed/Power Trials

1. Physical Quantities

The data to be acquired during trials have been grouped as follows:

a. Primary

These quantities represent the critical trial data that must be acquired in order for the trial to be considered valid for scientific purposes. The trial results are considered invalid for scientific purposes if one of these measurements is not available:

1. Ship speed through the water
2. Shaft torque
3. Shaft revolutions

b. Secondary

These quantities are important in order to correct trial data, if required, and to provide a more precise evaluation of the behavior of the ship during the speed runs. These measurements are used to determine the validity of the trial results:

1. Ship track
2. Rudder angle
3. Ship heading

c. Tertiary

The following is a suggested list of data to be acquired in the course of conducting speed runs to increase the level of confidence in the trial results and/or to add scientific knowledge in the development of procedures to correct for environmental actions.

1. Wave height and relative direction
2. Relative wind speed and direction
3. Ship pitch
4. Ship roll
5. Propeller pitch
6. Propeller shaft thrust
7. Water depth

2. Accuracy Requirement

The requirements in ship's speed/power trials are mainly driven by the contractual agreement and are usually expressed in terms of speed to be achieved at a given engine power and rpm (e.g. 85% of Maximum Continuous Rating), at given ship loading conditions (e.g. loaded or ballast) and at "ideal" environmental conditions (e.g. calm water, no wind, etc.).

Such an explicit statement has a straightforward impact on the accuracy requirements that have to be achieved during the standardization trials. Since penalties are associated with the ship failing to meet speed/power performance requirements, a margin is usually associated with the required figures. This implies that the instruments that are utilized to provide the contractually specified measurements are accurate and that the methodology for conducting the trials to obtain the contractual measurements is consistent and scientifically sound.

The following activities are impacted:

1. Determining ship conditions at trials (drafts and displacement)
2. Measurement of ship speed
3. Measurement of propulsive power and propeller rpm
4. Monitoring of environment during trials
5. Correction of trial data to contractual conditions

As to the accuracy of the physical quantities referred to in section 4.9 (Johnson 1993), Table 2 provides an example of bias and precision limit values for each of them, including units, and uncertainty.

3. Instrumentation

Addressing only the primary and secondary group of data, the SC has taken in consideration the most common instruments/ techniques actually in use, to compare with the uncertainty table shown as Table 2. However, in the choice of the instrumentation for speed/power trials, the SC strongly recommends that the equipment or technique chosen be capable of providing a time history of the recommended measurements occurring during trial operation. Acquisition of these data will allow for the calculation of the uncertainty analysis and the assurance of quality control.

a. Determination of ship's speed

Ship speed is one of the main components of a sea trial and any error in speed has a significant effect on the speed/power curve due to the cubic relationship. The speed that is of particular interest is the speed through the water. At this time, there is no proven device that provides accurate and consistent speed readings directly. A display of ship speed from the speed log is displayed on the bridge of many ships. However, no one relies on this display as an accurate sea trial measurement. It is mainly used as an indicator during ship service. Hence, the present practice is to determine the speed over the ground and to use methods (experimental or analytical) to take out the effect of any current and to determine ship speed through the water.

The most common techniques are listed below with comments on their reliability and impact of each method on trial conduct.

- The measured mile course

Advantages are the simplicity of this method and low maintenance costs. However, demand for uncertainty analysis and quality control recently introduced within the scientific community cannot be fulfilled if a time history of the speed is not recorded during the trials.

- Radio-location systems

A continued increase in the use of radio-location systems has been observed in the last 30 years (Forst, 1996, RTCM, 1990, Sitzia and Della Loggia, 1981). Many of these systems are privately developed and operated. They operate in the radio-location frequency bands using a variety of measurement techniques. A partial list of these systems and their frequency of operation are given below:

a. LORAN (Sercel) 1800-2000 kHz
b. Raydist (Teledine-Hastings) 3300 kHz, 1650 kHz
c. Hyperfix (Racal) 1600/3400 kHz
d. Syledis (Sercel) 430 MHz
e. Mini-Ranger (Motorola) 5570/5480 MHz

The advantage of using an accurate position fixing system is that trials can be carried out in almost any location where shore stations can be established. Systems utilizing the HF band increase the flexibility of this system by expanding the range covered by a system using lower frequencies. Costs associated with the shore station maintenance and management during trials are the recognized disadvantages.

- The Differential Global Positioning System (DGPS)

Even though this system can be regarded as a radio-location device, its uniqueness lies in the use of reference signals from a satellite network orbiting around the earth. Task 5 of this report is totally devoted to this newly available technique and its application to ship sea trials. Based on direct experience and findings referred to in the literature (Stenson and Hundley, 1991, Akroyd and Lorimer, 1990, Hogarth, 1991, Zachmann, 1988, Lauro, 1994, Cortellini and Lauro, 1995, Stenson, 1995, Hubregste, 1995, Lauro, 1996), the SC recommends exclusive reliance on differential GPS speed and position measurements. Additionally, the possibility of choosing a course without the constraints of reference station location is a definite advantage when conducting trials (see section 4.7.1).

Therefore, the SC recommends that DGPS be used whenever possible. If GPS is not available, radar location systems may be utilized.

b. Measurement of shaft power

Shaft horsepower, together with ship's speed, is a primary parameter to be determined during trials, both to ascertain that the propulsion plant is correctly working and to comply with the speed/power contractual requirements. Shaft horsepower can be determined "indirectly" by measuring shaft rpm (revolution per minute) and fuel rate or mean indicated pressure of pistons (in a diesel engine plant) or electric parameters in the case of electric motors. However, this practice, which is frequently used during service, lacks precision. Therefore, "direct" methods have been developed and provide the required precision and reliability for use during sea trials. These "direct" methods combine the measurement of shaft torque and revolutions over a measured time interval with indicator systems, which electronically integrate the signals deriving shaft power. The complete system is comprised of sensors, signal conditioner, processor and display unit and is known as the "shaft torsionmeter". The SC recommends the use of such a device for the determination of shaft power during trials. The torsionmeters listed below differ only in the method of gaging torsional deflection (Stenson and Hundley, 1991, Cortellini et al., 1972, "The Onboard Monitoring Session", 20th ITTC, 1993, Morandi and Scavia, 1992).

Torsionmeter sensors can be of different types, such as:

1. Metallic membrane
2. Wire
3. Magnetic field
4. Optical
5. Strain gage

One of the most practical and cost effective ways to measure torque during a sea trial is to measure the strain in the surface of the propeller shaft using strain gages. The four-arm bridge is directly applied onto the shaft to detect the deflection produced by the torque load, according to the following relation:

$$Q = \frac{4GJ}{D}\varepsilon \qquad (2)$$

where:

D = shaft diameter, m
J = polar moment of inertia, m^4
G = shear modulus of rigidity of the shaft material, N/m^2
Q = shaft torque, N-m
ε = torsion deflection

Strain gages directly attached to the propeller shaft are subject to the inaccuracies due to misalignment when installed and are not capable of in-place calibration.

c. Measurement of ship's track
In regard to ship's position, all systems allowing a position fix (e.g. radio-location, radar and GPS) can be used for this purpose. Successive positional fixes allow for the calculation of ship speed.

d. Measurement of ship's heading
A gyro compass should be used to record ship's heading.

e. Measurement of rudder angle
Rudder angle should be measured by an angular potentiometer installed on the rudder stock.

4.6 Acquisition Systems

Acquisition systems must be able to record time histories of the measurements described in the previous paragraph in order to assure quality control and to provide information that will allow for the development of the uncertainty analysis. The technological advances of the electronic industry over the last twenty years have suggested changing the analog data acquisition systems into computer-based systems capable of acquiring all signals instantaneously, reducing the data and providing "near real time" results.

At a minimum, the data acquisition system should be capable of recording the signal time-trace relevant to the following quantities:

1. Ship position

2. Shaft torque and rpm
3. Rudder angle
4. Ship heading

4.7 Operation During Trials

1. Choice of Run Direction

If wind and waves can affect results, it is best to choose the wind/wave direction that will minimize these effects. Test runs should be conducted into the waves (head seas). The normal practice is to also conduct runs in the opposite direction of the initial runs in order to account for the effects of wind and waves. Conducting trials into head and following seas is possible when utilizing DGPS but may not be possible when using a measured mile course or radio-location system.

2. Choice of Number of Points to Define Speed/Power Curves

The number of different powering conditions conducted in order to develop complete curves of power and rpm versus speed will vary depending on the ship type. A minimum of four speeds covering the speed range are recommended by the SC to adequately define a ship's speed/power curve. However, for high speed ships or naval vessels, a minimum of 6 powering conditions is recommended.

3. Choice of Number of Opposite Runs

A minimum of two runs at each rpm condition should be conducted in alternate directions. This allows a reasonable compensation to be made for the effect of wind, current and tides.

4. Length of Approach or Steady Approach Conditions

Speed/power data should be obtained with the ship operating in a steady state condition. For this reason, the approach should be of a duration and distance long enough to guarantee a steady state ship condition prior to the commencement of the run where actual test data are taken. With inadequate attention to the approach requirements, the speed data obtained would in fact underestimate the actual ship speed. With the advent of computer based acquisition systems and DGPS, steady conditions can be monitored in real time, thus greatly facilitating the conduct of the trial. In the case where the measured mile is used, the criteria can still refer to Taniguchi, (1966). Therefore, the SC recommends the utilization of a computer based acquisition system, which will allow for the real-time display of ship position and the monitoring of all critical measurements. This flexibility reduces the dependence on artificial means of determining approach distances and puts the decisions in the hands of the ship master and the trial director.

5. Length/Duration of Run

The SC is well aware that the length of a run is dependent on ship's speed, type and dimensions. Therefore, the SC has not addressed the issue of defining a definitive criteria for length of a test run. However, the SC suggests that a range of run duration from 5 to 10 minutes is practical for most types of ships, with longer times between runs required for ships with relatively lower power/size relationships such as VLCCs.

6. Ship Conduct During Speed/Power Runs

Propeller rpm or engine load setting should be held constant for each of the runs comprising a speed spot. The amount of rudder used to turn the ship at the end of a run should be minimized so as not to excessively reduce the ship's speed. To maintain heading during the run, the helmsman should keep rudder movement to the minimum necessary, typically ±3°. Autopilot use is acceptable if it is demonstrated that rudder movement is within the acceptability criteria. The SC suggests that control of the rudder, using both humans and automation, be compared to determine the best means of controlling rudder movement during the speed/power runs.

Appendix I provides more details on particular run conduct.

4.8 Measured Data Reduction

Results of speed/power runs are usually given as average figures over the run duration. However, some acquisition and data reduction strategies have to be adopted, especially when dealing with computer based acquisition systems.

1. Choice of Measurement Sampling
   Data sampling during a run is suggested to vary between 0.5 and 2 samples/second, depending on the measurement duration (see section 4.7.5).

2. Data Filtering
   Filtering data of a run is recommended to avoid "spikes" in the recorded time histories. The SC suggests the use of the Chauvenet's Criterion (Coleman and Steele, 1999) 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.

3. Run Data Presentation
   At the end of each run, all recorded time histories should be stored for "on-line" graphical presentation and the following statistical values displayed for each physical quantity:

   a. Trial date
   b. Start time
   c. Number of samples taken
   d. Maximum
   e. Minimum
   f. Average
   g. Standard deviation

   The SC encourages shipyards, at the conclusion of each test run, to evaluate the time histories and corresponding statistics. These statistical values will provide the basis for defining objective test criteria. These criteria will then be used to assess the level of confidence in the test data.

4.9 Uncertainty Analysis

Trial data uncertainty analysis should be carried out to assess the level of confidence in the trial results and to provide the statistics associated with ship trial measurements. The SC recommends the use of the American National Standards Institute (ANSI) and the American Society of Mechanical Engineering (ASME) (1986), standard on Measurement Uncertainty and the approach described by Coleman and Steele (1999) when conducting an uncertainty analysis.

The following schematic approach is suggested:

1. Identification of Error Sources
   Error sources for speed/power trials can be listed as follows :
   a. Determination of ship displacement and trim (direct impact)
   b. Measurement of environment during trials (low impact if corrections not applied)
   c. Measurement of primary data (direct impact)

Hine (1976) suggests that the main sources of error are due to the following factors:

- Modulus of Rigidity
  Prior to the conduct of the trials, a shop test is carried out on the shaft lines by applying a known torque load to the shaft and reading the torsionmeter output. When the torsionmeter reading agrees with the known torque load, the modulus used in the calculation is considered to be the modulus

of the shaft. This test will allow for the acquisition of the shear modulus. Usually, the conduct of a shop test is not always the practice in commercial ship delivery. Hence, data from statistics or information provided by the shaft manufacturers are often adopted. The recognized bias error is ±2%.

- Shaft Diameter (inner and outer)

The shaft diameter is assumed to be within tolerances of ±0.02 mm. For shafts greater than 200 mm, the accuracy of measurement will be less than 0.01%.

- Strain Gage Resistance and Gage Factor

Using manufacturers quoted values for the strain gages, the resistance is known to within ±0.2% accuracy with a gage factor of ±0.5%. Alignment of the strain gages during installation is extremely critical and must also be considered.

- Shaft Revolutions

A simple photo-electric cell that counts the passes of steel bars mounted rigidly on the shaft can be used to measure shaft revolutions. The measurement accuracy is typically within ±0.5%.

A preliminary estimate of shaft power accuracy is ±3% if the shear modulus is not determined during shop tests. Uncertainty analysis related to DGPS is discussed in greater detail in Task

2. Determination of Bias Limit

Bias limit can be derived depending on the experimental set-up adopted by the organization in charge of the measurement. Table 2 shows typical bias limits.

3. Determination of Precision Limit

Precision limit is strictly dependent on the knowledge of the standard deviation of each physical quantity measured during the trials. The uncertainty assessment is contingent upon the availability of continuous data recording during the conduct of the trial.

4. Calculation of Uncertainty

By combining the bias and precision limit and according to the error source relationships, the uncertainty associated with the contractual speed determination can be calculated and included in the trial report (see section 4.12).

In case corrections of trial data are performed as described in the following sections, the assessment of uncertainty should also include the error propagation associated with the correction procedures.

Table 2. - Example of Bias and Precision Limit Values for Surface Ship Trial Data (17,900 kW and 100rpm)

Quantity	Units	Bias Limit	Precision Limit	Uncertainty
Ship Speed	kn	±0.05	±0.10	±0.11
Shaft Torque	N-m	±17,195	±40,145	±43,670
Shaft Revolutions	rpm	±0.392	±1.854	±1.895
Shaft Power	kW	±193	±536	±569
EM Log	kn	±0.37	±0.74	±0.83
Rudder Angle	deg	±0.562	±4.43	±0.531
Heading Angle	deg	±0.531	±1.336	±1.437
Wind Relative Speed	kn	±0.46	±1.24	±1.32
Wind Relative Dir.	deg	±5.02	±3.26	±5.98

Uncertainty values were calculated by the root-sum-square method for a 95% confidence level.

4.10 Corrections Due to Environment

Proposals, guidelines and procedures for data correction based on sound scientific basis are available in the international literature (Yoshino, 1997, SRAJ, 1993, Taniguchi, 1966, Taniguchi and Tamura, 1966, Thomson, 1978, and Lackenby, 1963). Currently, the Japan Maritime Standards Association (JMSA) ISO/Committee is attempting to standardize a method for analyzing speed trials' data under the International Organization for Standardization (ISO).

It is obvious that if the trials were limited to very calm conditions, then the analysis procedure to correct for environmental conditions would not be necessary. Furthermore, correction procedures become increasingly less certain as the weather becomes more severe. The accuracy of the corrected speed trials data is dependent upon the accuracy of the correction procedure. Most of the proposed methods are accurate within moderate weather conditions.

If the contractual delivery schedule is such that the sea trials are carried out in site and weather conditions not recommended by the SC, the following corrections could be applied:

1. Correction for added resistance due to wind
2. Correction for added resistance due to waves
3. Correction for shallow water
4. Correction due to water temperature

For each of the above corrections, more than one reference from the international literature can be found. The SC did not examine all procedures to ascertain if they are reliable and/or applicable, but strongly recommend that, if one of the above corrections is applied to trial results, procedures must be clearly referenced and documented.

4.11 Correction Due to Ship Conditions

The SC recommends that sea trials be conducted in the contractual loading and trim condition. If this is not possible (which is frequently the case of cargo vessels), corrections should be applied as suggested in the following:

1. Correcting Power and RPM for Different Displacement and Trim
   Correction of trials data for displacement and trim other than for contractual purposes should be carried out according to:

   a. Admiralty Coefficient, for small displacement differences (±3% to ±5%).
   b. Interpolation using model test results for higher differences. In such a case, model tests should be available for two different displacements, preferably contractual and trial loading conditions, in order to calculate corrective coefficients for the trial data. Particular care must be taken to account for different trim at rest, since hydrodynamic effects at the bow and stern can seriously affect ship resistance.

2. Often, the speed and power during trials do not match the contractual conditions. In such cases, calculations can be made to:

   a. Determine speed for different powers
   b. Determine power and rpm for different speeds

   However, the SC recommends that whatever correction is applied to the trial results, the procedures must be clearly referenced and documented.

4.12 Trial Report Breakdown

The SC recommends that the results of the trials should be presented with all the information necessary to undertake post-processing of the trials data including:

1. Correcting for environment
2. Correcting for ship conditions
3. Performing uncertainty analysis
4. Utilizing for scientific purposes (database, ship/model correlation).

The trial report breakdown should be as follows:

1. Trial Report Summary

In particular, the following groups of information are required:

a. Ship/Hull Characteristics

Type, Length L, Beam B, Draft, T (fore, mid, aft), Trim, Displacement, Block coefficient.

b. Propeller Characteristics

Number and Type, Diameter, Design Pitch (0.7 R), Number of blades, Blade area ratio, Expanded area ratio

c. Engine Data

Manufacturer, Engine type, Nominal Output Power, Nominal Revs, and Gear ratio (if any).

d. Appendages and Rudder

Dimension and Type, possibly drag and lift coefficients (C_D, C_L)

e. Hull/Propeller Conditions before Trials

Qualitative (visual observation) and Quantitative (if roughness measurement is available), Time of last Dry-dock, Type and Layers of paint.

2. Description of the Instrumentation

Provide information describing the experimental set-up with a description of the instrumentation used to obtain each measured quantity. This includes the acquisition system and calibration procedures utilized for each instrument used to obtain trials data.

3. Description of the Trial Site

Provide information on the geographical location of the trial site, including the average water depth, air temperature, water temperature and density.

4. Trial Program

Present the sea trials agenda which includes the speed/power measurement, number of rpm/engine load settings to be investigated, number of alternate runs at each rpm/engine load setting and the choice of the run direction.

5. Environmental Conditions During the Trials

Provide quantitative indication of the wave, wind and current at the time of the trials' conduct (if variable in time, to be updated). Indicate if the data was derived by visual observation, weather forecast/ hindcast or direct measurement (wave buoy, onboard anemometer).

6. Trial Results

In this section the following information in tabular format should be presented for each trial run:

a. Date
b. Time
c. Run number
d. Ship position data
e. Ship heading
f. Run duration
g. Average ship speed
h. Average shaft torque (per shaft)
i. Average shaft rpm (per shaft)
j. Average shaft power (per shaft)
k. Propeller pitch (only if CPP)
l. Average rudder angle
m. Relative wind speed and direction
n. Significant wave height and direction (sea conditions)
o. Comments on the use of control surfaces, roll/pitch behavior (unless measured),

7. Conclusions

Present a synopsis of trial results at each powering condition, including speed/power trial curves.

8. Appendix

All tabulated time histories of primary data and associated statistics may be enclosed in the Appendix. Associated uncertainty analysis of data channels may also be included.

5. TASK 2: MANEUVERING TRIALS AND ANALYSIS

There is no definitive international standard for the conduct of maneuvering trials. Many shipyards have developed their own procedures driven by their experience and with consideration to the efforts made by the International Towing Tank Conference (Proceedings ITTC 1963 – 1975).

SNAME has produced three guidelines; Code on Maneuvering and Special Trials and Tests (1950), Code for Sea Trials (1973), and Guide for Sea Trials (1989). The Norwegian Standard Organization has produced Testing of New Ship, Norsk Standard (1985), and the Japan Ship Research Association has produced a Sea Trial Code for Giant Ships, JSRA (1972) for maneuvering trial procedure and analysis of measurements. IMO Resolution A.601 (1987) and IMO Resolution A.751 (1993), were adopted to address ship maneuverability. IMO Resolution A.751 (1993) provides criteria for turning, initial turning, stopping, course-keeping and course-changing ability, as well as information for the execution of the maneuvering trials.

The SC has developed guidelines for performing maneuvering trials, as given below.

5.1 Preliminary Controls

The IMO standards are applied to the full load and even keel conditions. This draft is chosen based on the general understanding that the poorest maneuvering performance (poor coursekeeping capability) of a ship occurs at this condition. When it is impractical to conduct trials at full load because of ship type (bulk carrier etc.), draft, trim and displacement must be as close as possible to the specified trial condition and/or the condition in which model tests have been carried out. This will allow for predicting the full load maneuvering performance. Draft, trim and displacement of the trials are obtained by the same procedure outlined in Task 1, section 4.1.3.

5.2 Trial Site Criteria

Maneuverability of a ship is strongly affected by interactions with the bottom, banks and passing vessels. The trial site should therefore be located in waters of adequate depth with as low a current and tidal influence as possible. Maneuvering trials are generally conducted at the same site as the speed/power trials. Therefore, the SC suggests that the same trial depth criteria be used. It should be noted that the IMO standards require that the water depth should exceed four times the mean draft of the ship.

5.3 Trial Environmental Conditions

Environmental conditions should always be reported even though they may be considered to have no influence on ship behavior. Maneuvering trials should be performed in the calmest possible weather conditions. IMO Resolution A.751 (1993) prescribed the maximum environmental condition to carry out the maneuvering trials as follows:

1. Wind

   Trials should not be conducted with a true wind speed greater than Beaufort 5.

2. Waves
   The trials should be carried out in sea states less than 4.

5.4 Selection of Tests

In selecting tests, consideration should be given to their purpose. Some are intended to demonstrate performance of vital machinery and satisfy regulatory requirements. Some are essential to verify that the vessel has satisfactory basic course keeping and course changing qualities, and emergency maneuverability, while others are intended to obtain maneuvering data to be used in establishing operating regulations.

For course keeping qualities the suitable test method proposed is the direct spiral test, the reverse spiral test, the Z-maneuver test with small rudder angle, the modified Z-maneuver test and pullout test.

For course changing qualities, the Z-maneuver test, initial turning test and new course keeping test have been considered.

For emergency maneuver qualities the suitable test methods proposed are the turning test with maximum rudder angle, stopping test (crash stop astern test and stopping inertia test), man-overboard test and parallel course maneuver test.

Table 3 summarizes the different types of maneuvering tests recommended or required by various organizations. The purpose of each test is described below and suggested procedures on how to conduct the tests are presented in Appendix II.

Table 3. – Recommended Maneuvering Tests by Various Organizations

	Type of Test	IMO A601	IMO A751	ITTC 1975	SNAME 1989	Norsk Standard	Japan RR
1	Turning test	√	√	√	√	√	√
2	Z-maneuver test	√	√	√	√	√	√
3	Modified Z-maneuver test	-	-	-	-	-	√
4	Direct spiral test	-	-	√	√	√	√
5	Reverse spiral test	-	-	√	√	√	√
6	Pull-out test	√	-	√	√	-	-
7	Stopping test (Crash stop astern test)	√	√	√	√	√	√
8	Stopping inertia test	√	-	-	-	√	√
9	New coursekeeping test	√	-	-	-	-	√
10	Man-overboard test	√	-	-	-	-	-
11	Parallel course maneuver test	√	-	-	-	-	-
12	Initial turning test	-	-	-	√	-	-
13	Z-maneuver test at low speed	√	-	-	√	-	√
14	Accelerating turning test	√	-	√	-	-	-
15	Acceleration/deceleration test	√	-	-	√	-	-
16	Thruster test	√	-	√	√	√	-
17	Minimum revolution test	√	-	-	√	√	-
18	Crash ahead test	√	-	-	√	√	√

1. Turning test

The purpose of the turning test is to determine the turning characteristics of the ship. Basic information obtained from the turning test are advance, transfer, tactical diameter, steady turning diameter, final ship speed and turning rate in the steady state. It is suggested to perform turning tests at different speeds, and for different rudder angles.

2. Z-maneuver test

The Z-maneuver test is used to express course changing (yaw checking) and course keeping qualities. The essential information to be obtained is the initial turning time, time to second execute, the time to check yaw, and the angle of overshoot. Values of the steering indices K (gain constant) and T (time constant) associated with the linearized response model are also obtained.

3. Modified Z-maneuver test

The modified Z-maneuver test is used to express course keeping qualities under an actual operation. The test procedure is the same as the Z-maneuver test, but the heading angle for the switching of the rudder is made as small as 1° and the rudder angle being 5° or 10°.

4. Direct spiral test

The purpose of the direct spiral test is to determine whether the ship is directionally stable or not. Data defining the relationship between rudder angle and steady turning rate are presented. Important parameters are width and height of the loop for an unstable ship.

5. Reverse spiral test

The purpose of the reverse spiral test is to obtain for an unstable ship the complete loop, when it is not determined by the direct spiral test.

6. Pull-out test

The pull-out test represents a simpler way to give the height of the loop for an unstable ship than the direct spiral test and the reverse spiral test.

7. Stopping test

The stopping test is used to express the qualities for emergency maneuvers. The obtainable information are stopping time and stopping distance of the ship from the time at which an astern engine order is given until the ship is stopped dead in the water.

8. Stopping inertia test

The stopping inertia test is used to determine the running distance and time for the ship from the time at which an order for engine stop is given until the ship achieves a defined minimum speed. IMO Resolution A.601 (1987) requires that stopping performance information using maximum rudder angle be displayed in the wheelhouse.

9. New course keeping test

The new course keeping test is used to provide the information for changing a ship course. The obtained data are presented in an operational diagram of ship heading versus advance and transfer.

10. Man-overboard test

The man-overboard test is used to simulate the rescue of a man who has fallen overboard. Rudder angle and ship trajectory are checked throughout this test.

11. Parallel course maneuver test

Parallel course maneuver test provides the information for the emergency avoidance of a passing ship when maximum rudder angle is used. The obtainable data are an operational diagram of rudder angle and lateral displacement from the original base course.

12. Initial turning test

The initial turning test is used to provide the information on the transient change of heading after application of a moderate rudder rate.

13. Z-maneuver test at low speed
The Z-maneuver test at low speed is used to determine the minimum speed at which the ship does not respond to the helm.

14. Accelerating turning test
This test provides the turning characteristics of the ship accelerating from dead in the water. Maximum rudder angle and maximum engine output are applied simultaneously.

15. Acceleration/deceleration tests
These tests determine speed and reach along the projected approach path versus elapsed time for a series of acceleration/deceleration runs using various engine order combinations.

16. Thruster test
The thruster test is used to determine the turning qualities using thruster(s) with the ship dead in the water or running at a given speed.

17. Minimum revolution test
The ability to proceed at steady slow speed is determined from the ship's speed associated with the lowest possible engine revolutions per minute.

18. Crash ahead test
The crash ahead test is used to express the qualities for emergency maneuvers similar to the stopping test. An order for full ahead is given when the ship is moving steadily astern. The obtainable information are stopping time and stopping distance of the ship from the time at which an order for full ahead is given until the ship is stopped dead in the water.

5.5 Maneuvering Trial Measurements

Data are collected in order to evaluate maneuvering performance. In addition to general measurements described in Task 1, sections 4.3 and 4.5, the following data will be recorded using ship indicators and observations:

1. Primary data
   Primary data that must be acquired in order for the trial to be considered valid are listed in Table 4.

2. Secondary data
   Secondary data will enable a more precise evaluation. These data are:

   a. Torque
   b. Wind velocity and direction
   c. Roll angle

All data can be measured using the same instruments noted in Task 1, sections 4.3 and 4.5.

5.6 Acquisition Systems

SC recommends that data be acquired by a computer-based system because almost all of the maneuvering trials require time history data. The system should be able to collect, record and process real-time trial data. A data sampling rate of 0.5 - 2 samples per second is suggested.

5.7 Correction Due to Environment

The immediate environment such as wind, waves, and current can significantly affect ship maneuverability. IMO Resolution A.751 (1993) suggests a method to account for environmental effects only for turning tests.

5.8 Correction Due to Ship Conditions

Ship maneuverability can be significantly affected by the draft and trim condition.
Course stability in ballast condition is usually better than in full load even-keel condition.

Therefore, the SC recommends that maneuvering trials should be conducted in full load even-keel conditions. If this is not possible, the maneuvering characteristics in full load even keel condition should be predicted and corrected using a reliable method (e.g. model tests or proven computer simulation) that ensures satisfactory extrapolation of trial results, as also suggested by IMO Resolution A.751 (1993).

However, the SC recommends that, if the above correction is applied, the procedure must be clearly referenced and documented.

5.9 Trial Report Breakdown

The trial report should contain the following items:

1. Ship characteristics
2. Instrumentation
3. Trial site and environmental conditions
4. Trial program
5. Trial results

Table 4. – Recommended Maneuvering Trial Measurements

	Type of test	Heading	Position	Speed	Rudder angle	Revolution	Rate of turn	Torque
1	Turning test	√	√	√	√	√	√	**
2	Z-maneuver	√	√	√	√	√		
3	Modified Z-maneuver test	√		√	√	√		
4	Direct spiral test	√		√	√		*	
5	Reverse spiral test	√		√	√		*	
6	Pull-out test	√		√	√		*	
7	Stopping test (Crash stop astern test)	√	√	√		√		**
8	Stopping inertia test	√	√	√		√		
9	New course keeping test	√	√	√	√			
10	Man-overboard test	√	√	√	√			
11	Parallel course maneuver test	√	√	√	√			
12	Initial turning test	√		√	√			
13	Z-maneuver test at low speed	√		√	√			
14	Accelerating turning test	√	√	√	√	√		
15	Acceleration/deceleration test	√	√	√		√		
16	Thruster test	√	√	√		√		
17	Minimum revolution test			√		√		
18	Crash ahead test	√	√	√		√		**

* If the rate of turn can not be obtained using a rate gyro and/or gyrocompass, then use the heading and elapsed time to derive this value.
**Data collected if ship is equipped with torsionmeter.

6. TASK 3: SEAKEEPING TRIALS AND ANALYSIS

The purpose of Seakeeping Trials is to define the seaworthiness characteristics of a ship by assessing the relationship between ship motions and the related environmental conditions in which the ship was tested. All operations that may be affected by adverse sea and weather conditions are being examined and problem areas documented. These results will be used to determine the limiting sea and weather conditions for conducting various operations. The objectives of these trials are as follows:

1. Observe ship performance and operations under a wide range of sea conditions
2. Measure the ship motions during any periods of significant response
3. Identify any limitations in conducting various ship operations due to ship motions and sea conditions
4. Identify any problems observed either in the ship design or in any sub-system design
5. Determine the seakeeping performance of the ship (e.g. location and cause of significant deck wetness, occurrence of slamming)
6. Document the sea and weather conditions prevailing during the trial
7. Develop graphs/tables of the effects of ship speed and heading changes on motion levels
8. Validate prediction tools utilized
9. Validate model experiment and analytical predictions of seakeeping characteristics

Seakeeping tests (NATO, 1985, O'Hanlon et al., 1974, Payne, 1976) performed to study sea loads and ship structural responses are not considered in the scope of this task.

6.1 Preliminary Control

Before leaving the harbor determine:

1. Draft
2. Metacentric height
3. Trim
4. List

Loading computers may be utilized when trials are performed over an extended length of time.

6.2 Selection of the Trial Area

The evaluation of the sea-state is one of the keys to the successful conduct of seakeeping trials. The trial site should be selected to avoid areas where wave refraction and diffraction are predominant. Fully developed sea conditions in deep water are required.

The trial site should be clear of shipping lanes, free from navigational restrictions, and have sufficient depth of water.

6.3 Duration of Runs

The seakeeping evaluation will be conducted during any operations anticipated to occur in rough seas. Sea state 4 and 5 conditions are required for these trials. When a required sea condition is encountered, 3 to 9 hours of dedicated time for speed and course changes are required. If wave height is not measured using an over-the-bow sensor, additional time will be required to launch and recover a wave buoy. As a result, the trials will be dictated by the weather and ship schedule.

A classical figure (NATO "Seakeeping Trials Procedure", 1994) for minimum run length is based on 100 wave encounters. Consequently, run length will depend on both ship speed and wave modal period according to the formula:

$$Th = \frac{100}{60\left| \frac{1}{T_o} - \frac{2\pi(V_s)}{T_o^2 g}\cos\mu \right|} \qquad (3)$$

T_h = minimum run time, min

T_O = modal period of the chosen motion, sec

V_S = ship speed, m/sec

μ = relative wave heading (where μ = 180 for head seas)

In common practice the duration of following seas ($\cos\mu$ = 1) run will be of at least twice the duration of a typical head seas run. Usual practice leads to 15 to 20 minutes run length for head seas.

During seakeeping trials of a ship fitted with an active stabilization system (e.g. fins, T-foils), it is often prudent to obtain a record of ship motions with the system " on " and " off ". In such cases the length of run can be doubled.

10 minutes	20 minutes	10 minutes
Stab off	Stab on	Stab off

Splitting the " Stab off " run in two, provides an opportunity to confirm that the sea state hasn't changed significantly during the length of the run. This check must be accomplished using a robust criteria such as significant amplitude or rms value.

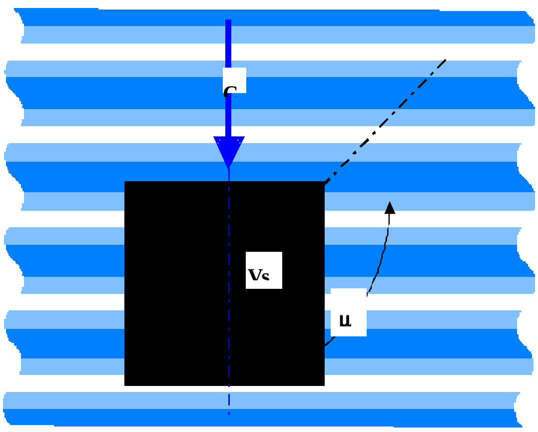

Figure 1. – Ship/Wave Relationship

6.4 Run Sequence

In cases where a wave measurement buoy is used, it may be necessary to conduct runs in close proximity to the buoy in order to obtain good signal reception from the buoy.
Conduct the first run into head seas.

Should time permit, the maneuvers should be repeated for an additional 3 to 4 hours for each additional ship speed. These trials should be conducted as rough seas are encountered.

The test program and run progress must take into account shipboard activity. Suggested procedures for the conduct of these trials can be found in Appendix III.

6.5 Ship Speed

Since ship motions are affected by ship speed (damping, frequency of encounter), the scientific approach to seakeeping trials would require that all runs of a set be performed at the same speed. A careful adjustment of rpm to obtain the same speed for all headings may require more time and space than usually allowed for sea trial tests. Therefore, a common practice is to maintain a constant rpm for all runs of the same set. In this case, the speed log output should be carefully recorded. The output of speed will be presented using V/Vo where Vo is a reference speed (head sea speed).

In the case of very rough weather, speed may have to be voluntary reduced. If this occurs, it should be documented and the corresponding rpm should be meticulously reported if it is not already being recorded.

6.6 Course Steering

Unless runs are governed by specific operations that may require appropriate responses from the helm, e.g. aircraft operation, the run must be accomplished steering the straightest course that is possible. Autopilot is generally the best option, but sometimes during very rough following sea runs, manual steering gives better results. In any case, the way the ship is steered must be carefully reported, including changes of helmsmen.

6.7 Data Collection and Instrumentation

The preferred method of data collection is digital collection directly to a computer. Data is collected in order to obtain factual documented evidence of the seakeeping performance of the ship. Data is used in statistical and spectral analyses. Data for seakeeping trials can be divided into three different categories:

1. Primary

Ship motion and ship course

a. Pitch (ship gyro-synchro amplifier)
b. Roll (ship gyro-synchro amplifier)
c. Vertical acceleration (accelerometer) at the center of gravity
d. Transverse acceleration (accelero- meter)
e. Ship speed (GPS or speed log)
f. Heading (gyro compass)
g. Shaft rpm (tachometer)
h. Fins and rudder deflection (angular potentiometer, actual position measurement should be preferred to ordered position)

Environmental data

i. Wave height (direction when available, see section 6.8)
j. Wind speed (anemometer)
k. Wind direction (anemometer)

2. Secondary

a. Ship position (GPS)
b. Shaft power (torsionmeter)

3. Tertiary

a. Longitudinal acceleration (accelerometer)
b. Acceleration at critical crew work stations

In addition to measurement, an audio tape recorder can be used to record special events such as slamming, local course changing (avoidance of obstacle), deck wetness, or changes in environmental conditions. A detailed video log, with event time recording capability, is recommended.

Furthermore, all weather deck activities related to the operations or disruptions induced by a combination of weather and/or ship motion may be filmed. A video camera equipped with time recording capability is recommended.

a. Observe (and record on video tape in some cases) any effects of motions on operational performance when possible.
b. Record ship motion data at intervals to be determined by the prevailing sea conditions and operations.
c. Log the environmental and ship operating conditions corresponding to periods of data collection.

The following environmental and ship operating data will also be tabulated using observations and ship indicators:

a. Significant wave height
b. Predominant wave direction
c. Water depth
d. Air temperature and atmospheric pressure

6.8 Sea State Estimation

The evaluation of sea state is a key point for accomplishing good seakeeping trials. Therefore, every means of obtaining information about sea state must be considered, with redundancy being recommended.

1. Buoys

Wave buoys are the most accurate way of measuring sea-state but require deployment and recovery operations. This may be tricky in the rough seas required for seakeeping trials. The signal is either transmitted to a receiver located onboard or recorded inside the buoy itself. The usual maximum receiving distance is 30 nm. Great care must be taken to ensure that during the trials the ship remains within the receiving area of the buoy.

To facilitate the recovery of the buoy after the trial program has been completed, it may be prudent to equip the buoy with a GPS receiver. The signal from the buoy will be transmitted to the ship. For the same reason, a radar reflector may also prove useful.

2. Bow sensors

A convenient alternative to wave buoys is bow mounted sensors. These sensors measure the distance between the ultrasonic or radar sensor and the sea surface and hence must be corrected for ship motion. A practical way to achieve this is to use an accelerometer located near the bow sensor. The signal must be integrated twice to subtract the heave motion of the sensor.

The use of bow sensors are limited by the ship size and apparent wave steepness. Spray and the bow wave of the ship can adversely affect this measurement. These sensors are commercially available.

3. Satellite observation

Satellite observation can now provide valuable information on sea state but its use is limited due to satellite availability.

4. Hindcasting

Hindcasting can complement sea state measurement but should not be used as a primary source of information.

5. Ship motion

If no other means are available, ship motion may be used to derive an estimation of sea state. For example, for large wave lengths or small ships, heave measured at zero speed (in most cases the ship will drift at an abeam wave direction) will provide an approximation of wave height. The estimation can be improved by the knowledge of the ship transfer function.

6.9 Data Acquisition

1. Recording

The data may be collected during the trial using removable disk cartridges (Zip). A computer should be used to provide real-time data reduction. Time histories and the resulting statistics can be correlated with the corresponding operations by using a common time basis for recordings, video tapes, and observations. Several new autonomous data collection systems have been recently developed. They can operate continuously and record during an entire voyage without an operator. This provides opportunities to obtain a data base of motions during the actual day-to-day operation of the ship.

2. Filtering and sampling

Since ship motions are of very low frequency compared to the capability of existing acquisition systems, anti-aliasing filtering and sampling rate don’t create too many problems. It is often much simpler to record all data channels using the same sampling rate. A common value for cut–off frequency, f_c, is 2 Hz. Sampling rates of 8 Hz are also widely used.

However, for specific observations such as structural data, slamming accelerations or pressure peaks, much higher frequencies may be required.

6.10 Data Analysis

1. Time domain analysis

Two methods can be deployed to derive statistics from time domain analysis Lloyd (1991).

The first method consists in deriving statistics from each sample of the recording. In that case the output is the probability of exceeding a certain level of amplitude for the considered parameter.

An alternative method more commonly used for seakeeping statistics called “wave analysis” requires a pre-processing stage during which cycles are derived from the original signal. Double amplitude is calculated for each cycle (wave) and statistics are derived for those waves.

It is generally accepted that this process can be reasonably used when the number of cycles is at least 100. A 100-cycle record is not necessarily obtained through 100 wave encounters.

2. Frequency domain analysis

Frequency domain analysis or spectral analysis is performed to derive energy density spectra. The use of existing numerical tools to obtain a spectrum from a time domain trace requires the calibration of different parameters (frequency resolution, frequency domain filtering). Those settings affect the overall results but their adjustment is mainly driven by experience.

Equivalent quantities can be obtained both from statistical and spectral quantities (with assumption of the propriety of the distribution in some cases, e.g. Ochi and Bolton, 1973). It is therefore recommended to perform both statistical and spectral analysis for each test.

6.11 Trial Report Breakdown

The trial report should contain the following items:

1. Ship characteristics,
2. Instrumentation,
3. Trial site (including environmental conditions)
4. Trial program
5. Trial results (e.g. time, speed, heading, wave spectra, significant/rms motion values, peak values)

7. TASK 4: PERFORMANCE MONITORING SYSTEM

The use of onboard instruments for measuring and monitoring data of ship motion, power consumption and location depends on the intended purpose of the measured and collected data. Data may fall into two categories:

1. Operational data: These data are sufficient for daily monitoring of the behavior of the ship and engine. The instrument requirements are not stringent in terms of resolution. Data are mainly displayed and manually reported.
2. Research & Development data: These data are the basis for developing scientific predictions and determining analyses techniques. Therefore instrument and sensor requirements are stringent in terms of resolution and accuracy. Data are electronically accessible for computer collection and analysis.

In general, most of the instruments installed onboard by shipbuilders fall into the first category. Therefore, the SC recommends that sea trials not be conducted using the ship instrumentation or equipment.

As to the state of the art of onboard monitoring systems, the SC collected references on what was currently available in the international literature, starting from the Proceedings “Onboard Monitoring Session ”, 20th ITTC (1993), Busch (1980), Mierau (1980), Froese (1990), Claus (1994), Claus (1994), Lauro (1995) and Lacey (1995).

The evaluation of their use has not been possible for a number of reasons:

1. Time constraints
2. Multitude of systems in use
3. Difference in the purpose of each system
4. Lack of standardization in

instrumentation
5. Lack of feedback from ship operators
6. Lack of documented evidence of the financial benefit (shorter transit time and damage avoidance) of these systems

In the future, involvement of ship-owner expertise is recommended to properly fulfil this task assignment.

8. TASK 5: USE OF GPS IN SEA TRIALS

8.1 GPS Overview

The general term Global Positioning System (GPS) will be used herein to imply the NAVSTAR (NAVigation Satellite Timing And Ranging) system, developed and controlled by the US Department of Defense. The system consists of 21 active and three spare satellites placed in six polar orbits, over 20,000 km high and each with 55 degrees orbit inclination. The orbit period is 12 hours. The final satellite in the constellation was inserted at the end of 1993, and official operational activity of the NAVSTAR GPS begun in mid 1994.

Each satellite transmits an unique coded sequence that allows for the identification of the satellite, the calculation of ranges to it, and the ability to decode data. There are two fundamental methods that are used to determine position using data transmitted by GPS satellites; pseudo-range and phase observable. Phase observable data requires more complicated software to obtain ship speed than pseudo-range but provides improved position and speed accuracy. Pseudo range provides adequate accuracy for ship trials with less expense and effort and, therefore, its use is recommended.

The radio travel time between the satellite and the receiver is essential for pseudo-range. It is obtained by decoding the satellite's data that contains position and time of transmission. This is compared to a receiver clock at the time of reception, thereby giving a time/distance measurement.

A more detailed description of the NAVSTAR GPS is found in the specialist literature (Akroyd and Lorimer, 1990 and Hogarth, 1991). The SC intends to focus on the need for using Differential GPS operation to determine improved accuracy of ship speed and position data. Two techniques are possible for providing real time correction on board, both of which utilize a GPS reference station in a known position and a radio-link to the mobile unit.

The first technique is used to generate a position correction (i.e. the delta latitude, longitude and height) while the second is used to generate range corrections for each satellite (i.e. delta pseudo-range).

As stated in reference RTCM (1990), Selective Availability may degrade the accuracy of the position to approximately 100 meters (2 rms or 95% level of confidence). Differential correction will improve the accuracy up to 1-5 meters and better, depending on the separation distance between mobile and reference station. This is mainly due to the fact that predominant errors of GPS are bias errors, whose major sources can be listed as follows:

1. Selective Availability (SA): The SA errors are introduced into the GPS signals on board the satellite to degrade the navigation accuracy provided by the system. The "epsilon" component of SA is an artificial degradation of the broadcast ephemeris, which can lead to errors greater than 20 m. The "dither" component is a rapidly varying error imposed on top of the normal satellite clock error.

a. Ephemeris error: The broadcast ephemeris is a predicted ephemeris based on global tracking data. The satellite co-ordinates calculated from this ephemeris can have an error on the order of 20 m.

b. Satellite clock error: This is caused by the difference in precision between the satellite and the receiver clocks.

2. Ionospheric delays: The effect of the ionosphere on radio signals is proportional to the number of free electrons along the signal path. In mid-latitude regions the signal delay can cause pseudo-range errors varying from 8 to 25 meters, depending on the satellite elevation angle.
3. Tropospheric delays: The troposphere is the lower part of the atmosphere and is generally considered to extend up to an altitude of about 10 km. The tropospheric delay is a much smaller error (about 2 m), and is mainly a function of local humidity, temperature and altitude.

The errors listed above are minimized by differential operation for stations located within 30 to 40 km. However, signal propagation delays can increase errors if the distance between the two stations becomes larger.

8.2 Application of DGPS During Sea Trials

Until now, most of the activity devoted to the definition of GPS accuracy has been finalized to navigation (marine, land or air) or fixed positioning. Therefore, it has been necessary to assess the accuracy of the application of DGPS to ship sea trials according to its specific requirements.

Independently, by the source of errors, it is necessary to define parameters to measure the accuracy of GPS (Zachmann 1988) and to define which type of accuracy have to apply, where the parameter definition depends on its application (navigation, positioning, etc.).

The most common methods of measuring accuracy, assuming that GPS data exhibits a Gaussian like distribution, are:

1. The Circular Error of Probability (CEP) in which the level of confidence is 50%.
2. Twice the Root-Mean-Square (2rms) in which the level of confidence is between 95% to 98% depending on the ellipticity of the distribution.

The last method is more conservative and is commonly selected to measure accuracy in experimental activity on ship trials.

As to the types of accuracy, they can be defined as follows:

1. Predictable Accuracy applies to positioning with respect to co-ordinates of the earth.
2. Repeatable Accuracy applies to the ability of returning to a previously surveyed position.
3. Relative Accuracy applies to positioning with respect to a reference own position.

Relative accuracy is applicable to ship sea trials in which the starting measurement point of a maneuver (or speed run) is assumed 100% accurate and all other position measurements are related to it.

Two different ways are possible to determine the ship's speed by using the GPS technique (Lauro, 1994, Cortellini and Lauro, 1995).

1. Speed calculated by the "Doppler-shift effect"
2. Speed calculated as a result of the ratio "travelled distance" over "elapsed time"

Both determinations utilize different hardware/firmware approaches.

Two distinct types of equipment, each with their own unique accuracy, are used to determine speed.

Two values of ship's speed should be provided:

1. The "traditional" distance/time ratio is

provided as the official speed figure for contractual purposes.
2. The “direct” speed figure is a result of the average value of the GPS speed data sampled at 0.5 to 2 seconds intervals and is provided for quality control purposes. A statistical analysis and filtering of the signal through the Chauvenet Criterion (Coleman and Steele 1999) should also be included.

The emphasis given to the DGPS technique within this section is mainly due to the fact that many organizations have adopted this system in sea trials (Stenson, 1995 and Hubregtse, 1995).

Lauro (1996) provides useful information to those interested in DGPS applications. So far as the correction message transfer to ship is concerned, various links (UHF radio-link, Racal Sky-fix via-INMARSAT, cellular telephone link) have been tested and a description of their applicability is given to coastal areas.

9. SC CONTRIBUTION TO ISO STANDARDS FOR SPEED TRIALS' EVALUATION

The SC provided input to the ISO/ Committee Draft 15016 entitled Ships and marine technology – General requirements – Guidelines for the assessment of speed and power performance by analysis of sea trial data via Mr. Fujino who served on the SC and the working group developing the proposed ISO guideline. The SC met with a group of Japanese shipbuilders to address their concerns with the SC's work. Their concerns were addressed in Task 1 and communicated to the ISO working group.

10. GENERAL CONCLUSIONS

1. No definitive standard for the conduct of speed/power trials exists.
2. A standardized method for correcting trial data for environmental effects is being developed by ISO TC8/SC 9/ WG 2.
3. Measuring propeller pitch during sea trials is difficult.
4. IMO resolutions reviewed do not address accuracy of instrumentation or trial conduct using unconventional steering and propulsion systems.
5. Sea states and environmental effects are difficult to quantify accurately.
6. Differential global positioning system (DGPS) was evaluated and its use is well accepted in the conduct of sea trials.

11. RECOMMENDATIONS TO THE CONFERENCE

1. The Committee recommends that the existing Guidelines for conducting Speed/ Powering trials developed by the 21st ITTC Powering Performance Committee continue to be used until modified, (ITTC Procedure 4.9-03-03-01.3).
2. Comprehensive tests should be performed on the first ship of a class. A reduced level of testing should be conducted on sister ships to verify that ship performance is similar to that of the first ship of the class.
3. Most ship equipment is not adequate in terms of resolution and/or accuracy for trials' purposes. Ship equipment should not be utilized for acquisition of trials data unless it can be calibrated and data can be continuously recorded.
4. The Committee recommends that all information relating to the correction of trials data for environmental effects be documented and referenced.
5. Computers should be used to collect data. A time history of each required trial measurement (as defined in the individual ship trial agenda) is necessary to increase confidence in the trial data

and to facilitate the conduct of an uncertainty analysis.
6. For seakeeping tests, it is recommended that sea state be measured using more than one source whenever possible.
7. DGPS is recommended as the instrument of choice in acquiring ship positional data and for the determination of ship speed.

12. RECOMMENDATIONS FOR FUTURE WORK

1. Due to the on-going efforts of international organizations preparing guidelines for speed/power trials, the Committee recommends the continuation of the Trials & Monitoring Specialist Committee.
2. The Committee recommends that the guidelines for conducting Speed/ Powering Trials established by the 21st ITTC Powering Performance Committee (ITTC Procedure 4.9.03.03.01.3) be updated.
3. Definitive procedures should be developed for the conduct of maneuvering and seakeeping trials similar to the proposed revised speed/power guide.
4. For maneuvering tests, it is recommended that a full scale trials database of ship maneuvering performance be established to include maneuvering in a high sea state environment.
5. Effort should be put into developing a means of obtaining reliable and accurate propeller pitch measurements.
6. The Committee recommends that maneuvering test procedures be developed for unconventional propulsion and steering systems.
7. Further evaluate onboard monitoring systems by soliciting input from ship operators and owners.
8. Since the range of data acquisition equipment is of varying complexity, resolution and accuracy, the Committee recommends that an appropriate ideal data acquisition system be defined.
9. The Committee recommends that the relationship between ship motions and power plant parameters be evaluated focusing on how to monitor and analyze this relationship.

13. REFERENCE LIST

Ackroyd, N. and Lorimer, R., 1990, Global Navigation: A GPS user's guide, Lloyd's of London Press, 1990.

Busch, C. W., 1980, "Realisierungsmöglichkeiten der Brückenautomation", "Feasibility of Automatic Navigational Bridge Functions", Jahrbuch STG, 74. Band, 1980.

Claus, J., 1994, "Nautisches Operationssystem", "Nautical Operation System", HANSA, 131. Jahrgang, Nr. 1., 1994.

Claus, J., 1994a, "Navigationskonzepte für schnelle Schiffe - Die integrierte Cockpitbrücke und die erforderliche Sensorik", "Navigation Concepts for High Speed Craft", Jahrbuch STG, 88. Band, 1994.

Coleman, H. W. and Steele, W. G., 1999, Experimentation and Uncertainty Analysis for Engineers, 2nd Edition, John Wiley & Sons, Inc., 1999.

Cortellini, L. and Lauro, G., 1995, "Assessment of Ship Performance Using a DGPS System", Proceedings of International DGPS Seminar, Genoa, Italy, 31 March 1995.

Cortellini, L., Martinelli, S., and Della Loggia, B., 1972,"Apparecchiatura per la misura di coppia, giri e potenza", Cetena Report No. 480, Genova, Dicembre 1972.

Forst, Chr., 1996, "Funknavigationskonzept für die maritime Verkehrssicherheit", "Radionavigation concept for maritime traffic safety", HANSA, 133. Jahrgang, 1996, Nr. 9.

Froese, J., 1990, "Integration von Brückendaten unter Einschluß der elektronischen Seekarte", "Integration of Bridge Data Including Electronic Sea Chart", Jahrbuch STG, 84. Band, 1990.

Hine, G., 1976, "A Re-assessment of the Use of Strain Gages in the Measurement of Propeller-Shaft Torque", BSRA Report No. 382, 1976.

Hogarth, B., 1991, "Global Positioning System", L&SS LTD & Diff. Techn. U.S.D., May/June 1991.

Hubregtse, A. H., 1995, "Differential GPS Application in the MARIN Sea Trials", Proceedings of International DGPS Seminar, Genoa, Italy, 31 March 1995.

International Maritime Organization (IMO), 1987, "Provision and Display of Maneuvering Information on Board Ships", Resolution A.601 (15), 19 November 1987.

International Maritime Organization (IMO), "Interim Standards for Ship Manoeuvrability", Resolution A.751 (18), 4 November 1993.

International Towing Tank Conference, 1969, "ITTC Guide for Measured-Mile Trials", Report of the Performance Committee, Proceedings of 12th ITTC, Appendix I, Rome, Italy, September 1969, pp 194-197.

International Towing Tank Conference, 1996, "An Updated Guide for Speed/Powering Trials", Powering Performance Committee Report, Proceedings of 21st ITTC, vol 1, Appendix I, Trondheim, Norway, September 1996.

International Towing Tank Conference, 1993, "The Onboard Monitoring Session", Proceedings of 20th ITTC, vol 2, San Francisco, USA, September 1993.

International Organization for Standardization, 1993, ISO 9000 "International Standards for Quality Management", 3rd edition, Geneva, Switzerland, 1993.

Johnson, E. H., 1993, "Uncertainty Analysis of Standardization Trials on a Navy Fleet Oiler", Carderock Division, Naval Surface Warfare Center, Report CRDKNSWC/HD-1428-01, September 1993.

Japan Ship Research Association, 1972, "Sea Trial Code of Giant Ships", JSRA, 1972.

Lacey, P. and Chen H., 1995, "Improved passage planning using weather forecasting manoeuvring guidance and instrumentation feedback", Marine Technology, 32 no. 1, pp 1-19.

Lackenby, H., 1963, "Note on the Effect of Shallow Water on Ship Resistance", BSRA Report No. 377, British Shipbuilding Research Association, 1963.

Lauro, G., 1994, "Application of DGPS to Ship Sea Trials", DSNS 94, London, United Kingdom, 18-22 April 1994.

Lauro, G., 1996, "DGPS for Marine Application: Ship Performance Monitoring System Around the Italian Coast", DSNS 96, St. Petersburg, Russia, 20-24 May 1996.

Lauro, G., 1995, "Performance Measurements for Ships in Service Full Scale Measurement Equipment and Uncertainty Analysis", CETENA Report No. 5615, Genoa, March 1995.

Lloyd, A. R. J. M., 1991, "Seakeeping", Philosophical Transactions of the Royal Society of London (PTRSL), Series A, vol 334, Number 1634, pp. 253-264, 15 February 1991.

Measurement Uncertainty, ANSI/ASME PTC 19.1-1985 Part 1, 1986. (Available from ASME Order Dept., 22 Law Drive, Box 2300, Fairfield, New Jersey 07007-2300)

Mierau, J. W., 1980, "Aktueller Stand und Zukunftsaussichten der Brückenautomation aus der Sicht des Nautikers", "Automation on the Bridge - at Present and in Future", Jahrbuch STG, 74. Band, 1980.

Morandi, D. and Scavia, F., 1992, "Applicazione dei sensori ad effetto Hall per il rilievo dell'angolo di deformazione torsionale di assi rotanti", Cetena Report No. 4883, 1992.

NATO Naval Armaments Group IEG/6 Sub-Group 5 working paper AC/141 (IEG/6)SG/5-WP/9 "General Criteria and Common Procedures for Seakeeping Performance Assessment - Proposed Revision of STANAG 4154", working paper, 4 April 1985.

NATO, "Seakeeping Trials Procedure", AC141 IEG6 Sub-Group 5, working paper 19, April 1994.

Norwegian Standard Organization, 1985, "Testing of New Ship", Norsk Standard NS 2780, 1 August 1985.

Ochi, M.K. and Bolton, W.E., 1973, "Statistics for Prediction of Ship Performance in a Seaway", International Shipbuilding Progress, vol 20, 1973.

O'Hanlon, J. S. and McCauley, 1974, "Motion Sickness Incidence as a Function of the Frequency and Acceleration of Vertical Sinusoidal Motion", Aerospace Medicine, vol 45, pp. 366-369, April 1974.

Payne, P. R., 1976, "On Quantizing Ride Comfort and Allowable Accelerations", AIAA/SNAME Advanced Marine Vehicles Conference, September 1976.

RTCM, "RTCM Recommended Standards for Differential Navstar GPS Service", Paper 134-89/SC 104-68, Version 2.0, Washington, D.C., USA, January 1990.

Shipbuilding Research Association of Japan SRT-208 Panel, 1993, "Standardization Speed Trial Analysis", SRAJ, Tokyo, Japan, March 1993.

Sitzia, G., and Della Loggia, B., 1981, "The Use of Raydist in Sea Trials" Cetena Report No. 16, Genoa, Italy, November 1972, rev. 1981.

Society of Naval Architects and Marine Engineers Technical and Research Program, Panel M-19 (Ship Trials), 1973, Technical & Research Code C2 "Code for Sea Trials 1973", SNAME, 1973.

Society of Naval Architects and Marine Engineers Ship's Machinery Committee, Panel M-19 (Ship Trials), 1989, Technical & Research Bulletin 3-47 "Guide for Sea Trials 1989", SNAME, 1989.

Society of Naval Architects and Marine Engineers Ship's Machinery Subcommittee of the Technical and Research Committee, 1950, "Code on Maneuvering and Special Trials and Tests 1950", SNAME, 1950.

Stenson, R. J., and Hundley, L. L., 1991, "Performance and Special Trials on U.S. Navy Surface Ships", David Taylor Research Center, Report DTRC/SHD-1320-02, December 1991.

Stenson, R. J., 1995, "Use of the Global Positioning System for the Conduct of U.S.

Navy Performance and Special Trials", Proceedings of International DGPS Seminar, Genoa, Italy, 31 March 1995.

Taniguchi, K., 1963, "Propulsion Trial Code", Propulsion Committee Formal Contribution, Proceedings of 10th ITTC, vol 1, Appendix V, Teddington, UK, September 1963, pp 80-86.

Taniguchi, K., 1966, "On the Distance of Approach Runs", Report of the Performance Committee, Appendix 6, Proceedings of 11th ITTC, Tokyo, Japan, October 1966, pp 127-130.

Taniguchi, K., 1966a, "The Data of the Change of Water Speed during the Approach Run and the Tidal Current Speed in Trial Course", Report of the Performance Committee, Appendix 3, Proceedings of 11th ITTC, Tokyo, Japan, October 1966, pp 118-123.

Taniguchi, K. and Tamura, 1966, "On a New Method of Correction for Wind Resistance Relating to the Analysis of Speed Trial Results", Report of the Performance Committee, Appendix 11, Proceedings of 11th ITTC, Tokyo, Japan, October 1966.

Thomson, G. R., 1978, "BSRA Standard Method of Speed Trial Analysis", BSRA Report NS466-1978, 1978.

Yoshino, M., 1997, "Application of Speed Correction Method Against Waves at Speed Trials", NAV 97, Naples, Italy, 18-21 March 1997.

Zachmann, G. W., 1988, "GPS Accuracy for Civil Marine Navigation", NMEA Annual Meeting, Braintree, MA, USA, October 1988.

APPENDIX I
SUGGESTED PROCEDURE FOR SPEED/POWER TRIALS

1. APPROACH PROCEDURES

1. Establish communications among all shipboard data recording stations.
2. Pass word to all shipboard data takers stating the run number, direction and any other pertinent information.
3. Bring the ship on the appropriate approach course toward the optimum tracking area on the trial site. During the approach of each run, the ship will be steadied on course and throttle controls adjusted to give the desired rpm or engine order specified. If there are multiple shafts, it is important that the rpms of all shafts be set according to the appropriate rpm schedule detailed in the trial agenda. Note that for locked shaft trials, it is recommended that the ship be dead in the water before the shaft is locked. For twin screw ships, common practice is to lock the longer of the two propeller shafts with the locking gear. For trailed shaft trials, declutch the longer of the propeller shafts so that the shaft will windmill as the ship is driven by the other shaft(s). For propeller pitch trials, adjust the throttle controls to give the desired propeller pitch and rpm.
4. The Mate on Deck will inform the Trial Director (TD) when the ship has attained the trial conditions required. The TD and the instrumentation operators independently confirm these conditions by monitoring shaft torque, shaft rpm, and ship speed on remote monitors. Note that the requested shaft rpm will be attained before the ship's momentum and speed stabilize, so matching shaft torque and shaft rpm for all shafts and a steady ship's EM log provide the best indications of steady approach.
5. For approximately 60 seconds before the start of the run, monitor the approach data to ensure that all data parameters are steady. After ensuring that steady conditions have been established,

COMEX the run. Once data recording has begun, do not adjust the throttles.

2. TEST CONDITIONS

1. Pass a COMEX command from the TD to all instrumentation operators signifying the start of the run. Record data for the duration of the run.
2. Propeller shaft speed and other engine parameters should be held constant for each of the runs.
3. The ship shall maintain heading during the run. The helmsman shall keep rudder movement to the minimum necessary, typically ±3°. Autopilot use within these guidelines is acceptable.
4. After the desired amount of steady data is recorded, pass a FINEX command from the TD to all instrumentation operators ending the data collection and the run. The steady power portion of the run may be extended to obtain the necessary amount of data, especially if weather conditions affect the data.

3. END TEST AND SET-UP FOR NEXT RUN

1. After FINEX, the ship should maintain speed and heading for at least one minute more before conducting a Williamson Turn. This allows room to establish steady powering conditions prior to passing over the same area as the previous run.

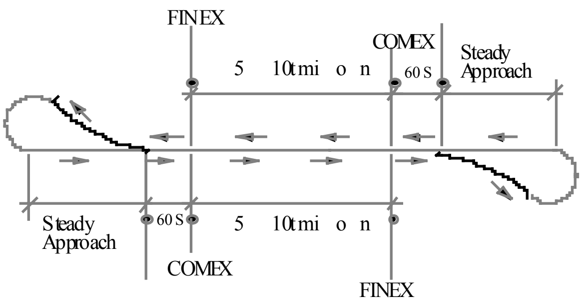

Figure A-1. Path of ship during typical speed/power maneuver.

APPENDIX II
SUGGESTED PROCEDURES FOR MANEUVERING TRIALS

This guide is intended to outline a procedure for obtaining data on maneuvering trials.

1. TURNING TEST

1. Establish steady ship speed to the conditions indicated in the trial agenda and adjust the ship's heading to a steady course prior to the point of required initial rudder execution. At this time, no further adjustment to the engine order is to be made until the conclusion of the test. Start the data acquisition system.
2. Steer with the prescribed minimum rudder angle. Record the time at which the rudder is moved to the angle denoted in the trial agenda. Once the rudder angle is set, no further adjustment should be made, even if the rudder angle achieved deviates to some degree from the rudder angle prescribed in the agenda.
3. The test is concluded when the change of heading reaches an angle between 540° and 720° (the larger the angle the better). Set the ship's heading to a straight course, in readiness for the subsequent test. At the conclusion of the test, steer the ship on a straight course in readiness for the subsequent test. A suitable approach distance should be chosen to establish the desired approach speed specified in the trial agenda.
4. The normal rudder angle to be used is 35° or maximum rudder right and left, supplemented with 15° right and left rudder angles.
5. The approach for right and left turns should preferably be conducted at the same headings.

2. Z-MANEUVER TEST

1. Establish steady ship speed at the conditions indicated in the trial agenda and adjust the ship's heading to a steady course prior to the point of required initial rudder execution. At this time, no further adjustment to the engine order is to be made until the conclusion of the test. Start the acquisition system.
2. Order "10° right rudder". Maintain rudder at the ordered angle. In the case of a neutral angle, the rudder commands should be issued relative to the neutral angle

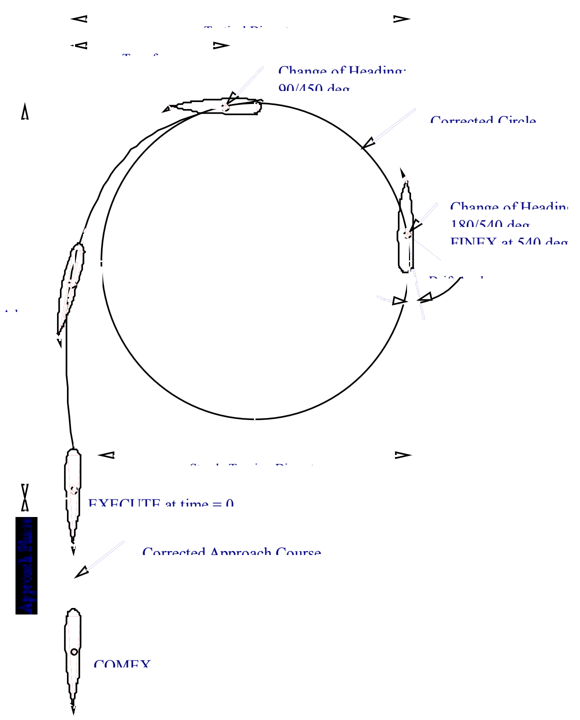

Figure A-2. Drift corrected turning circle

3. When the change of heading nears to 10° to starboard, order "stand by for 10° left rudder". Upon attainment of 10° to starboard heading, order "execute". Reverse rudder at normal rate from 10° right to 10° left, and thereafter maintain rudder at 10° left.
4. The ship will keep turning to starboard for a while until reaching the overshoot angle. Eventually the ship will turn to port. When the change of heading nears to 10° to port from the original approach heading, order "stand by for 10° right rudder". Repeat step 3 above with right and left reversed.
5. Upon attainment of approach heading, the test is terminated, and the ship is reset to a steady course.

6. Bring the ship to the same initial heading as in the previous run. Establish the next steady ship speed indicated in the trial agenda. Repeat steps 2 to 6 above with term 'left' and 'right' reversed. (The initial procedure steps 2 to 6 starting with right rudder is hereafter referred to as "+ 10°" and the reversed procedure starting with left rudder "-10°").
7. IMO requires Z-Maneuver tests be performed at ±10° and ±20° degrees. For large full ships it is recommended to also perform tests at ±5° and ±15° rudder angles.

Note: The rudder commands should be issued for a rudder angle relative to the neutral angle. The neutral angle is the mean rudder angle at which the ship keeps steady course at approach heading during an extended seaway.

The SC recommends that the procedure be extended to include four additional rudder throws to determine the repeatability of the overshoot headings and angles. GPS should be used to determine ship's trac

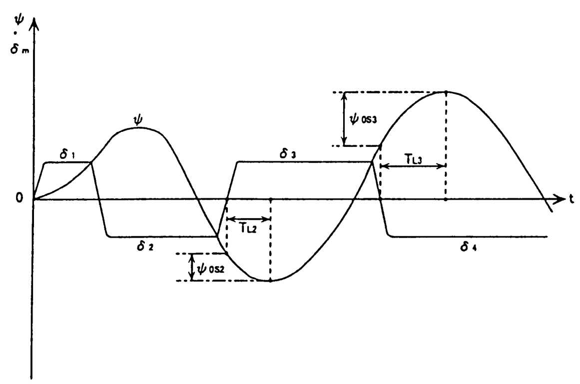

Figure A-3. Z-maneuver test

3. MODIFIED Z-MANEUVER TEST

The modified Z-maneuver test can be executed using the same procedure as the Z-maneuver test, except that the rudder angle is only 5° or 10° and the rudder changes when the change of heading becomes 1°.

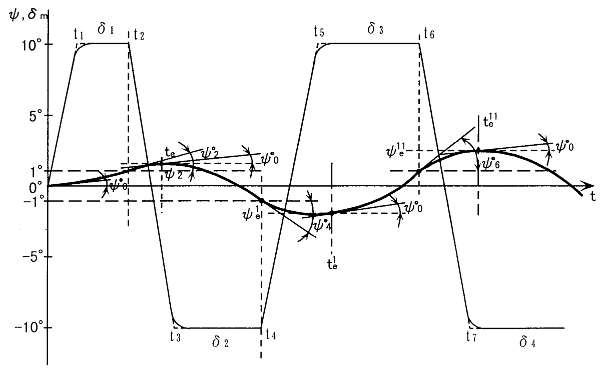

Figure A-4. Modified Z-maneuver test

4. DIRECT SPIRAL TEST

1. Set ship to steady speed and to steady course, then order “10° right rudder”. Actuate rudder at normal steering rate to 10° right. Maintain rudder at ordered angle.
2. When a steady rate of change of heading is achieved, record the rate of turn, rudder angle and propeller revolution.
3. Order “ shift rudder to right 5°” and repeat measurements as in step 2 above.
4. Order “shift rudder to right 1°” and repeat the step 2 measurements.
5. Order “shift rudder to midship”. Repeat the step 2 measurements. The ship will normally maintain a steady rate of turn to starboard for a while. Record this residual rate of turn.
6. Order “1° left rudder” and repeat step 2 measurements.
7. If the ship still keeps turning to starboard, order “2° left…”, “3°…”. Incrementally increase the rudder angle by 1° until the ship starts turning to port. At every rudder angle, repeat the step 2 measurements.
8. When the ship starts to turn to port, wait until the rate of turn becomes steady and record both the rate of turn and the rudder angle.
9. Order “5° left rudder”. Repeat the step 2 measurements. Proceed to “10° left rudder” and repeat the step 2 measurements. If step 7 above has been attained only beyond 5° port, start the present step 1 at “10° left rudder”.
10. Repeat step 4 to 5, or 3 to 5, whichever is relevant. (Left and right are reversed in step 6.)
11. Order “1° right rudder” and repeat the step 2 measurements.
12. If the ship still keeps turning to port, order “2° right…”, and “3° right…”, incrementally increase the rudder by 1° until the ship starts turning to starboard. Repeat the step 2 measurements.
13. When the ship starts to turn to starboard, wait until the rate of turn becomes steady and record both the rate of turn and the rudder angle. Terminate the test.

Note: Tests should preferably be conducted in a sea state below 2 or 3. Reliable measurements can not be expected in a sea state beyond 4.

If a test has to be temporarily suspended, it should be resumed using the rudder angle associated with the step preceding that at which the suspension took place.

5. REVERSE SPIRAL TEST

1. The ship shall proceed at the prescribed heading and speed. The yaw rate setting is adjusted to a defined value. The ship is steered around this value according to the following scheme.
2. Rudder is turned to left 5° when the indicator passes through the 0 point from the port to starboard side, and to 5° right in the converse case. If the time to steer left 5° proves to be shorter than the corresponding time for 5° right rudder, substitute 5° left with 4° left, and 5°

right with 6° right. Proceed in similar gradations until the times of both steering become balanced.

3. When the second step is completed, a rough regular yawing motion is obtained upon which the measurements at the defined setting are determined.

Note: Increasing yaw angular rate inevitably increases the difference between left and right rudder angle. In such cases, the procedure may be started using the angle set in the preceding cycle.

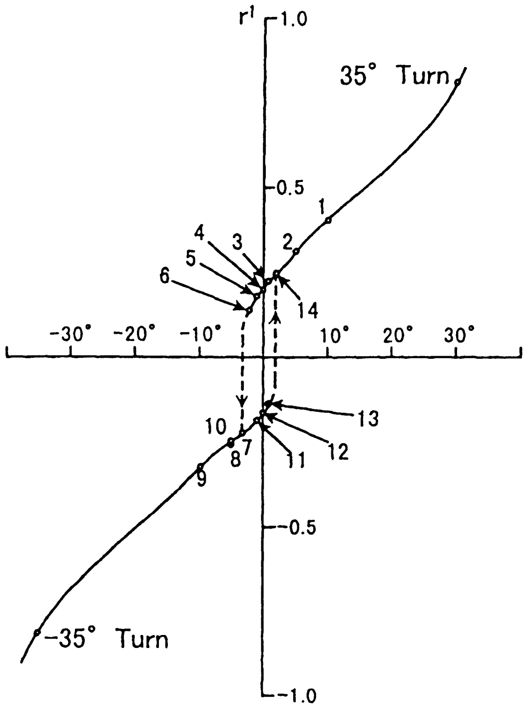

Figure A-5. Direct spiral test

6. PULL-OUT TEST

1. Establish steady speed and course conditions, then order the "right rudder" prescribed in the trial agenda. Actuate the rudder at a normal rate to the prescribed right rudder angle. Maintain the rudder at the ordered angle.
2. When the ship's turning rate has steadied, order " rudder midship"
3. Maintain the rudder at the midship position until the ship shows a steady residual rate of turn.
4. Repeat steps 1, 2 and 3 using "left rudder".

Note: Tests should preferably be conducted in a sea state below 2 or 3. Reliable measurements can not be expected in a sea state beyond 4. The pull-out tests should be performed as a continuation of the turning tests. The pull-out test must be performed using both left and right rudder to show possible asymmetry.

7. STOPPING TEST (CRASH STOP ASTERN AND CRASH AHEAD)

1. Establish steady ahead ship speed at the condition noted in the trial agenda and adjust the ship's heading to a steady course. At a position roughly one ship length before the point where the engine order is initiated, start the data acquisition system.
2. Order "engine astern " at prescribed position noted in the trial agenda (full, half, slow).
3. With rudder at midship, the test will proceed until the ship is stopped dead in the water.

Note: At the end of the ahead stopping test, the test should be repeated with the ship initially moving at an initial steady astern ship speed and using an ahead engine order to stop the ship.

8. STOPPING INERTIA TEST

1. Establish a steady ship speed in accordance with the trial agenda and adjust the ship's heading to a steady course. At a position roughly one ship length before the point where the engine order is initiated, start the acquisition system.
2. Order "engine stop" and move the rudder to either midship or 35° port or starboard.

3. The test will proceed until the ship achieves a defined minimum speed.

Note: When the prescribed rudder angle is "0°" the stopping inertia is named "free stop". When the prescribed rudder angle is "35°", left or right, the stopping inertia is named "IMO stop".

9. NEW COURSE KEEPING TEST

1. Establish a steady ship speed in accordance with the trial agenda and adjust the ship's heading to a steady course. At a position roughly one ship length before the point where the rudder movement is initiated, start the acquisition system.
2. Move the rudder to 15° right, and maintain that rudder angle.
3. When the change of heading reaches 10° starboard from the initial approach heading, quickly move the rudder to 15° left.
4. When the rate of turn reaches 0 degree/sec, return the rudder to midship. This completes the test.
5. Repeat the test using an initial rudder angle of left 15° port. Repeat steps 2 and 3 with the term 'left' and 'right' reversed.
6. Repeat the test using initial rudder angles of 20° and 30° (total of 6 runs).

Note: Move the rudder to the prescribed angle as accurately as possible. Ensure that speed and heading are steady during the approach.

10. MAN-OVERBOARD TEST

1. Establish a steady ship speed in accordance with the trial agenda and adjust the ship's heading to a steady course. At a position roughly one ship length before the point where the rudder movement is initiated, start the acquisition system.
2. Order 35° rudder angle, left or right.
3. When the ship has turned between 20° and 60° from the initial base course, order 35° opposite rudder and hold the rudder until the ship has turned 120° to 150° from the initial approach course.
5. Gradually reduce the rudder angle until the ship's heading is reversed 180° from the initial approach course.

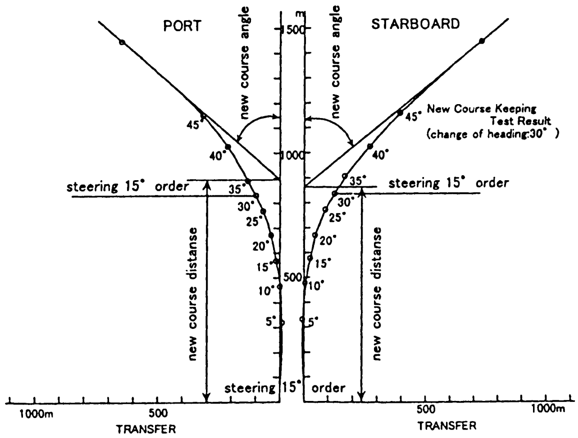

Figure A-6. New Course keeping test

11. PARALLEL COURSE MANEUVER TEST

1. Establish a steady ship speed in accordance with the trial agenda and adjust the ship's heading to a steady course. At a position roughly one ship length before the point where the rudder movement is initiated, start the acquisition system.
2. Order 35° rudder angle
3. When the ship has turned 30°, order 35° opposite rudder and steer the ship to regain the original course.

Note: The maneuver is repeated with the sequence of left and right commands reversed. Additional tests are conducted where the ship will be turned after 60° and at 90° course deviations have been achieved. Further tests may be performed with the rudder angle modified from 35° to 30°, to 25° and so on.

12. INITIAL TURNING TEST

1. Establish a steady ship speed in accordance with the trial agenda and adjust the ship's heading to a steady course. At a position roughly one ship length before the point of steering execution, start the acquisition system.
2. Order the rudder moved in accordance to the values noted in the trial agenda. Once the rudder angle is set, no further adjustment is made, even if the rudder angle achieved deviates to some degree from the desired rudder angle.
3. When the ship has reached a steady turning rate, the test is completed and the ship is made ready for the subsequent test.

Note: The normal rudder angle to be ordered is 10° and 20° for both port and starboard turns. It is desirable that the approach headings for port and starboard turns be the same.

13. Z-MANEUVER TEST AT LOW SPEED

1. Establish a steady ship speed in accordance with the trial agenda and adjust the ship's heading to a steady course. At a position roughly one ship length before the point where the rudder movement is initiated, start the acquisition system.
2. Stop the engine, and let the propeller idle. Order the rudder to be moved to 35° right.
3. When the ship turns to 1° starboard heading, reverse the rudder angle to 35° left.
4. After the ship reverses turning direction and the approach heading reaches 1° port, reverse the rudder angle to right 35°.
5. Repeat steps 3 and 4 until the rudder is no longer effective and the ship does not respond to the rudder. At this point the test is complete.

14. ACCELERATING TURNING TEST

1. Bring the ship to dead in the water with the engine set to "Stop engine". Start the acquisition system.
2. Order the rudder angle prescribed in the trial agenda. Simultaneously order "ahead" at the prescribed engine order. Once the rudder angle is set, no further adjustment is made, even if the rudder angle achieved deviates to some degree from the desired rudder angle.
3. When the change of heading reaches an angle between 540° and 720°, the test is complete.

Note: The normal rudder angle to be ordered is 35° or maximum rudder angle left and right. It is desirable that the approach headings for left and right turns be the same.

15. ACCELERATION/DECELERATION TEST

1. Establish a steady ship speed in accordance with the trial agenda and adjust the ship's heading to a steady course. At a position roughly one ship length before the point where the engine order is initiated, start the acquisition system.

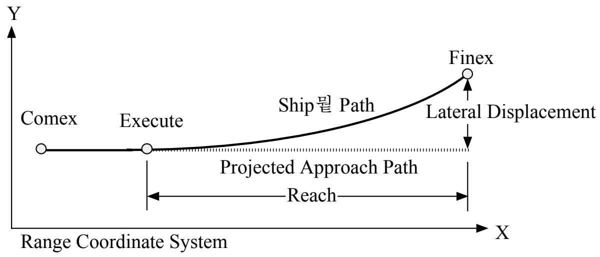

Figure A-7. Acceleration/deceleration test

2. Execute the prescribed engine order.
3. When the ship attains the steady terminal speed stated in the trial agenda, the test is complete.

Note: Use minimal rudder throughout the run to maintain heading. It is desirable to conduct all of the acceleration/deceleration runs from the same initial base heading and general location. The trial agenda details the combination of approach and execute engine orders that should be used in this series of tests.

16. THRUSTER TEST

1. With the ship dead in the water at the heading prescribed in the trial agenda and the engine set to "Stop engine", start the data acquisition.
2. Order the bow thruster(s) to full thrust .
3. When the thruster(s) operate over 10 minutes or the ship's heading reaches 30°, the test is complete. The ship is brought back to a dead in the water condition at the desired heading, in readiness for the subsequent test (reverse bow thruster).

Note: The same procedure is applied using an initial forward speed designated in the trial agenda (starting point being a stable pre

scribed speed). Approach headings for left and right turns should be the same. With the ship in trial ballast condition, it should be noted that reduced thrust may result unless the thruster is properly submerged. The thruster should be submerged so that its axis is at a depth of at least 0.8 times the thruster diameter. Bow thruster tests for dry cargo ships in the trial ballast condition are severely influenced by sea and wind and should be conducted only in protected areas or in the open sea when sea conditions are exceptionally smooth. Refer to Guide for Sea Trials, SNAME (1989) for other special thruster tests using combinations of rudder.

17. MINIMUM REVOLUTION TEST

1. Establish a steady ship speed in accordance with the trial agenda (normally maximum speed in harbor) and adjust the ship's heading to a steady course. At a position roughly one ship length before the point where the rpm is changed, start the acquisition system.

2. Main shaft revolution is gradually decreased until the minimum revolution necessary to keep the engine running smoothly is found.

3. A confirmation run at minimum revolution is carried out for about one minute.

Note: The test should be performed in calm sea conditions. Rudder should be set midships during the confirmation run.

18. CRASH AHEAD TEST

This test is a part of the stopping test whose procedure is described in 7.

APPENDIX III
SUGGESTED PROCEDURE FOR SEAKEEPING TRIALS

1. Once the ship has reached the selected test area, the buoy is launched according to ship internal procedure. The correct reception of the buoy signal is verified.
2. The engine is set to the predefined value stated in the trial agenda and the course is adjusted for a head sea run.
3. Once a steady mean speed is achieved, the data acquisition is started for the desired duration of run noted in the trial agenda.
4. When the run is completed, data acquisition is stopped and the ship's course is

adjusted to the new wave relative direction (see Figure A-8 below).

5. Repeat step 3 and 4 for each successive run indicated in the trial agenda.

Note: When developing the trial agenda, the time between runs should not be underestimated. Ten minutes is not considered unusual. Constant attention must be given to verify that the weather and wave conditions remain relatively constant during the entire sequence of runs.

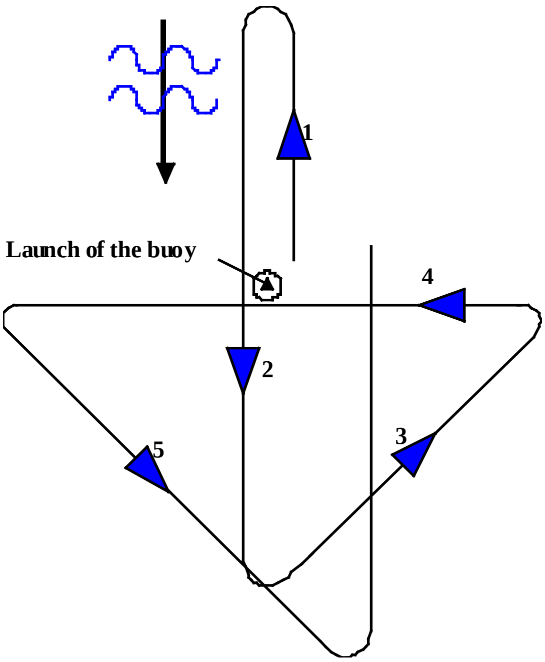

Figure A-8. Typical sketch of runs for an " all headings " evaluation around a wave measurement buoy

The Specialist Committee on Trials and Monitoring

Committee Chair: Dr. Giorgio Lauro (CETENA)
Session Chair: Prof. Robert F. Beck (Univ. of Michigan)

I Discussions

Discussion of Trials and Monitoring Specialist Committee Report

by Mr. Richard J. Stenson, David Taylor Model Basin, Bethesda, Maryland, USA

The Trials and Monitoring Specialist Committee is to be congratulated on compiling this committee report. One of their members resigned early on, and unfortunately, due to a change in employment their chairman was unable to attend a number of their meetings and the final conference. Their efforts to pull together this committee report under these circumstances are most commendable.

As chairman of the 21st ITTC Powering Performance Committee, which produced the Guide for Speed/Power Trials, discussed in this report, and having chaired the special session on Onboard Monitoring of the 20th ITTC, the report of this committee is of special interest to me.

The tasks assigned to this committee were in my opinion too numerous to enable all of them to be addressed in sufficient detail, given the limited time available combined with the reduced committee membership. It is therefore not surprising to me that the committee appears to have concentrated their efforts on the first task assigned, Speed/Power Trials, somewhat to the detriment of the remaining tasks, Onboard Monitoring, Use of the Global Positioning System, and Maneuvering and Seakeeping Trials. In my opinion however, this was probably appropriate, as the PPC's Guide for Speed/Power Trials resulted in considerable discussion and controversy during the 21st ITTC.

The committee report references the International Standards Organization document ISO/CD 15016, "Guidelines for the Assessment of Speed and Power Performance by Analysis of Speed Trial Data". I note that one of the members of the Trials and Monitoring Committee is the project leader for the working group preparing this ISO Guideline. In addition, the committee in one of its meetings took the opportunity to meet with Japanese ship owners representatives and shipyard personnel concerned with the conduct of Speed/Power Trials. I myself participated in the working group meeting reviewing the ISO Guideline as the U.S. delegate. It is encouraging to me to see the interchange of ideas and the cooperation between these two international organizations.

It is my opinion that the two documents, the ITTC "Guide for Speed/Power Trials", and the ISO "Guidelines for the Assessment of Speed and Power Performance by Analysis of Speed Trial Data", are mutually supportive. The trial analysis Guideline picks up where the Guide for the conduct of trials leaves off. The Guide produced by the ITTC, a scientific body, is appropriately rigorous in its recommendations as to the conduct of the trial, including ship preparation, trial site selection criteria, and instrumentation selection and calibration. The Guide is intended to produce accurate trial results requiring minimum corrections in order to enable correlation with model test data obtained in the tow tank. The ISO Guideline on the other hand provides a means to analyze and correct data that may have been obtained in less than ideal conditions. As it is somewhat less rigorous in its criteria for trial conduct, it includes a detailed example of how to correct trial data for known deficiencies.

I was pleased to see that the recommendation of the Specialist Committee is to not revise the Guide for Speed/Power Trials at this time. It is hoped that the newly formed 23rd ITTC Specialist Committee, which will address only Speed/Power Trials, will be able to convert the present guide into a procedure which complies with ISO 9000 requirements. This procedure can then be used by ITTC member organizations for the conduct of these important trials used for correlation purposes. For trials where all of these rigorous criteria cannot be meet, the ISO Guideline will provide appropriate correction procedures to be used in the analysis of the trial data.

In regards to the other task areas of the committee report, there is lots of work still to be done. The use of the Global Positioning System along with advances in onboard data collection and analysis by use of high speed computers is definitely the trend, as pointed out by the committee. In the area of maneuvering trials, reference is made to International Maritime Organization (IMO) procedures, Society of Naval Architects and Marine Engineers (SNAME) Trial Codes, and others. I am encouraged to see this work assigned to the Maneuvering Committee of the 23rd ITTC to develop procedures compliant with ISO 9000. I would encourage the Maneuvering Committee to make contact with ISO TC 8 SC 9, which has a newly established working group on Trials in General.

In summary, I again congratulate the committee, and applaud them and their ISO counterparts on their cooperative efforts.

Comments on the Report of the Specialist Committee on Trial and Monitoring

by Prof. Dr. Eng. Kinya Tamura, Nagasaki Institute of Applied Science, Japan

First of all, I would like to express my sincere appreciation to the members of the Specialist Committee for their effort and achievement.

As stated in the committee report, the SC was established at the 21st ITTC in order to "recommend updated procedures for conducting full-scale trials and so forth". This came from the fact that several discussions were made to criticize "the Guidelines for conducting Speed/Powering Trials" presented by the Powering Performance Committee to the 21st ITTC and that its modification would be necessary.

Following the task assigned by the 21st ITTC, the present SC has made a tremendous effort and its results are completed in Chapter 4 of the committee report. I appreciate it very much and would like to propose to the SC that item 1 of the recommendations to the Conference should be replaced as:

"The Committee recommends that the chapter 4 of the committee report is to be tentatively used as guidelines for conducting Speed/Powering trials until finally settled."

Secondly, it is stated in 4.10 of the committee report that the present SC did not examine all procedures to ascertain if the correction due to environment are reliable and/or applicable. I am afraid this decision may bring a shortcoming to the report, because the correction due to environment, including tidal effect, is a very useful and practical means to obtain good quality speed trial results, if it is applied properly.

I would like to point out that reference [A], which was already presented to the SC, should be a useful guide for this examination.

Reference [A] is as follows: Tamura, K., "An Appraisal of Correction Methods of Wind and Tidal Effect on Speed Trial Results of a Ship", The West Japan Society of Naval Architects No. 97, 1999.

Written Contribution to the Report of Specialist Committee on Trials and Monitoring

by Drs. Mitsuhiro Abe and Masayoshi Hirano, Akishima Laboratories (Mitsui Zosen) Inc., Tokyo Japan

We highly appreciate that the Specialist Committee on Trials and Monitoring (TMC) has completed a fine report. Update Guide for Speed/Powering Trials (ITTC Procedure 4-9-03-03-01.3) proposed by the 21st ITTC Powering Performance Committee (PPC) has been well reviewed and useful descriptions to refine this Guide are given in the report, although a revised Guide for Speed/Powering Trials itself is not presented. We have submitted some comments, which are fundamentally similar to our previous discussion to the 21st PPC (M. Abe and M. Hirano: “On an Update Guide for Speed/Powering Trials”, 21st ITTC Proceedings, Vol.2, pp.95-96), to improve the above-indicated Guide (by 21st PPC) to 22nd TMC through Advisory Council activities, and we understand that our comments are basically reflected in the TMC report. A revised Guide for Speed/Powering Trials and Analysis is needed based on the 22nd TMC report and further discussions.

In this context, we would like to strongly request that such a revised Guide noted above and which can be applied to a practical use, especially for commercial ships, be developed and established in earlier time through future ITTC activities.

Comments on the Report of the Specialist Committee on Trial and Monitoring

by Mr. Naoji Toki and Dr. Tetsuji Hoshino, Nagasaki Experimental Tank, Nagasaki R&D Center, MHI, Japan

We would like to express our sincere appreciation to the members of the Trial & Monitoring Specialist Committee for their effort to revise the "Guidelines for conducting Speed/Powering trials" recommended by the 21st ITTC Powering Performance Committee.

As pointed out by many people, the guidelines for speed/powering trials presented at the 21st ITTC has too much emphasis on the scientific trial in ideal conditions. On the other hand, the guidelines updated by the present Specialist Committee are more practical by introducing the corrections due to environment, such as wind, waves and so on, which we have to expect inevitably to encounter, especially during the commercial acceptance trials. We hope the majority of the delegates will appreciate this significant improvement.

However, the committee report still recommends that 21st ITTC guidelines continue to be used until modified. We wonder why. The improved guidelines should be used, although there may still remain several points of discussion, like the one shown in the following. For such points, discussions can be continued and the guidelines may be modified.

Although the Specialist Committee report doesn't refer to the correction due to current and tide, we cannot agree with this point. The current including the tidal effect is considered to vary like a sinusoidal curve with period of about 12 hours. When the interval is long (one or two hours) between the reciprocal runs, the current effect may not be ignored. The correction should be made in order to obtain reliable data as shown by Taniguchi and Tamura. We consider that "Correction due to current and tide" should be added in the report at "4.10 Corrections Due to Environment".

The SC report recommends that "Trial data uncertainty analysis should be carried out to assess the level of confidence in the trial results and to provide the statistics associated with ship trial measurements." However, we consider the following statement is more appropriate as a recommendation for the present. Because we do not necessarily have enough experience of the analysis, we think it is too early to impose the application of the analysis to commercial acceptance trials.

"It is desirable that trial data uncertainty analysis is carried out to collect the statistics data associated with ship trial measurements, and to assess the level of confidence in the trial results."

New ISO/CD 15016 Example

by Prof. Michael Schmiechen, Germany

With great interest the discussor has read the sections on Speed Trials in the Report of the Specialist Committee on Trials and Monitoring. In view of his involvement in the discussion of the Japanese ISO/CD (Committee Draft) 15016, the discussor feels that most of the discussions on the fundamental problems in Section 4 remain very vague, maybe too vague for practical applications, and concerning these matters they are not up-to-date.

The SC only mentions the problem of determining the current velocity, which has been discussed at great length without mentioning the rational procedure proposed by the discussor. The propeller performance in the behind condition, i. e. in the full-scale wake (!), and the current velocity can be identified simultaneously by solving one set of linear equations. After the 'calibration' the propeller power characteristic in the behind condition can be used for monitoring purposes, e. g. to determine the value of current velocity from measured values of the rate of revolution and the torque.

The discussor fully endorses Recommendation 5 to the Conference concerning the recording of 'time histories'. Even if runs are considered stationary, sound performance and confidence analyses have to be based on instantaneous values of the data. It needs to be stated that many problems in the evaluation of trials are due to waiting for steady conditions and using ill-defined average values. In the METEOR and CORSAIR trials, quasi-steady test maneuvers have been shown to be much superior to steady testing, providing not only much more information, but at the same time the necessary references for the suppression of the omnipresent noise, even at service conditions in heavy weather.

The statements of the Specialist Committee concerning the ISO/CD 15016 in Section 9 of their final report are extremely short, particularly in view of the fact that on 1999.07.29 the secretariat of ISO/TC8/SC9 at JSMA (Japan Marine Standards Association) circulated a revised version of ISO/CD 15016 to be voted on by P-members.

The discussor would like to know the opinion of the Specialist Committee on Trials and Monitoring concerning the course of action to be taken by the ITTC in view of the responsibilities of its member organizations. The opinions expressed in the Conclusions and Recommendations are more than unsatisfactory!

The discussor is surprised at Conclusion 2 which leaves the evaluation of speed trials to ISO/TC8/SC9/WG2, particularly in view of the inconsistency of the procedure proposed so far; and concerning the Recommendation 1 for Future Work requiring the Specialist Committee to be continued, even though it will not actively contribute to work of the ISO/TC8/SC9/WG2.

Written Contributions to the Report of Trials & Monitoring Committee

by Dr. Mohammad Saeed Seif, Technology Cooperation Office, Tehran, Iran

I appreciate the work of the committee and would like to comment on the seakeeping trials.

Since the real condition of the sea waves are often short crested waves & irregular, we need more detailed procedures & recommendations for such seakeeping trials. Besides the methods for data analysis is very important and should be included in the recommendations.

I think the committee agrees that without solving the above-mentioned problems, we can not get ahead.

Written Contributions to the Report of Trials & Monitoring Committee

by Dr. Gerhard Strasser,
Schiffbautechnische Versuchsanstalt, Wien, Austria

The report and the oral presentation are not in agreement. There are suggested procedures for speed and power trials and suggested procedures for maneuvering trials in Appendix I and II, respectively (pp 497-505) whereas now the SC does not suggest any procedure.

In the recommended procedure 4.9-03-03-1.3, there is a graph describing the speed runs, which obviously is not quite correct. This graph has been presented in the oral presentation in the correct form. I therefore suggest that the graph from the oral presentation be used to replace the graph in the existing procedure.

The recommended maneuvers are described quite well. However, there are some graphs (especially the Z-maneuver) where the definitions of the different measured values are missing. On top of this, it is not explained what has to be measured. In the oral presentation the "time" measurement has been forgotten.

The SC can not delegate the decision of whether enough data has been collected to the captain (master) of the ship. This decision must be made by the Trials Director (or the person who has to evaluate the results), who is in charge. Nowadays a preliminary onboard evaluation of data is usual and common practice in the field of commercial ships.

II Committee Replies

Reply of ITTC Specialist Committee on Trials and Monitoring to Mr. Stenson

The Trials and Monitoring Specialist Committee would like to thank Mr. Richard J. Stenson of the David Taylor Model Basin for his kind remarks regarding our committee report. As noted, the tasks assigned to our committee were comprehensive and the viewpoints, experiences, and opinions of the committee members were quite varied. This wealth of experience and perspectives enabled us to better consider the needs of the scientific research and development community, the shipbuilding industry and the ship owners. However, this was to the detriment of creating definitive guidelines for conducting ship trials, determining an ideal performance monitoring system, and doing a thorough study of the Global Positioning System suitability for ship trials work. Hence the committee concentrated its efforts in the conduct of the ship trials. The focus was on defining the necessary requirements, conditions, and processes needed to obtain ship trials data using a consistent uniform approach. This would increase the level of confidence in the quality of the trials data while decreasing variability. This would also simplify the task of analyzing and reducing the data to meet contract requirements and adding to the database of trials knowledge.

We were fortunate in that one of our committee members was instrumental in the preparation of the International Standards Organization document ISO/CD 15016, "Guidelines for the Assessment of Speed and Power Performance by Analysis of Speed Trials Data" draft. Our committee agrees with Mr. Stenson's assessment that the work of both committees is mutually supportive. The efforts of the ISO committee takes the next logical step forward in reducing the trials data to a format useful for determining the fulfillment of contract requirements and increasing the understanding of ship response when operating under different conditions. We feel that the work of the 23rd ITTC Speed and Powering Trials Specialist Committee will be enhanced through continued contact with its ISO committee counterpart.

At this point in time, the committee felt that it was inappropriate to revise the Guide for Speed/Power Trials developed by the 21st ITTC Powering Performance Committee. It was the belief of the committee that once our report was issued, other members of ITTC should be given an opportunity to comment upon our recommendations. The future forum for these remarks should be the 23rd ITTC Speed and Powering Trials Specialist Committee and the Maneuvering Committee. Guidelines should not be changed every three years just for the sake of change. Changes should be made after considering and understanding the sensibilities and concerns of those who have to use the guideline. The committee believes that the recommendations presented were made in this spirit and based upon the extensive trials experience of the committee members. However, others may also wish to contribute and their opinions should be considered.

In summary, the committee would like to thank Mr. Stenson for his insightful comments and his clear vision for the future work of the 23rd ITTC.

Reply of ITTC Specialist Committee on Trials and Monitoring to Prof. Dr. Eng. Kinya Tamura

The SC is grateful to Dr. Tamura for pointing out an obvious omission in Section 4.10 of the SC report. We agree that the correction for wind and tidal effect should be included in this section. This issue was touched upon in Section 4.3 where the SC recommended conducting a low speed circle to determine global drift but was not specifically mentioned in Section 4.10. The reference provided by him should also be included in the Reference section of the SC report.

The SC would like to thank Dr. Tamura for his vote of confidence in our work as evidenced in his proposal to use Chapter 4 of the SC report as the tentative guideline for conducting Speed/Powering Trials. Our suggestions should certainly be used on a trial basis. After many organizations test them, they should provide feedback to the 23rd ITTC Speed and Powering Trials SC for incorporation into the definitive guideline. If our suggestions prove to be less than practical, it is better that this situation occurs before it becomes and official guideline. A guideline or standard that has many mistakes loses its credibility.

Reply of ITTC Specialist Committee on Trials and Monitoring to Drs. Mitsuhiro Abe and Masayoshi Hirano

The SC would like to thank Dr. Abe and Dr. Hirano for their very kind comments All concerned agree with their remarks that the 21st ITTC Guideline for Speed/Powering Trials needs to be revised. However, the SC believes that ITTC must move slowly to achieve consensus when creating guides/standards. If standards are changed frequently, they lose their credibility. Again, we request that the members of the Conference provide their comments to the 23rd ITTC Speed and Powering Trials SC so that the future revised guide developed by the new SC truly becomes a definitive guide that is used by all. The SC believes that it would be prudent to start implementing the procedures and recommendations suggested in our report at this time. This is a dynamic process. Feedback from those who implement our suggestions should be given to the new SC so that the final guide will have the advantage of being field tested before it goes into publication as an ITTC guideline. The SC thanks you for your perceptive comments.

Reply of ITTC Specialist Committee on Trials and Monitoring to Mr. Naoji Toki and Dr. Tetsuji Hoshino

The SC is grateful for the insightful comments provided to us by Mr. Toki and Dr. Hoshino. The SC hoped to strike a balance between the needs of the scientific community, ship owners and ship builders in developing our suggested trial procedures. As mentioned in the oral presentation, the SC felt that it was of paramount importance to adequately describe the ship being tested and the site where the test are being conducted. Then it was important to standardize the procedure to conduct the trial. The SC was deliberately vague in recommending a single procedure to correct for the effects of environment and ship condition. We did not want to miss the opportunity to acquire consensus when creating a new guide for speed/power trials or any other trials for that matter. (see SC reply to Mr. Stenson and Drs. Abe and Hirano). By creating a new guide without achieving a sense of ownership in the process, a guide created by this SC would be doomed to failure. How many organizations are using the 21st ITTC Powering Performance Committee Guidelines for Conducting Speed/Powering Trials at this time?

The discussors are absolutely correct in bringing to the SC's attention the glaring omission of "correction due to current and tide" in section 4.10 of the SC report. Please refer to the SC reply to Prof. Tamura on this issue.

In response to the discussors comment regarding uncertainty analysis of commercial acceptance trials data, the SC feels that it would be advantageous to apply these techniques as soon as possible. Firstly, it should be done as a matter of pride of workmanship. How does one know if the data obtained is truly good and acceptable? What is acceptable? Secondly, in these litigious times, a smart lawyer can find the means to void or change a contract and ultimately cost a ship builder and ship owner more money (the lawyer always gets the bulk of the settlement). The best way to do this is to cast aspersions upon the validity of the trials data. Our professionals should take back control of our industry from the lawyers. We should take steps to build a mutual trust between ship builders, ship owners and the R & D community. The SC has provided references that can assist an organization in conducting uncertainty analyses in our report. Even if an organization does not have a past history of conducting uncertainty analyses, it must start somewhere. Why not start today?

The SC greatly appreciates the kind suggestions and genuine concern of the discussors for the need to be thorough and create the most useful set of ship trials procedures possible.

Reply of ITTC Specialist Committee on Trials and Monitoring to Prof. Michael Schmiechen

The SC thanks Prof. Schmiechen for his contribution. The SC is of the opinion that the success of trial tests depends on a standardized procedure for conducting trials. This requires the proper documentation of the ship and propeller condition being tested as well as the detailed documentation of the trial site conditions. A reliable evaluation of the test data is possible only with carefully acquired and documented test data. Therefore, the SC concentrated on determining what needed to be documented in order to create a sound scientific basis from which corrections could be made to account for environmental and ship conditions. This increases the confidence level in the trials data and ultimately the reported conclusions describing the ship and/or propeller performance. Section 4 of the SC final report summarizes the minimum, but necessary effort, needed to get the information required to achieve this goal. The SC did not define a definitive method to evaluate trials data. However, many means of doing so were gathered and documented in the Reference section of the SC final report. There was no time to properly evaluate all of the existing methods or of the work being done by the ISO TC8 group. As recommended by the SC, this should be one of the tasks of the 23rd ITTC Speed and Powering Trials SC.

The SC does not agree with all of the statements in Prof. Schmiechen's contribution and is not able to evaluate the mentioned 'superiority of the rational method' proposed. This should be left to a wider circle of experts.

The discussor's proposal to acquire all data continuously during the different maneuvering trials is commendable and is in agreement with the SC. The SC did not thoroughly review the current methods used to correct maneuvering and seakeeping trials data and hence is not in a position to fully develop and use all of the interesting information.

As in any guideline or standard, credibility must first be established before widespread use occurs. Feedback should be obtained and compared with other methods of acquisition and analysis prior to the proclamation of a new standard. In order for a standard to be considered definitive (universal use), a great majority of the existing organizations should utilize it. This will not happen unless many organizations utilize the proposed standard and comment on its strong and weak points. The draft standard should be a dynamic one with constant feedback being obtained from ITTC Conference members as well as outside organizations. Hopefully, at the end of the next three years, the 23rd ITTC Speed and Powering Trials SC will produce a definitive standard that is agreed upon by most organizations and used by most organizations. A unilaterally proclaimed "standard" tends to be only used by the parties promulgating it and no one else. The SC did not want to go down this road and hence recommended the continuance of the existing 21st ITTC Guidelines for Conducting Speed/Powering Trials.

It should be noted that the ISO/TC8/SC9/WG2 standard for evaluating Speed/Powering trials and specifically the correction for the effect of environmental and ship conditions is currently in the "achieving consensus" stage. One of our SC members served on the ISO/TC8 Work Group and provided the SC input to the ISO/TC8 work group. The SC emphasis was in standardizing the conduct of trials and documenting the ship and trial site conditions. Our contribution to the ISO/TC8 group was to provide a list of references on how to conduct the trial and how to analyze the trial data. The ISO/TC8 group has used many of our recommendations on trial conduct and the SC is certain that they have considered many of the analysis methods that we brought to their attention.

The SC is grateful for Prof. Schmiechen's comments and is thankful for the opportunity to again clarify the interaction between ITTC and ISO/TC8/SC9/WG2. We again encourage all ITTC Conference members to provide the 23rd ITTC Speed and Powering Trials SC with the vital feedback necessary to develop a truly definitive trials guideline for conducting Speed and Powering Trials. Information on Maneuvering Trials should be forwarded to the 23rd ITTC Maneuvering Committee.

Reply of ITTC Specialist Committee on Trials and Monitoring to Prof. Mohammad Saeed Seif

Due to the limited time, the SC concentrated its efforts on refining the Speed/Power Trials conduct and identifying/ highlighting the many trial data correction methods currently in use. This was done at the expense of the Maneuvering and Seakeeping Trials. The SC is in agreement with Prof. Seif's discerning comments. We thank him for specifically identifying some of the difficulties involved in developing more detailed trial conduct procedures as well as touching upon the need to include methods for data analysis in any future seakeeping trials work.

Reply of ITTC Specialist Committee on Trials and Monitoring to Dr. Gerhard Strasser

The SC thanks Dr. Strasser for his helpful suggestions. The SC believes that the procedures detailed in the appendices of the SC's final report be reviewed and unofficially utilized by members of the Conference over the next three years. As the procedures are utilized in conjunction with the existing guidelines introduced by the 21st ITTC Powering Performance Committee, they should be refined and officially introduced as ITTC guidelines by the 23rd ITTC Speed and Powering Trials SC. In lieu of introducing an official guideline without achieving consensus among all interested parties, the SC counsels patience. We want the guideline that is finally introduced to have scientific and practical credibility as well as to be used universally

The SC agrees that Figure A-1, Speed/ power maneuver, shown in Appendix I is not quite correct and this is reflected in the corrected figure presented in the oral presentation of the final report. In addition, an explanation regarding the length of the run should also be added. The 5 to 10 minutes indicated on the original figure may be misleading. This explanation should indicate that the length of the run is dependent upon the trial director's discretion. The trial director should be aware of or involved in the trial data analysis and hence be cognizant of the minimum trials data requirements.

As pointed out by Dr. Strasser and mentioned by the SC during the oral presentation, the graph of the Z-maneuver is incorrect. The definitions of the overshoot heading angles and overshoot times are incorrectly depicted in Appendix II Figure A-3. The correct figure was presented at the oral presentation of the final report. Important measurements were identified but were not specifically shown in the figure. The corrected figure with the appropriate measured values should be included in the errata for Volume 3 of the 22nd ITTC Proceedings.

The SC would like to thank Dr. Strasser for his great attention to detail and for his contribution.

III Errata

The Trials and Monitoring Specialist Committee would like to amend and correct its report.

In Volume II of the Proceedings of the 22nd ITTC, the measurement of time was inadvertently left off the list of recommended measurements. Even though it was implied that this measurement was to be obtained, it is more consistent with the final report content if this measurement is specifically identified.

The time measurement should be added to Section 4.5 Measurement Taken During Speed/Power Trials (p. 470 list of primary measurements), Section 4.6 Acquisition Systems (p. 474 list of minimum data acquisition capabilities), Table 4 Recommended Maneuvering Trial Measurements (p. 484) and Section 6.7 Data Collection and Instrumentation (p. 486 list of primary measurements).

Section 4.10 Corrections Due to Environment (p. 477) should be amended so that the list of environmental corrections includes a correction for wind and tidal effect.

On page 496 of the Reference List, the following reference should be added. Tamura, K., “An Appraisal of Correction Methods of Wind and Tidal Effect on Speed Trial Results of a Ship”, The West Japan Society of Naval Architects No. 97, 1999.

Figure A-1 on page 498 in Appendix I Suggested Procedure for Speed/Power Trials has been modified and appears as follows.

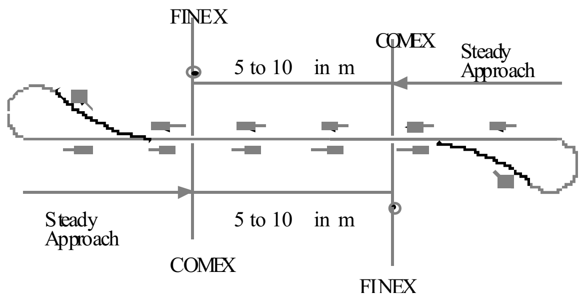

Figure A-1. Path of ship during typical speed/power maneuver.

It should also be noted that the 5 to 10 minutes shown in the figure representing the portion of the run where steady state data should be taken is only a suggestion. This time frame was determined based upon the experiences of SC members during full-scale trials and corresponds to ships of different lengths and speed capabilities. The actual time is dependent upon the Trial Director’s discretion. His decision should be based upon the needs identified in the trials agenda, the amount of scatter in the data, and whether enough data has been collected to conduct a satisfactory uncertainty analysis.

The SC would also like to correct Figure A-3 appearing on page 499 of Appendix II Suggested Procedures for Maneuvering Trials. The definitions for overshoot angle and heading are incorrectly labeled in the original figure.

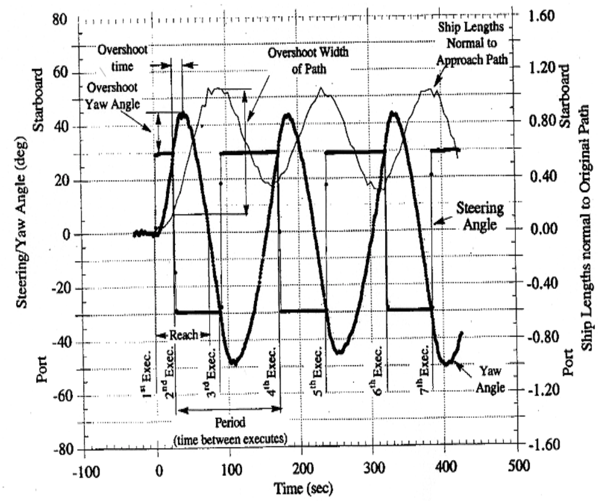

Figure A-3. Z-maneuver test