ITTC Quality System Manual

Recommended Procedures and Guidelines

Procedure

Full Scale Manoeuvring Trials

7.5	Process Control
7.5-04	Full Scale Measurements
7.5-04-02	Manoeuvrability
7.5-04-02-01	Full Scale Manoeuvring Trials

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Table of contents

Full Scale Manoeuvring Trials

1. PURPOSE OF PROCEDURE

To provide a guideline for performing full scale trials to determine ship manoeuvring characteristics as a reaction to rudder and engine actions.

2. RECOMMENDED PROCEDURES FOR MANOEUVRING TRIALS

For operation purpose, tests must concern following qualities which have been identified by IMO:

inherent dynamic stability,
course- keeping ability,
initial turning/course-changing ability,
yaw checking ability,
turning ability,
stopping ability.

Table 1 shows a total of 19 manoeuvring tests recommended by various organisations. This procedure provides detailed information on a selection of 14 tests which provide information on above mentioned six ship-handling characteristics.

- Furthermore, recommendations are formulated for operation purposes, including low speed operation in channels and harbour environments.
- Test procedures should document trials in a way which is compatible with both ship design and scientific purpose (e.g. validation of predicted manoeuvres).

2.1 Trial Conditions

2.1.1 Environmental Restrictions

Manoeuvrability of a ship is strongly affected by interactions with the bottom, banks, passing vessels, wind and waves. Therefore the trial site should be located in waters of adequate depth with low current and tidal influence as possible, and manoeuvring trials should be performed in the calmest possible weather conditions. It is recommended that

1. the test must be executed in open water, far away from banks and ship traffic;
2. the water depth should exceed four times the mean draft of the ship;
3. the maximum sea state should be chosen taking into account the ship's characteristics such as ship speed, ship displacement, etc. Although IMO Resolution MSC.137(76) requires trials to be conducted with a sea state not greater than 4, some ships may require sea states as low as 1 in order to provide accurate full scale data;
4. the maximum wind speed should be chosen taking into account the ship's characteristics such as ship speed, ship displacement, accurate full scale data. Although IMO Resolution MSC.137(76) requires trials not to be conducted with a true wind speed greater than Beaufort 5, some ships may require wind speeds not exceeding Beaufort 2 in order to provide accurate full scale data.

Table 1: Recommended Manoeuvring Tests by various Organizations

Type of test		IMO A601	IMO MSC.137(76)	ITTC 1975	SNAME 1989	Norse Standard	Japan RR	ISO	ITTC 2017	Re-marks (*)
1	Turning circle test	√	√	√	√	√	√	√	√	5
2	Zig-zag test	√	√	√	√	√	√	√	√	3,4
3	Modified Zig-zag test	-	-	-	-	-	√	-	√	1,3
4	Zig-zag at low speed test	-			√		√		√	1,2
5	Direct spiral test	-	-	√	√	√	√	√	√	1,2
6	Reverse spiral test	-	-	√	√	√	√	√	√	1,2
7	Pull-out test	√	-	√	√	-	-	√	√	1
8	Stopping test (from ahead)	√	√	√	√	√	√	√	√	6
9	Stopping inertia test	√	-	-	-	√	√	√	√	6
10	Man-overboard test	√	-	-	-	-	-	√	√	4,5
11	Parallel course manoeuvre test	√	-	-	-	-	-	√	√	4,5
12	Initial turning test	√	-	-	√	-	-	-	√	3
13	Accelerating turning test	√	-	√	-	-	-	√	√	5
14	Thruster test	√	-	√	√	√	-	√	√	4,5
15	Crabbing test	-	-	-	-	-	-	√	√	3
16	New course keeping test	-					√			
17	Acceleration/deceleration test	√						√		
18	Crash stop ahead test (from asten)	-			√	√	√			
19	Minimum revolution test	√			√	√				

(*) 1 inherent dynamic stability
2 course-keeping ability
3 initial turning/course-changing ability
4 yaw checking ability
5 turning ability
6 stopping ability

2.1.2 Loading Conditions

It is recommended that the trials are to be carried out with the ship in the full-load condition at zero trim, because in this condition the manoeuvres are most critical, or in a normal operational condition within a five percent deviation of the full-load draft and trim.

Where it is impractical to conduct trials at full-load draft, they may be conducted at a draft as close to full-load draft as possible with minimum trim, or in a ballast condition with minimum trim and sufficient propeller immersion.

2.1.3 Approach Conditions

The approach speed according to IMO is to be at least 90 per cent of the ship's speed corresponding to 85 per cent of the maximum engine output, but some tests should also be carried out at low speed (below 8 knots).

Before the execution of the relevant manoeuvre, the ship must have run at constant engine(s) setting with minimum rate of change of heading (steady course) for at least two minutes. The helmsman must be advised to keep heading with minimum rudder actuations.

2.2 Test procedures and parameters to be obtained

2.2.1 Turning Circle Test

Turning circle tests are performed to both port and starboard at approach speed with a maximum rudder angle. It is necessary to do a turning circle of at least 540 degrees to determine the main parameters of this trial.

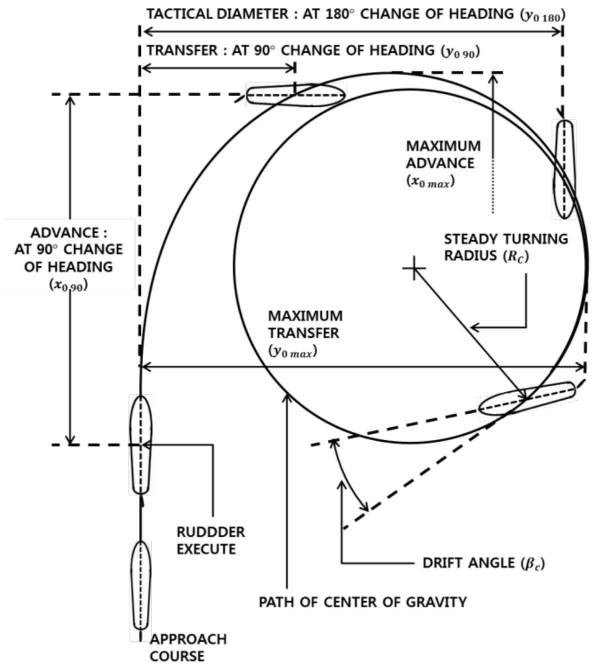

Fig. 1 Turning circle: definitions

The essential information referred to the midship to be obtained from this manoeuvre consists of (see Figure 1):

- tactical diameter,
- advance,
- transfer,
- loss of speed on steady turn,
- velocity loss and time to change heading 90 degrees
- velocity loss and time to change heading 180 degrees
- velocity loss and time to change heading 270 degrees

The first three of these may be presented in non-dimensional form by dividing their values by ship's length between perpendiculars (L_{PP}). Maximum advance and maximum transfer can be measured, too.

When it is possible, turning circle at low or half speed should be considered.

2.2.2 Zig-zag Test (Z-Manoeuvre)

The zig-zag test is obtained by reversing the rudder alternately by δ degrees to either side at a deviation ψ from the initial course. After a steady approach the rudder is put over to starboard (first execute). When the heading is ψ degrees off the initial course, the rudder is reversed to the same angle to port (second execute).

After counter rudder has been applied, the ship initially continues yawing in the original direction with decreasing yaw rate until it changes sign, so that the ship eventually yaws to the left in response to the rudder. When the heading is ψ degrees off the course port, the rudder is reversed again to starboard (third execute). This process continues until a total of 3 rudder executes have been completed.

Hence, a zig-zag test is determined by the combination of the values of change of heading Ψ and rudder angle, and is denoted δ/ψ. Common values for these parameters are 10/10 and 20/20. However, other combinations can be applied (see 2.2.3).

The manoeuvres are to be executed at approach speed (see 2.1.3) and if possible at low speed also.

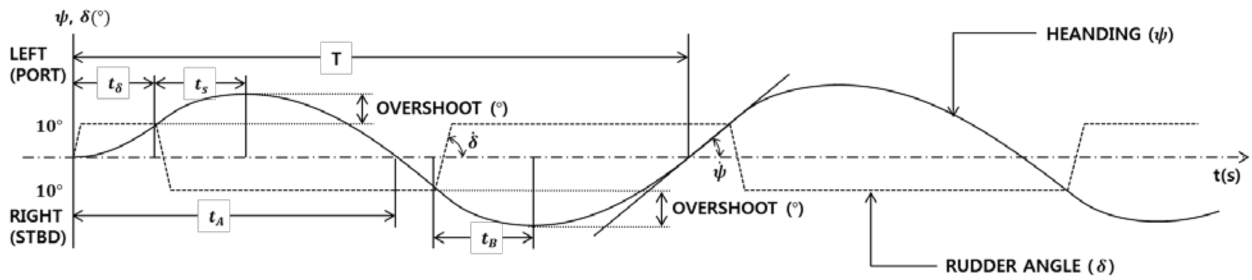

Figure 2. Time trace of zig-zag test parameters

Zig-zag manoeuvres are carried out starting with both starboard and port rudder, in order to identify the environmental effects (e.g. wind). From the nautical point of view, however, i.e. the interpretation of the international rules of navigation at sea, the turning and the yaw checking ability using starboard rudder angles δ are of special interest, since emergency turns should be carried out to starboard.

For a first simple analysis of the results, characteristic steering values defined in Fig. 2 can be used; the values are plotted as a function of the rudder angle δ.

Results of zig-zag tests are defined as follows**:**

Initial turning time t_a (s): the time from the instant the rudder is put at the outset of the manoeuvre (first execute) until the heading is ψ degrees off the initial course. At this instant the rudder is reversed to the opposite side (second execute).

Execute heading angle (degrees): heading ψ at which the rudder is reversed.

Overshoot angle (degrees): the angle through which the ship continues to turn in the original direction after the application of counter rudder. The first and second overshoot angles correspond to the maximum heading angle reached after the second and third execute, respectively.

Time to check yaw (t_S, t_B) (s): the time between the rudder execute and the time of the maximum heading change in the original direction.

Heading ψ (degrees): the course deviation from the straight initial course.

Reach t_A (s): the time between the first execute and the instant when the ship's heading is zero after the second execute.

Time of a complete cycle T (s): the time between the first execute and the instant when the ship's heading is zero after the third execute.

Angular speed $\dot{\psi}$(deg/s): constant yaw rate (time gradient of heading) established after the second execute. In this phase the ship executes circular motion, if steady speed is assumed.

Unit time (s): the time required for the vessel to travel her own length at approach speed (= L/V). The time for a complete cycle is expressed in unit times.

2.2.3 Modified Zig-zag test

The test procedure for a modified zig-zag test is the same as for 2.2.2. (zig-zag manoeuvre), but the execute heading angle is chosen to be as small as 1 degree, the rudder angle being 5 or 10 degrees (see section 4 of IMO MSC/Circ.1053 for modified zig-zag manoeuvres definitions).

The modified Zig-zag test is used to express course-keeping qualities in conditions similar to actual operations characterised by small heading changes and rudder values.

2.2.4 Zig-zag test at Low Speed

This manoeuvre is executed while the ship is running ahead by inertia after stopping the main engine. When the ship's speed drops below 5 knots, a 35/5 zig-zag test is initiated. The above procedure to be repeated until the ship's heading does not react to the rudder actions.

2.2.5 Spiral Manoeuvre

Spiral manoeuvres are applied to assess the course stability of the ship (see Figure 3). For ships, which show stable characteristics either the direct (Dieudonné) or reverse (Bech) spiral methods can be used to obtain response at low rudder angles. For unstable ships, the reverse (Bech) spiral is recommended within the limits indicated by the results of the pull-out manoeuvres.

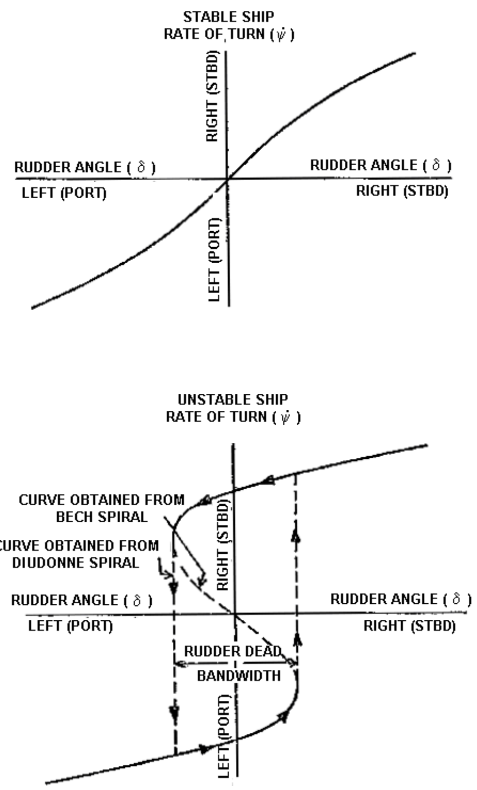

Figure 3: Presentation of spiral manoeuvre results

Direct Spiral Manoeuvre. With the ship on an initial straight course, the rudder is put to about 25 degrees to starboard and held until the rate of change of heading is constant. The rudder angle is then decreased by 5 degrees and again held until steady conditions of yawing have been obtained. This procedure is repeated until the rudder has covered the range from 25 degrees on one side to 25 degrees on the other side and back again. Over the range of rudder angles of 5 degrees on either side of zero or neutral rudder angle these intervals should be reduced.

The achieved steady rate of turn is registered for each rudder angle.

<u>Reverse Spiral Manoeuvre</u>. In the Bech reverse spiral the ship is steered at a constant rate of turn and the mean rudder angle required to produce this yaw rate is measured.

The necessary equipment is a rate-gyro (alternatively the gyro compass course Ψ may be differentiated to provide $\dot{\Psi}$), and an accurate rudder angle indicator. Experience has shown that accuracy can be improved if continuous recording of rate of turn and rudder angle is available for the analysis.

When several spiral tests are to be made, an auto-pilot can be used to perform the reverse spiral.

If manual steering is used, the instantaneous rate of turn must be visually displayed for the helmsman, either on a recorder or on a rate of turn indicator.

Using the reverse spiral test, points on the curve rate of turn versus rudder angle may be taken in any order. However, if the ship is steered manually, the procedure originally proposed by Bech can be recommended. The ship is made to approach the desired rate of turn, $\dot{\Psi}$, by applying a moderate rudder angle. As soon as the desired rate of turn is obtained, the rudder is actuated such as to maintain this rate of turn as precisely as possible. The helmsman should now aim to maintain the desired rate of turn using progressively decreasing rudder motions until steady values of speed and rate of turn have been obtained. Steady rate of turn will usually be obtained very rapidly, since rate steering is easier to perform than normal compass steering. However, adjustments to the rudder angle may be required until the ship achieves a steady speed; therefore, it is necessary to allow some time before the values of $\dot{\Psi}$ and δ are measured.

2.2.6 Pull-out Test

The pull-out manoeuvre is a simple test to give a quick indication of a ship's course stability.

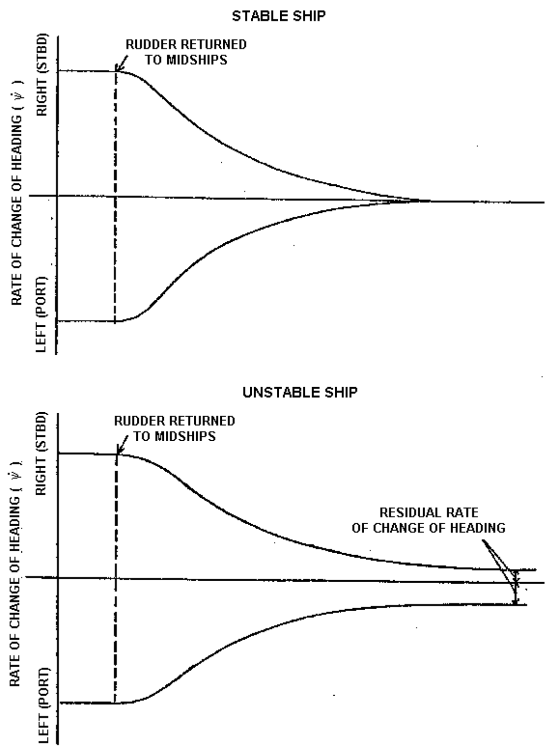

Figure 4: Presentation of pull-out manoeuvre results

A rudder angle of approximately 20 degrees is applied until the ship achieves a steady rate of turn; at this point, the rudder is returned to midships. If the ship is stable, the yaw rate will decay to zero for turns to both port and starboard. If the ship is unstable, then the rate of turn will reduce to some residual yaw rate. The pull-out manoeuvres have to be performed to both port and starboard to show a possible asymmetry (see Figure 4). Pull-out manoeuvres can be performed at the end of a zig-zag or turning circle test.

2.2.7 Stopping Test

During stopping tests a ship's speed is reduced from some initial steady value to zero by applying full astern power.

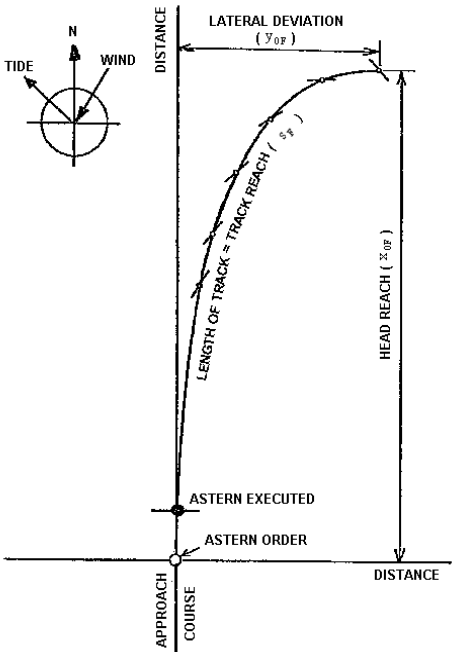

Figure 5. Definitions used in stopping trials

The most common stopping trial starts from full ahead speed. When the approach conditions are satisfied, the demand for full astern power is given from the engine control position on the bridge.

When the propelling unit has reached steady full astern rpm and ship's speed becomes zero, the test is completed.

The parameters measured during crash-stop and stopping trial are (see Figure 5):

- the head reach which is defined as distance travelled in the direction of the ship's initial course;
- the track reach which is the total distance travelled along the ship's path;
- the lateral deviation which is the distance to port or starboard measured normal to the ship's initial course.

Ships usually are directionally uncontrollable during this manoeuvre so that the trajectory is, to a large extent, determined by the ambient disturbances, initial conditions and rudder actions. Although existing procedures allow rudder activity to keep the ship as close to the initial course as possible, it should be noticed that IMO requires the rudder to be maintained at midships throughout the trial.

2.2.8 Stopping Inertia Test

Stopping inertia tests are performed to assess the behaviour of a ship during deceleration without propeller action.

Starting from full ahead speed, the engine is stopped quickly. When the ship's ahead speed has reduced to 5 knots, the test is completed.

The parameters measured during a stopping inertia test are:

- the head reach which is defined as distance travelled in the direction of the ship's initial course;
- the track reach which is the total distance travelled along the ship's path;

- the lateral deviation which is the distance to port or starboard measured normal to the ship's initial course;
- the duration of the manoeuvre.

2.2.9 Man-overboard Manoeuvre Test

Man-overboard manoeuvres are performed to provide information on the time taken and the deviation from course necessary to retrieve a person or object from the sea. The elliptical and Williamson turns are two well-known man-overboard manoeuvres. These manoeuvres will, in the absence of wind and current, bring the ship back to the position where the man overboard incident occurred.

<u>The elliptical turning manoeuvre.</u> With the ship initially under approach speed, the rudder is moved quickly to hard over starboard and held until ship has altered course by 180 degrees from initial course. At that time, the rudder is moved quickly to hard over port and the ship is steadied on the original course. This manoeuvre is to be terminated when the ship has returned to the position, or nearest position, where the manoeuvre was initiated.

<u>The Williamson turning manoeuvre</u>. With the ship initially under approach speed, the rudder is moved quickly to hard over starboard and held until ship has altered course by 70 degrees from initial course. At that time, the rudder is moved quickly to hard over port, until the ship is heading 180 degrees from initial course. This manoeuvre is to be terminated when the ship has returned to the position, or nearest position, where the manoeuvre was initiated.

Following data are to be derived from the trials:

1) a plot of the ship’s track,
2) the time taken to return to the point, or nearest position to that point, at which the manoeuvre was initiated
3) the lateral deviation from the initial course at the point, or nearest position to that point, at which the manoeuvre was initiated are to be derived.

2.2.10 Parallel Course Manoeuvre Test

The parallel course manoeuvre provides information on the ship's side reach.

With the ship initially under approach speed, the rudder is moved quickly to hard over starboard and held until the ship has altered course by 15 degrees from initial course. At that time, the rudder is moved quickly to hard over port. When the ship’s heading resumes the initial course, the rudder is moved to midship.

The test has to be repeated for 30 degrees and 45 degrees change of heading from initial course.

Following data are to be derived from the trials:

1) a plot of the ship’s track,
2) the time taken to reach parallel course,
3) the lateral deviation between the initial and final positions.

2.2.11 Initial Turning Test

The initial turning trial provides information on the effectiveness of the rudder in transient manoeuvres and to ascertain the ship’s initial turning ability.

With the ship initially under approach speed, the rudder is moved quickly to 10 degrees and held until the ship has altered course by 10 degrees from initial course.

Following data are to be derived from the trials:

1. a plot of the ship's track,
2. the track reach, being the total distance travelled along the ship's path, non-dimensionally expressed in ship lengths.

These data can also be obtained from the first phase of a 10/10 zig-zag manoeuvring trial, between the first and the second execute.

2.2.12 Accelerating Turning Test

Accelerating turning test provide the ability to make a "kicking" turn at slow speed, which is used in harbour manoeuvres.

The ship is initially at standstill with zero speed and propeller stopped.

The manoeuvre is started by ordering the rudder hard over and the engine half ahead on telegraph. Rudder and engine control are thereafter kept constant during the turn. The turn continues until a 180 degrees change of heading has been completed.

The essential information to be obtained from this manoeuvre consists of:

- tactical diameter,
- advance,
- transfer,
- final speed,
- time to change heading 90 degrees
- time to change heading 180 degrees

The first three of these may be presented in non-dimensional form by dividing their values by ship's length between perpendiculars (L_{PP}). Maximum advance and maximum transfer can be measured, too.

2.2.13 Thruster Test

For a ship fitted with lateral thrusters the following tests are recommended.

Turning Manoeuvre. With the ship initially at low speed (between 0 and 6 knots), the thrusters are ordered to deliver full power while the rudder is kept amidships. The manoeuvre should be continued until 90 degrees change of heading has been completed. Tests should be conducted both to port and starboard, with the bow and stern thrusters independently. The initial conditions include the ship bow being oriented directly into the wind.

The essential information to be obtained from this manoeuvre consists of:

- time to change heading 15, 30, ..., 90 degrees.
- turning rate must be continuously recorded. If possible, a steady state turning rate must be provided.

Zig-zag Manoeuvre. With the ship initially at low speed (between 3 and 6 knots), the thrusters are ordered to deliver full power while the rudder is kept amidships. The test follows the same sequence as the zig-zag test (see 2.2.2) where at the instants of the executes, the thruster action is reversed instead of the rudder action. An execute heading angle of 10 degrees is suggested.

It is recommended for special types of ships such as ferries to carry out zig-zag manoeuvres as above with a speed of approximately 3 knots astern.

2.2.14 Crabbing Test

A ship's ability to move transversely at zero forward speed without altering heading is verified with a crabbing test. The purpose of the test is to document the maximum possible transverse speed.

All available propellers/rudders/thrusters should be used to perform the test. Obviously a conventional ship with only one propeller, one rudder and no bow thruster cannot perform crabbing according to this definition.

The essential information to be obtained from this manoeuvre consists of the final steady lateral speed of the ship. The forward speed and the change of heading should also be documented, although they should be kept as low as possible.

The use of propeller(s), rudder(s) and thruster(s) should be documented, including power, rpm, pitch, thrust direction, rudder angle, etc.

The test should be carried out in as still air and calm water conditions as possible. If the wind is in excess of Beaufort 2 the test should be carried out in beam wind, crabbing both with the wind and towards the wind. Wind, current and sea conditions should be documented.

3. DATA ACQUISITION SYSTEM

During the different trials, the data listed in Tables 2 and 3 have to be measured and recorded from the start of the approach run until the end of the manoeuvring trial.

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

3.1 Instrumentation

This section presents specific procedures and necessary equipment for the instrumentation of full-scale manoeuvring trials. A general on the calibration of the instruments can be found on the ITTC Procedure 7.5-01-03-01 Uncertainty Analysis: Instrument Calibration (ITTC, 2014).

3.1.1 Ship speed and position

Ship speed and position should be determined using either the measured mile, electronic tracking or GPS. It is preferable to use GPS due to its flexibility. As mentioned previously, trials should be conducted in sheltered waters, of adequate depth, with minimal currents and tides. GPS, when used in the differential mode, allows correction of the data to a known reference site. Pulse radar track is also recommended, however, the flexibility is not as great as with GPS. DGPS must be considered for small vessels.

3.1.2 Ship’s heading

A gyrocompass should be used to record ship’s heading. The gyro repeaters are to be adjusted until they are synchronised with the master gyro compass reading.

3.1.3 Rudder angle

Rudder angle should be measured by adequate instrumentation (e.g. angular potentiometer) installed on the rudder stock. The steering gear is to be tested to calibrate the rudder angle indicator(s), over the full range of movement against the actual rudder angle reading given on the rudder stock.

3.1.4 Rate of turn

The rate of turn indicator can be calibrated against the actual change in heading per second during a turn.

3.1.5 Shaft rpm

Propeller shaft rpm should be determined by installing either a magnetic probe or infrared optical sensing device. Sixty metal strips or reflective tapes should be installed so that instantaneous rpm can be determined.

3.1.6 Torque

The torque should be measured using a torsion meter that can be calibrated. The residual shaft torque (zero of the torsion meter) should be taken immediately before and after the trials by rotating the shaft slowly in both directions with turning gears and the torque values derived from the torsion meter should be adjusted accordingly. Obtaining torque by attaching strain gages on the shaft is not recommended since alignment of the gages is most difficult and they cannot be physically calibrated once installed.

3.2 Ship Parameters

Following ship related parameters should be documented:

- Ship type and design parameters (L/B, B/T, C_B)
- Hull conditions at trial condition (L/B, B/T, C_B, GM)
- Submerged lateral area
- Lateral/longitudinal projected area above waterline
- Draft and Trim
- Stern type parameters at trial condition
- Rudder type
- Number of rudders
- Rudder area
- Rudder angle or pod angle
- Propeller type
- Propeller diameter and pitch
- Number of propellers and turning direction of each propeller
- Engine type
- Power and percentage of Maximum Continuous Rating to which ship speed and RPM apply

3.3 Initial Conditions

The following data is to be clearly recorded for each trial:

- Date
- Time
- Area of trial
- Initial approach speed and heading
- Ship's loading condition (draft, trim, longitudinal centre of gravity and transverse metacentric height)
- Radii of gyration
- Heel angle
- Water depth
- Environmental conditions, including
  - Current speed and relative direction
  - Wind relative speed and direction
  - Sea state

4. DATA ANALYSIS

4.1 Correlation between Model Scale and Full Scale

If the full scale trials are to be compared to numerical simulation in model scale or free running model tests, the scale effects must be taken into account. The ITTC Procedure 7.5-02-06-01 (ITTC, 2014) includes important comments about the scale effects in the free running model tests and how to compensate them.

The rudder angle actuation speed must be properly defined according to the model scale. Some techniques are still being developed in order to assure that the rudder lateral force is relatively equivalent in the model and full scale (27th ITTC Manoeuvring Committee, 2014).

If using autopilot, it is important to check if the controller gains are equivalent in model scale and full-scale.

4.2 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.

For the uncertainty analysis of ship position and speed, shaft rpm and torque, reference can be made to the uncertainty analysis section of the Final Report and Recommendations to the 23rd ITTC - The Specialist Committee on Speed and Powering Trials (ITTC, 2002).

The effect of errors in rudder angle or manoeuvring device setting on the manoeuvre is difficult to assess through conventional uncertainty analysis. It is recommended to make use of simulation techniques for this purpose.

4.2.1 Correction due to Environment

The immediate environment such as wind, waves and current can significantly affect ship manoeuvrability. IMO Resolution MSC.137(76) (2002) suggests a method to account for environmental effects only for turning tests. Recent research concerning environmental effects on zig-zag tests has shown that no straightforward correction method can be applied. For such complicated manoeuvres simulation techniques are the only possible solution.

4.2.2 Correction due to Ship Conditions

Ship manoeuvrability can be significantly affected by the draft and trim condition. For example, course stability in ballast condition is usually better than in full load even-keel conditions. If it is not possible to perform the test in full load even keel condition, the manoeuvring characteristics should be then predicted by the ballast condition test and corrected using a reliable method (i.e. model tests or proven computer simulation) that ensures satisfactory extrapolation of trial results, as also suggested by IMO Resolution A.751 (1993). In this case, however, the procedure must be clearly referenced and documented.

Table 2 Recommended Manoeuvring Trial Measurements

Type of test		Heading	Position	Forward speed	Rudder angle	rpm	Rate of turn	Torque
1	Turning test	√	√	√	√	√		√**
2	Z-manoeuvre test	√	√	√	√	√		
3	Modified Zig-zag test	√	√	√	√	√		
4	Zig-zag test at low speed	√	√	√	√	√		
5	Direct spiral test	√		√	√		√*	
6	Reverse spiral test	√		√	√		√*	
7	Pull-out test	√		√	√		√*	
8	Stopping test	√	√	√	√	√		√
9	Stopping Inertia test	√	√	√	√	√		√
10	Man-overboard test	√	√	√	√			
11	Parallel course manoeuvre test	√	√	√	√	√		
12	Initial turning test	√	√	√	√			
13	Accelerating turning test	√	√	√	√	√		
14	Thruster test	√	√	√	√	√	√	
15	Crabbing test	√	√	√	√	√	√	

* If the rate of turn cannot be obtained using a rate gyro and/or gyrocompass, the differential of the heading angle has to be used to derive this parameter

** Recommended for trials with twin propeller ships

Table 3 Data sampling rate and accuracy requirements

Parameter	Turning test	Pull-out test	Stopping test	Zig-zag test	Spiral test	Man-overboard test	Minimum accuracy
Time	Continuously	Continuously	Continuously	Continuously	Continuously	Continuously	± 1 s
Position	1s	-	1s	1s	-	1s	± 5 metres
Forward Speed	4s	-	4 s	4 s	Initially, then once at each steady rate of turn	4s	± 0.2 knots
Heading	1 s	1 s	1 s	1 s	1 s	1 s	± 0.5 degrees
Setting of manoeuvring device (Rudder angle)	2s	2 s	2s	2 s	2 s	2 s	± 1 degree
Propeller rpm and torque	2s	2s	2s	2 s	2s	2 s	± 1% of initial setting
Rate of turn	2 s	2 s	-	2 s	2 s	-	± 0.05 degs/s
Heel angle	2 s	2 s	2 s	2 s	2 s	2 s	±0.5 degree
Propeller pitch	2 s	2 s	2s	2 s	2 s	2s	± 1% of initial setting
Note All parameters are to be measured at the initiation and termination of points of each manoeuvring trial It should be indicated how position and speed have to be measured. A distinction should be made between forward speed, length of speed vector, speed corrected for current, etc.							

(adapted from Lloyd's Register Provisional Rules, 1999)

4.3 Benchmark Tests

(1) Preliminary Analysis of ITTC Co-operative Tests Programme (11th 1966 pp.486-508) A Mariner Class Vessel

(2) The 11th I.T.T.C. Standard Captive-Model-Test Program (11th 1966 pp.508-516) A Mariner Type Ship " USS COMPASS ISLAND"

(3) Co-operative Tests for ITTC Mariner Class Ship Rotating Arm Experiments(12th 1969 pp.667-670)A MARINER Model

(4) The Co-operative Free-Model Manoeuvring Program (13th 1972 pp. 1000) Co-operative Test Program - Second Analysis of Results of Free Model Manoeuvring Tests(13th 1972 pp. 1074-1079) A MARINER-Type Ship

(5) The Co-operative Captive-Model Test Program (13th 1972 pp.1000) To Determine the Ability with which Full-Scale Ship Trajectories Could Be Predicted from the Test Data Acquired.

(6) Co-operative Tests Program - Review and Status of Second Phase of Standard Captive-Model Test Program (13th 1972 pp. 1080-1092)

(7) The Mariner Model Co-operative Test Program -Correlations and Applications- (14th 1975 Vol.2 pp. 414-427) A New Large Amplitude PLANAR-MOTION-MECHANISM. The MARINER Model

(8) Comparative Results from Different Captive-Model Test Techniques(14th 1975 Vol.2 pp.428-436)

(9) A MARINER CLASS Vessel and a Tanker Model

(10) Ship Model Correlation in Manoeuvrability(17th 1984 pp.427-435) To Conduct Model Tests and Compare Their Results with "ESSO OSAKA' Deep and Shallow Water Trials Joint International Manoeuvring Program (JIMP) A Working Group Called JAMP (Japan Manoeuvrability Prediction)

(11) Free-Running Model Tests with ESSO OSAKA(18th 1987 p.369-371)

(12) Captive Model Tests with ESSO OSAKA (18th 1987 pp.371-376)

(13) Manoeuvring Trial Code(14th 1975 pp.350-365)

(14) ITTC – Quality Manual (22nd ITTC QS Group 4.9-03/04-01)

(15) Guide for Planning, Carrying out and Reporting Sea Trials (ISO/TC8/SC9, 1999-10-19)

(16) Standards for ship manoeuvrability (Resolution MSC.137(76), 2002)

(17) Classification of the Manoeuvring Capability of Ships (Lloyd’s Register Provisional Rules, May 1999)

(18) Excerpts regarding the Conduct of Speed/Power Trials, Uncertainty Analysis and Correction of Trials Data (22nd ITTC Trials & Monitoring Specialist Committee.

5. REFERENCES

29th ITTC, 2020, Quality Manual, (2020). “Testing and extrapolation methods manoeuvrability. Free Running Model Tests”, 7.5-02-06-01 ITTC Quality Manual.

27th ITTC, 2014. "Uncertainty Analysis: Instrument Calibration", 7.5-01-03-01 ITTC Recommended Procedures.

International Towing Tank Conference, 2014, "Manoeuvring Committee - Final Report and Recommendations to the 27th ITTC", Proceedings of 27th ITTC, Copenhagen.

International Towing Tank Conference, 2002, "The Specialist Committee on Speed and Powering Trials - Final Report and Recommendations to the 23rd ITTC", Proceedings of 23rd ITTC, Venice.