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INTERIM PROCEDURE

COMMENTS OF THE ICE COMMITTEE OF 22nd ITTC

The committee felt that this section was acceptable with minor editorial changes as suggested by S. Jones. Nonetheless, this section should be reviewed by the next committee

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Ship Trials in Ice

1. PURPOSE OF PROCEDURE

- Definition of standards for performing ship trials in ice
- Ensure that the recommended procedure follows a defined structure and format

2. RECOMMENDATIONS FOR SHIP TRIALS IN ICE

2.1 Recommended Measurement Procedures

- Hull condition: The hull should be inspected visually (ideally both underwater and above water portions), particularly in the ice belt region. Type and condition of coating should be recorded, as well as length of time from coating application. Roughness measurements at several locations along the ice belt should be taken. As an option, a mould of the hull surface may be produced for later friction experiments in the laboratory.
- Shaft thrust: Shaft thrust is normally measured using strain gauge technology. This may introduce large errors into the recorded data due to the inherent difficulty in measuring the axial strain of a large shaft. An alternative method is for measurements to be taken of the deformation of the thrust bearing, or by measuring the pressure in the Mitchell thrust meter, if the ship is so equipped.
- Shaft torque: Shaft torque can be measured accurately from strain gauges attached to the propeller shaft. Calibrations and zero level checks are important to ensure reliability. It is also recommended to determine shaft friction levels by recording torque at very low shaft speeds.
- Power: Power can be calculated from torque and shaft speed. For electric propulsion plants the motor input current and voltage can also be used to calculate power, provided the motor efficiency is known accurately.
- Rudder angle: Rudder angle should be measured at the rudder stock with a potentiometer.
- Propeller speed: Propeller speed should be measured by a pulse transducer installed on the propeller shaft.
- Propeller pitch: Propeller pitch should be measured from a pressure sensor in hydraulic lines, or from potentiometers on mechanical arms.
- Ship draft: Ship draft should be measured by visual observation of the draft marks at the beginning, during, and at the end of the tests.
- Ship speed: Ship speed should be measured with Differential GPS. A backup system should also be used, such as calibrated over-the-side video, markers on the ice, or micro-wave position fix.
- Ship Motions: Ship motions may be measured by use of a gyro-stabilized platform with fixed accelerometers and yaw rate gyro.

- Propeller and Ice Interaction: Occurrences of propeller and ice interaction should be determined from the records of torque and thrust.
- Propeller Blade Loads: Propeller blade moments, forces, and torque are usually measured for special trials only. These measurements can be performed by strain gauging one of the blades and then calibrating that blade.
- Ice Thickness: Ice thickness should be measured along the ship's track, by either measuring the thickness at the channel edge or by drilling holes through the ice. Measurement frequency should be one to two per ship length. Measurements may also be taken from calibrated recordings of an over-the-side video which records upturned ice pieces (if this method is used then these measurements should be ground proved with direct measurements).
- Ice Flexural Strength: Ice flexural strength should be measured by the failure of a standard ice beam (Williams & Parsons 1994) in three-point bending. Other methods include in-situ flexural tests, which can be difficult to perform if the ice is very thick. Ice flexural strength is sometimes determined from a formula developed by Vaudrey which relates brine volume estimates to strength. Research (William & Parsons 1994) has since shown that other factors may influence results obtained from this formula.
- Ice Compressive Strength: IAHR recommendations should be followed (Schwarz & al.1981).
- Ice State: The type of ice and other parameters describing the ice conditions should be recorded. The ice type description includes temperature and salinity profiles, ice density and crystallography. Ice conditions should be described by stating the morphology of ice and noting the possible presence of ice pressure.
- Broken Ice Cusp Dimensions: Cusp dimensions may be obtained from calibrated photography.
- Water Depth: Water depth should be determined from charts or ship instrumentation, or manually if the water is very shallow.
- Snow Density: The density of full thickness snow samples should be measured. A snow sample may be collected with a cylinder of known diameter to determine sample volume. Snow thickness should be measured directly before or after taking the sample. The snow or the snow melt water is placed on a balance to determine the weight of the sample.
- Snow Cover: Snow thickness should be measured along with ice thickness. Snow type should be classified according to the frictional properties of the snow (Williams 1995).
- Ice/Hull Friction: There are several methods for the measurement of ice/hull friction. These include moving an ice block along the side of the ship under specified conditions, and installation of a friction panel in the ship's hull
- Wind Speed and Direction: Wind speed and direction should be recorded from the ship's instruments.

- Seawater Temperature and Salinity: Seawater samples may be collected and then tested with the ice measuring instrumentation.
- Water Current: Water current should be determined (or its effect eliminated) for any accompanying open water tests.
- Air Temperature: Air temperature should be monitored with the ship's equipment, and on-ice measurements should be recorded if possible.
- Location of Test: Test location should be determined from charts and GPS.
- Ridge profile: Ridge profile should be measured both above water and underwater. The above water portion may be profiled by survey equipment or by stereo photography. The underwater profile may be measured with sonar or by drilling holes through the ridge. Measuring frequency should be sufficient to accurately describe the ridge profiles (if the, underwater profile is measured by drilling then more than one profile should be completed).
- Ridge Structure and Consolidation: Full thickness cores of the ridge should be removed to investigate ridge consolidation and structure. Temperature and salinity profiles of the cores should be performed and plotted as a function of depth. Compressive strength tests of the ice cores removed from the ridge may be performed. The use of cores to determine the porosity and thickness of the consolidated layer of the ridge is, albeit accurate, very tedious. These quantities may be estimated by drilling.
- Ice piece Size and Channel Coverage: Ice piece size and channel coverage may be recorded by use of calibrated video or photography.
- Channel Profile: The profile of the cross section of the channel can be measured through holes drilled through the channel edges.
- Channel Width: Channel width can be measured directly or by calibrated video or photography approximately twice per ship length

2.2 Recommended Procedures for a Propulsion Test in Level Ice

The standard propulsion test in level ice is a constant speed / constant power test. The objective of this test is to determine the continuous icebreaking capability of the ship in unbroken level ice. The collected data is to provide information so that the speed / power relationship for the ship in specific environmental conditions can be determined.

The propulsion test in level ice may also be used to evaluate the resistance of the ship's hull. This may be achieved by eliminating the influence of the propulsion system. This analysis is most effective if there is very little, or no, ice interaction with the propeller(s). The thrust deduction factor for the vessel's propulsion system must be determined to carry out this analysis. This is typically estimated from model tests or, if model test data is not available, from the manufacturer's propeller curves. Thrust deduction is a very difficult number to know accurately, because it is usually determined by subtracting two large numbers, each with some error, to give a small number with consequently a very large relative error.

The recommended procedures for the propulsion test begin with the selection of an area of unbroken level ice. For each test the ship is to proceed at constant speed and constant power for two to five ship lengths. The test should be repeated for a number of different speeds (power levels) in order to determine the speed / power relationship for the ship. These tests may be carried out continuously, without stopping the vessel. During each test all ship parameters are to be held constant, with rudder at amidships. If an evaluation of the ship in various level ice conditions is desired, then the tests should be repeated in several other conditions of different ice thickness and strength. The amount and type of snow cover also influences the ship's performance, and therefore the effect of the snow must be included in the performance evaluation. It is recommended that these tests be recorded on video tape.

The data acquisition system used by the vast majority of organizations conducting full scale trials in ice is digital, although some magnetic tape recorders are still in use. It is recommended that a digital data acquisition system be used. This system should be installed and checked by a qualified engineer or technician. In-situ calibrations should be performed, if possible, to ensure the reliability of the data. Frequent zero checks should also be made. Collected data should be backed up regularly to ensure security of the data.

The analysis of the ship trials data should include open water test results. Bollard pull or push tests and open water power/speed tests can provide information on propeller characteristics and open water performance as well as providing a check of the ship trials instrumentation. If model test results for the vessel are available then the thrust deduction factor from these results may be used to determine the average resistance from average measured thrust. Propeller curves may also be used to estimate a thrust deduction. Dynamics of the propulsion system should be taken into account in the analysis as this may influence the measurements recorded, particularly in situations of propeller and ice interaction.

Standard statistical processing of the measured data to determine steady state thrust, torque, and ship speed should be performed. Thrust torque, and power can be plotted as functions of ship and ship speed for the different ice and snow conditions. and ship speed can be plotted as a function of ice thickness. The analysed data may be compared to data from similar ships and to model test data, if available.

2.3 Procedures for a Test in Ridges

The standard full scale ship test in a ridge is ridge penetration by ramming. The objective is to determine the ramming capability of the ship in ridges in terms of penetration distance as a function of impact speed, ridge characteristics and penetration force (propeller thrust plus inertial force). Correlation of' ridge profile and ship penetration is important for the subsequent analysis.

The test ridge is selected and the intended line for the ship’s progress is marked. The surrounding ice thickness and strength, and the above water and underwater ridge profiles must then be measured. Ridge consolidation and structure are also important factors, and should be determined through the analysis of cores taken from the ridge. The water depth is to be noted to make sure that the ridge is not grounded or likely to be grounded.

The ship is accelerated to full (or other) speed toward the ridge. The time of impact with the ridge should be noted on the recording instrumentation. If the ship proceeds through the ridge then the power level is maintained for about two ship lengths. If the ship is stopped by the ridge then the penetration distance is measured and astern power is applied in steps so as to determine the extraction power level. The ship is then backed out of the ridge to a distance of three ship lengths. The second ram is then begun as the power is increased to full (or other) power, and the ship accelerates. The second ram time of impact and penetration distance are also measured. This cycle is continued until the ship penetrates the entire ridge.

The recorded data include impact time and speed, ridge penetration distance, level ice properties, ridge profile and properties, ship acceleration distance, as well as ship propulsion parameters and other ship parameters as for level ice tests. It is also highly recommended that these tests be recorded on video tape.

The recommended data acquisition system is the same as that for propulsion tests in level ice. In-situ calibrations and pre-trial system checks should also be carried out.

The analysis to be performed for the ridge ramming tests includes the calculation of ridge penetration force, or ridge resistance. This is the sum of the propeller thrust and the ship inertial force (which includes the added mass of the water). The ramming cycle can be presented schematically by plotting the speed of the ship as a function of advance, with the profile of the ridge on the same graph. The ramming cycle may be broken down into several different phases, such as time to back down the channel acceleration time in channel, time from instant of impact to complete stop, and time to free the ship from the ridge.

2.4 Procedures for a Test in Ship's Channel

The standard test for a test in a channel is a constant power, constant speed propulsion test in the ship's own channel. Tests are to be performed both ahead and astern. The objective of this test is to determine the resistance of the ship in a broken channel.

This test is usually performed immediately after the propulsion test in level ice so that minimal additional preparation and effort are required. Additional measurements required for these tests are the recording of the ice block dimensions and channel coverage, ice piece consolidation, and channel width. Length of time since first breaking of the channel should also be recorded.

An ice feature of similar composition to a pressure ridge is an old navigation channel. While ridge profiles are triangular shaped in cross section, these old channels may be almost uniform in thickness. They are also composed of ice pieces that are typically smaller than those in ridges. The tests described in this section may be performed in these old navigation channels by following the same procedures as in newly broken channels.

The measurements should include a thorough description of the channel profile. If the channel is relatively new then an estimate of the number of ship runs should be made since additional ship runs may produce features similar to the underwater portion of a ridge at the channel edges. The degree and thickness of consolidation of ice pieces should be measured.

The test procedures are very similar to those for the propulsion test in level ice. For each test the ship is to proceed at constant speed and constant power for about three ship lengths. The test is to be repeated for a number of different speeds (power levels) in order to determine the speed / power relationship for the ship in the channel These tests may be carried out continuously, without stopping the vessel During each test all ship parameters are to be held constant, with rudder at amidships.

The recommended data acquisition system is the same as that for propulsion tests in level ice and the ridge ramming tests. In-situ calibrations and pre-trial system checks should also be carried out.

The analysis of the channel tests will usually be performed in conjunction with analysis of propulsion tests in level ice and open water test results. Bollard pull or push tests and open water power/speed tests can provide information on propeller characteristics and open water performance as well as providing a check of the ship trials instrumentation. If model test results for the vessel are available then the thrust deduction factor from these results may be used to determine the average resistance from average measured thrust. Propeller curves may also be used to estimate a thrust deduction. Dynamics of the propulsion system may need to be taken into account in the analysis if situations of propeller and ice interaction occur.

Standard statistical processing of the measured data to determine steady state thrust, torque, and ship speed should be performed. Thrust, torque, and power can then be plotted as functions of ship speed for the different channel conditions.

3. PARAMETERS

3.1 Parameters of the Level Ice to be Measured

Parameter	Priority
Hull condition	1
Shaft thrust	1
Shaft torque	1
Power	1
Rudder angle	1
Propeller speed	1
Propeller pitch	1
Ship draft	1
Ship speed	1
Ship Motions	3
Propeller/Ice interaction	1
Ice Thickness	1
Ice Flexural strength	1
Ice Compressive Strength	1
Ice Type	1
Ice Temperature	1
Ice Salinity	2
Ice Morphology	3
Ice Pressure	1
Broken Ice Cusp Dimensions	3
Water Depth	3
Snow Density	2
Snow Cover	1
Ice/Hull Friction	2

Wind Speed and Direction	3
Water Current	3
Air Temperature	2
Location of Test	1

3.2 Additional Parameters For Tests In Ridges

Parameter	Priority
Ice Thickness (for ice surrounding ridge)	1
Ridge profile	1
Ice Flexural Strength (for ice surrounding ridge)	2
ice Compressive Strength (for ice surrounding ridge)	2
Ridge Structure and Consolidation	1
Ice Type (for ice surrounding ridge)	3
ice Temperature (for ice surrounding ridge)	3
Ice Salinity (for ice surrounding ridge)	3
Ice Density (for ice surrounding ridge)	3
Ice Pressure (for ice surrounding ridge)	3

3.3 Additional Parameters For Tests In Ship's Channel

Parameter	Priority
Ice Shear Strength	3
Ice Density	3
Ice Piece Size and Channel Coverage	1
Channel Profile (for tests in old channels)	1
Channel Width	1

3.4 Recommendations of ITTC For Parameters

None.

4. VALIDATION

4.1 Uncertainty Analysis

None

4.2 Benchmark Tests

Report of Committee on Ships in Ice-Covered Water (16th 1981 pp. 363-372)
g) Catalogue of Available Model and Full Scale Test Data (16th 1981 pp. 370-371)

Reanalysis of Full Scale R-Class Icebreaker Trial Results(18th 1987 pp.528-531) To Get Reliable Full-Scale R-Class Data CCGS "Pierre Radisson" and CCGS "Franklin"

Repeatability Tests for Quality Control (20th 1993 pp.488-490)