INTERNATIONAL STANDARD

ISO 22098

First edition
2020-05

Ships and marine technology — Full-scale test method for propeller cavitation observation and hull pressure measurement

Navires et technologie maritime — Méthode d'essai grandeur nature pour l'observation de la cavitation de l'hélice et le mesurage de la pression de la coque

Reference number
ISO 22098:2020(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword

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

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

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

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

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 8, *Ship design*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Cavitation is responsible for significant propeller performance degradation and occurs at nearly all propellers, causing often vibrations, noise and propeller blade erosion. It has been a common practice to evaluate the propeller cavitation behaviour and its related hull pressure through model tests. However, the model test might not show the full-scale cavitation phenomena.

Full-scale cavitation observations and hull pressure measurements are very helpful as feedback for propeller design and prediction of full-scale performance through model test. This full-scale test method is needed to establish more accurate model-ship correlation, to come up with better experimental methods and to identify the cause of unexpected problems such as blade damage.

This document was developed to provide a standardized full-scale test method for propeller cavitation observation and hull pressure measurement.

Ships and marine technology — Full-scale test method for propeller cavitation observation and hull pressure measurement

1 Scope

This document specifies a full-scale test method for propeller cavitation observation and hull pressure measurement. The objective of the test is to investigate the propeller cavitation behaviour and its effects on the hull vibration problems.

The test method comprises the specification of the test instrumentation and implementation, construction requirements to ensure structural safety, test and measurement procedures, and reporting documentation.

This document is applicable to ships in the following stages:

— before or during sea-trial, prior to delivery stage (vessels under constructions), and

— after delivery stage.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
measured ship speed
ship's speed during a speed run derived from the headway distance between start and end position and the elapsed time of the speed run

3.2
observation window
transparent window allowing to observe and investigate the occurrence of cavitation of a ship propeller

3.3
propeller plane
plane normal to the shaft axis and containing the propeller reference line, i.e. contain the reference point of the root section

3.4
ship speed
speed of the ship that is realised under stipulated conditions

Note 1 to entry: See also *measured ship speed* (3.1).

3.5
side scuttle
round or oval opening with an area not exceeding 0,16 m^2

Note 1 to entry: Round or oval openings with an area exceeding 0,16 m^2 are “windows”, as defined in IACS UI LL62[3] or IMO Resolution MSC. 143(77)[4].

3.6
sea chest
fitting in a hull below the water line, for admitting or discharging water

4 Instrumentation and implementation

4.1 General

For the ship installation of all test equipment, it is necessary to thoroughly review the drawings on the ship subject to test, and the selection of sensor and equipment installation location, workspace and transportation route should be reflected in the design and construction stage.

4.2 Cavitation observation

4.2.1 General

Various methods for observing full-scale cavitation have been developed so far. This document introduces the characteristic of various cavitation observation methods and specifies the criteria for the necessary preparations for the cavitation observation test.

4.2.2 Cavitation observation method

A traditional method using a CCD camera with a stroboscopic lighting source has been commonly used for full-scale cavitation observation. Recently, a technique using a high-speed camera in daylight condition has been used. This technique minimizes the number of observation windows compared to the traditional method and enables to observe detailed motion of cavitation to study the phenomenological behaviour of the cavitation.

Furthermore, instead of the existing observation window, a high-speed bore-scope technique has been used in consideration of relative installation time and cost reduction. The small penetrations needed for the bore-scope equipment can be drilled with the ship in a float condition, which reduces the installation time from days to hours and saves money from expensive ship docking operations.

However, the high-speed bore-scope technique requires strong sun light and good water quality. The observation windows are more robust against the weather conditions and sea conditions. Thus, observation windows are still useful if there is sufficient construction time and space. Appropriate equipment should be selected depending on the purpose, situation and timing of the installation.

Although frequency of image heavily depends on illumination condition, Table 1 shows several examples of various observation methods for full-scale propeller cavitation.

Table 1 — Examples of cavitation observation methods

Observation method	Window/ hole size	Dry docking required for preparation	Dependence on daylight	Comments
Photographs/videos in daylight using a bore-scope	about M20 bores	no	yes	Easily affected by the environment (daylight, water quality, etc.) Easy installation Low frequency image
Photographs/videos in daylight using windows	about 200 mm to 300 mm	yes	yes	Moderately affected by the environment (daylight, water quality, etc.) To be installed during docking Low frequency image
High speed camera in daylight using windows	about 200 mm to 300 mm	yes	yes	Moderately affected by the environment (daylight, water quality, etc.) To be installed during docking High frequency image
High speed camera in daylight using a bore-scope	about M20 bores	no	yes	Easily affected by the environment (daylight, water quality, etc.) Easy installation High or low frequency image subject to light intensity
Photographs/videos under strobe light using windows	about 200 mm to 300 mm	yes	no	Relatively unaffected by the environment (daylight, water quality, etc.) To be installed during docking Time-lapse image

4.2.3 Observation window

The observation window should be designed, manufactured and installed with the following considerations:

— observation visibility;

— convenience in the setting-up;

— structural safety;

— water-tight performance.

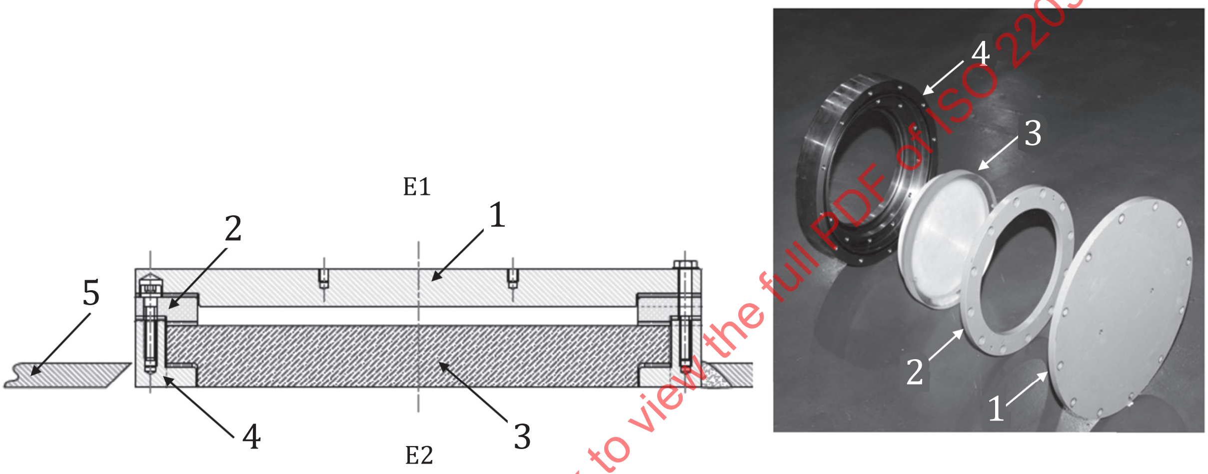
The designed observation window should be verified for safety through structural strength analysis or classification approval. It should be manufactured in compliance with the suitable materials and specifications so as not to cause problems in the installation of the ship.

Table 2 shows the components and materials of a typical observation window.

Figure 1 shows an example of a typical observation window.

Table 2 — Components and materials of a typical observation window — Example

Item	Materials
Steel plate cover	Mild steel or stainless steel
Frame 1 for fixing the window	Mild steel or stainless steel
Window glass	Acrylic or similar material
Frame 2 for fixing the window	Mild steel or stainless steel
Frame lockable bolts, For tightening various bolts, O-ring	Mild steel or stainless steel, Mild steel or stainless steel, Rubber or similar material



Key

1 steel plate cover
2 frame 1 for fixing window
3 window glass
4 frame 2 for fixing window
5 hull
E1 air
E2 water

NOTE See also Table 2.

Figure 1 — Example of a typical observation window

The number of observation windows depends on the observation method used. The installation, location and size of the observation windows should be selected by considering the following items through an analysis of the stern structure of the ship:

— cavitation occurrence position and observation range;

— easiness of installation, securing of workspace and moving route;

— ship operating draft;

— structural safety and arrangement onto the shell.

The exact position of the observation window can be selected through a 3D analysis of the hull shape using CAD modelling, as shown in Figure 2.

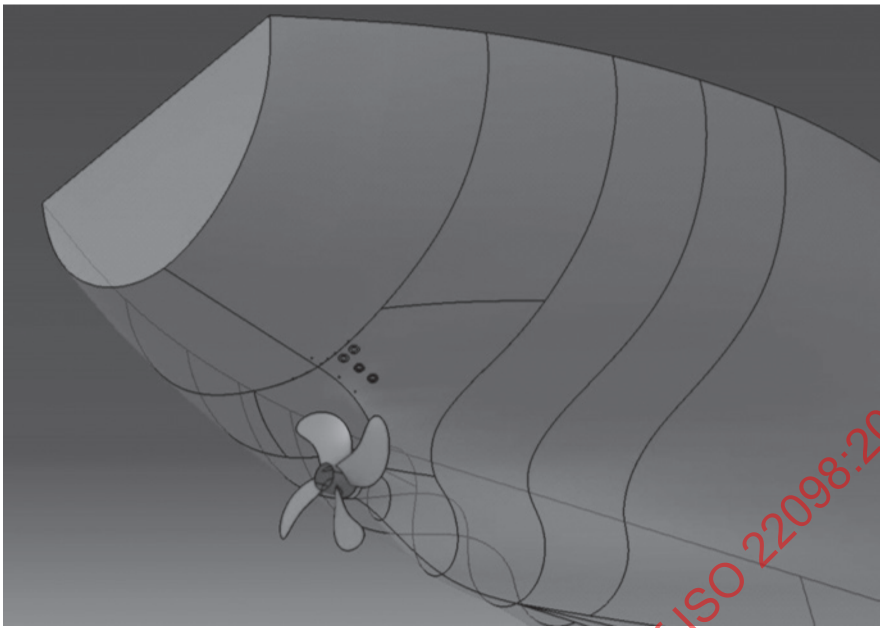


Figure 2 — Example of 3D modelling for the positioning of observation windows

4.2.4 High-speed camera

The high-speed camera used for the observation should be capable of shooting at weak daylight sources. The appropriate frame rate should be selected according to the weather conditions and the rotational speed of the full-scale propeller, since the frame rate and resolution have conflicting relationships. Several high-speed cameras can be used depending on the number of observation windows. In this case, a system configuration is recommended in which the cameras can be synchronized and recorded.

4.3 Hull pressure measurement

4.3.1 General

The hull pressures should be measured at the stern surface near the propeller where the maximum pressure fluctuation due to cavitation is generated. Pressure transducers should be installed on the stern surface above the propeller plane, and the measured hull pressures should be analysed by the signal processor.

4.3.2 Pressure transducer

The installation, position and number of the pressure transducers should be determined by considering the hull structure, the test purpose, the measurement range and the installation space.

The pressure transducers, if used, should be calibrated in accordance with the manufacturer's calibration reference.

An example of pressure pick-ups as mounted is a strain-gauge transducer, rated at a maximum pressure of 345 kPa and suitable for a frequency range from 0 Hz to 6 000 Hz in water, which is shown in Figure 3.

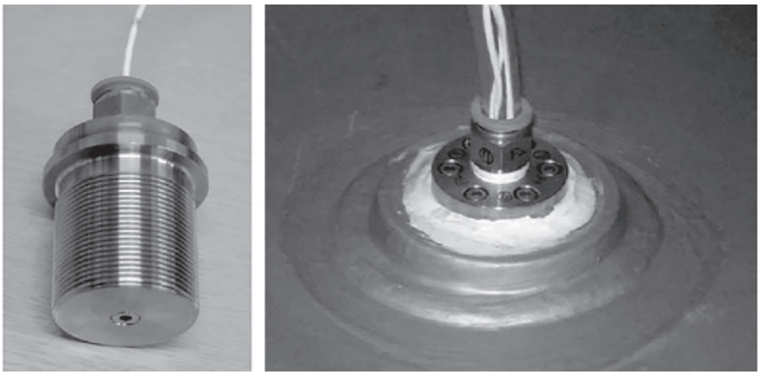
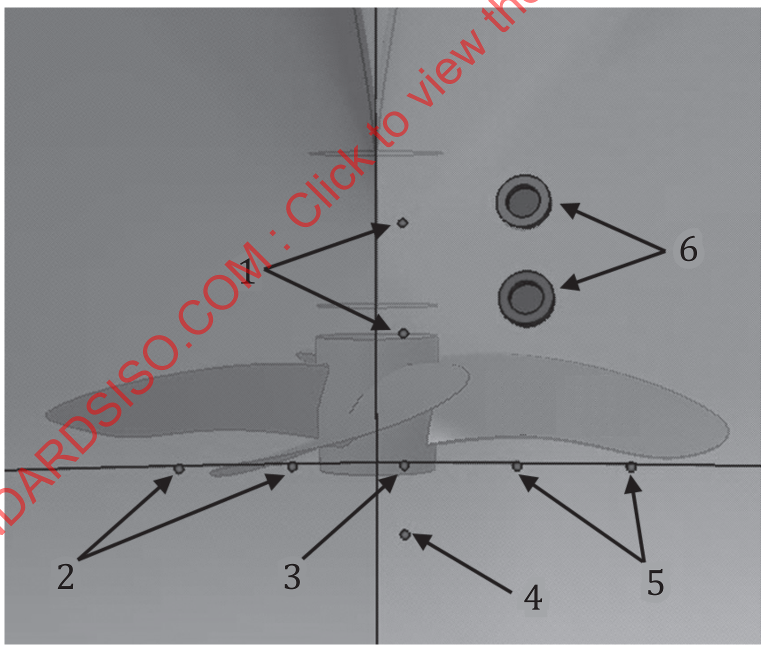


Figure 3 — Example of pressure transducers as mounted

In practice, the pressure transducers for a single-screw ship extend roughly from a distance 0,8*D* ahead of the propeller plane to 0,6*D* behind the propeller plane, where *D* is the propeller diameter. The maximum extension to port and starboard should be about 0,6*D* to 0,8*D*, depending on the hull structure of the installation location. In general, the distances between the transducers are in the range of 0,15*D* and 0,35*D*. If possible, a minimum of 5 transducers should be installed.

The installation position of the pressure transducers can be selected through a 3D analysis of the hull shape using CAD modelling. The position of the transducers should be carefully selected also taking possible model test results or CFD analysis into account. Figure 4 shows an example of position of pressure transducers.



Key

1 forward pressure transducers
2 port side pressure transducers
3 centre pressure transducer
4 afterward pressure transducer
5 starboard side pressure transducers
6 observation windows

Figure 4 — Example of the positioning of pressure transducers

4.3.3 Pulse controller

The pulse controller is needed to synchronize the location of the cavitation with the observation equipment, such as the camera, video, bore-scope and high-speed camera, etc. and pressure transducer due to propeller rotation. A rotary encoder or an optical sensor is commonly installed on the propeller shaft to generate continuous pulse and to control the generated pulse through the controller.

Figure 5 shows an example of a pulse generator installed on a propeller shaft.

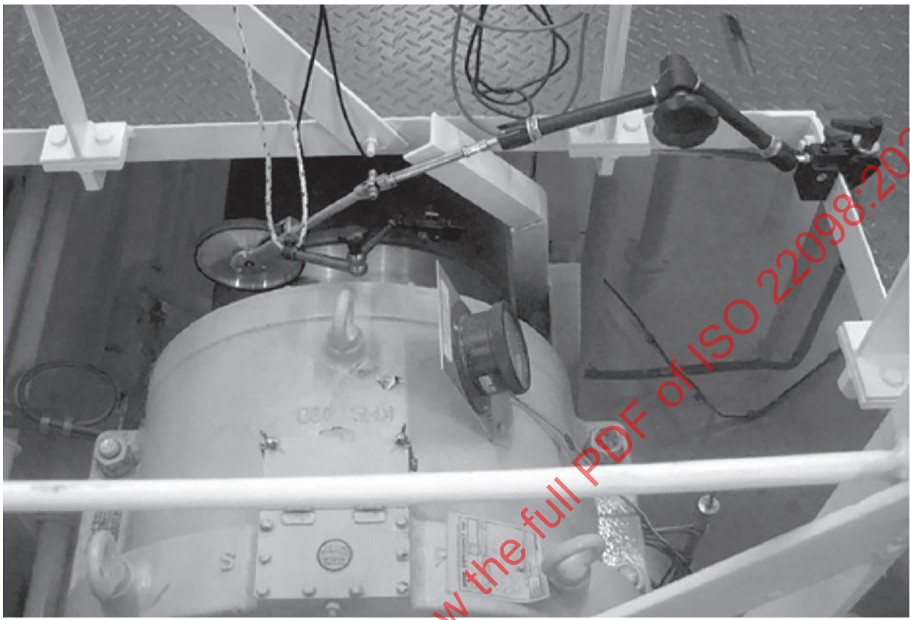


Figure 5 — Example of a pulse generator installed on a propeller shaft

4.3.4 Data processing system

A signal processing device should be installed for supplying power to a variable pressure sensor, and for amplifying and processing an output signal. It is necessary to support more than the sampling rate supported by the pressure transducer. It is also necessary to configure the measurement system that can simultaneously sample the number of channels according to the number of pressure transducers.

Sampling frequency of the pressure transducer should satisfy the Nyquist-Shannon sampling theorem, i.e. it should be at least twice the highest frequency under test. If possible, it is recommended to be over four times the highest frequency.

5 Construction requirements

5.1 General application

When the ship for full-scale test is in “after delivery stage”, the measurement section on the ship shells, where the observation windows shall be located, shall be designed and constructed not as a part of the ship shell, but as a “sea chest”. The thickness of the shell plates shall be carefully designed.

The observation windows shall be considered as “side scuttles”, as a practicable construction that shall meet the applicable requirements, such as IACS UI LL62[3] and/or IMO Resolution MSC. 143(77)[4]:

The observation windows together with their glasses, deadlights and storm covers, if fitted, shall be of approved design, and substantial construction of structural strength safety including water-tightness in accordance with, or equivalent to, recognised national or international standards. Non-metallic frames are not acceptable.

An example of configuration of cavitation observation is shown in Annex A.

Bore-scope holes and/or pressure transducer holes, when fitted with bottom plugs, shall also be treated as described above.

The observation windows shall be manufactured using such materials, and installed in accordance with such specifications, so as not to cause any problems in the installation of the ship.

The size and shape of the observation windows, the pressure transducers and window camera configuration can be decided on a case-by-case basis.

5.2 Safety clearance and water-tightness

When the observation windows are covered by a plate of bolted cover, safety clearance of possible leakage detection shall be confirmed (see ISO 5894[1]).

When cables cross the water-tightening section, such as bulkhead or deck, the cable holes shall be also proved to be watertight subject to approval of the relevant classification society and concerned flag administration.

6 Test and measurement procedure

The following items should be considered for the cavitation observation test and hull pressure measurement:

— test preparation of the propeller blade (cleaning and/or radial marks on the blade if necessary);

— installation and check of the observation equipment (camera, video, bore-scope, high-speed camera and strobe light, etc.) and/or the pressure measurement equipment;

— determination of the test conditions (ship speed and/or shaft power);

— resolution setting of the observation equipment (camera, video, bore-scope, high-speed camera and strobe light, etc.) as determined by considering the weather environment, the cavitation observation range and the shaft rotation speed, in case of cavitation observation;

— measurement time as set enough, considering the observation equipment resolution and the shaft rotation speed;

— test and measurement records more than twice under the same operating condition considering uncertainties.

During the sea-trial test, the measurement of the environmental data and the ship operating conditions that shall be reported, as listed in Clause 7, should be in accordance with the procedures given in ISO 15016[2]. In particular, the ship speed and the measured ship speed should be in accordance with the ship's speed in ISO 15016[2].

When the measurement of the pressure fluctuation and the observation of the cavitation pattern using high-speed cameras are planned at the same time, it is recommended to conduct both simultaneously so that the measured pressure signal can directly be correlated with the observed cavitation pattern[5].

Regarding hull pressure measurements, data should be recorded in the time domain and spectrum analysed. The most commonly used data treatment is harmonic analysis after averaging the measured values. From the frequency domain analysis, the signal amplitude can be determined for the harmonics of blade frequency. Thus, the amplitudes and the corresponding phase angles for the signals, such as maximum, minimum, mean and per cent highest amplitude, are determined.

In order to analyse the fluctuating pressure signal induced by the propeller, frequency analysis is performed for each blade frequency component. Since the pulse sensor is installed on the propeller rotary shaft, one pulse in the pulse signals corresponds to exactly one rotation period of the propeller.

Using information of one pulse per revolution, the entire interval of the measured signals can be divided into *m*-revolution intervals for one revolution.

A frequency analysis method of fluctuating pressure signals is shown in Annex B. Experiments of model scale hull pressure measurement can be analysed by data in accordance with appropriate procedures[6].

7 Reporting

The results of the full-scale cavitation observation test and the fluctuating pressure measurement data shall be reported with the following ship operating conditions:

— ship data (draughts measured at fore and after perpendiculars, arrangement of windows and transducers, location of shaft centre);

NOTE The draft of the vessel can be measured by observation or calculated.

— propeller data (propeller diameter and number of blades);

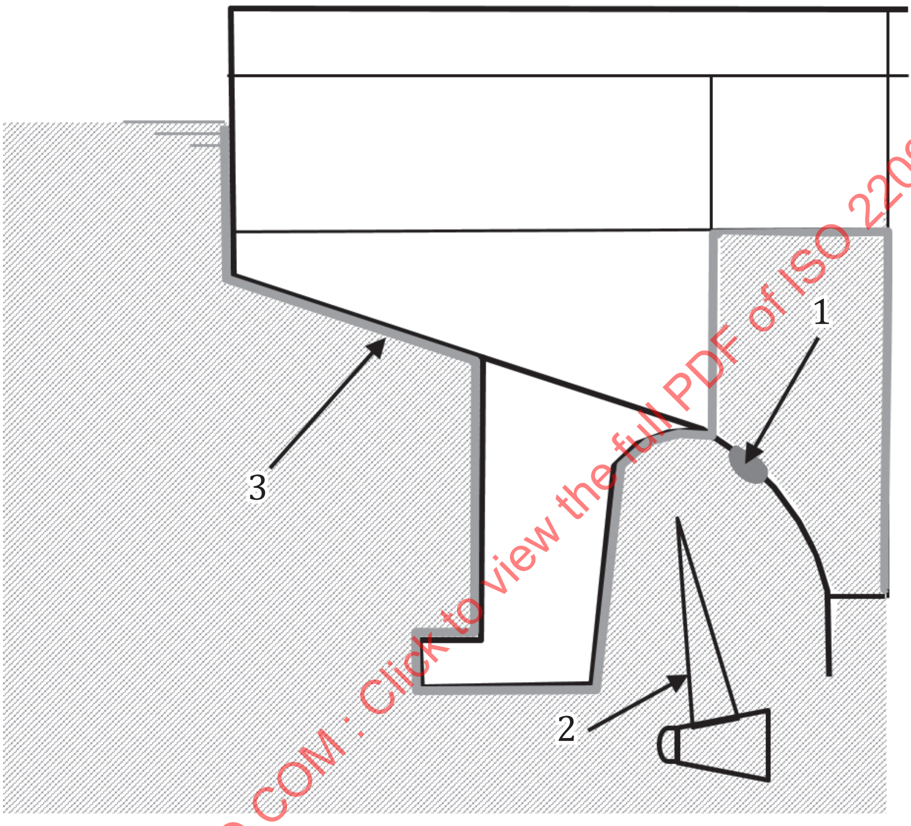
— test condition (ship speed, measured ship speed, engine brake power, propeller rate of revolutions and/or torque and/or thrust);

— environmental data (wind, sea state, water depth).

Annex A
(informative)

Example of configuration of cavitation observation

Figure A.1 shows an example of a sea chest structure fitted on the shell.



Key

1 observation window

2 propeller

3 sea water boundary

Figure A.1 — Example of a sea chest structure