INTERNATIONAL MONOHULL OPEN CLASS ASSOCIATION 60 FEET

WORLD SAILING INTERNATIONAL CLASS

MEASUREMENT PROTOCOL 2021

(English version)

Text applicable from 15 April 2021

Version V1

In relation to 'Measurement Protocol 2020 V0', modifications are indicated by a vertical line in the left-hand margin.

CONTENTS:

PREAMBLE:

In accordance with the current IMOCA Yearbook, the document entitled *'Measurement protocol'* is under the authority of *IMOCA*'s Technical Committee, which is responsible for defining the measurement and inspection procedures.

This document is associated without exception to the *IMOCA* Class Rule 2021 V4.0.
It uses the same abbreviations and with the exception of the titles of the appendices and paragraphs, the terms printed in:

- '**Bold**' refer, without exception, to an ERS definition,
- '*Italic*' refer to an RRS definition,
- '*Italic*' and '*underlined*' refer to a definition contained in the CR and in paragraph A.24 of the *measurement protocol*.

Each measurement, except where modified by the CM, shall be done in compliance with the ERS instructions and/or the ISO standards in force.
Where there is a conflict between the latter, the CM shall decide which ones apply.
The CM applies the various *measurement protocol* procedures and methodology for measurement, calculations and inspections used to establish the MC for the *IMOCA 60s*.

GENERAL PRINCIPLES

A.1 PROCEDURE

A.1.1 The procedures for measuring and inspecting the boats are outlined in CR A.8.
A.1.2 Paragraphs A.4 and A.5 of the *measurement protocol* must be applied prior to starting any measurement operation.
A.1.3 The presence of the *skipper* or their official representative is compulsory during the measurement procedures.
The skipper, in the event that they cannot attend, must designate their official representative.
A.1.4 All manœuvres and handling carried out are the responsibility of the *skipper* or their official representative designated above.

A.2 EQUIPMENT FOR MEASUREMENT, MEASUREMENT DATA AND CALCULATION SOFTWARE

A.2.1 Equipment for measurement

The following systems are used:
(a) Lead line, tape measures and rulers
(b) Laser telemeter
(c) Electronic level, laser level, sight and optical level with automatic setting
(d) Electronic load cell, force sensors, load sensors
(e) 3D recording system (via photogrammetry, laser tracker and laser scanner)
(f) Flow meter.
The CM will ask the IMOCA Measurer for certification of each piece of equipment used.
The CM will be able to impose the measurement system as well as the accuracy class for each measurement system.

A.2.2 Measurement data

The CM will record all the measurement data on a document called "**Fiche d'entrée (Listing report)**..."

A.2.3 Official calculation software

The software used for the various computer calculations (stability, righting moment, determining the air draught, water draught…) is the MAAT Hydro + software.

A.3 UNITS OF MEASURE

A *Measurement protocol* rule can modify the units of measure below.

Linear measurements:	Metres to 3 decimal places.
Weight measurements:	Kilograms and grams.
Force measurements:	daN and Newton.
Angle measurements:	Degrees to one decimal place.
Volume measurements:	Litre.

A.4 CONDITIONS OF MEASUREMENT

A.4.1 Lightweight configuration for the measurement operations

A document listing the *lightweight configuration* (CR Appendix H) details the different items that make up the *lightweight configuration*.
It is available and can be downloaded on the website www.IMOCA.org.
According to the measurement operations, the boat shall be in *lightweight configuration* and adhere to the configurations set out in CR Appendix H.
The *lightweight configuration* applied during the measurement operations is determined with the *hull appendages,* which must be in place and 'fully lowered' except when their respective positions are:

- o detailed in a rule
- o or by the CM.

The CM can specify a modification of these conditions, notably in terms of the hull appendages which, in this case, are the subject of a specific measurement with integration in the numerical model supplied and used prior to calculation.
Any other missing piece of equipment, which is listed in CR appendix H and is supposed to be aboard in *lightweight configuration*, is numerically added to the calculation model used.
Similarly, any piece of equipment not required in *lightweight configuration*, which is aboard the boat during measurement operations and whose weight and CG has been checked beforehand can be numerically subtracted in the calculation model under the authority of the CM.
The CM reserves the right to make changes to it in a bid to improve the data acquisition process generally.
When several measurement methods are proposed or possible, it is the CM who will choose which method to use.

A.4.2 Measurements ashore

Measurements ashore shall be made in such a way that they are sheltered from the rain and wind.
The optimum temperature requirement is 20° Celsius.
If the temperature requirement differs from this, corrections may be made to the measurements at the CM's discretion.

A.4.3 Measurements afloat

Measurements afloat must take place on flat water, with waves of less than 15mm, less than 5 knots of wind, no rain and no current.
If conditions differ, corrections may be made to the measurements at the CM's discretion.
The salinity (SG) of the water is recorded during measurements afloat.
The salinity of 1,025 is used for all the numerical calculations (water draught, air draught, stability, RM, etc.)

A.5 INSPECTIONS ACCORDING TO CHECKLISTS

A CR checklist is available in the form of 2 PDF documents from the *IMOCA* secretariat (contact@imoca.org):

- *Measurement checklist* which takes up CR relating to certain aspects of the measurement (deck layout, cockpit, watertight bulkheads, etc.)
- *Safety checklist* which takes up CR relating to safety equipment aspects.

An *IMOCA* measurer will carry out these checks with the *skipper* or their official representative, filling out the different items in the documents, which must be signed by the *skipper* or their official representative.

A.6 BUOYANCY

(See CR D.4)

A.6.1 The volumes taken into account for the buoyancy calculations

- The combined volumes of the fixed elements to the exclusion of the empty compartments of the following elements of the boat for which the filled sections will be taken into account (including Nomex and foam sandwich):
  - The hull shell including the transom, the deck including the whole superstructure (roof + fixed cuddy), the internal structure including the cockpit(s) and the ballast tanks but without the associated fit-out
  - *keel*
  - *rudders*
  - *foils*
  - traction engine + inverter / 20L fixed volume
  - hydraulic keel equipment / 60L fixed volume
  - Any volume of closed cell foam, that is non-detachable, laminated or bonded directly onto the structure of the hull or firmly attached.
    This foam volume must be protected using suitable covering or protection, which is sufficiently hardwearing to preserve the integrity of the material for its required function.
- The spars and all the rigging are not taken into account in the calculation of the buoyancy volume.
- An empty compartment (such as a former ballast tank or ballast tank section) not filled with closed cell foam, will not be taken into account in the buoyancy volumes.

Comment regarding recycled ballast tanks:

- In order not to be counted as water ballast (volume), a former ballast tank shall be sufficiently open (substantial removal of walls).
- A hole in the lower section is not sufficient to warrant its exclusion for the water ballast.
- Any filling and draining equipment related to this former ballast tank shall be completely stripped out.
- The complete filling of a former ballast tank with closed-cell foam is strongly recommended and enables the volume not to be included as a ballast tank.
- The CM may not validate these modifications if they do not adhere to the recommendations above.
- The *skipper* or their official representative shall get in contact with the CM prior to any operation to modify ballast tanks.

The sum of the different elements retained above is referred to as the buoyancy volume for calculating insubmersibility.

A standard form is available below.

Conformity to CR D.4

Buoyancy volume	Rule D.4(a)
SANDWICH	
Hull sandwich	
Deck sandwich	
Cuddy sandwich	
Internal structure sandwich	
INTERIOR FIT-OUT	
Chutes	
Winch furniture	
Chart table	
...	
...	
Buoyancy foam already in place	
...	
...	
Traction engine + inverter	
Fixed volume	20 litres (Fixed volume)
KEEL & SYSTEM	
Keel fin	
Bulb	
Canting system	60 litres (Fixed volume)
Rudders	
Foils	
...	
Total volume taken into account in m3	

Boat weight (*lightweight configuration*)	
Displacement of the boat (weight / 1.025) in m3	
Buoyancy volume in m3 to be added to obtain (buoyancy/Displacement of the boat) > 105%	
Buoyancy volume ratio	

A.6.2 Buoyancy calculations

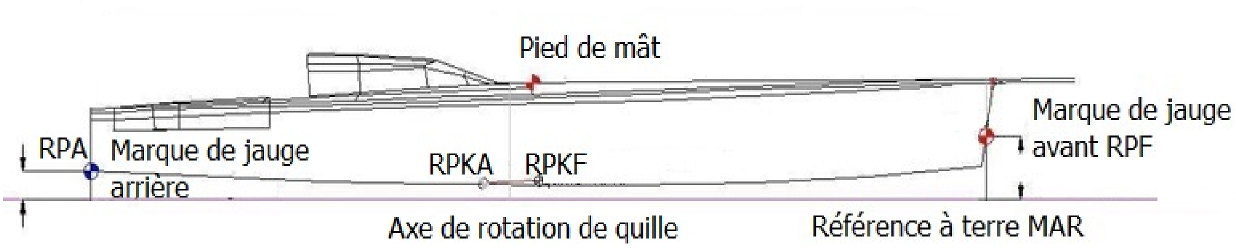
- The displacement of the boat in m3 is obtained in the following way:
  Boat weight in lightweight configuration / 1.025
- The buoyancy volume ratio of the boat's displacement in *lightweight configuration* must be equal to or greater than that defined in CR 2021 & 2025 D.4(a).

A.6.3 Longitudinal distribution of the buoyancy volumes

The fixed buoyancy volumes shall be distributed in the boat in such a way as to favour buoyancy, in the event of damage, thus enabling the *skipper* to move around inside the boat and isolate themselves in the best possible conditions.

A.7 MEASUREMENTS ASHORE

Diagram of the principle of measurement markers or points:
(the values indicated are given by way of an example)



A.7.1 Implementation of the forward and aft measurement markers

These markers shall be visible (marked by a small diameter drill hole, a screw or any other permanent device) and enable a freeboard measurement (distance between the marker and the boat's flotation waterplane).
These markers will be put in place under the authority of the *skipper* or their official representative and with the consent of the CM.

(a) RPA, marking to aft on the boat
(b) RPF, marking up forward on the boat

A.7.2 To check the hull in 3D (overall check)

Preamble: The aim of the measurements below is to verify the numerical model used in MAAT hydro+ which is the one provided by the *skipper* or their official representative.
The check involves creating point clouds.
The latter is carried out using photogrammetry, laser tracker or laser scanner...
The process used will be capable of producing a 3D numerical file of points (x, y, z), which are to scale.
This numerical file of points will be compared, in the form of a cartography of the deviations, with the numerical model provided.
If necessary, where there are differences between the 3D model made with the measurements and the numerical model provided, the latter will be corrected under the authority of the CM.

The method enables:
- The geometric validation of the **hull** with its coachroof and possible cuddy

The aim of the operations is to position the actual boat into the boat reference to check that the boat conforms to the CR.

A.7.3 *Hull length* and *LOA*

(See CR D.2(a)&(b))
Necessary when the overall check outlined in A.7.2 of the *measurement protocol* does not enable the measurement to be obtained.
In the case of an overall check, it is necessary to at least check the *hull length* using another measurement procedure.

A.7.4 Hull beam

(See CR D.2(c)&(d))

Necessary when the overall check outlined in A.7.2 of the *measurement protocol* does not enable the measurement to be obtained.

A.7.5 Position of the mast foot

(See CR AC.2.2)

Necessary when the overall check outlined in A.7.2 of the *measurement protocol* does not enable the measurement to be obtained.

A.7.6 Longitudinal position and angle of the axis of rotation of the keel

(See CR E.2(c))

Necessary when the overall check outlined in A.7.2 of the *measurement protocol* does not enable the measurement to be obtained.

A.7.7 Parameters associated with the keel

These procedures are carried out with the *keel* laid flat on the ground.

(a) Checking the 3D numerical model of the fully assembled keel using photogrammetry or a laser system.

The aim of this check is to verify the actual model of the *keel* in relation to the numerical model of the *keel* provided.

- Enables the geometry of the underside of the bulb to be recorded in relation to the axis of rotation of the bulb.
- Enables the bulb shape to be checked in order to establish its volume and verify its density
- Enables the compliance and non-modification of the keel fin for standard keel fins.

(b) Prior to assembly, recording the weight of the keel fin and the weight of the bulb.
Note the filling of bulb cavities when these are present.

(c) Establish the *keel*'s weight and CG:

c.1. *Keel* weight measured at 1 hoist point (load cell at keel head).

c.2. The keel fin and its bulb being suspended horizontally (trailing edge and axis), with two load cells, one load cell at the keel head (keel ram pin) and one load cell at the bulb.
The horizontal distance between the two vertical load cell axes shall be noted.

These measurements will enable the *keel*'s centre of gravity to be calculated.

A.7.8 Water draught

Vertical distance between the boat's flotation waterplane and the lowest point of the boat in *lightweight configuration*.

The water draught is established on the MAAT Hydro+ software from the numerical model validated by the CM for the different calculations necessary for obtaining the Measurement Certificate.

A.7.9 Air draught

Vertical distance between the boat's flotation waterplane and the highest point of the boat measured in *lightweight configuration*.

The masthead equipment (mast wands, VHF and AIS antennae, cameras and other systems validated by the CM, and their brackets) is not taken into account in the air draught.

The air draught is the sum of:

- the mast length measured from the control point on deck modified by the mast rake (maximum 4.0 degrees) under fixed forestay in *lightweight configuration*,
- the freeboard at the mast foot,
- possible overhangs by sails and their equipment (these overhangs are measures on the sails in question, see paragraph A.7.9(c))

(a) Freeboard at the mast foot

The freeboard at the mast foot is established.

(b) Mast length

The mast receives a conformity certificate which refers to its length.

(c) Geometry of the highest sails.

- Angle of the highest section.
- Position of the head of the mainsail at the highest possible point on the mast.
- Check that no sail exceeds the top of the mast (outside masthead equipment).

A.7.10 Weighing the boat

The Measurer ensures that the boat is in *lightweight configuration*.
It is the responsibility of the *skipper* or their official representative to ensure that the boat is correctly in this configuration and notably that all the compartments, ballast tanks, etc. are empty.
The only exception relates to the tanks for the hydraulic systems and the traction engine (See CR C.6.1), which must remain operational and contain the levels of liquid (oil, minimum of 5 litres of fuel…) necessary for normal working order.
The weight recorded using 1 or 2 load cells will be expressed in kg.
In the event that a boat's weighing procedure fails to respect the 1-hoist point weighing process, the 2-hoist point weighing process which may be envisaged shall be agreed by the CM prior to implementation.

A.7.11 Locating and proportioning of the ballast tanks in the boat

(See B.3.7 of the *measurement protocol*)

A.7.12 Installing the standard rig on the boat

- Record the penetration of the mast step (see A.7.2 of the *measurement protocol*).
- Record the installation of the anchorage points of the *standard mast* rig.

A.7.13 Establishing the sheer line.

Each transverse half section of the **hull** contains a sheer line point, which is established according to the method outlined below.
In the event that the method below does not enable this point to be established, the CM will decide what this point is.
Method for determining a sheer line point:
- Consider a transverse half section in the *boat reference*.
- From the point located at the widest point of the half section, look into the possibility of making a 45° line tangent (line represented by an electronic level or equivalent) by moving this line up to the highest point on the section.
- The 1st tangential point located corresponds to the sheer line point to be considered.

The theoretical sheer line shall be provided in the numerical model supplied and referred to in Appendix C.3 of the *measurement protocol*.

A.7.14 Establishing whether the points curve of the sheer line shows any curve inversion.

(See CR D.2(e))
The points curve points of the sheer line shall be provided in the numerical model supplied and referred to in Appendix C.3 of the *measurement protocol*.

A.8 MEASUREMENTS AFLOAT.

The on-the-water measurements or tests to be carried out with the boat in *lightweight configuration*:

A.8.1 Measurement of the freeboard at points RPF and RPA, boat at 0° heel.

A.8.2 Measurement of the density of the seawater (SG).

A.8.3 Mast rake

A.8.4 Angle between the outrigger and its tie-rod (standard rig).

A.8.5 90° test:

- freeboard at point RPF
- load at masthead FDYNA
- angle of the hull
- distance deck/LDYNA load cell.

A.8.6 Measurement of each ballast tank

A.8.7 Measurement of any overhang by the spars at the boat's aft section.

A.8.8 Measurement of the engine traction using the load cell (traction at a fixed point) and the speed of the boat under power (5 hours at a minimum 5 knots).

A.9 RESERVED

A.10 NDT OF THE KEEL

A.10.1 NDT for all keels

Preamble

The NDT report of the keel must be drawn up by an expert or experts with recognized know-how, using appropriate and relevant means, and in good faith.
The aim is to identify the type of surface and volume defects, as well as the presence of corrosion, which may have an impact on the reliability of the keel fin.
A detailed report of the checks and tests will be provided to the CM.
It shall be endorsed by the *skipper* and their official representative.

A.10.1.2 NDT on any keel fin and associated attachment systems

(See CR A.8.3)
The NDT must adhere to the period of validity outlined.
It is the full responsibility of the *skipper* and their official representative to have the test performed and it is designed to highlight any defects that may be detrimental to the reliability of the keel.
The checks will be a minimum of those recommended below according to the keel fin type, but they must be completed, if it is deemed useful to do so, by the experts involved in these checks (designer/manufacturer/inspector/*skipper* or their official representative...)
With the expertise and means associated with these NDT tests changing all the time, any other technology can be brought in that improves the relevance of these checks in relation to the desired objectives.
In this case, specifications for preparing the keel fin for testing will be able to modify points (a) and (b) of paragraph A.10.1.2 of the measurement protocol regarding preparation of the keel fin for its test.

For all the keels, the following elements must be supplied by the *skipper* or their official representative to the NDT operator who will carry out the NDT. The test report shall contain these elements:

- Keel builder
- Designers
- Date of manufacture
- Keel material
- Test document from the pre-processed block prior to milling
- Date and report from the latest tests (all)
- Builder/designer's document detailing the planned lifespan of the keel
- Owner's attestation about any damage and modifications to the keel
- Keel plan

These documents must be a prerequisite prior to testing.

(a) **Keel fin according to Appendix A-1 or Appendix B-1 and solid steel keel fin built before 2013**

All keel fins shall have a minimum of:

- Keel boss plate removed
- Access to 2 sides of the keel

Removal of the bulb at each test.
Taken back to bare metal to enable the implementation of the various NDT test processes.
Tests are of the visual type, dye penetrant inspection, magnetic testing, etc. with a search for flaws of a fatigue crack nature and the presence of corrosion.
Any other test will be set up when it is deemed necessary to do so by the NDT tester and/or the keel fin designer.
Dye penetrant inspection/magnetic testing or the replacement of the bulb locking pins.

(b) **Carbon keel fin**

(See CR AA.1.8 with NDT valid for 2 years)
An expert (or a reputed competent body) shall impose the necessary inspections and, at the end of the inspection, shall validate the keel integrity.
Submitting of the NDT test to the designer of the keel fin, who will then supply *IMOCA* with the keel fin validation.

A.11 DEFLECTION TEST OF *IMOCA*'S STANDARD ELEMENTS

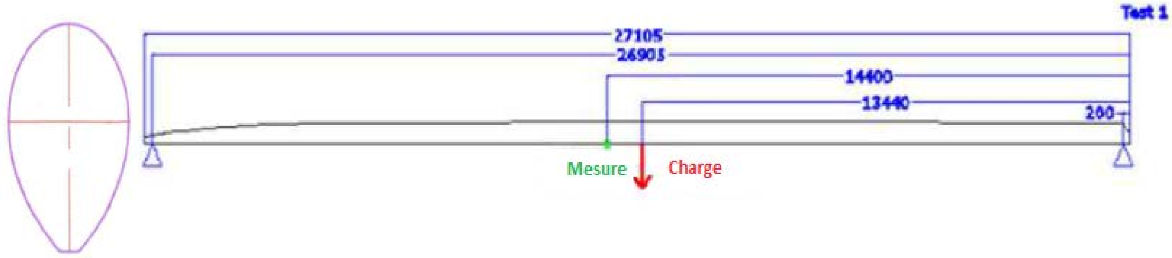
The values of the deflections recorded below will be indicated in the corresponding compliance certificates.

A.11.1 Principle of the deflection test of standard keel fins

This test is performed on a bench developed specifically for carrying out this test.
The keel fin shall be placed in the theoretical horizontal position.
To achieve this the keel fin is supported on its 2 trunnions specifying its axis of rotation and located at the keel head by the keel head pin (keel ram liaison).
This configuration is referred to as 'upright keel fin'.
(a) A vertical load of 3000 kg is applied at the tip of the keel fin in the upward direction then the load is removed and the keel fin returns to the upright position.
(b) A vertical load of 3000 kg is applied at the tip of the keel fin in the downward direction.
The deflection is recorded and will be the deflection indicated in the keel fin compliance certificate.
The keel fin deflection shall be measured vertically from the zero position, which is outlined by the 'upright keel fin' configuration.

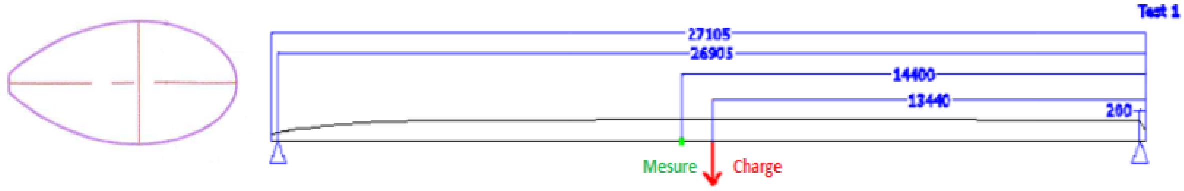
A.11.2 Principle of the deflection test of standard masts (bare tube after release from mould)

The deflection test shall be carried out on the bare tube on release from the mould.
The mast is supported across 2 zones as specified in the diagrams below.
(a) Longitudinal deflection test (aft face of the mast supported according to the diagram)
Application of a 500 kg load some 13,440 mm from the end of the mast foot and recording of the deflection some 14,400 mm from the end of the mast foot.



(b) Transverse deflection test

Application of a 250 kg load some 13,440 mm from end of the mast foot and recording of the deflection some 14,400 mm from the end of the mast foot.



A.12 WEIGHT OF THE STANDARD MAST

[See CR AC.4]
Measurement trim of the position of the CG and weight of the 'basic mast':
The 'basic mast' comprises all the elements of the rigging, which can be attached to the tube via screwing or gluing like the reinforcements and any screwed and/or glued plates required for the different pieces of rigging equipment as outlined in the specifications for the standard mast, and all the equipment directly linked to the tube like the pins, sheaves and the only head car on the mast track.
The 'basic mast' does not include the components related to navigation lights, mast wand/anemometer, radar (and its bracket) or other systems like the camera(s) and the various cables (electric, VHF, fibre optic…) and any equipment mentioned by the CM.
Added to the 'basic mast' weight is all the transverse standing rigging (lower shrouds, top shrouds and outriggers with their pins without the outrigger tie-rods).
Put in place the corrector weights to obtain a total weight for the *standard mast* defined in CR 2021 & 2025 AC.4(c))

A.13 COMPLIANCE FORM FOR *IMOCA*'S STANDARD ELEMENTS

The standard elements compliance forms recap the data supplied by the firm, which built these elements.
The aim of these forms is for *IMOCA* to ensure the specifications have been adhered to.
There are 3 types named under the following generic names:
1 – STANDARD MAST COMPLIANCE FORM…
2 – STANDARD KEEL COMPLIANCE FORM…
3 - STANDARD KEEL CANTING SYSTEM COMPLIANCE FORM

A.14 INSPECTION REPORT FOR THE AIS INSTALLATION

Rule CR C.7.2 states that the AIS installation conformity certificate must be submitted to the CM in order to obtain the MC.

The rule is intended to check the coherence of the coaxial feeder cable installation in relation to the antenna.
- The cable and the antenna shall have the same impedance,
- The cable shall have no more than 40% power loss.

A coaxial feeder cable causes an attenuation of the signal being transmitted according to:
- the transmitting frequency (marine VHF, AIS: 156 to 162 MHz);
- the length of the cable;
- the cable type.

The signal attenuation in the cable is expressed in decibels (dB).
The power loss in the coaxial feeder cable is due to the attenuation (A) of the signal.
P1 relates to the output power of the transmitter and P2 relates to the power received by the antenna.
Attenuation A in dB = 10 * log (P1 / P2)

Where the AIS is a Class B, namely 2W power transmission:

A supply of 2W via the input cable corresponds to an output of at least 1.2W from the coaxial feeder cable.
The attenuation A in dB related to the coaxial feeder cable is calculated using the following formula:
A dB = 10 * log (2/1.2) = 2.2185 dB (corresponds to the maximum allowable attenuation)

A spreadsheet is available from the *IMOCA* Secretariat (contact@imoca.org).

The mounting compliance certificate issued within the past year shall include:
- The name of the organisation that checked the installation
- The type of VHF antenna and its impedance
- The type of coaxial feeder cable (e.g. LMR400), its impedance and attenuation per metre in dB for a frequency of 156.8 MHz
- The length of the coaxial feeder cable
- The connectors, if any, (apart from the connection to the antenna and the transponder) and attenuations in dB
- The brand and type of AIS and VHF transponder
- An SWR measurement of 160 Mhz.

A.15 SELF-RIGHTING TEST

For the 180-degree self-righting test, the boat's CG in *lightweight configuration* is modified to take into account the specification of the CR D.5.5 and that the boat is considered without the mast, outriggers, rigging and boom, and with the *foils* in the least favourable position.
In this way, we define the weight and the CG of the equipment which is not taken into account.
The boat must right itself by canting the keel at its maximum authorised angle, which enables the whole stability curve area to be completely inside the positive zone (GZ always positive).

A.16 MINIMUM WEIGHT OF THE RADAR

(See CR C.3.14(b))
A list of radar(s) is drawn up by the CM and made available from the *IMOCA* secretariat (contact@*IMOCA*.org).

A.17 SYSTEM FOR DETECTING USE OF THE PROPELLER SHAFT

(See CR 2025 C.6.1(g))
A procedure is drawn up by the CM and made available from the IMOCA secretariat (contact@IMOCA.org).

A.18 VALIDATION OF THE ASSOCIATED FOIL SYSTEM

(See CR E.4(l))
A file which includes the diagrams, construction plans, materials used, etc. and a specific file of the *foil* system shall be presented to the CM detailing how to check and measure the first *degree of freedom* as well as the second *degree of freedom*, if there is one.
These files shall be validated by the CM to check they adhere to CR E.4:
1) 'on the files' => pre-validation prior to being built and installed on the boat.
2) on the boat => validation.

A.19 STATIC MOMENT OF THE FOIL

(See CR E.4(c)(i))

The *boat* is placed in the *boat reference*, in accordance with the CR in force, at rest, with zero heel and in *lightweight configuration* with the two *foils* retracted fully and symmetrically (See Paragraph C.3 of the *measurement protocol*).
The *foils* are then extended, which gives the maximum static moment, without modifying the position of the boat in the *boat reference*.
The second *degree of freedom* of the *foils*, if there is one, is taken into account.
To achieve this, the *foils* are positioned at their minimum and maximum angle of rotation.
We determine the case which leads to the maximum static moment.
Solely the *foil* sections whose Y coordinates are greater or equal to 2925 mm are taken into account for the next stage of the calculation procedure.
The calculation takes into account:

- the same section of the *foil* for each 1 degree step in the rotation of the boat between 0 degrees and 25 degrees.
  This rotation is made around the X axis from one side to the other.
- the projected surface on the XY plane of the contour of the *foil*, whose points have Z values less than or equal to 0.
- the Y of the centroid of this projected surface.

The static moment in m3 of each projected surface is equal to:

- The projected surface area * Y value of its centroid.

The greatest static moment calculated is that which characterises the *foil*.

A.20 DEVELOPED SURFACE AREA OF THE FOIL

[See CR E.4(c)(ii)]
The whole of the developed surface area of the *foil* corresponding to its exterior is taken into consideration according to the lower surface and upper surface of the *foil*.
The surface of the trailing edge is not included and nor are the surfaces generated by the apertures or other devices unless the CM deems that these surfaces shall be included in the calculation.

A.21 FOIL LENGTH WHEN RETRACTED

[See CR E.4(d)]
The *boat* is at rest, at zero heel and in *lightweight configuration* with both *foils* retracted fully and symmetrically (See Paragraph C.3 of the *measurement protocol*).
We check that both *foils* are fully retracted simultaneously and symmetrically as far as the boat's centre plane.
We measure the distance between the XY plane of the *boat reference* from the point on each foil that has the greatest Y.

A.22 Y VALUE OF THE CENTROID OF THE SECTIONS

[See CR E.4(e)]
We place the *foil* in the position that presents the maximum static moment and we check the Y value of the centroid of all the section sections.

A.23 DIMENSIONS OF THE FOIL FENCES

[See CR E.4(f)
Diagram of a 50 mm fence.

A.24 DEGREES OF FREEDOM OF THE FOIL

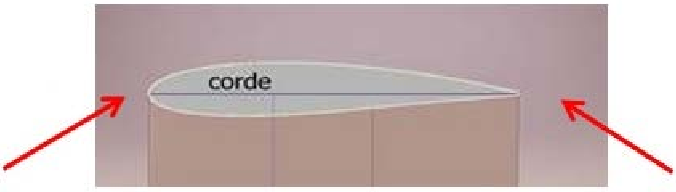
(See CR E.4(h)&(i))
We specifically use the following definitions applicable solely for this procedure:

Leading edge: Foremost point of the *section* that has maximum curvature (minimum radius).

Trailing edge: Aftermost point of the *section*.

Chord line: Straight line segment connecting the *leading edge* and *trailing edge* of a *section* {See diagram below}.

Section: Normal surface area of the *foil* {Grey element in the diagram below}.



Leading edge *Trailing edge*

Head of the foil: Section of the *foil* which retracts into and extends out of the hull shell, whose *sections* are constant and which enables the A1 axis to be characterised.

We check that the *head of the foil* is an extrusion of the following *section*:
- an A1 axis (rectilinear *head of the foil*)

or

- a surface of revolution with a constant radius of curvature around an A1 axis (curved *head of the foil*).

We check that the first degree of freedom is:
- a translation following A1 axis (rectilinear *head of foil*)

or

- a rotation following this A1 axis (curved *head of foil*).

And this is the case whatever the angle of rotation of the second *degree of freedom*, if there is one.

We check that the second *degree of freedom*, if there is one, is a rotation of the *foil* following an axis referred to as A2 when the *foil* is in the fully extended position.
The A2 axis shall be secant with a *chord line* on the foil.

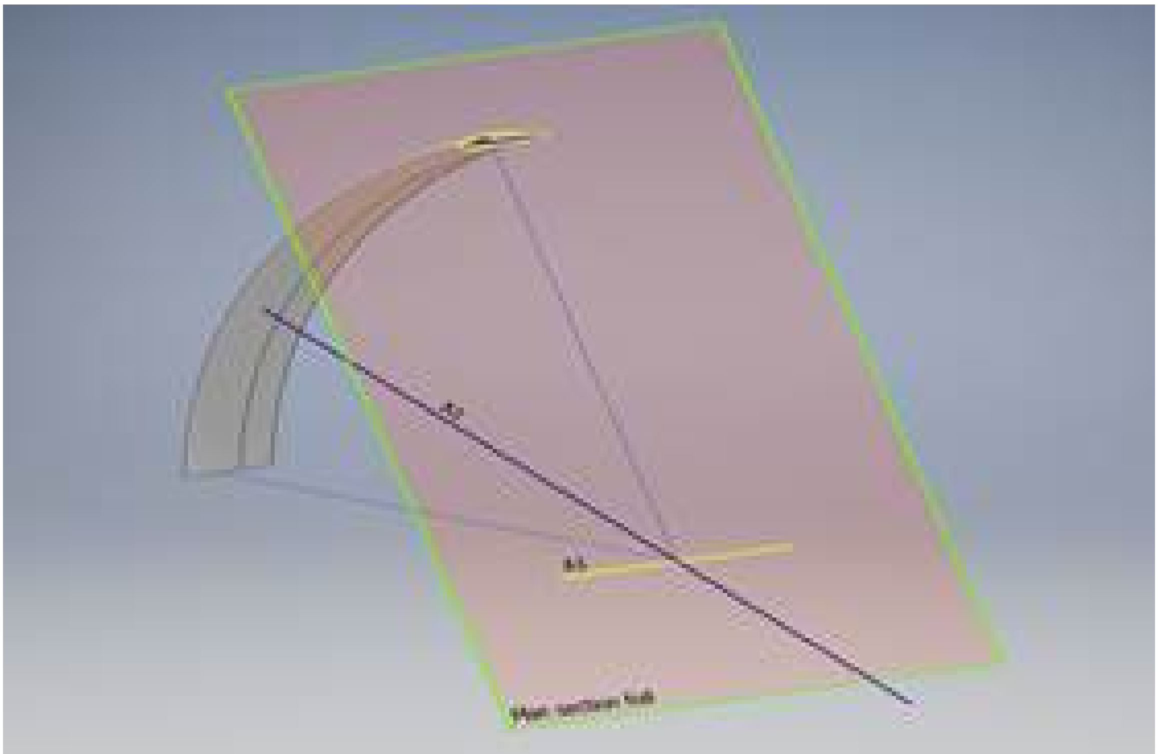
We check whether:

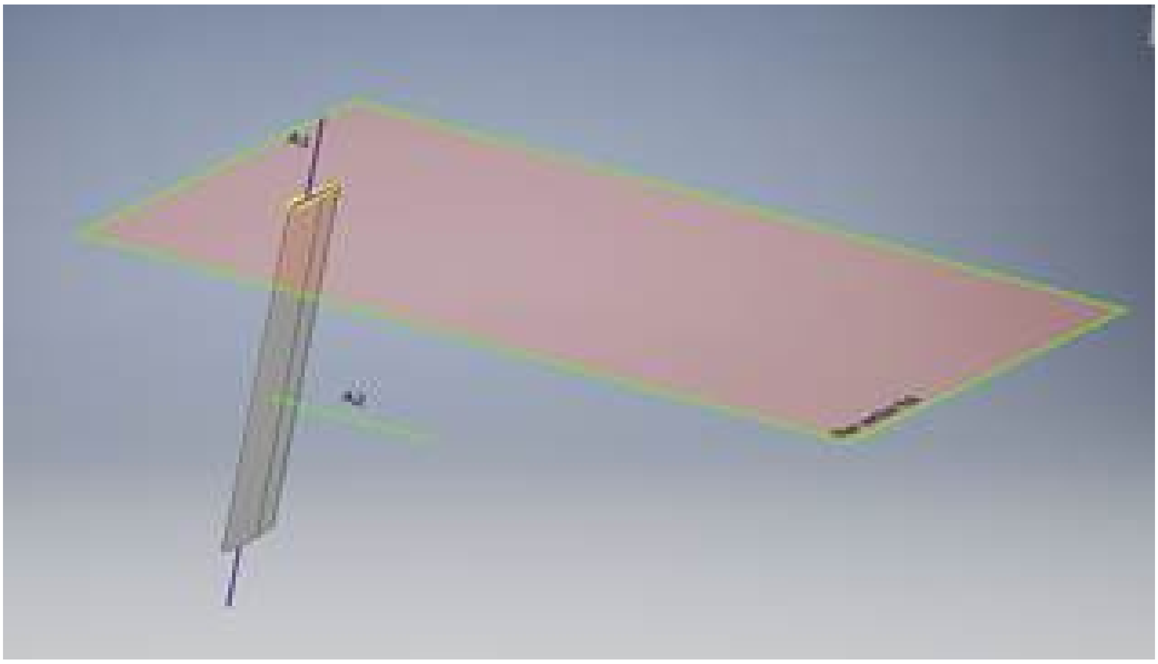
- the A2 axis is perpendicular and secant to the A1 axis and to the *chord line* of the foil (rectilinear *head of foil*)

or

- the A2 axis is perpendicular and secant to the A1 axis (curved *head of foil*).

We check that the second *degree of freedom*, if there is one, is a rotation of the foil limited to 5.0 degrees.
We also check that there is an intersection (a point 'A') close to the hull between the A2 axis and the *foil* for all the angles of rotation linked to the second *degree of freedom*, if there is one.
It can be assumed that the A2 axis is not isolated in the *boat reference*.
The A2 axes produced by the second *degree of freedom* shall be secant at point 'A'.
All the A2 axes shall be included in a half-angle cone of revolution at the top of 1.0 degrees culminating in point 'A'.
In the event where the second *degree of freedom* leads to one or some parasitical movements, the CM deems whether or not the system provides any advantage in terms of the trimming of the *foil* and the possibility of considering whether or not any system adheres to the CR.





A.25 VALIDATION OF THE FOIL GROUNDING

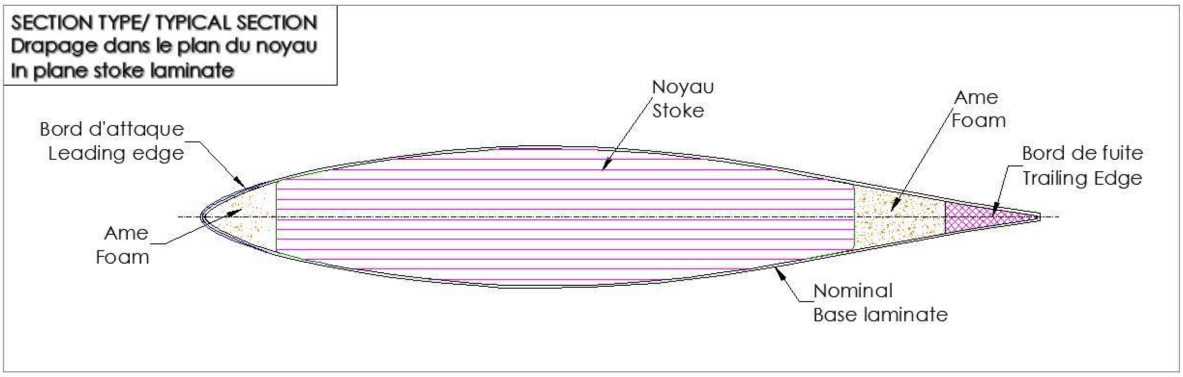
[See CR E.4(k]

A.26 ACTIONS LINKED TO THE FOIL

- Compare the actual *foil* with the provided 3D (CAD) numerical model used in MAAT Hydro+ software using a process of photogrammetry or a laser system.
- Determine the weight and CG of the actual *foil*.

A.27 FOIL STOCK MANUFACTURING METHOD

[See CR 2025 AG.2(c)]



The core of the *foil* is built (lay up) according to the so-called (In the Plane) principle; the HM fibres are then permitted on the sole proviso that they are arranged in such a way that they strictly adhere to the diagram above (parallel to the *foil* chord line).
When the core of the *foil* is built (lay up) according to the so-called 'Outside the Plane' principle, the HM fibres are strictly prohibited in this case.

A.28 COMMERCIALLY PRODUCED SENSOR

[See CR 2025 Section H]
The CM draws up a list of sensors which conform to the demands of CR Section H.

MEASUREMENT SESSION

B.1 MEASUREMENT

Paragraphs B.2 and B.3 of the *measurement protocol* specify, when necessary, the methodology and/or measurement operations indicated in the GENERAL PRINCIPLES of the *measurement protocol*.
All the operations require interventions on the boat and/or on a computer.

B.2 MEASUREMENTS ASHORE

B.2.1 Measurement plane (MAR: Measurement ashore reference)

The boat must be in a measurement plane ashore so that the DWL stated in the numerical model provided is horizontal and notably for the operations defined in paragraphs A.7.3, A.7.4, A.7.5, A.7.6, A.7.13 and A.7.14 of the *measurement protocol*.
Some of these measurement procedures are not required if they have been carried out during the overall check outlined in A.7.2 of the *measurement protocol*.
The Measurer can request a modification to the MAR drawing if he deems it is too 'far' off the actual waterline plane.

B.2.2 Overall hull check

(See A.7.2 of the *measurement protocol*)
The *skipper* or their official representative shall make the hull of the boat exclusively available for an entire day for this operation.
No other procedure or access to the boat will be possible.
The mast step shall be in position on deck.
The keel bearings shall be in position on the hull.
To enable access to the whole of the boat's exterior hull in the conditions imposed by the photogrammetry or laser scanning technologies, it will be necessary to adhere to the points below:

- Boat not protected (deck totally clear with deck fittings in position)
- Boat entirely clear of any element linked to the construction (scaffolding, etc.)
- Minimum 4-metre space around the boat
- The possibility of lifting the hull to calculate the hull bottom and the keel axis

The *skipper* or their official representative shall provide stable and safe mobile scaffolding enabling either shots to be taken for the photogrammetry or positioning of the laser scanner.
The height must be sufficient for a clear, overhead view of the deck (a minimum of 3 metres above the deck), and the same for the hull bottom.

B.2.3 Positioning of the axis of rotation of the keel

See diagram in A.7 of this *measurement protocol*.
In the case of the non-overall measurement according to A.7.6 of the *measurement protocol*, it is necessary to record the longitudinal positions of the following 2 points:

- o RPKF: centre of the forward bearing of the keel rotation on the keel side.
- o RPKA: centre of the aft bearing of the keel rotation on the keel side.

B.2.4 Weight of the keel fin and bulb and CG of keel

B.2.4.1 The keel fin and bulb shall be weighed independently at 1 hoist point.
The configuration will be recorded with the filling of the bulb cavities if these are present.

B.2.4.2 Weighing of the complete keel at 1 hoist point.
The *skipper* or their official representative shall allow the necessary means for lifting the entire keel (fin with its fairings and bulb attached) at 1 hoist point, enabling the weighing of the latter.

B.2.4.3 Weighing of the keel at 2 hoist points.

To determine the position of the CG of the keel (fin with its fairings and bulb attached), the *skipper* or their official representative shall allow 2 means enabling the weight at the bulb as well as at the keel ram axis to be determined with the keel horizontal.
On the bulb side, the *skipper* or their official representative shall anticipate straps to hold the bulb. The 2 load lines must be vertical and the distance between the 2 load lines will be recorded.
The keel's CG can also be established using a system of weigh pads or adapted scales.

B.2.5 Weight and CG of the mast

B.2.5.1 Standard mast

(See A.16 of the *measurement protocol)*
Weighing of the basic mast at 1 hoist point on the head car of the mast track positioned at the centre of gravity (CG) of the mast suspended horizontally.
The mast's static moment will be calculated from the elements recorded above.

B.2.5.2 Weight and CG of the mast and outriggers with the standing and running rigging

(See A.12 of the *measurement protocol)*
The various elements of the standing rigging are brought back along the mast and those of the running rigging are in the positions specified by the CM.
The Measurer will check that each element of the rigging is present and correctly positioned.
It is considered advisable to establish the weight and CG of the various elements of the standing and running rigging independently of one another.
A precise record of the equipment will be noted and photos will be taken.
2 measurement methods:

- At 1 hoist point with a load cell positioned at the mast's centre of gravity.
- At 2 points with two load cells, the mast being suspended horizontally, one load cell in the mast step area and one load cell in the masthead area.
  We will record the horizontal distance between the axes of the 2 load cells and the distance of the load cell located in the mast foot area in relation to the mast step.

B.2.6 Weight and CG of the boom

The boom shall be fully equipped (reef, mainsheet...).
The weight and CG will be recorded according to the method using 1 or 2 load cells.

B.2.7 Weight, CG and Extreme positions of the foils

B.2.7.1 Weight and CG of the foils

Each *foil* will be weighed from 1 hoist point to obtain the *foil* weight.
The CG of each *foil* shall be established using 3 hoist points, with the use of weigh pads recommended.
Make provision for a flat, stable area for using the weigh pads.
These control points (in the case of weigh pads) shall be recorded in relation to a *foil* reference.
The method for determining the CG of the *foil* shall be approved by the CM.

B.2.7.2 Determining the movement of the foil

(i) location of the foil in relation to the hull in its position 0 (the foil is fully in)
(ii) location of the foil in relation to the hull in position 1 (the foil is fully out)

The displacement of the foil corresponds to the movement between position 0 and position 1. This movement is exclusively linear or circular.

B.2.7.3 Foil rotation (5.0 degrees maximum)

(See CR E.4(i))

The aim is to validate the set-up of the *foil* bearings and associated systems as outlined in the numerical model provided and the files referred to in paragraph A.16 of the *measurement protocol*.
In the event where the angle of rotation of the *foil* is greater than 5.0 degrees, the mechanical stops must be installed and sealed.

B.3 MEASUREMENTS AFLOAT

B.3.1 Water density (SG)

A sample must be collected approximately 300 mm beneath the surface.

B.3.2 Weighing of the boat

The *skipper* or their official representative shall provide all the suitable means for lifting their boat. All the operations to organise the lift are the responsibility of the *skipper* or their official representative.
The boat must be lifted from a single hoist point.
The bottom attachment of the load cell must be attached to this point. The top attachment of the load cell must be attached to the crane hook.
To avoid any constraint that is detrimental to the good working order of the load cell, allow for 2 shackles above and below the load cell.

B.3.3 Measurements of freeboard at 0° trim

The freeboard at noteworthy points RPF and RPA are measured.

B.3.4 Measurement of maximum keel canting angle

The maximum angle of rotation of the keel must be recorded.
The checking of the travel in the keel ram from one side to the other will be done from the boat's upright trim at 0°, (keel in the boat's centre plane).
Record the lengths of the ram rod(s) then swing the keel to the mechanical stop on each side (do not take into account the electric or electronic limiters).
The mechanical stop can be provided by exterior bushings limiting the travel of the ram. These bushings must be sealed.

B.3.5 Stability tests (90.0 degrees)

The *skipper* or their official representative shall provide and implement the necessary means to heel the boat to 90.0 degrees.
The *keel* is along the boat's symmetry plane (in a position of 0 degrees, emergency keel ram locked in position) and the position of the appendages (daggerboards, foils) shall be raised. The daggerboards shall be in the upper position and the foils (if they are present) retracted, whilst the *rudders* shall be 'fully lowered'.
The *foils* are positioned symmetrically and retracted as far as possible (around the hull's symmetry plane).
It is considered advisable to perform the 90.0-degree test without *foils* to determine the CG of the boat in *lightweight configuration* without the *foils*.
In this case, the *foils* are numerically added to the numerical calculation model.
The boat is inclined to a measured heel angle.
This angle shall be as close to 90.0 degrees as possible and held in this position by a strop around the mast (as close as possible to the masthead).
We measure the force exerted at this position using a load cell and we record its position in relation to the masthead.
The spreaders, mast or deck (outriggers) shall not be made watertight for the test.

The CM may request that the test be carried out on both sides.

B.3.6 Reserved

B.3.7 CHECKING OF BALLAST TANKS

B.3.7.1 Volume

The Measurer will ensure that the ballast tanks are empty.
Each ballast tank shall be accessible via a hatch, which opens at the lowest point of the tank.
The measurement shall be made by ensuring that the ballast tanks are filled one by one in turn and the filled volume is measured using a precision flow meter validated by the CM.

B.3.7.2 Geometry

The Measurer will make a geometric record of the ballast tanks and note their position with the aim of verifying the numerical model provided by the naval architect and notably determining the CG.
The CM will tell the Measurer which measurements to record according to the required ballast tank configuration.

APPENDICES

C.1 COMPUTER CALCULATIONS

For information purposes, the calculations are made using MAAT Hydro+ software.

C.1.1 Determining of the position of the boat's CG

Unrestricted trim and heel, lightweight configuration (determining of the boat's longitudinal CG (X))

Placing in upright trim in Maat Hydro+ is obtained from the PDYNA weight and the aft freeboard record from the aft RPA measurement marker (where the boat floats).

90.0-degree test (determining of the height of the boat's CG (Z))
The numerical model in Maat Hydro+ software will be put in the 90.0-degree test configuration.

C.1.2 Correction of the position of the boat's CG established in paragraph C.1.1 above

For a *lightweight configuration* determined by the CM, equipment may be integrated and/or removed to satisfy the defined *lightweight configuration*; these elements shall be added to and/or removed from the boat's numerical model, which is chosen by the CM.
These elements shall be known numerically (weight, centre of gravity (CG), volume if submerged).
In this case, the boat's CG outlined in paragraph C.1.1 above, is corrected
Solely the CM can decide on the use of this correction method.

C.1.3 The parameters obtained in MAAT Hydro+

(a) water draught;
(b) freeboard at the mast step for the air draught
(c) AVS
(d) ratio of the stability curve areas (keel along the centreline, ballast tanks empty)
(e) AVSwc
(f) RM
(g) angle of heel (10.0 degrees)
(h) self-righting test.

C.2 DOCUMENTS TO BE SUPPLIED TO THE CM

(See CR Appendix K-3)
Documents to be supplied by the *skipper* or their official representative for a boat to renew the MC (whatever the date of the boat's first MC):

- Form according to CR Appendix K-4
- According to CR A.8.3, the keel's NDT report.
- According to CR A.8.4, the mast's ultrasound test report.
- According to CR A.8.5, the hull's NDT report.
- According to Article AA.1.2, the boat's NDT report.

Documents to be supplied by the *skipper* or their official representative for a boat to obtain the first MC (whatever the date of the boat's first MC) or when the related document in the list above is modified:

- According to CR A.8.3, the keel's NDT report.
- According to CR A.8.4, the mast's NDT report via ultrasound.
- The boat's complete numerical model (Rhino format).
- Numerical models (IGS) of the whole boat (excluding rig) with ballast tanks and appendages in the various extreme positions.

- Numerical models (IGS) of the foil bearings.
- The 2D/3D plan relating to the various watertight bulkheads with hatches and details about the greatest distances between each bulkhead.
- The boat's flotation waterplanes in lightweight configuration at an angle of heel of 0 degrees and 180 degrees with the position of the emergency exit located within 500 mm of the aftermost point of the boat. The boat's waterline may be requested at any other angle of heel as the case may be.
- A diagram of the boat's draining system (See CR C.3.2) detailing the types of pumps used and the outputs.
- Calculation notes attesting to the compliance of CR D.8.2 (Watertight bulkhead doors).
- Certificate attesting to the compliance of CR D.9 (Resistance of the hatches and emergency exits).
- A diagram of the volumetric set-up of buoyancy materials accompanied by a table summarising the elements with the characteristics of the closed cell foam taken into account for calculating buoyancy (See CR 2021 & 2025 D.4(a)).
- The installation diagram for the plumbing of the ballast systems with a description of each ballast tank (size, volume, centre of gravity, etc.).
- The technical drawing (set-up) of the canting keel system installed in the hull in a position where the boat is at its theoretical 0-degree trim (numerical 2D format).
- The document attesting to the density of the bulb.
- The technical drawing (2D longitudinal section) of the bulb with the cavities where they are present.
- Document relating to the compliance of CR C.6.1:
  The brand and type of engine.
  The certificate will detail:
    - the installation of an independent starter battery with its capacity or another source for starting the engine.
    - that CR C.6.1 (d) is fully adhered to and that the system may be sealed whilst racing so as to prohibit the boat's propulsion with the technical description enabling the system to be sealed.
- Propeller purchase invoice attesting to the brand, type and features of the propeller used.
- 'AIS assembly' test certificate (See CR C.7.2 (b))
- General diagram of the boat's electrics with a table detailing the various batteries aboard and their positions in the boat reference.
- Diagram of the rated working deck (See CR C.9.1) with the height of the cockpit sole (lowest point)/DWL, including the toe rail, stanchions, pulpits and pushpits.
- In the event that cockpits are closed, a calculation note shall be supplied regarding cockpit draining requirements (ISO 11812).

<u>Additional documents to be supplied for a boat, which receives its first MC after 1 January 2015 or when the related document in the list below is modified:</u>

- The document attesting to the respect of the hull materials (See CR D.2.2).
  This document includes the list of different materials used with the conformity certificates for each batch of fibres used.
- The signed certificate of conformity for the standard mast
- The signed certificate of conformity for the standard keel
- The signed certificate of conformity for the standard canting system
- The certificate attesting to the assembly of the bulb with a pin made of Inconel 718 H, 17-4 PH or equivalent
- Installation diagram for the standard mast with the various chainplates (numerical document detailing the various installation values, as well as the angulation outlined in CR Appendix C).

- Certificate of compliance of the *IMOCA 60* construction drawing issued by the identified reputable body [See CR 2021 & 2025 D.1(d)
- Signed and dated declaration from the builder confirming that the boat has been built to comply with the plans checked by the identified reputable body [See CR 2021 & 2025 D.1(d)].

C.3 OTHER DOCUMENTS TO BE PROVIDED TO THE CM BY THE SKIPPER OR THEIR OFFICIAL REPRESENTATIVE

[See CR Appendix K-3]

- Numerical model of the boat:
  The boat in *lightweight configuration* with both foils retracted fully and symmetrically shall be placed in the theoretical *boat reference* [see CR DEFINITIONS].
  Boat reference: orthonormal X, Y, Z reference in which the boat is positioned at rest, with zero heel and in *lightweight configuration*. The X axis is the intersection between the *hull's plane of symmetry* and the flotation waterplane. The X axis originates from the **hull**'s aftermost point on the *hull's plane of symmetry*. The X values increase towards the forward section. The XY plane is horizontal and corresponds to the flotation waterplane.
- Any additional document upon the CM's request.

End of the document