International Sailing Federation

International Measurers Manual

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INTRODUCTION

Racing of all classes of sailing boat under the **Racing Rules for Sailing** (RRS) and **Equipment Rules of Sailing** (ERS) is based on the assumption that each boat complies with its **Class Rules**, the class rules complementing the RRS-ERS by defining the boat and equipment that may be used. Normally it is necessary to measure the physical dimensions of a boat, its equipment and sails to establish if it complies with the class rules and this is the principal role of the `**measurer**'.

Measurers therefore play a fundamental role in the organisation of sailboat racing, and their ability to apply the class rules correctly and accurately is essential. Equipment must be measured for **certification** before being used for racing, but it is normally inspected at events as well. Techniques vary in general as **certification** requires derivation of actual dimensions and **inspection** means comparison with known minimum / maximum limits. The latter is one of the roles the ISAF International Measurer is expected to perform. This Manual is a guide to most aspects of measurement but focuses mainly on event inspection and hull prototype measurement, giving information firstly on good measurement practice with specific Class examples, and secondly on practical techniques and equipment for taking accurate measurements. It is meant primarily –but not restricted in any way- for use by the ISAF International Measurers.

It is essential that measurers always keep in mind that **this Manual is only a guide**, and also refers to the current class rules of the boats they are measuring. The class rules/regulations override this Manual when there is any conflict between them. In addition, proper study of the ISAF guide to sail measurement and any other future guides is essential, as this Manual is not meant to be a fundamental measurement instruction booklet; ISAF International Measurers already possess the necessary basic measurement skills.

*Note: Parts from the ISAF **Guide to Sail Measurement** (2001 edition) have been included in this manual's sail measurement and Event Inspection Guidelines sections.*

The greatest part of this manual has been prepared by **Jean-Pierre Marmier**, IM (Soling & Yngling), Former Chairman of the ISAF Measurement Committee and Chief Measurer at the 2000 and 2004 Olympics. During the Spring of 2007, the ISAF International Measurers Sub Committee (IMSC) and a dedicated group of IMs finalized the manual, with modifications added in early 2009 to correct references to the 2009-2012 RRS and the 2009 ISAF Regulations.

The following persons have been involved in building up this manual :

Tony Watts ✞, past Chief Measurer of IYRU
who wrote the first "ISAF Measurement Manual" and who prepared the base of this new Manual with **Jean-Pierre Marmier** in Seoul – Korea (1985 – Measurement Seminar) – Some of his original drawings have been reproduced in the present Measurement Manual.

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ERS Working Group 2001-2004 (**Jim Hartvig Anderson †**, chairman)
In House Certification Working Group 2001-2004 (**Bengt Gustavson**, chairman)

Thanks to all of them.
Dimitris Dimou
Chairman of IMSC

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1 MEASURERS

This section considers the role of measurers, their qualifications, appointment, conduct and responsibilities and serves as an introduction to the rest of the manual.

1.1 Role of the Measurer

Boats are measured principally to establish compliance with the class rules, but there are different cases when compliance is checked and the role of the measurer varies in each case as follows:

(a) Measurement for Certification

Most classes require all new boats to be measured in order to establish that they have been built in accordance with the class rules before they are eligible to race. Once a new boat has been measured and found to be in compliance with the class rules it is normally issued with a Measurement Certificate which has to be retained by the owner as proof of eligibility to participate in class racing, RRS Rule 78. The procedures for measurement of new boats for certification are covered in Section 3.

(b) Measurement of Alterations

The RRS (Rule 78) make the owner responsible for ensuring that all alterations are in accordance with the class rules, but it is usually a requirement in the class rules that certain replacements, e.g. sails, and other alterations like significant repairs, must be measured before racing. Sometimes an endorsement is required on the Measurement Certificate, particularly if the weight has changed and weight correctors are removed or added. Procedures for measurement of alterations are covered in Section 4.

(c) Periodic Measurement

A few classes require periodic measurement checks of boats, sometimes to check buoyancy and other safety factors or possibly to check weight of larger boats.

(d) Event Inspection (Regatta Measurement)

Formal measurements to check compliance with the class rules are often conducted at major competitions ranging from checking certain items only, like the weight of boats or sail measurements, to complete measurement of all competing boats. Regatta measurement is covered in Section 6. In major regattas like World or Continental Championships this task ideally has to be done by the International Measurers.

(e) Prototype Measurement

The majority of new boats are 'production' boats, i.e. they are produced in quantity by the builder to the same specification as their prototype boat rather than as a series of one-off or custom designed boats. In these cases, particularly for GRP and other moulded boats, thorough measurement of the prototype can help to minimise measurement problems with the subsequent production boats. For this reason, it is a requirement for many of the ISAF International Classes that the prototype boat (first boat out of the mould) be measured and approved before production of subsequent boats commences.

(f) Batch Measurement

Classes which require prototype approval sometimes reduce or even waive measurement of subsequent boats subject to full measurement being conducted on one boat from each batch, e.g. every 10th boat.

1.2 Qualifications of Measurers

The work of a measurer requires technical skills, including the ability to read and understand class rules and to apply them correctly, and the ability to take accurate measurements of length, weight and other physical parameters. Section 5 describes techniques for accurate measurement, but it is essential that the measurer measures as prescribed in the Class Rules where details are given.

The measurer must be familiar with the use of standard measurement tools, and sometimes more specialised tools, as detailed in Section 8. The ability to make your own special tools is also useful so that a comprehensive tool kit can be assembled to enable quick and efficient measurement. Some classes sell purpose-designed tool kits for their class.

For regatta measurement, unlike measurement for certification or of alterations where the measurer is often working on a single boat without time pressure, a measurer often has to work against the clock and the ability to work quickly as well as accurately is important. A regatta measurer may therefore be involved with the design of special equipment to speed up the process of measurement, like spar or hull measurement jigs. He will also need to be able to work as part of a team, possibly leading the team, and be able to train helpers to assist with measurement.

It is also essential that a regatta measurer understands the relevant parts of the RRS as, in the event of a measurement protest, the procedures given in the RRS must be followed correctly. The RRS also contain other requirements on sail markings, advertising etc. which the measurer must be aware of.

One of the best ways for a person to acquire measurement skills is to attend a regatta as a helper assisting the regatta measurers. Most classes normally welcome offers of assistance in this area. Some classes and National Authorities run occasional seminars and courses to train measurers.

1.3 Appointment and Authority of Measurers

Before measuring boats for any reason a measurer must ensure that he has been appointed to undertake that measurement by the proper authority. The body for appointing the measurer and the authority granted to the measurer varies with the type of measurement and the National Authority (NA).

(a) Official Measurers

For measurement for certification or of alterations, the measurer must be recognised and authorised by the body administering the class. This body will normally be the National Authority (N.A.) of the country in which the owner or builder lives, but for some classes it will be the national or international class association, and in such cases measurers may be authorised to measure by the class association (LIGHTNING, SNIPE, STAR).

Measurers are often recognised by, i.e. registered with, both the national authority and class, so that both organisations can be aware of measurement activity, however only one of these organisations will be the administering authority responsible for processing measurers' reports and issuing measurement certificates (see Section 3). Official measurers are not authorised to issue measurement certificates themselves only recording measurements as required by the Class Rules and to report accordingly.

Some classes and national authorities require a measurer to have trained with an existing measurer or to have attended a seminar on measurement of the boat or to have passed a test before recognition is granted. Classes often have their Chief Measurer to co-ordinate training and appointment of measurers.

Although most are trained and authorised to measure all aspects of a boat, including sails and equipment, sometimes measurers are authorised for specific tasks only, i.e. sail measurement or hull measurement.

(b) Equipment Inspectors

Equipment inspectors are normally appointed by a race committee (or the regatta organisers) and authorised to conduct equipment inspection checks as required by the organisers. It is acceptable for some event inspectors to be helpers with little or no previous measurement experience provided that they are overseen by experienced class measurers or national authority measurers.

An inspector is not authorised to reject an entry to a regatta because he knows, or believes, that the boat does not comply with the class rules, but he shall report the matter in writing to the Race Committee, which shall protest the boat (RRS 60.2). The procedures that must be followed are covered in Sections 6 and 7.

(c) International Measurers (IMs)

Since 1980 the IYRU (now the ISAF) has acknowledged measurers who have a particularly wide experience and knowledge of a class by recognising them as International Measurers. According to the 2009 version of the ERS, they are persons authorized by the ISAF to inspect prototype boats of specific classes and recognised by ISAF as qualified to assist in equipment inspection at international events for those classes. The International Measurers provide a direct line of communication from the ISAF to classes on measurement matters. International Measurers should pass on their experience and train other measurers, thereby leading to an improvement in general standards of measurement. International Measurers have the same authority as Class or National Authority measurers when measuring for certification if they are also official measurers appointed or recognized by the MNA of the country where the control takes place or that particular Class.

To be appointed as an International Measurer, the measurer’s application must be supported by the relevant International Class Association, the National Authority and an other IM and finally be approved by the ISAF. More on the role of the IM in section 1.5 below.

(d) Prototype Measurement

The body responsible for approving the builder subject to prototype approval is responsible for appointing the measurer for measuring the prototype. In the case of International Classes with ISAF Licensed Builders, this body is the ISAF in consultation with the International Class Association, who will appoint somebody in consultation with the National Authority and National Class Association. The measurer appointed will normally be an International Measurer of that Class, but sometimes it is a very experienced class or national authority official measurer..

(e) Inspections

A class administering authority may authorise a measurer to conduct an independent measurement inspection of any boat at any time if they wish to establish some information regarding compliance with the rules. The owner should be given prior notice of their intentions and should not be expected to pay for the inspection unless previously agreed.

1.4 Measurer's Practice

A measurer should conduct his work in a professional manner to ensure that sailors have confidence in sailing administration and its officers, and to ensure that he is not open to subsequent criticism or action for failing to correctly follow the rules and procedures. The following points should be remembered:

(a) Formalities

The general administration rules at the beginning of the Class Rules describe the procedures that measurers, builders and owners should follow for getting a boat formally measured and certified. It is important that the measurer properly understands these rules and ensures that they are applied correctly, remembering that he is acting as an agent for the administrating authority.

(b) Integrity

A measurer must be completely impartial. So as to prevent any questioning of his integrity, a measurer is not normally permitted to measure a yacht or its equipment of which he is an owner, designer or builder, or in which he has any personal involvement (e.g. if he is a member of the crew) or financial involvement other than receiving a measurement fee.
An exception to this rule is made for boat and equipment manufacturers which are licensed to measure their own equipment, with the current ISAF IHC (Inhouse Certification) scheme.

(c) Measurement Fees

A measurer should require a payment for his services to a builder or owner. Some national authorities and classes lay down the fees to be charged for measurement and where this is the case that scale of fees should be the basis for the charges made. If significant travel is involved the measurer should ensure that the travel expenses are covered in addition to the measurement fee.

(d) Travel

Most measurement for certification and alteration takes place locally to reduce travel expenses, but sometimes measurers are required or requested to measure in a country other than their own. As a matter of courtesy, the measurer should always notify the National Authority of that country of the intended visit.

(e) Discretion

A measurer should have respect for the feelings of an owner or builder who may have just learnt from the measurer that his boat requires substantial modification before it can be used. However, a measurer must remember that he is checking that boat for the eventual owner who will be bound by all the class rules when racing. The measurer must therefore not allow himself to be swayed by the thought that an item is not important or that it does not affect the speed of the boat, nor allow any additional tolerances outside those permitted.

(f) Measurer's Liability

However diligent, it is possible for a measurer to make a mistake, either as a result of misinterpreting the rules or possibly a numeric error. Hopefully, careful study of this manual will help to minimise errors and any error will be minor. However, even a small correction to a boat at a later date can be a costly exercise and an owner may try to claim against the measurer.

To cover for such a possibility it is best if the measurer can have some form of indemnity insurance, and some national authorities and classes operate such a scheme.

(g) Measurer's Reports

If measurement is to achieve its objective of establishing that a boat complies in all respects with the class rules, irrespective of whom or where the boat is measured, it follows that it is essential that the interpretation of all class rules must be uniform. Therefore, if a measurer has any doubts about the legality of any item he should report the matter to the administering authority for advice. Also, as a result of such feedback from the measurers lessons can be learnt and rules can be regularly updated and improved for the future.

A good measurer should report ideas and errors found in rules, remembering that he is part of a team of administrators who are effectively the guardians of the rules.

1.5 Role of the International Measurer

The basic definition of the International Measurer according to the ISAF ERS C.4.7 is given in section 1.3 paragraph (c) above. ISAF Regulation 33 covers the requirements and qualifications for appointment as an IM and Regulation 26.5(g) covers the Class responsibilities regarding their IMs. Excerpts from the ISAF Regulations are given below:

Requirements for Initial Appointment as an International Measurer

33.5 A candidate for Initial Appointment shall:

(a) be nominated by the candidate's Member National Authority, an ISAF Class Association or the Race Officials Committee;

(b) be recommended by the candidate's Member National Authority;

(c) send the application on the official form so that it is received by the Secretary General by 1 September; and

(d) meet the general qualifications and the additional qualifications for the discipline concerned.

33.6 A candidate for re-appointment shall:

(a) apply directly to ISAF;

(b) send the application on the official form so that it is received by the Secretary General by 1 September; and

(c) meet the general qualifications and the additional qualifications for the discipline concerned.

General Qualifications for all International Race Officials

33.9 A candidate for appointment or re-appointment for any discipline shall

(a) except in the case of International Measurers, be an experienced racing sailor;

(b) have a sufficient knowledge of the Racing Rules and a detailed knowledge of the rules, manuals and other requirements and publications relating to his discipline;

(c) be proficient in the English language and have the skills to communicate both with other race officials and with competitors on matters relating to his discipline;

(d) display the temperament and behaviour expected of an International Race Official at an event;

(e) have the health and physical capacity to fulfil the requirements of his discipline;

(f) have the observation skills necessary to perform the duties of his discipline;

(g) agree to support the policies of ISAF and further its objectives, rules and regulations;

(h) have unimpaired eyesight and hearing, natural or corrected, at a level to enable him to carry out the duties of his discipline; and

(i) be able to contribute to the development of the programme relating to his discipline.

Additional Qualifications for Individual Disciplines

International Measurer

33.13.1 The appointment is made for a specific Class. An International Measurer can only be appointed to a maximum of three Classes except the Race Officials Committee may authorize additional Classes if they are very similar to measure as a Class the International Measurer is already appointed to.

33.13.2 A candidate for appointment as International Measurer shall:

(a) have acted as an Equipment Inspector in at least two principle events (as defined by the International Measurers Sub-committee) of the Class he is applying for, within the last four years prior to 1 September of the year of application;

(b) have attended an ISAF International Measurer’s seminar within the last four years prior to 1 September of the year of application but not later than 14 October in that year; and

(c) have an intimate knowledge of the relevant Class rules and the ISAF Equipment Rules of Sailing.

(d) be recommended by the relevant class association and another International Measurer.

33.13.3 A candidate for re-appointment as International Measurer shall:

(a) have acted as an Equipment Inspector in two principle events (as defined by the International Measurers Sub-committee) within the last four years prior to 1 September of the year of application; one of the events shall be of the Class he is applying for. As an alternative, one of the events may be substituted by one hull prototype measurement of the Class he is applying for;

(b) have an intimate knowledge of the relevant class rules and the ISAF Equipment Rules of Sailing.

(c) be recommended by the relevant class association.

33.13.4 Once appointed, an International Measurer shall not be employed by or act as a consultant to or regular official measurer at a builder for that class.

According to Reg 26.5 (g) (v): Classes must

1) have sufficient ISAF recognized class International Measurers to represent the class regionally,

2) ensure that at least one class International Measurer attends each ISAF Equipment Inspection Symposium,

3) have at least one class International Measurer present at the class World Championships,

4) organize regular class Equipment Inspection Seminars to train class Equipment Inspectors with the class International Measurers as instructors,

5) ensure that only class International Measurers measure prototypes of moulded production boats.

Therefore, the IM's role is to lead the equipment inspections at the major events of their class, train class equipment inspectors and measure prototypes of their class. In practice, International Measurers should possess the following necessary skills to fulfil their major roles:

- Be technical experts with a deep Class background, including knowledge of the class rules evolution
- Have the ability to read and understand Class Rules, ERS, design drawings, construction plans, technical specifications;
- Have practical skills with measurement and power tools.
- Have sound understanding of technical English
- People Management skills: Ability to effectively communicate with relevant people (Sailors, Coaches, Jury, Race Committee, Organizers, Class officers). Ability to communicate with and control disruptive and agitated people should the need arise.
- Have the ability to clearly present technical facts to a (non technical) Jury

The main responsibilities of the IMs can be summarized as follows:

- Follow the ISAF Code of Behaviour for IMs
- Ensure that all equipment is class compliant and teams are competing on equal terms (As event inspectors)
- Maintain a high level of consistency and accuracy in their work
- Keep information from measurement in general and especially prototype inspections confidential within the ISAF and the Class
- Train people on the measurement process for their class; Explain the rules to sailors, coaches; Assist Class with Measurement Guides, forms etc
- Take part in the Class Rules development by giving feedback to the Class technical committee, including any new developments in equipment and any shortcomings of the present rules
- Follow developments in tools and techniques

1.6 International Measurer's Code of Behaviour

ISAF International Measurers are among the most exposed officials of the sport. It is therefore essential that measurers behave with the highest degree of competence, propriety and integrity, and at no time do anything to bring the sport into disrepute. An International Measurer shall follow ISAF policies. A Measurer who does not, risks the termination of his/her appointment.
Specifically measurers are expected:

(a) to maintain a high level of knowledge of the relevant Class and Racing Rules and the ISAF ERS as well as the Measurement Manual;

(b) to be impartial, polite and courteous at all times. This is important not only with respect to competitors, but also to colleagues, coaches, regatta officials, hosts and other personnel involved in the administration of the regatta;

(c) to declare any conflict of interest before accepting an invitation to become a event measurer (see below and ISAF Regulation 50);

(d) to treat every hearing, and every other matter in which he/she is involved with care, discretion, objectivity and without prejudice; and to ensure that no personal interests affect his/her judgement;

(e) to ensure that justice is done, and is seen to be done;

(f) to follow the procedures in the Class and Racing Rules, and promote and support ISAF policies promulgated in these and other official publications;

(g) not to betray the confidence of the competitors, the jury; or the builders, not to disclose anything noted at any builders premises as long as it complies with the current Class Rules, (if there is a feeling, it does not, to contact either the Class chief measurer, his NA or the ISAF), or the jury's deliberations relating to any particular case outside the jury hearing, both during and after an event;

(h) not to consume alcohol before or during measurement or a hearing or jury meeting and not to become inebriated at any time during an event, always acting with dignity and decorum;

(i) not to smoke while measuring or inspecting sails, in the jury room or whilst working on a jury boat with other officials;

(j) to be on time for measurement inspections or jury meetings and to give full attention to the matters under consideration;

(k) to plan to remain at an event from the opening ceremony until the close of the time limit for protests after the last race and thereafter, should a measurement protest be lodged;

(l) to wear appropriate clothing both on the water and ashore;

(m) not to incur any more expenses than necessary- and where relevant, to reclaim only legitimate essential expenses;

(n) to maintain a good standard of physical health, in order to maintain concentration, observation and listening skills at events that may last for several days;

(o) to be aware of cultural differences;

(p) to remain visible and approachable and to display the temperament and behaviour expected from an IM at an event;

(q) to see other points of view and be diplomatic at all times;

(r) to have the ability to make difficult decisions and be capable of handling pressure, but not to make any interpretations to Class Rules. In cases where the Class Rules are open to interpretation, the path outlined in ISAF Regulation 26.11 shall be followed;

(s) not to give any advice to owners or builders, concerning how to affect or optimise the performance of the boat, or how to optimise the construction techniques;

(t) shall assist Class Associations in improving / simplifying their Class Rules keeping in mind: "No measurement for measurements sake".

Conflict of Interest (Excerpt from ISAF Regulation 51: Conflict of Interest)

50.1 A conflict of interest exists when an ISAF Race Official has, or reasonably appears to have, a personal or financial interest which could affect the official's ability to be impartial.

50.2 When an ISAF Race Official is aware of a conflict of interest, he/she shall decline an invitation to serve at a regatta at which an International Jury is appointed.

50.3 When the ISAF Race Official has any doubt whether or not there is a conflict of interest, the ISAF Race Official shall promptly consult the ISAF, prior to accepting the invitation and be bound by its decision.

50.4 When, at an event, an ISAF Race Official becomes aware of a conflict of interest, the official shall disclose the potential conflict to the International Jury which shall take appropriate action.

2 APPLICATION OF CLASS RULES

A measurer must be completely conversant with the class rules of any boat he measures in order to apply them correctly. To properly use class rules the measurer must understand and follow the general administration rules as well as the specific measurement rules.

2.1 Objectives of Class Rules

One of the most important sections of the class rules is that describing the objectives of the class and, in the case of one-designs, the rules on protection of one-designs. These rules are normally in the first few paragraphs of the class rules and explain the purpose and aims of the rules for that particular class. When applying the rules the measurer must always keep those objectives in mind.

(a) One-Designs or Classes with closed or open Class Rules

The main objective of One-Design class rules is to ensure that the boats are sufficiently alike in performance to ensure close racing so that races are won primarily as a result of the skill of the crew. The rules of a One-Design class therefore define the hull shape and limit what may be used in the way of fittings, equipment and sails.

Each class is slightly different, but the extent of limitation of the layout and the equipment that can be used should be defined in the class rules. At one end of the scale classes allow the owner very little choice over the fittings which can be used, particularly in mass production manufacturer's classes, whereas at the other end the type and choice of fittings is extremely large.

With closed Class Rules, anything not specifically permitted is prohibited. Wherever the word 'optional' appears, then the fundamental rule is overridden and features are permitted even if not specifically mentioned in the class rules.
In the case of Open Class Rules, anything not specifically prohibited is permitted.

(b) Development boats

Development boat classes (sometimes known as Restricted Classes) are boats built to class rules which set limits on certain parameters (like length, sail areas), and development of any ideas within these parameters is encouraged. As a result there are usually fewer measurements to be taken on a development class than on a one-design class, and the measurers should assume that anything which is not specifically prohibited is permitted, although it is essential to report any unusual or possibly undesirable features to the administering authority.

(c) Handicap Rules

Handicap rules enable yachts of unequal performance to race together by applying handicap factors to their performance which attempt to even out the speed differentials. Some handicap rules are based on past performance of the boats, known as performance yardsticks, but other handicap rules attempt to predict performance with complicated equations using data of the physical dimensions of the boats (ORC-IMS). In the latter case a considerable amount of measurement may be necessary to establish the required data before the handicap can be calculated.

2.2 Changes to Class Rules

Classes are constantly trying to improve their class rules and accordingly changes are made on a regular basis. For measurement for certification, and for measurement of most replacements, the measurer must refer to the class rules current at the time of measurement. However, hull re-measurement and measurement of repairs and rebuilds are normally to be made in accordance with the class rules that were in effect when the boat was first measured for certification. This is often known as a 'grandfather clause' and may necessitate researching to find out what the rules were some years in the past. If in doubt, then consult the administering authority.

The class rules of International Classes are published on the “Internet” by either the ISAF or International Class Association and may be amended. Changes to the rules of International Classes are normally approved by the ISAF at its meetings in November to be effective from 1st March the following year. The Measurers should always be aware of the procedures followed for changing the class rules of their class in order to keep up to date copies. Occasionally, class rule changes are made during the year at short notice to resolve urgent issues, so the measurer must ensure that he is on the mailing list of the relevant administering authority to receive all changes made.

2.3 Interpreting Class Rules

There will be occasions when the meaning of a class rule is not clear to the measurer. When measuring for certification the measurer should contact the administrating authority for clarification before signing the measurement form (Section 3), and describe on the measurement form what he has found, so that the administering authority can determine whether a measurement certificate is to be issued or not. For International Classes, if the administering authority is unable to determine whether the detail is acceptable it will seek an official interpretation from the ISAF or from the International Class Association in the case of a class administered by that body. As with rule changes a measurer should ensure that he will receive all official interpretations as soon as they are received.

If measurement is to achieve its objective of establishing that a boat complies in all respects with the class rules, irrespective of whom or where the boat is measured, it follows that it is essential that the interpretation of all class rules must be uniform. Therefore, if a measurer has any doubts about the legality of any item he should consult the administering authority for advice.

Sometimes, new developments, particularly control systems for sails or rigging, are seen for the first time at a regatta, having been fitted after measurement for certification. In such cases it is not always practical within the competition time scale to seek an official interpretation and the measurer, on behalf of the race committee, may have to make a temporary ruling - see Section 9.

2.4 Plans

The class rules may refer to official plans and require the boats to be built in accordance with the plans. In these cases the measurer has to check compliance with the plans and thus he is faced with a difficulty in that tolerances cannot be given for each and every item or feature and so a judgement decision has to be made.

The criteria which a measurer should use to determine whether a boat complies with the plans should be stated in the class rules. If not, the measurer should assume as a guide that all parts of the boat have to 'look' like a boat built in accordance with the plans, i.e. that if a line is drawn as straight on the plan, then that part of the boat should be nominally straight, not curved or stepped. The degree to which this general rule applies varies greatly from class to class and the measurer should be guided by what is accepted class practice.

If a new variation from the plans is found or if the measurer is in any doubt about the compliance of a part with the plans he should refer to the administering authority. The boat must comply with any stated measurements in the class rules and with dimensions given on the plans.

2.5 Construction Rules

For many classes the construction rules are incorporated into the class rules and the measurer must establish that they are complied with by taking the relevant measurements. Measurement of scantlings (dimensions of the various parts of a boat's structure) can need special techniques and equipment and this is covered in Section XXX.

For classes with GRP (glass reinforced plastic) construction there are sometimes detailed "lay up" specifications with which the builder has to comply, which may not be incorporated in the class rules available to measurers. As it is clearly impractical to check that the specification has been followed after the boat has been built, it is usually the builders' responsibility to sign a declaration that the specification has been followed. The measurer must clearly establish from the class rules which measurements, if any, to take in respect of construction.

Instead of having defined construction rules specific to the class, some classes state that construction must be in accordance with the scantling rules of a Classification Society and may further state that a recognised Classification Society must certify that the construction was in accordance with the scantling rules. In these cases the boat may have to be built under the supervision of a surveyor from the Classification Society, and a Classification Certificate issued on completion. As this can be a costly process it is a practice normally confined to large yachts.

3 MEASUREMENT FOR CERTIFICATION

Many classes require all new boats to be measured to establish that they are in accordance with the class rules before they are allowed to race. When the measurement process is complete a Measurement Certificate is normally issued. This section considers the procedures normally followed.

3.1 The Measurer

Measurement for certification is carried out by Class or National Authority measurers as described in Section 3. In some cases manufacturers are licensed to measure their own equipment (schemes of self-certification of sails in GER-AUT-NED-DEN-SWE and the new ISAF IHC scheme).

3.2 Arrangement of Measurement

When a new boat has been completed by a builder, it may be sold as an unmeasured boat or the builder may arrange for an approved measurer to measure it for certification in order to sell it with a Measurement Form. Most classes with licensed builders require the builder to arrange measurement and sell all boats (at least the hull) with a Measurement Form.

If the boat is being sold in a part-complete state, as is often the case, for the owner to complete to his own specification, then the boat will have to be sold unmeasured, or partly measured (see 3.4 below) and the owner will have to arrange measurement. In the case of amateur construction the same person is normally the builder and owner and is responsible for arranging measurement.

Accordingly a measurer will be commissioned by either a builder or owner and will be providing a service for that person on behalf of the Administrating Authority in return for a measurement fee.

3.3 Measurement Conditions

When arrangements are made and a convenient time chosen the measurer should also establish that the conditions for measurement will be satisfactory. This means ensuring adequate space, relatively level ground preferably being under cover when measuring on land, or ensuring relatively secluded calm water with good access for buoyancy or floatation measurement. If measuring a lot of boats on a regular basis for a production builder it may be possible to set up a special measurement area with measurement equipment at the ready and possibly permanent measurement jigs.

The measurer must take all measurement equipment that will be needed and will not be on hand plus notebook and documentation including the current Class Rules, RRS, ERS (if applicable), and the appropriate number of current Measurement Forms, if not supplied by the builder.

3.4 Measurement Forms and Certificates

The Class Rules normally refer to a Measurement Form which is a document listing all the measurements that need to be taken and, where appropriate, the maximum and minimum values permitted.

There is often confusion between the terms "Measurement Form" and "Measurement Certificate". The Measurement Form (MF) contains all the measurements taken by the measurer and a statement from the builder that the boat has been built according to the class rules and specifications.

The Measurement Certificate (MC) do not include the measurements taken. It is only a statement from the National Authority (NA), the National Class Association (NCA) or the International Class Association (ICA) that the boat has been measured by an approved measurer, and that the boat complied with the Class Rules. A few items from the MF, like weight and corrector weights, may be part of the MC.

Most class rules state that the Measurement Form is part of the Class Rules in which case you must use an official copy, recognised by the authority for the Class Rules. It is not acceptable to make up your own Measurement Forms for certification, although you may edit a Measurement Form if corrections are needed provided reasons are given on the form for the benefit of the administration authority which has the responsibility of issuing the Measurement Certificate. Most of the measurement forms and International Measurement certificates can be loaded on the website of the ISAF or of the relevant classes.

3.5 Recording Measurement

A measurer is normally required to record all the measurements indicated on the Measurement Form when he undertakes measurement for certification. When recording measurements on the measurement form, it should be noted that unless specifically permitted in the class rules it is not sufficient to insert ticks or write "OK" against items which require an actual measurement.

Occasionally a measurer may mistakenly enter an incorrect measurement on the measurement form, due to incorrectly reading the measurement or due to reversing digits. Mistakes can cause considerable problems to the boat owner at a later stage, so the measurer should carefully check that all recorded measurements are within the permitted tolerances, and re-measure if necessary, before finalising measurement.

A measurer may keep a record of all his measurements by making a duplicate copy of each measurement form. This is particularly useful if he is involved with the measurement of many boats in the same class as he will be able to quickly see whether he has made a mistake in taking a measurement or whether there has been some change in boats being produced. Also, if any question is subsequently raised he can see what measurements were taken, and what comments he made.

3.6 Declaration

When all the measurements on the forms have been completed the measurer is required to sign a declaration on the Measurement Form. Unless the measurer has made any comments to the contrary, this signature indicates that to the **best of his knowledge** and belief, he considers the boat to be in accordance with **all** the class rules even if there are rule requirements which are not included on the measurement form.

If the measurer is in any doubt regarding the compliance of an item he **must** describe it in the "Remarks" section on the Measurement Form or, by reference to his administering authority obtain a further guidance on the matter before signing the form. If remarks are made the declaration should still be signed in this case indicating that to the best of his knowledge the boat is in accordance with the rules **subject to remarks made**. The decision whether or not to issue a Measurement Certificate then lies with the Administrating Authority.

Some Measurement Forms have space for a Builders Declaration, which normally require the builder to declare that he has built the boat in accordance with the rules. This declaration is particularly important in the case of GRP boats with construction rules with specifications for the moulding lay-ups as in such cases the measurer commonly examines the exterior of the moulding, states that 'to the best of his knowledge' it is OK based on appearance, whereas the builder actually constructed the laminate. The measurer should not sign the declaration until the builders' declaration has been signed.

3.7 International Class Fees and ISAF Plaques

It is common practice for a royalty to be paid to the designer of a yacht on each hull built. In the case of the classes administered by the ISAF the royalty is included in an International Class Fee (referred to as the Building Fee) which also includes amounts which go to the International Class Association and to the ISAF. A plaque is fixed permanently in the yacht to indicate that the International Class Fee has been paid. Where this is a requirement, the measurer **must not** sign the Measurement Form unless this plaque is fixed as required in the Class Rules.

3.8 Application for Measurement Certificate

When the measurement form has been signed the form should be either sent to the administering authority or handed to the owner, as required by the class rules, to enable the boat to be registered in the class and a Measurement Certificate issued. The Measurement Certificate is the document that states the boat has been measured and found to be in compliance with the class rules. The Measurement Certificate must be endorsed by the administrating authority, normally the national sailing authority. Measurement Certificates may be a separate document from the Measurement Form or may be combined with the Measurement Form (meter classes) to give easy reference to the original measurements.

4 MEASUREMENT OF ALTERATIONS

During a boat's life there are likely to be many alterations to the original specification, as a result of replacement of items that wear, performance modifications which are permitted by the rules, repairs to damage and even major structural rebuilds. For any of these reasons it is normal for a boat to have new sails, fittings, rigging, spars, foils, structural changes, etc., after it is first measured for certification.

4.1 Replacements

Many items of equipment are replaced on a regular basis either because the originals are worn or damaged, or because the owner believes that a different product will improve performance. Unless the rules require measurement of replacement items then it is the sole responsibility of the owner, in accordance with RRS 78, to ensure that the equipment is in compliance with the rules, and an item that may have to be measured for certification, e.g. the centreboard, may **not** require measurement if it is replaced.

If the rules do require measurement of significant replacement items, e.g. sails, mast, centreboard, then they must be measured by an approved certification (official) measurer.

Replacement sails are normally required to be measured and identified by the measurer signature and stamp near the tack - see Section 15.

4.2 Performance Alterations

Alterations to improve performance may range from something as simple as replacing a control line or block to refairing the entire hull of a keelboat. Each modification, however small, can affect the compliance with the Class Rules in a number of ways and this should be born in mind when measuring. For example a change to the fittings may slightly affect overall weight. Because alterations do not require re-measurement before the boat may be raced again, alterations are often seen for the first time at regattas and can thus make regatta measurement complicated, as interpretation has to be made at short notice under pressure.

4.3 Repairs

Repairs roughly fall into two categories, those of a seasonal maintenance nature and repairs to structural failure of either hull or equipment. The greater the content of a repair, the greater its effect on the performance of the boat and accordingly some Class Rules state that 'substantial' repairs shall require re-measurement. Some rules go on to define substantial repairs but if not it is up to the owner to decide whether or not to commission a measurer to check it.

If conducting a measurement check on a substantially repaired boat it is important to check if the overall weight has changed as well as checking that the materials and shape are correct, and, ***if required by the class rules, to control weight distribution.***

5 ACCURACY, PRECISION AND REPRODUCIBILITY IN MEASUREMENT

5.1 Introduction

Taking accurate measurements is essential so that measurements can be repeated by another measurer at another time with similar results. There are two main elements that affect accuracy of measurement - measurers' errors and the accuracy of the equipment used.

Measurers' errors can result from either misinterpreting the rules, and hence measuring in the wrong way to the wrong point, from miss-reading of recording a measurement, or as a result of incorrectly using measurement equipment.

To avoid misinterpreting the rules the measurer must be completely conversant with the rules. It also helps to occasionally measure with other class measurers, at a regatta or attend a measurement seminar to ensure that your understanding of the rules is correct. If in any doubt, contact the relevant authority for guidance.

To reduce the chances of misreading, measure twice or get someone else to re measure whenever possible, do not rush, do not measure when tired, take breaks if measuring for a long time, and if measuring with assistants give them responsibility and keep them occupied, or they will loose interest and make mistakes.

Techniques for using measurement equipment correctly are covered in the next few sections, and some typical causes of error are described below.

Measurement

A measurement is the comparison of the quantity to be determined with a standard, and is therefore a ratio plus a unit.
For accurate, precise and reproducible results the measured parameter must be precisely defined and prescriptions given for the measurement tools and procedures.

Units

Although Imperial units are still sometimes used, the Standard International (SI), i.e. metric units should be used for sailboat measurement.

Accurate and precise measurement requires :

1) Precise definition of the quantity to be measured.
2) Calibrated instruments, to ensure accuracy.
3) Correct procedures, designed to optimize precision and reproducibility
4) Appropriate measurement facilities and conditions.
5) Careful record keeping, with immediate comparison with the mandated value.

Basic standards

Fundamental quantities	Units		Derived quantities
Length	**meter**	**(m)**	**area (m^2), volume (m^3)**
Time	**second**	**(s)**	**period (s), frequency (Hz)**
Mass	**kilogram**	**(kg)**	**weight (N), density (kg/m^3), moment of inertia ($kg \cdot m^2$)**

All other mechanical quantities can be expressed in terms of these three basic quantities

Length measurement:

	Range	Instrument
1)	greater than a meter	measuring tape
2)	50 to 1000 mm	meter stick
3)	1 mm to 150 mm	digital calliper
4)	20 microns to 20 mm	micrometer

Time period measurement:

1)	precision of 0.1 s	manual stop watch
2)	precision of 0.1 ms	photocell and digital clock

Mass and Weight

The amount of matter an object contains is its mass "**m**". The mass of an object determines its inertia, that is, how difficult it is to get it to change its motion. Newton's second law is **F = ma**, or if a given force **F** is applied to the object then the bigger the mass **m** the smaller the acceleration **a** that results. The weight **W = mg** of an object is the attractive force **W** that the earth exerts on the object and is proportional to the mass **m**. The proportionality constant "**g**" is the weight force per unit mass, in Newtons per kg, and varies with location.
Weighing an object actually measures the upward force **N** exerted by the scale on the object which is required to balance the downward weight force **W**. This upward force only equals the weight if the object is not accelerating and these are the only two forces acting.

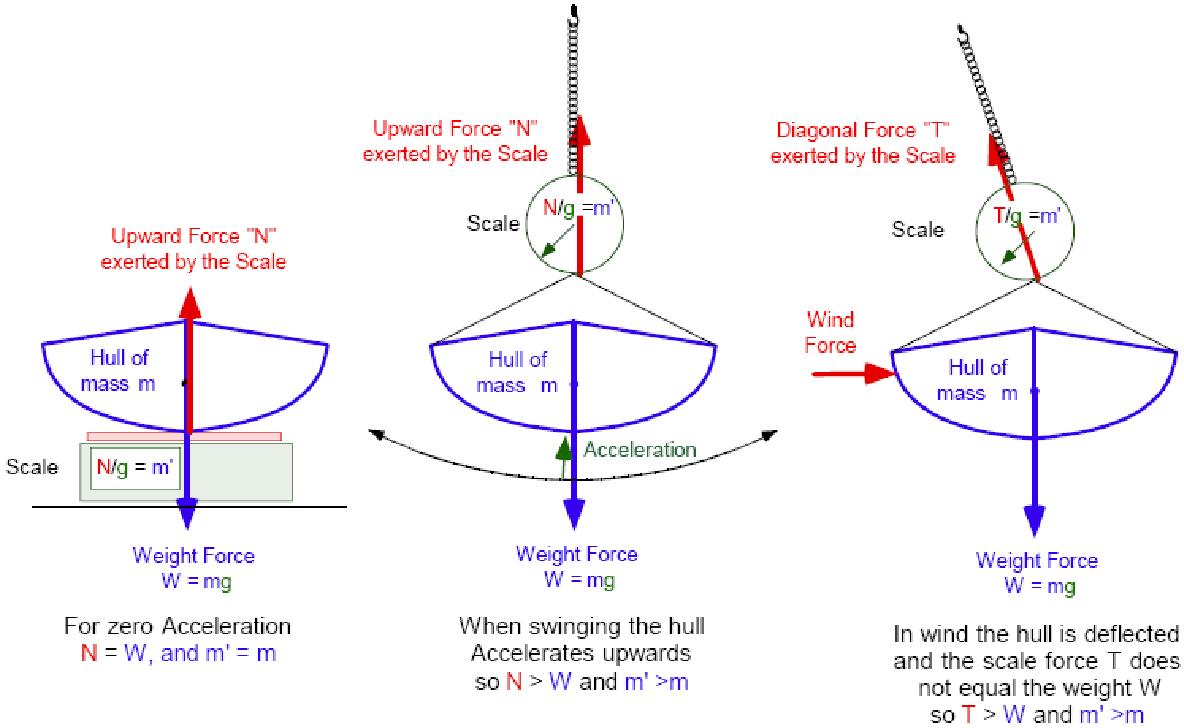


Figure 5.1.1 The physics of weighing. The scale reads the force it exerts to counteract the weight and assumes a value of g to convert this force to a mass reading m'.

The act of weighing, strictly speaking, measures the force of gravity on the object, however scales are calibrated to read "the mass on which the gravitational force would be the same as that measured" rather than the force **N** which is actually measured, and therein lies the problem.. That is the scale manufacturer builds in the equation **m** = **N/g**, and assumes a local value of "**g**". Thus when a scale is moved (from one country to another, so "**g**" changes) the scale calibration is no longer valid. Thus for accurate weighing the scales must be calibrated (span adjusted) in the location in which they are to be used. If however, this is not possible then a correction to the scale reading can be made as the variation of **g** with latitude and height above sea level is well known. The variation with longitude is only small. The major variation of the effective gravitational force per unit mass **g'** is due to the rotation of the earth which caused an equatorial bulgeand hence a variation of the radius R with lattitude, and the centrifugal force $\omega^2 R \cos \varphi$ in the rotating system of the earth. These combine, as shown in figures 5.1.2 & 5.1.3 to give the effective gravitational force per unit mass **g'** at sea level as:

$$g' = 9.78049\left(1 + 0.0052884 Sin^2\phi - 0.0000059 Sin^2 2\phi\right)$$

While the variation with height is

$$g'_h = g' - \left(0.30885 + 0.00022 Cos 2\phi - 0.000072 h\right)h$$

Where g' is given above and h is in km. These equations can be used to estimate the change in scale calibration to within the resolution of a 1:5000 scale. The earth's gravitational field is now routinely measured tomuch better precision than this by the GRACE satellites, as shown in figure 5.1.4. Assuming that a scale has been calibrated at the ISAF office in Southampton then the corrections for a number of sailing venues are listed in table 1.

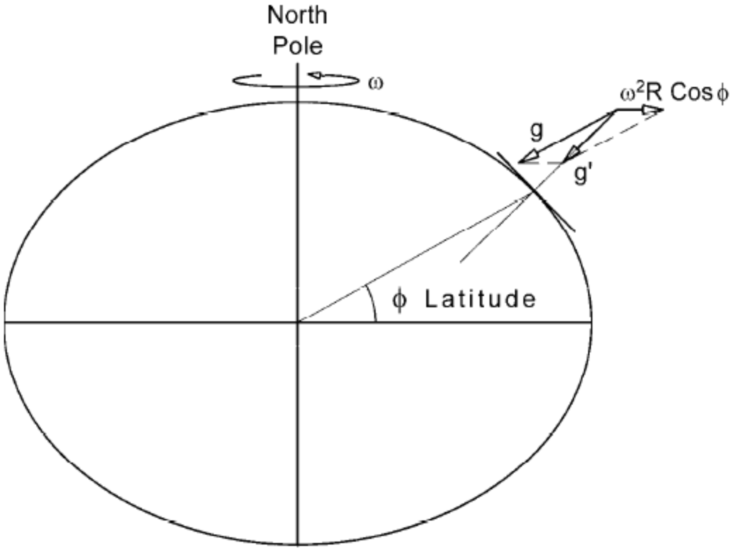


Figure 5.1.2 The Earth's figure (equatorial bulge exaggerated) showing the variation of the gravitational force per unit mass, g', with latitude φ, due to the varying radius R and the centrifugal force ω R Cos φ.

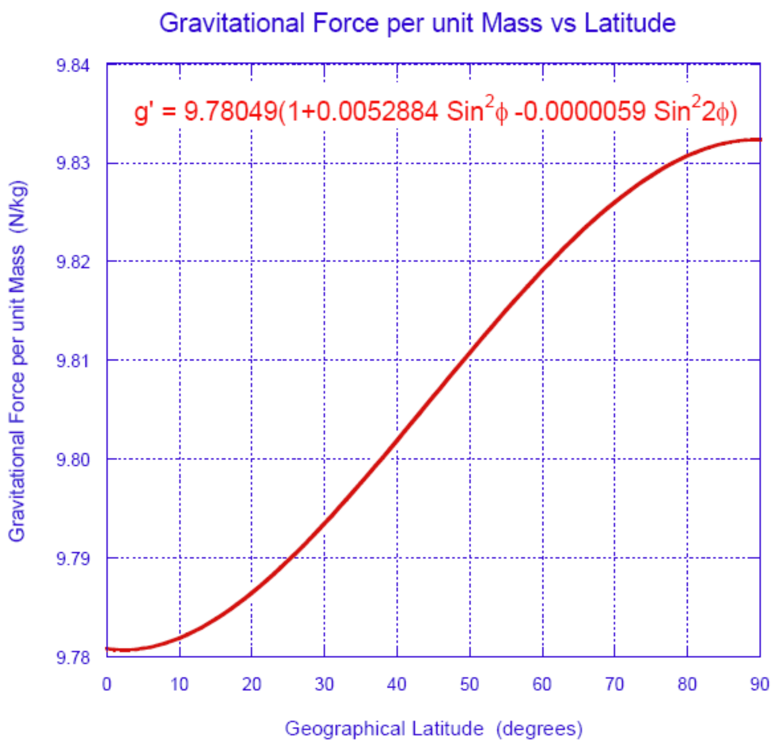


Figure 5.1.3 The variation of the effective gravitational force per unit mass with latitude.

Table 1 Variation of the gravitational force per unit mass with latitude

Place	Latitude Degrees	Gravity N/kg	Correction gms/kg	Place	Latitude Degrees	Gravity N/kg	Correction gms/kg
North Pole	90.000	9.832	-2.09	**San Francisco**	37.872	9.800	1.20
Helsinki	60.170	9.819	-0.79	**Quingdao**	36.095	9.798	1.35
Malmo	55.722	9.816	-0.42	**Long Beach**	33.889	9.797	1.54
Kiel	54.378	9.815	-0.30	**San Diego**	32.806	9.796	1.63
Medemblik	52.789	9.813	-0.16	**Miami**	25.815	9.790	2.18
Southampton	50.992	9.812	0.00	**Dubai**	25.271	9.790	2.22
Vancouver	49.331	9.810	0.15	**Acapulco**	16.867	9.785	2.74
Trieste	45.654	9.807	0.49	**Singapore**	1.308	9.781	3.17
Halifax	45.086	9.806	0.54	**Equator**	0.000	9.780	3.18
Kingston	44.233	9.806	0.62	**Rio de Janeiro**	23.033	9.788	2.37
Hyeres	43.219	9.805	0.71	**Sydney**	33.935	9.797	1.54
Marblehead	42.510	9.804	0.78	**Capetown**	33.961	9.797	1.54
Palma de Majorca	39.608	9.801	1.04	**Melbourne**	37.972	9.800	1.19
Annapolis	39.044	9.801	1.09	**Wellington**	41.345	9.803	0.88

The correction is that required for a scale calibrated in Southampton, UK, i.e. if used at the North pole it reads 2.09 gms high for each kg.

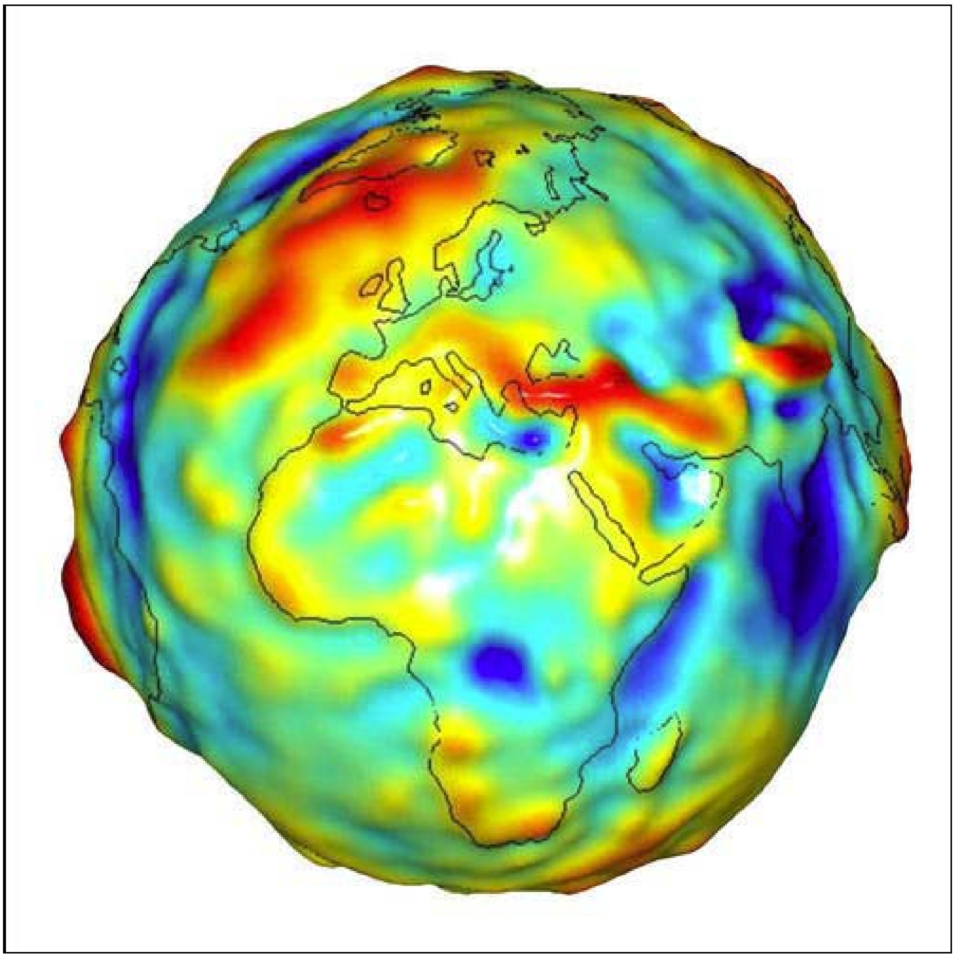


Figure 5.1.4 A Grace Satellite map of the detailed variation of the Earth's gravity. Note these variations are in mm/s^2, so can be ignored when correcting scales with resolution of 1:5000.

5.2 Definition of terms

True value:

Mean of an infinite number of accurate measurements, an unattainable ideal

Error:

The error, or deviation, is the difference between the measured value and the true value, but as we cannot know the true value the error has to be estimated from a series of measurements and theory.

There are six types of errors:

1) Mistakes in recording or calculating results
2) Systematic errors, which determine accuracy
3) Random errors, which determine precision
4) Quantization, due to finite resolution
5) Reproducibility, determined by methodology and stability
6) Round-off errors, due to poor calculational practices

Accuracy:

How close the measurement is to the true value. It is a measure of the correctness of the result. The use of a miscalibrated instrument leads to inaccurate measurement which can however be very reproducible. Accuracy is determined by how well the systematic errors are treated.

Precision:

Precision is a measure of how exactly the result is determined and depends on the scatter of the measurements. A qualitative estimate of the precision is obtained by asking “how much would a second measurement differ from the first one?”. Many calculators will give you the “standard deviation”, which is a measure of the precision for a large set of readings.

Reproducibility:

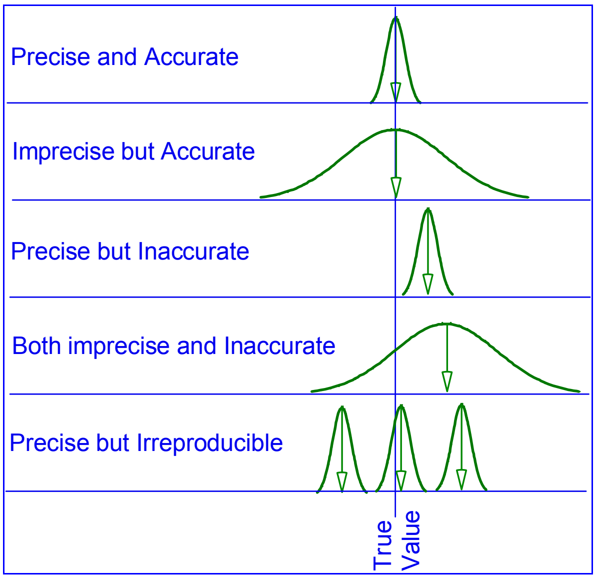
The difference between two independent measurements, generally at different locations or times. Lack of reproducibility can be due to either systematic or random errors, or different measurement protocols.

Round off error:

The error in a calculation or measurement due to using only a finite number of significant digits to represent the data. With modern calculators, which typically use 9 digits, calculator round off errors are insignificant with respect to the random errors of measurement.

Significant figures:

The number of digits, including trailing zeros, used to specify a measurement. For digital instruments such as electronic scales, micrometers and watches this is the number of digits displayed.



Accuracy, Precision and Reproducibility

5.3 Errors

Systematic errors:

These are errors which are reproducible from measurement to measurement.
Caused by :

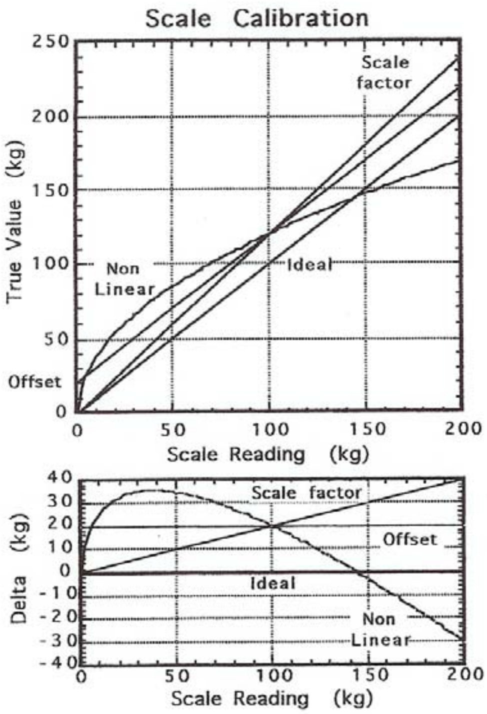
a) Imprecise definition of the quantity to be measured.
b) Faulty methods or procedures.
c) Defective or inappropriate instruments.
d) Incomplete or approximate equations.
e) Bias on the part of the measurer.

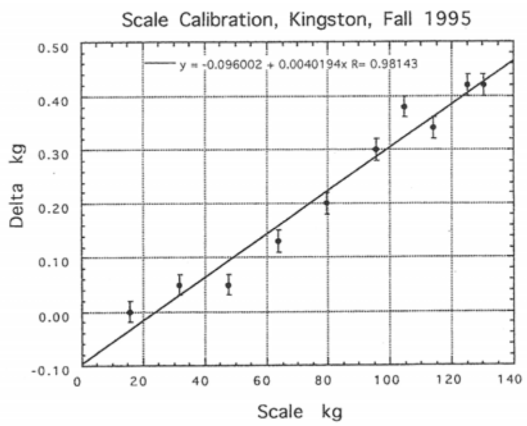
Properties :

a) Cannot be reduced by averaging, as any given systematic error is reproducible and of constant sign.
b) Systematic errors add algebraically, **$\Delta=\Sigma\cdot\Delta i$**.
c) Can be corrected later if recognized.
d) They determine the accuracy of the measurement.

Examples of systematic errors :

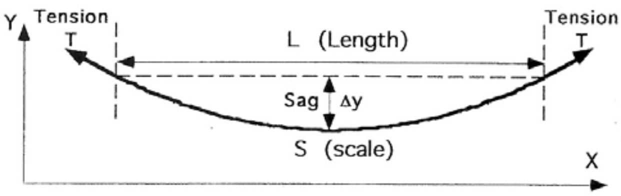
- *End hooks or damage on end of measuring tapes or rulers. These can be eliminated by using the 10 cm mark instead of the zero.*
- *Tension and elasticity of measuring tapes (use only calibrated steel tapes, not woven tapes).*
- *Stretching and distortion of templates (use mylar for sail templates and master drawings not paper).*
- *Expansion due to temperature. Measuring an aluminium mast with a steel tape under a hot sun for instance.*
- *Incorrect calibration of scales. Zero offset, or tare, and scale factor*
- *Nonlinear calibration of scales. High precision scales require multi point calibration adjustments.*
- *Approximate conversion from 1kg = 2.2046 lbs*





A plot of the true value versus the scale reading, for scales with various types of calibration error (exaggerated for illustration). The lower graph shows the correction, so the true value = scale reading + Delta. The second graph shows such a correction plot for a real scale.

Measuring tape sag



The form of a flexible hanging tape or line (catenary) is :

$$y = (e^{\alpha x} + e^{-\alpha x}) / 2 \cdot \alpha$$

Where $\alpha = \lambda \cdot g / T$, λ is the mass per unit length of the tape and T the horizontal tension. Then the length S along the tape when the ends are a horizontal distance L apart is:

$$S = [2 \cdot \sinh (L \cdot \alpha / 2)] / 2$$

and the systematic error in the length ΔL, and the sag Δy are approximately :

$$\Delta L = (S - L) = (L^3 \cdot \alpha^2) / 24 \qquad \Delta y = (L^2 \cdot \alpha) / 8$$

Example :

470 LOA and keel rocker - Steel tape (10 mm x 0.17 mm) λ = 13 gm / m = 0.013 kg / m

Tension T = 49 N, i.e. weight of 5 kg Then $\alpha = \lambda \cdot g / T = 0.013 / 5 = 0.0026$

For a 470 the error in LOA is $\Delta L = (L^3 \cdot \alpha^2) / 24 = 4.70^3 \times 0.0026^2/24 = 0.029$ mm

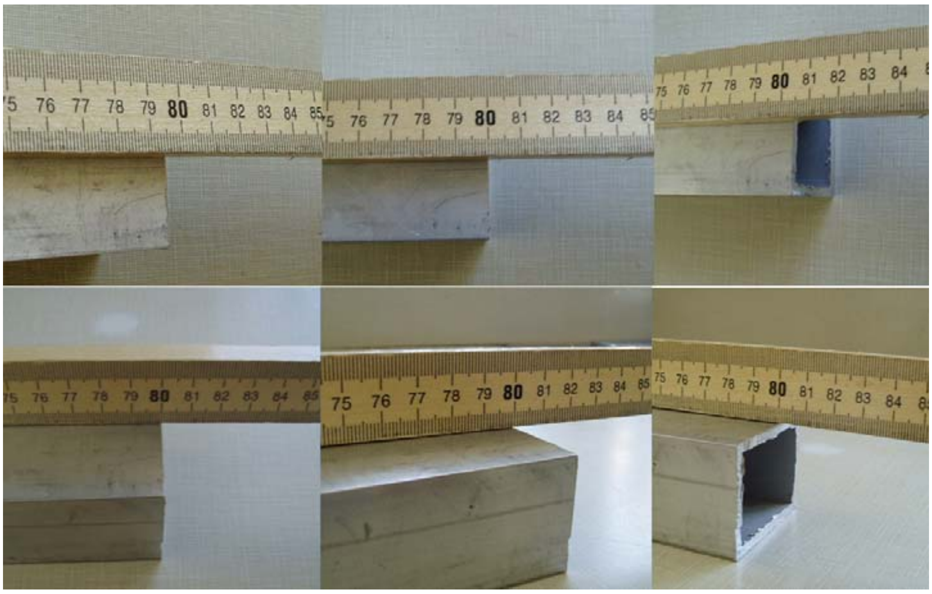
The sag would be $\Delta y = (L^2 \cdot \alpha) / 8 = 4.70^2 \times 0.0026/8 = 7.2$ mm

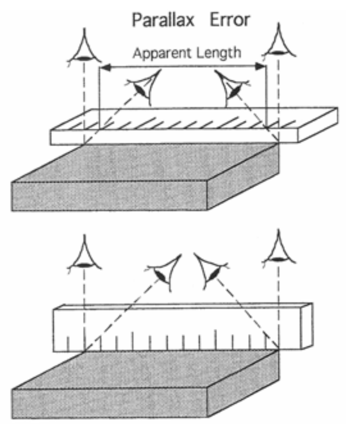
So for keel rocker measurement use a very light line, i.e. twine

λ = 1.3 x 10-4 kg / m T = 49 N, Δy = 0.069 mm

Parallax Error:

This is a miss reading of a scale which is not contiguous with the object being measured when the line of sight is not perpendicular to the scale. Parallax errors can be eliminated by placing the scale adjacent to the object being measured.



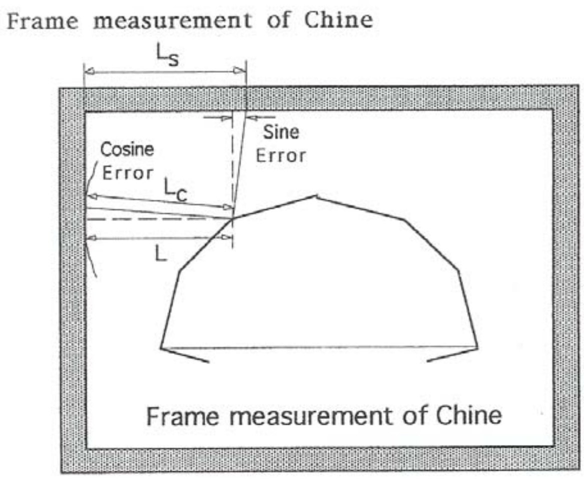


Sine and Cosine errors

Example:
Frame measurement of chine.

In general do not sight down or use a plumb line to transfer the measurement point perpendicular to the measurement, as this involves a sine error $\Delta = (L_S - L)$, i.e. an error proportional to the sine of the angular error.

It is much better, if possible to measure directly in the direction of the dimension, i.e. L_C. For the same angular error $\Delta = (L_C - L)$ which is proportional to the cosine of the angular error, and much smaller than the sine error.
Swing the tape in an arc to avoid the cosine error.



Example:
On an EUROPE dinghy,
measurement of LOA along the deck differs from the design LOA by a cosine error, i.e. an error proportional to

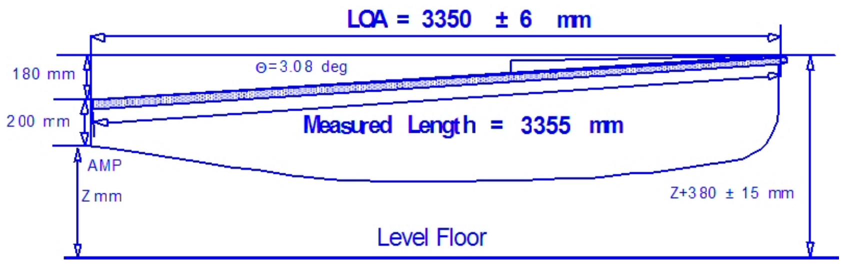
$$\textbf{Cos } \theta = 1 - \theta^2 \textbf{ (deg.) / 6566}.$$

Europe Dinghy LOA = 3350 ± 6 mm

Sheerline angle = Atan (180/3350) = 3.08 degrees

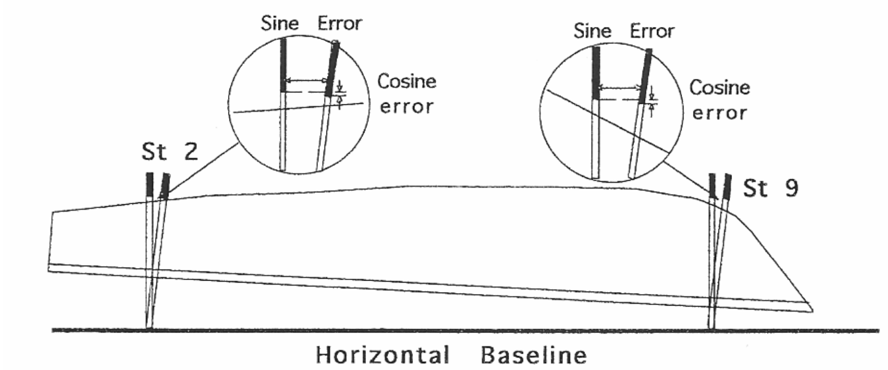
Length along deck = 3350 / Cos (3.08) = 3355 mm

Difference Δ = 4.8 mm (0.144 %)



Template hull shape measurement

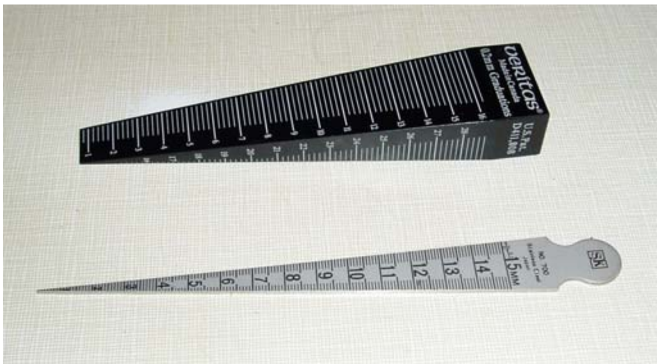
Leaning templates involve a sine error, i.e. a displacement from the correct fore and aft position, which is generally more serious than the vertical displacement of the template which is a cosine error.
At station 9 the change in the gap due to the vertical displacement (cosine error) is small in comparison to the change due to the horizontal displacement (sine error).

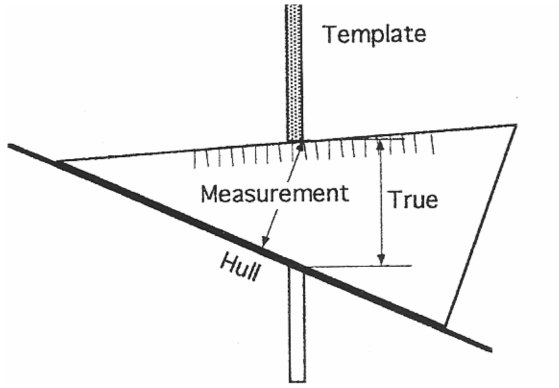


Wedge gauges

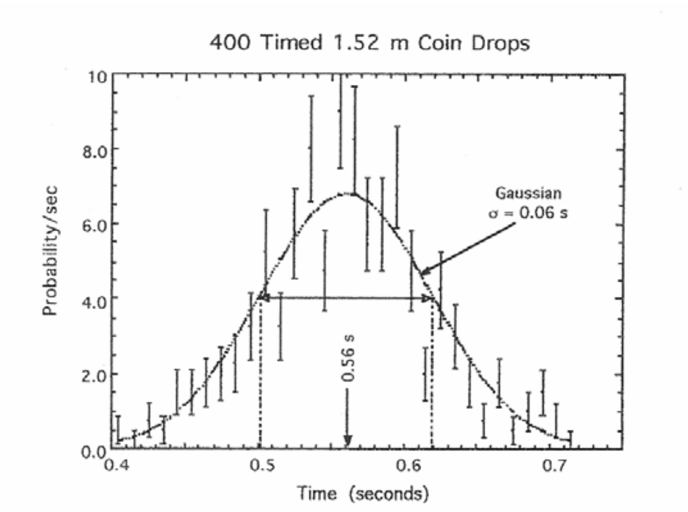
Wedge gauges come in two varieties
a) Those that measure perpendicular to one edge, and
b) those that are intended to measure inside diameters and measure perpendicular to the bisector of the gauge angle.

Most sailboat classes intend the template gap to be measured in the plane of the template, and perpendicular to the template edge. A wedge does not measure this correctly if the section is angled as shown. The Yngling class states that the gap shall be measured “perpendicular to the hull” so in this case the wedge gives the required gap measurement.





Random errors



Random errors are due to fluctuations leading to results which are randomly different from measurement to measurement. They are:
The sum of uncontrollable small variations in many factors,and so they are statistical in nature.
Present to some degree in all measurements.
Cause repeated measurements to vary randomly.
Positive or negative (Gaussian distribution).
Can be reduced by more precise instruments, better procedure and averaging.
A quantitative estimate, the standard deviation σ, can be derived from the scatter of the measurements.
Random errors add in quadrature, $\delta^2 = \Sigma\ \delta_i^2$
Random errors limit the precision of the measurement.

Example:
The plot is a histogram of 400 readings of the time a dropped coin took to reach the floor, as manually measured using a stop watch.
The variability in manually starting and stopping of the timer produces a random error such that there is a 63 % chance that the next reading will be within ± 0.06 s of the 0.56 s mean. However, the standard deviation of the mean is

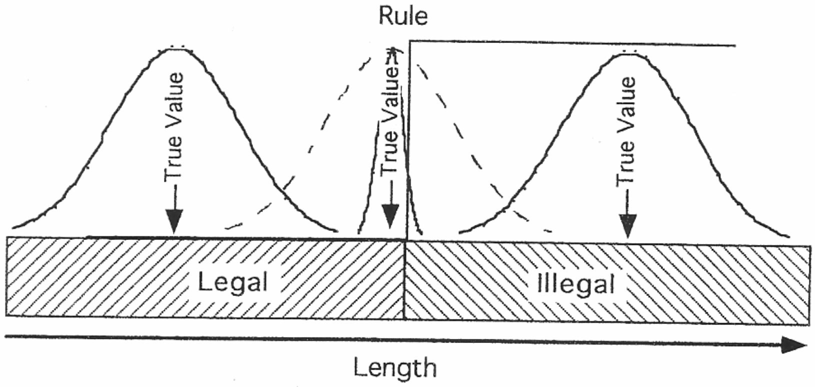
$$\sigma_m = 0.06 / \sqrt{400} = 0.003 \text{ s}$$

i.e. there is a 63 % chance that the mean of the next 400 readings will be within ± 0.003 s of this mean.

It will be seen that taking many readings is not an efficient way to reduce the random error, it is much better to improve the technique, i.e. in this case to use photogates to start and stop the timer.

The effect of precision

The definition of a class rule measurement implies a sharp boundary between the legal and the illegal values. In principle if a 645 kg hull is 1 g under the minimum weight it is not class legal, in practice however it would be extremely difficult to measure with this precision as measured values always have some uncertainty due to random errors. When the measurement is either well inside or well outside the boundary the uncertainty is not a problem, i.e. one can even eyeball the measurement for a rough value. For regatta inspection, obviously legal items can just be inspected. If there is doubt a quick measurement may settle the question, however if there is still doubt, then a careful more time consuming measurement has to be made.
When the measurement is close to the boundary one must be more careful and reduce both systematic and random errors.



The diagram illustrates a length measurement, which is initially made quickly with a tape measure, so the precision, as represented by the wide distribution that many such measurements would produce, is definitive if the value is either bigger or smaller than the legal limit by more than the width of the distribution. However, if the value is close to the limit, the random errors could lead to measurements on either side of the limit, and so are not precise enough to decide the issue. The precision can be improved by tensioning the tape, using the 10 cm graduation not zero, and having an assistant ensure that it is on the mark, making sure the tape is not kinked etc., then the distribution would be narrower, as shown, and can more reliably be used to show the component is legal for this case.

Problems due to imprecision

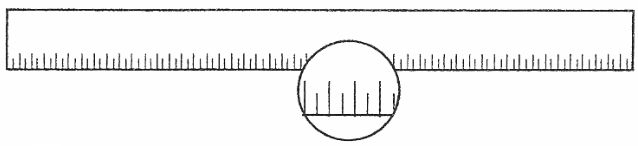
A classic example is the uncertainty in a gyradius measurement.

1. A hull which is quite illegal is measured and found to be only just illegal because the first measurement happens to overestimate the true value, i.e. the random error is positive. Hull is illegal but because of the random errors there is a 20% chance of finding it legal.
2. The competitor then adds lead at the bow as instructed, and makes sure by adding a little extra! The hull is now legal but there is a 40% chance of finding it illegal, i.e. the random errors could be negative.
3. The hull is re-measured and found to be more illegal than before (?), because now unfortunately, the measurement underestimate the true value.
4. The competitor then adds even more lead at the bow as instructed and now, because the measurement is larger than the true value finds a huge gyradius (!) … And wants to remove lead ….

Conclusion : the measurer is incompetent !!!

Quantization errors

Length :
Finite size of scale divisions limit the precision to which a measurement can be made.
Ruler divisions, 1 mm for a 10 m tape (0.01 %) can estimate to 0.3 of a division.



Vernier scales 0.01 mm for 150 mm (0.007 %).

Time :
Stop watches typically limited to 1/100 sec.
This more than adequate for hand operation.

Electronic timer 0.1 ms for 5 sec (0.002 %)

Weight :
Digital scales. Should be at least four digit,
i.e. 0.1 kg for a 200.0 kg scale (0.05%)
1g for a 2.000 kg scale (0.05%).

Kitchen and bathroom scales are not suitable for measurement unless tested for reproducibility and calibrated.

Measurement techniques and reproducibility

Technique :
- Do not measure a quantitiy as the difference between two values, e.g. skin thickness, large tare weight, etc.
- The use of two scales (or tongue weight) is to be discouraged.

Templates :
- Aluminium hull templates.
- Mylar master to check templates.
- Rudder and centreboard templates.
- Gunwale, rubbing strake gauge.
- Gauges for masts, booms and spi poles.
- Mylar templates for sails.

Records :
- Comparison with measurement certificate.
- Record keeping, paper and computer.
- Records available to mesurers on the Internet.

Calibration :
- Fortunately in yacht measurement we generally use SI units and standards.
- For the precision required in dinghy measurement the calibration of steel tapes, callipers, etc. are generally not a problem.
- Quartz timing devices generally do not need recalibration, but computers used for timing often do.
- Mechanical watches should vary les than 1 second a day (0.001 %).
- Calibration of weighing scales should, if possible be checked on site against standards of similar mass to object to be weighed.

Tools and equipment

see 8.0

Measurement Axes

Unless specifically required by class rules to be taken in another way, it should be assumed all measurements denoted by words such as 'above', 'below' or 'forward' in relation to parts or items are taken parallel to or at right angles to one of the three main axes of the hull, related to the waterline or baseline (see Section 9) and the fore-and-aft centreline of the hull, as shown in the figure below.

Measurements are normally taken parallel or perpendicular to the main axes and some class rules require the axes to be levelled (mainly horizontal axes).

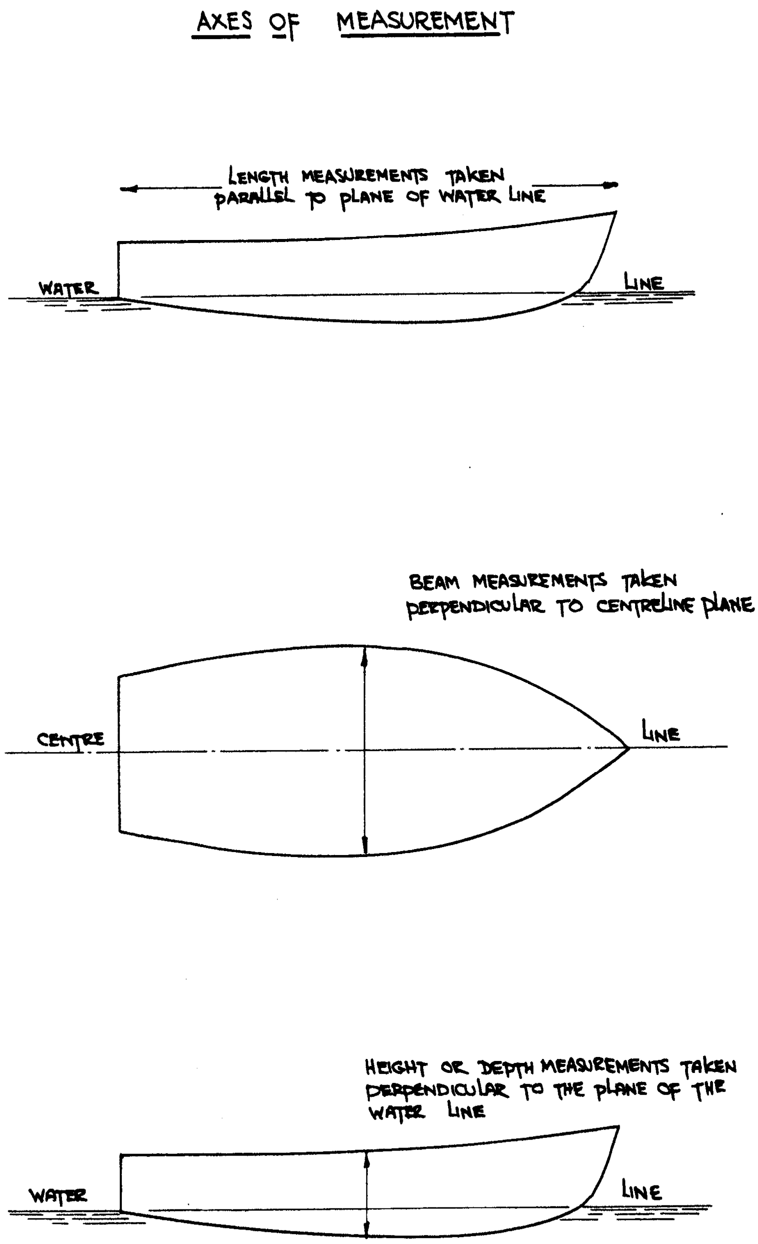


Figure 5.1.1

Any deviation from the correct axis will result in an error in the recorded measurement. Although small deviations from the correct line will cause negligible errors for measurements of short distances, the error can become appreciable when taking a long measurement such as the length of the hull. The extent of such an error can be approximated as shown in the following example. The additional overall length is approximately given by the formula:

$$\Delta L = h \cdot (H - h / 2) / L$$

where h is the additional depth of immersion of the stem
H is the height of the stem
L is the nominal length overall.

The graph in the figure 5.1.3 is for a 4270 mm (14 ft) boat.
As an example, if the measurement of the length of a boat is taken as being from the top of the transom to the stem head instead of the horizontal distance between perpendiculars, an error will occur. If the stem of a boat 4.5 m long is 200 mm higher than the transom the error is 4 mm. The error causes an over-reading of the measurement.

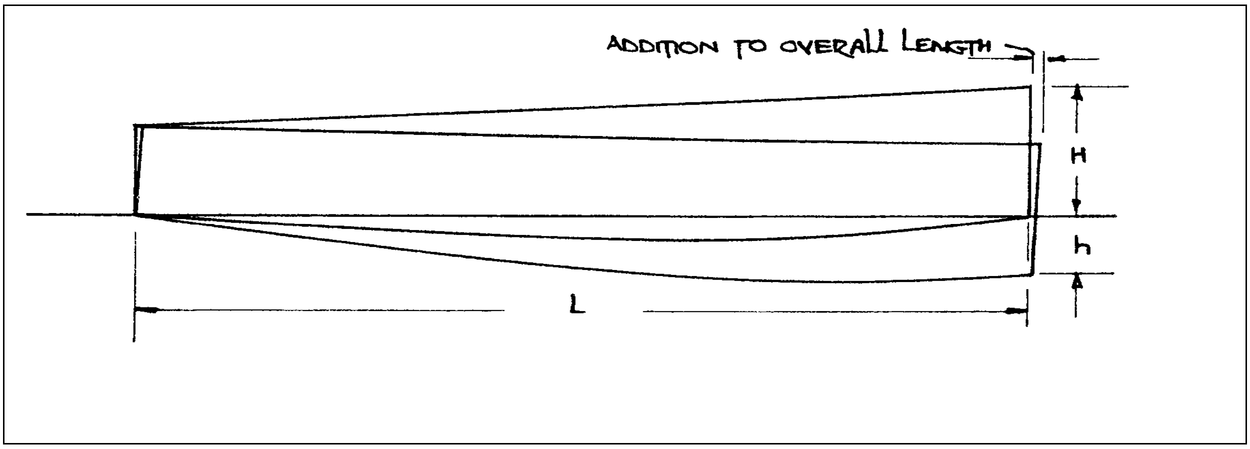


Figure 5.1.2

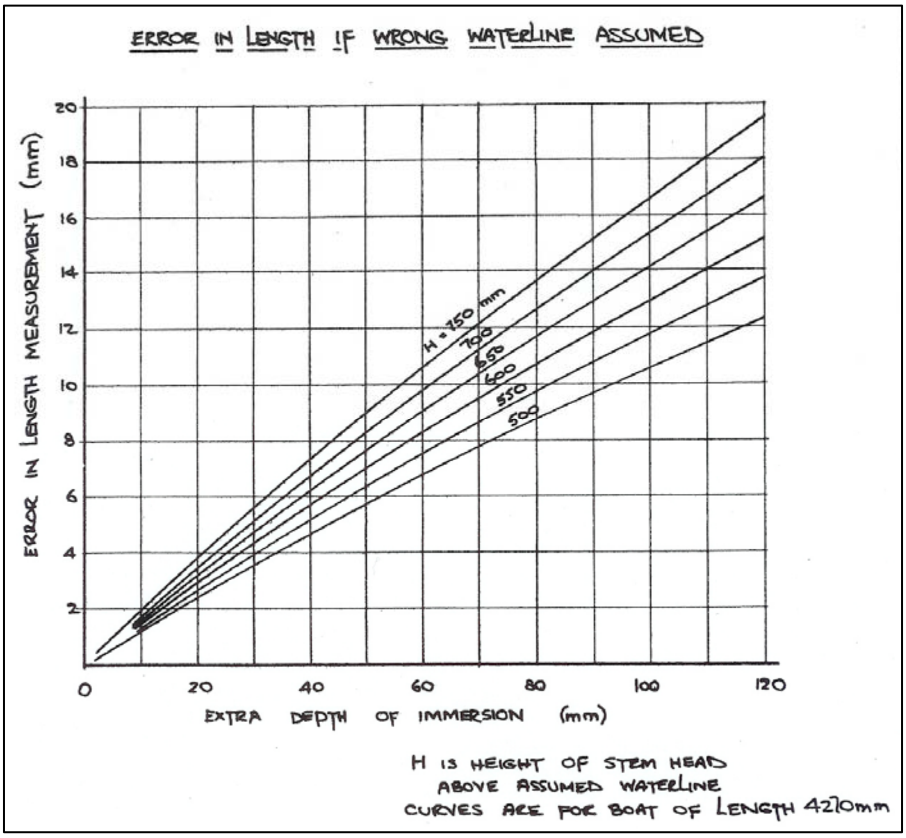


Figure 5.1.3

Tape Measurement Errors

End error
If the end of the tape or rule is damaged there may be an error in the measurement. It is good practice to check that the length of the tape or rule over its first 100 mm is correct.

Tension
Most tape measures are calibrated while a particular tension is applied to the tape. It follows therefore that the most accurate results will be obtained when that tension is being applied. The normal tension 5 kg at 20° C and in the absence of a tension being stated on the tape this figure should be assumed. The error due to the application of more or less tension is not great provided it is not greatly different. In practice other factors, such as sag of the tape, are more significant.

Sag in tape
Unless the tape is laid along a straight surface it will always have some sag in it and this will cause an error, however small. The amount of sag and hence the error, depends on the tension applied. The graph in **the figure** (next page) indicates the error that can occur in measuring a length of 4.5 m. The error causes an over-reading of the measurement.

Permanent bent of the tape
A bent tape (by stepping on it) will also give wrong dimensions.

Temperature

Most substances expand slightly as they get hotter. This applies to tape measures as well as to the items to be measured. The effect on measurements of changes in temperature is usually small. Steel has a coefficient of expansion of 0.000011/1°C and steel tapes are normally calibrated at a temperature of 20°C.

If a mast is measured while it is in the sun both it and the tape measure can easily reach a temperature of 40°C. The change in length of a tape measure nominally 10m long would be 2.2 mm. However, the mast itself would expand also (aluminium has a coefficient of expansion of 0.000025/1°C) and assuming it too was standard at 20°C its increase in length would be 5.0 mm. There would, therefore, be an error of nearly 3mm in the length measurement - in this example it would have appeared to be longer. The error can be reduced by carrying out the measurement in the shade when for most practical purposes the effect of temperature can be ignored.

6 EVENT INSPECTION

Time for measurement is almost always very short and frequently there are too few measurers. In these circumstances the work of the measurers becomes physically demanding and special techniques to reduce the time required are needed. Chapter 17 presents examples of class procedures including forms etc.

6.1 The level of measurement

It should be remembered that measurement at a regatta is being done to check that the boat is correct in at least some respects. Normally a full measurement is not undertaken and so items not measured are assumed to be correct. However, this in no way relieves the owner or competitor from his responsibility to sail a boat complying with all its class rules. There should be no confusion between a regatta measurement and a fundamental measurement, in the first case the measurer is appointed and obtain his authority from the Race Committee of the specific event, in the second case the measurer has a contract either with the builder or with the owner of the boat.

Being a check measurement, the actual measurements do not usually need to be known or recorded, and procedures can be adopted which reduce the measurement time required.

Five levels of checking can be mentioned; of course the level zero exists when nothing is done with respect of measurement:

Level 1 : **where only the measurement certificates are required.**
On all the levels the safety equipment must be checked.

That's normally the task of the skipper but a general check either when the boats are going on the water or when they come back is strongly recommended. Think about the liability problem if there is an incident during the regatta… Time required : 5 minutes for each boat – One measurer.

On level 2 : **you can add the checking of the sails and the corrector weights.**
Time required : about 15 minutes – One measurer and two helpers.

On level 3 : **one step further, the weight and the marks on the spars are added to the checking.**
Time required about 20 minutes – One measurer and 5 helpers.

Level 4 : **that's the revel recommended for the Continental and World Championships and for the qualifying events for the Olympics.**
To the previous mentioned measurements, you can add some selected items. The choice of those items have to be discussed between the Class technical officers and the Event Measurer, normally an International ISAF approved Measurer.

Level 5 : **the "Olympic level" where an almost full measurement is done.**

As a suggestion the following grid could be used:

• LEVEL 1 – (National qualification events)	Only Measurement Certificate + Safety equipment
• LEVEL 2 – (National Championships)	Measurement Certificate + Corrector weights (CW) Sails + Safety equipment
• LEVEL 3 – (National Championship of Olympic Classes or International Events)	Measurement Certificate + Sails + Weight and CW Safety equipment + Marks on spars
• LEVEL 4 - (International Qualifying Events, Continental+World Championships)	Measurement Certificate + Sails + Weight + CW + Marks on Spars + selected items + Safety equipment
• LEVEL 5 – (Olympic Regatta)	Measurement Certificate + Almost full Measurement + Safety equipment

6.2 Facilities required

The facilities required to undertake a programme of measurement at a championship will depend on the work which is to be carried out. It is very rare that all the facilities needed are available and the measurers will have to adapt their work or methods to take account of what is available.

Wherever possible all measurement should be done on solid ground, under cover and in any case out of the wind.

Hull measurement can be fairly readily carried out in any building with suitable access, or in a large tent. Whatever is used it should have a fairly level floor, particularly if the boats are to be moved. Weighing machines, if of the platform scale type, require a firm foundation.
Sail measurement, ideally should be carried out on tables about 85-90 cm high. These tables have to be specially made to suit the particular class and consequently are not always available. Therefore sometimes the sails may have to be measured on the floor. If so, the floor should preferably be of wood or some other smooth and dust free surface.

Measurement Stations

Since the time available for measurement is invariably short it may be necessary to adopt a production line method of carrying out the work with one measurer (with assistants) running one measurement station where for instance, the hull templates would be applied. The boat is then passed on to the next station and so on. Sails would normally be measured separately. If the boats are being moved from one station to another it is a help if the distance which they have to be moved is kept as small as possible, as this is less tiring for those involved in moving the boat, and results in less time being wasted.

6.3 Measurers and helpers

Wherever possible only qualified measurers should be used. In any case the measurer in charge of the whole measurement operation must be qualified to carry out the work. It is also essential that he has a very good knowledge of the rules of the class.

If the measurement programme is to include hull measurement, centre of gravity or weight distribution test, weighing, rudder and centreboard measurement, spar measurement and sail measurement, it is clearly impractical for all the work to be carried out by only one or two measurers.

It is frequently necessary to use unqualified assistants. This is acceptable provided the assistants are adequately instructed on how to undertake the measurement and on what to expect to find and they report to a qualified measurer for him to make decisions on the various features if something unexpected is found.

Some operations require the boat to be moved - for instance weighing - and it is very helpful if there are people available to assist with this work.

6.4 Measurement period

Time allocated for measurement will have been decided in advance and usually before the number of boats to be measured is known. It is usual for the period to appear to be too short. If competitors are told that measurement takes place between certain times on certain days, they tend to arrive towards the end of the period, with the result that the measurers have considerable difficulty in getting through the work. Therefore, it is advisable to allocate a certain time to each competitor in advance of the regatta, or split the entire into groups which are required to attend at certain times. This can be done when processing entries.

6.5 Measurement techniques

The use of measuring rods - lengths of extended metal sections, or plastic or wooden battens clearly marked with the minimum and maximum permitted dimensions of an item, can improve the speed and consistency of the measurement. If it is necessary to use tape measures it is a good idea to mark the tape at the appropriate measurements. This can be done by wrapping the tape measure at the selected positions with masking tape and indicating on this what the measurement is and which edge of the tape to use.

For sails it is also not desirable to use tape measures. It is usually a simple matter to place marks on the measurement table or floor indicating the limits of the dimensions being checked. It should be remembered that floors are almost never clean enough and moreover, working on them is a physically demanding process. Therefore, tables about 85-90cm high are the best solution.

If possible it is desirable to arrange it so that sails do not overlap on the measurement surface as it is frequently helpful to be able to proceed with the work independently. For this reason, some classes use separate tables for mainsails and jib/spinnakers, or even use two sets of tables to work faster if they deal will a lot of boats (Optimist). If it is impossible to get separate tables, then color-coded marks should be used for each type of sail. It is also helpful if a sail is available when placing marks on the table or floor as, with a little forethought, the marks can be placed so that the sail does not need to be moved very much during measurement.

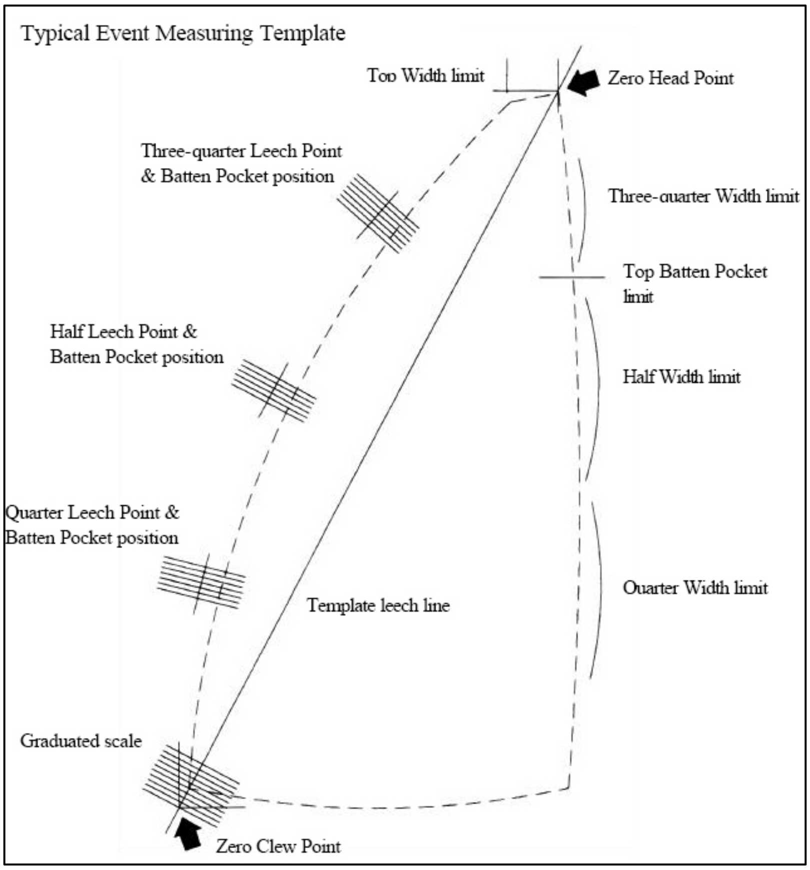


Figure 6.5.1 Typical sail inspection table

Figure 6.5.1 shows a typical arrangement of markings for measuring a mainsail. The graduated scales shall have appropriate spacings (full, ¾, ½ and ¼) as shown in Figure 6.5.2. Measurers must have prior knowledge of the amount of mainsail roach typically found in their class (or the range of it), so they can position the scales accordingly, especially the half-leech point one since the ¼ and ¾ ones depend on that. Graduated scales may be used also for the jib mid-foot point, and also for spinnaker leech points and foot mid point. The use of the scales is not mandatory, but it facilitates measuring of sails without folding. In some cases, classes use simplified systems to avoid sail folding: they prescribe measurements taken at "upper leech point"-style leech points, at predetermined distances from the head point (ERS G.5.4)

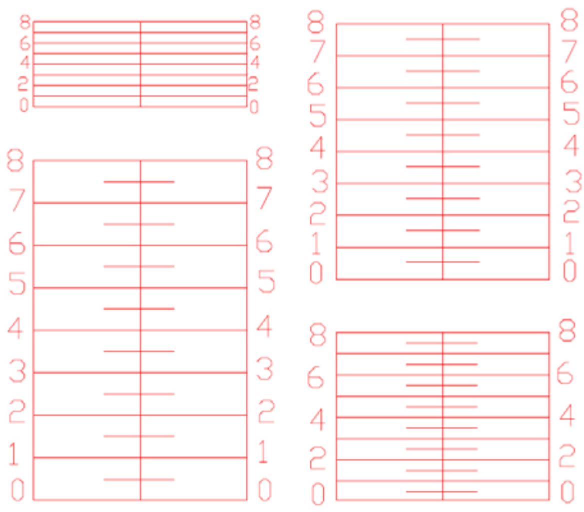


Fig. 6.5.2 Graduated scales for sail inspection tables

To check that items such as sail reinforcement and sail numbers are of the correct sizes simple templates of plastic or card can be used.

6.6 Non-Compliant Equipment

When a measurer finds something which is not in compliance with the relevant Class rules he should follow the procedure laid down in Racing Rule 78.3 and considered in Section 7.

6.7 Personal / Portable Equipment

6.7.1 Lifejacket

Sailing instructions usually state that wet suits will not be considered to be adequate personal buoyancy and therefore competitors have to have proper life jackets or buoyancy aids.
Requirements and standards vary from one country to another and therefore it is not possible to give firm statements on what can be accepted. However, if personal buoyancy is required then it must be an item of equipment which has been made as a life-jacket or a "buoyancy aid". Personal buoyancy shall comply with the specific class rules. Where not specified in class rules, personal buoyancy compliance with CEN Standards N° 1 CEN 393 (50 Newtons) or an equivalent may be accepted. Inflatable buoyancy aids are only permitted if the Class Rules specify them.
The measurer should not accept it if it is damaged in any way which can affect its performance or which would allow it to come off the wearer, or move thus reducing its effectiveness.

6.7.2 Trapeze Harness

There are often two requirements for a trapeze harness, or hiking strap; maximum weight and positive buoyancy.

Ballasting the harness with lead or other material in order to bring it up to the maximum weight is not permitted.

To check for positive buoyancy the harness should be immersed in water. As no time for floating is specified it is sometimes asked how long the harness shall be able to float. The requirement is that it shall not sink.

6.7.3 Anchor

Unless the Sailing Instructions, National Authority prescription, or the class rules prescribe otherwise, the racing rules require a boat to carry an anchor and chain or rope when racing.

If an anchor is required, the class rules normally specify the minimum weight of the anchor and the length of line required.

If an anchor is slightly underweight it is normally accepted that its weight can be increased by attaching additional weight. If this is done the weight has to be added in such a way that it is permanently fixed (glued with resin) and furthermore does not impair the anchor's efficiency. An anchor should be able to hold the boat which effectively means it has to be either a commercially available anchor or to be similar in its design.

The anchor line has to be used only as the anchor line and shall not be used as spinnaker sheets etc. as well.

The stowage of the anchor is sometimes considered in the class rules but, if it is not, the measurer should check to see that it is not stowed in one of the buoyancy tanks. Buoyancy tanks are part of the safety equipment and should not have to be opened at any time while the boat is sailing.

6.7.4 Paddle

If a paddle is required to be carried it shall be capable of performing its function satisfactorily. A paddle may be dismantled for stowage provided it is made especially to do so and is adequately strong. The minimum length of the paddle is taken as the overall length, and not the length of each part.

6.7.5 Bucket

One or more buckets or self-bailer may be prescribed by the class rules to bail water from the cockpit.

6.7.6 Hand pump

If a hand pump is requested by the class rules it should be capable of pumping water from the bottom of the bilges to the outside of the deck.

6.8 Wet clothing

The ISAF racing rules of sailing control what a competitor is permitted to wear with regard to increasing his weight in order to assist him to keep his boat upright.

RRS 43 COMPETITOR CLOTHING AND EQUIPMENT

43.1 *(a) Competitors shall not wear or carry clothing or equipment for the purpose of increasing their weight.*

(b) Furthermore, a competitor's clothing and equipment shall not weigh more than 8 kilograms, excluding a hiking or trapeze harness and clothing (including footwear) worn only below the knee. Class rules or sailing instructions may specify a lower weight or a higher weight up to 10 kilograms. Class rules may include footwear and other clothing worn below the knee within that weight. A hiking or trapeze harness shall have positive buoyancy and shall not weigh more than 2 kilograms, except that class rules may specify a higher weight up to 4 kilograms. Weights shall be determined as required by Appendix H.

(c) When an equipment inspector or a measurer in charge of weighing clothing and equipment believes a competitor may *have broken rule 43.1(a) or 43.1(b) he shall report the matter in writing to the race committee.*

43.2 Rule 43.1(b) does not apply to boats required to be equipped with lifelines.

This rule (RRS 43) does not give information on how to determine the weight of clothing and equipment but Appendix H of the Racing Rules gives a recommended method:

Appendix H - Weighing Clothing and Equipment

See Rule 43. This appendix shall not be changed by sailing instructions or prescriptions of national authorities.

H1 *Items of clothing and equipment to be weighed shall be arranged on a rack. After being saturated in water the items shall be allowed to drain freely for one minute before being weighed. The rack must allow the items to hang as they would hang from clothes hangers, so as to allow the water to drain freely. Pockets that have drain-holes that cannot be closed shall be empty, but pockets or items that can hold water shall be full.*

H2 *When the weight recorded exceeds the amount permitted, the competitor may rearrange the items on the rack and the measurer shall again soak and weigh them. This procedure may be repeated a second time if the weight still exceeds the amount permitted.*

H3 *A competitor wearing a dry-suit may choose an alternative means of weighing the items.*
(a) The dry-suit and items of clothing and equipment that are worn outside the dry-suit shall be weighed as described above.
(b) Clothing worn underneath the dry-suit shall be weighed as worn while racing, without draining.
(c) The two weights shall be added together.

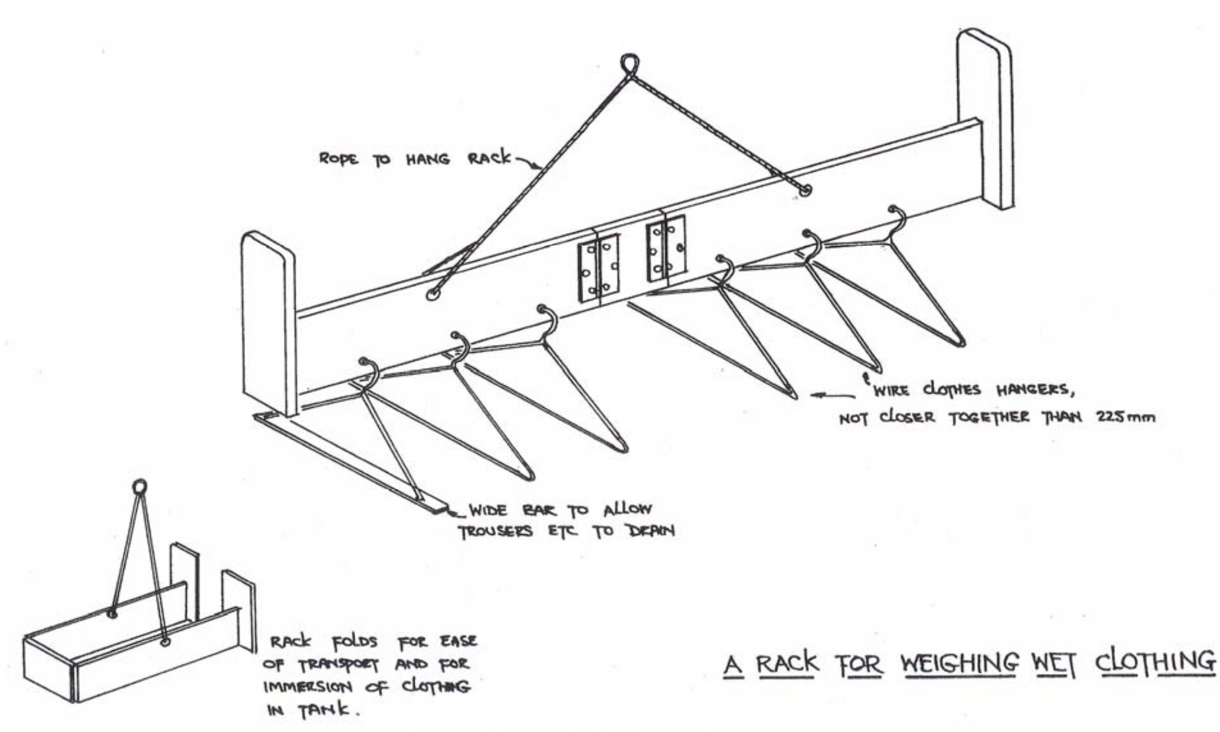
Procedure for weighing clothing

To test the weight of clothing and equipment worn by a competitor all items to be weighed shall be taken off and thoroughly soaked in water. Note: equipment includes items such as trapeze harness, life jacket.

The manner in which the clothing and equipment is arranged on the rack has a considerable effect on the weight recorded and it is important that free draining is achieved without the formation of pools of water in the clothing, It is recommended that a rack comprising "clothes hanger" type bars be used and that provision is made for suspending boots or shoes in an inverted position.

However, this may not be practical if a large tank is not available. In this case the items will have to be put on the rack one at a time. Provided that the less absorbent ones are put on first there is no reason why the resultant weight should not be accurate. Most clothing drains very rapidly during the first few seconds but later draining is much slower so that by the end of the one minute draining period little change is taking place. See figure below.

Pockets in clothing which are designed to be self-draining - i.e. those which have drain holes and no provision for closing them - shall be empty during the weighing, however, pockets or equipment designed to hold water are prohibited. Boots and shoes, if they are part of the weighing, shall be empty when weighed.



Ordinary clothing becomes saturated within a few seconds but water absorbent clothes should be immersed for not less than 2 minutes.

On removal from the water the items shall be allowed to drain freely for 1 minute, at the end of which period the weight shall be recorded.

When the weight recorded exceeds the amount permitted, the measurer is recommended to allow the competitor to rearrange the clothing and equipment on the rack and then to repeat the test by re-soaking and re-weighing. When a lesser weight results, that weight shall be taken as the actual weight of clothing and equipment.

It is good practice to ensure that very absorbent items are not touching each other and, that if possible, the absorbent parts of a garment are not touching another absorbent part.

The wide bar on the rack assists with this for trousers. Items like wet suits with absorbent linings and "polar suits" are best hung on the rack inside out as this facilitates draining.

Boots, socks and gloves are weighed empty. Pockets in oilskins etc., have to be full unless they automatically drain through permanently open drain holes, in which case they are empty during the weighing.

The following alternative can also be chosen:

1. Dousing the competitor and filling the pockets (if any) with water or at least 2 minutes.
2. Draining for 1 minute.
3. Weighing the competitor with their personal equipment >> **W1**
4. Taking all the personal equipment and the clothing down to underclothes.
5. Weighing the competitor again >> **W2**

Weight of equipment and clothing : W = W1 – W2

If less than maximum permitted according to Class Rules >>> OK,

if more than permitted, ***proceed to RRS, appendix H***.

7 RACING RULES AND MEASUREMENT

7.1 Measurer's responsibility – Racing rule 78.3

This rule lays down the procedure which a measurer is to follow when he finds that a yacht does not comply with the class rules or rating certificate.

The rule reads:

78 COMPLIANCE WITH CLASS RULES; CERTIFICATES

78.1 *A boat's owner and any other person in charge shall ensure that the boat is maintained to comply with her class rules and that her measurement or rating certificate, if any, remains valid.*

78.2 *When a **rule** requires a certificate to be produced before a boat races, and it is not produced, the boat may **race** provided that the race committee receives a statement signed by the person in charge that a valid certificate exists and that it will be given to the race committee before the end of the event. If the certificate is not received in time, the boat shall be disqualified from all races of the event.*

78.3 ***When an equipment inspector or a measurer for an event decides that a boat or personal equipment does not comply with the class rules, he shall report the matter in writing to the race committee.***

It is important to note that the measurer has no authority to disqualify a yacht or to rescind its entry.

A measurer is sometimes called upon to report on the circumstances of a protest to a protest committee (or to an International Jury). This report should record **only the facts** - i.e. the measurements or details of the shape of the item concerned and, if requested, the wording of the class rules.

The protest committee may decide the protest after a hearing, if it is satisfied there is no reasonable doubt as to the interpretation or application of the class rules. However, if it is not so satisfied, the protest committee is required to refer the matter to an authority qualified to decide the matter.

The racing rules do not make it clear who such an authority is and therefore the protest committee or international jury can decide which authority it consults. ISAF Regulation 26.11 covers Interpretation Procedures but there are also Classes who follow different patterns and thus prescribe them in their Class Rules.

Suitable persons or bodies who could be considered to be qualified authorities include:

International Sailing Federation **(for International Classes administered by ISAF)**

National Authority **(if that body is administering the class in that country)**

Chairman of the International Class Association's Technical Committee who should be in contact with the ISAF

Whichever person or body is consulted it is important that they really are qualified to make a decision. It is an unfortunate fact that in many cases measurement at a regatta is carried out by someone who is not really familiar with the class, and while competent to measure sails, he may not be familiar with other rules governing the class.

7.2 Damage or deviations in excess of tolerances, measurement protests - RRS 64.3

This rule specifically permits a yacht time to put right any damage or wear and tear which has caused her not to comply with her class rules, provided that her performance is not improved as a result of this.

64.3 Decisions on Measurement Protests

(a) When the protest committee finds that deviations in excess of tolerances specified in the class rules were caused by damage or normal wear and do not improve the performance of the boat, it shall not penalize her. However, the boat shall not race again until the deviations have been corrected, except when the protest committee decides there is or has been no reasonable opportunity to do so.

(b) When the protest committee is in doubt about the meaning of a measurement rule, it shall refer its questions, together with the relevant facts, to an authority responsible for interpreting the rule. In making its decision, the committee shall be bound by the reply of the authority.

(c) When a boat disqualified under a measurement rule states in writing that she intends to appeal, she may compete in subsequent races without changes to the boat, but shall be disqualified if she fails to appeal or the appeal is decided against her.

(d) Measurement costs arising from a protest involving a measurement rule shall be paid by the unsuccessful party unless the protest committee decides otherwise.

It is a matter of judgement whether performance will have been improved but, for instance, a dinghy would normally not be disqualified if through being dragged up a slipway part of her keel band had a cross section less than that required by her class rules. Likewise a protest committee would not be expected to disqualify a yacht whose buoyancy equipment had been rendered ineffective by a collision for which she was not responsible.

7.3 Identification on sails - RRS 77

A boat shall comply with the requirements of Appendix G governing class insignia, national letters and numbers on sails.

See Section 15 “Sail measurement”

7.4 Advertising - RRS 80 and ISAF Regulation 20

A boat and her crew shall comply with ISAF Regulation 20, Advertising Code.

7.5 Right to Protest (RR 60.2)

When the race committee receives a report required by rule 43.1(c) or 78.3, it shall protest the boat.

8 MEASUREMENT EQUIPMENT

The equipment which the measurer uses to carry out work is very much a matter of personal preference although certain items are essential to all measurement. This section describes the basic equipment required and some simple purpose built equipment which can be made using only basic tools, as special equipment is often designed for particular applications, unique to one class. Some classes produce documents describing such tools and measurement techniques specific to their class, known as a class measurement guide or handbook. Such handbooks are valuable reference guides to measurers and should be obtained.

8.1 Tools and accuracy.

Not all tools are certified. The following requirements apply to certified tools.

Certification error: this is the error permitteded when the tool is certified. This error is the permitted maximum figure for positive or negative deviation from the correct value. The value of the Standard (Normal) or the Standard Measurement Installation is considered to be the correct value.

Handling error: If the error exceeds this value, then the tool must be recertified. Normally it is twice the certification error.

Correctness of results: tools must be build so that when used for the intended purpose and within the intended measurement conditions, correct results may be expected.

Tolerances: are normally plus or minus or within. But they may be added all in the direction plus or in the direction minus. We never know.

Mechanical tools for length measurements.

The certification error is for:

Calipers, measurement capacity up to 500 mm 0,1 mm
Calipers, measurement capacity greater than 500 mm 0,2 mm
Micrometer, measurement capacity up to 100 mm 0,01 mm
Micrometer, measurement capacity greater than 100 mm 0,02 mm
Indicator (Messuhr), till a length of 10 mm 0,02 mm

Standards:

For calibrating callipers or Micrometers, they are classified by DIN 3650
Length tolerances in µM (+/- 0,60 = 0,0006 mm)

Length in mm	Class 00	Class 0	Class 1	Class2
- 10	+/- 0,06	+/- 0,12	+/- 0,20	+/- 0,45
10 - 25	+/- 0,07	+/- 0,14	+/- 0,30	+/- 0,60
25 - 50	+/- 0,10	+/- 0,20	+/- 0,40	+/- 0,80
50 - 75	+/- 0,12	+/- 0,25	+/- 0,50	+/- 1,00
75 - 100	+/- 0,14	+/- 0,30	+/- 0,60	+/- 1,20

Another standard, common as company classification is:
Error = (1 + L (mm) / 50) µM.

Electronic tools for length measurements.

Normally the reading shows better results than the granted accuracy. Users must check carefully what is written about it in the manual. Certified electronic tools are rare and expensive.

Tapes and Rulers.

The quality must be so, that at a deviation of temperature of +- 8º C from the standard (normally 20º C) the changing in length are within the certification error. If there is a prescribed tension, a changing in the tension of +- 10 % may not create a changing in length bigger than the certification error.

There are three classes of accuracy: I, II, III, marked on equipment with the respective roman numeral.
The certification error in mm is a + b x L for those classes. L is the length in rounded up full meters, a and be are coefficients found in the following table:

Class of accuracy	a	b
I	0,1	0,1
II	0,3	0,2
III	0,6	0,4

The so calculated errors are valid for the whole length and steps bigger than 1 cm.

Taking into account that **the allowed handling error** is twice as big as the allowed certification error, the final and legal deviation when working may be as big as shown below:

	Handling error in +/- mm		
Length in meter	Class I	Class II	Class III
1,00	0,4	1,0	2,0
2,00	0,6	1,4	2,8
3,00	0,8	1,8	3,6
4,00	1,0	2,2	4,4
5.00	1,2	2,6	5,2
6,00	1,4	3,0	6,0
10,00	2,2	4,6	9,2

Influence of Temperature.

The certification temperature for measurement tools is 20º C. Depending on the actual temperature and the materials of our tapes and rulers they become shorter or longer depending on their expansion coefficients. Our measurement objects will do the same. In practical work this is normally not a problem, but we should bear in mind when we are working with figures close to the limit.

Some expansions coefficients:

Aluminium	0,000024
Brass	0,000018
Copper	0,000017
Stainless steel	0,000016
Steel	0,000013
Iron	0,000012
CRP	< 0,000003 the more resin the bigger the value
GRP	< 0,000003 the more resin the bigger the value
PVC	~ 0,00008
Polyurethane	~ 0,00005 – 7
Polybuthylene	~ 0,00013
Polyethylene	~ 0,0002
Wood	depending on variety, direction and humidity
Plywood	~ 0,3 % depending on quality and humidity

Calculations are as follows:

Expansion coefficient x Length of object in mm x Difference in temperature in º C = Expansion in mm.

For example:
Length expansion for different temperatures and steel.

	Object, Length in mm										
ΔºC	250	500	750	1000	1500	2000	2500	3000	4000	5000	6000
20°C	0	0	0	0	0	0	0	0	0	0	0
+/- 5°	0,016	0,032	0,049	0,065	0,097	0,130	0,162	0,192	0,260	0,324	0,384
+/-10°	0,032	0,065	0,097	0,130	0,195	0,260	0,325	0,390	0,520	0,650	0,780
+/-15°	0,049	0,097	0,146	0,195	0,292	0,390	0,487	0,584	0,780	0,974	1,168
+/-20°	0,065	0,130	0,195	0,260	0,390	0,520	0,650	0,780	1,040	1,300	1,560
+/-25°	0,081	0,162	0,244	0,325	0,487	0,650	0,813	0,974	1,300	1,626	1,948

Straightness.

A well-tensioned fishing line is more or less straight, depending on length, own weight, air flow and force of pulling. The problem is taking distances to this line as the rulershould be just clearing but with no distance to the line.
An alloy or steel profile (appr. 40 / 60 mm)normally is straight in an unkown size but at least it is stiff enough to work with.

Straight Edges are classified by DIN 874.
Supported at the “Bessel” points, that is from the ends at 0,22 of the whole length the certification tolerance is in mm

Length of edge	100mm	500 mm	1000 mm	1500 mm	2000 mm	3000 mm
DIN 874 / 00	0,002	0,004				
DIN 874 / 0		0,007	0,012	0,017	0,022	0,032
DIN 874 / 1		0,012	0,021	0,029	0,037	0,054
DIN 874 / 2		0,021	0,033	0,046	0,058	0,083

Square Edges.

They are classified by DIN 875
The certified angle tolerance is in mm :

Length of angles	150/100	200/130	300/200	500/330	750/375	1000/500
DIN 875 / 00	0,004	0,004				
DIN 875 / 0	0,008	0,009				
DIN 875 / 1	0,018	0,020	0,025	0,035		
DIN 875 / 2	0,035	0,040	0,050	0,070	0,085	0,120

Spirit Level.

At normal, uncertified spirit levels the error is appr. at 1 mm / meter and better ones go up to 0,7 or 0,5 mm / meter.

They are classified by DIN 877.

DIN 877 / Klasse 1a → 0,02 mm / Meter
DIN 877 / Klasse 1b → 0,1 mm / Meter
DIN 877 / Klasse 2 → 0,4 mm / Meter

Standard Weights.

These are needed to check or calibrate scales. The error in use is +- the positive certification error.

The certification error in milligrams is:

Standard weight	Class F1 Fine weights	Class M1 Precision weights	Class M3 Commercial weights
1 g	0,1 mg	1 mg	10 mg
100 g	0,5 mg	5 mg	50 mg
1 000 g	5 mg	50 mg	500 mg
2000 g	10 mg	100 mg	1 000 mg
5 000 g	25 mg	250 mg	2 500 mg
10 000 g	50 mg	500 mg	5 000 mg
50 000 g	250 mg	2 500 mg	25 000 mg

Standard weights should be rechecked every 4 years. They should be stored in boxes and been kept well, clean and show no damages.

Scales.

Uncertified scales should have installations to calibrate them.
Certified scales have four classes of accuracy :

Class	Certification unit e	Min load	Number of certification units n = max / e	
		Min unit	Min unit	Max unit
I	0,001 g < e	100 e	50 000	
II	0,001 g < e < 0,05g	20 e	100	100 000
	0,1 g < e	50 e	5 000	100 000
III	0,1 g < e <2 g	20 e	100	10 000
	5 g < e	20 e	500	10 000
IIII	5 g < e	10 e	100	1 000

Tolerances (limit of errors), Certification error.

Load				Limit of error
Class I	Class II	Class III	Class IIII	
0 < m <50 000 e	0 < m <5 000 e	0 < m < 500 e	0 < m < 50 e	+/- 0,5 e
50 000 e < m <200 000 e	5 000 e < m <20 000 e	500 e <m <2 000 e	50 e < m <200 e	+/- 1,0 e
200 000 e < m	20 000 e < m <100 000 e	2 00 e < m <10 000 e	200 e < m <1 000 e	+/- 1,5 e

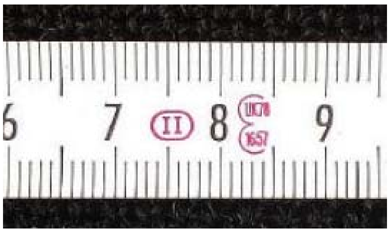
The error in use is twice as big than the certification error.

8.2 Standard Measurement Tools

The following items of equipment are needed for measuring most boats. Most classes use the metric system of measurement so equipment should be calibrated in metric, but some classes still use imperial units so dual calibration may be helpful.

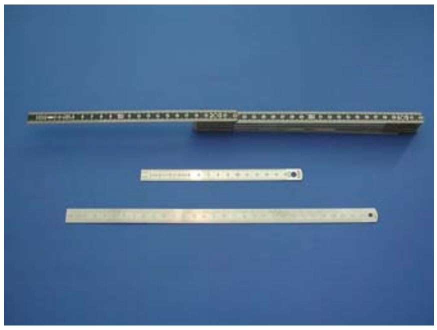
8.2.1 Tape Measure

Must be of steel (with offset zero), as fabric tapes can be very unreliable. 15 m and 5 m tapes are practical sizes for most classes, although for large yachts a longer tape measure is needed. Class II metric tapes are of an acceptable level for normal measurement.



8.2.2 Steel Ruler

One, either 150 mm or 300 mm long is usually sufficient. Articulated or folding rules if not officially certified are not always accurate and are not recommended.



8.2.3 Straight edge

One straight edge about 2 m long is normally required. Steel or aluminium channel or angle is the most satisfactory. A shorter straight edge may also be required for some work. Some of them are combined with a spirit level, while laser straight line pointers have also become readily available and are quite useful for certain applications.

8.2.4 Spirit Level

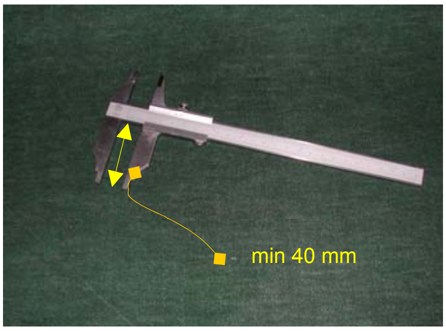
Preferably not less than 500 mm long and having both horizontal and vertical "bubbles". The sensitivity, and hence the accuracy, of some cheap spirit levels is not very great and these should be avoided. Electronic levels with digital readouts are available, but should be sensitive to at least 0.1 degree. Some spirit levels have an additional laser beam and can be used to make a baseline. At normal, uncertified spirit levels the error is appr. at 1 mm/m. Better ones go up to 0.7 or 0.5 mm/m. Classified go up to 0.02 mm/m. To minimize the reading error always do the reading twice, turning the spirit level around 180 degrees. The reading of the clinometer sight varies depending on the light conditions.

8.2.5 Plumb bob

A plumb bob and line may be required in order to establish a vertical line or to transfer a position to a point vertically below it. A heavy plumb bob with thin line is less likely to be affected by a slight movement of air when measuring in the open. The swing of the plumb bob may be dampened by suspending it in a bucket of water.

8.2.6 Set Square Two tri-squares are normally required, an ordinary carpenter's square having arms not less than 150 mm long, and a larger one with arms about 600 mm long. Laser squares are also available.

8.2.7 Callipers Vernier callipers for measuring such items as the diameters of wire, the thickness of small items or the diameter of spars may be required.



8.2.8 Thread Nylon or terylene (Dacron) thread may be required for use as the base line for measuring the keel rocker (curvature of the keel). The thread used needs to be thin so that errors do not occur due to its thickness, light so it does not sag much and strong as it is used under considerable tension. Fishing line is very good, but some types are liable to kink.

8.2.9 Calculator To carry out the calculations required to assess the area of a sail an electronic calculator is an invaluable piece of equipment. It should have a capacity for doing square roots. Programmable calculators are good for making instant calculations, e.g. for calculating sail area in a development class. Portable computers have the additional advantage that they can store data in a presentable form as measurement proceeds, and can be particularly useful for recording data during regatta measurement.

8.2.10 Scales The size of the equipment needed will depend on the work that is to be done. Weighing machines need to be regularly checked for accuracy - at least annually - and carefully stored and transported. It is important that the scale has adequate capacity with a capacity of at least 20% more than is needed. Weighing equipment should meet the requirements of OIML Class III in EU or equivalent standards in other parts of the World.

One should keep in mind however that the accuracy of an electronic scale is a % of the maximum weight allowed (to take a 2000 kg scale to weight a dinghy is a nonsense).

Electronic scales with digital readouts are ideal but should always be calibrated before use. For weighing dinghies a steelyard beam scale is accurate but a spring scale is normally satisfactory. For weighing keel boats Load cells are very accurate, but should be calibrated (twist problems).
Alternatively dial reading beam scales can be used.

8.2.10a Calibration Whatever machine is used it should be calibrated i.e. the readings noted when known weights are added. It is particularly important that this is done over the range of the instrument which is to be used.

8.2.11 Micrometer Micrometers for sail ply thickness measurement shall have the following characteristics:

- Ratchet stop
- Measuring surfaces diameter as specified in **class rules** or, as a default, of 6.5 mm
- 400gf – 600gf applied to the measuring area
- Throat depth of approximately 21mm minimum
- Graduations to 0.001mm (0.00005in)
- Overall accuracy of plus or minus 0.002mm
- Flatness of anvil and spindle tips: 0.0006096mm or better or a parallelism of anvil and spindle tips: 0.00124mm or better
- Spindle lock

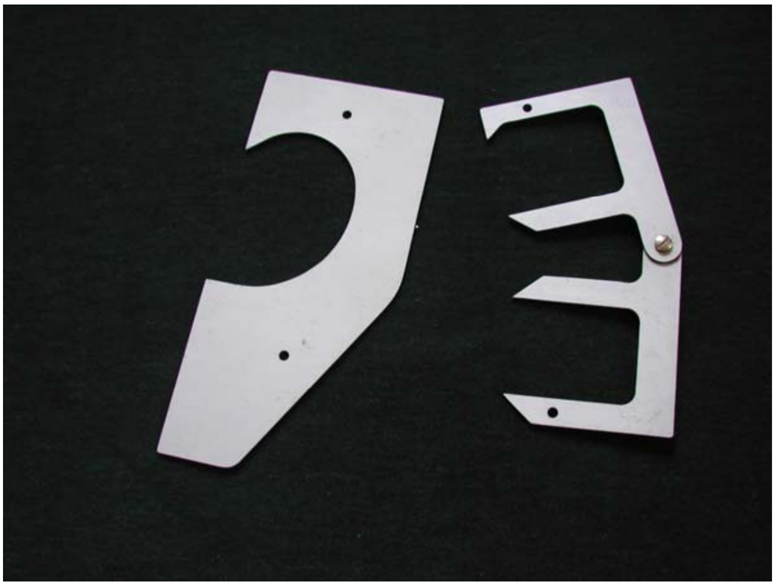
A set of standard feeler gauges are also required.

8.3 Purpose-designed measurement tools

The following items of equipment are useful for measurement in a wide range of classes and may be produced form simple materials using only basic tools. Some classes offer packs of tools for the class produced by a builder to proven designs and occasionally run measurement seminars to demonstrate their use.

8.3.1 Sheerline Jigs

A means of accurately determining the positions of the sheerline by transferring the line of the topsides to the top surface of the deck is often required. For boats with straight or nearly straight topsides, such as most hard chine boats, a `C' template shown in Figure 8.3.1 is adequate.



FiFig 8.3.1

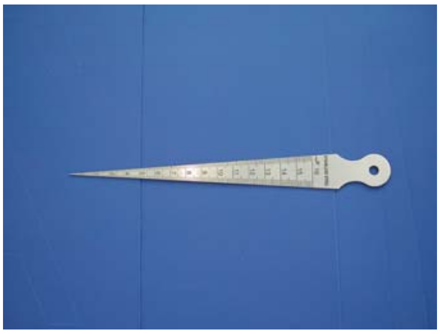
Fig 8.3.2

If there is considerable curvature then the sheerline jig shown on Figure 8.3.2 is better. This jig adjusts to the curvature of the hull and projects the curve up to the sheerline. However, it should be noted that this device assumes the topsides to be a circular curve, and if it is not then an error will occur.

To overcome this point in one-design classes with curved topsides C-templates can be made for each measurement station using the lines plan, or preferably full size sections, of the hull.

8.3.2 Wedges

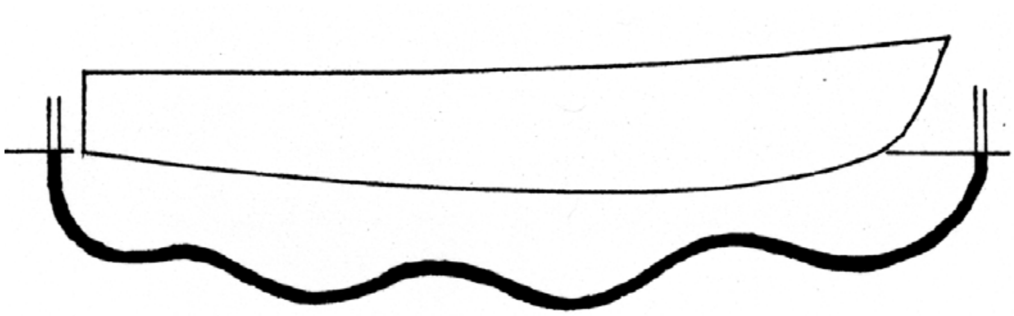
A calibrated wedge to measure the clearance between items and a hull template and the hull is often helpful. It can be made of metal or plastic and should have its thickness at various points marked on it. However, a wedge should be used with caution see Section 9.3



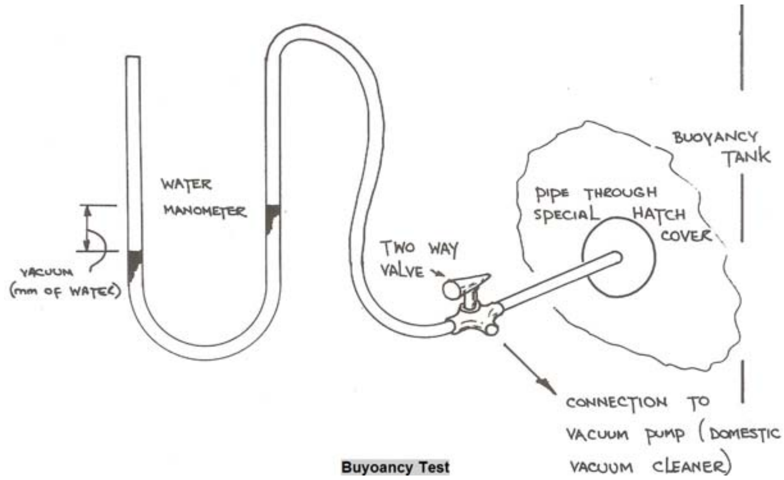
8.3.3 Go~No go Gauge

An example of a purpose made measurement tool would be a "go-no go" gauge for measuring a spar section.

8.3.4 Water tube Measurement of boats on uneven or sloping ground requires a means of transferring a level from one end of the boat to the other. Although a surveyor's level can be used, a cheap and simple alternative is a flexible tube filled with water. The tube must not have any `air locks' in it and the internal diameter of the tubes should be at least 8 mm. The smaller the tube the more rounded the top of the water will be, which is our reference plane, and the more difficult it gets to take accurate readings. The length of the tube required of course depends on the length of the boat to be measured. About six metres is required for a boat 4.70 metre in length, but for a larger boat additional length would be needed to allow for the increased depth of the hull as well as its longer length. For ease of use it may be desirable to use a reservoir of water and to have the tube in two pieces.

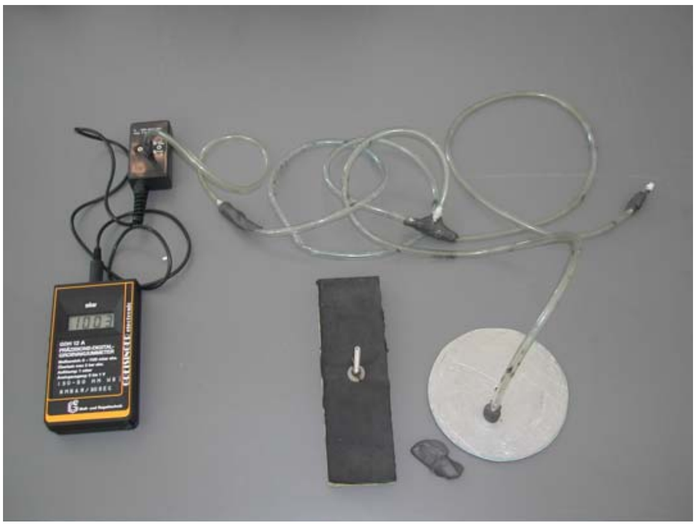


8.3.5 Water Manometer A simple manometer for testing the air tightness of buoyancy tanks, such as that illustrated below is needed.



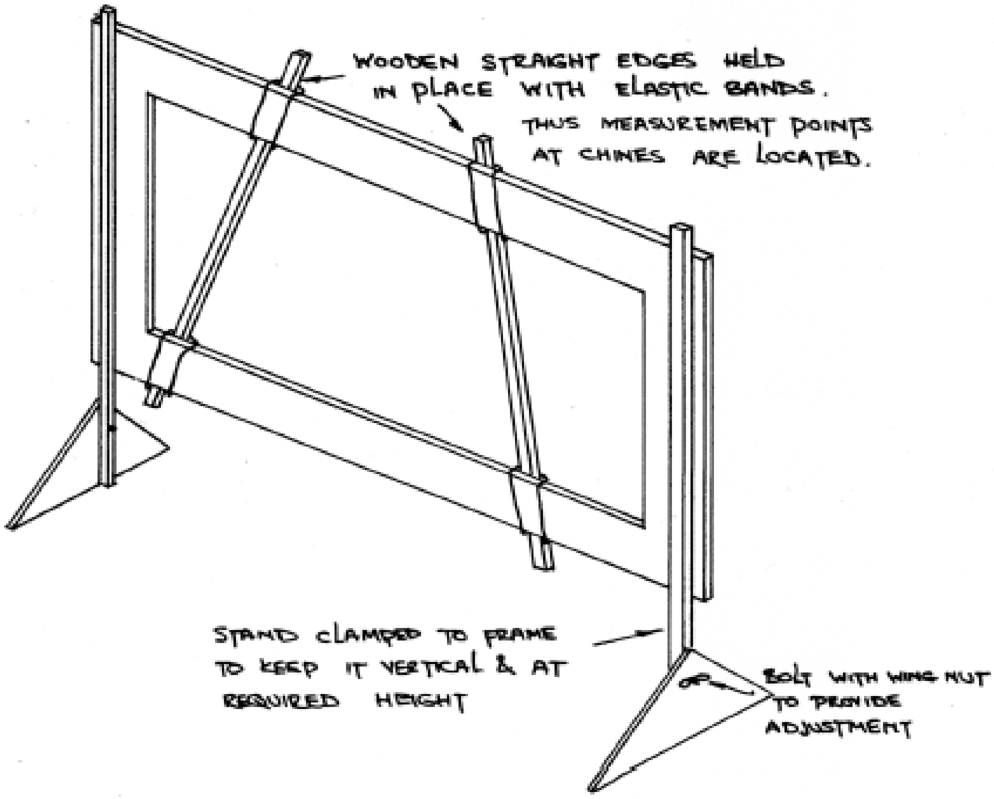
Buyoancy Test

Similar device with a digital pressiometer (needs a battery)



8.3.6 Weights Some classes require that the boats' buoyancy be tested by placing iron weights in the swamped boat. A selection of weights totalling 200 kg will normally be sufficient, and should include 8 x 20 kg, 3 x 10 kg and 2 x 5 kg.

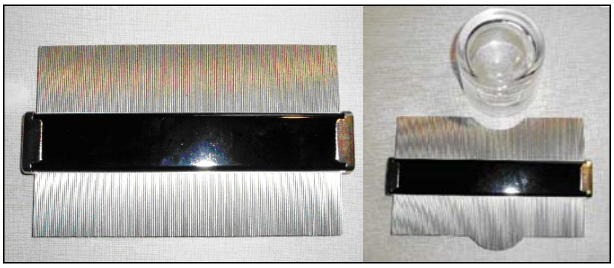
8.3.7 Measurement Frame This piece of equipment (sometimes known as a Chippendale Square, after its inventor) is illustrated below. It is used for taking cross section measurements of hard chine boats such as the Fireball and Enterprise.



8.3.8 **Stop watch**
Electronic with 1/100 sec resolution.

Electronic timer
with photo gate (quartz crystal, not RC), resolution 0.1 ms. Computer MUST be calibrated.

8.3.9 **Specialized tools**



The gadget on the left can be used to measure centerboard case inside widths. The two cylinders are spring loaded and adjust to the width, then the knob i at the bottom s tightened and they stay in place; the actual dimension can be taken by using a caliper.
The tool on the right picture is a finger gauge, very useful for checking items like keel edge inside and outside radii

8.3.10 Surveyor's Level When setting up a large keelboat of, say, one of the ISAF metre classes, it may be more convenient to use a surveyor's level or a theodolite although a water tube can be used.

Figure 8.3.8 a - Surveyor's level and theodolite

A laser beam level (see picture 8.3.8.b below) is also suitable if a great accuracy is not needed.

Figure 8.3.8.b

8.4 Special Equipment

Optical or Laser Beam measurement and electronically storing of shape

Laser Measurement

The aerospace industry was the pioneer in developing a portable and accurate laser coordinate measurement system. The industry had a great need to get large parts manufactured at different locations to fit together seamlessly (hold a tolerance).

There are two main portable laser coordinate measurement instruments, the Leica Man Cat and the Faro\SMX Tracker. Laser Trackers send a beam of laser light into three or four cornered mirrors mounted in the center of the sphere. The light is reflected back to the instrument sensors which update angle and distance giving an X, Y, Z position. After a few milli seconds the Tracker instrument has a history, and can track the sphere.

When tracking the sphere, the Tracker has two main modes. Single point mode takes 500 to 100,000 readings then averages this to a single point. Scan mode takes 20 to 70 readings then finds a point. As light moves quickly a 100,000 measurements can be taken in approximate a second.

When starting a new measurement or an inspection project it is important to be able to move from the “instrument coordinate world” into a part alignment. This enables the software to inspect or measure the part in its coordinate system and control the output data with the correct coordinates.

With the Yngling project in Athens I wrote a measurement program that ran inside the Faro/SMX Tracker software. This enabled me to measure the hulls and keels quickly and ensured that all boats were measured the same way. Having this quality control ensures that any chance to staff, location, temperature, hull trim, or list would not change the data in years to come.

In order to get the Faro Tracker coordinate system to match the Yngling hull class rule (Appendix 3 drawing), nine centerlines points were taken establishing a best fit center plane. Then an iterative alignment was used to make the hull coordinate alignment. The results were good, allowing the tracker software to “best fit” to 0.02mm of the class drawing.

As the Yngling keel has its own measurement diagram the hull alignment can not be used. A new keel alignment is generated using the keel centerlines, underside and back edge. Similarly, placing straight edges on the back edge of the keel and underside of keel to find the intersection. Then using the intersection (keel datum) marking parallel waterlines. This new alignment is generated almost instantly.

The macro software that runs within the Faro software uses an alpha prompt to guide the user to the next area or task. When measuring a template station on the hull at 1350mm the software says:

“Scan Hull at 1350”
Press Insert to Start
Press Insert to Stop
Press Home to End

When the sphere is placed on the hull the operator hits Insert. The Tracker then collects a point when the sphere crosses the 1350 station. The data can be out put as a point, line, or curve.

As the program progresses it is possible to switch between the different alignments, take measurements between alignments and reference an individual tolerances then waning the operator is an item is out of tolerance.

With some planning Laser measurements can be done quickly and with a very high repeatability, I believe that the Laser Tracker can work hand and hand with the templates and be of benefit to all classes.

8.5 Hull Measurement with Ultrasonic Thickness Gages

8.5.1 Introduction:

This section discusses non-destructive ultrasonic methods for measuring the thickness of fibreglass boat hulls and decks. Some general measurement guidelines are provided along with some particle limitations related to the use of ultrasonic testing.

Ultrasonic testers operate on a pulse-echo principle much like sonar. They measure thickness by precisely measuring the round trip travel time of very high frequency sound waves emitted from a piezoelectric transducer and returning to it. The transducer is held in contact with the outer surface of a boat hull. Sound waves emitted from it bounce off the inner wall of the hull and back to the transducer. A calibration process determines the speed of travel of the sound waves passage through the hull allowing an accurate measure of the hull thickness to be obtained.

Thickness = Sound Velocity x Round Trip Time / 2

Many electronic ultrasonic measuring devices have built-in calibration programs that do the velocity of sound calibration calculation automatically by measuring two different samples of the material of known thickness. Usually, the samples span the expected range of thickness to provide as accurate a calibration as possible in between. For thickness measurement on fibreglass boats it is important to perform calibration with actual samples that are taken from the hull or deck of that type of boat because the velocity of sound can vary significantly depending on the specific material used in the lay-up and the quality of workmanship used. Once calibrated, the electronic ultrasonic thickness gage can measure a hull or deck thickness in a matter of a few seconds without any damage whatever to the boat.

The reasons for measuring the thickness of the lay-up are to detect problems with the fabrication process or to identify subsequent alterations to the hull or deck lay-up that are not authorized. This can be accomplished because the construction plans specify a lamination schedule and finishing schedule than can be converted to an overall thickness for the hull or deck at any point. With the ultrasonic gage it is easy to look for changes in thickness at the expected location to determine if the lay-up was correctly performed and the proper material was used. The ultrasonic gage is an excellent tool to spot check for alterations in the hull or deck construction because even minor changes in thickness are easily determined. Because voids or improper types of material have a proportionately large effect on the velocity of sound, significant changes of the local reported thickness result. This spot check can help pinpoint suspect areas that could be candidates for further investigation using destructive measurement methods.

8.5.2 Considerations:

There are a number of practical considerations that need investigation before ultrasonic thickness measurement should be undertaken. Some of these considerations may make using ultrasonic techniques inadvisable.

There is a practical upper limit and a lower limit of thickness for ultrasonics to work on fiberglass hulls. The range of thickness measurement is also a limitation, often necessitating more than one transducer to cover the range needed for hull and deck measurement. Thicker hulls require larger diameter and more expensive transducers to achieve a good return echo signal. The larger transducers often do not conform well to the curvature in the surface of a hull. This may limit its use in some critical areas of interest. As a guideline, expect good performance over a thickness range of about ten to one for a single transducer. For a large transducer of 30 mm diameter, this may be 2mm to 20mm of thickness in fiberglass. For a small transducer of 10 mm diameter, the useful range is typically from 0.5mm to 5 mm thickness.

The ultrasonic technique requires coupling of the piezoelectric transducer to the hull or deck using a gel type ultrasonic couplant between the active surface of the transducer and the surface of the hull or deck. The couplant layer thickness is part of the measurement. Some practice is required to get the correct contact force to squeeze the couplant out uniformly time after time so as to not adversely affect the thickness repeatability. This is harder to do with large diameter transducers than with small ones. When the hull surface is curved the contact force is not a problem because the contact area is a line and the couplant is easily displaced. However, it is important here to use only enough couplant to obtain a reading because excess couplant will form a fillet between the transducer and the hull where sound can be trapped causing erroneous readings of thickness.

The roughness of the inner surface of the hull or the inner or outer surface of the deck can adversely affect the accuracy of the thickness reading in two ways. First, the amount of couplant required to obtain reliable reading increases with the roughness of the outer surface. Too much couplant can reduce measurement accuracy. Second, the minimum thickness that can be measured increases because the sound reverberates from a rough outer surface while the maximum thickness that can be measured decreases when the echo producing inner surface is rough. In fibreglass lay-ups, voids or large air bubbles produce scattering echoes that can appear just like the desired inner surface making the true surface difficult to discriminate. The presence of voids or de-laminations can result in measurements that seriously understate the actual thickness. Surface geometry can effect thickness measurement as well. A particularly difficult problem arises when the inner and outer surfaces are not parallel. The taper produces echoes that are distorted and this can reduce accuracy.

In most cases there are easy workarounds for most of these considerations but it is important to understand the factors that adversely effect ultrasonic performance.

8.5.3 Getting Started:

In order to get started checking thickness it is necessary to know what the nominal thickness should be at the locations on the hull or deck selected for measurement. There are a number of ways to determine nominal thickness. One easy way is to measure a boat known to be built correctly, first with ultrasound then with a micrometer or calliper. It may not be necessary to drill any added holes as there are often holes for fittings available, at least in the deck. This is harder to do in the hull where it may be necessary to resort to a depth micrometer and a drill. Another approach is to measure a lot of hulls in exactly the same place on the hull using a calibrated ultrasonic tester and begin to build a data base of expected thickness readings. After a while the expected values become the nominal standard for comparison. This method works best when there are a lot of boats built in serial production because it takes a reasonably large sample size before the nominal thickness readings can be determined with confidence. The best approach to knowing the expected thickness is to look at the construction plans for building the boat. There should be a schedule of materials for the lay-up specifying what to use and where to use it. Once the type of material and the location for its use are known, simply adding up the layer thicknesses gives a good estimate of the nominal thickness at any point.

Here are some guidelines for estimating the thickness of various materials:

Coatings: While not technically considered part of the laminate, all coatings are measured by the ultrasonic tester and therefore need to be accounted for when calculating thickness. Gel coat thickness can be determined by sanding it down in an area and measuring the thickness. A good starting value is 0.6mm. Similarly, the thickness of the topcoat needs to be accounted for. A good estimate is 0.4mm. It is harder to measure by sanding because the inner laminate surface is often rough. The gel coat and topcoat together account for an estimated 1.0mm of the total thickness reading taken from the ultrasonic tester.

Glass Mats: There are good general guidelines that serve the purpose of estimating the thickness of a resin/mat build-up. For 1 kg mat build-up assuming a 1/3 glass content, a good estimate of the thickness is 2.0 mm. “Fat” or “dry” laminates can cause this thickness to vary by about 0.1 mm. For 2 kg mat the nominal thickness is 4.0 mm +/- 0.2. Use this as a general guideline to scale for the type of mat specified for the lay-up under consideration.

Woven Roving: Where woven roving is specified in the lay-up, special attention is necessary to account for its reduced build-up rate. As a good rule of thumb, the build-up of a specified woven roving layer will only be 75% as thick as the same nominal weight glass mat build-up would be. When calculating the thickness of a nominal weight of woven roving, calculate it just the same as glass mat then reduce the thickness by ¼.

When other materials are specified, some testing may be required to determine the rate of build-up. Once done, a similar calculation will allow conversion to thickness. Thus the total hull or deck thickness at any point can be estimated knowing the details of the lay-up specified in the build plans for that point on the hull or deck.

8.5.4 Technique:

The electronic ultrasonic tester is a battery operated hand held portable device that can be used effectively by one person. The tester typically has a remote transducer attached by electrical cable of about one meter in length. To use the tester, apply the couplant that is furnished by the manufacturer to the active surface of the transducer. Place the tester in the calibrate mode and follow the instructions for calibration using a thick and thin sample. Once the tester is calibrated, it is ready for use on the boat.
Place the tester in one hand and the transducer in the other. Apply couplant before every reading. All testers have an indicator to show the presence of a valid reading. Some testers log the thickness automatically. If this feature is not available record each valid reading in a logbook for future reference. Fully charged batteries last for about one full day of operation. Recharging is required in between.

There are two methods for using an ultrasonic tester. The first is the spot-check method; the second is the grid layout method. The spot-check method is a quick and easy examination for obvious defects in construction or for any alterations afterwards. As few as ten readings can be taken in just a few minutes to get a general idea of the validity of construction. Points on the hull and deck are identified and measured and the thickness value recorded. These values are checked against the predetermined nominal expected value. If the readings are within the expected tolerance the boat is OK. It is recommended to do half the readings forward of the mast and half aft. Concentrate on the ends of the boat as there could be an advantage to lighter ends.

The grid layout method is a much more thorough investigation. It requires that the hull be marked with the location of expected thickness changes determined from the construction lay-up. In effect, a grid system is applied to the hull and the transition lines where the thickness is expected to change are related to a grid location. If the hull shape is controlled using hull templates, an easy way to construct the grid is to mark the location of the transitions in thickness on the templates so they may be directly transferred to the hull. Otherwise, a scale or batten may be used to find the transition locations by measuring from the deck line and other construction datums.
Look for three things: The thickness, the presence of a transition in thickness, and the amount of change in its value. This process takes more time than the spot-check but provides a more complete examination of the hull and deck lay-up. It is not uncommon to record sixty thickness values from the grid for each boat. Serious defects can relatively easily be isolated for appropriate destructive testing to determine the precise details of fabrication irregularity.
It is important to emphasize that the spot-check and grid layout are screening methods useful in determining the possible locations of unauthorized construction or modification. It is not recommended to rely exclusively on ultrasonic testing as the definitive indication of

the use of an improper material or as proof of error in lay-up. Ultrasonic testing has proved an excellent tool because it quickly locates possible irregularities. However, destructive methods are usually required for verification.

8.5.5 Data:

Accurate record keeping is an essential part of ultrasonic measurement. In order to be able to faithfully reproduce readings the details of the procedure need to be recorded.

- Type of gage (Manufacturer and serial number)
- Type of transducer (serial number if available)
- Calibration artefacts used (thickness of samples and where they were taken from)
- Velocity of sound calculated from the calibration (reported by the tester)

The rest of the data recording process relies on specifying the location for a reading and the thickness found there. The location should be specified sufficiently so that the readings can be repeated. This may require a location accuracy of **5 mm** or better.

One reason for keeping this data is that the economic consequences of discovering improper construction may be considerable. Often there is follow-on investigation work that will depend on repeating the data recorded at measurement time. Ultrasonic measurement has been used at the championship level to identify boats where unauthorized material was used, where layers of laminate were missing, and where layers were not of the prescribed thickness. In each case destructive follow-on investigation supported the initial ultrasonic findings.

A final caution: Always check your data. In-process verifications are available if you look for them. For example, the ultrasonic tester may not be recording a change in thickness as required in a hull lay-up but you can feel a transition at the proper location by reaching inside the hull with your hand. Here the hull thickness may be correct but the local bonding of the layer in question may not be good enough for ultrasonics to pick up the thickness change. In another example, the ultrasonic tester can show excessive thickness at the hull/deck joint. The actual thickness should be verified by removing a nearby fitting and using callipers. Local build-up near the hull/deck joint often produces a taper condition that can sometimes cause the tester to display a value that is higher than is actually there. In-process verification provides valuable assurance needed by an inexperienced user in order to apply ultrasonic measurement methods to fibreglass hull and deck thickness measurement with full confidence.

List of sources for ultrasonic testers:

GE Power Systems Series 25 Ultrasonic Precision Thickness Gage www.gepower.com (was Panametrics)

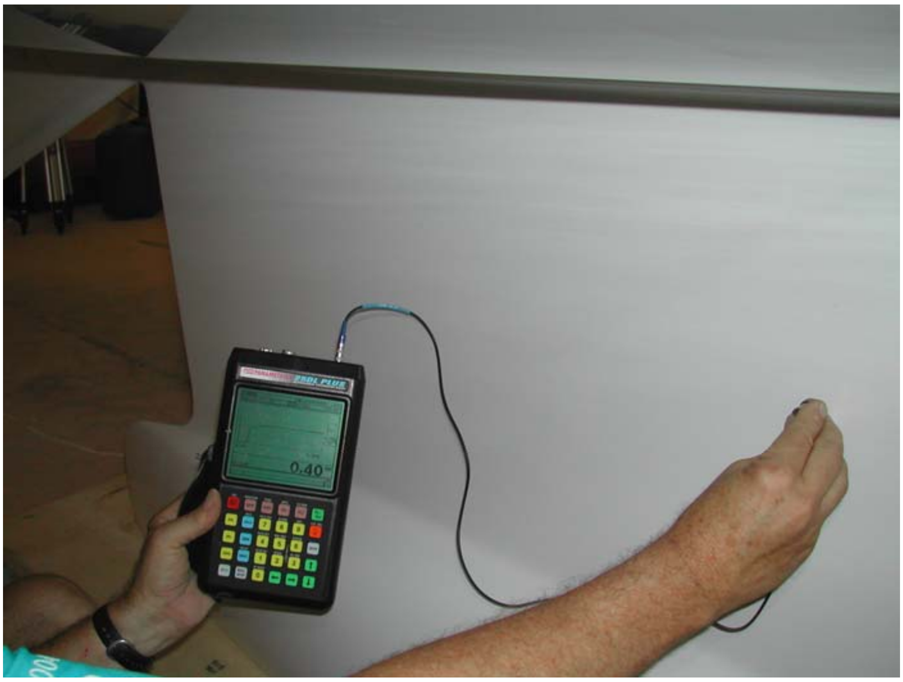
ElektroPhysik Dr. Steingroever GmbH & Co. KG www.elektrophysik.com (special unit required)

8.6 Coating thickness measurement

To control the shape of the keel, some classes require to check the thickness of the coating. Mainly two typical non destructive ways to achieve this control are usual:

a. Magnetic based instruments,
they work only on steel keels
Picture of the Elcometer

b. Ultrasonic velocity based instruments, they work on any materials
Picture of the Panametrics-NTD – Model 25 DL PLUS
This precision microprocessor-based instrument uses pulse-echo techniques to measure material thickness. It can be linked to a computer (RS-232 communications port).



8.7 Inclinometers (see 11.1, Swing Test)

8.8 Fibrescope

The Olympus fibrescope is a useful piece of equipment that allows the inspection of confined spaces from an external location. It consists of:

- a light source, typically a 150 watt tungsten lamp
- a fibre optic cable to convey the light to the point of inspection
- another fibre optic cable to return the reflected light from the object of inspection to the view finder
- a viewing piece with focusing elements

Also incorporated in the viewing piece are four way angulation's controls that allow the steering of the inspection end of the fibre optic cable. A 50mm length at the end of the fibre optic cable can be steered to allow viewing over a hemispherical arc.

With an appropriate camera photographs of the object under inspection can be taken.

9 HULL SHAPE MEASUREMENT

Establishing a practical method of measuring a hull to determine its shape to a high degree of accuracy is probably the hardest aspect of creating a good set of class rules, particularly for one-design classes where the objective is to ensure that the hull shapes are as identical as possible. The following section outlines the principal methods used to determine hull shape and appropriate techniques for measurers. However, it is important to measure in the way prescribed in the class rules if details are given.

9.1 Hull Length and Width

The length of the hull has a fundamental effect on the performance of any sailing boat and it is therefore one of the principal measurements. To measure length accurately it is important to measure along the correct axis and to establish the exact end measurement points of the boat.

For one-designs the length is normally measured parallel to a **base line** which is an imaginary reference line usually parallel to the design waterline.

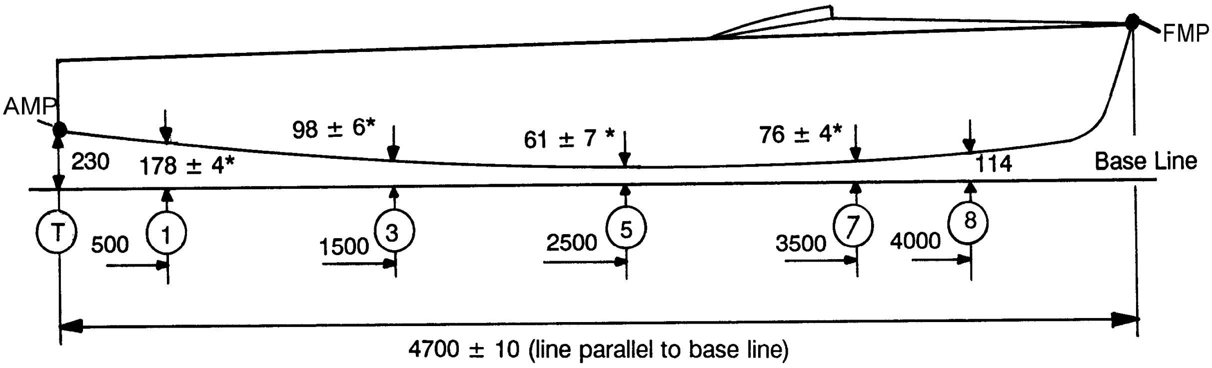


Figure 9.1.1

However, for some one-design classes, length is measured along the deck to facilitate measurement. In these cases the axis of measurement is not necessarily parallel to the baseline and care must be taken to avoid errors caused by the tape measure being deflected from a straight line by fittings or a breakwater on deck.

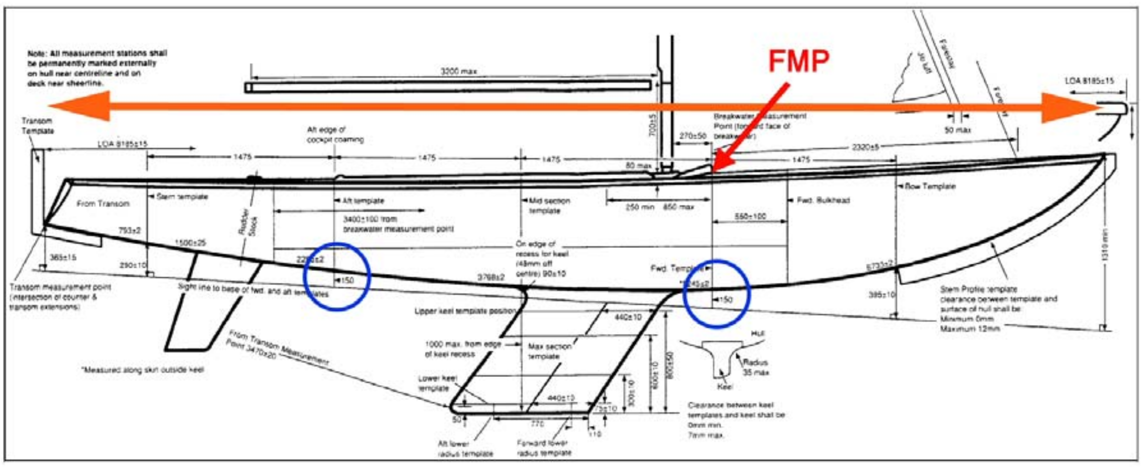


Figure 9.1.2

The aft point from which length is measured is usually on an imaginary plane perpendicular to the baseline (or vertical if the baseline is set up horizontally) passing through a point defined by the intersection of the transom and the centreline of the hull (**see figure 9.1.1**).

Normally the overall length LOA excludes the deck overlap as indicated in **the figure 9.1.3.** However, unless the class rules actually state that the deck overlap is excluded it is included (see 9.1.2). Ideally the class rules will define a Forward Measurement Point (FMP) and then, with the baseline horizontal, the measured length is the distance horizontal between vertical planes through the AMP and FMP. Normal rudder fittings are excluded from the overall length measurement.

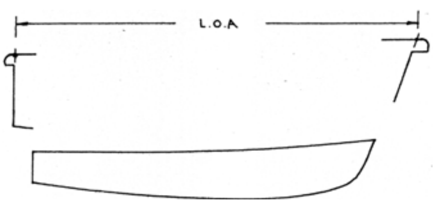


Figure 9.1.3

The measurement of the overall length of a dinghy can be carried out with the hull either the right way up or inverted. However, if working on a level surface it is frequently more convenient to measure the overall length when the boat is inverted. With the baseline horizontal the ends may then be plumbed down from the measurement points to the floor using a plumb bob or vertical spirit level and the length measured between the marks made.

For development classes length measurement can be difficult as they do not have base lines and the waterline position is not clear. In dinghies it is common to have a vertical stem and transom in order to gain as much advantage as possible from the available length. If the measurer sets the boat up with the stem and/or the transom vertical he has no means on knowing whether the boat is level because the waterline may not be in the assumed position.

Although the physical problems of levelling up a large boat of, say, one of the International Metre classes, are greater than for a dinghy, the problems of locating the waterline tend to be simpler. The designer will have gone to considerable trouble in order to accurately establish its position during the design stage. If the yacht is being measured for the first time the plans will be made available to the measurer, or the builder will have accurately positioned a mark to indicate the position. In the metre classes the marks are required at each end of the waterline and the yacht has to float to these marks.

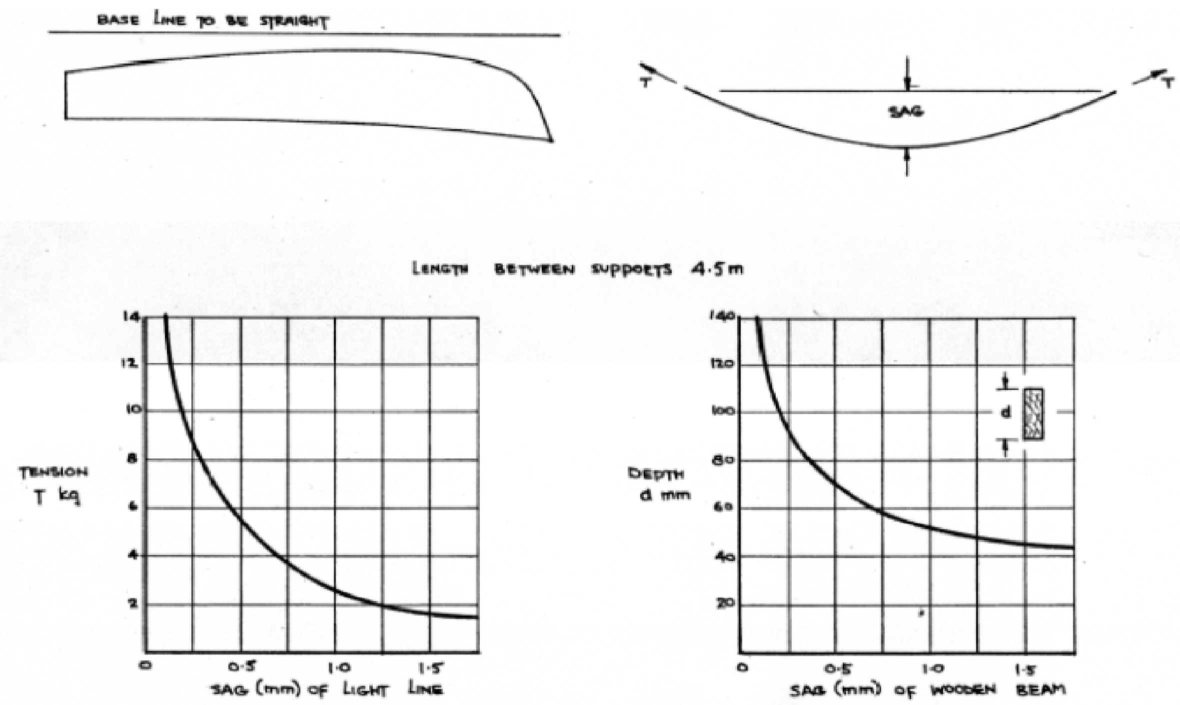
Width or beam measurements are taken perpendicular to the hull's centreline in plan view.

9.2 Hull Profile

The hull profile on the centreline, sometimes called the keel rocker or hull rocker, is normally measured perpendicular to a base line. If the base line is set up horizontally, then all depth measurements can be taken in the vertical plane.

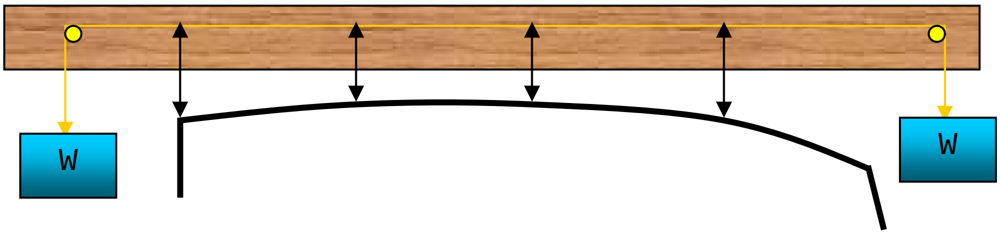
There are many ways in which the base line can be supported, but whatever method is adopted it has to be such that the base line is accurately and strongly supported, and that the sag of the line is very small. Sag cannot be eliminated totally although by using a thin, and therefore lightweight, line and considerable tension the sag can be reduced to negligible proportions. The amount of sag which can be expected is indicated in the **graph below**.

Some measurers claim that the only satisfactory equipment to use is a beam. However, as can be seen from the **figure** below a beam also sags. A further disadvantage of a beam of wood is that it may warp. Stiff aluminium beam sections yield acceptable results, having maximum vertical deflections at mid-span of less than 1mm, and that may be checked on the spot with laser lines/levels.



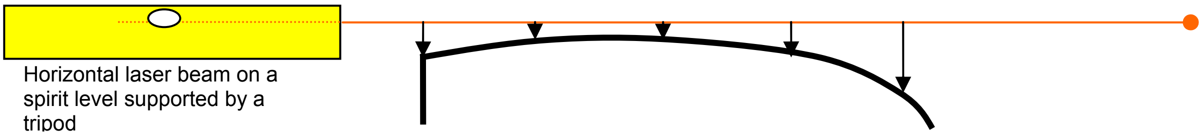
EXAMPLES OF ERRORS IN KEEL ROCKER MEASUREMENT

A combination of both systems, where the beam is only there to support the line, works also well, the lightweight line is going around two screws or nails fixed at the ends of the beam.



In this case, the problem to introduce the tension of the line is easily solved by one weight at each end of the beam.

The base line can also be materialised by a laser beam combined with a spirit level:



The thickness of the laser beam (1 - 2 mm, for the cheapest tool) can be a problem if rocker at the limit.

The forward attachment point of the base line is usually positioned on part of the boat where it is difficult to support a base line. As it is necessary to fix it at the correct height only, the base line can be tied to anything that will provide a rigid support forward of the hull, for example a nail in a wall or door frame. In some classes such as the Enterprise, 470 and OK, it is necessary to extend the base line forward in order to carry out the measurement of the stem, and thus supporting the base line beyond the hull can assist the measurement. In this case the boat must not be able to move even if the measurer leans on it.

The International Tornado Class controls the keel rocker by sighting through 12,5mm diameter holes in the templates when all the hull section templates are in place. This provides an accurate and convenient method in the case of the Tornado because the templates are fairly small. With larger templates on a hull there might be difficulties in positioning all the templates simultaneously and keeping them in place.

The hull has to be supported in such a way that it is not twisted and does not sag or hog. Whatever method is used to support a hull it is advisable, if the hull is a long one, to place the supports to minimise any deflection of the hull. This can be achieved by putting the supports about one-quarter of the length of the hull from each end. It must be made clear that all hulls of that particular class should be supported for measurement in the same way, and it should be part of the class rules or hull measurement instructions when possible.

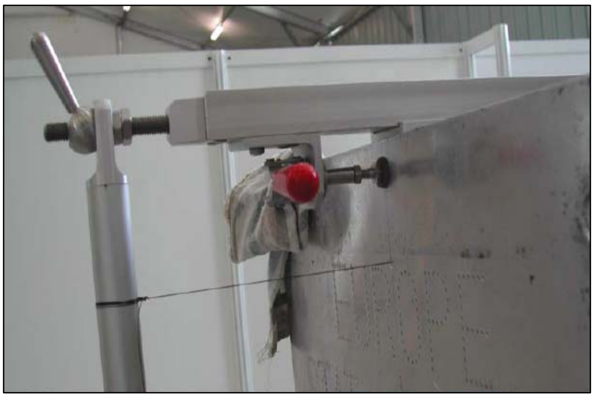
Some classes have developed special jigs for hull measurement, which are used mostly at events, but similar systems are sometimes set-up in builders' premises for normal fundamental measurement of production hulls.

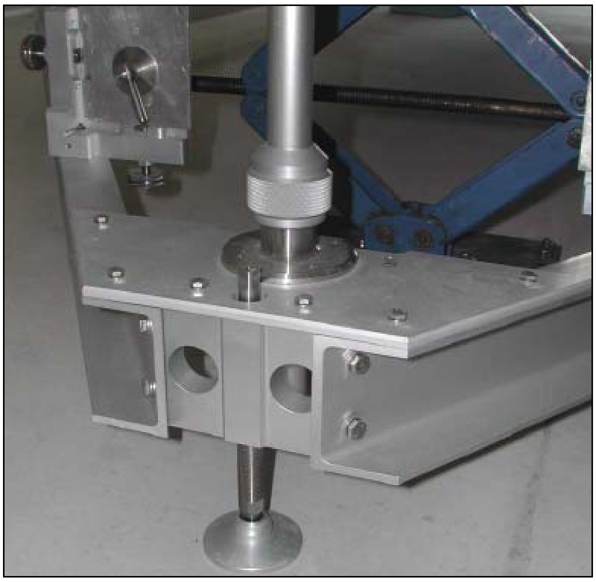
The Spanish 470 Jig developed for the Barcelona Games

470 Jig with a hull on top (left) and the modular framing and levelling screws detail (right)

The Europe Jig

The Europe hull inside the jig, levelled and aligned using car jacks





The template clamp, fine adjustment system, precision alignment line and levelling feet used to precisely position the templates so that they are vertical and in the section planes.

The systems shown above are ideal but enormously expensive, and in the case of the 470 and the similar Finn ones, they are bulky and thus not easy to transport even when dismantled. They require significant time and care to assemble and align, and require a solid concrete floor to rest on. During measurement, they need to be checked frequently for alignment and guarded against accidental movement.

9.3 Hull Section Measurement

The shape of the hull is usually checked by measuring the shape of a series of sections through the hull, each a set distance from a reference point (Hull Datum Point), usually located at the intersection of the transom, the hull surface and its centre plane. Distances are to be measured along the defined baseline. Each section through the hull where measurements are taken is refereed to as a measurement station. It is easiest to achieve this by using vertical and horizontal axes for the for the co ordinate system, and so this method may be called the "Gravitational Co ordinate System".

Locating the measurement stations at the sheerline and keel by this method requires special equipment, is time consuming and difficult to do accurately. Therefore, some classes locate the measurement stations using a simplified method of measuring around the curve of the sheer and the keel, as indicated in the figure 9.3.1. Positioning of the templates relative to reference marks on the hull itself eliminates the need for hull levelling. This technique may be called the "Hull Co ordinate System".

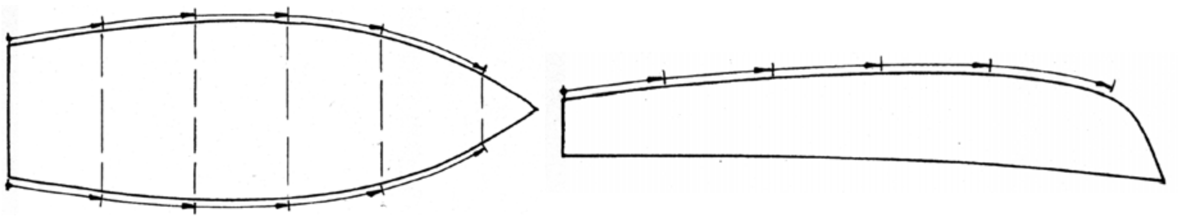


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Figure 9.3.1

The major advantages of the "Gravitational co ordinate system" are:

- It precisely conforms to the design hull sections
- Controls hull twist and bend as the templates are precisely aligned
- The keel rocker is defined by the template positions.

The major disadvantages are:

- Precise alignment systems are very expensive.
- Although the Europe system can be easily transported, the 470 and Finn systems are cumbersome and bulky.
- Requires a stable floor.
- Take significant time to set up.
- The hull has to be carefully aligned relative to the template system, which takes time.

The major advantages of the "Hull Co ordinate System" are:

- The hull need not be levelled, or even very stable (has been used on a grass lawn)
- Very fast to set up the templates, especially if the template reference marks are permanently scribed on the hull.
- No expensive frame for locating the templates or levelling system for the hull are required.
- The templates and measurement equipment can be easily transported.

The major disadvantages are:

- The planes of the template may not precisely correspond to the design section planes, but in most cases this is negligible.

- The FD system allows “banana boats” and hulls that are twisted. Neither of these would be fast, so this is unimportant. Furthermore it is to some extent controlled by the keel rocker measurements.
- The obvious criticism of the hull co ordinate system is that if hulls have significant tolerances on the beam or keel rocker, then for a given measurement around the sheer line, or centreline, the fore and aft position of the template will not be identical for different hulls. For the Yngling and Soling, where the reference marks are in the deck moulding, all of which derive from the master plug, the distances around the deck flange should be essentially identical for all hulls, so there is no irreproducibility of template position at the deck. The Star Class has resolved the issue by having different station positioning distances for each approved mould. In that case, each station is marked in the same position as if the hull was leveled using a baseline Gravitational co ordinate system first.

There are also cases like in the Yngling Class, where a mixed system is used, including elements of both gravitational nd hull coordinate systems: the template positions are specified by measurements along the sheer lines but not along the centreline. The latter are replaced by measurements along the baseline, i.e. in a “Gravitational Co ordinate System”. This, at least in principle, makes template measurement at regattas impractical and fundamental measurement much more time consuming.

Whatever the system followed, the position of the measurement stations should be clearly marked to facilitate easy measurement. This can be done by marking them with pencil or pen on paper masking tape stuck on the hull or by marking the hull using a `china graph' pencil. It is not recommended that felt pens be used directly on the hull as sometimes they contain dyes which can stain the gel coat of GRP boats.

a) Section measurement using templates

After the 1940’s there were many new designs of racing sailboats which took advantage of new glues and moulded plywood construction to build boats such as the Firefly, Finn, 505 and Flying Dutchman, etc. and for these non hard chine boats a means of hull shape control was required. The lines plans were available giving waterlines, buttock and transverse sections, and these were used to develop section templates at a number of stations along the hull. Many classes also have bow and transom templates which control the center plane shape as well as serve to establish a baseline for keel rocker measurements.

The amateur construction of moulded ply hulls was not the precision technique that modern fibreglass moulding of hulls is today, and furthermore they tended to change shape with age, especially if not well looked after. Thus there had to be significant tolerances on the allowed shapes, typically ± 12.5 mm for example in the FD case. Since templates are designed to be the same shape as the design shape of the relevant section, plus an additional offset equal to the tolerance permitted at that station, the FD templates were thus made with studs on the centreline for location, with a shape that was then 12.5 mm larger that the design lines of the hull. The permitted gap between the template and the hull was then between zero and 25 mm. Now most fibreglass hulls are within a few mm of each other and furthermore, experimentation with hull shapes within the tolerances have lead to hull shapes which differ significantly from the original design and are used by essentially all modern competitors. The template gap tolerances have therefore often been adjusted and reduced to accommodate these developments.

Measurements of hull shape with templates are only as good as the templates themselves. There are therefore a number of features which are required for accurate template measurement. Modern templates are produced by CAD-CAM systems with the shape derived directly from digitized hull sections, so, apart from care having to be taken with precise scaling, the shapes accurately reproduce the design hull shape. However, modern water-jet cutting of templates require the use of soft aluminium rather than the harder Dural, and furthermore only allow cut outs (Fig.9.3.2), rather than lines to be marked on the template. Considering the soft material this has two major disadvantages, namely that the measurement is taken at a sharp point which can easily be damaged, and that there is no reference line 10 mm from the template edge which can be used to check that the template has not been damaged. Some templates are designed to have chamfered edges but these are difficult to produce by water cutting and considering the soft aluminium used should be very fragile.

Figure 9.3.2 The ISAF produced Yngling templates showing the triangular cut outs at the measurement points and the lack of a reference line 10 mm from the template edge. The crossbeam and brass adjuster are essential added details. Note the locating pin, which precisely maintains the width of the template.

Most sailboat hulls are symmetrical, or at least intended to be, so many templates are made of two identical half templates and then assembled. For such templates it is essential that there are machined locating pins as well as solid clamping screws at the keel line join, and that a cross bar, also with machined locating pins., as shown in figure 9.3.2 is used, if the template is not clamped into a frame as shown in figure 9.3.3. The Yngling templates as supplied by ISAF have no crossbar and are joined by small plates and six 2 mm diameter screws, which is considered insufficient. The gap at the sheer between the two halves when screwed together in this way can vary by 7 mm. For accurate measurements cross bars with machined locating pins which define the beam measurement at the sheer, are essential and should be checked before any hull measurements are made.

Figure 9.3.3 A full section FD template made of Dural with a pinned rigid crossbar and adjustable lugs at the sheer, for alignment. However, again there is no reference line at 10 mm from the template edge. The signature shows that this template has been checked against the Mylar plan.

All template sets should have an identifying number, which should be recorded together with the data for the hull. Many classes have template sets from different eras and it is important to identify the set used for the measurements. In order to ensure that the templates have not been damaged or altered they should have a reference line precisely 10 mm from the measurement edge, however in many instances this is not the case. In that eventuality the measurer should have an accurate drawing of the templates on stable Mylar, see figure 9.3.4. Such a Mylar plan is easy to transport and should, if there is any doubt, be used to check the templates before measurement.

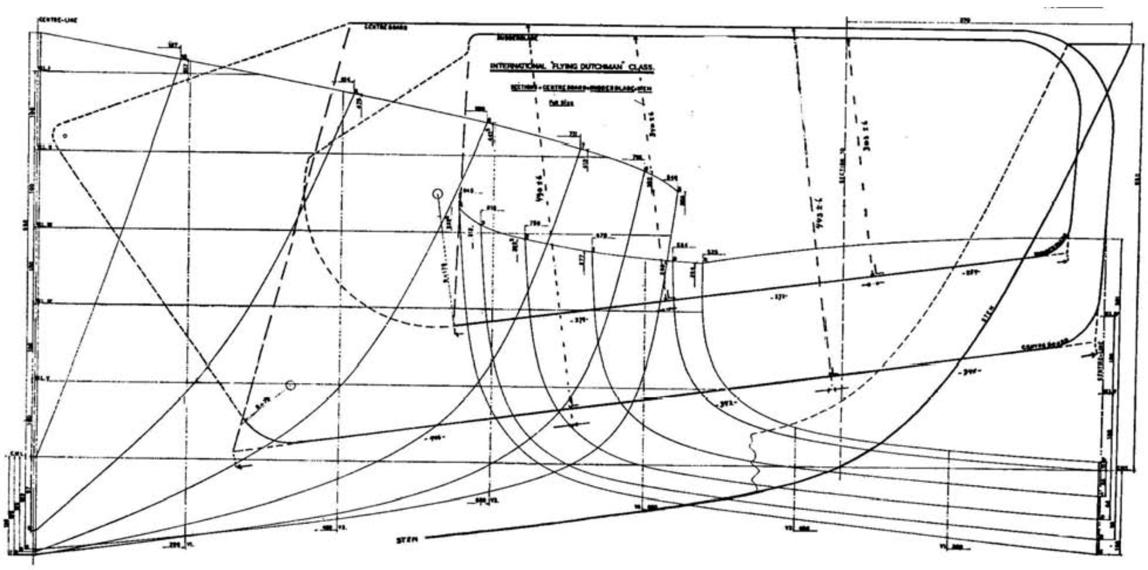


Figure 9.3.4 The Flying Dutchman Mylar plan used for checking the templates, rudders and centreboards.

If a plan is not available then there may be set control distances marked on the template and these should be checked. If there has been any distortion due to insufficient thickness of the metal then it is desirable to stiffen the template with wood or other backing.

Having located and marked up the measurement stations in one of the way described above, the following procedures may be generaly used to set up the templates, unless otherwise stated in the class rules:

(i) Position the template with its centreline coincident with the centreline of the boat and with one face of the template coincident with the station marks.
(ii) Equalise the clearance between template and hull near the sheerline on each side.
(iii) Measure clearances all round template, where necessary recording both maximum and minimum clearances.
(iv) Measure height of sheerline on each side.

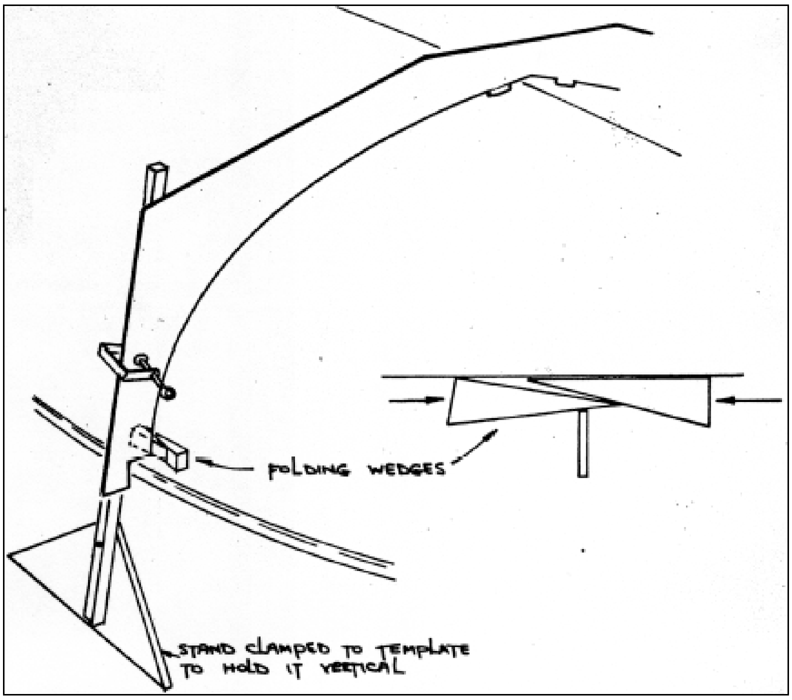


Figure 9.3.5

It is essential that the template is accurately located, particularly towards the ends of the yacht, since the shape of the yacht changes rapidly towards the bow and stern and a small error in position can make a significant difference to the clearance recorded. The template can be held in its correct position using folding wedges at or near the sheerline as shown in the **figure 9.3.5**. or plasticine pieces. At the centreline masking tape or plasticiline will hold the template in place. There are other ways in which the templates can be held in place for measurement using jigs. One simple way, which is shown in **figure 9.3.5,** uses a simple wooden prop

Clearance between the template and the surface of the hull is best measured using a steel rule held parallel to the face of the template (figure 9.3.7). Clearance may also measured using calibrated wedges (figure 9.3.8), about 125mm long and of different thicknesses. However, wedges can lead to errors, particularly near the bow and stern (**see figure 9.3.6**) because the wedge measures the shortest distance between the hull and the template and not in the plane of the measurement station.

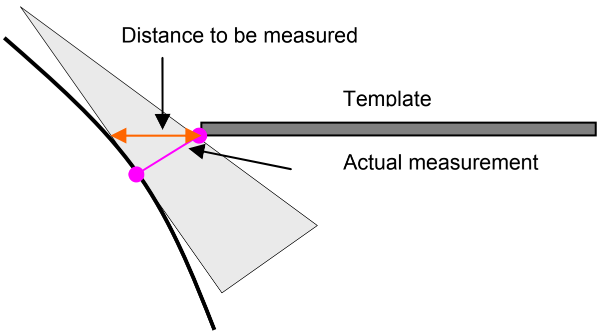


Figure 9.3.6

Figure 9.3.7

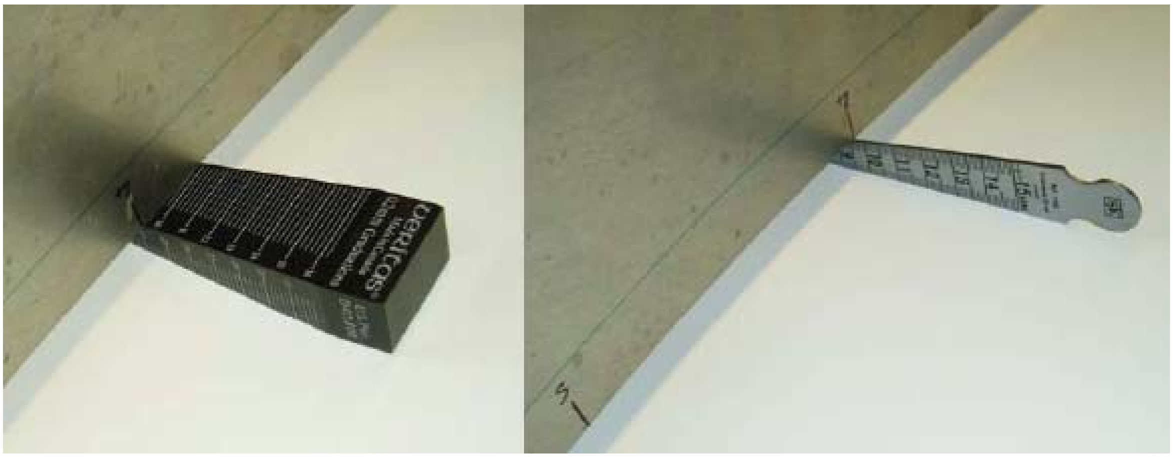
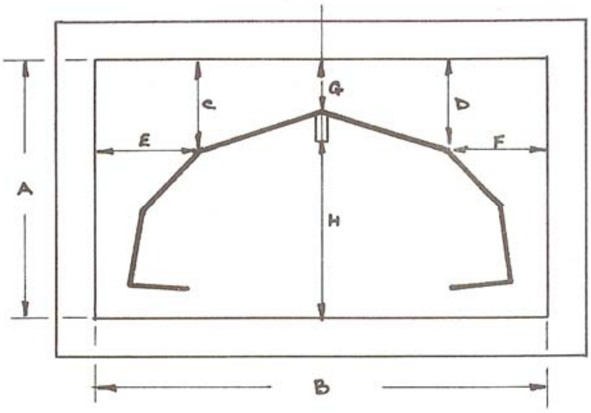


Figure 9.3.8 Wedge gap measurement

b) Section Measurement for hulls with chines

The section shape of a chine hull is normally checked by measuring the height of chines and sheer lines above the base line and the beam at the chine(s) and sheerline. Height measurements of the chines and sheer lines are taken perpendicular to the plane drawn through the base line. For ease of measurement, some classes measure chine rise and sheerline height from the keel at the centre line, **see below**.

The chine measurement point should be defined, the normal definition being the intersection of the extensions of the surface of the hull each side of the shine, as **shown below.**



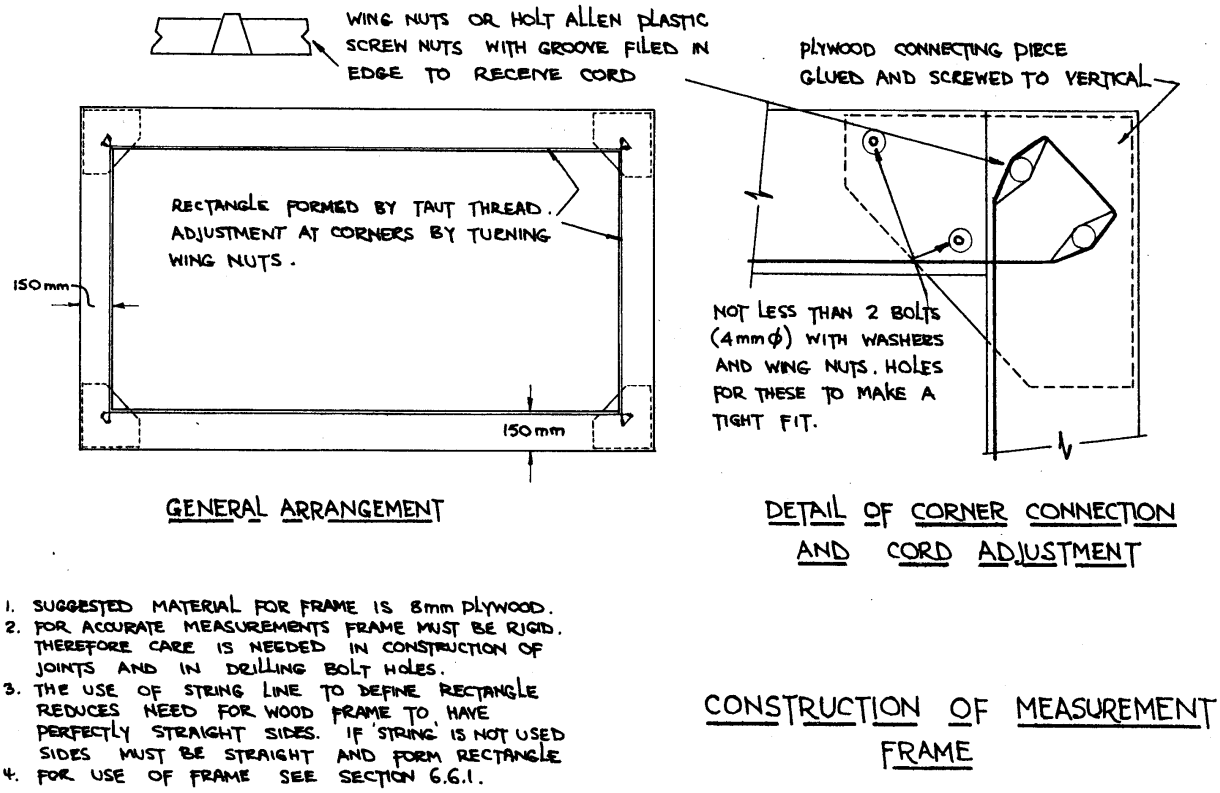
The sheerline is normally defined by the intersection of the lines of the top of the deck and the outside of the skin of the hull, projected if necessary and can be found using a `C' template or one of the sheerline jigs indicated in **figures 8.3.1 and 8.3.2**.

Before measuring chine and sheerline heights the hull should be level athwart ships. Normally the hull will not have a twist in it and therefore the height of the two sheer lines at the transom can be equalised and the hull will then be level. However, if there is a twist the measurer has to establish a mean position. This can be done by measuring heights to the sheerline at a number of points on each side and then adjusting the hull until the sheerline on each side at each location is as close to being horizontal as possible. All measurements of height to base line etc. have to be taken without moving the hull from this position.

Alternatively, the height can be measured on both sides and averaged, eliminating the need to accurately level the boat athwart ships. However, if the hull appears to be significantly asymmetric the measurer should note it on the measurement form.

If a floor grid system has been used to establish the measurement stations at the sheer lines, the measurement points on the chines may be established by erecting two verticals at the sheerline marks. A string line held tight to touch both straight edges and the mark on the keel will locate the point on the chine.

Alternatively, a good way to measure the section shape of a chine hull is by using a measurement frame as shown **below**. This device was developed by Jack Chippendale and is sometimes known as a Chippendale Frame.



The frame can either be supported at the level of the base line or directly on the keel. In the latter case the frame is more readily supported, but an allowance has to be made if height measurements are to be related to the base line. In either case the centre of the frame is supported vertically over the centreline of the hull and with the top frame horizontal. Care should be taken to see that the frame lies in the plane of the measurement section. Measurements are taken from the point on the hull to the nearest point on the frame. Beam at the chines is B - (E + F). The height of sheer above the base line is (A - J)

c) Section measurement for development classes

Small development classes often have a 'rise of floor' restriction, i.e. a minimum permitted hull width at a fixed height above the hull centreline, to prevent very narrow beam in the area of the waterline. Rise of floor may be measured using callipers or by using a special template made from plywood to the dimensions given in the class rules. If callipers are used the bar must be horizontal when the measurements are taken.

d) Hull measurement with a model template

Some classes (49er) use a hollow hull template made from the master plug to check the compliance of the hull. The hull template can be easily fitted to the inverted hull and a visual inspection can be undertaken in a very short time.

The only other tools required are a set of feeler gauges for measuring the gap, if found, between the hull and the template. Any variation is then checked against the tolerance as specified within the builders' construction manual.

9.4 Stem profile

There are several ways of controlling the shape of the profile of the stem, some of which are described below.

a) Stem Templates

This is a template made in the shape of the curve of the stem allowing for the permitted tolerances. The method of using it varies from class to class and therefore reference to the appropriate class rules is essential.

The aft end of the template is usually located at one of the measurement stations although in some cases (for instance the Finn, 470 and Europe classes) allowance has to be made for any deviation from the designed overall length. For the 420 Class the template has to be positioned relative to the base line in addition to locating its aft end at a measurement station.

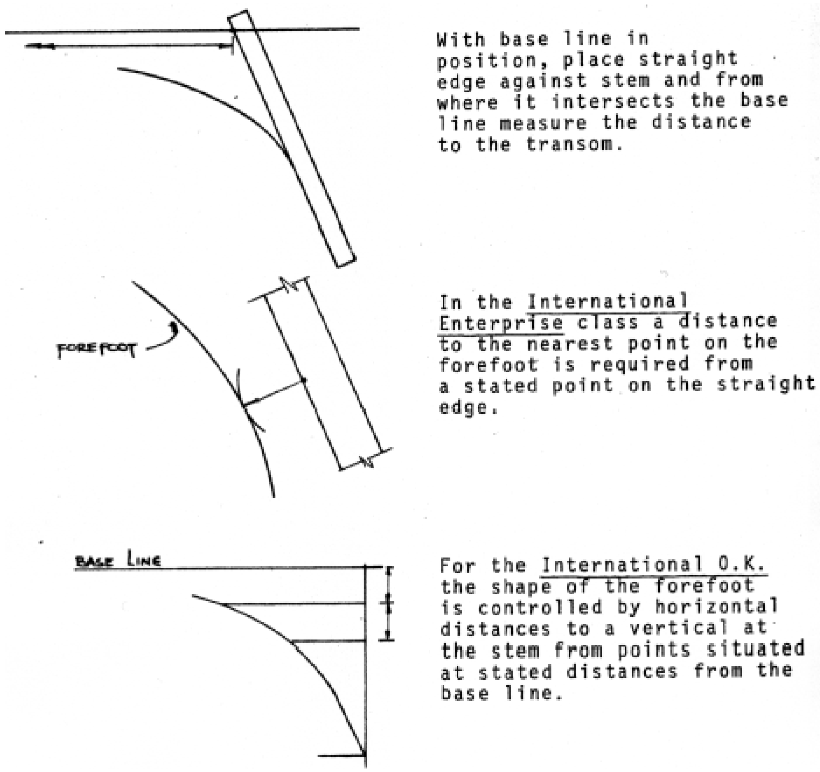
b) Rake of Stem

Some classes with a straight but raked stem control the rake by measuring the position of the intersection of the base line and the extension of the straight portion of the stem.

With base line in position, place straight edge against stem and from where it intersects the base line measure the distance to the transom,

You may also need to measure the distance to the nearest point on the forefoot is required from a stated point on the straight edge,

Alternatively, the shape of the forefoot is controlled by horizontal distances to a vertical at the stem from points situated at stated distances from the base line.



9.5 Transoms

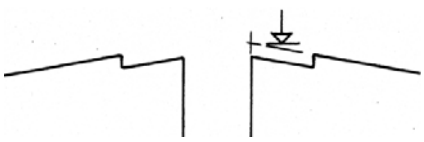
Transom rake can be measured using a spirit level or a plumb bob, but a simple and accurate way of doing it is to use a plywood rectangle

The measurements from the base line to the keel may be required to be taken perpendicular to the base line or vertically.

9.6 Measurements in way of centreboard slot

Usually there is at least one measurement station which coincides with the centreboard case opening.

When this occurs, unless the class rules say anything to the contrary, the measurements are taken to the bottom of the hull projected to the boat's centreline as this is the point that would have been measured to when the hull plug was originally made.



9.7 Radius of chines

Sometimes the class rules impose a limitation of the radius of the chine. The accurate measurement of this radius is not easy. However, in many cases actual measurement is not necessary because compliance with the rule can be checked visually by comparing the actual radius with the curves shown in the picture 9.7.1.

If a measurement has to be made it is necessary to use a template made with the maximum permitted radius. It should be noted that the angle at the centre of the radius must not be greater than the angle between the adjacent panels.

Picture 9.7.1

9.8 Deck camber

Deck camber at any transverse section is the maximum height of the deck above the sheerline at that section. It is measured by placing a straight edge athwart ships approximately horizontally on the deck and measuring its height above each sheerline as indicated in the figure 9.8.1.

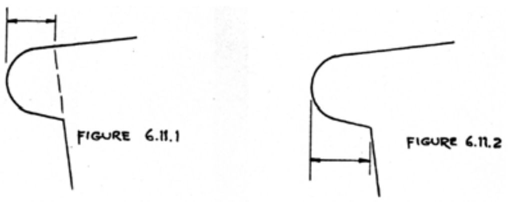
Deck camber = (A + B) / 2

Figure 9.8.1

9.9 Sheer guards or rubbing strakes

The usual way of measuring the width of these is illustrated in figure 6.11.1 at right. The width is a plan width, i.e. it is measured horizontally from the sheerline.

However, there are exceptions to this method. For instance the Finn Class measures the width in the way indicated in figure 6.11.2.



The depth measurement is either the vertical depth or the depth measured parallel to the hull side. The class rules should specify this.

9.10 Internal measurements

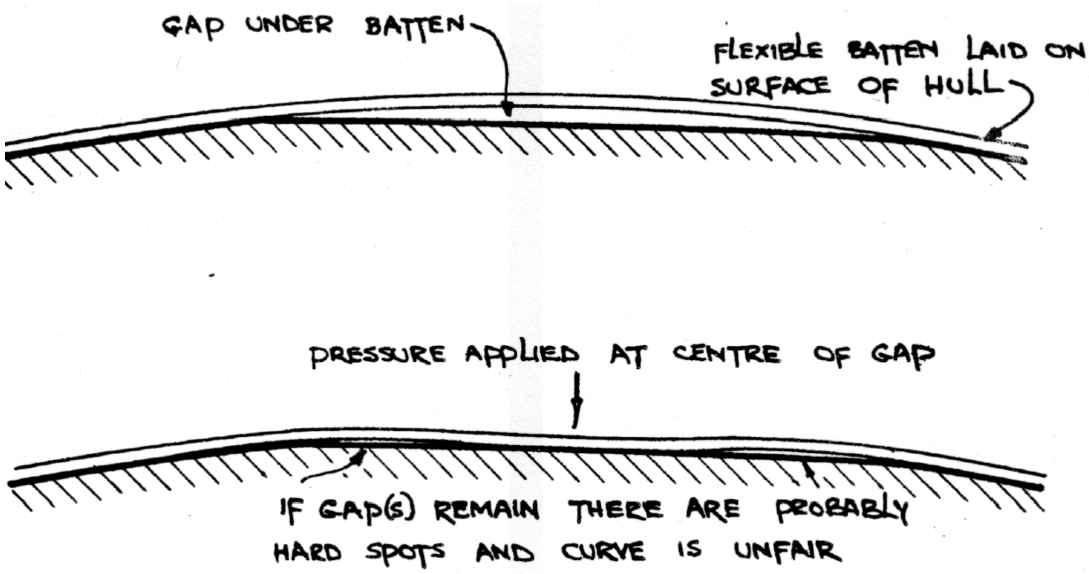
Measurements along the hull and to bulkheads, mast step and fittings etc. may be taken from the plane through the aft measurement point. It should be noted that this datum plane may not be accessible for all measurements so the measurer may need to display some ingenuity in carrying out those measurements accurately. In respect of this, some class rules specifically refer to the inside of the transom as the measurement point.

Width, thickness, length etc., of components are measured as appropriate for that component or part and without reference to the hull axes.

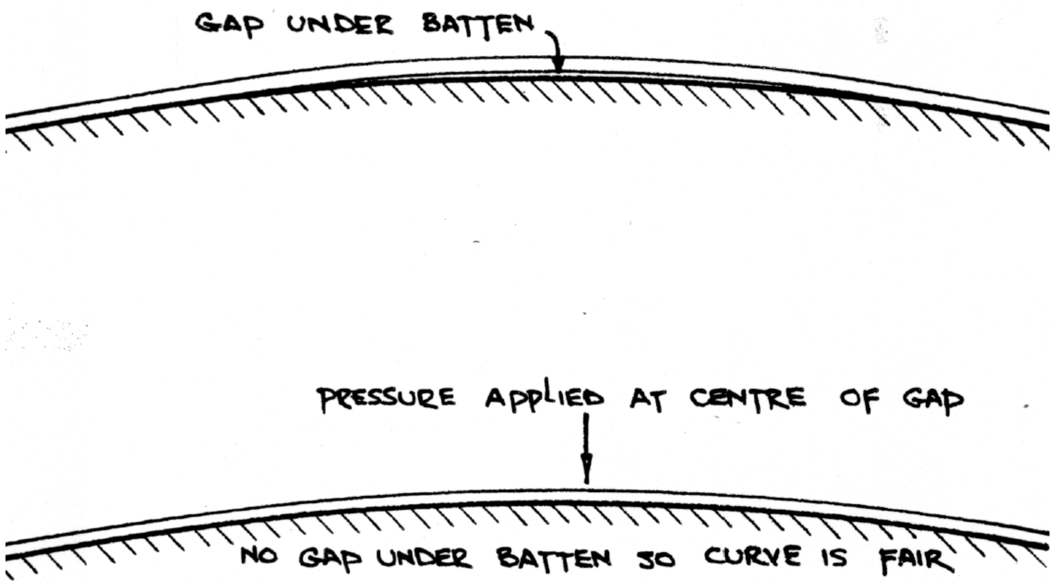
9.11 Fairness of the surface of the hull

Several classes require the measurer to check that the surface of the hull is fair. This is normally done with the hull inverted, by laying a flexible wooden batten on the hull surface. The ends of the batten are held down on the surface and the area of contact examined.

What is being looked for is an unfairness which will be shown by the presence of a `hard spot' which causes the batten to lie away from the hull, or by a definite concavity in the surface. A concavity can be detected by means of a straight edge.



Care should be taken when examining a hull for fairness that a gap between the batten and the hull caused by the fact that the batten does not take up the same curve of the hull, is not mistaken for a gap caused by a `hard spot'. Often it will be found that the batten, when held at its ends on the hull surface, will not lie on the surface. Light pressure applied to the batten over the centre of the gap will normally close the gap completely. If it does not there may be a hard spot and therefore an unfairness.



9.12 Hull measurement with templates: Case study for the 420, 470, Finn & Europe Classes: comparison with the FD measurement.

9.12.1 Introduction

The following is a guide on hull measurement using a beam baseline, as applied in four centerboard classes.
The base line will be a straight beam of aluminum, with a rectangular section, as light and stiff as possible. Aluminum sections should be high and thin-skinned, to increase the stiffness and decrease the weight of the section, and stored carefully to avoid permanent deformations. Sag in the middle is always present due to self-weight of the beam, but with the correct selection of section it can be minimized. For example, a 60mmX25mmX2mm aluminum section (height X width X skin thickness) sags about 0,75mm in the middle of the span in the case of a 420 hull (3780mm/2=1890mm from HDP). This is the maximum found, and in other stations towards the ends of the hull it will be much less. The measurer should always take these figures into account when measuring a hull. All measurement stations may be clearly marked on the beam along with notes such as the minimum and maximum limits, and a steel tape can also be fixed on the upper surface for quick reference. Obviously this is a clear advantage of this system compared with the thread baseline.

Of great importance is the way of making the “legs” of the baseline, that is the pieces that actually touch the hull at the respective points according to the clas rules, and there are various ways to do that:

- Using pieces –preferably of the same aluminum section as the baseline- cut in the correct length and fastened with bolts or clamps on the baseline beam. Great care must be taken to ensure that they are fixed at right angles to the baseline and the bearing points are exactly at the correct heights from the baseline i.e 200mm and 92 mm from it in the case of the 420. Another thing to consider is the designation of the baseline “edge” on the baseline beam, because the legs must be attached so they follow that edge: the recommendation is to assign the lower left edge of the beam as the baseline, and while the aft (transom) leg may be flush with the baseline beam’s left side, the front leg is better made in a configuration similar to that shown in the picture. In this way, it will be easier for the baseline system to stay put on the hull keel while in use. Otherwise, the baseline will be prone to slipping aside at the front end. Teflon pieces may be attached at the edges of the legs, because aluminum tends to leave marks on the hull gelcoat –as long as their length is included in the total length of the legs.

- Using the stem and transom templates themselves –if the class uses those like the 420, fastened with clamps (or even bolts) on the baseline beam. Great care must be taken to ensure that their scribe lines are perfectly aligned to the baseline. When using the templates as “legs”, it is impossible to have an arrangement on the front one to facilitate the safe positioning of the baseline. Therefore, great care must be exercised to keep the baseline in place during measurement, and external supports may be used as well in the form of beams where the baseline may be clamped for extra security. In all other classes of this example, there is a stem template but it cannot be used in this fashion, as the exact positioning depends on the actual measured length of the hull and it’s difference from the “standard” class length.

- It is also possible to use external supports for the baseline beam and fix it at the correct height from the hull but this is not recommended because it is time consuming to setup and not as easy to keep in place as the other systems during measurement.

Using removable legs makes for a truly “universal” system, which may be used for various classes similar in length simply by substituting the legs for the class specific ones.

9.12.2 Hull setup

The setup of the hull is fairly straight-forward: Above all, the hull has to be supported in such a way that it is not twisted and does not sag or hog. To minimise errors from hull sagging, it is recommended that all hulls of the same class are set up in the same way:
For the aft support, the transom edge is not a good choice because all classes of this example have curved transom tops, so the hull will sit on the highest point which is on the center plane, and therefore it will be unstable and prone to rotate. Therefore, the hull shall be supported at a point some distance in front of the transom: 420s and 470s can be supported only a few cms in front of the transom, while the Finn needs to be supported just in front of the aft tank. Our target is to support the hull on the side tanks, and that will facilitate the correct atwartships leveling: using small wedges or even cardboard pieces as shims on one side, the hull shall be leveled athwartships with the help of a simple water-tube or bubble level. Reference points for the leveling shall be the sheerline points at the transom corners. Alternatively, more sophisticated systems using car jacks and attached levels may be used as well.

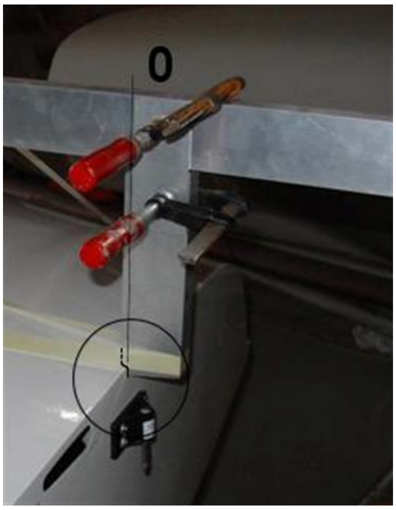
 

For the bow, a car jack with some foam pads attached is needed and positioned near the stem, and it must not obstruct the positioning of the stem template.

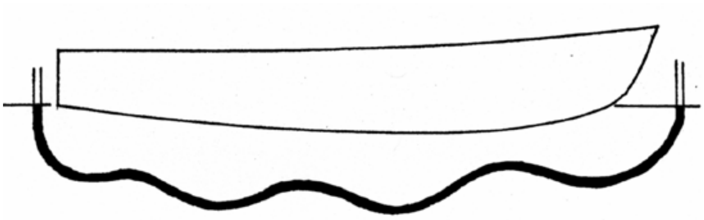
The HDP of the hull shall be defined next: This is the intersection on the hull centre plane of the transom external surface with the underside of the hull surface, both extended as necessary. For hull measurement purposes, and lacking another way of finding the symmetry plane of the transom, this shall be the point at the above said intersection at equal distances from the two sheerline points at port and starboard transom corners. It can be found using a measurement tape and it shall be clearly marked on the hull with a pencil or pen and a piece of masking tape for protection.

The baseline is then ready to be set on the hull and fixed with masking tape. Note that if legs are used, the aft leg must be made in such a way that the longitudinal “zero point” is actually a few millimeters inside the leg front edge, unlike the front leg, where the appropriate point as defined in the class rules is the aft edge of the leg. This is done because we need a small “dent” to help the baseline “sit” on the hull. The transom template –if there is one- may be used for tracing the correct shape of this dent. In the 420 case, if using the template as leg, the dent is already built-in.



The front leg shall be positioned so that the baseline is above the highest point of the keel at the appropriate station (st 9½ at 3780mm from HDP for the 420, st 8 at 4000mm for the 470 etc). The baseline beam system must be made vertical (atwartships) using a plumb bob or a level. In this way, the vertical plane passing through the baseline, set as described above, is the hull centreplane for measurement purposes.

Using a water tube (principle shown on picture below) or a level, the hull can then be leveled fore and aft with a few turns of the front support jack screw (“C” on figure 1 below). The whole procedure takes very little time to complete. The fore and aft leveling of the hull is not really necessary but will really help with some measurements as it permits using simple tools like plumb bobs and with template positioning at the later stages.



It is very important to fix the baseline system on the hull so it doesn’t move, and even mark the contact points with pencil fore and aft for quick reference during measurement: if at some point it is discovered that they are not aligned, then the setup process should be repeated. Tape is one way to fix the baseline, but also ingenious systems with suction cups and fixing screws are possible.

9.12.3 Keel profile measurement

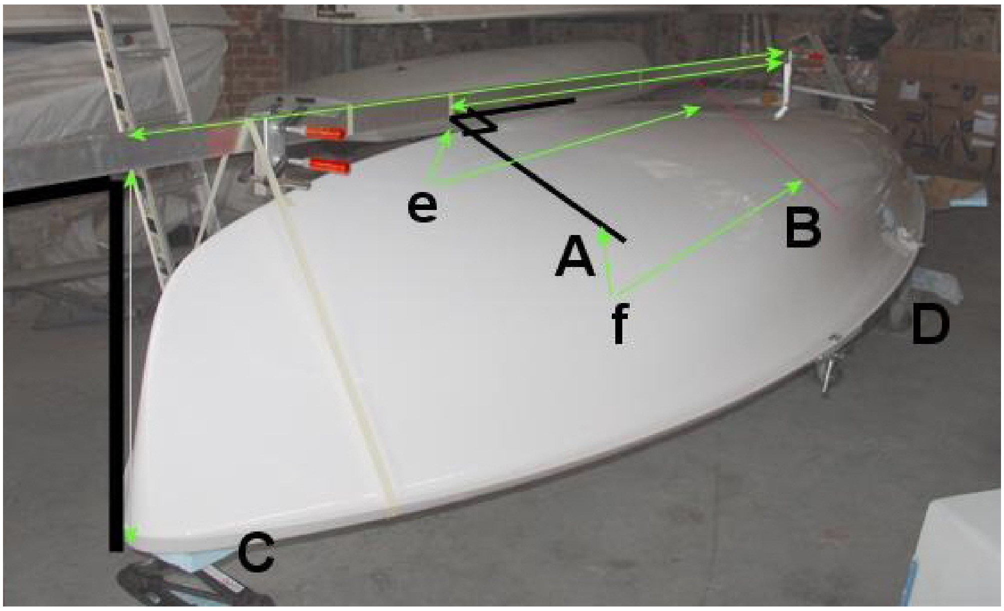
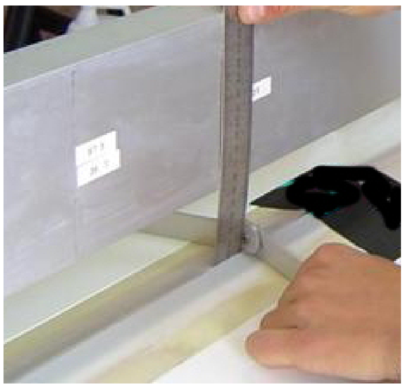
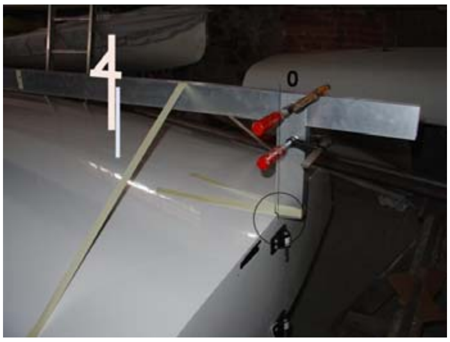
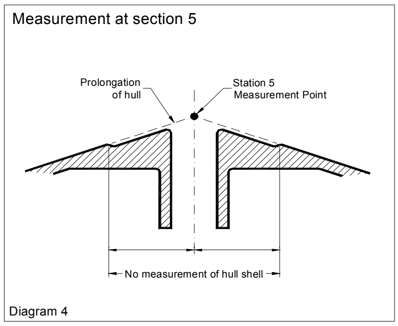


Figure 1 Baseline setup on Hull

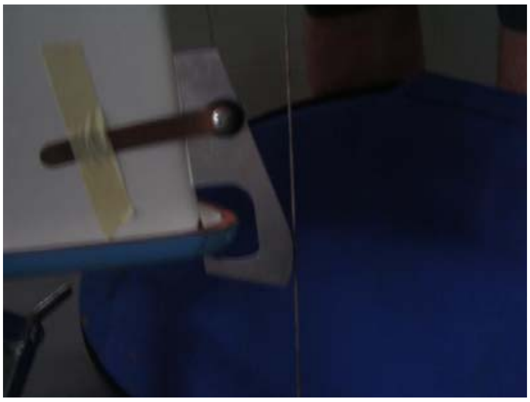
With the baseline set and fixed on the leveled hull, the next step is to check the keel profile at the various stations, and then the marking on the hull of the stations for template positioning. The first can be done with an adjustable square and a steel ruler, but for the second a carpenter's square (figure 1 "A") or a laser square (figure 1 "B") are needed to extend each station on the hull sides (figure 1 "f"). The gunwale positions for each station can be marked using a plumb bob, and then the sheerline points can be marked using appropriate tools for each class: Finn and Europe need a tool like those shown in 8.3.1, 420 & 470 define those points at a set distance inwards from the gunwale. Centreline station points shall be those found exactly under the baseline, even if the hull is not perfectly symmetric in construction: If the highest point on the keel seems to be offset to the side, the point under the baseline will be still marked as the "centre" of that station, but the keel height shall be the one found by measuring from the baseline to the highest keel point. The last step for this part of the job is to measure the sheerline heights at the stem and the top of the transom, as well as the transom top deviation from the vertical (horizontal distance from HDP); these measurements will be needed later, to set the deck baseline. For those stations that are in the centerboard case area a special tool is needed to bridge the gap: it may be made from two aluminum strips bolted together. Pencil or pen marks covered with masking tape shall be done at all measurement points. Warning: keel profile measurement for the Finn is done excluding the keelband (if present), but the keelband is included in the latest class rules for the positioning of the baseline.





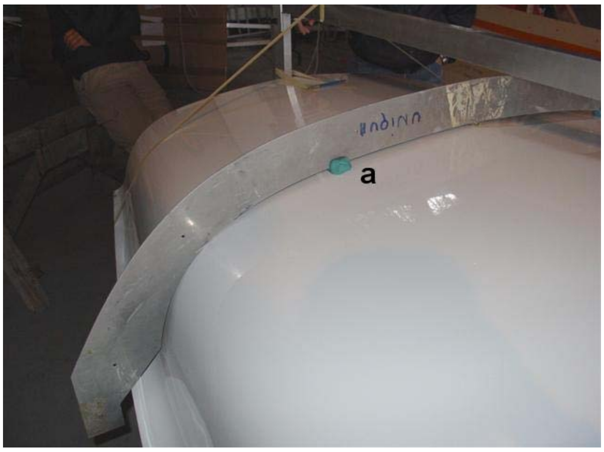


At this stage, the centerboard case position can be also checked, and in the 420 case, if the stem/transom templates have been used as baseline legs, the profiles of the stem and transom should be checked as well. For that class, the transom radius shall be checked at this point too. The point at 400mm below the baseline shall be marked on the transom centerline, and then the measurement taken using an aluminum bar/straight edge at least 1040mm long, a spirit level, a square and a ruler. Finally, for all classes except from the 420, the hull length between the transom corner and the stem must be measured using the baseline and a plumb bob or a square. Differences between the actual and the “designed”length will specify the correct position of the stem template for Finn and Europe.



9.12.4 Template Measurement

When the keel profile measurements and the station marking has been done, the baseline must be removed (without disturbing the leveling of the hull), to make way for the templates. With three points marked on the hull for each station (centre and two sides, see figure 1 “e” and then “f”, done for both sides), each template can be positioned easily and fixed on the hull with small pieces of plasticine on each side. The centre of the template shall be coincident with the mark on the hull centreplane and one face of the template coincident with the station marks. It is recommended that for the aft part of the hull, the measurement face of the templates shall be the one facing aft, and for the front part of the hull it shall be the opposite. For the 420, 470 and Finn, the templates shall be initially leveled so that the sheerline marks on both port and starboard sides are on the same horizontal level. If the hull is leveled correctly, the self weight of each template will help it stand vertically, without any other outside assistance, but for extra security, a support system may be used as well. It is essential that the stations for template positioning are accurately located, particularly towards the bow of the boat, since the shape of the boat changes rapidly towards the bow and a small error in positioning can make a significant difference to the clearance recorded. Finn and Europe stem templates have two nibs, one near each end, and they are positioned so that both nibs touch the hull. 420 and 470 stem templates have only one nib, at the keel end and are aligned with the baseline using a scribe line on the templates themselves as reference for the baseline (horizontal) level. This is one extra reason for leveling the hull horizontaly fore and aft, as you may position the stem templates using a simple level.
The Europe hull is measured in a fundamentally different way, as the templates are always leveled horizontaly sideways and remain so at all times. Moreover, the templates are positioned in the centerplane at a height depending on the actual keel profile difference from the as-designed values. One can imagine the Europe hull being checked exactly against the as-designed shape, with templates “floating” in space always at the same position relative to the “designed” shape. In the 420-470 cases, the templates “follow” the as-built- shape, since they are always positioned at a fixed distance from the hull at the centreplane (i.e 8mm for the 420, 10mm for the 470). The Finn excludes any keelbands from hull shape measurement, so the templates actually have a cut in the centre to allow keelbands to fit inside. Therefore, the templates are touching the hull on both sides near the keel.

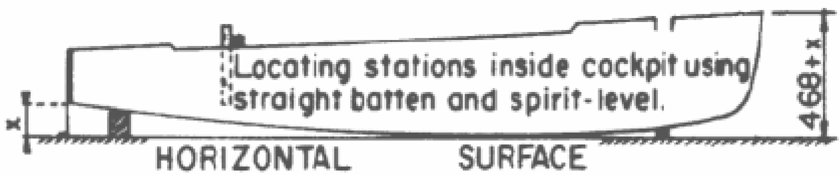


Minimum and maximum hull clearances from templates are to be measured and recorded for both sides. The sheerline height is also to be recorded both for port and starboard sides. If the hull is not perfectly symmetric, and the template clearance is outside the limits at some point, the template may be rotated (NOT in the EUROPE!) at the centerline if that solves the problem, but the sheerline points shall be at all times within their respective limits and the exact positions of both sheerlines recorded to facilitate the repeatability of the measurement. A metal ruler held parallel to the face of the template shall be used for measurement of the template clearance. Use of a calibrated wedge is not recommended because it may lead to incorrect measurements as shown in fig.9.3.3.

9.12.5 Deck Measurement

The last step is the upturning of the hull and the measurement of the deck, using the same bar baseline but with different height legs, according to the following system: by measuring the difference of the sheerline height between the stem and the top of the transom, two legs with lengths differing by that amount can be made. Enough length must be added to both legs for the baseline to clear the breakwater (420-470). It is recommended that one of the legs shall be adjustable in length, to compensate for differences in sheerline heights between boats. Alternatively, the aft leg may be fixed at a set height and the baseline positioned -with the help of a vertical bar- at the appropriate height at the stem. There is no need to level the boat fore and aft for deck measurement, since there are no templates to hang, unless the measurer is using plumb bobs to transfer measurement points vertically. It is recommended to use squares instead since they are easier to use, especially laser ones. If leveling is needed, the hull shall be leveled athwartships using the sheerline points at the transom corners, and the baseline for fore-aft leveling, as done previously for the hull.
Taking into account the horizontal distance of the transom top from the HDP, the HDP can be “transferred” on the transom top and the baseline AMP set fore and aft without significant errors.

The Finn Class is using a simplified method for setting up the hull for cockpit measurement, by taking a fixed difference between the transom and stem of 468mm (the recommended method described above for the other cases is to measure exactly the equivalent of these “468mm” for each particular hull).

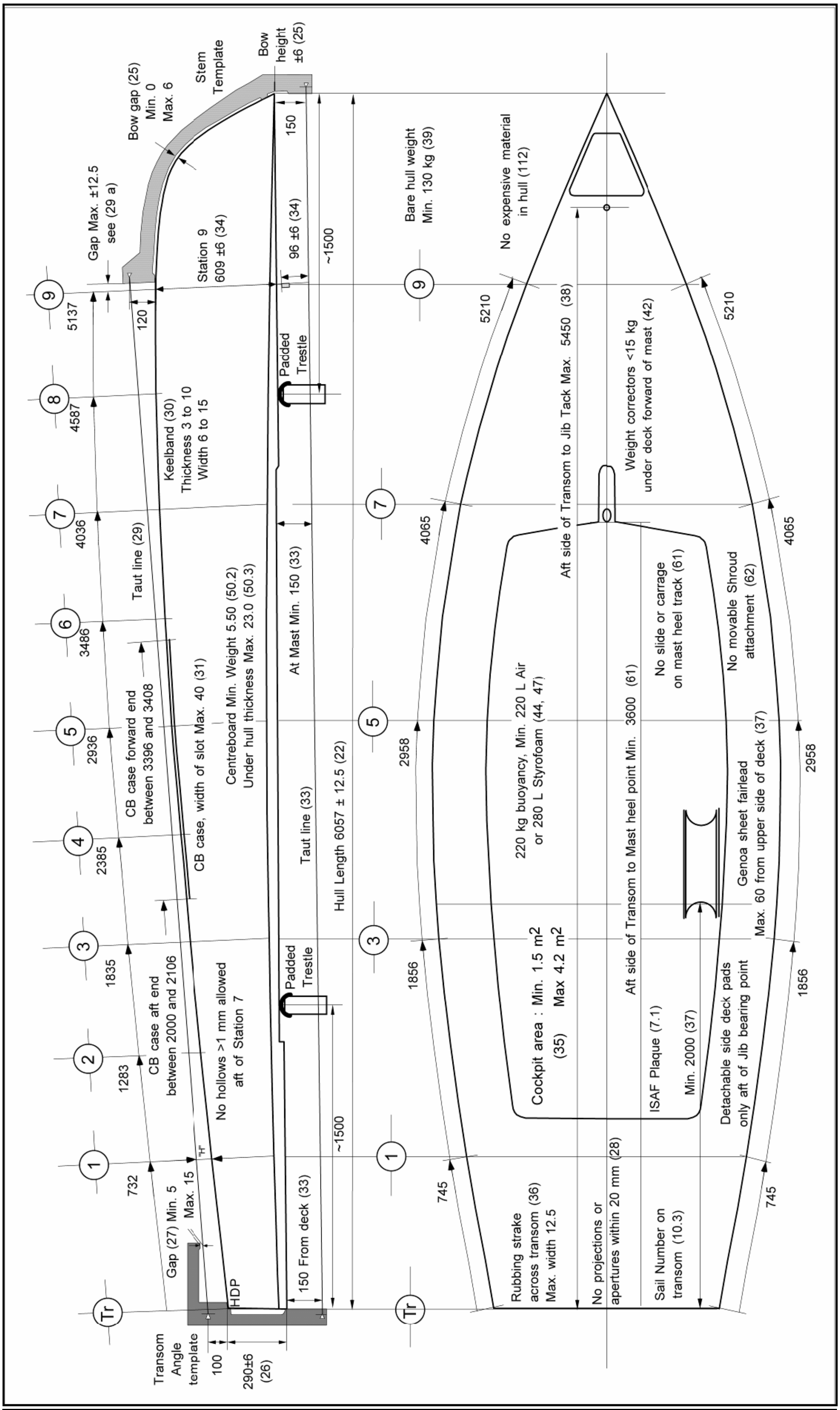


9.12.6 Comparison with the FD system

The Flying Dutchman Class is using the simpler “Hull Co ordinate System” and applies the following procedure (taken from the FD Class Rules):
*After measuring the overall hull length (done along the deck line), the **hull** is turned upside down and supported on trestles. The positions of the stations at the keel and the gunwale are to be determined by taking the following measurements from the outside of the transom along the keel and along the skin at the gunwale.*

Station	1	2	3	4	5	6	7	8	9
Keel mark	732	1283	1835	2385	2936	3486	4036	4587	5137
Gunwale mark	745		1856		2958		4065		5210

By using the numbers on the table, the three points required to define the template plane, which it should be pointed out may not now precisely correspond to the section plane of the design drawing are determined and marked on the hull and then the templates can be positioned. The measurement edge of the template, usually the forward side for the bow sections and the aft side for the stern sections, should be aligned with the reference marks. The centreline of the template must be aligned with the centreline of the hull, but this still leaves the rotation of the template around this point to be determined. This is generally fixed by making the template gap at the port and starboard sheer lines equal, and a lug is provided in order to maintain this alignment.



The FD measurement plan showing the positions of the template reference points on the sheer lines and centreline. Only the odd stations and the transom are templated

Left, a Flying Dutchman hull with the templates positioned relative to the hull.

Above, the adjustable lug used to equalize the gap at the port and starboard sheer lines and hold the template at the reference mark (here made on the tape). The horizontal rule is positioned for measurement of the sheer line height.

From the FD measurement diagram it can be seen that the hull is to be supported at ¼ and ¾ of the hull length, as suggested to minimise hull sagging. Doing a similar thing for the Finn or 470, would result in great difficulties for the leveling of the hull: When trying to level a hull for the "gravitational coordinate system", it is much more efficient if the adjusting screws are positioned very close to the transom corners and the stemhead.
Compared with the beam baseline systems described in the previous sections, it is obvious that here the equipment needed is only the templates themselves. However the price to pay is lack of direct comparison to the as-designed shape, as outlined in 9.3.

9.13 Hull measurement of a “chine” hull: Case study for the Lightning Class.

HULL MEASUREMENT - PROCEDURES
For purposes of measurement use feet-inches-eighths or millimeters.
Place hull upside down on three supports with a hydraulic jack on a level floor as the third support near the front of the bow. Fixed supports may be used if enough manpower is available for leveling the bow.

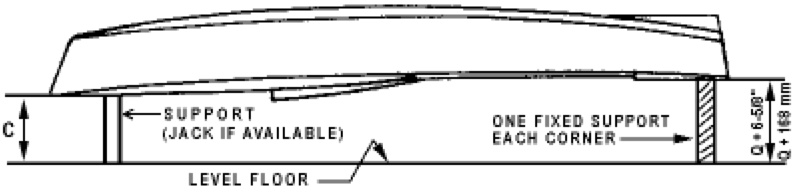


FIGURE 1

Measure to see that each corner of the chines or sheer at transom is the same height from the floor. Then adjust the hull so that the deck at the stem is 142.875 mm (0-6-5) lower than centerline of deck at transom. Use a carpenters square with leading edge to centerboard pin per figure 2 to locate A dimension.

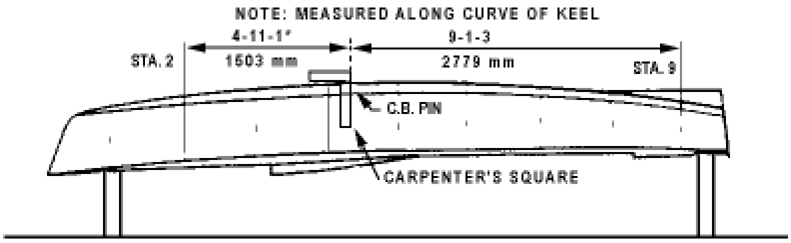


FIGURE 2

After A dimension is located measure along the curve of the keel 1501.775 mm (4-11-1) and mark approximate location of station 2. Then measure aft along the curve of the keel 2778.125 mm (9-1-3) and mark the approximate location of Station 9. Before erecting the baseline the amount that the keel stands proud of the bottom must be taken into consideration per figure 3.

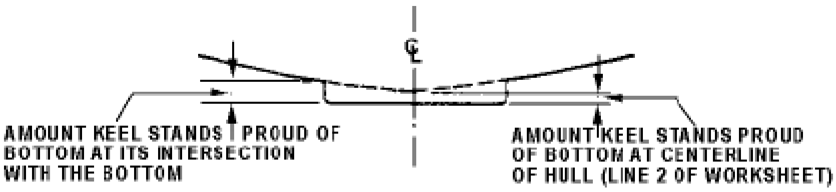


FIGURE 3

This amount may vary from station to station dependent on keel width and the relationship between chine height and breadth and centerline height. The important point is to measure from the base line to a point at which the outside bottom would intersect the centerline without the keel.
The exact distance from baseline to keel plank for the establishment of the baseline is obtained by subtracting line 2 from line 3 on the worksheet for stations 2 and 9. This is the figure recorded on line 1 of the worksheet.
For maximum speed and accuracy in establishing the baseline it is suggested the baseline be supported from the hull itself. It may however be supported from separate posts securely attached to the floor at each end of the boat.

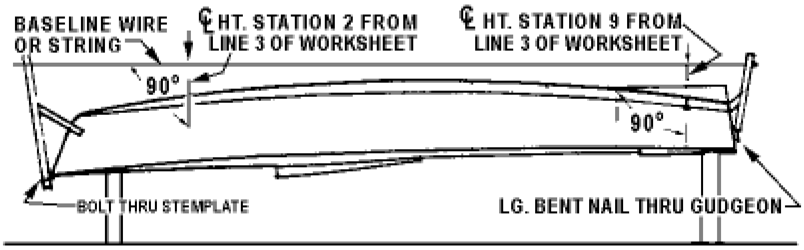


FIGURE 4

For measuring heights choose a scale or steel ruler so that, by turning it end for end, you can always measure directly from keel plank to baseline.

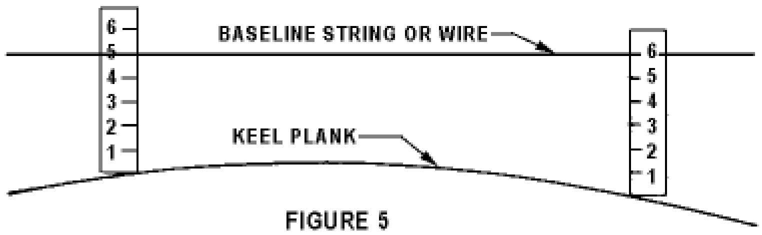


FIGURE 5

For accuracy always hold the scale beyond the baseline and place the eye of baseline height so that wire will pass directly in front of the measurement to be taken. If possible use 1.5875 mm (1/ 16") piano wire stretched as tight as practicable and free from kinks. Extreme caution must be used to prevent sag.
Jockey baseline so that the perpendicular distance from baseline to top of keel at stations 2 and 9 agree with the figures placed on line of the worksheet for those stations.

EXACT LEVELING OF BOAT
LOCATION OF BASELINE AND STATIONS AND CENTERLINE HEIGHTS
Recheck location of A on keel with the carpenters square, and if necessary relocate stations 2 and 9, and recheck baseline for level. It is imperative that the baseline be level.

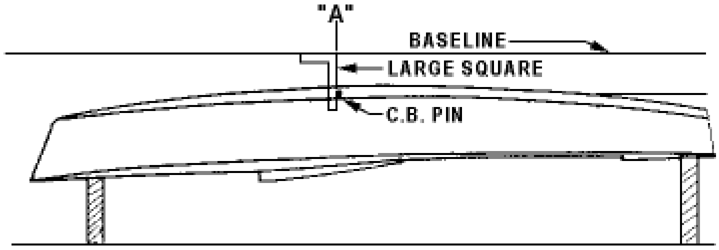


FIGURE 6

Locate and mark from A to stations
- 1 forward 2117.725 mm (6-11-3)
- 3 forward 888.20 mm (2-11-O)
- 4 forward 276.225 mm (O-1O-7+)
- 5 aft 330.20 mm (1-1-O+)
- 6 aft 939.80 mm (3-1-O+)
- 7 aft 1552.575 mm (5-1-1)
- 8 aft 2159.00 mm (7-1-+)

Measure the vertical distance from baseline to keel plank at all stations (except 2 and 9) and record on line 1 of the worksheet.

HULL LENGTHS
Using a plumb bob, mark the following horizontal locations on the baseline per figure 7
- Stem at deck
- Intersection of W and X
- Intersection of transom and fairbody (bottom)
- Intersection of transom and deck

Paper clips are useful in marking locations on the baseline. To find the intersection of W and X, hold the plumb bob on a string against a vertical scale until the point stands exactly 457.20 mm (18") below the fingers. Then hold the string against the baseline with the fingers just touching the baseline. Move the bob along the string horizontally until the point of the bob just touches the stem.

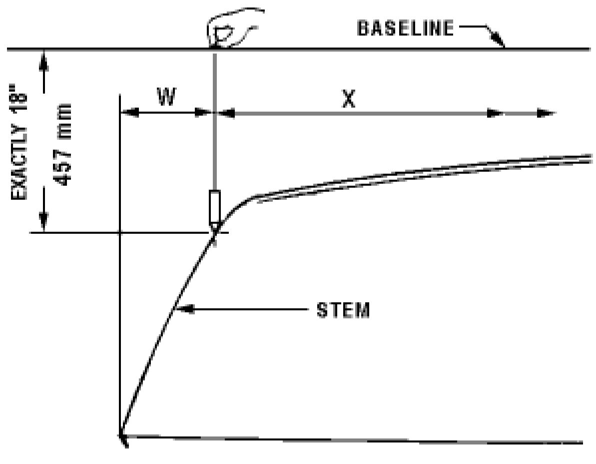
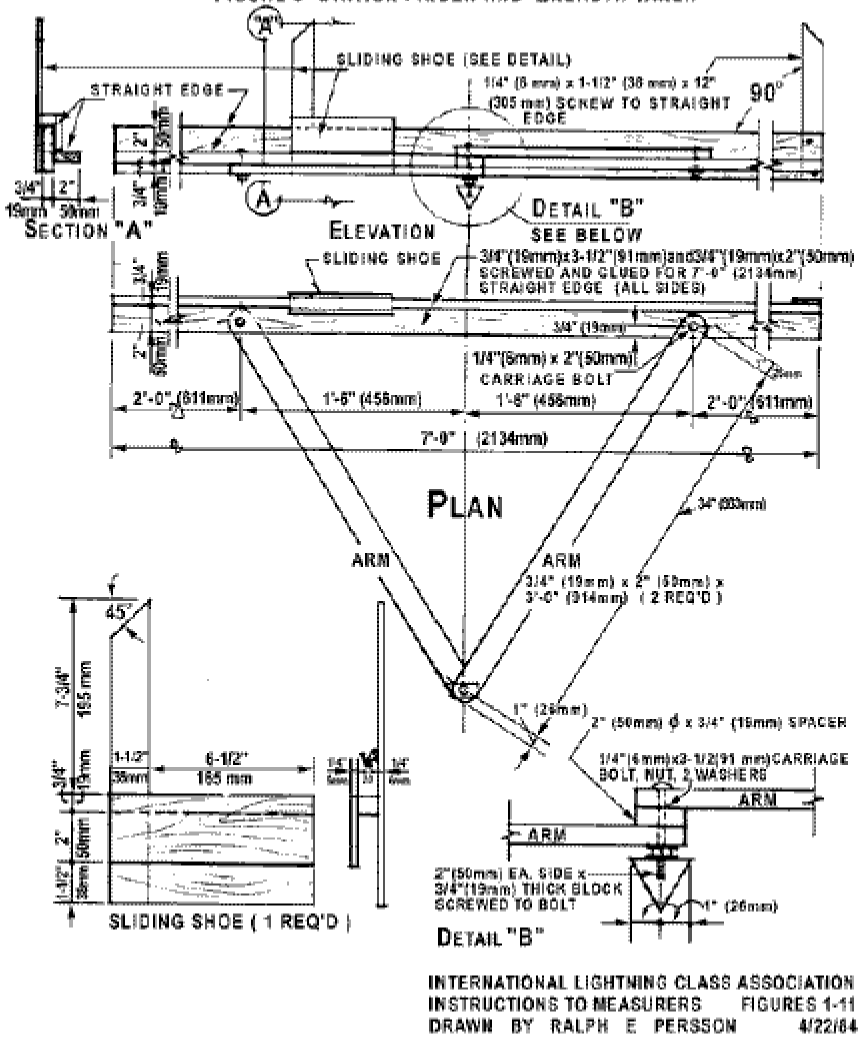


FIGURE 7

CHINE AND SHEER HEIGHTS

The use of a combined "station finder" and "breadth taker" as illustrated below will simplify the measurement of chine and sheer heights and breadths.

FIGURE 8 STATION FINDER AND BREADTH TAKER



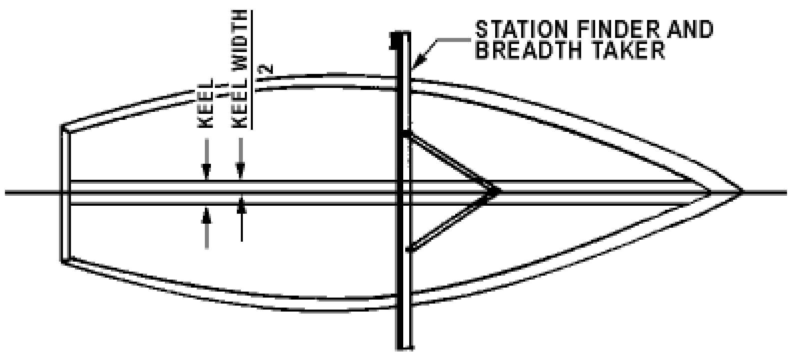


FIGURE 9

Place a "Station Finder" with its centerline progressively on the centerline of the keel at each station. At station I use a straight ruler by eye. At station 2 through 7 the arms of the station finder must be down hill. At station 9 the station finder should be on top of the skeg with arms forward. Place pin of station finder on centerline of keel.

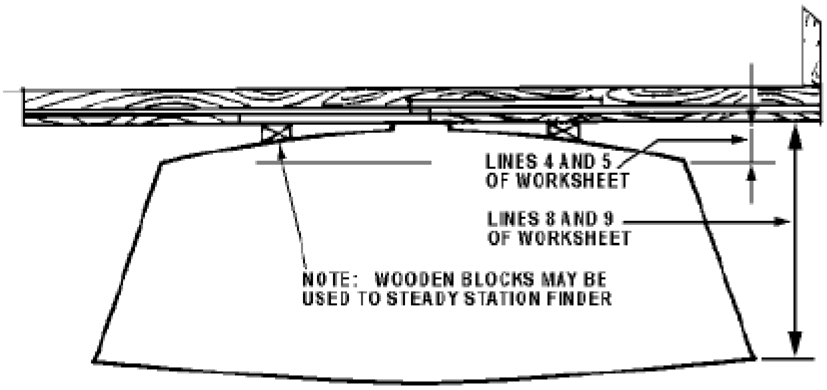


FIGURE 10

With station finder located per figure 10, use a plumb bob to mark each station on the chine and sheer, both sides of boat.
With the station finder in position at the stations, measure and record on the worksheet in lines 4 and 5 the perpendicular distance from station finder to chine on each side of the boat. Repeat for sheer entering figures in lines 8 and 9. At station 9 subtract the height of station finder above height of skeg at this point.
Using line drawn across transom below from chine to chine measure directly vertical distance from this line to baseline and record under T in line 7 of the worksheet.

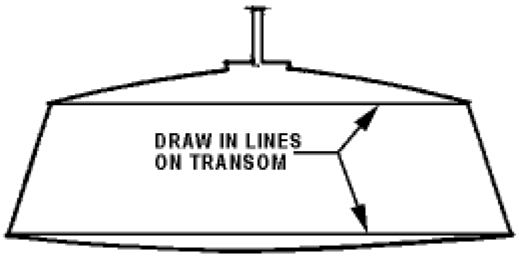


FIGURE 11

Repeat using line on transom from sheer to sheer and record on line 11 of the worksheet.
Measure sheer height at 0 directly perpendicular to baseline at point marked in D1.

CHINE AND SHEER HALF BREADTHS
Place the sliding shoe on the station finder so that it becomes a breadth taker. Place the pointers simultaneously at both chines for each station progressively. Squeeze the shoe firmly to the straight edge, then measure the distance between pointers and record on line 12 of the worksheet.

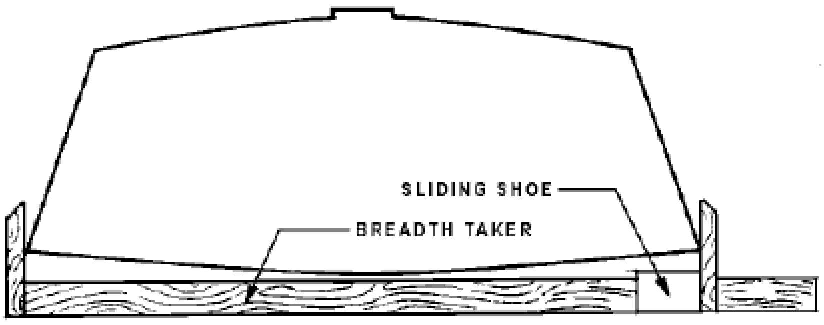


FIGURE 12

Repeat at all stations measure breadth and T directly across transom.
Repeat at sheer recording in line 14 of the worksheet. If rubrails are in place be sure to subtract both. Note: If the chine is rounded special precautions must be taken in measuring. To find the exact intersection of bottom and topsides use a corner finder below.

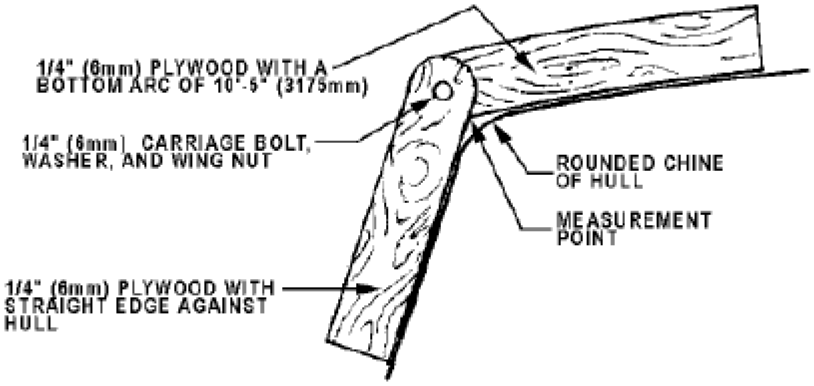


FIGURE 13

INTERPRETING THE WORKSHEET
Centerline Height - Add line 1 plus line 2 and record on line 3. Line 3 is the centerline height and may be transferred to the Certificate.
Chine Height - Add line 4 plus line 5 and divide the sum by two and enter on line 6 to get the average port and starboard chine height above the keel. Add line 6 plus line 1 and enter the sum in line 7. Line 7 is chine height and may be transferred to the Certificate.
Sheer Height - Add line 8 plus line 9 and divide by two and enter in line 10 to get the average port and starboard sheer height above the keel. Add line 10 plus line 1 and enter the sum in line 11. Line 11 is sheer height and may be transferred to the Certificate.
Chine Half Breadth - Divide line 12 by two and enter the result in line 13. Line 13 is chine half breadth and may be transferred to the Certificate.
Sheer Half Breadth - Divide line 14 by two and enter the result in line 15. Line 15 is the sheer half breadth and may be transferred to the Certificate.
Keep your worksheet until all figures have been approved.

OTHER HULL MEASUREMENTS
Measure and record on the Certificate keel widths as required.
Measure along the bottom edge of the skeg from the after end to the intersection of the skeg with the keel, and record on the Certificate. Measure the thickness of the skeg, checking to see that the skeg has parallel sides and does not taper and record on the Certificate. Measure the height of the skeg from its aftermost bottom edge along the after edge of the keel and add the amount the keel stands proud of the bottom at the centerline from line 2 of the worksheet and record on the Certificate.
Check and record hull thickness wherever visible.
Measure the bottom of the keel to the bottom of the edge of the centerboard pin and record on the Certificate.
Check the diameter of the centerboard pin and check to see that no bushings are present - diameter of pin is 15.875 mm (5/8").
Measure the width of the centerboard slot through the keel and record on the Certificate. Verify that the slot and space is uniform throughout.
Check the bottom arcs.
Two templates should be used of metal, plastic, presswood, or 6.350 mm (1/4") plywood 1 meter (about three feet) long per figure 14.
The 2438.40 mm (8' arc) should be first slid over the bottom holding it perpendicular to the centerline. This arc should touch the hull at the keel and at the chine simultaneously for the entire length of the boat. If it does not touch, the arc is less than the minimum 2438.40 mm (8'). The 4572.00 mm (15') arc should likewise be slid over the bottom in the same manner. This arc should never touch the hull at the chine and keel at the same time. If it does the arc is greater than 4572.00 mm (15'). However, the Measurer should use judgment as to whether the arcs don't measure because of small areas of bumps or pockets.

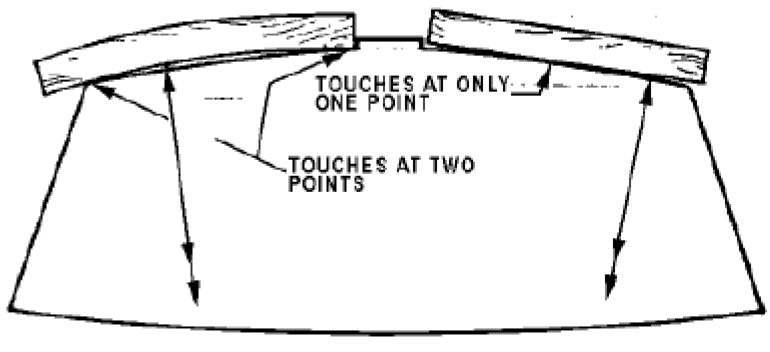
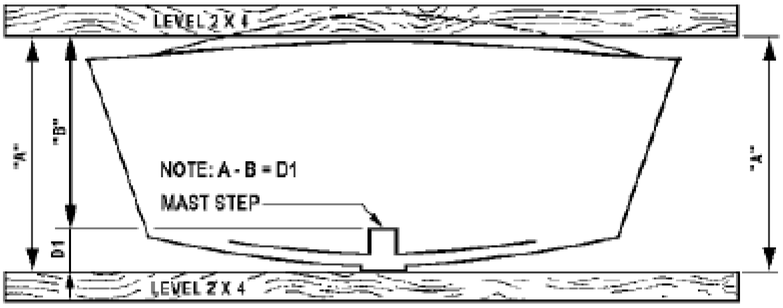


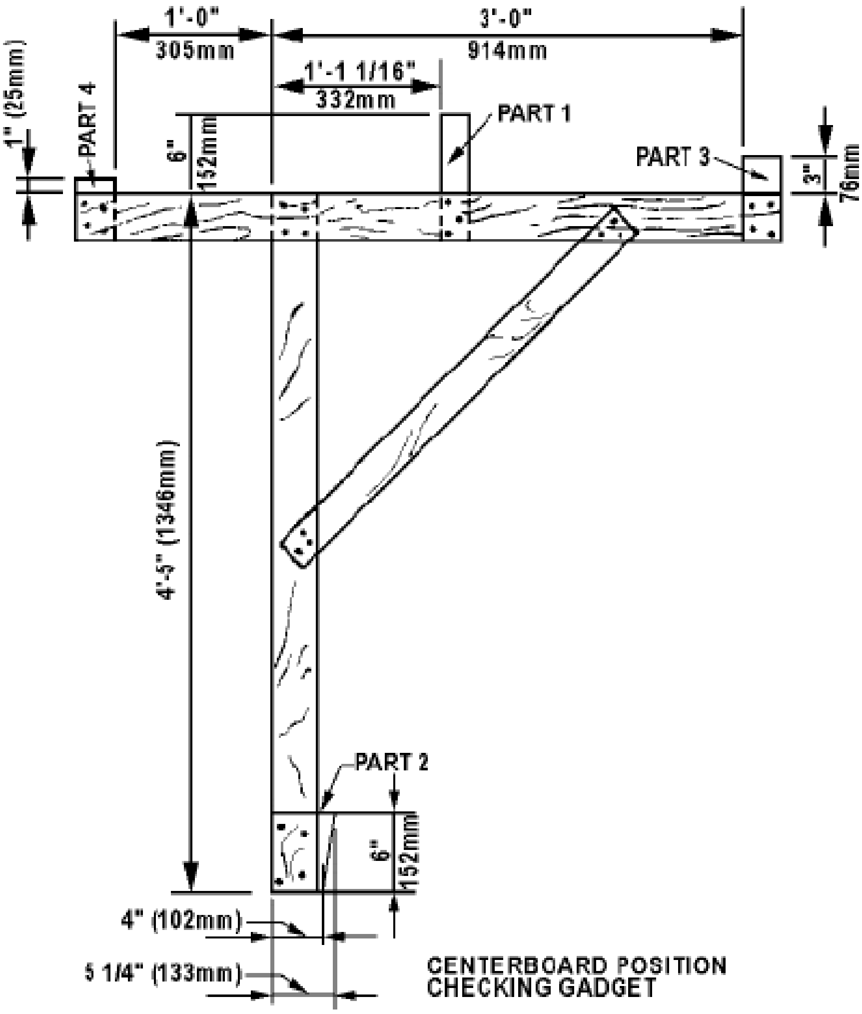
FIGURE 14

If the hull passes both of the arc tests, record "yes" in the box. D1 measurement is done as below

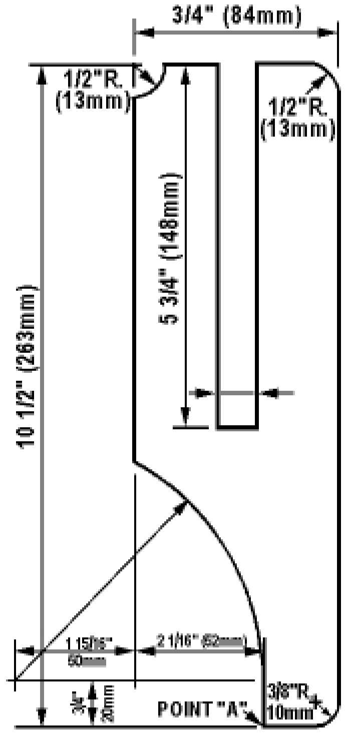


FIGURE

Angle of Dangle Device:



Centerboard Thickness Measuring Device:



10 HULL WEIGHT

The class rules lay down the condition in which the boat is to be weighed and what equipment has to be on board, and what is excluded.

10.1 Weighing conditions

In all cases the boat must be dry and there must be no water in the boat or in the buoyancy compartments. Likewise there must be nothing on board that is not required, or permitted to be included in the weight.

Wind can affect the recorded value of weight. Even though the scale may be registering a steady weight there may be a steady up thrust or down thrust due to wind. It is therefore important that the boat be sheltered from the wind while it is being weighed.

The weighing machine has to have adequate capacity and preferably should be operating within about the range of one-half to three-quarters of its capacity.

The weighing machine should preferably be calibrated before use with a calibration weight similar in weight to the expected weight of the boat. Regular calibration is particularly important for electronic scales and load cells. Wear in mechanical weighing machines affects their accuracy and any error needs to be known.

The measurers should also be careful to avoid a zero error. The weight of the slings is **not** normally included in the weight; therefore the reading of the scale with only the slings on it should be noted and deducted from the reading obtained with the boat on it. This procedure automatically takes account of any zero error in the instrument.

Dinghies are normally weighted with an electronic platform scale, a spring scale or a steelyard. Some of these require the scale to be suspended from a suitable fixed point and the boat hung from a scale. Since headroom may be limited, and in any case so that the scale can be read or adjusted easily, the scale needs to be low down. If the centreboard is out of its case the boat can be supported by passing a rope through the case and inserting a short bar underneath the hull. Lines can then be used to stabilise the boat fore and aft and athwart ships, usually attached to fittings.

Keel boats normally require a crane or gantry to pick up the scale and the boat.

Most keel boats have lifting eyes in the hull and the owner has his own slings for launching and recovery by crane. In any case the owner or his representative should be told that he is responsible for the arrangements for suspending the boat.

10.2 Underweight boats and weight correctors

Class rules lay down minimum hull weights (and in some cases maximum weights as well) and it is normal for builders and owners to attempt to keep the weight of the boat to the minimum. Boats which are below the minimum weight are required to have the weight brought up to the minimum by having weight correctors fixed in the hull. The class rules lay down the location of these. It is normal for these correctors to be of lead, but whatever material they may be made of they have to be properly fixed in the hull. This weight, and in some cases position, normally has to be entered on the measurement form and this information will appear on the measurement certificate.

In most of the classes removal or alteration of weight correctors renders the measurement certificate invalid and the boat then has to be officially re weighed by a measurer and a new measurement certificate obtained.

Some classes have a maximum limit on the weight of correctors permitted. If the weight required to bring the hull weight up to minimum exceeds the maximum corrector weight permitted, then the measurer should not sign the measurement form until the owner or builder has rectified the problem within the constraints of the class rules.

10.3 Weighing at Major Events

The quality of weighing results depends on

-the equipment,

-the conditions,

-the qualification of operator.

Equipment

The requirements for scales are stated in the following documents:

1. OIML R76 – 1:1992. Nonautomatic Weighing Instruments. Part 1: Metrological and technical requirements – Tests.
2. OIML R 111: 1994. Weights of Accuracy Classes E1, E2, F1, F3, M1, M2, M3.
3. Council Directive 90/384/EEC of June 20, 1990 (Harmonization of laws in member countries…).

Class II, III and IV scales are used for official weighing. Class II scales for precise weighing, class IV scales are for example truck boogie scales.
Class III is sufficient for sailing. Problems disappear if class III scales that are verifiable for legal metrology are available. The display step value of these scales is 1/3000 or 1/6000 of the scales' measuring span. There are respective stickers on the scales.
Class M3 weights are sufficient for checking scales.

Usability in legal metrology and legal trade provides, in general, a guarantee for the obtained reading under ideal conditions. If the scales are not verifiable for legal metrology, credibility is provided by a valid calibration certificate. Span adjustment, which is sometimes also referred to as calibration, is not sufficient. Weighing within the first 50 display steps is prohibited by legislation. If it is still necessary to weigh small objects, it is recommended to place a larger object on the scales, tare the weight of this object (zero weight appears on the display) and then determine the weight of the small object (unfortunately inaccurately due to the large step value).

Conditions

The weighing station should meet the following requirements:

- Change in the temperature of the environment should be minimum
- Direct sunlight to the scales must be avoided
- There should be no vibration or strong draught
- Scales must be on a stable base and levelled (floor scales)

A check in accordance with the scales manual is recommendable before official weighing. The verification or calibration marking of the scales must be clearly legible and the verification or calibration date (period) valid. If no documents are available, then the following tests help to establish the suitability of the scales:

1. Place a load in the centre of the platform (20% of max. load) and tare the scales reading. When you now weigh the load on the corners of the scales and the difference with the tared quantity does not exceed one step, things look good.
2. Sensibility test. A load of ca 50 display steps. When a weight equalling the value of one step is added, the reading must change by one step.
3. Deviation of readings. Repeatedly place the same load on the scales. The reading should not change. A few occurrences of a 1 step change in the same direction are acceptable.

It is certainly necessary to carry out a span adjustment during which the scales are told the value of gravity acceleration at the place where the weighing takes place. Electronic scales measure the force applied to them and the mass that we are interested in is calculated with the formula $M = F/g$. In this formula g is the local gravity acceleration value, which takes into account the latitude, the altitude from the sea level, geological conditions, etc. In practice a good indicator of the conditions is the stabilizing of the scales reading. If the reading of proper class III scales has problems stabilising, there are problems with the conditions, the weighing results are unreliable (due to the conditions) and reading should not be used. A typical example is the weighing of keelboats outside in the wind. If a stable reading cannot be obtained, you should find suitable conditions or a weather with less wind. Nobody has the right to force a measurer to breach professional ethics.

Qualification

A measurer cannot be at all measurement stations at the same time. Although scales develop towards the simplification of procedures, a certain problem is often presented by the teaching of assisting persons. It must be taken into account that this takes quite a lot of time.Once a stable reading has been reached, a new character appears. The rules usually provide the weight of the boat together with certain equipment in dry condition. A boat meets these conditions after birth. A dry boat that has been sailed is heavier than a new dry boat etc. Damp control lines are surprisingly heavy. Some folks dampen them on purpose. There is no point in weighing a boat that has been out in the rain prior to weighing! A "Finn" that has sailed today is up to 1.5 kg overweight even on the day after tomorrow. Almost each boat class has an official procedure for weight correction. In practice this situation can be avoided only by the class measurement consistency and educating of the yachtsmen. The young topguns are enviably clever. The majority of yachtsmen violate the rules because they are not familiar with the rules. Indeed we should start from teaching. A measurer is also a teacher. Everybody must be treated equally. Each case is a new one. Old sins do not count.

11 WEIGHT DISTRIBUTION

It is well known to most sailors that the speed of their boat is adversely affected by excess weight. Heavy boats accelerate more slowly and have greater resistance, as the hull floats lower in the water. The depth of the average position of the mass, i.e. the center of gravity (CG), below the center of buoyancy affects the righting moment and hence the ability to carry sail. Thus most classes, including the Yngling, have rules controlling the minimum weight and height of the CG. The fore and aft position of the CG is also important so that the hull sails on its lines, and so it can surf easily and does not dig the bow into waves. Many sailors, especially in dinghies, like to have the CG as far aft as possible for these reasons, and because the addition of the crew generally moves the total CG aft.

The degree of concentration of the weight in the boat is described by its radius of gyration. A boat which has light ends has a smaller radius of gyration than one with heavy ends. However, the effect of the distribution of the weight about the CG, which is what a swing test measures, is a little more sophisticated. If we consider the weight as if it was equally divided at the ends of a dumbbell, then it will always balance at its center, i.e. the CG. However, as the length of the dumbbell is increased it becomes more difficult to start or stop it turning. Pitching is a rotational motion, and the more of the weight that is in the ends of a boat the lower the frequency at which it will naturally pitch. This affects the pitching response in waves, and hence to some extent the boat speed.

The advantages of swing testing are that it eliminates separate controls of the hull and keel weights and CG positions, which can only be checked during manufacture. If the radius of gyration is controlled, then it is normally not necessary for the class rules to control the construction scantlings. If carefully designed, swing testing can be performed at major regattas in conjunction with other measurements. This is the case in the Finn class which swing tests all entrants to the Gold Cup. The disadvantages are that the procedure is a dynamic measurement, and is often not understood by the competitors. Swing testing also requires rigid supports and an enclosed space free of draughts.

11.1 Swing Test

The test was first introduced as part of the class rules by the Finn Class in 1973, by Gilbert Lamboley, and is often known as the Lamboley test. It is still the most popular test for dinghy classes and has been adopted for use with some keelboat classes. The weight distribution is established by a swinging boat like a pendulum when it is suspended by the hooks.

If a hull is suspended from a horizontal athwartships axis which is a distance $\boldsymbol{a}$ vertically above the CG, so that the hull is free to pitch, and is then displaced, it will oscillate under the influence of gravity. The undamped small amplitude period of oscillation $\boldsymbol{T_1}$ is given by

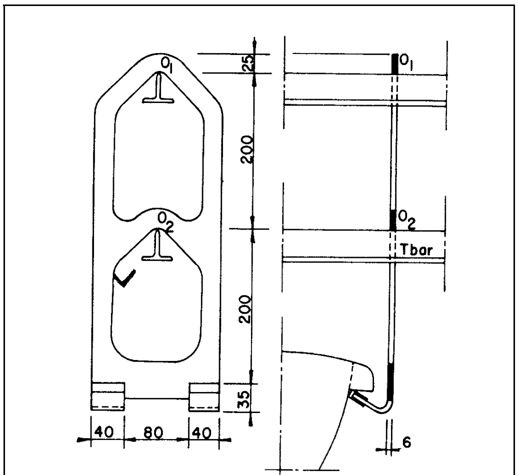
$$T_1 = 2\pi \sqrt{\frac{a^2 + \rho^2}{ag}} \qquad (1)$$

Where $\boldsymbol{g}$ is the local acceleration due to gravity and $\boldsymbol{\rho}$ is the pitch gyradius about the CG. Unfortunately, in order to extract the gyradius $\boldsymbol{\rho}$ from one measurement of the period of oscillation $\boldsymbol{T_1}$ one has to also separately measure $\boldsymbol{a}$. For keelboats where the CG is far below the pivot axis we can measure "α" directly using a static test. For dinghies, "$\boldsymbol{a}$" is a short distance and cannot be measured easily directly. In the Lamboley test, this is accomplished indirectly by solving two equations: the second one is obtained by choosing a new oscillation axis exactly 200 mm below the first one.

$$T_2 = 2\pi \sqrt{\frac{(a - 0.2_m)^2 + \rho^2}{(a - 0.2_m)g}}$$

Hence by measuring T_1 and T_2 we may calculate both "α" and "$\boldsymbol{\rho}$".

The equipment used to carry out a Lamboley swing test is shown below.



Larger sized drawings are available

The boat is suspended by using hooks inserted under the sheer guards. These are hooked so that the boat is level fore aft (i.e. the hooks coincide with the fore and aft position of the centre of gravity). Care needs to be exercised to ensure that the hooks are engaged properly - otherwise the boat may fall! (a mattress may be placed under the boat as a precaution)

The pivot is a T bar supported on each side of the boat, or two short pieces of T bar rigidly fixed to supports on each side.

A pointer - a piece of light plastic is suitable - is attached to the stem by masking tape and a reference point erected adjacent to this when it is in the stationary position. The boat is oscillated through a fairly small angle - say about 200mm total movement of the stem head and the period of oscillation taken. The time taken for 10 complete oscillations is measured (after the boat has completed a few oscillations to enable it to settle down) and the time for one oscillation calculated and noted. For other classes, the starting amplitude and number of oscillations to record are sometimes defined in the class rules.

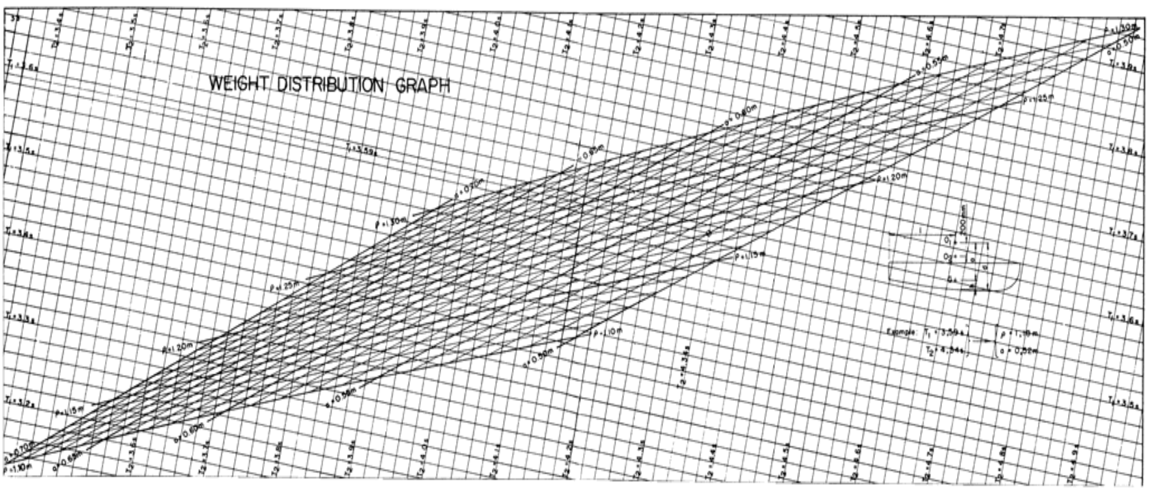
The greatest accuracy is achieved if the stop watch is started and stopped as the pointer passes the reference point while moving fastest. If the reference point is at the top or bottom of the swing an assessment will have to be made of the precise moment when the boat is still and this leads to error. Record times to 1/5th of a second, but calculate the period to 1/100 of a second. The procedure is repeated for the second pivot position and the radius of gyration calculated with a calculator, graph or simple computer program.

Electronic timers connected with a photocell trigger give the best results, eliminating start/stop errors by the measurer and therefore enabling results to be calculated from fewer oscillations The period of individual oscillations can be read out, and several consecutive oscillations can be checked for consistency. For Equipment Inspection of many boats at the start of a Regatta, electronic timing is essential.

11.2 Weight Distribution and Centre of Gravity: Practice (diagram references taken from the Finn Class Rules)

It is essential that the measurements be made in a sheltered place. The boat shall be hung from the brackets on axis 0_1, 0_2 and the periods of oscillation T_1 T_2 measured.
Plot the position with co-ordinates T_1, T_2 on the graph, and read off the values for "a" and "r" from the curves. The distance "l" is measured parallel to base line from Station 0 to axis 0_1 (diagram 20). If "l" is found close to limit values make sure that base line is level as in diagram 1. The distance "d" can usually be measured from axis 0_1 to the underneath of the hull (excluding keelband) by means of a rule or tape passed down through the centreboard box (diagram 20). If this is impossible, use the principle shown in diagram 13. It is wise to provide a protection under the boat but the boat shall not touch anything while oscillating. The oscillations shall be small, but should not become damped in less than about 100 periods. There shall be no twisting oscillations about a vertical axis. There shall be no movement of the supports.

Diagram 24



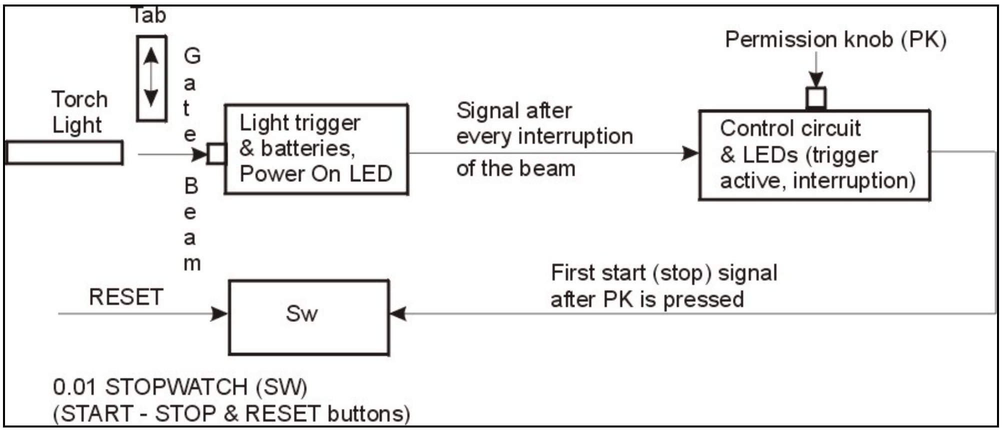
Errors and their reduction.
Errors can be introduced by
Draughts, such as from a door opening. The measurer should ask for an enclosed space in a rigid building, not a tent. Perturbations due to draughts show up when one out of several swings checked by the electronic timer gives a markedly different time. Usually one can notice the draught "gust" at the time. This answer should be discarded
Lack of rigidity. The supporting structure for the swing hooks must be very rigid. In particular, the swing frame needs to be on a concrete base or similar. The result of flexibility is that the oscillation periods will be too great, causing the calculated radius of gyration to be larger than the correct distance. At a regatta Equipment Inspection, try a known boat first!
Water in the hull. Erratic results are an indicator of free water moving somewhere (buoyancy tanks, double bottom longitudinals etc).

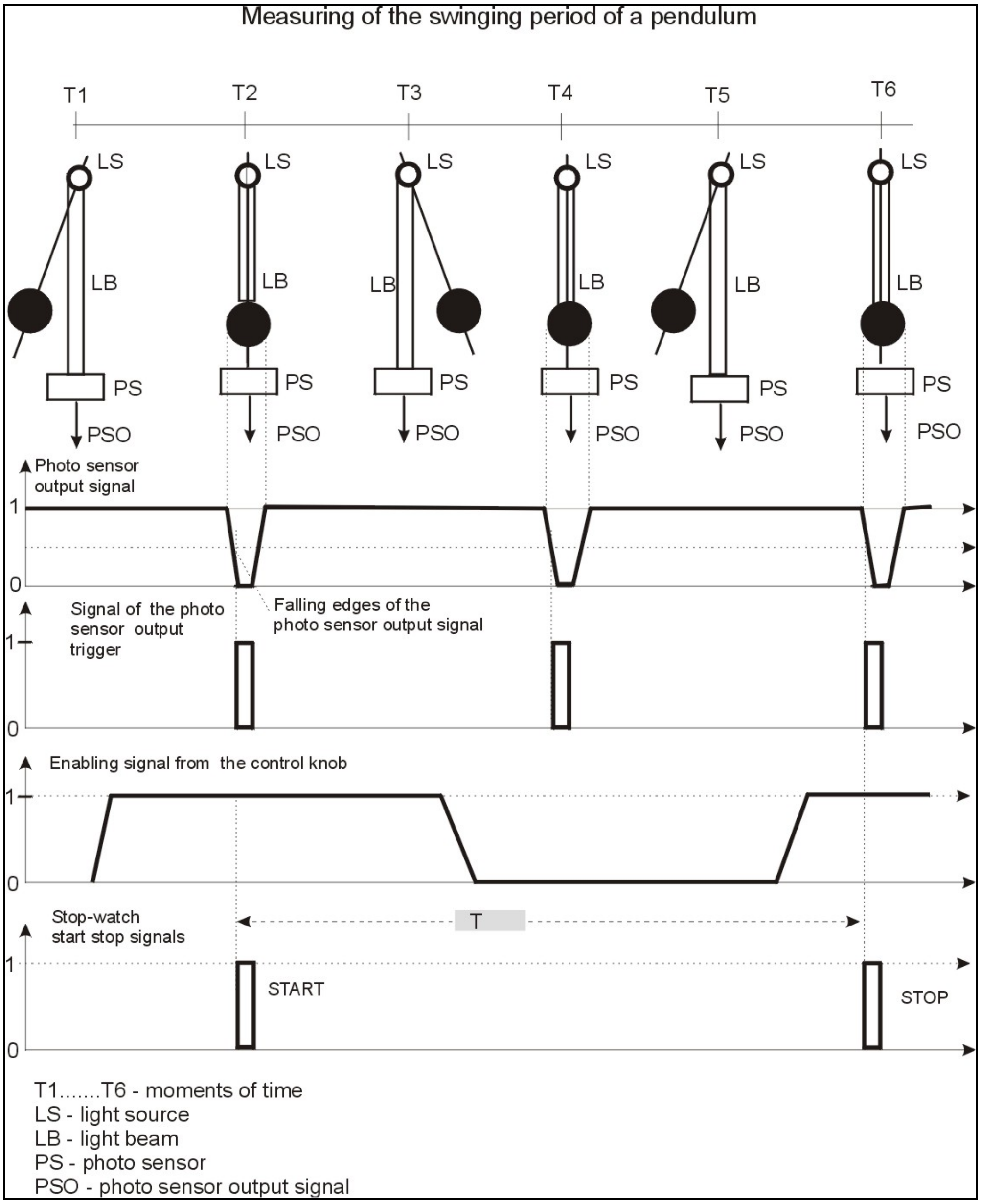
Regatta Equipment Inspection.
When weighed during the preliminaries to a regatta, the boat must be in a clean and dry condition. If, during a regatta, further inspection is required, the boat will not be dry. In particular, water absorption will have taken place on hiking straps and padding (pussy pads), which are likely to be nearer the CG of the boat than the radius of gyration distance. If the boat is swung in this condition, the radius of gyration may well be smaller than the minimum distance allowed. You can get a very good idea about whether the boat would be correct when in the dry condition by using Moments of Inertia.
Since the Moment of Inertia is given by
$M\rho^2 = \Sigma(m_1 r_1^2 + m_n r_n^2)$,
the Moment of Inertia cannot be reduced by the addition of weight.

If the boat in question is re-weighed and swung, then the new Moment of Inertia should never be less than the dry original, even though the Radius of Gyration may have become less.

Wet $M_w \rho_w^2 \geq$ Dry $M\rho^2$

11.3 Electronic timer with photocell trigger: Schematic diagrams





12 BUOYANCY

Most dinghies and some of the smaller keel boats have buoyancy equipment which will keep them afloat in the event of a capsize or knockdown. It will normally be of sufficient size and distributed so that crews can recover from the situation without outside assistance.

12.1 Buoyancy apparatus

The buoyancy equipment will normally be in the form of one or more of the following:

Inflated air bags,
Buoyancy compartments or tanks in the hull,
Foam blocks,
Foam between the skins of an FRP sandwich construction boat.

Many classes are required to have, inside the buoyancy tanks, sufficient foam blocks to keep the boat, its equipment and crew, afloat in the event of a major accident causing the tanks to flood. (GRP boats and keel boats might otherwise sink).

Once the boat has been completed it is always not possible to determine whether the secondary buoyancy is of the required quantity - that can only be done during the manufacture of the boat - but it is possible to see whether foam blocks, or other approved equipment, have been fitted.

12.2 Immersion buoyancy tests

Many classes require the buoyancy equipment to be tested by immersing the boat in water to simulate a capsize or swamping. Such a test may be used to establish immersion firstly, that there is sufficient buoyancy to prevent the boat from sinking, secondly to check that there are no leaks in the buoyancy equipment, thirdly to show that buoyancy is distributed in the boat satisfactorily, so that the boat floats approximately level when waterlogged, and finally to ensure that the buoyancy, if moveable, is strongly fixed in position.

When a buoyancy test is prescribed in the class rules, the test must be conducted strictly in accordance with those rules.

An immersion test is normally carried out by flooding the boat by opening drain ports etc. and loading the boat with a specified minimum weight, either by means of weights or by having people on board. It is usual to require the test to be carried out in three stages; with the boat upright and then on each side in turn.

When weights are used in a test special care needs to be taken during the time they are in the boat as the failure of a buoyancy unit or its fastenings may cause movement of the boat and dislodgement of the weights with resultant damage to the hull.

Loss of air in bags is not acceptable. It is frequently not possible to see evidence of leaks in bags while the test is in progress, due to the movement of the water in and around the boat. Apparent deflation of a bag due to cooling by the water should not be confused with a leak.

Inflated buoyancy bags exert a considerable upward force on their fastenings, and because they are flexible they may distort extensively when the boat is swamped. A bag which does distort exerts a considerable load on the loops over the fastenings and should not be accepted. The loops on the buoyancy bags are not for the attachment of fastening straps, they are there to position them. There should, in general, be not less than three straps for each buoyancy bag although the number depends on the size of the bag. The straps should be fairly tight so that the bag does not lift - in addition to allowing the swamped hull to sink further they permit the bag to move with the result that chafe occurs with subsequent leakage. The attachment of the fixing straps to the hull should be carefully inspected before and after a buoyancy test to ensure adequate strength.

12.3 Buoyancy tank air test

The design of many modern dinghies is such that it is difficult to test satisfactorily all the joints of a buoyancy tank without applying a very large load to the waterlogged boat.

Because of this some classes now specify a test which does not rely upon immersion in water. This is a test in which the tank is subjected to a small increase in internal air pressure or, in the case of the vacuum test, a small decrease in pressure. The pressure difference between the inside and outside of the tank is indicated on a water manometer fitted to a hatch cover or drain hole, as indicated in **figure 8.2.5.** The test will be satisfied if the difference in water levels in the two halves of the manometer does not decrease faster than a certain rate; the rate and initial pressure difference being specified in the class rules.

Since buoyancy tanks are designed to be subjected to external pressure it is preferable to carry out the test by reducing the internal pressure of the tank.

A major object of testing a buoyancy tank is to test as many of its joints as possible. There are frequently inspection hatches and drain plugs all of which must be firmly closed before the test is begun. Nevertheless, these are sometimes the source of a leakage into the tank. The fact that there is a small leak in a tank does not necessarily indicate that it is unsatisfactory.

12.4 Buoyancy inspection

There are many classes which do not specify a buoyancy test but which nevertheless require the measurer to satisfy himself as to the effectiveness of the buoyancy. He can often see if there are any very major deficiencies or leaks but the only way to be certain that the construction is entirely satisfactory is to carry out either an immersion test or an air test.

13 CENTREBOARDS, KEELS AND RUDDERS

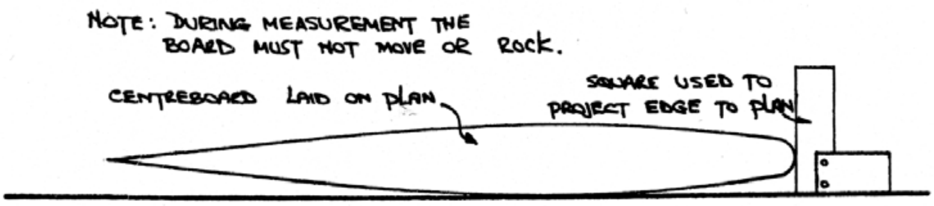
13.1 Profile

The profile of a centreboard or rudder, that is the shape when viewed from the side, may be controlled by one of three methods:

(a) Measurements stated in the class rules,
(b) Plan or measurement diagram giving dimensions,
(c) Template.

The effect of each method is the same, to control, within tolerances laid down in the class rules, the shape of the centreboard.

Where it is a requirement that the centreboard or rudder is laid on a plan it is essential that any instructions in the class rules on how this is done are followed exactly. For instance, the leading edge of the board may have to be over the leading edge indicated on the plan.



The thickness of the board makes it difficult to check its conformity with the plan. The measurement has to be carried out on a flat surface, using a small square to project the edge of the board down to the plan.

When a template is used the position of the template in relation to the centreboard can be varied in order to achieve the "best fit". If the measurement is carried out with a solid template the remarks above concerning laying the board on a flat surface apply. If the template is a hollow one which fits round the centreboard the problems are not the same and, depending on the class, the measurement is carried out with the centreboard in the boat and fully lowered. In this case, if the centreboard has to be in the fully lowered position there must be stops to prevent it being lowered any further.

13.2 Section and thickness of section

The thickness of the centreboard is usually controlled, although this may be achieved by limiting the width of the centreboard slot in the hull.

Where a maximum thickness is quoted in the class rules this can be measured using inside/outside callipers. However, a purpose made go/no go gauge as indicated in figure 13.2.1 is very useful if many centreboards for the same class have to be measured. This gauge can be used in conjunction with either a calibrated wedge (see section on hull template measurement) or a stepped gauge to obtain the actual thickness. Figure 13.2.2 shows a custom built system using an electronic micrometer which gives actual thickness in virtually every point of the appendage.

Some classes require the centreboard and rudder to be of even thickness. In order to check that this is the case it is necessary to take several measurements of the thickness. It follows that if the centreboard is symmetrical and of even thickness the two sides must be flat, and therefore two straight-edges placed one on each side must be parallel and touch the surface of the board. However boards warp sometimes and therefore may not be flat. A variation of thickness of 1mm is normally permitted, but in some classes the tolerance is ½mm.

Figure 13.2.1

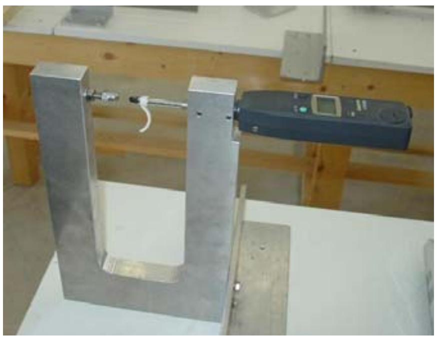
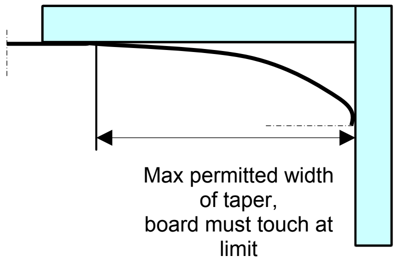


Figure 13.2.2

The leading and trailing edges need to be checked to ensure that it does not exceed the limits of taper permitted for foils of even thickness.



13.3 Maximum extension below hull

The maximum extension of a centreboard below the hull is taken, as the words indicate, when the centreboard is in the position of maximum depth. This is normally, but not always, when it is in the `fully down' position.

The measurement is most conveniently made with the boat on its side and, initially, with the centreboard in it's fully down position, as follows:

(a) Identify the lowest point on the tip of the board,
(b) Measure the distance from that point to the nearest point on the keel,
(c) Repeat the measurement from another point at the tip of the board if there is any doubt, about which point gives the greatest depth,
(d) Repeat steps (a), (b) and (c) above with the centreboard slightly different positions,
(e) The greatest measurement obtainable is the maximum extension of the centreboard.

The depth of the rudder blade below the hull is normally taken in the manner indicated in figure 13.3.1. It is, unless otherwise indicated in the class rules, the vertical distance below the lowest point of the transom.

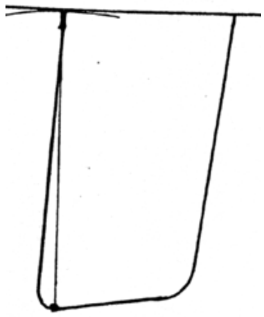


Figure 13.3.1

13.4 Pivot centre

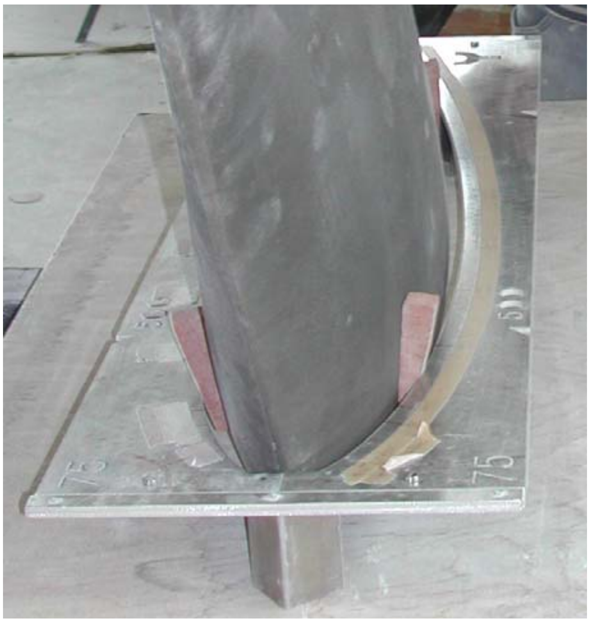
It may be necessary to establish the position of the pivot of the centreboard or lifting rudder.

13.5 Keel, centreboard and rudder templates

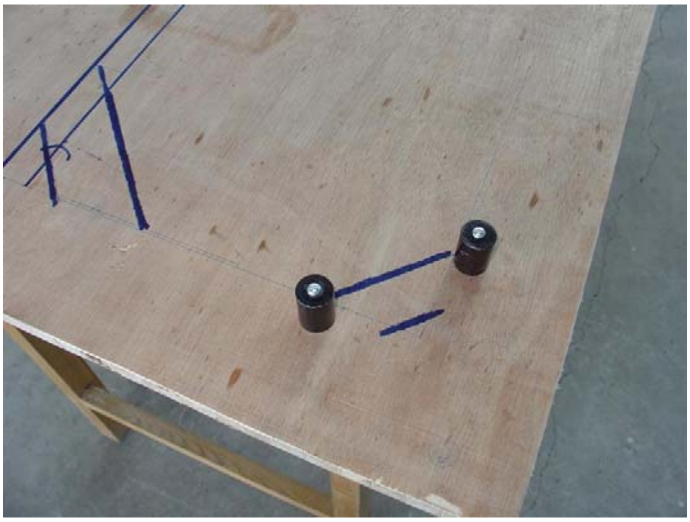
Yngling appendage templates

Finn rudder template & centreboard depth gauge

For most Dinghy and multihull classes only the profile of the immersed part of the rudder and centreboard, as well as the maximum section thickness and edge radii or tapering are controlled, as well of course as their weights. However, for keelboat classes the keel shapes are a critical factor in boat speed and are therefore carefully controlled in both shape and alignment. For the Yngling class the positions of the keel templates are specified by distances along the leading and trailing edges from the base of the keel (despite the fact that the templates are labelled by the height above the base plane, as is the rule for the Soling Class). In practice the two halves of the keel templates should be joined by end plates which are pinned. It is much more convenient to provide a horizontal plate on which the keel rests and then support the template at the correct height by three precision pillars. This allows the template centreline to be aligned with that of the keel, and for the front of the template to touch the leading edge. In the case of the Yngling the pillars were made so as to comply with the distances along the leading and trailing edges. This system makes it easy to align the template, which is then wedged in place for gap measurement.
Care should be taken to ensure that the gap measurement is made at the appropriate edge of the template, and ideally ball bearings of the appropriate minimum and maximum sizes should be used to test the gap.



Demonstration of keel template measurements. The templates are pinned together and supported by three pillars at a precise height above the base plane. They can then be easily aligned and wedged in place for gap measurement. The actual measurements are made on the finished keel, not the casting as shown here.



Left, 420 Centreboard template prepared for event inspection on melamine coated surface, and right, detail from a 470 rudder template. Both classes are using a similar system to define their measurement axes, with the origin point at the intersection of the leading and bottom edges.

13.6 Keel coating check

See Section 8.5

14 SPARS AND RIGGING

14.1 Measurement bands (limit marks, see ERS)

Measurement bands (limit marks) are required to be marked distinctly (in a colour contrasting sharply with that of the spar) on the mast and boom so as to be clearly visible while racing. The mainsail has to be set within the limits indicated by the inner edges of the bands. Some classes required additional bands to indicate the positions of the forestay or spinnaker halyard.

Although paint is the most commonly used method of applying bands, anodised aluminium does not take paint very well so that it soon peels off. Therefore durable adhesive plastic tape is now sometimes used and has been approved by the ISAF, provided that the measurement side of the band is permanently marked on the spar by means of punch marks or scribe lines in the surface of the spar.

Limit marks on mast

The datum point for the measurement of bands on the mast (**Mast Datum Point**) will be one of the following (see also Class Rules and ERS):

- heel of the mast, or
- sheerline, or
- deck in way of mast.

Measurement from the heel is usually referred to the bearing surface of the mast. A mast such as that indicated in figure 14.1.1 which has a tenon may have its bearing point either at the bottom of the tenon or on the shoulder. It is necessary to check the mast step in the boat.

Because masts are frequently measured separately from the boat, and also to enable manufacturers to produce a standard spar for a class, there are now many classes which measure from the bottom to the tenon (**Heel Point**) whether or not it is the bearing point.

If the datum for measurements is the sheerline the location of this point on the mast may be made difficult by the fact that the deck has a camber. The datum point can be found in a similar way to that indicated in section 9.8.

Band on Boom = limit mark

The band on the boom is, unless otherwise indicated in the class rules, located with reference to the **aft face of the mast** but excluding the effects of local curvature or cut away track. This is indicated in the figure 14.1.2

A few classes measure to the inside of the sail track. This is also indicated in figure 14.1.3.

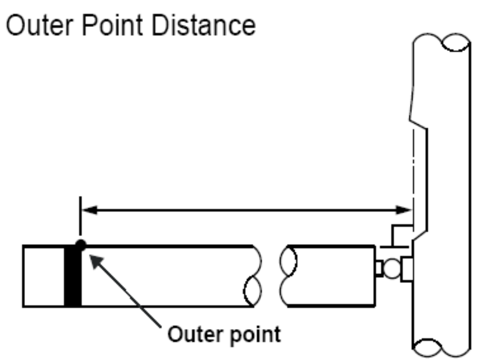


Figure 14.1.2

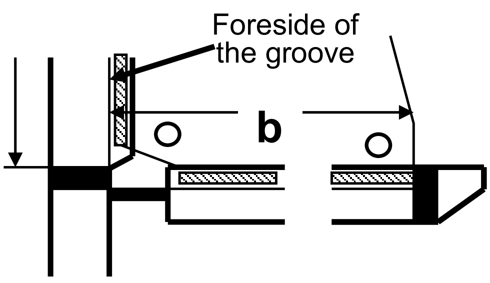


Figure 14.1.3

14.2 Section measurements of spars

Most class rules include limitations on the cross section dimensions of the mast and boom. This is done either by stipulating minimum and maximum dimensions for the depth and width of the section or by stating that it shall be capable of passing through a circle of a given diameter.

Sections Including Sail Track

There are two principal ways in which the mast and boom sections are made. They are either made with the sail track integral with the main part of the section or the sail track is separate and permanently fixed on by riveting, welding or gluing. These are illustrated in figure 14.2.1, which although drawn for metal extrusions are applicable to wooden spars as well.

The dimensions of spar sections include the sail track unless otherwise specified (AC).

Extruders of aluminium sections require relatively large tolerances and as many spar sections are designed very close to the limit of the tolerances specified in the class rules sections are sometimes found which do not comply. In view of this it is necessary to obtain very accurate measurements and therefore Vernier callipers are recommended although accurately made go/no-go gauges are suitable.

Wall Thickness of Extrusions

Some classes lay down the minimum wall thickness which is permitted. This usually cannot be measured except at the heel of the mast or at the ends of a boom.

It should be noted that the extrusion process can cause variations in the wall thickness so that both sides may not be the same. Accordingly, it is necessary measure the thickness at several points. At no point is the thickness to be less than that permitted.

Mast Taper

Most masts are tapered at their upper ends. For a number of reasons the length of the taper may be controlled as well as the size of the mast at its head. The class rules may also lay down the manner in which the taper can be made.

The usual way of forming a taper is to cut a `vee' from the leading edge, closing the gap and welding together the two sides. The point at which the taper commences cannot always be determined by noting the point at which the weld commences because manufacturers sometimes add a saw cut to the bottom of the `vee' to reduce the possibility of an unsightly hollow in the profile.

14.3 Straightness of spar

It is a common requirement that spars are "substantially" straight. It is usual to further define this by saying that a "a permanent set not exceeding X mm is permitted." This permanent set cannot be determined when the mast is erected because the loads applied by the rigging can temporarily distort the mast. Therefore the test is carried out with the spar lying horizontally on the ground.

A string line stretched from the heel to the head of the mast provides a straight line from which to measure the maximum offset of the "permanent set". As the spar may be curved in the opposite direction it is sometimes necessary to position the string line at some short but equal distance from the head and heel.

14.4 Mast weight

The way in which masts are weighed varies considerably so that it is necessary to follow precisely the requirements laid down in the class rules.

Commonly the mast is weighed complete with "fixed fittings". Unfortunately it is not easy to state exactly what this expression means, in view of the fact that it is interpreted in different ways in different classes. In general, anything which is bolted or riveted or welded to the mast is included under the heading of fixed fittings although spreaders usually are excluded.

A number of classes state the weight of the extrusion which may be used to make the mast. Unless the measurer is provided with a piece of the mast extrusion he cannot determine whether the weight is correct or not. He therefore has no alternative but to assume it is correct, provided that all the other requirements with regard to section size, thickness, deflection tests and spar weight are complied with.

14.5 Centre of gravity & tip weight of masts

It used to be common practice to specify the lowest acceptable position of the centre of gravity of the mast. This usually refers to the bare mast i.e. without rigging and fittings. A number of classes still have this requirement although a tip weight is now commonly required.

In order to carry out the measurement of the location of the centre of gravity, the rigging is removed together with the appropriate fittings and the spar supported horizontally at its point of balance. The distance to the heel is then measured.

To overcome the problems frequently associated with the measurement of the position of the centre of gravity, notably the requirement to remove the rigging, the "tip weight" test was introduced. In this test the rigged mast is supported at its lower end (or at the lower measurement band) and the weight of the spar at its top measurement band taken. Halyards are fully hoisted and their tails allowed to rest on the ground. Shrouds, forestay and backstay are lashed along the mast with the lower ends allowed to rest on the ground. Figure 14.5.1 indicates this. In conducting the test the measurer has to be satisfied that any shackles etc. are of normal weight and are not being used as a means of increasing the tip weight. The same remarks apply to the halyards.

14.6 Deflection tests

An important feature affecting performance of the rig is the manner in which the mast bends under load. Some one design classes require the mast and/or boom to have certain deflections when supported horizontally and loaded with a stated weight.

The test is carried out by supporting the mast at points laid down in the class rules, usually its lower end and the upper measurement band. The mid-point of the spar is then found and the vertical distance from the underside of the mast at the mid-span to the floor measured. The weight is applied and the distance measured again. The deflection is the difference between the two measurements. Although it is normal to measure the deflection at mid-span it should be noted that some classes require measurement of the maximum deflection. This may occur at a point other than the middle.

There are a number of points which need to be observed carefully if the results of the test are to be accurate:

(a) The supports have to be solid and not able to settle or move when the load is applied. The supports should be narrow but if that is not possible their inner edges should be positioned at the required points.

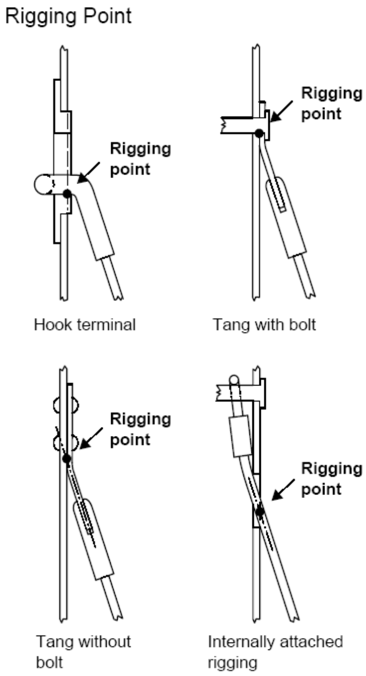
(b) The spar has to be supported with its major axis either vertical or horizontal, depending on whether the fore and aft or athwart ships bend is being tested. If the spar rotates, the test becomes invalid.
(c) Measurements from the spar to the floor require to be very carefully taken. If the floor below the spar is uneven the same point on it has to be used for the measurement in both the loaded and unloaded condition.
(d) When the load is removed the measurement from the mast to the floor should return to the original figure. If it does not the test must be repeated.

14.7 Position of shrouds and sheaves

Shrouds are attached to tangs on the outside of the mast or they are fixed internally as indicated in figure 14.7.1, or hooked into slots in the side of the mast.

Most class rules stipulate the position of the shrouds, by referring either to the point of attachment or to the point at which the shrouds intersect the side of the mast. Although the point of attachment on a mast with internal fixing is theoretically the fixing bolt, it is normal to consider the point of intersection as being the measurement point. However, if the measurer is confronted with this situation he should check with the class authority before accepting this.

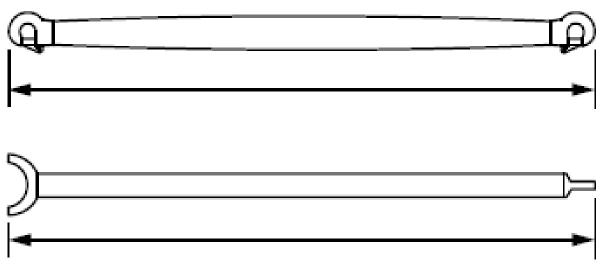
It should be noted that some classes require the shrouds to be attached to tangs in which case measurement is taken to the centre of the clevis pin on the tang.



If the bearing point of the spinnaker halyard on its sheave has to be measured (Spinnaker hoist height in ERS) this is done in the manner indicated in ERS F.7.10 The measurement is taken to the bottom of the groove.

14.8 Spinnaker pole

The only measurement usually required to be taken on a spinnaker pole is its length. This is normally the overall length and is measured to the outer ends of the fittings, and ignores the point at which the spinnaker guy will bear. See figure 14.8.1.



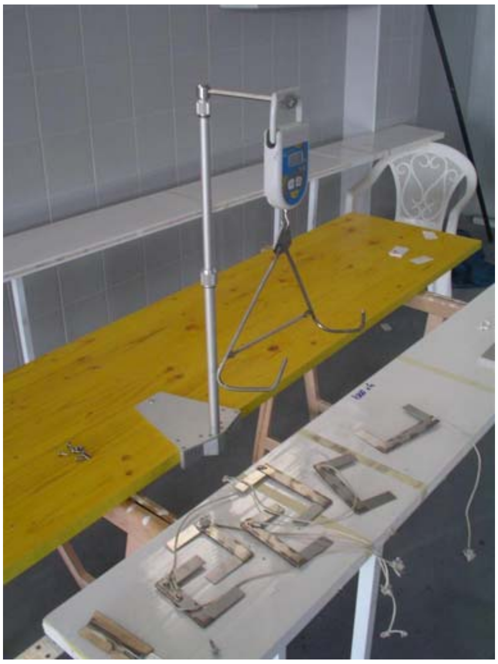
Where the rules state that the spinnaker pole shall not extend more than a specified distance from the mast, the pole is placed in the position which gives the greatest possible measurement. Depending on the location of the fitting on the mast this may be forward or athwart ships. The spinnaker pole has to be pulled away from the mast until it is restrained by the fitting on the mast.

If the mast fitting for the spinnaker pole is to be measured, the height measurement is taken to the centre of the ring and the distance from the face of the mast is taken as the greatest measurement and is irrespective of the position of the bearing surface.

14.9 Event inspection templates

Event inspection for spars is better performed in purposely built tables/benches, preferably from melamine coated surfaces. Special tools are needed for mast spar alignment such as the cylindrical fittings shown above, or even simple aluminum squares. A strong fitting is required for setting the mast heel if this is the datum point. Thick aluminum sections like the 5mm shown below work well, withstanding the punishment by dozens of mast been pushed against them. Whatever system is used, its mast heel bearing surface should be vertical and perpendicular to the line of measurement. Centre of gravity checks may be done using knife-edges as shown above.

To facilitate the positioning of masts with spreaders, either a cut-out is to be made on the bench (as shown above) or the tables shall be separated and fixed at that position. It is advisable to use benches that are made on purpose and not normal tables that the host club is using for other purposes after the event. In this way, holes may be drilled to fix fittings, cut-outs are opened and marks painted on the surface without problems



Go-no go gauges are used for checking spar section dimensions. The scale shown above has a special hanger to accommodate the Finn mast. In other cases, a platform scale might be easier to use.

15 SAILS AND SAIL MEASUREMENT

15.1 General

BASIC TO SAIL MATERIALS

This section is aimed at giving guidance on sail materials and construction methods for those classes which wish to place controls on these issues.

Background

Construction of a Sail

The Equipment Rules of Sailing define some basic principles regarding the construction of a sail. These are:

G.1.3 Ply :	A sheet of sail material
G.1.4 Soft Sail :	A sail where the body of the sail is capable of being folded flat in any direction without damaging any ply other than by creasing.
G.1.5 Woven Ply :	A ply which, when torn, can be separated in to fibres without leaving evidence of a film.
G.1.6 Laminated Ply :	A ply made up of more than one layer.
G.1.7 Single-ply Sail :	A **sail**, except at **seams**, where all parts of the **body of the sail** consist of only one **ply**.

The majority of classes then go on to specify in their class rules, the material of the ply and, in some cases, control the method of the construction of the sail.

Many classes used the IYRU Sail Measurement Instructions, (last published in 1986), as a guide to definitions concerning sails. In particular, it contained a default prescription which prohibited sail material that shows evidence of a film when torn. Accordingly classes which specified, “Sails shall be made and measured in accordance with the IYRU Sail Measurement Instructions”, prohibit Mylar sails.

For new classes the Sail Measurement Instructions have been superseded by the Equipment Rules of Sailing (ERS) and the Standard Class Rules (SCR) and no longer contain this default and accordingly **any restrictions on permitted sail material need to be specified in the class rules.**

Further sail definitions can be found in the ERS and in Appendix B of this section.

Exclusion of Sail Materials from a Class

Class Rules are a means for Class Associations to limit development, control costs and therefore ensure fair and safe sailing. Where sail materials are concerned, class rules may restrict the permitted materials to be used whilst racing. As many existing class rules were written before the introduction of modern sail materials, they do not extend to the full market of materials that they are intended to cover. Below are examples of rules used to restrict wording and how some sail materials aren’t covered.

“**Polyester**” refers to the following materials only:
Polyethylene Terephthalate (PET), Polyethylene Napthalate (PEN) and all of the associated Trade Names including Dacron, Terelene, Teteron, Trevira, Diolene and Pentex.
Examples of some classes that refer to Polyester as the only permitted sail material are the Optimist and J-24.
The essence of these class rules is to allow woven materials only and to exclude expensive high performance materials. However, Class Associations should note that Pentex is classed as a polyester which is a high performance material that falls under the basic polyester definition.

“**Aromatic polyamide**” refers to the following materials only:
Poly p-phenylene terephthalamide and all of the following associated Trade names including Kevlar.
An example of a class that refers to Aromatic Polyamides is the Soling.
Here the essence is to restrict the use of aramids in the class. The wording used is probably too definitive and does not include other aramids such as Twaron and Technora which are referred to as aromatic copolyamides.

“**Polyamide**” refers to the following materials only:
Nylon, Poly p-phenylene terphthalamide, and all of the following associated Trade names including Kevlar, Twaron and Technora.
Examples of some classes that refer to Polyamides are the Soling and the 470 Class, and is used in reference to the spinnaker only.
The wording used is too vague with many other modern materials falling into this category such as Kevlar, Twaron and Technora. It was presumably originally intended only to allow for Nylon to be used in spinnakers as well as polyester.

“**Polyethylene Terephthalate**” or “**PET**” refers to the following materials only:
Polyethylene terephthalate (PET) and all of the following associated Trade names including Dacron, Terelene, Teteron, Trevira and Diolene.
An example of a class that refers to PET is the J-80 Class.
This is very specific wording and refers to single type of sail material.

Some classes have tried to ban certain sail material types but have used incorrect wording and “loopholes” have appeared in the rules. Some sail materials are not considered in any of the above wording, including PBO, Spectra, Dyneema, Vectran, Carbon Fibre and Cuben Fibre.

Recommendation:

Classes are recommended to use the terms as defined in the **Equipment Rules of Sailing**, which minimises the chance of mis-interpretation. Below is a list of recommended wording and the sail materials they will allow.

Polyethylene Terephthalate refers to the following materials:
Polyethylene Terephthalate (PET), and the associated trade names including Dacron, Melinar, Melinex, Terelene, Teteron, Trevira and Diolene.

Polyester refers to the following materials:
Polyethylene Terephthalate (PET), Polyethylene Napathalate (PEN) and the associated trade names including Dacron, Melinar, Melinex, Terelene, Teteron, Trevira, Diolene and PENTEX.

Aramids refers to the following materials:
Poly p-phenylene terephthalamide and all of the associated trade names including Kevlar, Twaron and Technora.

High Performance Polyethylene (HPPE) refers to the following materials:
Spectra and Dyneema and all associated types and trade names.

Liquid Crystal Polymer refers to the following materials:
PBO and Vectran and all associated types and trade names.

Carbon Fibre refers to the following materials:
Carbon Fibre and all associated types and trade names.

Cuben Fibre refers to the following materials only:
Cuben Fibre and all associated types and trade names.

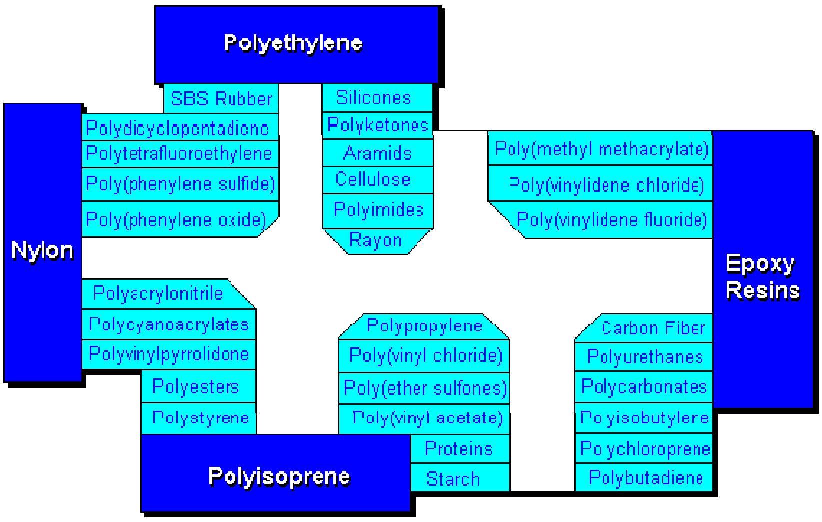
As there are so many different variations on the chemical structure of a fibre and so many different trade names it is very difficult to include all associated fibres without writing out a complete list.

Appendix A - Fibres that can be found in Sail materials

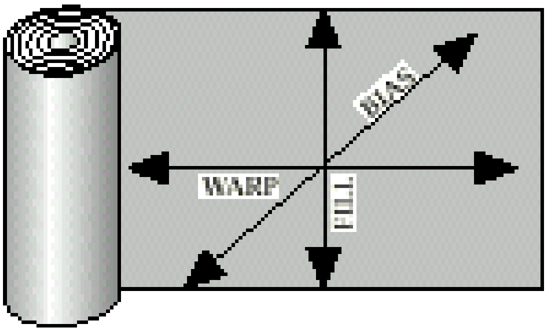
Below is a list of some of the different fibres that may be found in modern sail materials. However, it should be noted that in the majority of cases the fibre name is only a trade name and does not represent the actual properties of the fibre.

There are several chemical groups into which these fibres can be split. They are; **POLYESTERS, NYLONS, POLYETHYLENES** and **ARAMIDS**. Where a description is given in *italic* it is a direct quote from the Federal Trade Commission list of Rules and Regulations under the Textile Fibre Products Identification Act.

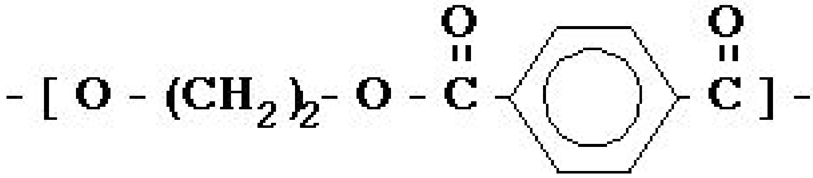
Below is a diagram illustrating the different chemicals and the families they are derived from.



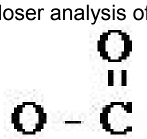
Polyester: "*A manufactured fibre in which the fibre-forming substance is any long-chain synthetic polymer composed of at least 85% by weight of an "ester" of a substituted aromatic carboxylic acid, including but not restricted to substituted terephthalate units, and para substituted hydroxyl-benzoate units.*" Polyester is the most common fibre used for woven sail material. Its properties include good UV and flex resistance, as well as being relatively inexpensive. Traditionally white in colour although it can easily dyed to suit the sailmaker's demands. A proven fibre for durability, polyester has over recent years been replaced by higher modulus fibres, such as modern aramids, for most racing applications (where class rules permit). Woven Dacron, Polyester laminates and Polyester spinnaker cloth are all products made from this versatile fibre. Polyester fibres are also called by other manufacturers brand names of Dacron, Terelene, Teteron, Trevira and Diolene. The standard woven polyester weave can come in two forms. The first is balanced plain weave sail material, where the warp and the fill have the same amount of crimp. This induces a tight weave which is stretchy along both the warp and the fill but not so along the bias which is held by the interlock between the fibres. The second is a highly orientated weave where the crimp is limited to the warp fibres. This produces a cloth which is stretchy along the warp and the bias but not along the fill.



Dacron®: (Polyethylene terephthalate) or PET. Dacron is the original polyester fibre and was first introduced in 1953 by Dupont. This fibre is the foundation of traditional woven sail material. Dacron fibres are also used in cruising laminates and Polyester laminated sailcloth where the use of expensive, low stretch, aramid fibres is not necessary. The chemical structure for PET is shown below:



This can be further broken down into its chemical groups by closer analysis of the structure. The ester group is represented by the chemical structure of

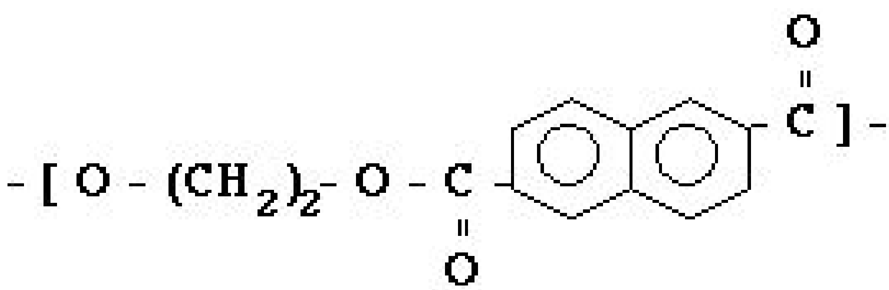


This is the backbone of all polyesters and is present in the chemical make up of both PET and PEN. The ethylene group is represented by the chemical structure of

$$- [\ CH_2 - CH_2\ ] -$$

This is the linkage part of the structure which is also represented in the structures of both PET and PEN. The ester groups in the polyester chain are polar with the oxygen atom having a negative charge and the carbon atom having a positive charge. The positive and negative charges of the different ester groups are attracted to each other. This allows the ester groups of nearby chains to line up with another in a crystalline order which forms a stronger fibre. The ethylene group used in both reactions is called "ethylene glycol". This is mixed with different acids, depending on what fibre you are trying to make, and heated to burn off any unwanted residue such as methanol and ethylene glycol, which are both by-products of the reaction.

Pentex®: (polyethylene napthalate) or PEN. PEN has twice the stretch resistance of regular Dacron polyester (PET). Pentex also offers a higher modulus alternative to that of woven Dacron's. It is best when used in a laminate form as weaving of PEN is too expensive compared to PET. Although its modulus and stretch resistance are higher than PET, it has the same tenacity to PET and is more affected by UV degradation. This fibre is developing an impressive track record as a laminate, and is commonly found in the sails of most small offshore keelboats. The chemical structure for PEN is shown below:



It is very easy to see the differences between the PET and PEN chemical structures. Where PET has only one amide ring, the PEN has a double ring structure, increasing the linear strength of the fibre.

Nylon: "*A manufactured fibre in which the fibre-forming substance is a long-chain synthetic polyamide in which less then 85% of the amide linkages are attached directly to two aromatic rings*." A man-made fibre used to make the traditional woven spinnaker fabric; this material is very lightweight, but not very stretch resistant. Nylon is a generic name for any long chain polyamide and very similar to Aramids. Where para-aramids such as Kevlar are ring compounds based on the structure of benzene, nylon is based on linear compounds. Due to the wide product base of nylon, there are many different variants of the base chemical. The most common type of nylon that is used in sailcloth is the type 6,6 nylon, where the first “6” indicates the number of carbon atoms in the diamide, and the second “6” indicates the number of carbon atoms in the acid. Nylon is manufactured in varying weights ranging from 0.4oz to 2.2oz (see section on ply weights). The cloth is also sometimes coated to increase performance, such as a silicon coating to reduce friction and the cloth holding water. Nylon is also more susceptible to UV and chemical degradation than polyester. As nylons uses become more varied then extra fibres are introduced into the cloth. Available from one supplier is a nylon cloth with interwoven vectran strands for a very strong storm cloth with low stretch along both the warp and the fill. Below is the basic chemical structure of Nylon 6,6.

$$- [\overset{\overset{\displaystyle H}{|}}{N} - (CH_2)_6 - \overset{\overset{\displaystyle H}{|}}{N} - \overset{\overset{\displaystyle O}{\|}}{C} - (CH_2)_4 - \overset{\overset{\displaystyle O}{\|}}{C}] -$$

Aramids: “*A manufactured fibre in which the fibre-forming substance is a long-chain synthetic polyamide in which at least 85% of the amide linkages are attached directly to two aromatic rings.”*

Kevlar®: (Polyphenylene terephthalamide) or PPTA/PPD-T. This is termed as a aromatic polyamide. A gold coloured aramid made by DuPont, Kevlar's modulus is five times greater than that of polyester. Of all the high modulus fibres, Kevlar has the most proven track record, mainly due to it being the most common fibre used in racing applications. It is available in both standard K-29, and high modulus K-49 fibres, with the latter being used increasingly for applications such as boat building and high performance sail manufacture. Recently other types of Kevlar such as Type 149 have been introduced. These recent introductions are primarily due to a refinement of the liquid crystalline spinning process used to manufacture Kevlar. Despite its high modulus, Kevlar is not very durable in terms of fatigue and UV resistance. It is also more expensive. Kevlar is UV sensitive and it's gold colour turns brown as it is affected by sunlight. Another factor of its low UV resistance is a liability to stretch under load. This is seen in the used sails where the fibre has had its modulus reduced to half of its original form over a period of 3 months. Kevlar is more commonly being used as a hybrid material where it is mixed with fibres such as PBO or Carbon.

Technora®: This is an aromatic copolyamide and although an Aramid, is a different type of fibre to PPTA due to its chemical structure and process of manufacture. Made by the Japanese company Teijin, Technora is a high modulus fibre developed as a reinforcement for drive belt applications. In sail material, it is dyed black to help its UV resistance but is also available in its original colour of gold. Technora’s properties are very similar to that of Kevlar, although it has slightly better abrasion resistance, it is more expensive than Kevlar. Technora’s flex resistance is almost 20% better than other para-aramids such as Kevlar and Twaron. Although once used as the primary fibre in a sail material, Technora is now seen more as bias support for higher modulus composite laminates.

Twaron®: Twaron is in the same group as Technora, where its classification is of an aromatic copolyamide. High Modulus Twaron or HMT is a fibre very similar to Kevlar and Technora in its properties of modulus and tenacity. The main difference in HMT is that its UV resistance is much higher than that of Kevlar and Technora. Originally made by Asko Nobel, the rights to HMT have recently been sold to Teijin, the maker of Technora. Like all other para-aramids, it is bright gold in colour, although due to its higher UV resistance it doesn’t fade. Twaron is also used in the boat-building sector where its high absorption of energy and high modulus is a benefit to creating stiff racing hulls.

PBO Zylon®: Poly (p-phenylene-2,6-benzobisoxazole)(PBO) is a rigid-rod isotropic crystal polymer. PBO fibre is a relatively new high performance fibre developed by TOYOBO Co. PBO fibre has superior tensile strength and modulus to Aramid fibres (such as Kevlar, Technora and Twaron). It also has outstanding high flame resistance and thermal stability. PBO fibre, furthermore, shows excellent performance, in such properties as creep, chemical resistance, cut/abrasion resistance, and high temperature abrasion resistance, which far exceed para-aramid fibres. PBO is commonly used in high performance grand prix racing laminate sail material. Although a very expensive fibre, PBO creates a high performance sail material with few disadvantages. However, it does have one major drawback. This concerns the fibres inability to resist almost all spectrums of light. Where some fibres are sensitive to UV light, PBO is sensitive to a much wider spectrum. The solution to this was to cover the fibre in an orange film which was found to be the most protective towards the fibre. (See films)

Polyethylene: Polyethylene is simply formed by the polymerization of ethylene. This is done using a catalyst to initiate the process and an accelerator to allow the reaction to take place at room temperature. There are two different types of polyethylene, LDPE and HDPE. These represent LOW Density Polyethylene and HIGH Density Polyethylene respectively. It is HDPE that is more often used in the manufacture of sail material. HDPE has a *linear* molecular structure where LDPE has a *branched* molecular structure. The *linear* structure is important as it makes the fibre very strong along its length where the *branched* structure is not as strong. The chemical structure for ethylene is shown below:

$$- [CH_2 - CH_2] -$$

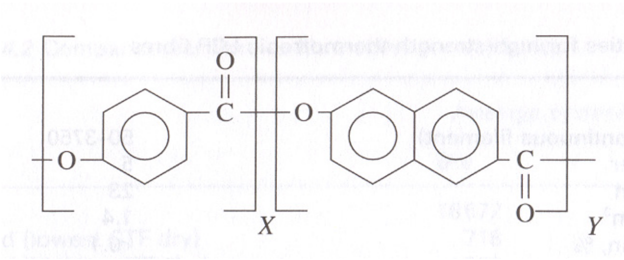
All of the fibres below are made out of HDPE which can sometimes be known as UHMW (**U**ltra **H**igh **M**odulus **W**eight).

Spectra®: A high modulus weight polyethylene or long chain polymer, Spectra is a product of the Allied-Signal Corporation, now known as Honeywell. Spectra has a higher modulus than most fibres, except for carbon and PBO. First used in sail materials around 1987, it was originally used instead of Kevlar but its low stretch resistance meant that it was soon discarded from racing applications. This stretch makes it difficult for the sail designer to guarantee the shapes they want after manufacture. As a result, Spectra is viewed more as a performance cruising fibre where its excellent flex, UV and chafe properties along with its traditional white colour are perfect for large cruising boats where cloth strength and durability as well as weight are considerations. Spectra is often found in laminates where it is bonded between taffeta for performance cruising sail materials.

Dyneema®: Produced by the Dutch company DSM, Dyneema, like Spectra is a highly processed polyethylene, which offers good UV resistance, high theoretical initial modulus and breaking strength. It also shares Spectra's creep characteristics. It has almost exactly the same properties as Spectra except that it is more commonly available and slightly cheaper to produce.

The method of manufacture for both Spectra and Dyneema are very much the same. In normal polyethylene the molecules are not orientated (like a branched molecular structure), and can be easily torn apart. To make strong fibres, like Spectra and Dyneema, the molecular structure needs to be orientated and crystallised in the direction of the fibre. This is why a HMPE (High Modulus Polyethylene) is used as a starting material as this is of a linear molecular structure. This is then processed using a gel-spinning process which draws the fibres out of the melt. As the fibre is drawn through the gel solution, it is disentangled and once cooled, it forms filaments. Due to the low degree of entanglement the fibres can be super drawn which straightens the structure and produces a high level of orientation. It is this orientation that defines the initial modulus of the fibre.

Vectran®: A wholly aromatic polyester-based, liquid crystal polymer fibre manufactured by Hoechst Celanese. First produced for the US Navy for towing arrays from submarines. Vectran has a modulus comparable to Kevlar but due to its molecular composition has better flex and abrasion resistance, although its UV properties are worse. Vectran, unlike Spectra or Dyneema, does not creep. These characteristics make Vectran an interesting candidate as a performance fibre, although it is more expensive than either Kevlar or Spectra. Vectran is uncommon as a laminate and can normally be found as a hybrid cloth with polyester. The chemical structure for Vectran is shown below.



Certran®: A high modulus polyethylene fibre, similar to Spectra, manufactured by Hoechst Celanese. This fibre shares the same resistance to flex fatigue and UV as Spectra so its applications in sailcloth are limited to secondary fibres and areas which can take advantage of its flex, chafe and UV resistance. Very rarely used in modern sails as the price of Certran limits its use to a small percentage of the market. Due to its limited availability and cost, production of Certran has been stopped.

Carbon Fibre: Carbon has only recently been accepted into offshore classes over the past couple of years, although the fibre has been under development for over fifty. Carbon was first used during the 2000 America's Cup with varying degrees of success. Due to the many different types of manufacturing processes there are various chemical types of carbon fibre available. Carbon is originally a very brittle, but strong fibre. Its primary application was in building applications such as boats. Here its brittleness isn't such a worry as the fibre is cured with resins to form an extremely strong hull. However, when carbon fibres were first introduced into sail materials, which are constantly being folded and creased, the brittle nature of the fibre led to many failures of the sail. A lower grade fibre is now used in sail materials, which still has an exceptionally high modulus and tenacity, but also has the lowest amount of stretch of any fibre and more importantly, has a good flex life. It is also completely resistant to UV degradation making it perfect for high end racing applications. Since Carbon has become a legal sail material in Offshore Classes, its cost has dropped to that of Kevlar as the development continues to improve the fibres properties. Carbon is being used in all methods of sail manufacture where in the 3DL and TapeDrive process it is being used alongside Kevlar in a hybrid form to create a super strong, low stretch sail.

Cuben Fibre: Firstly it should be pointed out that Cuben Fibre is only a trade name and a process for manufacturing sail material. It is not a specific cloth or contains any one fibre. The Cuben Fibre Corporation claim that its fibre/film content is very similar to other laminate cloths. The fibres may vary from spectra or dyneema to aramids such as Kevlar etc. The film is a polyester film called Mylar with another similar material called Tedlar on top of everything. As Cuben Fibre can be made out of many different materials it is hard to define exactly what type of cloth it is but it is essentially a very expensive laminate. The method used to produce the cloth makes it expensive seeing that it is virtually hand made. A combination of films and fibres are laid down by hand to form the essential sandwich of the laminate. This is all then bonded under extreme pressure in an autoclave to produce a very light cloth. The autoclave itself is only 30 feet long so therefore only roll lengths of this length can be produced. This and the complex nature of the manufacturing process makes Cuben Fibre the most expensive and the most demanded sailcloth on the market.

N.B It should be remembered that the chemical structures displayed in this report may be displayed in different formats.

SAIL CLOTH FIBER COMPARISON CHART

SAIL CLOTH FIBER	Initial Modulus grams/ denier	Tenacity grams/ denier	Flex Life % lost after 60 bend cycles	UV-Resistance 50% strength loss (months)	Elongation at Break Pecentage
PBO Zylon†	1830	44	27%	2-3 months	2.5%
High Tenacity Carbon Fiber	1350	60	22%	not effected	1.2 - 1.5%
Spectra®/ Dyneema®	1250	33.5	no effect	6-7 months	5.0%
Kevlar® Edge*	956	29.4	22%	2-3 months	3.0%
Kevlar® 49*	945	23.9	25%	2-3 months	1.5%
Twaron® 2200 (HMT)*	810	23.5	25%	2-3 months	1.5%
Cetran®	650	15	no effect	6-7 months	4.0%
Technora® Black	540	28.3	7%	3-4 months	4.2%
Vectran®	510	23	15%	1-2 months	2.0%
PEN Fiber (Pentex®)	250	10.2	no effect	6 months	6.0%
High Tenactiy Polyester	135	7.9	no effect	6 months	8.0%
Nylon®	45	9.5	no effect	3-4 months	13%

† *UV-Resistance tested with Magna Shield cover*
* *ASTM 885 (American Standard Testing Method #D885)*

INITIAL MODULUS: A yarn's ability to resist stretch. Higher numbers indicate less stretch.
TENACITY: A yarn's initial breaking strength. Higher numbers indicate that greater load is needed to break the fiber.

FLEX LIFE: A measure for a yarn's ability to resist flexing & folding. Lower numbers indicate less loss after 60 cycles.

UV-RESISTANCE: Amount of time it takes for a yarn to lose 50% of its initial modulus. UV tests are normally conducted with artificial UV exposure.

ELONGATION: Elongation at break is a measure of a yarn's ability to resist "shock" loads.

Data Courtsey of Dimension Polyant Sailcloth

Appendix B – Frequently Asked Question's

Taken from the ISAF Guide to Sail Measurement 2001-2004.

What is Ply?

A ply is a sheet of sail material made up of one or more lamina. For example a layer of film bonded to a woven fabric is a ply; in fact a laminated ply. A sail with its body made from one sheet of this ply would be a single-sail ply. If two sheets of the material were used next to each other this would be a two-ply sail. The word ply is both singular and plural. If the class rules give no restriction as to the number of ply that may be used it can be assumed that the number is optional.

What is Woven Ply?

When a woven ply is torn it will be possible to separate the fibres without leaving evidence of a film. Thus ply, (often referred to as "Mylar" a trade name for one particular polyester film), which compromises a woven base in which a plastic film has been bonded is considered to be non-woven.

What is meant by a "Soft Sail"?

It is normally quite easy to establish if a sail is soft without having to fold it and risk "damaging the ply". However, in cases of doubt, if it is claimed that the sail is soft, a measurer should fold the ply, usually in an area of secondary reinforcement. If the measurer is unable to flatten the ply when applying pressure between the forefinger and thumb or the sail suffers damage more than a crease line, then the sail is not soft.

What is ply weight?
There are many classes that specify minimum ply weights. Before looking at how to find out how to determine the ply weight, it should be noted that there are many different units in which this can be measured.
These are:

- Ounces (oz)
- Ounces per square yard (oz/sq yd)
- Grammes per square metre (g/m2)

When the weight is given as x ounces, this refers to the weight of one yard run of cloth 724mm (28.5 inches) wide – this being the standard width in which the ply used to be woven. It is the way in which most sailcloth is described in the United States. A manufacturer's quoted ply weight may be for the material before the addition of finishes. This will not be the same as the weight of the material used in the construction of sails, so care should be taken to avoid confusion. It is difficult to determine whether or not a ply is in accordance with a weight control in class rules. There are two ways of undertaking this: -

a) Determining the weight of the ply. This is done with five samples of sail material, "die-cut" from different places in the sail, not less than 25% of the foot length apart. All five samples must be carefully placed in a draught free compartment of a levelled laboratory scale. The combined weight of the samples is taken and then divided by five and corrected to the units specified in the class rules. This shall be the ply weight. Great care should be taken to ensure that the scales are zeroed before the weighing procedure takes place.

b) Measuring the thickness of the ply Folded thickness mm. Some classes control the ply thickness and as there is a loose relationship between the thickness of woven ply and its weight, some classes use this to approximate ply weight by thickness measurement. There are, however, a number of factors, including closeness of the weave, the nature of the filaments and the types if finish applied, which makes this relationship less than precise. Where the classes control the thickness, this is usually the minimum thickness allowed. It is thus important that measurement is taken at the thinnest area, particular if the sail is lofted from a laminated ply with open weave scrim. If the micrometer measuring surfaces permit, thickness measurements should be taken between the scrim. If the ply has no scrim then a feeler gauge used alongside a micrometer will be used. Before taking any measurements always check the zero of the gauge and clean the measuring surfaces of the micrometer. When taking double thickness measurements, which will be necessary to measure in the body of the sail:
    a) Fold but do not crease the sail.
    b) Open the micrometer wide enough to enable the jaws to pass over the doubled roll without scraping.
    c) If the ply has no scrim, place the feeler gauge between the two-ply layers. This prevents the surface of one layer meshing with the other. Subtract the feeler gauge thickness from the micrometer reading. Repeat this measurement as many time as required to be satisfied that the sail is in compliance with class rules.

FURTHER Frequently Asked Question's
How do I tell the difference between Polyester spinnaker cloth and Nylon spinnaker cloth?
Unfortunately there is no easy answer to this.
The only real difference between polyester and nylon spinnaker cloths is the actual fibre. Physical differences are hard to see or feel.
Polyester has a tighter weave, making it more stable in structure, soaks up less water and stretches less.
Nylon on the other hand has more stretch to it making it easier to trim, especially in waves.
Polyester, due to its low stretch, has low tear strength and can be easily ripped.
A stretch test is a simple method of testing between the two cloths. Polyester will not stretch at all under hand tension where as nylon will have a visible, although small, amount of stretch.
Dimension Polyant, a sailcloth manufacturer, say that their polyester cloth is easy to distinguish from nylon, as the rip-stop construction in polyester is larger than that in nylon. This however this can be misleading and should not be used as a guide to determining the difference between two cloths.

How did Cuben Fibre get its name?
The America^3 Syndicate first used Cuben Fibre during the 1992 America's Cup. They were the first to use the sail material built using spectra and spectra / graphite fibre composite. These were dubbed Cuben Fibre by the media. This was a result of the America3 campaign being called the "Cuben's" as a nickname.

What is a laminated ply sail material?
Laminate sailcloth is when assorted layers of film, taffeta, scrims and knits are bonded (laminated) together, often using a heat process, to form a composite material.
A simple laminate consists an open scrim fibres, to take the load, with a simple film bonded to each side. However there are many different types of laminates, of which four are most popular.
The first is the Woven/Film/Woven type laminate. This consists of a loosely woven Dacron taffeta laminated to a layer of film. In this application, the film provides most of the stretch resistance and the taffeta is mainly utilized to enhance tear and abrasion resistance. A higher end version of this would be to change the Dacron taffeta for a harder wearing Kevlar or spectra taffeta.
The second is Film/Scrim/Film type laminate. This construction method has the structural fibres sandwiched between two layers of film. This way, the load bearing fibres are laid straight which takes away the effect of crimp on the cloth. When laminating film on film, the bond is very strong which allows a minimum amount of glue to be used making the cloth lighter without sacrificing strength. This, however, is the weakest type of lamination when it comes to abrasion or flex resistance. This is because the film is not as good as the woven film when it comes to flex and abrasion and also exposes the structural fibres to harmful UV rays. This type of lamination is more often used for short-lived racing sails where the life expectancy of the sail is short. Sometimes a UV film is used instead to better protect the structural fibres.
The third type of lamination is a combination of the first two. This is where a film/scrim/film laminate is bonded on each side with a woven material. This takes advantage of the bonding strength of the film on film structure and adds flex resistance and UV protection using the taffetas used in the woven/film/woven structure. This cloth is very popular with long distance racers as it combines strength and durability is a single cloth.
The fourth and final type of lamination is Woven/Scrim/Woven. Where woven materials are on both sides of the scrim with no film used. This would be the ideal type of lamination as it eliminates the film element, which is the main cause of shrinkage in sail materials. The problem with this type of laminate is that bonding two woven fabrics to each other is not easy and adding inserted yarns in the middle makes bonding even more difficult.

What is defined by the term “Polyamide”?

The technical definition for a “polyamide” is as follows: “*A synthetic thermoplastic material produced by the condensation polymerization of an Adipic Acid with a Diamide*.”

Sail materials that fall under the term polyamide include Nylon’s and Aramids. Both these fibres are defined by the percentage of amide linkages attached to the aromatic rings. Where Nylon has LESS than 85 percent of linkages attached, Aramids have MORE than 85 percent of linkages attached.

Although both Twaron and Technora are listed as Aromatic Copolyamides they still fall under the term Polyamide as they are constructed using an Adipic Acid and a diamide.

What is film?

Film is generally made up of a polyester sheet material, otherwise known as Mylar, made by Dupont.

In the early days of laminated sailcloth, the film layer was a major structural part of the cloth. As technology progressed, the role of the film has increasingly become secondary, acting mainly to keep the fibres in place.

Mylar film is made using an identical resin that is used to finish Dacron. This resin starts off as a block, which is subsequently stretched into thin sheets.

Whilst being stretched, the polyester molecules are moulded in a uni-directional manner, which both stiffens and stretches the polyester. This process forces the film to behave like a woven fabric without any crimp in the warp and fill, but with some bias stretch.

Film technology has progressed at the same level as the fibres, where films have different dyes to either protect the fibres from UV or to simply enhance the colour of the cloth. There is as yet no coloured film that completely solves the problem of UV degradation. Special films have been developed for PBO fibres in particular to help reduce their susceptibility to UV light.

Why are sail materials different colours?

The colour of the sail material tends to depend on the fibre.

Where polyesters are concerned, they are naturally white (slightly off-white).

With aramids where the fibre is more susceptible to UV degradation then the film is very often dyed to protect the fibres. Laminated Kevlar, for example, is the most popular sail material used in modern racing yachts. It is also one of the worst fibres affected by UV light. As the fibres are sandwiched between the two layers of Mylar film, this film can be dyed to help protect the fibres. The most common dye to the film is called MagnaShield. This is a dark film, which contains a UV barrier in it and has a dark, smoky colour.

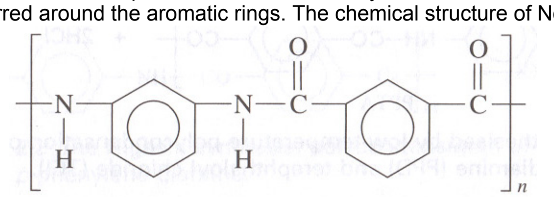
Other reasons for dying the film is to simply make the cloth stand out. One sailmaker has dyed all off their laminated Kevlar cloth a bright orange so that on a busy day on the water, the sails stand out and are more noticed.

What defines an aramid?

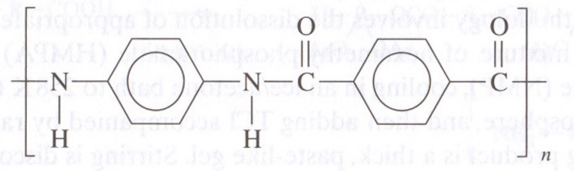
The chemical definition of aramids can be viewed above.

There are many different variants of aramids with a range of chemical terms to describe them.

The original aramid fibre was Nomex. This was first produced around the early 1960’s and was described as a meta-aramid fibre. This was due to the way the linkages occurred around the aromatic rings. The chemical structure of Nomex is shown below.



Next to be created was Kevlar. This was a development of the process used to make Nomex and is described as a para-aramid fibre. Again the name describes the linkage around the aromatic rings. The chemical structure for Kevlar is shown below.



The difference between the aromatic rings can be clearly seen in the above two structures. Although chemically very similar, where they have the same amount of hydrogen linkages etc, except that the stations of linkages are different.

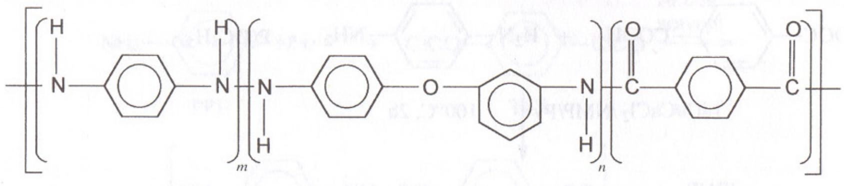
Para-aramids can be split further into groups where aromatic polyamides and aromatic copolyamides occur. Kevlar is listed as an aromatic polyamide where other para-aramids such as Twaron and Technora (both trade names) can be listed as aromatic copolyamides.

In the US Federal Trade Commission description of Aramids, it states that all amide linkages (-CO-NH-) are attached directly to two aromatic rings. For those of us who aren’t chemically minded, CO shall be called “A” polymer and NH shall be called “B” polymer. Therefore an aramid created by the generic reaction of an amine group and a carboxylic acid halide group, can be associated with AB polymers. (A and B polymers being defined above). An aromatic polyamide is created with AABB polymers which involve double linkages of CO and NH respectively. These can be seen in the chemical structures of both Nomex and Kevlar above.

Kevlar or PPTA (polyphenylene terephthalamide) is the simplest example of an AABB para-orientated polyamide.

Copolyamides are created using a different number of “ingredients” but still remain in the para-orientation of the rings similar to Kevlar. Copolyamides consist of <u>two</u> phenylene groups which are connected to a single atom as opposed to the one phenylene group found in polyamides. The market for copolyamides was defined by the need for a fibre which displays high tensile stress properties as well as a high resistance to hydrolysis.

Technora is a good example of an aromatic copolyamide fibre. Shown below is the chemical structure of Technora.

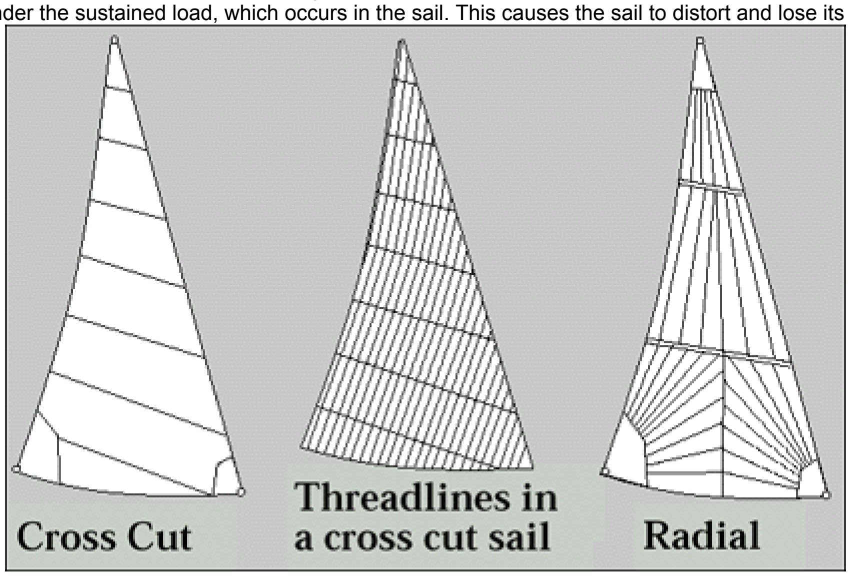


From this structure you can see obvious differences between the polyamide and copolyamide fibres. It is clear that in the copolyamide structure, the added phenylene group has increased the number of rings and therefore strengthened the longitudinal bonding of the fibre.

Appendix C – Different Methods of Sail Manufacture

Traditionally, sails have been made out of cotton. As technology has crept into the sport, then the method of producing sails, and the materials used, have moved along with this advance in technology.
Due to this, some classes have begun to restrict the method of sail construction. For example, the Finn has the following passage in their rules: "continuous layers or fibres crossing the seams are prohibited". This eliminates 3DL and TapeDrive as a method of manufacture but not Genesis or the D4 process.
Below are described the different methods of making sails
Panelled sails are the most common and traditional method of constructing sails. So called because they are made up of numerous strips of sail material (panels). Modern materials have advanced methods but there are still two distinctive methods of producing panelled sails. Though the two methods are very different, they can both be constructed using both laminate and woven materials using any fibre. The main disadvantage of the panelled process is that the load concentrates around the seams causing stretching and distortion – often at different rates from panel to panel.
Crosscut Panel Layout. A sail where all panels are parallel to each other and perpendicular to the leech. The cross cut is used mostly in

the constructing of Dacron or polyester sails, although modern laminates are now being marketed to suit cross cut construction. It is a popular method as it is very simple, minimises cloth wastage and allows sail makers a better control over shape as there broad shaped seams. As the panels are perpendicular to the leech, the cloth needs to be of a fill-orientated variety. This is mainly because the highest loads in a sail are found along the leech and the tack of the sail. A highly orientated polyester cloth is best used for the cross cut layout.
Radial Panel layout. Radial sails are made with long, thin triangular panels or "gores". These panels are aligned along the primary load paths of the sail by lining up the warp thread of the laminate. In order to match up the warp along the load paths more accurately the gores need to be very narrow. Wider gores are used in low load areas, allowing the cloth to be more economically used. As there are more panels, different weights of cloth can be used to accommodate the different loads in the sail. Heavier cloths would be used along the leech and the tack where a taffeta-coated cloth would be used along the foot to accommodate the chafing of the sail over the lifelines.
In the construction of the sail, the gores radiate out of the corners of the sail because loads start from a corner of the sail and then run in arcs through the sail. Joining both types of panel layouts is done in a variety of methods, the most traditional being stitching. Since the introduction of laminates, joining methods have developed to incorporate the new demands. Most laminate sails are now bonded using an adhesive. Where before a light adhesive was used to hold the sail temporarily together until it was sewn, modern adhesives are much stronger and are relied on to hold the sail together for the duration of the sails life. The downside to all types of methods is that the seams slip under the sustained load, which occurs in the sail. This causes the sail to distort and lose its preferred shape.



3DL^{tm} is a very high tech process that is dominating the world of top-level racing. The sail starts off as a CAD design which is the sails flying shape or "mould". This data is translated into information for an articulated mould that assumes the designed shape. A sheet of Mylar film is then laid over the mould and tensioned. An overhead arm carrying the sails fibres then crosses over the sail in a predetermined pattern that precisely matches the anticipated loads in the sail. Once the fibres have been laid a second sheet of film is laid over the top of the skin, where a vacuum is then placed onto the skin to compress the laminate into a single skin. The fibre-laying arm is then changed to a heating element, which then passes over the whole sail curing the final laminate to form a very strong bond between the two skins.

Tape Drive[tm] is a similar but less complicated process. Here, a skin is produced of light sail material, which is stuck together in a crosscut fashion. This skin takes the shape of the sail and is not designed to take much of the load. Tapes are then laid by hand onto the skin in a pre-designed pattern to take the load. Each tape has only one individual strand, which comes in a variety of fibres and weights. This process also allows the sail to have mixed fibres which form a hybrid sail. Tape Drive is different to all of the other processes as the load-bearing fibres are on the outside of the sail instead of being laminated into the sail or sail material. Tape Drive is sometimes referred to as a moulded sail as it involves a different method of construction to a conventional panelled sail. As with all the other processes, the combination of base material, tape material and tape alignment defines the finished product.

Genesis. This process is a combination of both panelled and moulded sail making. The sail is constructed up of panels which are joined together in a crosscut panel layout. However, each individual panel has its own fibre layout and is laminated individually. Once all of the panels have been constructed the panels are then joined together and are bonded into one piece to form the finished sail. Shape is not put into the panels but into the seams, very much the same way as a normal cross cut sail. However, this process differs to both 3DL and the Tape Drive as the fibres stop at each panel. This creates the problems that occur within a panelled sail, which is the issue of seam slippage.

D4. D4 is the latest method of sail making construction to be introduced. D4 uses very much the same technology as Genesis except that the panels are larger. The panels are individually constructed in the same method as in Genesis and do not carry any of the sails shape. The sail is then joined together, bonded, to form the final sail. The shape is again put into the sail using the joining seams in the sail. As the sections are larger there are less seams which means the chance of seam slippage, and sail distortion, is smaller. Although D4 is marketed as a moulded sail it is, like Genesis, essentially a panelled sail (with moulded sections).
The same bonding and curing process that is described in the 3DL method is used for making the panels in Genesis and D4 panels.
With all of the moulded sails there are a choice of fibres and films that can be used to suit the customers requirements from the sail.

Appendix D – History of Sails and Sail Materials

Sails were first probably used in the Middle East, where Egyptians pioneered early sails made out of reeds and grass to propel their canoes down the Nile. The Romans and Vikings used sails of hemp coated in tar to sail their warships great distances. Around the 1400's, the trend changed towards flax for sails. This remained the common cloth until 1851. This was when the schooner "America", challenged the British in a race around the Isle of Wight for what was to become known as the Americas Cup, and was the first known use of cotton sails. They were markedly faster than the flax sails and much easier to handle. Although better than flax, cotton still had undesirable properties, as it was known to stretch, rot and absorb water.

The next change came in 1937 with the introduction of Rayon. Since then, all fibres had been natural and with Rayon came the first artificial fibre to be used in the fore and aft sails. Again it was the America's Cup that was the spawning ground for this fibre with the Defender "Ranger" being the first to use it successfully. Three years later another artificial fibre called Nylon was introduced. Nylon overtook expensive silk in the use of spinnakers and is still the principal fibre used in spinnaker sail material today!

1953 saw the launch of polyethylene terephthalate (PET) as a sail material fibre. Commercially woven in USA, PET is more often known as its trade name of Dacron, and is manufactured by Dupont. This quickly became the leading fibre in sail making with very early successes in the 1954 Star World Championships and the 1955 Fastnet Race. Boats sporting complete sets of Dacron sails won both of these prestigious events.

The 1970's saw a high increase in the number of man-made fibres being used in sailcloth. The biggest breakthrough came with the introduction of Kevlar. This is again manufactured by Dupont, now one of the worlds leading fibre producers. Kevlar was first introduced into sails, after being used in boat building for three years, around 1980. Again it was in the America's Cup arena where it was first successfully used by many of the syndicates. Due to Kevlar's high cost, almost three times that of Dacron, it was initially banned, but by 1985 the IOR (International Offshore Rule) finally allowed Kevlar in some parts of the sails with 1986 seeing its unlimited use.

At the same time that Kevlar was making its impact on the sailing industry, Mylar (again by Dupont) was being introduced as a new form of polyester.

Mylar is a clear film version of PET. Although structurally not very strong on its own, when bonded or laminated with other fibres, it creates a very light and strong sailcloth. This is the original example of laminate sailcloth and its modern equivalent is available in a variety of forms.

Since 1986, when Kevlar was finally allowed into offshore rule sails, many other fibres were starting to be introduced into the market. Among these were Spectra, Dyneema, Vectran, Technora, Twaron and PBO. All of these fibres have different properties making them suitable to different aspects of the sailing market, either racing, cruising or offshore.

Since the introduction of laminate sail materials, there has been a revolution in the manufacturing process of sails. Many companies have been trying to develop racing sails to make them lighter and stronger. This led to the development of the "seamless sail". The process, known as 3DL, discards the traditional method of sail making of using panels and strips of cloth to make the sails. 3DL instead creates a sail that is a continuous piece of cloth with various fibres running the length of the sail, usually along where the loads are greatest. Other sail makers have come up with similar concepts along these lines and are called such names as "TapeDrive", "Genesis" and "D4".

Glossary (of Sail Material Terms)

Aspect Ratio The luff length divided by the foot length is the final aspect ratio of the sail. A tall, thin sail has a high aspect ratio.

Bias Diagonal at 45 degrees across the warp and the fill.

Count The number of yarns per inch in either the warp or the fill of the cloth.

Creep The amount a fibre gradually stretches under constant load.

Crimp The length added to a yarn when it is woven over-and-under a piece of fabric. A tight weave will have less crimp than a more open weave.

Denier The coding system for filament yarns and fibres. A low denier indicates a fine yarn where a high denier is a heavier, thicker yarn.

Elongation The difference a sample of fabric has stretched from its original form.

Fill The fibres running at right angles to the warp, usually across the cloth.

Flex Strength The ability of a fibre to resist flex movement and retain its original strength. Measured as a percentage of its original modulus.

Hand The softness or firmness of the fabric.

Modulus Is referred to as Modulus of Elasticity. This is the measure of stretch or elasticity of a fabric, where a high modulus is equivalent to low stretch.

Stretch Resistance The ability for a fabric to resist stretch over a period of time under sustained load.

Taffeta An unfinished fabric employed as a covering, usually in laminate sailcloth, often enhancing durability and abrasion resistance.

Tenacity The breaking strength of a yarn or fabric stated in force per unit of the cross-sectional area.

Tensile Strength The ability of a fibre, yarn or fabric to resist breaking under tension.

Threadline The direction of the yarns.

UV Resistance Measures the effect of sunlight on cloth. UV Resistance is usually expressed in the time taken for a material exposed to sunlight to lose half of its breaking strength.

Warp The yarn or fibre running along the length of the fabric.

15.2 Sail measurement

This section of the guide contains selected parts from the ISAF Sail Measurement Guide. The full SMG document can be downloaded from the ISAF website.

15.2.1 Class Rules

Where a particular **class rule** and the ERS are in conflict, the **class rule** shall prevail. Where no limits for a particular dimension are given in **class rules** nor in the RRS, then the item is not controlled and need not be measured.

15.2.2 Headsail or Spinnaker

Neither the ERS nor this guide attempt to make a distinction as to whether a particular sail is a headsail or a spinnaker. The difference should normally be specified in **class rules** or by he owner, as, due to the close similarity in shape of some of these sails, the difference between the two types is purely a matter of usage rather than measurement. Regardless of the shape of a sail, if **class rules** or the owner call it a headsail, or where **class rules** require it to be measured as a headsail, the sail should be measured as a headsail. Similarly, if **class rules** or the owner call a sail a spinnaker, or require the sail to be measured as a spinnaker, it should be measured as a spinnaker. In cases where a visual distinction as to type is unclear the measurer should mark the measurement type use on the sail i.e. *measured as a headsail* or *measured as a spinnaker.* The ISAF recommended **certification mark** design has a box where this can be inserted. Where neither **class rules** nor the owner make a distinction as to whether the sail is headsail or spinnaker RRS 50.4 should be applied.

15.2.3 Tools and Equipment

In the majority of cases, the accurate measurement of a sail may be undertaken using the following tools and equipment, see section -

- steel tapes of good quality
- micrometer
- feeler gauge
- batten of uniform flexibility
- pencil
- permanent marker pen
- stamp and ink pad
- Additional equipment is required to measure **ply** weight
- A measurer may supplement this list with other tools or equipment that either improves the accuracy of, or the time taken on, measurement. For pre-event check measurement this is highly encouraged.

15.2.4 Sail Construction (ERS G.1 and section 15.1)

(a) What is meant by the word Ply ?

A **ply** is a sheet of **sail** material made up of one or more lamina. For example a layer of film bonded to a woven fabric is a **ply**; in fact a **laminated ply**. A **sail** with its body made from one sheet of this **ply** would be a **single-ply sail**. If two sheets of the material were used next to each other this would be a **two-ply sail**. The word **ply** is both singular and plural.

If **class rules** give no restriction as to the number of **ply** that may be used it can be assumed that the number is optional.

(b) What is Woven Ply ?

When a **woven ply** is torn it will be possible to separate the fibres without leaving evidence of a film. Thus **ply**, (often referred to as "Mylar" a trade name for one particular polyester film), which comprises a woven base on which a plastic film has been bonded is considered to be non-woven.

(c) Soft Sail

It is normally quite easy to establish if a **sail** is soft without having to fold it and risk "damaging the **ply**". However, in cases of doubt, if it is claimed that the **sail** is soft, a measurer should fold the **ply**, usually in an area of **secondary reinforcement**. If the measurer is unable to flatten the **ply** when applying pressure between forefinger and thumb or the **sail** suffers damage more than a crease line, then the **sail** is not **soft**.

(d) Ply Weight

There are a number of classes which specify minimum **ply** weights. Before discussing the problems associated with such rules, it is necessary to be aware of the different units used to describe **ply** weight.
These are:

- **ounces (oz)**
- **ounces per square yard (oz/sq yd)**
- **grammes per square metre (g/m2)**

When the weight is given as x ounces, this refers to the weight of one yard run of cloth 724 mm (28.5 inches) wide - this being the standard width in which the **ply** used to be woven. It is the way in which most sailcloth is described in the United States. Figure 1a shows the comparison between the three units, and enables conversion to be made from one system to another.

A manufacturer's quoted **ply** weight may be for the material before the addition of finishes. This will not be the same as the weight of the material used in the construction of **sails**, so care should be taken to avoid confusion.

It is difficult to determine whether or not a **ply** is in accordance with a weight control in **class rules**. There are two ways of undertaking this:

1) determining the weight of the **ply**
2) measuring the thickness of the **ply**

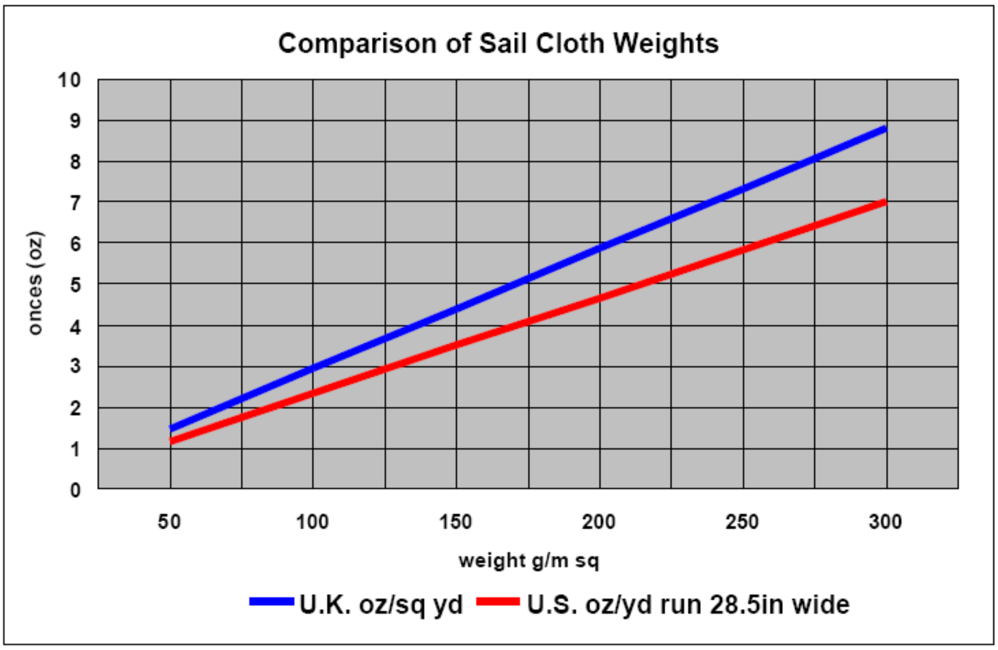


Figure 1a Comparison of Sail cloth Weights

15.2.5 Procedure for Determining the Weight of Ply

Equipment:

Any national governmentally approved laboratory type scale, approved to weigh samples to an accuracy of 0.01% to be used in accordance with its manufacturers' instructions. An example is:
Yield scale type "E/M" and Sample Cutter 'ERC-2' manufactured by Alfred Suiter Co. of Orangeburg, NY, USA.

Method

Five samples of **ply** should be accurately "die-cut" from different places in the **sail**, not less than 25% of the **foot length** apart. All five samples must be carefully placed in the draught-free compartment of a levelled laboratory scale, the scale carefully balanced, and the combined weight of the five samples read off. This weight, divided by five and corrected to the units specified in the **class rules**, shall be taken as the weight of the **ply**. Great care should be taken during the scale zeroing operation.

15.2.6 Ply Thickness

Some classes control **ply** thickness and as there is a loose relationship between the thickness of **woven ply** and its weight, some classes use this to approximate **ply** weight by thickness measurement. There are, however, a number of factors, including closeness of the weave, the nature of the filaments and the types of finish applied, which make this relationship less than precise. This is shown by Figure 1b which compares of **woven ply** weight with upper and lower limits of the folded thickness. Measurers should also be aware that sail material from a single roll might vary in thickness by up to 10%.

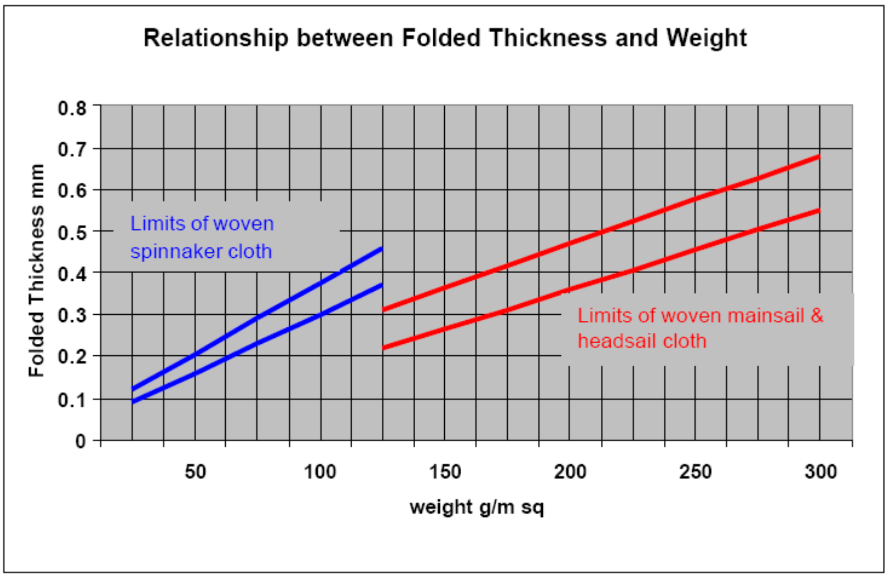


Figure 1b Relationship between FoldedThickness and Weight

15.2.7 Measuring the Thickness of Ply

Where **class rules** control **ply** thickness, this is usually the minimum thickness. It is thus important that measurement is taken at the thinnest area, particular if the **sail** is lofted from a laminated **ply** with open weave scrim. If the micrometer measuring surfaces permit, thickness measurements should be taken between the scrim. The measurer should take as many thickness measurements as necessary to be satisfied that a **sail** is in compliance with **class rules**. The dimensions recorded shall be absolute and not averaged.

Figure 2. Measuring the thickness of **Ply**

A micrometer and, if the **ply** has no scrim, a feeler gauge will be needed. Before taking any measurements carefully clean the micrometer measuring surfaces and zero or calibrate it using the feeler gauge.
Always bring the measuring surfaces together slowly and uniformly using the micrometer ratchet when checking zero and when taking measurements.
Do not scrape the sail cloth with the micrometer while positioning for a measurement or during removal, as this may result in a resin build up on the measuring surfaces, which can cause erroneous readings.
When taking double thickness measurements, which will be necessary to measure in the body of the **sail**:

a) Fold but do not crease the **sail**.
b) Open the micrometer wide enough to enable the jaws to pass over the doubled roll without scraping.
c) If the **ply** has no scrim, place the feeler gauge between the two **ply** layers. This prevents the surface of one layer meshing with the other. Subtract the feeler gauge thickness from the micrometer reading.

Stiff cloth may require two or more padded clamps carefully placed near the point of measurement to hold the two layers together.

Re-check for clean measuring surfaces and zero or re-calibrate frequently, especially before re-checking measurements close to or outside specified class limits.

15.2.8 Reinforcement

Check **class rules** for the permitted limits and material of **primary** and **secondary reinforcement**.

15.3 Condition of Sail During Measurement (ERS H.4.1)

15.3.1 General

The **sail** shall be as required by ERS H.4.1 and be at ambient humidity and temperature.

15.3.2 Shape of the sail edge (ERS H.4.1)

To check the shape of the **sail edge** the **sail** shall be flat in the area being checked. This is achieved as follows: -

a) lay the **sail** out on a flat surface. Figure 10
b) fold or flake the **sail** as shown in Figure 11
c) work any wrinkles near the edge into the fold
d) Without pulling out the fold, apply just sufficient tension to the edge to ensure it is flat.

The shape of the edge, which should now be flat, can be gauged against a straight line produced by a string, or the edge of a measuring tape, stretched along the edge of the sail.

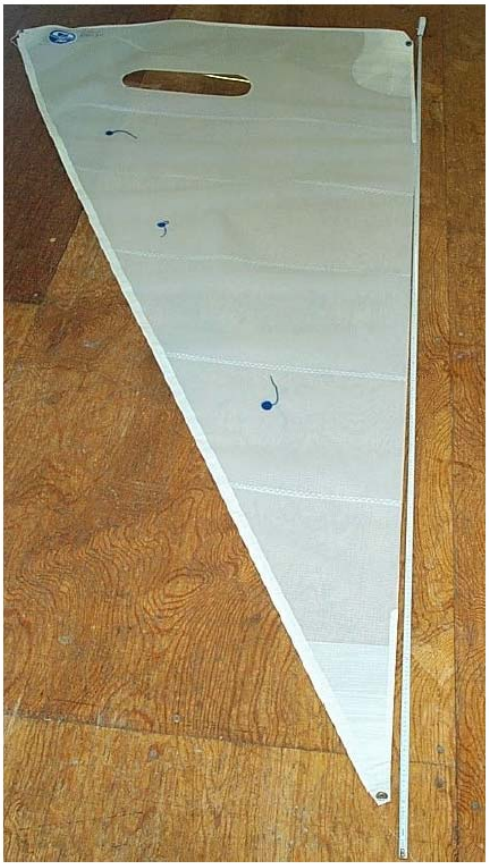


Figure 10. Sail before flaking

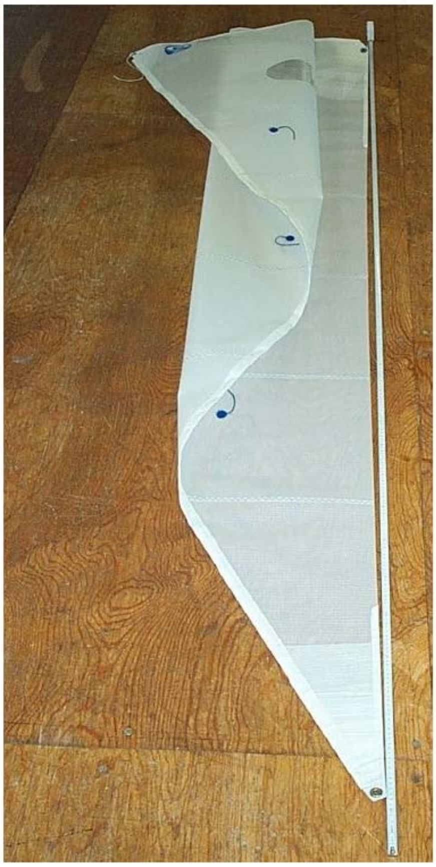


Figure 11. Sail after flaking

15.4 Other Measurements (ERS G.8)

15.4.1 Reinforcement size (ERS G.8.4)

Corner **reinforcement** size, whether **primary** or **secondary**, is measured from the **corner measurement point**, which may be outside the **sail**. The measurement is the greatest dimension from the **corner measurement point** to the outer edge of the **reinforcement**, and should be found by swinging an arc with the tape as illustrated in Figure 18. Permitted **tabling** is not included in the measurement of **reinforcement**.

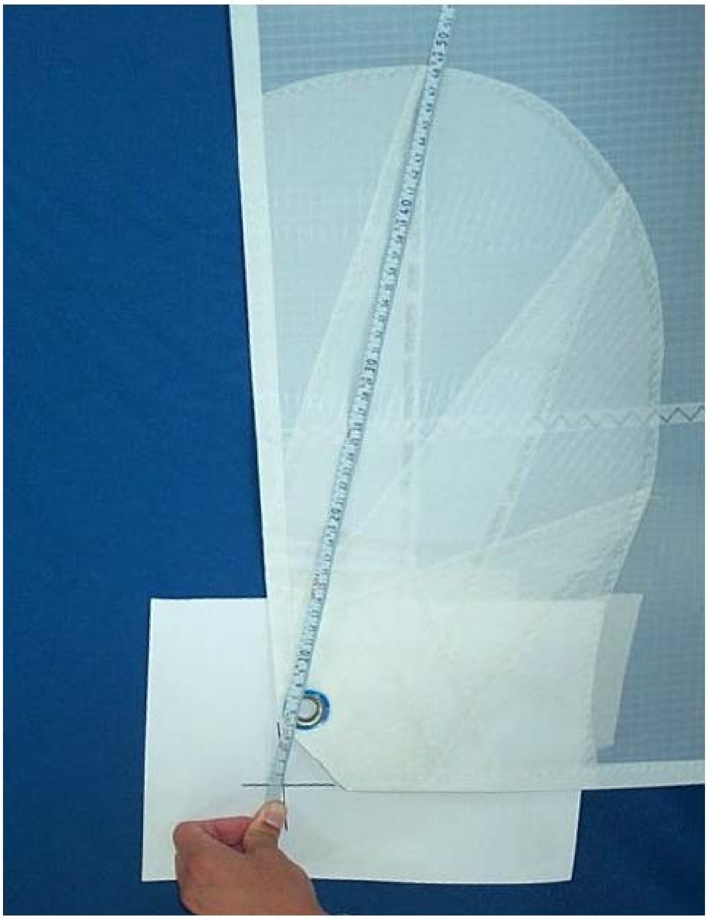


Figure 18. Clew Reinforcement

The measurement of any **reinforcement**, other than at one of the corners of the **sail** shall be taken to be the greatest dimension between any two points of the same **reinforcement**. This may not necessarily be continuous across the **reinforcement**.

15.5 Sail Numbers (RRS 77 & RRS Appendix G)

Measurement requirements for the size, shape and position etc. of class insignia, national letters and sail numbers are laid down in RRS 77& RRS Appendix G, and in most individual **class rules**. These shall be checked when required to be so by **class rules** or an MNA.

Where there are differences between the RRS and **class rules**, the **class rules** shall prevail. Where **class rules** invoke the RRS then, except when altered by **class rules**, the RRS shall be applied.

RRS Appendix G - 1.2(a) requires, amongst other things, the national letters and sail numbers to be "clearly legible". Determination of this requirement will be relative and is not strictly a matter of measurement.

Several classes specify the colour of insignia, letters and numbers. Where this is not the case, the RRS Appendix G - 1.2(a) rule should be applied. This requires the national letters and sail numbers (but not the insignia) to be of the same colour.

RRS Appendix G - 1.2(b) gives the boat's overall length as the criteria for character size and the space between adjoining characters. Overall length shall be taken as **hull length** (ERS D.3.1).

RRS Appendix G - 1.3(a) requires the class insignia, national letters and sail numbers on the starboard side of mainsails and headsails to be higher than those on the port side. For clarity, each of these items should be treated separately, i.e. the starboard insignia should be higher that the port insignia (subject to 1.3(b)), the starboard national letters shall be higher than the port national letters and the starboard sail numbers should be totally above the port sail numbers.

RRS Appendix G - 1.3(c) requires that, on sails measured after 31 March 1997, where national letters are displayed, these are placed above the sail numbers.

15.6 Advertising (RRS 79 & RRS Appendix G)

The size and position of permitted advertising on sails is governed by RRS 79 & RRS, Appendix 1.
There are two categories of advertising, A and C with Category A permitting only limited advertising and Category C much more advertising. There is no category B. The Category permitted for a particular boat will normally be as specified in **class rules.** If it is not specified in **class rules,** Category A will apply. **Class rules** may only specify the Category; they may not change the requirements of the RRS Appendix.

For Category A boats (the default category), the only advertising permitted on a **sail** (in addition to the class insignia) is one sailmaker's mark per side. Each mark shall fit into a 150mm x 150mm square and, except on a **sail** measured as a spinnaker, shall be totally within a distance from the **tack point** of either 300mm or 15% of the **foot length**, whichever is the greater. This limit should be measured in a similar manner to corner **reinforcement.**

Figure 19. Measuring limit of sailmakers mark

15.7 ICA Sail Buttons and Labels

Some classes require all **sails** to carry an ICA sail button or label. These are a means of raising revenue and can normally be purchased from the class association. Where the **class rules** lay down a requirement for sail buttons or labels no **sail** shall be accepted by a measurer unless the button or label is securely attached to the **sail**.
Buttons and labels are not transferable from one **sail** to another and therefore the measurer, when satisfied that the **sail** complies with all the relevant rules, should sign or stamp across the button or label and onto the **sail**. This is in addition to the normal sail **certification mark**.
It follows from this that a measurer should refuse to sign a **sail** where the button or label already has a signature across it.

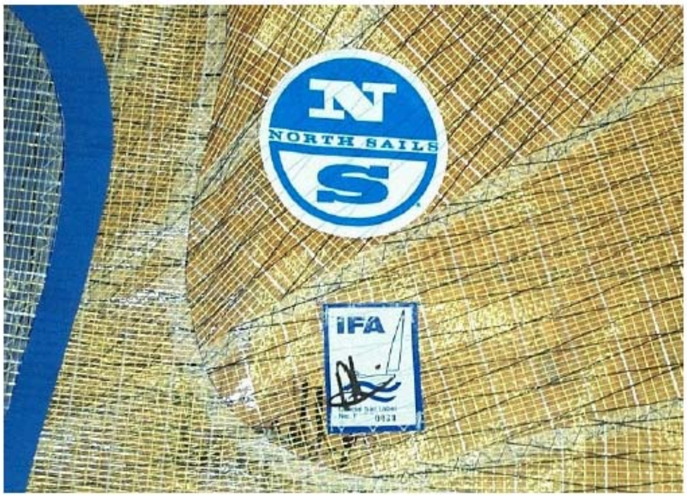


Figure 20. Mainsail tack with Sail Label

15.8 Certifying and Certification Marks (ERS C.6.3)

When satisfied that a **sail** complies with all applicable rules, the measurer is required to **certify** it by the attaching a **certification mark**. This is undertaken in different ways in different countries. In Germany, for example, the **certification mark** takes the form of a sail button marked DSV (Deutscher Segler-Verband).

Other countries use **certification mark** labels or stamps. The ISAF recommendation is a stamp or label of the design shown in Figure 21. Printed in black would indicate **official measurer** measured where as in red would indicate "in-house" certification.

Figure 21. Certification Mark labels from Sweden

In the absence of any specific national or class requirements, the measurer should **certify,** by signing and dating, the **sail** in the **tack** on mainsails and headsails and in the **head** on spinnakers. **Event limitation marks** should be in the **clew**. In addition, to enable a particular **sail** to be identified in the future, if it is not marked with a manufacturer's serial number then the measurer should add one. Also, if **class rules** limit the number of **sails** permitted to be used by a single boat then, to prevent the swapping of **sails** between **boats**, the measurer should add a sail or plaque number to the **mark**. A measurer should keep a record of all **certified** sails, detailing the date and serial number of each against the sail or plaque number of the boat. In addition, if required by **class rules**, this information should also be added on the **certificate**.

16 SAIL AREA MEASUREMENT

16.1 GENERAL

There are only a few classes which require sail area to be found in a manner other than by a simple formula indicated in the class rules. These classes include **the International Moth, A-Cat, C Class Catamaran, 10 square Metre division of multihulls and some other classes.** For these classes the ISAF Sail Area Measurement Instructions apply.

16.2 ISAF SAIL AREA MEASUREMENT INSTRUCTIONS

The Sail Area Measurement Instructions have developed over a number of years with various editions being published from time to time. Accordingly, before proceeding to measure a sail the class rules should be examined to see which set of Measurement Instructions is to be used. If no indication is given, the current edition is the one to be applied.

The current Sail Area Measurement Instructions are quoted here below.

16.2.1 Preliminary remarks

The intention is to establish a reliable and simple method of measuring the whole driving area of the sail plan, including the spars, foils and flaps (for wing sails).

It is not possible to frame methods to deal with every eventuality and therefore in the case of unique or difficult shape of rig, the measurer may need to use his judgement in dividing the rig for measurement in order to calculate the area accurately. Combined rigs such as a soft trailing edge on a heavily shaped wing spar or a rig where the camber and shape is produced by tensioning when it is on the boat, may be more conveniently and equitably measured in an “assembled for sailing” condition, rather than in component parts. In this cases the measurer shall record the method used.

Elements of the sail plan which are vertical, or nearly so, when the boat is not heeled shall be measured. Elements of the sail plan which are horizontal or nearly so, when the boat is not heeled, such as fences and end plates, are not measured provided that:

a) The surfaces of such elements are not able to make an angle, measured at right angles to the fore and aft axis of the boat , greater than 10° to the horizontal when the boat is not heeled, and,
b) the total area of their surfaces does not exceed ten per cent of the measured sail area excluding such surfaces.

For the purpose of measurement of sail area the term “sail” shall be deemed to be that part of a soft sail outside the spars and includes the headboard, tabling and battens which extend beyond the edge of the sail. It shall not include cringles which are wholly outside the sail or bolt or foot rope which are inside the spars.

The area of any hole in the sail, the maximum dimension of which does not exceed 50 mm, shall not ne deducted from the measured area.

16.2.2 Spars and “wing” sails

a) The guiding principle is the first sentence of 16.2.1. Except as provided in d) below, the area of that part of any spar (including the luff spar of a headsail) or wing sail which projects above the shaeerlinne, shall be measured.
b) Devices of fairings added to a spar or wing sail shall be measured as part of that spar or wing sail.
c) - If the mast, spar, flap, or sail is of constant section throughout its length then the area shall be its length multiplied by the mean half girth.
   - If the mast, spar or sait is not of constant section, and its profile forms a fair curve or curves, it shall be divided into a suitable number of equal lengths and Simpson's Rule used to calculate the area, using the half girth measurements (see e)) as offsets

Simpson's Rule is:

Area = L (a + 4b + 2c + 4d + 2e ………………. 2x + 4y + z) / 3

Where L is the uniform distance between offsets and a, b, c, d, e,………….x, y, and z are offsets.
Note: there has to be an odd number of offsets.

d) If the mast, spar or sail is not of constant section and its profile is not a fair curve, it shall be considered as a number of trapeziums and the half-girth measurements shall be found at the end of each. The sum of the areas of ail the trapeziums is then the area of the mast, spar or sail.

(e) The girth measurement shall be taken as the distance from the centrel ine round the surface of the spar or wing saï 1 to the same point on the centreline. The resultant dimension shall be divided by two to give the half girth measurement.

An articulated wing saïl, such as that shown in fig. (16.1) below, shall be measured as described in 16.2.2 above except that the skin girth shall be taken over all the sections when they are in the position which gives the greatest girth.
Note: the greatest girth may occur when the sait is at maximum camber. See fig (16.2).

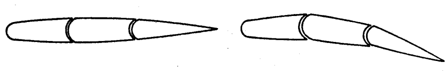


Fig. 16.1

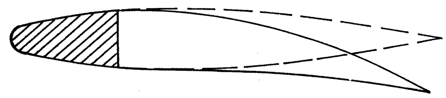


Fig 16.2

If, with the adjacent sections of an articulated sail in any position, the leading edge of one section is always recessed into the aft side of another, the sail shall be measured as in the above paragraph. For the purpose of this clause a fairing permanently attached to the sait shall be considered to be part of the sail.

A spar which supports the rig on which no sail is set directly, (e.g. a bipod straddling the hull, a structure fore and aft to support a main staysail or boom from which a loose footed sail is set) shall not be included in the measured sail area provided the maximum vertical or fore and aft dimension of the spar does not exceed one and a half times the maximum horizontal or transverse dimension.

The measured area of a boom shall be taken as its overall length multiplied by its mean depth in the vertical plane.

16.2.3 Soft sails set on spar (s)

When the saïl is set on spars and between measurement bands the distance between the bands is used to obtain the primary dimensions of the main triangle.

Area Using Measurement Bands

a.- With battens set in their pockets the sail shall be pegged out on a flat surface with just sufficient tension to remove waves or wrinkles from the edge rounds and to spread the sail, as far as possible, substantially flat. Once the sail has been pegged out in this way all the required measurements shall be taken and no alterations to the tensions shall be made.

b.- Needles shall be fixed at the head and clew, making allowance for that part of the sail inside the spars so that the distance between the needles is the length of the leech. A third needle shall be fixed at a point so that it is the distance between the measurement bands on the mast from the head needle and also the distance of the boom measurement band from the mast from the clew needle. If the boom is shorter than the foot of the sail or if there is no boom the lèngth of the foot shall be that found by measurement with the sail set on the mast. A thin line shall be stretched round these needles to define the main triangle. See figure (16.3).

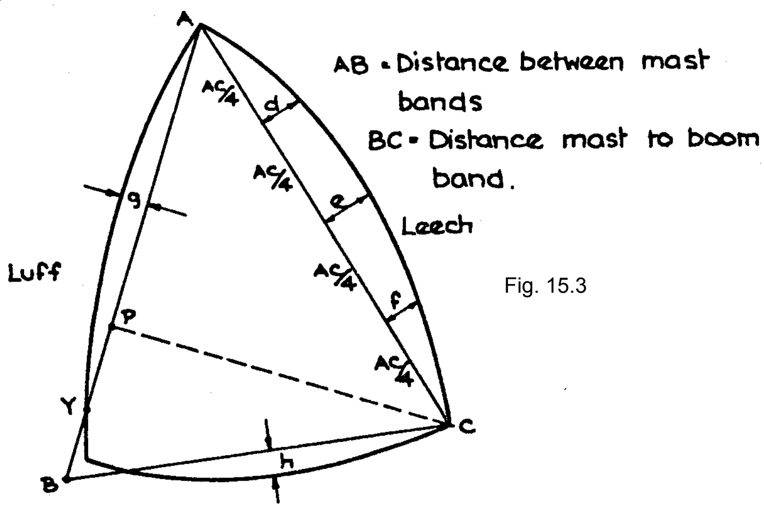


Fig. 15.3

The area of the main triangle shall be calculated from one of the following formulae or by a scale drawing.

(1) Area = $[(s \cdot (s-a) \cdot (s-b) \cdot (s-c)]^{0.5}$

where $s = (a+b+c) / 2$

and a = length of luff

b = length of leech

c = length of foot

(2) Area = $(AB \cdot CP) / 2$ where CP is the minimum distance from C to the thread from A to B.

The area of the luff round shall be calculated and added to or subtracted from the area of the main triangle. If the curve is fair and continuous its area shall be taken as two thirds of the product of the chord length and the maximum perpendicular offset to the chord. In fig (16.3) above the area of the luff round is $2 \cdot g \cdot (AY) / 3$.

The offset to the chord shall be taken as the maximum distance between the point on the sail corresponding with the aft edge of the mast, and the thread defining the main triangle.

The area of the leech round shall be found as follows:

Either (a), where the leech is a continuous fair curve from point A to point C in fig (16.3) the area is taken as

$AC \cdot (1.16 \cdot d + e + 1.16 \cdot f) / 4$.

where: AC is the leech length indicated in fig. (16.3); d, e and f are the perpendicular offsets between the points on the thread from A to C 1/4, 1/2 and 3/4 of the distance between the leech measurement points A and C and the edge of the sail. For the purposes of the measurement of the offsets, any hollows in the leech shall be bridged.

Or (b), where the leech is not a fair curve front point A to point C in fig. (16.3) the area of the leech round shall be found by dividing the area into trapeziums, triangles and segments and measuring each. For the purpose of this instruction the area of a segment shall be taken as two thirds of the product of the chord of the round and the maximum perpendicular offset to the chord.

The area of the foot round, if the sail can be pegged out substantially flat, shall be measured in the same manner as the luff round.

Where the foot has a "shelf1' or a substantial amount of shape so that when the foot is extended there is loosed or bulging material above it; then the area of the "flow" of the bulging material shall be determined as follows (see also fig (16.4) below).

A measurement shall be taken from the straight line joining the tack to the clew, in the way of the greatest fullness, to an arbitrary point where the sail does lie flat.

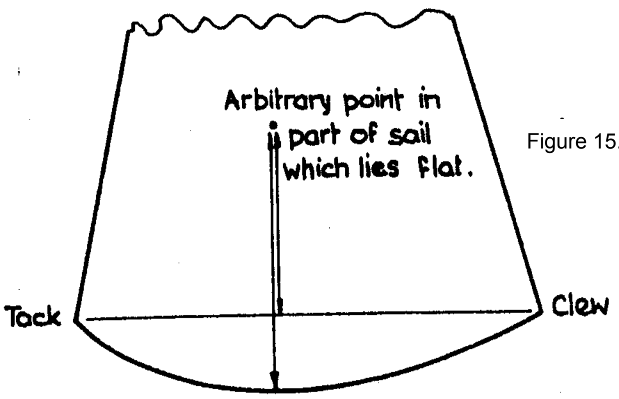


Figure 15.4

A second measurement is then taken from the arbitrary point of greatest fullness following the folds or bulges or material.

The difference between the two measurements represents the offset of the rounded foot. The area of the foot round is taken
as two thirds of the length between the tack and clew multiplied by the offset.

The area of the shape BYTX in fig (16.3) is not deducted from the area of the main triangle.

Where there are no Measurement Bands (limit marks) on the Spars

a. With the battens set in their pockets the sail shall be pegged out on a flat surface with just sufficient tension to remove waves or wrinkles from the edges and to spread the sail, as far as possible, substantially flat.

b. Needles shall be fixed at the head, tack and clew. A thin fine or thread shall be stretched tight between head, tack and clew ta define the main triangle.

c. The area of the main triangle shall be calculated in the manner indicated in the previous section.

d. The area of the luff, leech and foot rounds shall be found in accordance with the instructions above.

16.2.3 Soft sails not set on spar

a. A soft sail which is not set on a spar, such as a headsail, set on a stay or flying, shall be measured in accordance with instruction above, except that if the leech has an offset not exceeding 5 per cent of the leectl length and is a fair curve the area of the leech round shall be measured in accordance with 16.2.3

b. If the luff of the sail is wired, sufficient tension shall be applied to remove bends or kinks in the wire.

16.2.4 Sails of unusual shape

The foregoing instructions assume that the sails are essentially triangular.
If a quadrilateral or multilateral sail is to be measured the sail is to be divided into suitabie triangles whose area can be measured and added. The areas of the luff, foot and leech rounds shall also be added, or subtracted as the case may be. The measurer shall record the method he has used to assess the area of the sail.

16.2.5 Spinnaker

The area of the spinnaker shall be taken as:

(SF • SL) / 2 + 2 • (SMG – SF / 2) • SL / 3 where:

SF = Width of foot; measured round the edge of the sail between the lowest point on the leeches.
SL = Leech length, measured round the edge of the sail from the highest point on the sait at the head to the lowest point of the sail on the leech. If the two are not equal, SL shall be the mean of the two leech lengths.
SMG = Width at half height; shall be taken as twice the distance between the mid-point of the leeches and the nearest point on the centrefold. The mid-point of the leech shall be determined by measuring round the edge of the saïl half the length of the leech from the head.

16.3 RECORDING MEASUREMENTS AND CALCULATIONS

Because of the various ways in which a sail can be divided up for measurement, the measurer is required to state clearly the method he has used and show his calculations to support the answer he has obtained.

16.4 TEST CASE: THE MOTH SAIL MEASUREMENT (Taken from the Moth Class manual)

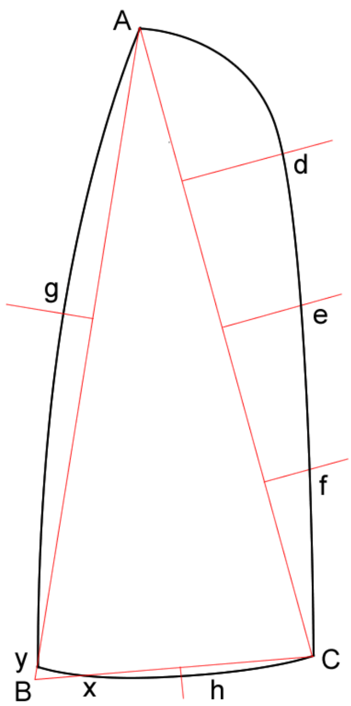
a. ISAF Rules for Sail Calculation

This method is valid for sails measured until 31.12.2004. After that date only the triangulation (chapter 9.5 b) may be used.

If a sail has not a triangular shape including a smoth curve for the leach the triangulation has to be used also because the formula for the leach does not cover unusual leach curves.

The twine should be stretched around these points (A, B and C) and tensioned until they revert to the same position once 'twanged'. Foot, luff and leach rounds should then be secured by bulldog clips fastened to short skewers, to prevent any transfer of areas.

Here follows an example using hypothetical measurements, of how to measure the sail using the ISAF-Rule method:



- AB has been measured from the spar as 5.185m twine set to this dimension.
- BC (say 2.000 m) is determined by measuring the foot length from Point C to the tack of the sail.
- Look along the luff to where the twine intersects the inside of the bolt rope or luff on a pocket luff sail at point (X).
- Take measurement AX (say 4.900m).
- Measure the maximum perpendicular offset (g) to the inside of the bolt rope or luff on a pocket luff sail at this point, using a tee square and small tape (say g = 0.150m).
- Similarly find where the twine cuts the foot of the sail at Y and measure CY (say 1.900m). Measure the maximum perpendicular offset (h) along CY (all as described for the luff round) (say h = 0.080m). Where the foot has a shelf or a substantial amount of shape so that when the foot is extended there is loosed or bulging material above it, a measurement shall be taken from the straight line joining the tack to the clew, in the way of the greatest fullness, to an arbitrary point where the sail does lie flat. A second measurement is then taken from the arbitrary point of greatest fullness following the folds or bulges or material. The difference between the two measurements represents the offset of the rounded foot.
- Next measure AC (say 5.200m).
- Divide this by four to give you the measuring intervals (eg, 5.200 / 4 = 1.300m), measuring stations are therefore at 1.300m, 2.600m and 3.900m from either A or C.
- Mark with a cross on the sail where each one of these stations occurs (on the line of the stretched twine) and using the twine as a base line project perpendicular offsets to the leech at each station and mark where this crosses the leech.

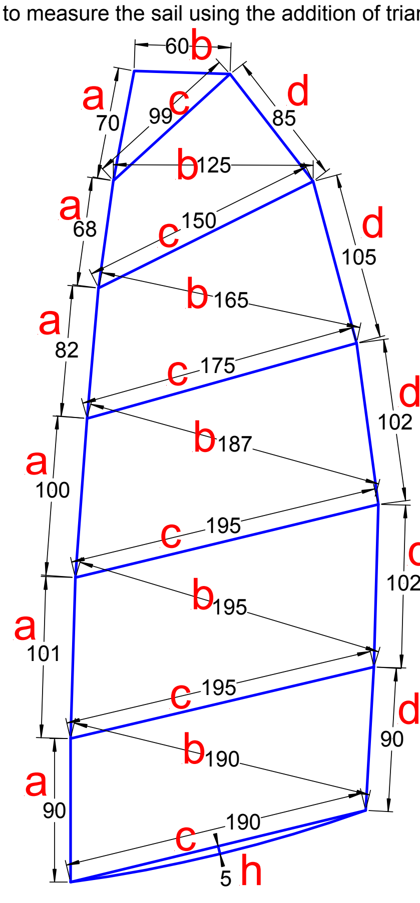
- Measure each offset with a square in turn d, e, f. (say 0.600, 0.500, 0.400). Your measuring should now be complete, assuming the sail does not exceed 8.00m2, but you are advised to leave it pegged out until the areas has been verified.
- The main triangle ABC is calculated using the half circumference S = (AB+BC+AC) / 2 with the formula: Area = √[S (S-AB) (S-BC) (S-AC)]
  [in the example: S = 6.193 m and Area = 5.095 m²]
- The foot area is calculated by: Area = 2/3 BC * h [in the example 0.101 m²]
- The luff area is calculated similar: Area = 2/3 AY * g [in the example 0.490 m²]
- The leach area ic calculated by: Area = AC/4 * (1.16d + e + 1.16f) [in the example 2.158 m²]
- The total area is summarized by main triangle, foor area, leach area and luff area
  [in the example 7.84 m²]
- All calculations have to be carried out to the 3rd decimal, which is rounded between 4 and 5
- The final result will be rounded down to 2 decimals.

b. Triangulation

Any sail measured after the 31.12.2004 has to be measured using the triangulation. Also sails with unusual shape, which are measured befor 1.1.2005 have to be measured by triangulation.

For the triangulation the sail has to be divided into a number of suitable triangles. Any arrangement of the triangles on the flattened sail is possible. For a common moth sail the subdivision according to the diagram is recommended, because a computer-spreadsheet is available to calculate the area of the triangles.

- Here follows an example using hypothetical measurements, of how to measure the sail using the addition of triangle areas method:Determine head point “A”, tack point “B” and clew point “C” as described above. (The tack point “B” is **not** identical with the Point “B” used in the ISAF method. It is the real tack point as described in the diagram above.)
- Mark the sail with crosses at both ends of the intersection centerline batten / sail. At the luff use either the inner side of the luff rope or prolong the centerline of the batten to the forward edge of the sail, if it is around the mast.
- The area between the battens (BC is treated as batten) is divided into two triangles by a diagonal, which always starts at luff segment top and ends at leech segment bottom.
- Each quadritateral consists of the bottom “c”, the 2 sides (luff “c” and leach “d”) and the diagonal “b”. The top is used as bottom for the upper quadrilateral.
- The top of the sail has only 3 lines, because the leech segment is the diagonal [b].
- Measure all distences “a” along the luff curve, all diagonals “b”, all battens “c” and all leechs segments “d”. At the top of the sail the leech segment “d” is ommited, because the diagonal represents that part of the leech.
- Measure the foot offset “h” as biggest perpendicular offset of the foot curve from the line BC if applicable.
- Put all values into the spradsheet and choose the additional calculation options for luff round or foot round sails.
- For the manual calculation the formula for the main triangle (ISAF-rule) can be used, using the distances a, b and **lower** c for the first triangle and the distances b, **upper** c and d for the second triangle.
- Example using the rows 10 and 9 for the lowest quadrilateral:
  S = 1/2 * (a10+b10+c10) and A1(10) = Square root [S*(S-a10)*(S-b10)*(S-c10)] for the first triangle and
  S = 1/2 * (b10+c9+d10) and A2(10) = Square root [S*(S-b10)*(S-c9)*(S-d10)]
- The foot area is calculated in the same manner as in the ISAF-rule: Area = 2/3 BC * h



- If the sail encloses the mast, a value of 0.05 * the sum of all segments “a” has to be subtracted.
- If the sail encloses the boom, a value of 0.09 * the lowest segment “c” has to be subtracted.
- The sum of all triangles and the foot area (subtracted by the luff pocket and the boom pocket if applicable) is the sail area, rounded mathematically to 2 digits.

Numerical example using the spreadsheet:

Triangulation	**Area:**	**7.68**	m²		**Version**	4
Luff round ->	**x**	0.256	Measurements in meter !			
Foot round ->		0.000	h	0.050	Foot area	0.063

		Luff	**Diagonal**	**Batten**	**Leech**				
	No.	**a**	**b**	**c**	**d**	S1	A1	S2	A2
Top	1					0.000	**0.000**		
	2					0.000	**0.000**	0.000	**0.000**
	3					0.000	**0.000**	0.000	**0.000**
	4					0.000	**0.000**	0.000	**0.000**
	5	0.700	0.600	0.990		1.145	**0.207**	0.000	**0.000**
	6	0.680	1.250	1.500	0.850	1.715	**0.421**	1.545	**0.419**
	7	0.820	1.650	1.750	1.050	2.110	**0.671**	2.100	**0.772**
	8	1.000	1.870	1.950	1.020	2.410	**0.919**	2.320	**0.880**
	9	1.010	1.950	1.950	1.020	2.455	**0.951**	2.460	**0.960**
Bottom	10	0.900	1.900	1.900	0.900	2.350	**0.831**	2.375	**0.841**
	Luff ->	5.110		Foot					

When measuring a sail using either the ISAF-Rule or the addition of triangle areas, the IMCA sail area calculation Excel spreadsheet will assist.

With the exception of the area reduction allowed by the rules for sails that enclose the mast or boom, small areas where there is no sail material present near the tack, head or clew should not be subtracted from the total sail area. An example of this would be where the luff pocket ends before the tack point.

When the sail area has been calculated as complying then the sail should be signed and dated in indelible ink near the tack.

If a sail calculates to 8.004m2, please remember that this does not exceed 8.00m2 when rounded to two places of decimals at the final total area. Always observe that 5 rounds up and 4 rounds down when applied to the trailing decimal number.

Making a sail 'Measure' If a sail is oversized, once measured, it is the responsibility of the owner to determine how to make it measure within the 8.00m2 line. This is most commonly done by trimming the foot of the sail.

17 EVENT INSPECTION GUIDELINES

This chapter presents examples of various procedures for event inspection preparation, including selections of sample instructions, regulations and forms. Classes are using a wide variety of systems and forms, and obviously it is impossible to present all existing material in this manual.

17.1 2001 ISAF SAIL MEASUREMENT GUIDE: PART C, EVENT MEASUREMENT

C.1 Introduction

In this part of the guide the term **event measurement** refers to the measurement, inspection, checking and/or control of equipment undertaken at an event solely in support of the event. It does not include any measurement necessary to obtain a **certificate** or **certification mark**, which might otherwise be a requirement of **class rules**. Care should be taken not to confuse **event measurement** with **fundamental measurement**, as a measurer's authority and channel of communications in each case are very different. Although **event measurement** can encompass the complete boat, this guide deals mainly with the measurement of **sails**. If more than just **sails** are to be measured then the recommendations given in this guide should be included as an integral part of the full measurement planning and strategy.

C.2 Event Measurer's Authority

Event measurers obtain their authority solely from the race committee of the event at which they measure (RRS 78.3). **Official measurers** and **International measurers** have no authority to undertake **event measurement** unless specifically appointed for the task by the race committee. ISAF appeal case 57 refers. Should an MNA or CA wish one of its measurers to be involved in **event measurement** then it should ask the race committee to appoint him well in advance of the event. Although it is common practice with a number of classes for **fundamental measurement** to be undertaken just prior to a major event, it is wise for such measurement to be undertaken by a measurer other than the **event measurer**. To act in both capacities creates a conflict of authority. It follows that where an **event measurer** is presented with an item of equipment, which he initially measured, then, if possible, he should pass the item to another **event measurer** for checking. An **event measurer** is under the sole jurisdiction of the race committee to which all formal reports of non-compliance should be made (RRS 78.3). Should an **event measurer** be in any doubt as to the application of a rule or measurement instruction, the question should be referred to the **certification authority** for the class in the country where the event takes place (ERS H.1.4).

C.3 Class Association Authority

A CA has no direct authority or jurisdiction over **event measurement** except in the capacity of an organising authority or part of an organising authority (RRS 87.1). A **certification authority** has no power to invalidate or withdraw the measurement **certificate** of a boat while it is competing in an event. ISAF appeal case 57 refers.

C.4 Racing Rules

The racing rule with most relevance to **event measurement** is RRS 78.3. This is reproduced below.
RRS 78.3
When a measurer for an event concludes that a boat or personal equipment does not comply the class rules, he shall report the matter in writing to the race committee, which shall protest the boat.

C.5 Event Measurer's Responsibility

RRS 78.3 gives **event measurers** initial authority for determining whether or not an item complies with **class rules**. This authority is only held while event measuring. If the measurer formally concludes that an item does not comply, he has no alternative other than to report the matter in writing to the race committee, which ***shall*** protest the boat. In most cases it is unlikely that a protest committee will take action against a boat until after it has raced and so, in reality, an **event measurer's** strategy in dealing with a boat found not to comply will differ depending upon whether he is acting before or after the boat has raced.

Prior to racing

Prior to racing, and in the case of a series this should be taken to mean the first race of the series, an **event measurer's** prime responsibility is to achieve a state where all equipment complies with the rules. In line with this responsibility, if a measurer establishes non-compliance then he should require correction. It is only after a measurer has done this and the defect is not corrected that he should report the matter to the race committee. In other words, prior to racing the **event measurer** should actively endeavour to achieve rule compliance, but be conciliatory, with the interests of the competitors in mind.

After the start of racing

After racing has started, an **event measurer's** prime responsibility is to judge compliance as required to do so by the race committee, through the Sailing Instructions, or by the protest committee as a result of a protest. When an **event measurer** is given the authority through Sailing Instructions to undertake spot checks, care should be taken in the choice of the items to be checked. It should be borne in mind that there are no alternative penalties for the infringement of an equipment rule. Non-compliance with even a minor, non-performance or nonsafety related measurement rule is likely to lead to disqualification. Measurers should be cautious when checking an item that was not measured prior to racing or which might have inadvertently changed or distorted since **fundamental measurement**. If a competitor deliberately cheats then the item will either be obvious, in which case it is incumbent on another competitor to protest, or be so obscure that it is unlikely to be found by random spot checks. Therefore, after racing has started the **event measurer** should be a reactive policeman in a similar manner to a Juror.

C.6 Event Measurement Planning

Pro-active **event measurement** of **sails** should be undertaken prior to the first race. Subsequent **sail** measurement will be reactive and, apart from ensuring that some measurement facilities are available, cannot be planned. Planning for pre-event measurement is usually a matter of "horse trading" between a CA, measurement authority, organising authority and the **event measurer** as to the amount of time, help and money available for the job. Before planning is started, the **event measurer** should open lines of communication with these organisations and continue to consult them on all matters of planning and resources. This dialogue will also highlight measurement concerns and areas where measurement data is needed, and may be important in cases where rule interpretations are required. Consultation should be started in sufficient time to enable the **event measurement** requirements to be included in the Notice of Race and Sailing Instructions.

C.7 Sail Limitations

It is important to know whether or not the event will be subject to **sail** limitations where each boat is permitted to use a limited number of mainsails, headsails and spinnakers. **Sail** limitations will help to provide an estimate of the number of **sails** to be measured and will also mean that **event limitation marks** have to be applied as a priority measurement task, with appropriate rubber stamps and ink pads available. If **sail** limitations are not in force then an indication of the likely number of **sails** each boat will use will be required. This will vary from class to class.

C.8 Time, People and Money

Start the planning process by calculating the amount of time needed to measure all **sails** fully. Apply the expected number of entries and the number and type of **sails** each is likely to use to estimates of time needed for measurement as given in the tabulation below. For example - if there are likely to be 50 boats each with two mainsails, two headsails and two spinnakers then, using the tables below, the total time will be: (50x2x10½) [Mainsail] +(50x2x7)[Headsail]+(50x2x7½)[Spinnaker] = 2,500 mins
increase this time by 20% as a contingency   2500 x 1.2 = 3,000 mins i.e. 50 hours
this estimate can be used to assess the time and the number of measurers/helpers needed. A typical event measurement day is 10 hours and the measurement team needed to measure each sail will consist of a measurer and a helper. (The owner/competitor should not be included as the helper). Taking the 50 hours requirement from the above example would give 5 days using one measurement team or 1 day using 5 measurement teams or any variation in between. If it is not possible to achieve the day/team requirement then the extent of measurement will need to be reduced until a balance is reached. This should be undertaken by omitting the measurement of the least performance related items as listed in the tables below. Omit items from the bottom of each table first and move up the lists omitting items until the balance is reached. Note that limitation stamping must not be omitted if the event is subject to **sail** limitation rules. Whatever is finally decided regarding measurement time and the number of measurers/helpers, this must be agreed with the organising authority and referred to in the Notice of Race and Sailing Instructions.
Each of the following tables lists individual **sail** measurements in the order in which measurement should be undertaken together with the approximate time needed for each. The times assume template measurement for mainsail and headsail and batten measurement for spinnakers with all measurement undertaken on tables.

Mainsail	Mins
Limit Marking and recording	2
Leech Length Half Width Three-quarter Width Quarter Width Upper Width Top Width Foot Length Luff Length	2
Cloth Type Cloth Weight	1
Upper Batten Pocket Position Upper Batten Pocket Length	1/2
Primary Reinforcement at Corners Primary Reinforcement elsewhere Secondary Reinforcement at Corners Secondary Reinforcement elsewhere	1
Lower Batten Pocket Position Lower Batten Pocket Length	1/2
Intermediate Batten Pocket Position Intermediate Batten Pocket Length	1/2
Tabling Seams Window area Window position Class insignia Sail numbers Sailmaker's mark	3

Headsail	Mins
Limit Marking and recording	1
Luff Length Leech Length Foot Length Foot Median Luff Perpendicular Top Width	2
Cloth Type Cloth Weight	1
Primary Reinforcement at corners Primary Reinforcement elsewhere Secondary Reinforcement at corners Secondary Reinforcement elsewhere	1
Tabling Seams Window area Window Position Sailmaker's Mark	2

Spinnaker	Mins
Limit Marking and recording	1
Leech Length Foot Median Foot Length Diagonals Half Width Three-quarter Width Quarter Width	3
Cloth Weight	1
Primary Reinforcement at corners Secondary Reinforcement at corners	1/2
Tabling Seams Sail Numbers Sailmaker's mark	2

C.9 Measurer's Fees

Any fees or expenses required by the measurers are the responsibility of the organising authority. It is important that agreement on this point is made prior to the event. The **event measurer** should not assume payment or expect to cover costs direct from competitors.

C.10 Facilities

Event **sail** measurement should be carried out under cover in good conditions of light, without wind or draughts. Ideally measurement should be carried out on tables. These should be about 85-90 cm high with a single flat working surface, although separate tables with their legs taped together will often suffice. Measuring on tables eliminates the need to bend down and to kneel and thus minimises the fatigue associated with **sail** measurement. If tables are not available then a gymnasium or dance floor is a good measuring surface. If the only available floor is concrete this can be covered with polythene sheeting taped down over the measurement templates. Measuring on grass will not give satisfactory results. Allow sufficient room for all measurement teams to be working simultaneously. A table and chairs should be provided for each measurement team and food and drink should be available at normal times.

C.11 Preparation

a) Documentation
In addition to the RRS, ERS, **class rules**, Measurement Forms, interpretations and the Guide to Sail Measurement etc, an event measurement form, a measurement log and a sail number change request form will be needed. The event measurement form, issued to competitors upon registration, should detail the boat and its sail and plaque number (taken from the **certificate**) and give advice as to where and when to attend for measurement, the number of **sails** permitted, the state in which they should be presented, and a section enabling the **event measurer** to record measurement details and stamp. The final part of the form, the declaration, should be signed by the competitor upon completion of measurement. This declaration officially confirms the items marked and that they will not be changed during the event without the prior approval of the Jury. The measurement log, which is often a simple exercise book, should be used by the measurer to record the number of **sails**, their serial number, manufacturer etc. against each of the boats competing in the event. It is recommended that at least one separate page is used for each boat and, within the time available, as much relevant information as possible is recorded. The sail number change request form should be a proforma for issue to

competitors wishing to request the permission of the race committee to use **sails** displaying different sail numbers from those required by their **certificate** and **class rules**. This is a request for a dispensation under RRS 77 & RRS Appendix G. These forms are not specifically related to measurement but do help to reduce time and are convenient for competitors.

b) Setting out
Event sail measuring to the ERS should be undertaken using templates and measuring battens for small and medium size **sails**. Large **sails** should be measured with steel tapes.

c) Mainsails and Headsails
CAs will often have ready made mylar or similar area check templates which, if possible, should be used. These can be laid flat on the measuring surface, taped or pinned down and checked against the **class rules** for accuracy using **fundamental measurement** procedures. If ready made templates are not available they can be created using masking tape directly on the measuring surface. If measurement is to be undertaken on a polythene sheet then the masking tape should be fixed to the surface below the sheet. Use actual **sails** to help position and lay out templates.

d) Spinnaker
Because of the difficulty in laying spinnakers flat, it is not advisable to measure these using templates. For small sized spinnakers measurement battens are recommended. If these are already available from the CA then the dimensions should be checked prior to use. Alternatively it is quite easy to make suitable battens, marking the dimensions with felt tipped pens. For large spinnakers, measurement with a steel tape using **fundamental measurement** procedures is recommended.

e) Reinforcement and sail numbers
For **reinforcement** and sail number sizes, perspex or rigid polythene transparent templates may be used. These can be placed over the item being measured and any deviation in size seen through the template.

f) Batten Pocket Lengths and Widths
Batten pocket length, inside and outside, and width may be checked using measurement battens similar to those used for spinnaker measurement.

g) Other Equipment
In addition to templates and battens, equipment recommended for **fundamental measurement** should also be available.

C.12 Undertaking Measurement

C.12.1 Prior to racing

a) Certification mark checks
Prior to measurement, checks should be made to verify that the sail number displayed on a **sail** corresponds with that of the boat and also that the **sail** possesses an authentic **certification mark**. If the sail number is different from the boat, the competitor should complete a sail number change request form for submission to the race committee. If a **sail** does not posses an authentic initial **certification mark** as required by most **class rules**, it should not be measured. The competitor should be asked to present an alternative **sail** or to arrange for independent initial measurement prior to resubmitting the **sail** at a later time.
Event measurers should be aware of the common misunderstanding that a **sail** has been measured and **certification marked**, usually at a previous event, when in fact such was purely check measurement. Sometimes **event limitation marks** have been marked at the tack and not the clew contrary to ISAF recommendations.

b) Limitation marking
Where the event is subject to sail limitations each sail to be used should be marked prior to the first race. Marking should be undertaken only when the measurer is satisfied that the sail complies with pre-event measurement requirements. The **event limitation mark** should be positioned at the clew. Additionally, on headsails, the sail number of the boat should be added next to the **event limitation mark** to enable the sail is attributed to the correct boat when checking **event limitation marks** during the event. Similar marking techniques as those used for initial sail **certification marks** may be used, although the mark will probably be to a unique design and if possible state, "sail limitation mark".

c) Mainsail Measurement
When checking a measurement by template, the sail shall be pulled with sufficient tension to remove the wrinkles across the line of the measurement, as specified in ERS H.4.1. The sail should be laid on the measuring template so that the **head point** is on the template's zero head point and the **clew point** is on the graduated scale of the template leech line in the area of the clew. Use the normal sail measurement batten to determine corner points if necessary. The measurer should be at the clew with helper at the head. The measurer should advise the helper of the gradation upon which the **clew point** rests and the leech points marked on the sail at the corresponding leech gradations. Lengths and widths may now be measured and the **batten pocket** positions and **top width** checked. If any of these is close to the rule limits then it should be rechecked using **fundamental measurement** procedures.
Cloth type and weight are checked using a standard thickness micrometer and feeler gauge.
The measurement helper can next check the inside and outside **batten pocket** lengths and widths, using measurement battens, at the same time as the measurer checks **reinforcement** and sail number using a perspex template. Any remaining measurement can be carried out using either perspex templates or battens as appropriate.

d) Headsail measurement
The headsail should be checked in a similar manner as the mainsail.

e) Spinnaker measurement
Due to difficulty in laying a spinnaker flat, it is not recommended that template measurement is used. Accordingly, if widths and the foot median are to be measured, it will be necessary to fold the sail to find **leech points** and **mid foot point**. This should be done first, with the points being clearly marked on the **sail**. **Leech length** and **foot median** should be checked against the measuring batten. The helper should zero the batten at the **head point** and the measurer check the **sail** at the other end. The batten should be placed on top of the sail, which should be pulled with the tension as required by ERS H.4.1. The sail may now be moved around under the measurement batten to enable the **widths** to be checked. Cloth weight, **reinforcement**, sail numbers and any other items may be checked in a similar manner as for the mainsail.

f) Action in cases of non-compliance
During pre-race measurement, if a measurer concludes that a sail does not comply with rules, in the first instance, the competitor should rectify the item either by alteration or by the submission of an alternative sail. If the competitor challenges the accuracy of the **event measurement**, the sail should be remeasured, preferably by another measurer, using the **fundamental measurement** procedure. If the sail still proves to be unsatisfactory (or in cases of doubt) the competitor should again be requested to rectify the item. If this request is still refused, the measurer should make a report to the race committee in accordance with RRS 78.3.

g) Recording
During pre race measurement, upon completion of the measurement and prior to stamping the sail, the event measurement form should be completed and details of the sail entered into the measurement log. It is important that the sail can be uniquely identified and so, if it does not possess a manufacturer's serial number or an initial measurer's unique number, the **event measurer** should mark such on the sail.

h) Impounding of sails prior to racing
It is sometimes the case that, subsequent to measurement but prior to the first race and where sail limitation is in force, a competitor decides to change his choice of sails and requests the measurement of alternatives. In such cases, prior to measuring the replacement, the competitor should present one of the previously checked and **event limitation marked** sails for the **mark** to be crossed out or the sail impounded for the duration of the event. Impounded sails should not be returned until after the last race (unless otherwise dictated by the Jury).

C.12.2 After racing has started

The only sail measurement that should be undertaken after racing has started is limitation stamp checking and any measurement required by the race or protest committee. In the latter case it is recommended that this is undertaken using the **fundamental measurement** procedures.

C.13 Notice of Race & Sailing Instructions

The pre and post race measurement requirements should be included in the Notice of Race and Sailing Instructions.

C.14 Measurement Protests & Appeals

a) Who can protest?
A boat and the race committee may protest a boat in respect of class rule and measurement/rating **certificate** infringements. An MNA, CA and an **event measurer** have no right to protest. RRS 60.1, 60.2 and 78.3 refer.

b) Making a report under RRS 78.3
Where a measurer makes a report to the race committee in accordance with the requirements of RRS 78.3, such report should be in writing, giving details of the sail number and plaque number, name and owner of the boat in question, together with details of the **class rule** or rules and interpretations considered defective, at what time these were noted as being defective, what action if any has been undertaken by the owner or representative and whether or not, in the opinion of the measurer, the defect was in existence before and/or after a race. In receiving a report under RRS 78.3 the race committee has no alternative other than to protest the boat. A measurer should bear this in mind and may consider discussing the matter informally with the chairman of the protest committee before making a formal report, particularly if the deficiencies are in respect of many boats.

c) Giving evidence
When asked to give evidence to a protest committee a measurer should restrict his comments to fact and not enter into discussions as to the meaning or interpretation of either class or racing rules. It should also be noted that convention and precedent only exist in cases of official rule interpretation by the authorised authority or racing rule appeal cases. The fact that something was permitted at the last major event of the class does not mean that it should be considered as a precedent for future events.

d) Damaged equipment
A competitor will sometimes request permission from a protest committee to use an alternative sail when that previously measured and limitation stamped has been damaged. The measurer may be asked to give evidence as to whether or not, in his opinion, the extent and cause of the damage justifies a replacement. In such a case the measurer should decline to give evidence respectfully pointing out that the cause and extent of damage to the sail and its possible future use is not a matter dealt with by class rules or measurement but a matter for subjective consideration. The protest committee itself may well be more qualified to judge these matters than an **event measurer**.

e) Class rule interpretation or application
Where, under RRS 64.3(b), a protest committee is in any doubt about the meaning of a measurement rule, it should refer the question, together with the facts found, to the authority responsible for interpreting the rule. This authority will usually be the ISAF, an MNA, or a CA technical committee. It is not an **event measurer**.

f) Action under RRS 69 - Gross Misconduct
Action or the promotion of action under RRS 69 is a very serious matter and should only be entered into after due consideration of all the factors involved in the alleged gross misconduct. To date there have only been two types of incidents where such action has been undertaken involving measurement or a measurer.
The first was where an **event measurer**, whilst carrying out his duties, was verbally abused by a competitor. In such a case only the measurer can judge the degree of abuse and whether or not this warrants promotion of action under this rule.
The second was where there was an undisputed case of either measurement cheating or fraudulent **certification marking**. In such cases, provided that there is no doubt whatsoever, the measurer should not hesitate to promote the initiation of action under RRS 69.

g) Appeals

The right of appeal is dealt with by RRS 70. This permits a race committee to appeal the decision of a jury provided that the race committee was a party to the protest. This would be the case if action had been taken under RRS 78.3 and the protest hearing was not undertaken by the race committee itself. An **event measurer** and a CA have no right of appeal.

C.15 Post Event Action

Subsequent to the event, the **event measurer** should ensure that all impounded sails and any **certificates** retained for the duration of the event are returned to their rightful owners. In addition, a written report giving details of the extent of measurement, any problems encountered and any subsequent action take, should be prepared and passed to the NA and class concerned. The measurer should also prepare a report of the event measurement and submit this to his authorising authority.

17.2 Measurement Preparation & Outline of Stations: OPTIMIST Class

BASICS

The Measurement Area must be close to the boats parking area and the perimeter must be free of cars, vans and trolleys in order to allow a good access to it. It is especially important that the circulation of cars with trolleys do no cross the perimeter in order to avoid problems with the flow of the Teams to be measured. It has to be possible to allow the access to the Area only to those to be measured by means of doors or fences; as well as the organization of flow channels of boats on the perimeter.

The Measurement Area must be indoors with a surface of not less than 200 $m^{2.}$ The entry and exit of the Area should be on opposite sides of the hall in order to allow a proper flow of the Team and equipment to be checked. This small detail is fundamental for a fast and well-controlled process. Inside the Area, there must be 2 lines of measurement control: one for the charter boats (fast way) and another for the rest of boats.

It should be possible to close the Area during lunch time and also at night. Electric Light and power for scales and computers will be needed.

During the races (once inspection is finished), the Area can be used for other purposes, but at least $60m^2$ must remain available for the Measurement Committee in order to do the post race controls (weight of boat, sails, etc).

The Measurement Committee shall have a rubber boat. The suitable size of it is 6m length and 40CV with a central helm in order to allow a safer control but also the towing of competitors to the ashore control. The boat shall have an small mast for the Measurement flag and also a proper anchoring system.

CONTROL OF EQUIPMENT: STAMPS AND STICKERS

The stamp for the sail must be of a size between 5x5 and 10x10cm aprox. and shall include the Championship logo and/or the words “Measurement Control”. If the stamp is small, is better not to use too many letters on it. As waterproof ink dries fast altering the shape of the stamp, it is necessary to have at least 3 stamps.
The ink to be used for the sail and at the markers must be waterproof and must be tested before the event.
Waterproof markers shall be Staedtler Lumocolor F or similar. As the spars are usually black, there’s a need for waterproof markers with white, silver or golden ink.
The plastic stickers shall be 6x3cm size including the logo of the Championship and/or the words “Measurement Control” over transparent background in order to allow a visible signature under the sticker. The number of stickers needed per boat is 6. If the number the entries are 250, there’s a need of 1500 stickers so the recommendation is to prepare about 2000 of them in order to avoid problems.

MEASUREMENT STATIONS :

Code letters and colours of each station have been taken according to those used on former World Championships. The helpers describe below must be competent and available during **all** measurement days. In case of illness, injury or not full-day availability there must be additional helpers which must be trained before starting measurement. The person in charge of each station shall be able to communicate in fluent English.

STATION A: MEASUREMENT SECRETARIAT. CHECK-IN

Function: Receive, check and classify the documentation shown by the Team Leader one hour before the measurement of his or her Team starts. The person in charge must be fluent in English and if possible in other languages (French, Spanish, German, etc…). Once verified the documentation, the measurement forms for the Championship must be fill in (include on them the National Code and Sail Numbers) which will be used on the other stations. Statistics of the used equipment shall be produced on that station (Access or Excel File including Sail Number, manufacturer of hull, sail, spars and foils)

Staff:
1 Responsible shall be experienced on the measurement procedures, but also with the documentation of the Optimist Class. It is suitable to have a peaceful and nice person on that job because it will have to deal with the team Leaders.
1 Helper: it will help the Responsible and be in charge of the entry to the Measurement Hall (check if the boats and equipment were dry or not, buoyancy bags inflated but out of the straps, mainsheet removed from blocks, towing line, foils and spars out from covers, etc..)
Total: 2

Equipment: One table-desk with 2 chairs.
2 chairs for the Team Representatives (Coach and Team-leader).
50 Folders or similar

Measurement Forms (aprox. 275 sets)
One Board (cork or similar)
Pens, pencils, paper, stapler, etc

STATION B: HULL WEIGHT. Green Measurement Form

Function: Check mould numbers, sail number on the mast thwart and ISAF Building Fee sticker (which must be the same than those stated at the green form by the Measurement Secretariat). Check that the hull complies with the weighing specifications (dry, no lines, buoyancy bags out of the straps, etc…) and weight them. Check the accuracy of the scales. It is important to place that station on a levelled concrete (not over wood or grass floors) and protected to the wind

Staff:
1 Responsible
1 Helper
Total:2

Equipment: 1 table with 2 chairs
1 Digital scales for 35Kg. It is suitable a digital scales for 50Kg with a precision of +/- 50gr.
1 Certified Weight of 35Kg
1 Master list with all the controlled boats including weights and correctors if needed..
Wooden pieces of 300, 200, 100 y 50 gr. aprox. (up to 10 or 15Kg)
Pens, waterproof markers, paper, etc

STATION C: HULL CONTROL Green Measurement Form.

Function: Check the items previously defined by the IODA T.C. A random measurement control of boats will be made, which may include: hull shape and materials, positioning of fittings, etc. Place the control sticker and signature on the mast thwart

Staff:
2 Responsible which will be members of the T.C. (bottom and deck)
2 Helpers.
Total: 4

Equipment: 1 IOD'95 Measurement Bar, IODA templates for IOD'95
1 Table with 2 chairs.
1 Metal detector.
4 Wrestles with foam. Aprox. height: 700mm.
Pens, pencils and paper.
Waterproof markers.

STATION D: CONTROL OF SPARS. Yellow Measurement Form.

Function: Check mast, boom and sprit. Verify that each piece has the sail number but also the serial number. Check the measurement bands at the mast and boom, which shall be permanently fixed.. Check the positioning of holes and fittings and also the length of the sprit. Place the control sticker at each piece

Staff:
1 Responsible
1 Helper
Total: 2

Equipment: 1table (3x1 meters) for the measurement templates
2 chairs.
2 wrestles or a small table to place there the equipment before measurement.
1 Punch for metal
1 Teflon hammer.
Pens, pencils and paper
Waterproof markers

STATION F: CONTROL OF SAIL. Red Measurement Form.

Function: It is the most complicated station due to the number of items to be controlled. For that reason the station is divided in 2 areas (2 sail measurement tables). It is important to fill in the form the sail button number of the sail. Check material of the sail and reinforcements, length of leech, luff, foot, diagonals, concavities and convexities at the leech, sail width, sail measurement band, foot mid point, etc. Check positioning and dimensions of Class Logo, Batten pockets, reinforcements, sail numbers, etc.

Staff:
2 Responsible which must be experienced on Optimist Sails measurement
2 Helpers.
Total: 4
It is very important a good coordination between the responsible and the helpers at that station in order to allow a fast and accurate measurement process .

Equipment: 2 Tables of 3,5 X 2,5 meters, which must be completely flan and smooth (like melamine i.e.). If possible, the table should be made with one single board with reinforcements underneath. Height of the tables 90cm
2 Sail Measurement Templates (shall be ordered at the IODA Secretariat)
1 table with 3 chairs.

1 Micrometer.
2 Flex meters (tape measure) class II of at least 3 meters length (Stanley or similar)
2 or 3 Official stamps of the Championship (between 5 x 5 y 10 x 10 cm. aprox).
Waterproof ink for cloth (like STK Berolin R9 or similar)
3 Pads for ink .
Waterproof markers
Pens, pencils and paper

STATION F: CONTROL OF FOILS. Blue Measurement Form

Function: Check the shape of foils using the templates. Check the materials, positioning of fittings of the rudder and centre of gravity of the Daggerboard. Verify the weight of foils, serial numbers and manufacturers. Place the stickers on each checked equipment

Staff:
1 Responsible
1 Helper
Total: 2

Equipment: 3 tables of 1,5 x 1 meters.
2 chairs.
1 Daggerboard Measurement Template .
1 Rudder Measurement Template.
1 Digital scales for 2 Kg. It is suitable a digital scales for 5kg. with a precision of +/- 10gr.
Pens, pencils and paper.
Waterproof markers.

STATION G: CHECK-OUT. Orange Measurement Form.

Function: Check the colour forms previously filled in at each station. When everything is found to be correct, then issue the "Regatta Measurement Approval" which will allow the competitor to participate at the event with the equipment checked by the M.C. When one or more items are found to be not OK, re-measurement will be needed. When possible, re-measurement time will be at the end of the day, or in periods with not heavy load of work. Once finished the measurement, all forms must remain on the Check out station organized by Teams and in folders. A good co-ordination between Check-in and Check-out is needed

Staff:
1 Responsible
1 Helper
Total:2

Equipment: 1 Table with 3 chairs.
Forms: Regatta Measurement Certificate
Re-measurement Schedule
Pen, pencil, paper
1 Master list (which shall include the names of the Teams and competitors that did finish the Measurement).

OTHER NEEDS:

- Radio and/or phone for communications with the Race Office, Race Committee Boat, International Jury.
- Photocopier when the Race Office is not nearby
- T-shirts and/or caps to identify the measurement committee members
- Refrigerator with water and other soft beverages.
- Wastepaper baskets
- Acetone and cloth
- 1 Table of 2x2 meters outside the hall for repairs.
- Transparent tape (scotch tape)

17.3 Class Rules Compliance Inspection Process: RS:X Class

Class Rules compliance inspections (event measurement) at all RS:X events should be undertaken using the same format. Shortcutting the system will only cause problems for both the competitor and the event managers (jury, race management and measurers) and that may bring the class into disrepute.

With the above in mind the RS:X Class have in consultation with its executive developed a simple but thorough pre event inspection process that maybe carried out without the need for an event organiser having to expend vast amounts of money. Under the new format a greater responsibility will be placed on the competitor to ensure that his/her equipment complies with the current class rules. The class and the ISAF now have at their disposal an excellent hull measurement jig that checks a number of points on the underside of the RS:X hull (board).

PRE-EVENT INSPECTION PROCESS

1. **HULL WEIGHT** All hulls shall be weighed with complete mast track, gasket assembly, centreboard including cover and side plates and air ventilation screw in place.
   Centreboard serial number shall be recorded before being event certified and stamped.
   Centreboards may be weighed where requested by the event measurer.
   Foot straps maybe left on the hull, as the measurer will have access to data relating to strap weight including fixings.
   Weight may be written on tail of hull for easy identification by the measurement team during post race inspections.

2. **FINS** Fin serial numbers shall be recorded before event stamping or sealing.
   Fins may be checked weighed and as such recorded
   Fin rake maybe checked

3. **SPARS** Top and Bottom section serial numbers shall be recorded before event stamping or sealing.
   Wishbone (Boom) shall be event stamped or sealed.

4. **SAILS** Sails shall carry country, division identification and number. Sails and Battens shall be inspected for class compliance before being event certified and stamped.

EVENT INSPECTION EQUIPMENT REQUIREMENTS

Event Organiser
Wind and Rain free area with electricity in close proximity to all competitors and their equipment.
Large layout table capable of laying out a sail.
30kgs x 0.005kgs digital readout bench scale for hull weighing.
Small table for inspection and event marking of spars and foils.
Internet café access.
Event certified equipment waterproof seals (stickers)

Event Measurer
Event Inspection Form
Hull measurement jig
5m and 8m measurement steel tapes.
Current Class rules
Event measurer to provide event organiser with Class Rule compliance check list prior to event for competitor distribution at event registration.

This document maybe updated or amended at any time. The ideals of the document is to provide competitors, event managers and measurement teams with the ideals of RS:X pre event class rule compliance inspection techniques. The intent of the measurers is to make the process open and transparent therefore providing an ideal opening to any event.

The final responsibility lies with the competitor to ensure HIS/HER equipment is class rule compliant. Post race checks shall occur and any competitor found to be outside of the Class Rules may find themselves before the event jury.

17.4 Measurement Regulations: 470 Class

1. - General requirements

1.1 - All boats (including their spars, sails and equipment) entered for the Championship shall be inspected in accordance with the Class Rules and any special rules contained in these Measurement Regulations, the Notice of Race, and the Sailing Instructions. Pre-race measurement inspections as defined in 1.2 here below, and measurement inspections at random during the Championship, shall be organised.

1.2 – Pre-race measurement inspections shall include, at least:

- full inspections (as defined in section 2) of boats used by crews within the Top 30 of the ISAF Men's ranking list or within the Top 20 of the ISAF Women's ranking list,
- full inspections (as defined in section 2) of 10 other boats per category, chosen at random by the Regatta Chief Measurer,
- for other boats, inspections limited to the weight of the complete boat (Class Rule C.6.1), to the conformance of the hull and sails to the measurement certificate and Class Rules B.4.2, C.17.3, C.17.4, D.1.4, G.2.2 and G.3.1 (identification marks on hull and sails), to Class Rules C.12.3(a)(2)&(12) and C.13.3(a)(5)&(6) (stoppers and limit marks on spars), and to specific inspections requested by crews for their own boats.

The International 470 Class Association, with the agreement of the Organising Authority, may decide on a case-by-case basis to apply full pre-race measurement inspections as defined in section 2 to all boats.

1.3 - In accordance with R.R.S. 78, competitors are responsible for maintaining their boat in accordance with the Class Rules (for the purpose of R.R.S. 78, competitors are considered to be the owners).

2. - Pre-race measurement inspections

2.1 - The boats shall be presented for measurement inspections with the full equipment as scheduled by the Measurement Committee. Locations and schedule for measurement inspections are posted on the official measurement notice board.

2.2 - Each boat shall be presented for measurement inspections as follows:

- the mast shall be down and the boat shall be accompanied by mast, boom, spinnaker pole, one set of sails, rudder, tiller, centreboard and all other equipment required on board by the Class Rules for the purpose of weighing,
- the mast shall be complete with the spreaders in position and with the standing rigging taught and secured at the lower measurement band. Halyards shall be in the sailing position. The mast head wind indicator, if any, shall be removed,
- the hull shall be empty, in dry condition, all hatches and covers removed for inspection,
- the hull shall carry the identification marks required by the Class Rules,
- hull, sails, spars and equipment shall carry all the measurement marks, bands, stickers and labels prescribed in the Class Rules.

2.3 - According to the Class Rules, the number of sails, spars and foils which may be approved during measurement inspections shall not exceed:

1 mainsail, 1 jib, 1 spinnaker,
1 mast, 1 boom, 1 spinnaker pole,
1 centreboard, 1 rudder.

Sails without the sail button required by Class Rule B.4.2, or without a sail number or the 470 emblem, will not be inspected. As specified in the Class Rules, all sails supplied by competitors shall have been certified in accordance with the Class Rules before being presented for measurement inspection.

2.4 - Each boat shall be presented for measurement inspection with her Measurement Certificate including the completed Measurement Form. These may be retained by the Regatta Chief Measurer for the duration of the event. If the completed Measurement Form is a photocopy, its authenticity shall be confirmed with an original stamp and signature from the issuing authority.

2.5 - Any item which is not in dry condition satisfactory to the Regatta Chief Measurer to be correctly inspected, and any item which is not found in compliance with the Class Rules during inspections, shall be presented again later on to the Measurement Committee, at the Regatta Chief Measurer's disposal, and as long as it is not satisfactory.

2.6 - The weight of clothing and equipment worn by a competitor may be self-checked using the official equipment, during the time scheduled on the official notice board.

2.7 - Only the team manager or his delegate and the boat's crew are allowed to be present during the boat's measurement inspection. At least one of these persons shall be present and shall be authorised to remedy any deviation from the rules or to withdraw the boat from the event.

2.8 - Unless authorised by the Regatta Chief Measurer, repairs or alterations to boats, equipment or sails shall not be made in the measurement inspection areas.

2.9 - All pieces of the boat's equipment subject to inspection are marked with an official measurement inspection mark or sail stamp (waterproof ink), preferably on the port side. Some items may receive two inspection marks, one in a readily visible position when afloat, and a second in a position protected from wear and tear (after the items have been marked, the sticker/stamp may be signed and numbered by the Measurer and the number recorded on the Regatta Measurement Inspection Form to prevent exchange of equipment from one boat to an other one). After the items have been marked, the crew leader of each boat is required to sign the Regatta Measurement Inspection Form declaring that all inspected pieces of equipment have been properly marked and that none of the marked pieces of equipment will be changed without the prior approval of the Regatta Chief Measurer. Any such piece of equipment not so marked shall not be used. If through wear and tear, a mark starts to become obliterated, the fact shall be reported to the Measurement Committee in order that the mark may be replaced.

3. - Pre-race measurement inspection proceedings

3.1 - Team managers or competitors shall apply for the allocation of a measurement time slot to the Chief Measurer. It is recommended to post on the official measurement notice board at 1400 hrs of the day before the first day of pre-race measurement inspections a time table over the two days (Junior Championships) or three days (World and European Championships) for pre-race measurement inspections, with free slots in sufficient number that competitors may choose and book by writing their sail number on the list (each boat inspection should last around 10 minutes). Boats and equipment as indicated above shall be presented at the designated time.

3.2 - The Regatta Measurement Inspection Form (on which date and time allocated for measurement inspection may be added) shall be collected by the representative of the entered boat at the Race Office.

3.3 - The representative of the boat shall be at the measurement inspection area with boat, sails, spars and equipment and with the Measurement Certificate, the Measurement Form and the Regatta Measurement Inspection Form at the designated time.

3.4 - At each measurement inspection station the representative of the boat shall present the Regatta Measurement Inspection Form to be filled in each time an inspection has been passed.

4. - Changes to inspected boats and equipment

4.1 - After boats, spars, sails and equipment have passed through pre-race measurement inspections and been stamped, they shall not be removed from the regatta area without the written permission of the Regatta Chief Measurer.

4.2 – <u>Alterations:</u> after boats have completed pre-race measurement inspections, no alteration shall be made except for the normal designed adjustment of fittings and equipment.

4.3 – <u>Repairs:</u> any competitor wishing to make repairs to his boat, her sails or equipment, after she has passed through pre-race measurement inspections shall make an application to the Regatta Chief Measurer. If permission is granted, the concerned competitor shall arrange a time for such repairs to be approved by the Measurement Committee.

4.4 – <u>Replacements:</u> any application for a replacement of boat, sails, spars or equipment to be used shall be submitted to the Regatta Chief Measurer. Approval can only be given when it can be satisfactorily demonstrated that the sails, spars or equipment are severely damaged, were not deliberately mistreated, and cannot be repaired satisfactorily. New pieces of equipment shall be inspected by the Measurement Committee before use. However, when a piece of equipment is lost or damaged immediately prior to a race and is replaced or repaired, the competitor shall notify the Race Committee prior to the start of the race, and then make an application to the Regatta Chief Measurer as described here above as soon as he arrives ashore after the race has finished, and within the protest time limit.

5. - Measurement inspections during the Championship

5.1 - Any boat, her spars, sails, equipment and crew's clothing and equipment may be inspected at any time during the regatta by the Measurement Committee, and any deviation reported by the Race Committee to the International Jury, on Regatta Chief Measurer request.

5.2 - After each race competitors (selected at random by the Measurement Committee or chosen by the Race Committee or the International Jury) may be informed by a member of the Measurement Committee that they have been elected for measurement inspection on the water or ashore (special pre-assigned area for such inspections may be defined). If the latter, the boats shall be inspected as soon as possible after coming back ashore.

5.3 - At least one representative of the crew is required to be present during the entire inspection period of the boat. When the Measurement Committee representative is not convinced that the boat would exceed in a dry condition the minimum weight required by Class Rules due to the weight reached in a wet condition during inspection, he may impound the boat for weighing the following morning before race.

5.4 - When a measurement varies from that prescribed by the Class Rules, or when the Measurement Committee representative has reason to believe that a piece of equipment has been altered, repaired or replaced without prior approval, the Race Committee, on Regatta Chief Measurer request, reports the matter to the International Jury for hearing and decision.

17.5 Forms

ATHENS 2004 OLYMPIC REGATTA

DATE : …… AUG 2004

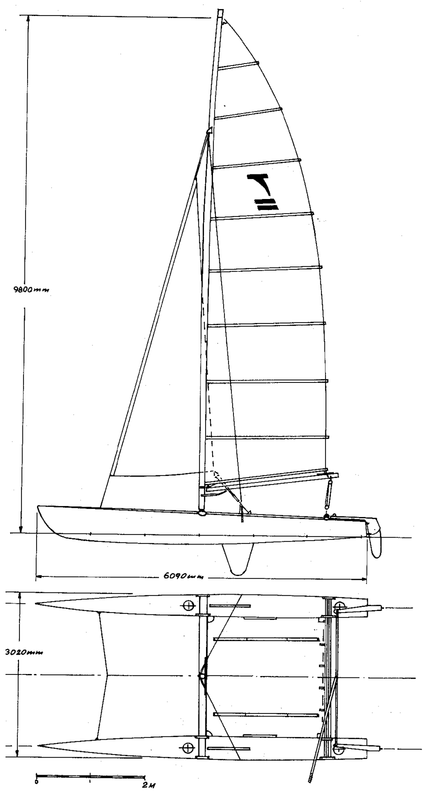
RACE N° :

EQUIPMENT SUBSTITUTION REQUEST

Name of person making request : …………………………………..
Damaged Equipment : ……………………………………….

SAIL / COUNTRY LETTERS

☐ ☐ ☐



MARK THE DAMAGED PLACE

PORT ☐

STARBOARD ☐

REASON FOR SUBSTITUTION (or REPAIR):

Signature : Date:

Official use only

Request approved ☐ for repair only ☐ and needs Measuring ☐ Request denied ☐
I have inspected the damaged equipment and I am satisfied such damage was accidental

Signature: …………………… Date:……………………………….

Official Measurer's or Jury Member's Name : ………………………………………………

Action if approved : If the equipment approved for substitution includes an item bearing a Country Code (eg; main sail) or needs measuring, then the following must be taken:

Advise Results ☐ Advise Race Committee ☐ Signature of Official Measurer

Equipment measured and approved Yes ☐ No ☐

ATHENS 2004 OLYMPIC REGATTA

ON-THE-WATER MEASUREMENT CLASS : ______

MEASURER'S REPORT

WET CLOTHING CHECK Yes / No

FINISHING POSITION ______

RACE N° ______ of the day ______

SAIL LETTERS ______

DATE : ______ AUGUST 2004

After the last race of the day, boats may be spot checked. Once finished, the selected competitors should be hailed and requested to sail to an area at the Marina and await inspection. During this time the boats should be watched carefully and not allowed to be approached by any other boats. Request for repair or replacement equipment on separate form available at Jury's secretary.

Post-Race Measurement Inspection

A measurer cannot disqualify a competitor, only the International Jury may decide if the competitor is to be penalised.
The Measurer may be called later by the International Jury to give evidence regarding the report, which will rank as a protest against the boat.
If, as a result of the measurement checks carried out a measurer has reason to believe that any boat does not comply with the Measurement Regulations he will report to the ISAF Measurement Office the matter, who will check the measurer's findings and interpretation and, if necessary, obtain a ruling from the Regatta Measurement Committee before reporting it to the International Jury. The time limit for filling a report to the Int. Jury is two hours after the inspection of the boat has been completed.
On shore the boats will be thoroughly inspected and checked for compliance with a number of specific items listed below :

	On Hull	On foils	On spars
Corrector Weights			
Olympic Stickers			

Illegal fittings (if any found) : ______

Electronics ______

Sail Stamps	Main: OK/NOK	Jib(s) : OK / NOK	Spin. (s) : OK /NOK

Hull weight (if needed) :

WET CLOTHING CHECK or CREW WEIGHT

Weighing stations are set up in the Marina (close to Measurement tent). Checks to be made according Class Rules.
Changing accommodation for men and women (separate areas) are adjacent to the measurement tents.

CREW 1 ______

CREW 2 ______

Comments from Measurer:

Date and signature:

Received by Jury Office at ….. h …… Date : …… August 2004 - Signature

INTERNATIONAL 470 CLASS

WORLD CHAMPIONSHIP XXXXXXXX 20XX

EVENT INSPECTION FORM

Country Code	Sail Number	Bow Number	FULL / PARTIAL

Name	Helm		M / W
Name	Crew		Inspector's signature

HULL

Builder		ISAF Plaque	
Builder Ser.		Mould Number	
Boat Weight		Compass weight	
Certificate: YES / NO	M. Form: YES / NO	Original	YES / NO
Fittings	Towing rope	Buoyancy aids	

MAST: | **BOOM:** | **SPI. POLE:**

Weight	Limit marks	Stopper	Limit mark	Stopper	Length

Fittings	Rigging

CENTERBOARD: | **RUDDER:**

Weight	Profile	Thickness	Weight	Profile	Thickness

SAILS

	Main:	Jib:	Spi:
Certification marked	YES / NO	YES / NO	YES / NO
Measurement marks	YES / NO	YES / NO	YES / NO
Sail number			
Dimensions			

I confirm that all the equipment has been approved and marked for the event

X. XXXXXX
Chief Measurer
470 Class

M / W SAIL NUMBER:

Helm

or

Crew

LASER STANDARD and RADIAL
MEASUREMENT AND SCRUTINY FORM

SAIL No: ____________________ NAT : SIZE: LASER RADIAL RIG ☐ PASS ☐

COMPETITORS NAME: ___________________ LASER FULL RIG ☐ ON HOLD ☐

Checked By:____________________________ FAIL ☐

Stamped	Yes	No
Top Section		
Bottom Section		
Boom		
Centreboard		
Rudder		
Hull		
Sail		

Top Section	Passed	Failed
Fitting locations within tolerance and standard types (with builder sticker)		
Section is Straight		
Section appears watertight		
No fairing around collar		
Balance Test		

Bottom Section	Passed	Failed
Fitting locations within tolerance and standard types (with builder sticker)		
Section is Straight		
Bottom drain hole open		

Boom	Passed	Failed
Fitting locations within tolerance and standard types (with builder sticker)		

Centreboard Foam ☐ GRP ☐	Passed	Failed
Thickness OK (max 33mm)		
Handle (if fitted) has not more than 2 holes of 12.5 mm diameter (max) & 1 piece of rope (plastic/ rubber tube and /or tape is permitted)		
Standard stopper assembly fitted		
Meets standard profile and shape. Fairing of the trailing edge OK (max 100mm) (with builder sticker)		
Refinishing OK (No reinforcing permitted)		
Retaining line / shock cord fitted and is adequate to retain board		

Rudder Foam ☐ GRP ☐	Passed	Failed
Thickness OK (max 20 mm)		
Meets standard profile and shape. Fairing of the trailing edge OK (max 60mm) (with builder sticker)		
Refinishing OK (No reinforcing permitted)		
Rudder Angle 78 degrees. Tape permitted to correct angle. Check for tampering of bottom of rudder box		
Rudder bolt 10 mm Diameter Max		
Rudder washers 20mm Dia. Max		
Downhaul line fitted (multiple purchases OK)		

Tiller	Passed	Failed
Tiller able to be removed from rudder box		
Fitted with cleat / hook / pin or eye for rudder downhaul		
Straight along topmost edge (from 30mm in front of rudder box)		
Wear strip / roller of not more than 200mm		

Sail	Passed	Failed
Sail No's correspond to Hull No unless appropriate application has been made to Race committee (see below)		
Sail No's are adhesive		
Starboard Sail No's uppermost (400 +/- 12mm below mid batten seam for full rig and below the underside of the middle batten pocket for radial) Port side 400+/- 12mm below		
Sail No's 300mm H, 45mm T, 200mm Wide (excluding # 1)		
Sail No's regularly spaced (min 50mm & 100mm in from leech)		
No's after 13100 (full rig) 153000 (radial) and those purchased after 1/6/93 - 2 plus 4 contrasting & distinctive colours		
Nat. letters are adhesive		
Nat. letters are same colour and could be different colour from the 2 colours of the numbers		
Nat. letters are regularly spaced (min 50mm & 100mm(+or- 12 mm) in from leech)		
Top of starboard letters along bottom edge of the bottom batten pocket and its extension (+12mm) for radial. Starboard letters along top edge of the seam below the bottom batten pocket (+12mm) for full rig. Port side 400 +/- 12mm below		
Sail button		
Are there any alterations or repairs?		
Notes:-		

Mainsheets	Passed	Failed
One continuous length		

Traveller	Passed	Failed
One continuous length		
Simple triangle configuration, no multi purchase systems permitted		
Blocks taped together, ball or spring, no plastic tubes		
Traveller and Cunningham fairleads are plastic or metal. (Stainless Steel inserts allowed only for Cunningham fairlead)		

General		
Thimbles of 40 mm max length		
Pulleys, sheave diameter between 15 & 30mm		
Rope handles permitted, with rubber, plastic or tape coverings		
Cunningham / outhaul cleat base & wire gate not modified in any way. The cleats may be mounted on wedges or pads to raise them		
All ropes must be of uniform thickness		
Splices in control lines at load bearing attachment points is ok		
Free ends of lines are not permitted to be attached to shock cord (except the mainsheet)		

Outhaul		
2 Lines max, it must pass through the fairlead and must be a moving line.		
6 turning points max (not including the deck mounted pulley)		
Line for optional block (center of the block) no further than 100mm from gooseneck bolt (acceptable 3rd line or a shackle)		
Quick release hook for clew, rope or shock cord loops for line retaining and shock cord for pulling back foot permitted		

Cunningham	Passed	Failed
3 Lines max		
No aramid (Kevlar) rope permitted		
5 turning points max (not including the fairlead or deck mounted pulley)		
1 line must pass through the eye of the sail (it must be a moving line) and be tied to the gooseneck or vang fittings		
The line shall only pass through the deck fitting once		

Boom Vang	Passed	Failed
2 lines max		
No aramid (Kevlar) rope permitted		
7 turning points max		
Standard Key – bent or straight (maximum of 2)		
Swivel and / or shackles permitted max length 80mm		

Outhaul Tie Down	Passed	Failed
Beads or rollers permitted		

Battens	Passed	Failed
Standard Section, length and Caps		

Hull	Passed	Failed
Hull OK (not extensively sanded, faired or refinished)		
Internal Skin OK (no reinforcing that is not a repair)		
Floatation OK (Foam Blocks or cube containers present)		
Centreboard case free of wedges, silicon, tape or padding except one layer of plastic at the top front corner max 30x30 mm + 2 mm thickness		
Mast step is free of any devices restricting fore and aft movement		
Self bailer (No fairing to the hull permitted but sealing in place OK)		
Hatches (if fitted) Max 153mm diameter and threaded		
Compass (if fitted) does not pierce hull except fasteners and is not part of an inspection port.		
Storage bags OK		

Hiking Strap	Passed	Failed
Non Stretch material		
Attached forward using the mainsheet pressure plate or the mainsheet pressure plate and centreboard friction attachment plate		
Shock cord attached either to traveller cleat or hiking strap eyes and the aft end of the strap		

Safety Equipment	Passed	Failed
Line or shock cord connecting mast and hull		

Compass and watches	Passed	Failed
Electronic compass and digital compass are prohibited. Watches with an electronic compass and digital compass are prohibited under rule 22.		

Did you find anything else unusual that has not been covered?

Advertising No advertising in the forward 25% of the hull except that required by the organizing authority.

Change of sail number
I request to use an alternate Sail No to the Hull No:

Sail Number used : ____________

Hull Number:_________________

DECLARATION (to be signed by the competitor):

I have passed measurement and I will not change anything on my boat without permission of the measurer or the race committee.

Sign here:....................................

Write your full name:...

18 GLOSSARY AND ABBREVIATIONS

For the definitions see also "The Sailing Dictionary", Joachim Schult, Ed. Adlard Coles Nautical, London)

	English	Français	Italiano	Español	Deutsch	
101	Abaft	sur l'arrière	A poppavia	A popa	achterlich	
102	Abeam	par le travers	Al traverso	Por el través	querab	
103	Accuracy	Exactitude				
104	Afloat	à flot	Galleggiante	A flote	schwimmend	
105	Alloy	alliage	Lega	Aleación	Legierung	
106	Amidships	au milieu (du bateau)	A mezza nave	Crujía	mittschiffs	
107	Anchor	ancre	Ancora	Ancla	Anker	
108	Aspect Ratio	proportion	Ratio atteso	Ratio esperado	Seitenverhältnis, Streckung	
109	Astern	à l'arrière, en poupe	Addietro, a poppa, di poppa	A popa, de popa	achtern	
110	Athwart	par le travers, en travers	Al traverso	transversalmente	dwars	
111	Athwartships	en travers	Per madiere, da banda a banda	Transversalmente al barco	querschiffs	
201	Backstay	pataras, galhauban	Paterazzo	Estay de popa, contraestay	Achterstag	
202	Bailer	écope	Gottazza	achicador	Lenzer	
203	Ballast	lest	Zavorra	Lastre	Ballast	
204	Barber hauler	rattrape	Barber	Barber	Beiholer	
205	Batten	latte, balestron	Stecca	Sable	Latten	
206	Beam	barrot	Baglio	Bao	Breite	
207	Bearing	relèvement, palier, coussinet	Rilevamento, Cuscinetto, Supporto	cojinete	Peilung	
208	Beating	louvoyage	Navigare sui bordi	ciñendo	kreuzen	
209	Bermudian	bermudien	Bermudiano	Bermudiano	Bermuda Tackelung, Hochtakelung	
210	Beveling	équerrage	Smussatura, ugnatura	biselando	Schmiege	
211	Big boy (blooper)	big boy, spinnaker asymétrique	Big boy (tipo di spinnaker)	Big boy	BigBoy, Lee Spinnaker	
212	Bilge	bouchain	Lombolo, sentina	Pantoque	Bilge	
213	Bilge keel	quille de bouchain	Chiglia di rollio	Quilla abatable o de balance	Kimmkiel	
214	Block	poulie	Bozzello	Motón, polea	Block	
215	Block binding	estrope de poulie	Stroppo per fissare il bozzello			
216	Boat	bateau, canot, embarcation	Imbarcazione, barca, canotto, battello, lancia	barco	Boot	
217	Bobstay	sous-barbe	Briglia, briglia del bompresso	baupres	Wasserstag	
218	Bolt	cheville, boulon	Bullone, perno. Chiavarda	Bulon , pasador	Bolzen	
219	Bolt rope	ralingue	Ralinga	Relinga	Liektau	
220	Boom	bôme, gui	Boma	Botavara	Baum	
221	Boom strap	ferrure d'écoute de bôme	Stroppo del boma	Aclaje de la botavara	Baumgei, Niederholer	
222	Boom vang	hale bas de bôme	Paranco del boma	Trapa o contra	Niederholer	
223	Bow	proue, avant	Prora, prua	Proa	Bug	
224	Bow rope	amarre	Cavo di prora	Cabo de proa	Bugtau	
225	Bowsprit	beaupré	Bompresso	Bauprès	Bugspriet	

	English	Français	Italiano	Español	Deutsch	
226	Brace	étrésillon,étrier, bras	Braccio (manovra corrente)	braza	Achterholer	
227	Breakwater	brise-lames	Para onde	Rompeolas o tajamar	Wellenbrecher	
228	Bridge	pont, passerelle, château	Ponte, passerella, plancia, cassero	pasarela	Bruecke	
229	Bridle	patte d'oie	Branca, patta d'oca, briglia	Cable de amarre	Spreiztrosse	
230	Bucket	baille, seau, bidon	Bugliolo	achicador		
231	Bulb	bulbe	Bulbo	bulbo	Wulst	
232	Bulb-keel	bulb keel	Chiglia a bulbo	Quilla de bulbo	Wulstkiel	
233	Bulkhead	cloison	Paratia	mamparo	Schott	
234	Bullseye	hublot	Màndola, oblò	Centro del blanco		
235	Bulwarks	bastinguage, pavois	Murata, impavesata, battagliola, parapetto	amurada	Bollwerk	
236	Bumpkin	queue de mallet	Gruetta, buttafuori			
237	Buoyancy	flottabilité	Galleggiabilità, spinta di galleggiamento	flotabilidad	Auftrieb	
238	Buoyancy aid	engins de flottabilité	Salvagente	salvavidas	Schwimmhilfe	
239	Buoyancy center	centre de carène	Centro di carena, di spinta, di volume	Centro de flotabilidad	Auftriebsschwer punkt	
240	Buoy rope	orin	Cavo di boa	Cabo de baliza	Bojenleine	
241	Burgee	guidon, fanion (de club) triangulaire	Guidone	Gallardete	Doppelstander	
252	Bustle			skeg	Eselsruecken, Skeg	
301	Cable	cable, grelin	Cavo, catena, gomena	cable	Kette	
302	Camber	bouge	Bolzone	camber	Woelbung	
303	Cam cleat	taquet coinceur	Galloccia	Mordaza	Kammklemme	
304	Cap shrouds	hauban de fleche	Sartia	Obenques altos	Verdeckstuetzen	
305	Car	curseur	Carrello		Schlitten	
306	Cast iron	fonte (d'acier)	Gettata, fusione di acciaio	fundicion	Gusseisen	
307	Cat	capon	Capone	cat	Kat	
308	Catamaran	catamaran	Catamarano	catamaran	Katamaran	
309	Catenary	caténaire	Catenaria	catenaria		
310	Centreboard	dérive	Deriva	Orza levadiza	Schwert	
311	Centreboard case	puits de derive	Cassa di deriva	Cajera de orza	Schwertkasten	
312	Centreline	axe	Asse centrale	Linea de crujia	Mittelachse	
313	Centre of flotation	centre de carène, de poussée ?	Centro di galleggiamento	Centro de flotabilidad	Verdraengungs schwerpunkt	
314	Centre of gravity	centre de gravité	Certro di gravità	Centro de gravedad	Schwerpunkt	
315	Centre of pressure	centre de pression	Centro di pressione	Centro de presion	Druckschwerpunkt	
316	Certificate	certificat, acte	Certificato	certificado	Messbrief	
317	Chafting patch	pièce de raguage	Pezza anti sfregamento	Parche de roce	Schamfielschutz	
318	Chain	chaîne	Catena	Cadena	Kette	
319	Chain plate	cadène	Landa		Puetting, Ruesteisen	
320	CHS	Channel Handicap System				
321	Check wire	câble de retenue	Cavo di ritegno	Cable de seguro	Stopper	
322	Cheek block	poulie à une joue	Maschetta di bozzello	Polea de seguridad		
324	Cheek	joue (d'une poulie)	Maschetta	aleta		

	English	Français	Italiano	Español	Deutsch	
325	Chine	bouchain	Lombolo, Stellato	Pantoque		
326	Chock	chaumard	Calastra, zeppa, bietta	calzo	Klampe	
327	Chord	corde (géométrie)	Corda (geometria)	cuerda		
328	Clam (cam)cleat	taquet coinceur	Galloccia	mordaza	Kammklemme	
329	Cleat	taquet	Galloccia	mordaza	Klemme	
330	Clench (clinch)	étalingure	Legatura con mezzo collo, gassa	entalingar		
331	Clew	point d'écoute	Bugna	Puño	Horn, Schothorn	
332	Clew outhaul	bras d'écoute ?	Alafuori di bugna	Ollado del puño	Unterliekstrecker	
333	Climbing rung	échellons de mât	Piolo (di scala)	Peldaño del mastil		
334	Clinker-built	à clins	A fasciame accavallato, sovrapposto, cucito, a labbro		Klinkerbauweise	
335	Clinometer	clinomètre	Inclinometro	clinometro	Neigungsmesser	
336	Cloth	laize, toile	Tela, ferzo	Paño lona tejido	Tuch	
337	Clothing	habillement	Abbigliamento	tejiendo	Bekleidung	
338	Cloth weight	grammage d'une toile, d'un tissus	Peso del tessuto	gramaje	Tuchgewicht	
339	Coaming	hiloire	Battente di boccaporto, Mastra	Brazola,	Suell	
340	Coating	couche de peinture, enduit	Stato, mano di pittura	acabado	Anstrich, Beschichtung	
341	Cockpit	carlingue, cockpit	Pozzetto	bañera	Cockpit	
342	Cradle	ber	Invasatura	Basada, camada, Cuna, carro		
343	Crazing	craquelures	Crinature	cuarteo	Haarrisse	
344	Crew	équipage	Equipaggio	tripulacion	Mannschaft	
345	Cringle	patte, oeil sur ralingue	Brancarella	grillete	Legel, Auge	
346	Cunningham (eye or hole)	oeillet de cunningham	Occhiello del Cunningham	Ollado del cunningham	Vorliekstrecker	
347	Cure	traitement, cure	Cura	Cura / vulcanizado	Verfahren	
348	Cutter	côtre	Cutter, fresa	Cuter, cuchillo	Kutter	
349	Cutwater	guibre	Tagliamare	Corta aguas	Steven	
401	Daggerboard	dérive sabre	Deriva a coltello	Orza Levadiza de sable	Schwert	
402	Deck	pont	Ponte, Coperta	cubierta	Deck	
403	Deck line	livet	Linea del ponte, linea di riferimento (bordo libero)	Linea de cubierta	Deckstrack	
404	Deck plate	tôle de pont	Copertura di bronzo delle aperture sul ponte			
405	Density	densité, masse volumique	Densità	densidad	Dichte	
406	Depth	profondeur, creux	Profondità, altezza di puntale	profundidad	Tiefe	
407	Device	dispositif	Dispositivo, apparecchio	aparejo	Einrichtung	
408	Diamonds	losange		Rombos Violin	Rombus, Jumpstage	
409	Dinghy	dériveur	Dinghy, barca a deriva	Chinchorro o balandro de vela ligera	Dinghy	
410	Double luff sail	Voile à double ralingue	Caliorna (vela a),	Vela de doble gratil	Doppelsegel	
411	Dowel	dé, douille, clé, goujon, cheville	Caviglia	cuña		

	English	Français	Italiano	Español	Deutsch	
412	Downhaul	hale bas	Caricabbasso	cargadera	Niederholer	
413	Draft	calaison, tirant d'eau	Pescaggio, immersione	calado	Tiefgang	
501	Earing	empointure	Borosa (di inferitura), matafione di inferitura, inferitoio	empuñadura		
502	Event Measurer	jaugeur lors d'une régate	Stazzatore ad una regata	Medidor de una regata	Vermesser bei Regatten	
503	Eye	oeil, piton , oeillet	Occhio	Ojo gaza	Auge	
504	Eye bolt	piton à oeil	Golfare	cancamo	Augbolzen	
505	Eylet	oeillet	Occhiello, occhiello di inferitura	ollado	Oese	
506	Eye plate	pontet		cancamo	Augplatte	
507	Eye splice	épissure		Gaza trenzada	Augspleiss	
601	Fairlead	chaumard	Puleggia, rotella di guida e di commando	guia	Klampe	
602	False keel	fausse quille	Falsa chiglia	Quilla falsa	Loskiel	
603	Fastening	chevillage, assemblage	Elemento di fissaggio	fijacion	Halterung	
604	Feeder	caisson	Alimentatore	alimentacion	Tank	
605	Fender	défense	Parabordo	defensa	Fender	
606	Ferrule	virole	Boccola, virola, ghiera	férula	Faser	
607	Fibre (fiber US)	fibre	Fibra	fibra	Faser	
608	Fiddle	poulie violon	Tavola di rollio	Violin	Violine, Violinblock	
609	Filler	mastic, bouche-pores	Riempimento	masilla	Fueller	
610	Fin	aileron, ailette	Aletta stabilizzatrice	ala	Finne	
611	Fin keel	quille à aileron	Ala della chiglia	Ala de la quilla	Kielflosse	
612	Fitting	accessoires, accastillage	Accessori	accesorio	Beschlag	
613	Flare	dévers, renvoi	Slancio della prora, segnale a lampi di luce, segnale pirotecnico	bengala	Flackerfeuer	
614	Flush-decked	plat-pont	A ponte raso / libero	Cubierta corrida	Flachdecker	
615	Foil	foil, aileron	Aletta, ala portante	Aleron		
616	Foot	pied	Piede, supporto, linea di scotta	Pie	Fuss	
617	Footrope	ralingue de bordure	Ralinga, gratile	Cinchas	Liektau	
618	Fore	avant	A prua, verso prua	A proa	vorne	
619	Foredeck	pont avant	Ponte di prua	Cubierta de proa	Vordeck	
620	Foresail	misaine, voile d'avant	Vela di prua	Vela de proa	Vorsegel	
621	Forestay	étai	Strallo di prora	Estay de proa	Vorstag	
622	Foretriangle	triangle avant	Triangolo di prora	Triangulo de proa	Vorsegeldreieck	
623	Frame	couple	Costole	Cuardena	Spant	
624	Freeboard	franc-bord	Bordo libero	Franco-bordo	Freibord	
625	Furl	ferlage, ferler		asir	bergen	
626	Furling gear	dispositif de ferlage	Dispositivo di serraggio delle vele	asidero	Fockroller	

	English	Français	Italiano	Español	Deutsch	
701	Gaff	corne	Gaffa, mezzomarinaio	pico	Gaffel	
702	Gasket	garcette	Gerlo, guarnizione	bridas	Reffbaendsel	
703	Gelcoat	gelcoat, couche de résine extérieure	Strato di resina esterna	gelcoat	Gelcoat	
704	Genoa	génois	Fiocco Genova, fiocco grande	Genova	Genua	
705	Ghoster	génois Volant	Gennaker	Genaker	Gennacker	
706	Girder	poutre, support	Trave longitudinale, supporto	eslora	Unterzug	
707	Girth	développement, chaine	Perimetro contorno	contorno	Abwicklung	
708	GRP (Glass fibre reinforced plastic)	résine renforcée par des fibres de verre	Resina rinforzata con fibra di vetro	Poliester reforzado con fibra de vidrio	Glasfaser verstaerkter Kunststoff	
709	Gooseneck	vit-de-mulet	Perno di rotazione del boma	Pinzote	Luemmelbeschlag	
710	Grandfathering	tolérance d'ancienneté	Dispensa per età	dispensa	Altersverguetung	
711	Groove	gorge	Scanalatura, gola	ranura	Keep, Mast/Baumnut	
712	Gunter rig	houari	Guntero		Gunter Takelung	
713	Gunwale	lisse de plat-bord	Falchetta	regala	Dollbord, Scheuerleiste	
714	Guy	retenue, bras	Cavo di ritenuta, vento, ostino	viento	Gei, Niederholer	
715	Gybe (jibe US)	empennage	Virare	virar	Halsen, schiften	
801	Halyard (halliard)	drisse	Drizza	Driza	Fall	
802	Hank (snap US)	manoque	Canestrello	garrucho	Stagreiter	
803	Harness	harnais	Bozzellame	harnes		
804	Hatch	écoutille	Boccaporto, portella	Escotilla / Registro	Luk	
805	Hawse hole	écubier	Cubia		Kluese	
806	Head	tête	Testa, prua, penna	Puño de driza	Kopf	
807	Headboard	têtière	Tavoletta	Tablilla	Kopfbrett	
808	Headsail	voile d'avant, foc	Vela di prua, fiocco	Foque	Fock, Vorsegel	
809	Heeling moment	moment de redressement	Momento raddrizzante	Momento de escora	Kraengungs moment	
810	Helm	barre, gouvernail	Timone, barra	Rueda/ Caña	Steuer, Ruder	
811	Helmsman	barreur	Timoniere	Timonel	Steuermann	
812	Hike	rappel		colgarse	ausreiten	
813	Hiking racks	barres de rappel		Asas de colgarse	Ausreithilfen	
814	Hoist	chute	Elevatore	izar	hochziehen	
815	Hull	coque	Scafo	casco	Rumpf	
901	Inclining test	test de stabilité	Prova di stabilità	Test de estabilidad	Aufricht Test	
902	Inglefield clip	crochet brummel			Brummelhaken	
903	IOR	International offshore Racing				

	English	Français	Italiano	Español	Deutsch	
1001	Jam cleat	taquet coinceur	Tacchetto a tenaglia	mordaza	Kammklemme	
	Jaw	machoire, ferrure de bôme	Gola del picco o del boma	Boca de crujia	Baumgabel	
1002	Jib	foc	Fiocco	Foque	Fock	
1003	Jib-boom	bôme de foc	Asta del fiocco	botavara	Fockbaum	
1004	Jib sheet	écoute de foc	Scotta del fiocco	Escota de foque	Fockschot	
1005	Jib-stick	tangon de foc	Tangone del fiocco	tangon	Fockbaum	
1006	Jockey pole	jockey pole	Jockey pole	Jockey pole	Jockeybaum	
1007	Jumper stay	guignol		Estay volante	Knickstag	
1101	Keel	quille, aileron	Chiglia	quilla	Kiel	
1102	Keelband	profil de quille	Fascia di ferro a difesa della chiglia	Perfil de quilla	Kielband	
1103	Keelboat	quillard	Barca a chiglia	Guillado	Kielboot	
1104	Keel bolt	boulon de quille	Bullone di chiglia	Pasador de la quilla	Kielbolzen	
1105	Keelson	carlingue	Paramezzale	Carlinga	Kielschwein	
1106	Ketch	ketch	Ketch	Queche	Ketch	
1107	Kicker lever	hale bas de bôme à levier	Alabasso del boma		Baumstuetze	
1107	Kicking strap	sangle de rappel			Niederholer	
1201	Laminated ply	pli plastifié	Strato laminato	Paño laminado	Laminierte Lage	
1202	Lead	plomb	Piombo	plomo	Blei	
1203	Leading edge	bord d'attaque	Bordo di attacco	Borde de ataque	Vorderkante	
1204	Leak	fuite, voie d'eau	Falla, via d'acqua	Via de agua	Leck	
1205	Lee	côté sous le vent	Sottovento	Caida	Lee	
1206	Leech (of sail)	chûte d'une voile	Caduta	baluma	Achterliek	
1207	Leech line	cargue, bouline, nerf de chûte	Caricaboline	Linea de baluma	Liekleine	
1208	Leech rope	ralingue de chute	Gratile di caduta	Balumero batidor	Liekleine	
1209	Length	longueur	Lunghezza	eslora	Länge	
1210	LOA	longueur hors tout		Eslora total	Laenge ueber alles	
1211	LWL	longueur à la flottaison	Lunghezza al galleggiamento	Eslora en flotacion	Wasserlinienlaenge	
1212	Life jacket (personal flotation device, PFD, US)	gilet de sauvetage	Giubbetto salvagente	Chaleco salvavidas	Rettungsweste Schwimmweste, Schwimmhilfe	
1213	Lifeline	filière de sécurité, sauvegarde	Cavo di salvataggio	Linea de vida	Sicherungsleine	
1214	Lifting keel	quille relevable	Chiglia abbattibile	Quilla abatible	Hubkiel	
1215	Lifting rudder	safran relevable	Timone abbattibile	Timón abatible	Aufholbares Ruder	
1216	Limber holes	anguiller, lumière	Anguilla, ombrinale	imbornal		
1217	Line	ligne	Linea, cima	cabo	Riss	
1218	Lines	formes	Linee	cabos	Riss	
1219	Lines plan	plan des formes	Piano di costruzione	Plano de formas	Linienriss	
1220	Link shackle	maillon	Maglia di unione			
1221	Loose-footed	bordure libre	Piede (di vela) non inferito	Pujamen libre	Loses Unterliek	
1222	Luff-rope	ralingue d'envergure	Ralinga di inferitura	Relinga de pujamen	Vorliektau	

	English	Français	Italiano	Español	Deutsch	
1301	Mahogany	acajou	Mogano	Caoba	Mahagoni	
1302	Main beam	maître-bau	Baglio Massimo	Cuaderna Principal	Grossbaum	
1303	Main mast	grand mât	Albero maestro	Palo Mayor	Grossmast	
1304	Mainsail	grand'voile	Randa	Mayor	Grosssegel	
1305	Mainsheet	écoute de grand'voile	Scotta di randa	Escota de Mayor	Grossschot	
1306	Mainsheet track	barre d'écoute de grand'voile	Carrello della scotta di randa	Barra de escota de Mayor	Grossschot traveller	
1307	Mast	mât	Albero	Palo	Mast	
1308	Mast bend controller	limitateur de flexion du mât	Limitatore della flessione dell'albero	Limitador de flexion / Cuña	Mastbiegungs begrenzer	
1309	Mast heel	pied de mât	Piede d'albero	Pie de Mastil- Coz	Mastfuss	
1310	Mast-hole	étambrai	Foro d'albero, mastra d'albero	Fogonadura	Mastloch	
1311	Mast partners	étambrai	Mastra d'albero	Fogonadura	Mastfischung	
1312	Mast stantion	épontille		Tintero Movil		
1313	Mast step	emplanture	Scassa dell'albero	Tintero	Maststufe	
1314	mast strut	Étresillon de mât		arbotante		
1315	Mast track	rail de mât	Cremagliera di regolazione dell'albero	Carril del Mastil	Mastnut	
1316	Measurement form	protocole de jauge	Verbale di stazza	Formulario de medicion	Measurement Form, Messprotokoll	
1317	Measurement certificate	certificat de jauge	Certificato di stazza	Certificado de medicion	Messbrief	
1318	Measurer	jaugeur		medidor	Vermesser	
1319	Microspheres or microballons	microsphères	Micro sfere	Microbalones	Microballons	
1320	Midship section	maître-couple	Sezione a metà barca	Seccion Media	Hauptspant	
1321	Mizzen mast	mât d'artimon	Albero di mezzana	mesana	Besan	
1322	Mould (mold US)	moule	Stampo, forma	molde	Form	
1401	National letters	lettres de nationalité	Lettere di nazionalità	Letras de nacionalidad	Laenderkenn-zeichen	
1402	Nut	écrou	Dado	Tuerca	Schraubenmutter	
1501	Oar	aviron, rame	Remo	remo	Riemen, Ruderriemen	
1502	Offsets (table of)	table des couples	Tavola delle coordinate delle superfici curve	Tabla de medidas	Tabelle	
1503	Outhaul	tire-bout	Alafuori	driza	Ausholer	
1504	Outrigger	outrigger	Buttafuori		Ausleger	
1505	Overhang	élancement	Slancio	Voladizo	Ueberhang	
1601	Paddle	pagaie	Pagaia	Pagaya	Paddel	
1602	Paint	peinture	Pittura	Pintura	Anstrich	
1603	Painter	remorque d'étrave	Barbetta, cima di traino	Boza	Schleppleine	
1604	Peak	coqueron	Picco, penna	Puño de driza	Piek	
1605	Pendant	pantoire	Penzolo	Gallardete	Stander	
1606	Pennant	flamme, pavillon	Pennello	Gallardete	Stander	
1607	PFD (see life jacket)	Personal Flotation Device				

	English	Français	Italiano	Español	Deutsch	
1608	Pin	cheville, goupille	Perno	Pasador	Pinne	
1609	Pintle	aiguillot	Agugliotto	Pivote Macho timon	Lagerzapfen	
1610	Pitch	brai, tanguage	Beccheggio, passo, distanza	Paso de tuerca	Stampfen	
1611	Plank	bordage, planche	Tavola di fasciame	Tablon	Planke	
1612	Planking	bordé	Tavolato	Forro	Beplankung	
1613	Plug	bouchon, tampon	Alleggio, tappo	Tapon / Tapa		
1614	Ply	pli, couche	Strato	Plegado	Lage	
1615	Plywood	contreplaqué	Legno compensato	Contrachapado	Sperrholz	
1616	Port	babord	Sinistra, lato o fianco sinistro	Babor	Backbord	
1617	Primary reinforcement	renfort primaire	Rinforzo primario	Refuerzo Primario	Verstaerkung Erster Ordnung	
1618	Precision	précision				
1619	Pulley	poulie	Puleggia	Polea	Block	
1620	Pulpit	balcon avant	Pulpito	Pulpito	Bugkorb	
1701	Quick release	déclencheur	Apertura rapida	Apertura Rapida	Sicherheitsoeffner	
1801	Rack	crémaillère	Cremagliera	Cremallera	Rack, Halterung, Regal	
1802	Rake	quête, élancement	Slancio, inclinazione	Lanzamiento	Fall, Mastfall	
1803	Rating	coefficent de jauge, de classe	Coefficiente di compensazione	Compensacion	Verguetung	
1804	Rating certificate	certificat de classe	Certificato del coefficiente di compensazione	Certificado de Rating	Verguetungsmess brief	
1805	Ratio	rapport	Rapporto	Ratio	Verhaeltnis	
1806	Recovery line	rattrape	Cima di recupero	Cabo de recuperación	Bergeleine	
1807	Reef band	bande de ris	Benda di terzaruolo	Faja de rizos	Reffleine	
1808	Reef cringle	oeillet de ris	Brancarella di terzaruolo	Gaza de Rizos	Reffoese	
1809	Reef earing	raban de ris	Borosa di terzaruolo	Empuñadura de Rizos	Reffauge	
1810	Reefing hook	crochet de ris	Gancio di terzaruolo	Gancho de Rizos	Reffkaken	
1811	Reproductibility	reproductibilité				
1812	Rig	gréement, gréer	Attrezzatura	Aparejo	Rigg, Takelage	
1813	Rigging	gréement	Sartiame, manovre	Aparejos	Rigg, Takelage	
1814	Rigging screw	ridoir	Arridatoio	Tensor de aparejo	Spannschraube	
1815	Righting lever	couple de redressement	Leva raddrizzante	Par de adrizamiento		
1816	Righting moment	moment stabilisant	Momento raddrizzante	Par de estabilidad	Aufrichtendes Moment	
1817	Ring bolt	piton à boucle	Golfare ad anello	Anilla del pasador	Ringbolzen	
1818	Rivet	rivet	Rivetto	remache	Niet	
1819	Roach	échancrure	Allunamento	alunamiento	Gillung	
1820	Roach reef	bosse de ris			Abflacher	
1821	Rocker	ligne de quille	Linea di chiglia	Balancín	Kielsprung	
1822	Rod rigging	gréement au moyen de monotorons	Manovre di barre d'acciaio	Jarcia de varilla	Profilwant	
1823	Roll	rouler, roulis	Rollata, rollio	Balanceo / Rollo	Rolle	
1824	Roller jib	foc à rouleau	Fiocco arrotolabile	Foque enrollable	Rollfock	

	English	Français	Italiano	Español	Deutsch	
1825	Roller reefing	bôme à rouleau, (arrisage avec..)	Boma che avvolge la randa terzarolandola	Rizos enrollables	Rollreff	
1826	Rope	corde, bout	Cavo, fune	Cabo	Leine, Tau	
1827	Roving	tissage de fibres de verre, mat	Tessuto di fibra di vetro	Mecha / Tejido	Gewebe	
1828	Rowlock	tolet, dame de nage			Dolle	
1829	Rubbing strake	boudin, bourrelet	Bottazzo	Banda de Goma	Scheuerleiste	
1830	Rudder	gouvernail	Timone	Timón	Ruder	
1831	Rudder blade	safran	Pala del timone	Pala del Timón	Ruderblatt	
1832	Rudder fitting	ferrure de gouvernail	Accessori / ferramenta del timone	Herraje del Timón	Ruderbeschlag	
1833	Rudder head	tête de Gouvernail	Testa del timone	Cabeza del Timon	Ruderkopf	
1834	Rudder stock	mèche de gouvernail	Asta del timone	Cajera del Timon	Ruderschaft	
1835	Runner	bastaque	Sartia volante	Burda volante	Laeufer	
1836	Running backstay	pataras volant (?)	Paterazzo volante	Burdas	Loses Backstag	
1837	Running rigging	gréement courant	Manovre correnti	Jarcia de Labor	Laufendes Gut	
1901	Sag	flèche, déformation	Freccia, deformazione	Arrufo	Kieldurchbuchtung, Durchhang	
1902	Sail	voile	Vela	Vela	Segel	
1903	Sailboard	planche à voile	Tavola a vela	Tabla deslizadora a Vela / Windsurf	Segelbrett	
1904	Sailcloth	toile à voile	Tessuto per vela	Tejido de Vela	Segeltuch	
1905	Sailmaker	voilier (ouvrier), voilerie	Velaio	Velero	Segelmacher	
1906	Sailor	marin	Velista, marinaio	Marino	Segler	
1907	Sail plan	plan de voilure	Piano velico	Plano Velico	Segelplan	
1908	Sail track		Trasto	Carril	Segelnut	
1909	Scantlings	échantillonnage des membrures	Dimensioni delle parti strutturali	Escantillón		
1910	Schooner	goêlette	Goletta	Goleta	Schoner	
1911	Screw	vis	Vite	Tornillo	Schraube	
1912	Seam	couture, joint	Comento, cucitura, giunzione	Costura	Saum, Naht	
1913	Self-bailer	auto-videur	Auto svuotatore	Auto achicable	Selbstlenzer	
1914	Self-trimming jib	foc automatique	Fiocco automatico	Autovirable	Selbstwendefock	
1915	Shackle	manille	Maniglia	Grillete	Schaekel	
1916	Sheave	réa	Puleggia, carrucola	Roldana	Scheibe	
1917	Sheer	tonture	Insellatura	Arrufo	Strak	
1918	Sheerguard	lisse, liston		Liston		
1919	Sheet	écoute	Scotta	Escota	Schot	
1920	Ship	vaisseau, bateau	Nave	Barco	Schiff	
1921	Shock cord	sandow	Cavo elastico	Goma	Gummizug	
1922	Shroud	hauban	Sartia	Obenque	Want	
1923	Shroud adjuster	ridoir	Arridatoio	Tensor	Wantenspanner	
1924	Shroud plate	cadène	Landa	Cadenote	Ruesteisen	
1925	Skeg	skeg	Skeg, calcagnolo	Skeg	Skeg	
1926	Skipper	barreur	Comandante	Patron	Steuermann	
1927	Sling	élingue	Braga	Eslinga, braga	Strop	
1928	Sloop	chaloupe, sloop	Sloop	Balandra	Slup	
1929	Snap hook	mousqueton	Moschettone	Mosqueton	Karabinerhaken	
1930	Spar	espar	Asta	Mastil	Mast und Baum	

	English	Français	Italiano	Español	Deutsch	
1931	Spinnaker	spinnaker	Spinnaker	Spinnaker, balón	Spinnaker	
1932	Spinnaker Pole	tangon	Tangone	Tangón	Spinnakerbaum	
1933	Spreader	barre de fleche	Crocetta	Cruceta	Saling	
1934	Stem	étrave	Dritto o ruota di prora	roda	Bug	
1935	Stern	arrière	Poppa	Popa	achtern	
1936	Stiffening	renfort	Rinforzo	refuerzo	Aussteifung	
1937	Strand	toron	Legnuolo, trefolo	Cordon	Strand	
1938	Stretch	bordée	Bordo	Bordada / Tensar	Dehnung	
1939	Stringer	serre	Corrente, trincarino	Trancanil	Laengsversteifung	
1940	Strop	estrope	Stroppo	Estrobo	Strop	
1941	Strut	étresillon	Puntello	Arbotante		
1942	Surfing	action de planer	Planata	Planear	gleiten	
1943	Swage	cosse	Stampo	Estampa		
1944	Swallow	gorge d'une poulie	Gola della puleggia	Moton	Schwalbe	
1945	Swedish hank	mousqueton suédois	Moschettone svedese	Mosqueton Sueco	Stagreiter	
1946	Swing	balancement	Bilanciamento (prova di)	Balancear	Drehen	
1947	Swivel	émerillon	Tornichetto	Grillete Giratorio	Wirbel	
1948	Swivel shacle	manille à émerillon	Maglia a mulinello	Grillete Giratorio	Wirbelschaekel	
2001	Table of offsets	numérisation des couples	Tavola delle coordinate delle superfici curve	Tabla de Offsets	Tabelle	
2002	Tabling	ourlet	Guaina, vaina	Vaina	Einfassung	
2003	Tack	amure, point d'amure	Mura, punto di mura	Amura / Bordo	Wende	
2004	Tackle	palan	Paranco	Aparejo	Laeufer	
2005	Tack tackle	palan d'amure	Paranco di mura	Aparejo de amura	Halstalje	
2006	Tail	Queue, fin	Coda	Cola	Schwanz, Ende	
2007	Talurit	telurit				
2008	Tang	ferrure de renfort		Espiga		
2009	Telltales	penons	Segna vento	Indicadores de Viento	Windfaeden	
2010	Tensile strength	résistance en traction	Resistenza alla trazione	Resistencia a la traccion	Reckwiederstand	
2011	Tensionning rack	crémaillère	Cremagliera	Cremallera		
2012	Thimble	cosse	Redancia	Guardacabo	Kausch	
2013	Throat	collet, machoire	Gola	Garganta en Poleas	Klau, Gabel	
2014	Tiller	barre	Barra	Caña	Pinne	
2015	Tiller extension	ralonge de barre	Estensione della barra	Cañin / Alargadera/ Stick	Pinnenausleger	
2016	Timber	pièce de bois	Legname	Cuaderna / Madero	Holz	
2017	Tip	pointe, extrémité	Punta, estremità	Extremo	Ende, Spitze	
2018	Tolerance	tolerance	Tolleranza	Tolerancia	Toleranz	
2019	Top	plafond,	Sommità	Tapa	oben	
2020	Torque	torque (rotation)	Coppia, momento torcente	Torsion	Drehung, Rotation	
2021	Tow-rope (towline US)	corde de remorquage	Cima di rimorchio	Cabo de remolque	Schleppleine	
2022	Track	rail (d'écoute, etc)	Binario	Rail	Schiene	
2023	Trailer	remorque	Rimorchio	Remolque	Anhaenger	
2024	Trailing edge	bord de fuite	Bordo di attacco	Borde de ataque	Hinterkante	
2025	Trampoline	trampoline	Trampoline	Trampolin	Trampolin	
2026	Transom	tableau arrière	Specchio di poppa	Espejo de popa	Spiegel	
2027	Trapeze	trapèze	Trapezio	Trapecio	Trapez	
2028	Traveller (or car)	coulisseau	Carrello	Traveller / Carrilera	Traveller, Grossschotwagen	

	English	Français	Italiano	Español	Deutsch	
2029	Trim	assiette, réglage	Assetto, orientamento di vele	Reglaje / trimado	Trimm	
2030	Trimaran	trimaran	Trimarano	Trimaran	Trimaran	
2031	Trysail	voile tempête (triangulaire)	Vela da tempesta	Vela de capa	Treisegel, Sturmsegel	
2032	Tumblehome	frégatage	Rientrata, restringimento delle murate	bocas		
2033	Tune	accordage	Messa a punto	Poner a punto		
2034	Turnbuckle	ridoir	Tornichetto	tensor	Vorreiber	
2035	Turn of the bilge	retour de galbord (?)		Curva de pantoque	Kimmrundung	
2101	Under	sous, inférieur	Sotto	debajo	Unter	
2102	Uphaul	hale-haut	Carica alto	varar	aufgeien	
2103	Upper	sur, supérieur	Superiore	superior	ober	
2201	Vang	palan de retenue, hale-bas	Carica basso	Trapa	Niederholer	
2202	Varnish	vernis, peinture	Vernice	Varniz	Lack, Anstrich	
2301	Warp	chaîne (tissage)	Catena	Urdimbre / Estambre	Kette	
2302	Warping drum	guindeau				
2303	Waterline	ligne de flottaison	Linea di galleggiamento	Linea de Flotacion	Wasserlinie	
2304	Waterplane	plan de flottaison	Piano di galleggiamento	Plano de Flotacion	Schwimmebene	
2305	Watertight	étanche	A tenuta d'acqua	Pleamar	Wasserdicht	
2306	Weft	trame (tissage)	Trama	Longitud / Paño de Vela	Schuss	
2307	Wet clothing	poids de l'équipement, détrempé	Abbigliamento umido	Ropa Mojada	Nasse Kleidung	
2308	Wet suit	combinaison étanche	Muta	Neopreno	Neoprene	
2309	Wheel	roue	Ruota	Rueda	Rad	
2310	Whisker pole	whisker	Tangone	Tangon		
2311	Winch	winch	Verricello	Chigre / Winch	Winch	
2312	Windlass	guindeau	Mulinello, ghinda	molinete	Ankerwinde	
2313	Window	panneau transparent, fenêtre	finestra	Ventana	Fenster	
2314	Wings	ailes	Ali	Ala	Fluegel	
2315	Wingsail	voile profilée	Vela con profilo alare	Vela con Perfil alado	Profilsegel	
2316	Wire rope	câble	Cavo	Cable	Draht	
2317	Wire splice	épissure de cable	Impiombatura	Empalme de Cables	Drahtspleiss	
2318	Wishbone	double corne (bôme)	Picco doppio	Botavara de Windsurf	Gabelbaum	
2319	Wooven	tissé	Tessuto	Tejido	gewebt	
2501	Yankee	grand foc	Yankee	Yankee		
2502	Yarn	fil, filin	Filaccia	Hilo	Garn	
2503	Yaw	balancement lateral horizontal	Bilanciamento laterale orizzontale	Guiñada	Gieren	

2504	Yawing moment	Moment de rotation horizontal	Momento di rotazione orizzontale	Momento de rotacion horizontal	Giermoment	
2505	Yawl	yawl	Iola	Yola	Yawl	
2601	Zipper	fermeture éclair	Cremagliera	Cremallera	Reissverschluss	

19 CONVERSION FACTORS

To convert		Multiply by
From	**to**	
mm	Inches	0.03937
inches	mm	25.4
m	feet	3.2808
fathom	m	1.83
m^2	sq. feet	10.764
sq. feet	m	0.0929
mm^2	cm^2	0.01
cm^2	mm^2	100
mm^2	sq. inches	0.00155
sq. inches	mm^2	645.16
litres	gallons (imp)	0.2200
litres	gallons (US)	0.2642
gallons (imp)	litres	4.546
gallons (US)	litres	3.785
m^3	litres	1000
kg (mass)	lb	2.204
kg	gr	1000
t (mass)	kg (mass)	1000
N (Newton)	kgf	~0.1
kN	N	1000
MN	N	10^6
N/mm^2	kgf/cm^2	~10
MN/ m^2		
oz/sq. foot	gr/ m^2	305.24
oz/sq. yard	gr/ m^2	33.916
gr/m^2	oz/sq. foot	0.00328
kg/m^3 (density)		
gr/cm^3		

20 MASS DENSITY OF SOME SUBSTANCES (t/m^3)

Plastic foams	0.01 – 0.04
Balsa wood	0.01 - 0.02
Spruce	0.40 – 0.43
Pine	0.45 – 0.65
Mahogany	0.55 – 0.85
Oak	0.68 – 0.95
Teak	0.88 – 0.95
Water at 4° C (in kg / m^3 or g / cm^3)	1.0
Salt water	1.02 – 1.03
Polyurethane	1.11 – 1.28
Cotton	1.54
Polyester fibres	1.4 – 1.72
Glass fibres	2.3 – 2.5
Aluminium	2.7
Antimonium	6.6
Titanium	4.5
Iron	6.9 – 7.85
Zinc	7.1
Steel	7.85
Brass	8.7 – 8.9
Copper	8.3 – 8.9
Silver	10.5
Lead (pure, without antimonium)	11.34
Mercury	13.6
Gold	19.3
Platinum	21.1