Guide to Certification Control 2017

sport / nature / technology

World Sailing

PREFACE

This guide is designed to be the standard reference material for official measurers, with the aim of contributing to consistency in measurement all over the world. Parts of this manual are used as textbook for World Sailing (WS) International Measurer clinics.

Since our sport is constantly changing and evolving, a guide such as this has to be a living document that needs to be updated constantly. Therefore, contributions to improve it are always welcome and will be posted on the WS website as updates are made. The responsibility for the contents of the Guide to Certification Control and keeping it up to date lies with the Equipment Control Sub Committee (EQSC) of WS.

This guide is based on the International Measurer's Manual. Official measurers interested in special topics or more detailed presentations should refer to that document instead.

Jan Dejmo
Chairman
WS Equipment Control Sub-Committee
December 2016

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SECTION A. THE BASICS

A.1 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 organization 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 or values in a measurement certificate for meter or rating boat. This is a guide to certification 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 essential that measurers always keep in mind that **this is only a guide**, and also refers to the current class rules of the boats they are measuring. The class rules/regulations override this guide when there is any conflict between them.

A.2 Meaning of Terms

Racing Rules of Sailing (the "rules")

The rules used by sailboats when racing under the jurisdiction of World Sailing.

Class Rules

Set of class specific rules that specify a boat, its construction and its use, the crew, personal or any other equipment and its use, and any changes to the rules as permitted by RRS 86.1(c).

World Sailing (WS)

The international body governing the sport of sailboat racing is World Sailing. It comprises member national authorities, class associations, and other affiliated organizations. Among the many WS responsibilities and programmes is the training and certification of International Race Officials such as the International Measurers.

National Authority (MNA)

The national authority is the organization that governs the sport of sailboat racing within its jurisdiction, and is a member of WS as well.

Certification Authority

According to the ERS, it is the body that manages certification as follows:

For hull certificates, it is WS, the MNA of the owner, or their delegates.

For all other items, it is WS, the MNA in the country where the certification shall take place, or their delegates.

However, a number of Classes are the certification authorities themselves (i.e. FD)

Official Measurer, National Measurer, International Measurer.

The term 'measurer' is a term often used to describe a person who performs either certification control or equipment inspection or both. However, it must be made clear that people performing equipment inspection at events should be called “equipment inspectors”, and those who perform certification control should be called “official measurers”. The title 'national measurer' is given to a suitably qualified person by a national authority that runs a ‘national measurers' scheme and usually refers to official measurers. The title of 'International Measurer' is awarded by WS to a person who meets the criteria set out in the WS regulations.

SECTION B. MEASUREMENT FUNDAMENTALS

B.1 “Measurer”

B.1.1 Role of the “Measurer”

Boats are measured principally to establish compliance or/and the rating with the class rules, but there are different cases when compliance is checked and the role of the person called a “measurer” varies in each case as follows:

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 Sections D (hulls), E (appendages), F (Rigs) and G (sails) and this task is performed by “official measurers”.

Measurement of Alterations

RRS 78 makes 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, and if major restoration activities have been done. This task is to be performed also by an “official measurer”.

Periodic Measurement

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

Equipment Inspection at an event (Regatta Measurement)

Formal inspections 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. Equipment inspection is covered in the separate Guide to Equipment Inspection, and is performed by “equipment inspectors”. In major regattas like World or Continental Championships this task ideally has to be done by the International Measurers.

Prototype Measurement

In most WS Classes, 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 WS International Classes that the prototype boat (first boat out of the mould) be measured and approved before production of subsequent boats commences, and this is a task to be performed by an International Measurer.

B.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 H describes some 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 and sometimes more specialized measurement tools, as detailed in Section C. 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/inspection. Some classes sell purpose-designed tool kits for their class.

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

B.1.3 Appointment and Authority of "Measurers"

Before measuring boats for any reason, a "measurer" must ensure that he/she 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 (MNA).

Official Measurers

For measurement for certification or of alterations, the measurer must be recognized and authorized by the body administering the class. This body will normally be the National Authority (MNA) 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 authorized to measure by the class association (i.e. LIGHTNING, SNIPE and STAR).

Measurers are often recognized by, i.e. registered with, both the national authority and class, so that both organizations can be aware of measurement activity, however only one of these organizations will be the administering authority responsible for processing measurers' reports and issuing measurement certificates. Official measurers are not authorized to issue measurement certificates themselves but only to record measurements as required by the Class Rules and to report accordingly to a certification authority.

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

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 WS Classes with Licensed Builders, this body is WS 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 (as per the WS regulations) be an International Measurer of that Class, but sometimes it can be agreed to be done by a very experienced class or national authority official measurer.

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.

B.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:

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.

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 equipment manufacturers which are licensed to measure their own equipment, within the current WS IHC (In-house Certification) scheme or similar schemes run by some MNAs.

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.

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.

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 (s)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 (herself) 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.

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 minimize 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.

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 (s)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 (s)he is part of a team of administrators who are effectively the guardians of the rules.

B.2 Application of Class Rules

B.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.

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.

Box Rules / Development boats

These 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.

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 (ORCi-IRC). In the latter case a considerable amount of measurement may be necessary to establish the required data before the handicap can be calculated.

B.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 WS Classes are published on the “Internet” by WS. Changes to the rules of International Classes may be approved by WS at any time so 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.

B.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, 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 WS Classes, if the administering authority is unable to determine whether the detail is acceptable it will seek an official interpretation from WS 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.

B.2.4 Plans – Drawings

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 judgment decision has to be made.

B.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.

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.

B.3 Certification Measurement

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.

B.3.1 Measurer

Measurement for certification is carried out by Class or National Authority measurers. 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 WS IHC scheme).

B.3.2 Arrangement for 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 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.

B.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, when needed (meter class) water density has to be recorded to adjust freeboard measures . 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.

B.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) does not normally 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 official 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.

B.3.5 Recording Measurements

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.

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 had made.

B.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.

B.3.7 Class Fees and WS 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 WS 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 WS. 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.

B.3.8 Application for a 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 MNA and/or the class shall check that recorded measurements are in agreement with class rules, and if a rating is extrapolated from the measurements, that there is no calculation error. 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. The Measurement Certificate may be a separate document from the Measurement Form or may be combined with the Measurement Form to give easy reference to the original measurements.

B.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.

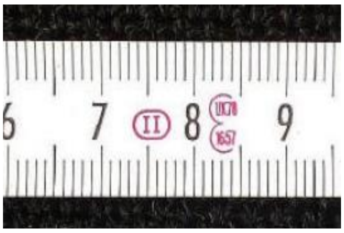
If alterations are done on the boat which may affect the rating (meter class, IRC, ORC), a new certificate has to be issued.

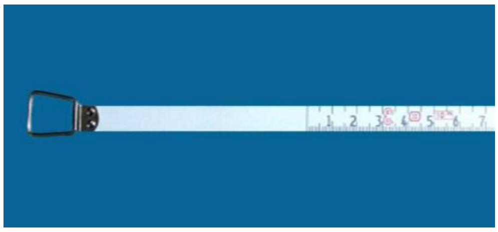
SECTION C. MEASUREMENT TOOLS

C.1. 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.

Tape Measure



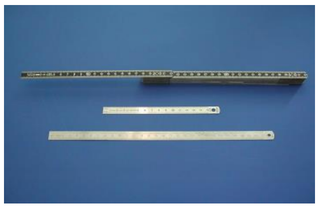


Must be of steel (preferably with offset zero), as fabric tapes can be very unreliable. 15 m and 5 m tapes are practical sizes for most classes, although for large yachts a longer tape measure is needed. Class II metric tapes are of an acceptable level for normal measurement.

Laser distometer

Laser distometers are now available at reasonable price with accuracy (1.5mm for 30m) comparable to a class II steel tape. These instruments are wind and temperature independent

Steel Ruler



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

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.

Spirit Levels

Preferably not less than 500 mm long, 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. For normal, uncertified spirit levels the error

is approx. at 1 mm/m while better ones go up to 0.7 or 0.5 mm/m and classified ones 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 lighting conditions.

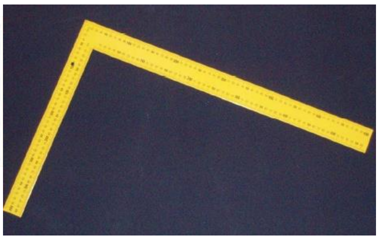
Plumb bob

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.

Set and/or Squares

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.





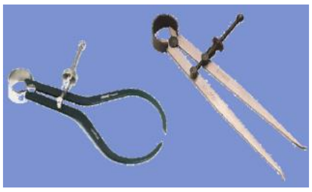
Laser squares and plumb bobs are also available in various



forms (2 and 3 axis shown here).

Callipers

Vernier callipers are used for measuring items such as the diameters of wire, the thickness of small parts or the cross section of spars. Inside or outside compasses may help to transfer figures where you cannot reach with a calliper.




Thread

Nylon or 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.

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.

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 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 <u>maximum weight allowed</u> (to take a 2000 kg scale to weight a dinghy is a nonsense).

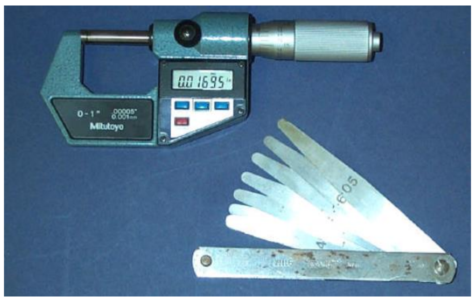
Industrial scales typically have an accuracy of 0.2% of the max load.

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.

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. See also section H of this guide.

Micrometre

Micrometres for sail ply thickness measurement shall have the following characteristics:



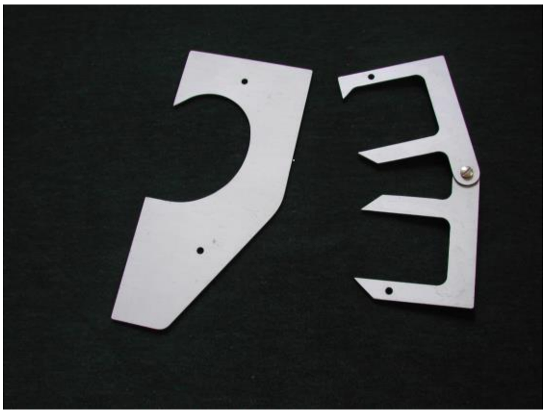
- Ratchet stop
- Measuring surfaces diameter as specified in **class rules** or, as a default, of 6.5 mm
- 400gf – 600gf applied to the measuring area
- Throat depth of approximately 21mm minimum
- Graduations to 0.001mm (0.00005in)
- Overall accuracy of plus or minus 0.002mm
- Flatness of anvil and 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 when checking cloth thickness.

C.2. Purpose-designed measurement tools

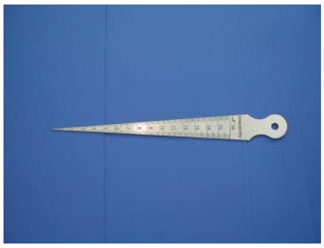
The following items of equipment are useful for measurement in a wide range of classes and may be produced form simple materials using only basic tools. Some classes offer packs of tools for the class produced by a builder to proven designs and occasionally run measurement seminars to demonstrate their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

Sheerline Jigs



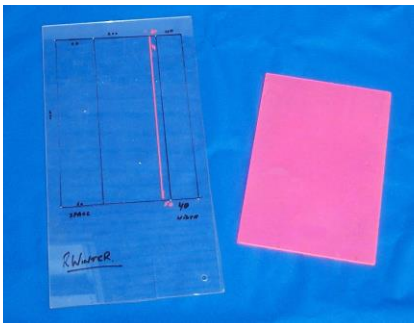
A means of accurately determining the positions of the sheerline by transferring the line of the topsides to the top surface of the deck is often required. For boats with straight or nearly straight topsides, such as most hard chine boats, a `C' template (on the left) is adequate. If there is considerable curvature then the sheerline jig shown on the right 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.

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 H).

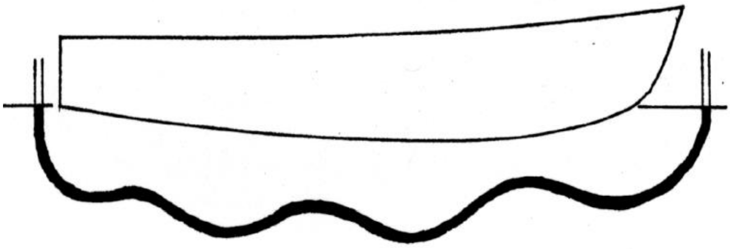
Go-No go Gauges



Examples of purpose-made measurement tools would be tools like a “go-no go” gauge for measuring a spar section or a transparent template to check sail numbers.

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.

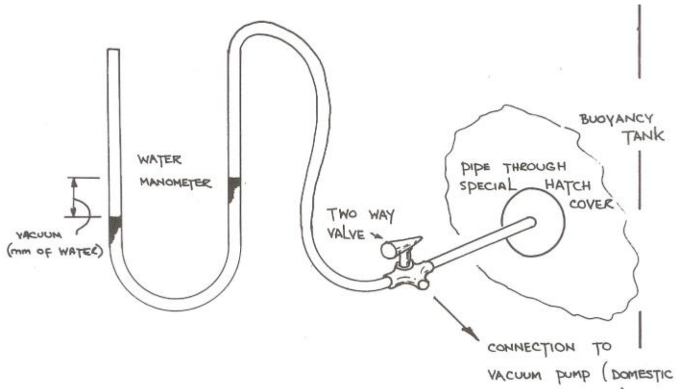


Auto-levelling transit

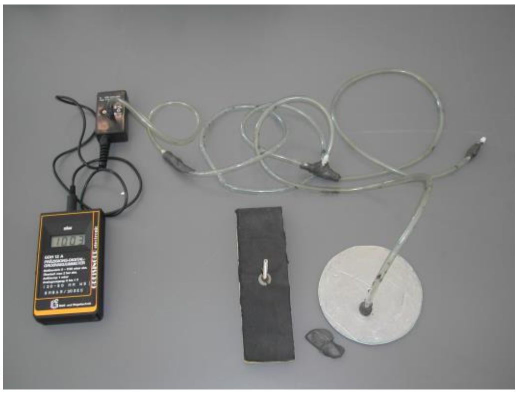
To set up a horizontal plane an auto-levelling transit is the most accurate instrument, especially useful when measuring big boats.

Manometers

A simple manometer or a similar device with a digital pressure meter may be used to test the air tightness of buoyancy tanks.



Buoyancy Test

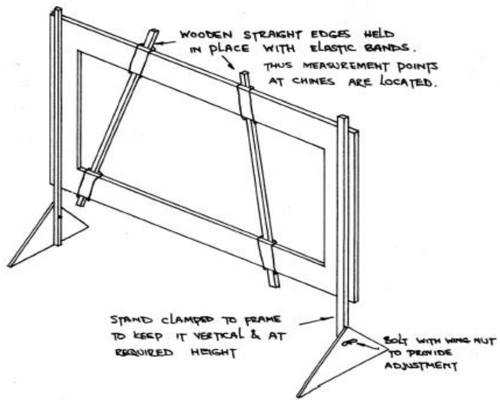


Weights

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.

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 small hard chine boats such as the Fireball and Enterprise.



Hull Baseline systems

Beam baseline systems are easy to use in dinghy hull measurement and an affordable alternative to specialized jigs. They can be crude or highly elaborate depending on personal taste and the desired level of flexibility: the system shown below may be adapted to suit a number of different classes in a matter of minutes using sets of interchangeable fittings. In addition, car jacks are useful in setting up the hull on the desired trim (hydraulic jacks for bigger boats).

Stop watch

Electronic stopwatch: 1/100 sec resolution.

Electronic timer with photo gate (quartz crystal, not RC), resolution 1/10000 sec

Surveyor's Level

When setting up a large keelboat of, say, one of the WS metre classes, it may be more convenient to use a surveyor's level or a theodolite (below left) although a water tube can be used. A laser beam level (below centre) is also suitable if a great accuracy is not needed. For smaller boats, a self-levelling laser (below right) may be used to draw a continuous virtual "baseline" or to set a horizontal reference line.

SECTION D. HULL MEASUREMENT

Hull measurement is not limited to shape control: hull weight and its distribution, scantlings (hull skin thickness, size and position of stiffening members) and buoyancy may also be prescribed in class rules and therefore have to be dealt with by the measurers. ERS 2017-2020 don’t offer a standard set of definitions so uniformity in methods and tools is impossible, but the principles are more or less the same and classes follow variations of a small number of main themes. Each of the following sub-sections deals with the main aspects of hull measurement in detail.

Hull Shape Measurement

D.1 Introduction

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. This 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.

Hull shape measurement is the procedure to get certain dimensions of a hull’s external surface, and finally compare the hull shape with the original as-designed shape. The latter may require the use of special templates which outline the “standard” shape of a particular “section” of the hull, or –in case the hull shape permits, as in chine hulls- may be accomplished with direct comparison to a set of XYZ offsets.

Measurements usually include hull length, width (beam) measurements between certain points, keel profile shape (rocker), bow and transom profiles and of course the external shape of the hull in specific sections (stations or “frames”). In addition, class rules may specify other construction details such as internal or external radii at corners, edges, gunwales etc.

D.2 Reference Systems

To measure a hull, one needs a Hull Datum Point which is the starting point for taking measurements from, and a Cartesian axis system to define the major axes: longitudinal, vertical and transverse. These are related to a “baseline” defined in the Class Rules (usually an imaginary line parallel to the designed waterline) and the hull centerplate (hull in Measurement trim). Once the reference system is defined and in place, measurement “stations” can be defined as transverse sections “cut” through the hull at certain longitudinal positions according to class rules.

ERS H.3 states: For a boat, unless otherwise specified, words such as “fore”, “aft”, “above”, “below”, “height”, “depth”, “length”, “beam”, “freeboard”, “inboard” and “outboard” shall be taken to refer to the boat in measurement trim. All measurements denoted by these, or similar words, shall be taken parallel to one of the three major axes.

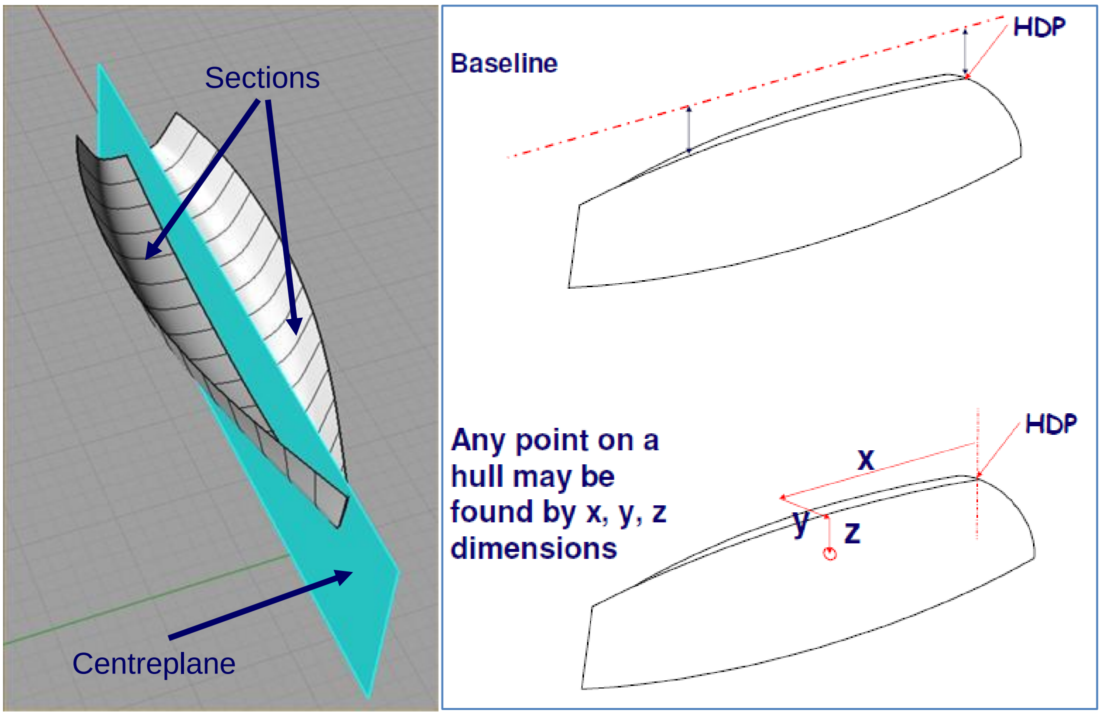


Figure D.2.1 Basic terms

The standard Cartesian axis system may be called the “Gravitational Coordinate system”. Locating the measurement stations at the sheerline and keel needs special equipment and takes time to set up properly and accurately; therefore some classes have taken another route, defining their measurement stations at pre-determined points along the curve of the sheerline and keel, eliminating the need for precise levelling of the hull: this is the “Hull Coordinate system”.

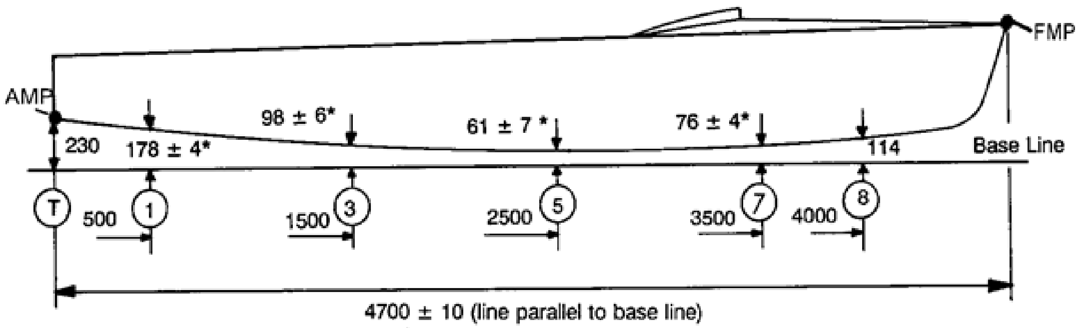


Figure D.2.2 Gravitational Coordinate System

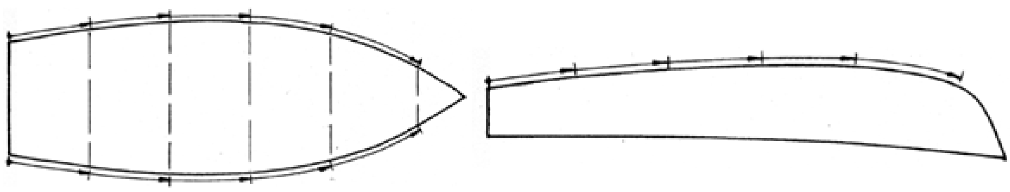


Figure D.2.3 Hull Coordinate System

D.3 Hull Length and Width

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, length is normally measured parallel to the baseline. 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.

The aft measurement point (AMP) from which lengths are measured (HDP or Hull Datum Point) is usually the intersection of the transom and the centerplane of the hull at the keel line (Figure H.1.3.1).

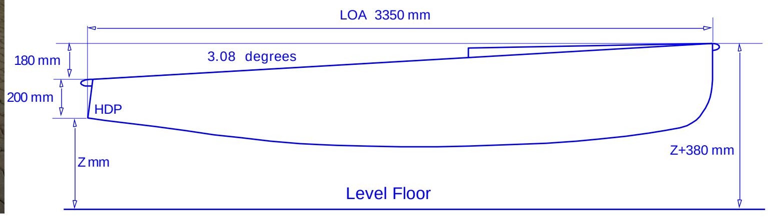


Figure D.3.1 ***HDP*** **Figure D.3.2** ***Deck overlaps***

The hull length according to the ERS includes any deck overlap, measuring up from the aft-most to the foremost point of the hull and excluding fittings (e.g. 420 Class). However, class rules (e.g. Europe, 470 Class etc.) may specify that the deck overlap is excluded (Figure H.1.3.2). Class rules may also define a Forward Measurement Point (FMP) and then, with the baseline horizontal, the measured length is the distance between vertical planes through the HDP and FMP. Normally, fittings (like the rudder fittings on the transom) are excluded from the overall length measurement.

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.

Width or beam measurements are taken parallel to the hull's transverse axis. Class rules may specify the measurement point as the sheerline (intersection of the hull surface and the deck), thus excluding any gunwale rubbing strake or deck flange.

D.4 Hull Profile

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

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 lightweight line (Figures D.4.1 & D.4.2) and considerable tension the sag can be reduced to negligible proportions. The sag can be measured with a laser beam.

Some measurers claim that the only satisfactory equipment to use is a beam. However, beams also sag and if of wood may warp. Stiff aluminium beam sections should always be used with the large dimension vertical (Figure D.4.3) and then yield acceptable results, having maximum vertical deflections at mid-span of typically less than 1 mm, which again may be checked on the spot with laser lines/levels.

Figures D.4.1 & D.4.2 *String Baseline*

Figure D.4.3 *Beam Baseline*

A combination of both systems, where the beam is only there to support the line, works also well, the lightweight line 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.

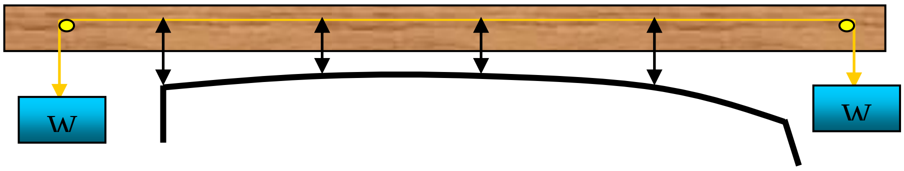


Figure D.4.4 *Combination Baseline*

The base line can also be materialized by a laser beam combined with a spirit level (figure D.4.5), or a surveyor's level (D.4.6):

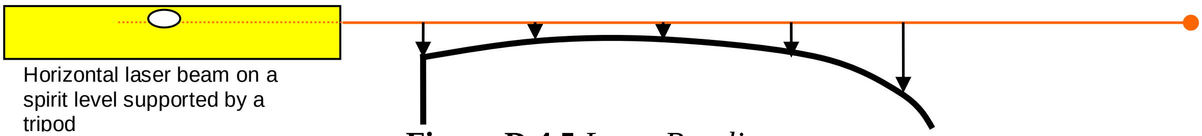


Figure D.4.5 *Laser Baseline*

Figure D.4.6 *Dumpy level Baseline*

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

When using a thin line as a baseline, the forward attachment point of it 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

The hull has to be supported in such a way that it is not twisted and does not sag or hog. This is especially important for keel boats for which the keel should be supported. 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 if possible.

D.5 Hull Sections

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). Each section through the hull where measurements are taken is referred to as a measurement station, and “Gravitational” or “Hull” Coordinate systems may be used. 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. These marks should be on the hull topsides or at the sheerline, and in some classes are required to be permanent.

D5.1 Section measurement using templates

Having located and marked up the measurement stations, the following procedures may be generally used to set up the templates, unless otherwise stated in the class rules:

- 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.
- Measure clearances all around the template, where necessary recording both maximum and minimum clearances.

- Measure height of sheerline on each side.

It is essential that the template is accurately located, particularly towards the ends of the hull, since the shape of the hull 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 figure D.5.1.1 or plasticine pieces (figure D.5.1.2). At the centreline masking tape or plasticine will hold the template in place.

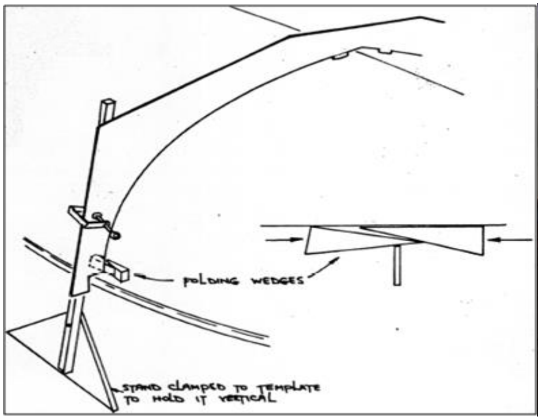


Figure D.5.1.1 *Template support*

Figure D.5.1.2 *Template fixing*

Clearance between the template and the surface of the hull is best measured using a steel ruler held parallel to the face of the template (figure D.5.1.3). Using wedges can lead to errors, particularly near the bow and stern (Figure D.5.1.5) because the wedge measures the shortest distance between the hull and the template and not in the plane of the measurement station.

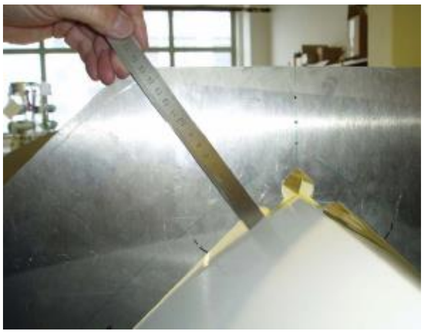


Figure D.5.1.3 *Ruler measurement*

Figure D.5.1.4 *Wedge measurement*

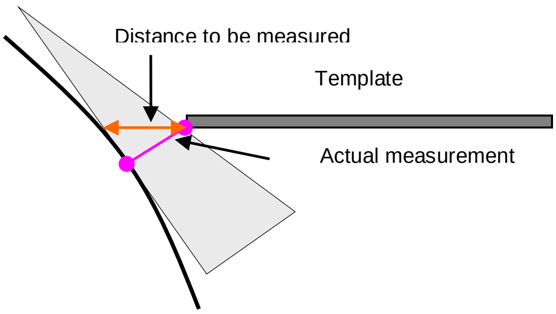


Figure D.5.1.5 *Wedge measurement errors*

D5.2 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. For ease of measurement, some classes measure chine rise and sheerline height from the keel at the centreline.

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 chine. The sheerline is normally defined by the intersection of the deck upper surface and the outside of the skin of the hull, projected if necessary and can be found using a `C' template or a sheerline jig.

Before measuring chine and sheerline heights, the hull should be levelled athwartships. Alternatively, the height can be measured on both sides and averaged, eliminating the need to accurately level the boat athwartships. However, if the hull appears to be significantly asymmetric the measurer should note it on the measurement form.

Another way to measure the section shape of a chine hull is by using a measurement frame as shown in figure D.5.2. 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).

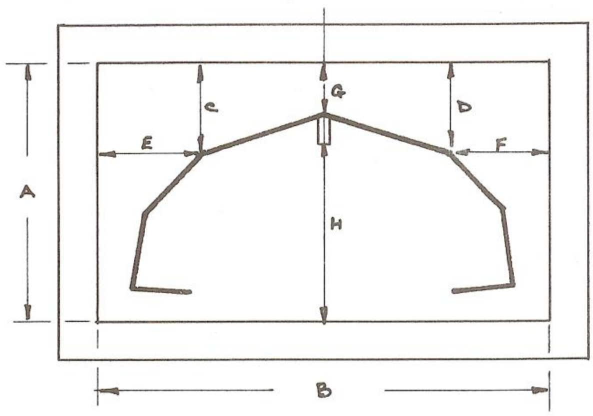
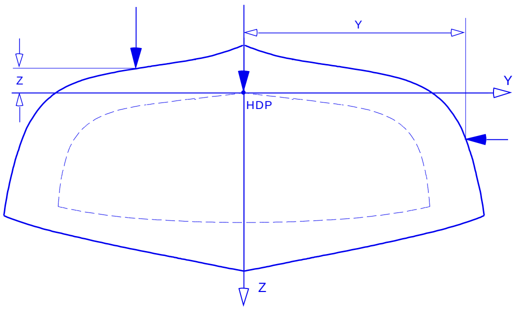


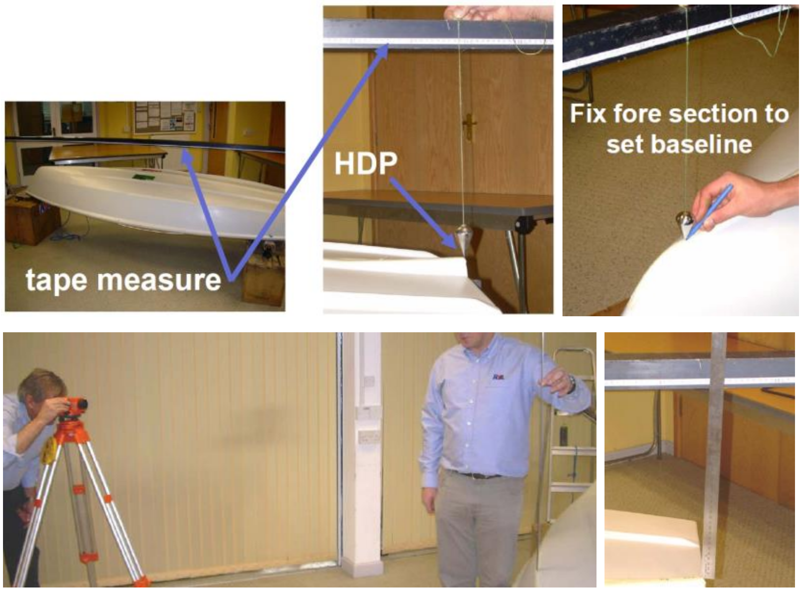
Figure D.5.2 *Chippendale frame*

D5.3 Generic Hull measurement: XYZ coordinates

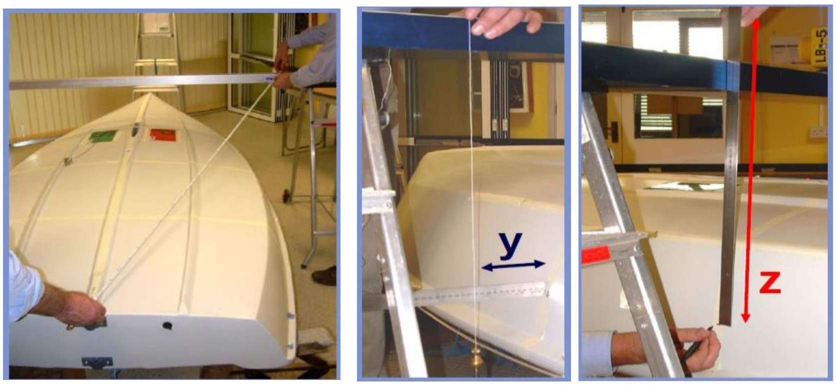
Any point on a hull surface may be described by its XYZ coordinates, using a 3-axis coordinate system with the HDP as its zero point. Sections have the same X coordinate so for points on a particular section a measurer needs to measure their Y and Z dimensions.



Using a surveyor’s level, plumb bobs, a ruler and a beam with an attached tape measure, the hull may be set up for measurement as shown below:



The beam is needed only to hold the tape measure and sight the centre plane, as the horizontal levelling is controlled by the surveyor’s level. Heights are measured with the level and the ruler, and not by using the beam. The hull is adjusted up and down until level (as defined by the rules). Then, sections are set forward of the HDP on the centre plane. Keel profile is measured again with the ruler and the level. Sections may be then set across the hull using a second beam and triangulation or a laser square. Any point on a section may be then defined by its height and beam dimensions.



D.6 Other measurements

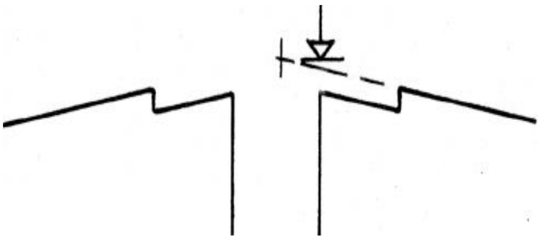
Stem profile

Stem templates are made in the shape of the curve of the stem allowing for the permitted tolerances. The method of using them varies from class to class and therefore reference to the appropriate class rules is essential.

Transom

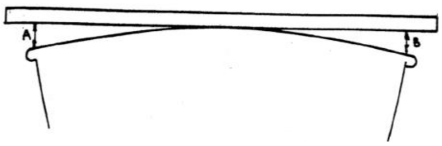
Transom rake can be measured using a spirit level or a plumb bob, but a simple and accurate way of doing it is to use a plywood rectangle

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.

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 athwartships approximately horizontally on the deck and measuring its height above each sheerline. Deck camber = (A+B)/2

Internal measurements

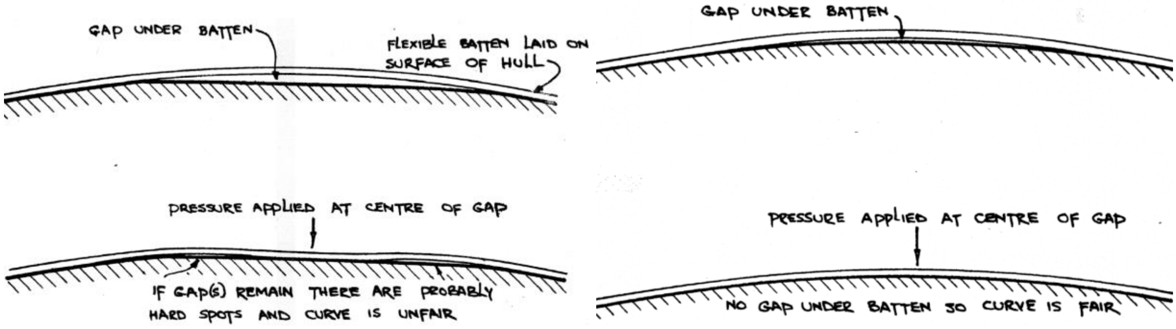
Measurements along the hull and to bulkheads, mast step and fittings etc. may be taken from a transverse plane passing through the aft measurement point. It should be noted that this datum plane may not be accessible for all measurements so the measurer may need to display some ingenuity in carrying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

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 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 doesn't, there may be a hard spot and therefore unfairness.



D.7 Hull measurement with templates: Case studies

The following is a guide on dinghy hull measurement using a beam baseline, as applied in various centreboard classes.

Toolkit

- A beam to serve as baseline, a little longer than the hull
- Big square (Torpedo Laser level or big Carpenter's square or equivalent)
- Self-levelling Laser or water-tube
- Ruler, tape measure, adjustable square
- Plumb bob, plasticine, pencils, masking tape
- Sheerline finder
- Official set of templates
- Car jack
- Trestles, support for the hull

D7.1 Baselines

The base line can be a straight beam of an aluminium rectangular section, as light and stiff as possible: that may be accomplished by using tall and thin-skinned sections, but in all cases they should be stored carefully to avoid permanent deformations or other damage.

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. The measurer should always take these figures into account when measuring a hull, especially in cases where the hull is made close to the limits.

All measurement stations should be clearly marked on the beam along with notes such as the minimum and maximum limits, and a steel tape can be fixed on the upper surface for quick reference. Obviously this is one of the main advantages of this system compared with a 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 class rules, and there are various ways to do that:

- Using pieces –preferably of the same aluminium section as the baseline- cut in the correct length and fastened with bolts or clamps on the baseline beam.

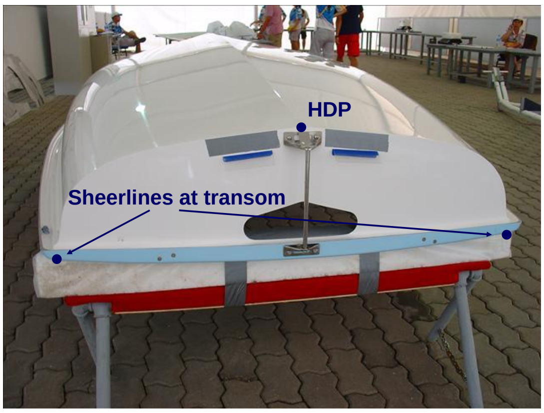

- Using the stem and transom templates themselves –if the class uses those like the 420, fastened with clamps (or even bolts) on the baseline beam. This arrangement cannot be used in cases like the Finn, as the exact positioning of the stem template depends on the actual measured length of the hull and its difference from the "standard" class length.


D7.2 Hull setup

For the aft support, the transom edge is not always a good choice because many boats have curved transom tops, so the hull will sit on the highest point which is on the centre plane, and therefore it will be unstable. 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 centimetres in front of the transom, while a Finn needs to be supported just in front of the aft tank. The aim is to support the hull on the side tanks in a way that will facilitate proper athwartships levelling: using small wedges on one side the hull may be levelled athwartships with the help of a simple water-tube or spirit level. Reference points for the levelling shall be the sheerline points at the transom corners. Alternatively, this may be accomplished by using car jacks.



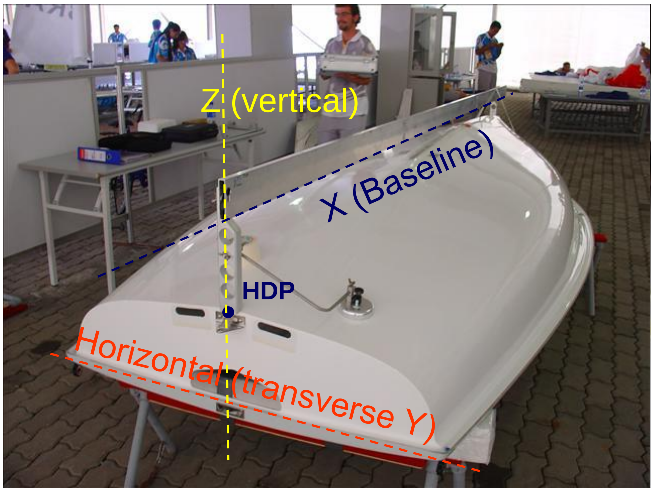
For the bow, a car jack with some foam pads attached is to be positioned near the stem, but it must not obstruct the positioning of the stem template. Then, it will be used to lift or drop the bow as needed.

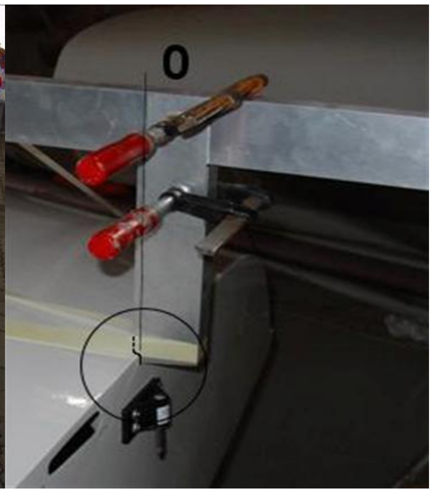



The HDP of the hull shall be defined next: This is the intersection on the hull centre plane of the transom external surface with the underside of the hull surface, both extended as necessary. For hull measurement purposes, and lacking another way of finding the symmetry plane of the transom, this shall be the point at the above said intersection at equal distances from the two sheerline points at port and starboard transom corners. It may 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.

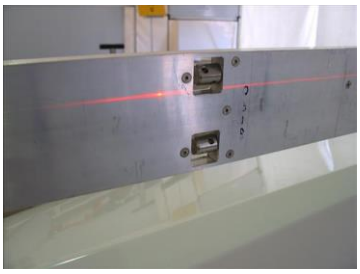
The baseline is then ready to be set on the hull and fixed with masking tape.

The front leg shall be positioned so that the baseline is above the highest point of the keel at the appropriate. The baseline beam system must be made vertical (athwartships) using a plumb bob or a level. In this way, the vertical plane passing through the baseline, set as described above, coincides with the hull centre plane for measurement purposes.





Using a water tube, a spirit or laser level the hull can then be levelled fore and aft with a few turns of the front support jack screw. The fore and aft levelling of the hull is not really necessary but will help with some measurements as it allows the measurer to use tools like plumb bobs and certainly helps with template positioning at the later stages.



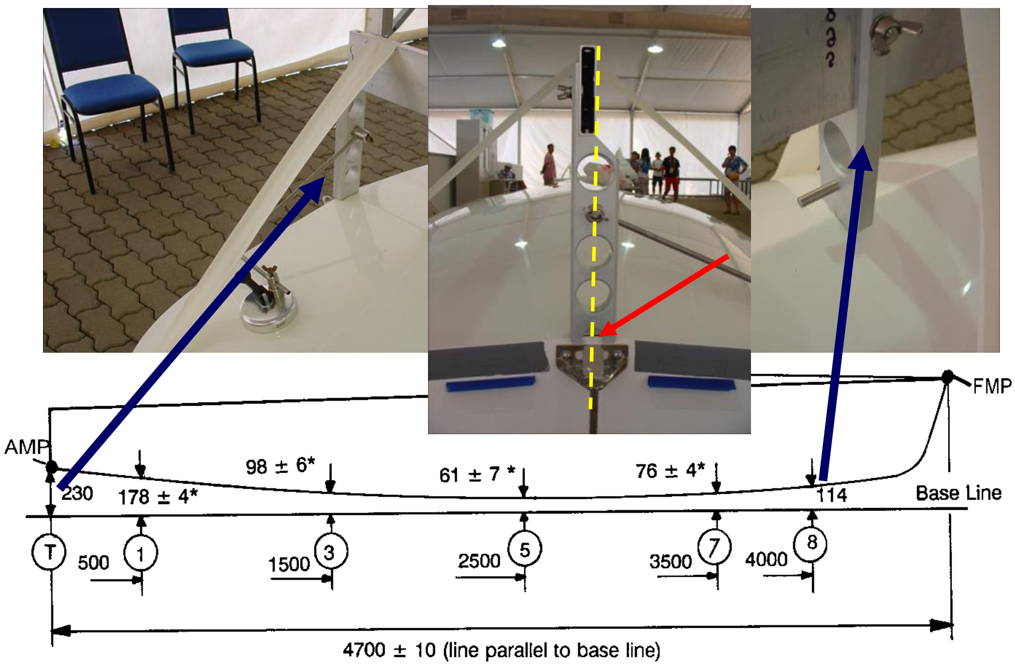
It is very important to fix the baseline system on the hull so it doesn't move, and even mark the contact points with pencil fore and aft for quick reference during measurement: if at some point it is discovered that they are not aligned anymore, then the setup process should be repeated.

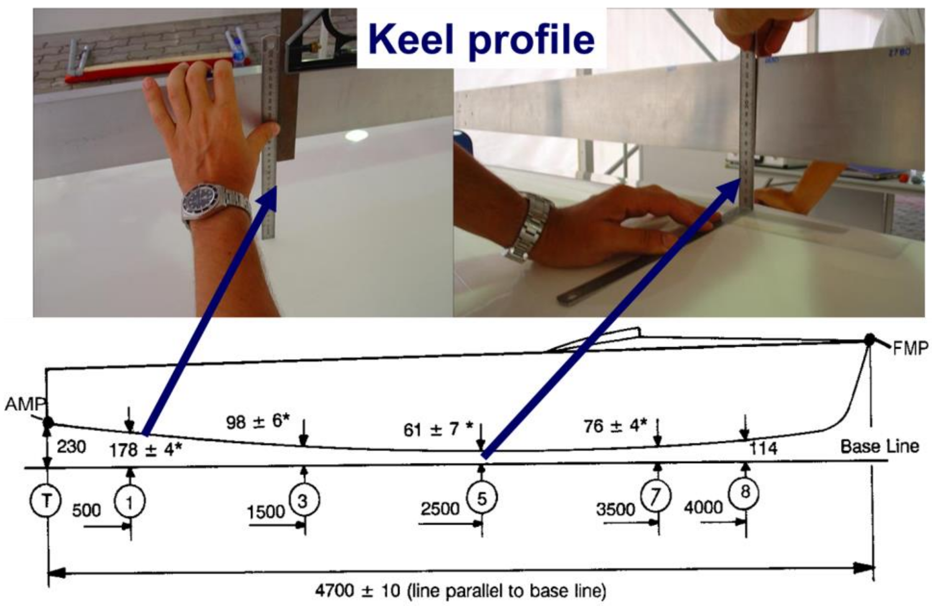
D7.3 Keel profile measurement

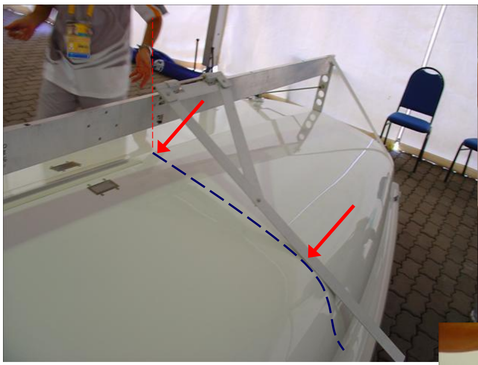
With the baseline set and fixed on the levelled hull, the next step is to check the keel profile at the various stations and mark on the hull the station points for template positioning. The first can be done with an adjustable square and a steel ruler, but for the second a carpenter's square or a laser square is needed to extend each station on the hull sides.

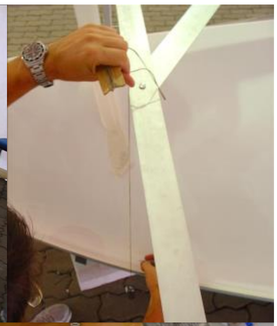
The gunwale positions for each station can be marked using a plumb bob, and then the sheerline points can be marked using appropriate tools for each class.

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.









Section marking by triangulation or laser square

Finally, the hull length between the transom corner and the stem may be measured using the baseline and a plumb bob or a square. If the forward measurement point is the extension of the stem on the deck, a tool similar to a sheerline finder may be used.

The height of the stem head from the baseline may be measured and recorded, even if there is no limit in the class rules for that: it will help the measurer set and level the hull for deck measurement.

Template Measurement

When the keel profile measurements and the station marking has been done, the baseline may be removed to make way for the templates. With three points marked on the hull for each station (centre and one per side), 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 coincide with the mark on the hull centre plane and one face of the template shall coincide with the station marks. 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.

Minimum and maximum hull clearances from templates should be measured and recorded for both sides.

Deck Measurement

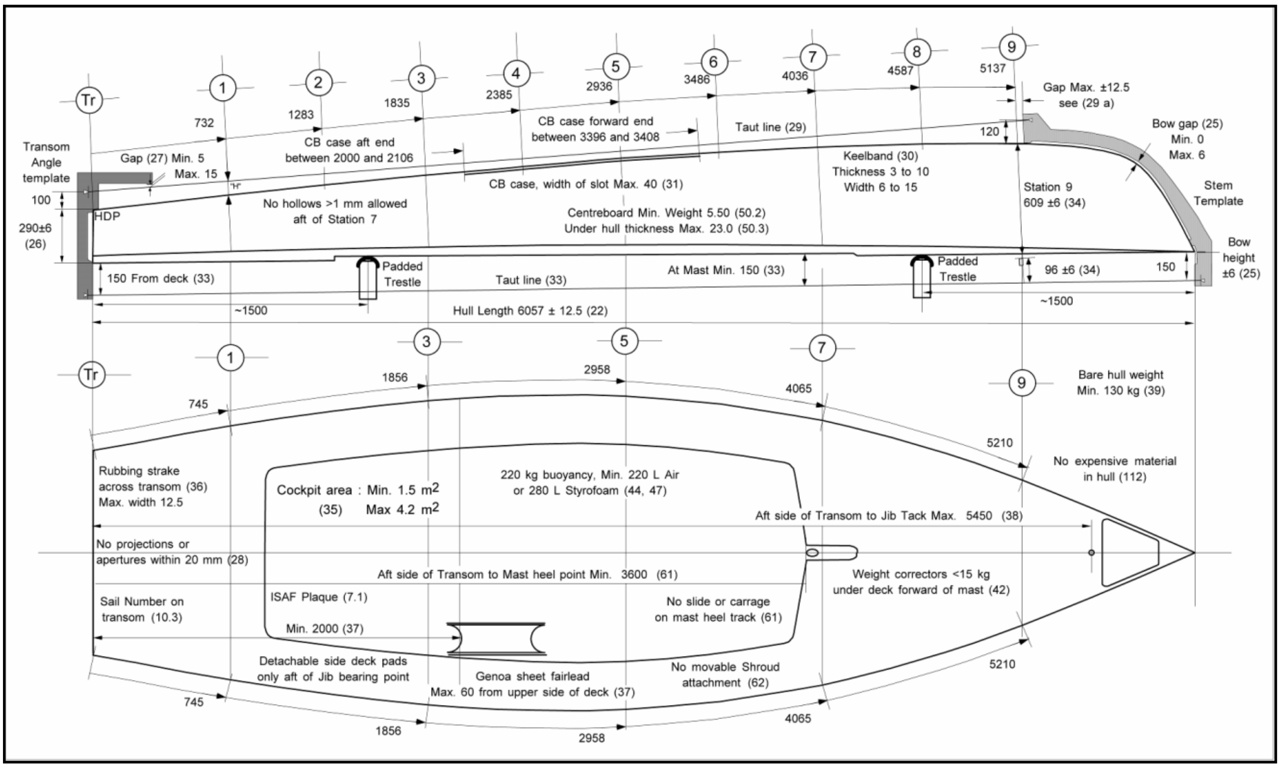
For deck measurement, the hull must be turned back upright; The same beam baseline may be used but with different height legs, according to the following system: by measuring the difference of the sheerline height between the stem and the top of the transom, two legs with lengths differing by that amount can be made. Enough length must be added to both legs for the baseline to clear the breakwater (if any).

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 levelling is needed, the hull shall be levelled athwartships using the sheerline points at the transom corners, and the baseline for fore-aft levelling, 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 without significant errors.

Hull Coordinate measurement system example

The Flying Dutchman Class is using the simpler “Hull Coordinate System” and applies the following procedure (taken from the FD Class Rules):



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 checked

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 minimize hull sagging.

D.8 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. Under ERS, there is a clear separation between **hull weight** and **boat weight**.

D.8.1 Hull 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 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. 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.

D.8.2 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, in positions specified by the Class rules. 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.

D.9 Buoyancy

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

D.9.1 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.

D.9.2 Immersion Buoyancy tests

Many classes require the buoyancy equipment to be tested by immersing the boat in water to simulate 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.

D.9.3 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. The test will be satisfactory if the pressure drop does not increase faster than a certain rate; the rate and initial pressure difference being specified in the class rules.

SECTION E. HULL APPENDAGES

Hull appendages are items of equipment found wholly or partly below the sheerline or its extension when fixed or when fully exposed if retractable; they are attached to the hull or to another hull appendage and they are used to affect any or all of the following: stability, leeway, steerage, directional stability, motion damping, trim and displaced volume. ERS 2017-2020 don’t offer a standard set of definitions other than the various type names, so uniformity in measurement methods is impossible. Therefore, classes follow their own systems but in general, class rules may control

- Profile shape (width and length, edge shapes)
- Section shape (thickness in various points)
- Position relative to hull
- Weight
- Materials

E.1 Profile

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

- Measurements stated in the class rules,
- Plan or measurement diagram giving dimensions,
- Template.

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

Where it is a requirement that the board 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.

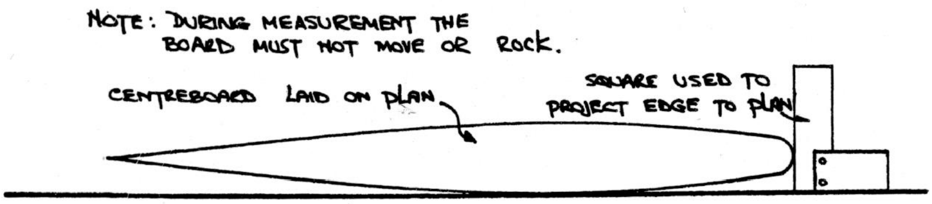


Figure E.1.1

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 or similar tool 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 board the problems are not the same and, depending on the class, the measurement may be carried out with the board in the boat and fully lowered. In this case, if the board has to be in the fully lowered position there must be stops to prevent it being lowered any further.

Figure E.1.2

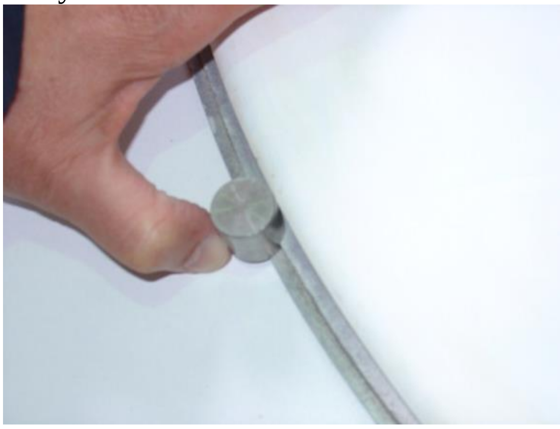


Figure E.1.3

Appendages should be carefully positioned on templates, observing any datum or other reference points. Depending on the specific class rules and the shape of each appendage, edge and corner shapes may be checked individually as in the 470 centreboard and rudder shown below, or the whole blade checked at once like the Finn rudder shown above.

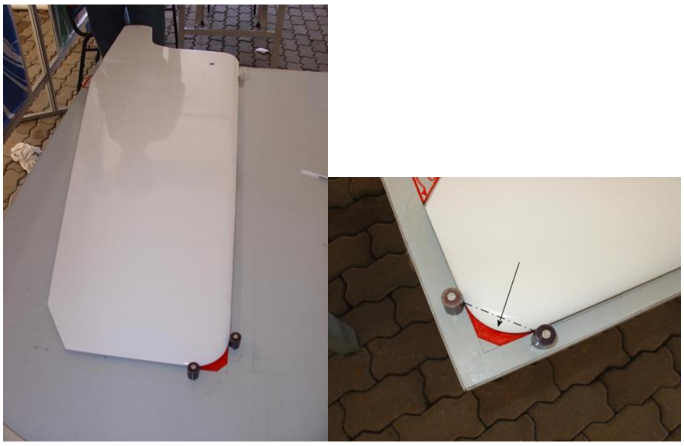


Figure E.1.4

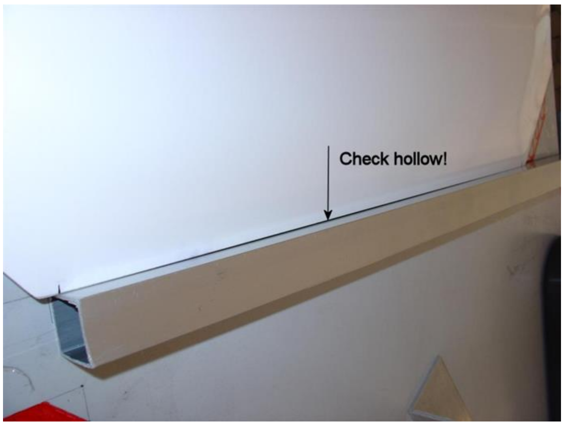


Figure E.1.5

E.2 Section

Section shape is usually controlled by measuring the thickness of an appendage. Where a minimum and/or maximum thickness is specified in the class rules this can be measured using inside/outside callipers. However, a purpose made go/no go gauge is the tool of choice if many boards for the same class have to be measured. This gauge can be used in conjunction with either a calibrated wedge or a stepped gauge to obtain the actual thickness. A custom made system using an electronic micrometre can give the actual thickness in virtually every point of the appendage, but the board must be properly placed inside it.

Figure E.2.1

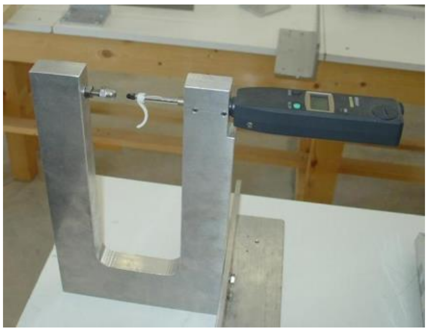


Figure E.2.2

Figure E.2.3

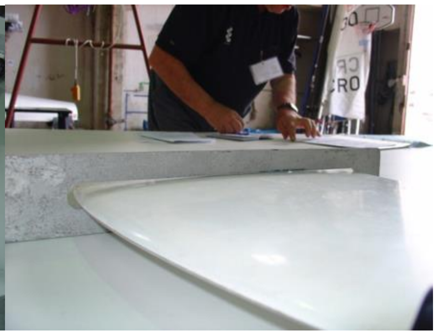


Figure E.2.4

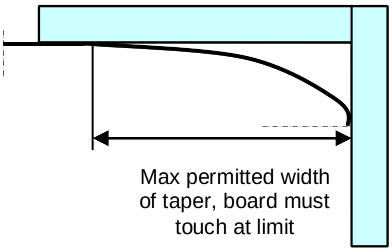


Figure E.2.5

For foils of even thickness, the leading and trailing edges need to be checked to ensure that the bevelling does not exceed the permitted limits.

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 section templates are specified by distances along the leading and trailing edges from the base of the keel.

Figure E.2.6

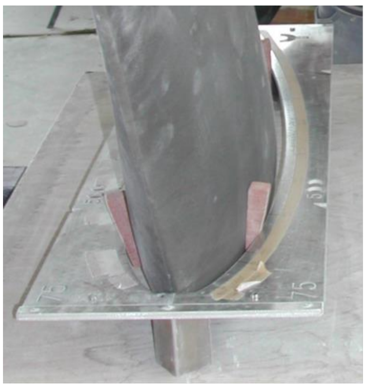


Figure E.2.7

Figure E.2.8

In any case, individual sections and points may be defined on an appendage using the same principles as for hull measurement, and then thickness measurements taken directly at each point to create a data sheet when needed. Vertical sections are extended from the hull as shown below, and then horizontal ones can be marked using a surveyor's or laser level.

Figure E.2.9

Figure E.2.10

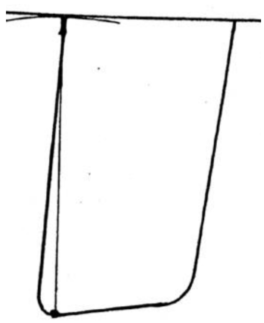
E.3 Position

For fixed appendages, the position may be controlled by a direct measurement from appropriate datum point(s) on the hull, to specific points on the appendage itself (i.e. the lowest point, or one of the corners at the bottom etc.).

For movable appendages, it may be done indirectly through a reference datum (i.e. the centreboard pivot position on hull and board, the ends of a daggerboard case on the hull etc.).

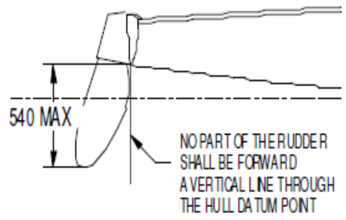
However, it is also possible to control the position of a movable appendage directly when it is positioned on the hull. The maximum extension of a centreboard below the hull is taken, as the words indicate, when the centreboard is in the position of maximum depth. This is normally, but not always, when 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 its full-down position, as follows:

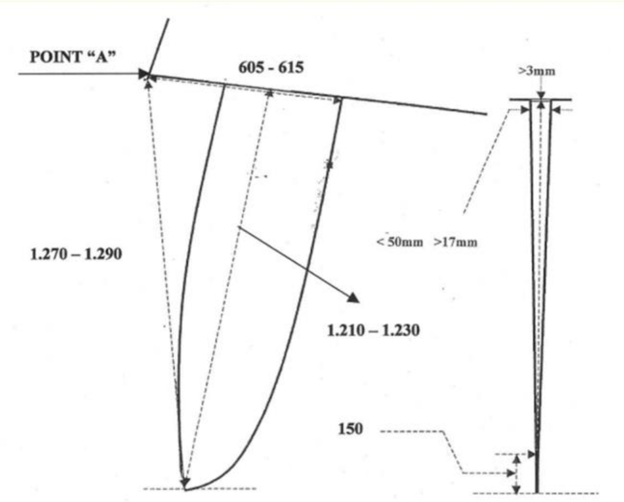


- Identify the lowest point on the tip of the board,
- Measure the distance from that point to the nearest point on the keel,
- Repeat the measurement from another point at the tip of the board if there is any doubt, about which point gives the greatest depth,
- Repeat steps (a), (b) and (c) above with the centreboard slightly different positions,
- 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 same manner. It is -unless otherwise indicated in the class rules- the vertical distance below the lowest point of the transom, which means that the hull must be also properly levelled before.



In the example to the right, class rules specify the length of the rudder when positioned on the hull as the minimum distance from the hull underside, the position of the leading edge relative to the Hull datum point, and the angle of the blade by checking the distance from the lowermost point to the HDP.



Similarly, keel fore and aft position may be controlled from the HDP, and depth from the keel line at certain stations. In some cases, this may be conveniently done with purpose made gauges as shown below.

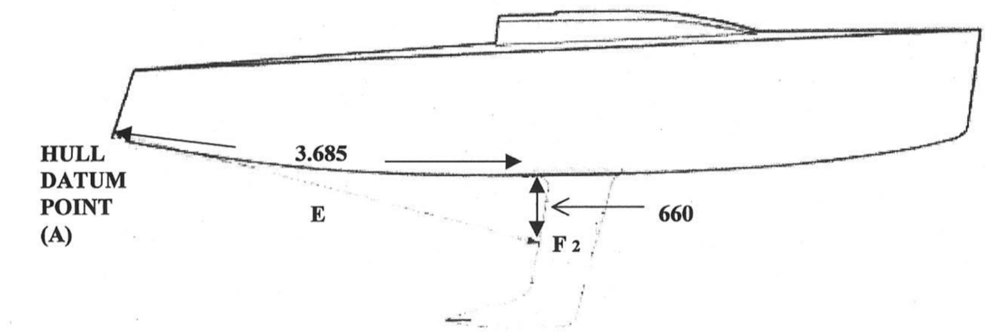


Figure E.3.1

Figure E.3.2

It may be also necessary to check the position of the pivot of a centreboard or lifting rudder. The pivot may be positioned relative to reference lines such as the leading and bottom edges of the foil. In the example below, the rudder jig has the limits of the pivot position marked with a red outline, leaving the white coloured inside to show the min/max area. Absolute values may be found using a ruler and appropriate means (like a square) to transfer the reference lines up to the foil surface level.

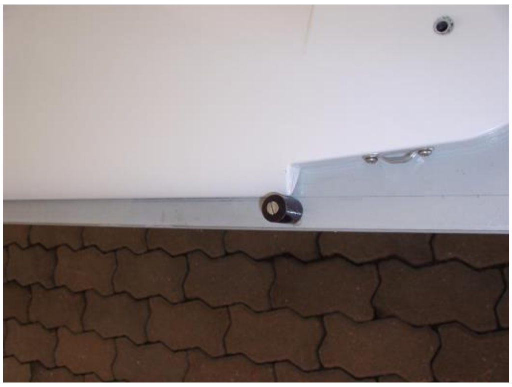


Figure E.3.3

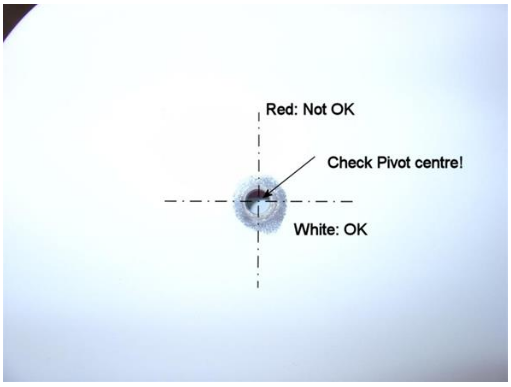


Figure E.3.4

E.4 Other controls

Appendage weight may be also specified in class rules: boards and rudders may be checked at any time using scales, but keels are usually controlled at the time of manufacture, before they are fixed on the hull. Materials are also limited in some cases so measurers should be able to identify and recognize them with a visual control. Destructive sampling should be undertaken only after consultation and permission of the appropriate certification authority.

On multihulls beam at foil level has to be checked (Class A and C) in down position and/or any position, as well as distance of foil to centreline

SECTION F. RIG MEASUREMENT

ERS 2017-2020 Section F provides a set of standard definitions for rigs (spars, rigging, spreaders, measurement points, dimensions and all associated fittings) facilitating uniformity in measurement methods and tools across classes. Many classes use these standard definitions and also have their class rules in the SCR format.

F.1 Introduction

The parameters that control the performance, strength and cost of a mast spar, and so are likely subjects of class rules are:

- Material, i.e. wood, the aluminium alloy and temper, carbon fibre, its modulus and resins
- The spar extrusion weight per unit length, or wall thickness
- The spar fore and aft and transverse dimensions
- The spar extrusion transverse and fore and aft areal moment of inertia
- The sail track, integral or separate
- The extent and dimensions of the mast taper
- Mast curvature and deflection
- The rigging points for stays and shrouds, spreader dimensions
- Sail hoist heights

Many of these properties are interrelated and so classes choose different combinations.

Rig measurement usually starts from the definition of measurement points: some of these are associated with limit marks which are meant to dictate proper setting of sails or other spars. Lengths –or heights when referring to masts- are then measured with reference to those points, but class rules may specify additional limitations on items such as spar section, deflection, curvature and weight, rigging specifications etc. ERS H.4 specifies conditions for measurement, which in the latest ERS cannot be modified by Class rules.

Some classes, especially those whose inventory includes more than one mast and boom such as the Finn, have rules that specify standardized dimensions; in this way spars are interchangeable, and can be measured completely independently of other parts of the boat.

F.2 Spar measurement points and limit marks

ERS specify a number of measurement points on spars: some are related to the geometry of the rig (e.g. rigging points) and others are used for setting sails or other spars. The latter are indicated by using limit marks (measurement or “black” bands). These are required to be marked distinctly (in a colour contrasting sharply with that of the spar) or even additionally engraved/punched on spars so as to be clearly visible while racing. Some classes require additional bands to indicate the positions of the forestay or spinnaker halyard.

The first measurement point on masts is called **Mast Datum Point** in ERS, and it is the datum for measurement. Other measurement points –except from the points defined on the extremities of the mast- and distances are taken with reference to the MDP. The datum point is defined in Class rules and is usually connected to one of the following:

- heel of the mast, or
- intersection with sheer, or
- deck in way of mast.

Measurement from the heel is usually referred to the heel point (ERS) but in non-ERS classes it may refer to the bearing point of the mast. Mast datum points that refer to the heel point make measurement and inspection easier, because it is independent of the hull and the mast step fitting. However, the heel is subject to wear, so measurements taken on a new mast may change after extensive use.

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.

ERS specify two limit marks on masts: the lower and the upper, which are associated with the lower and upper points respectively (Figure F.2.1). The upper mark is used for setting the mainsail, while the lower mark is used for setting the boom.

Figure F.2.1 *Mast Upper and lower marks and points*

The band on the boom is 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 figure F.2.2. A few non-ERS classes measure to the inside of the sail track. This is also indicated in figure F.2.3.

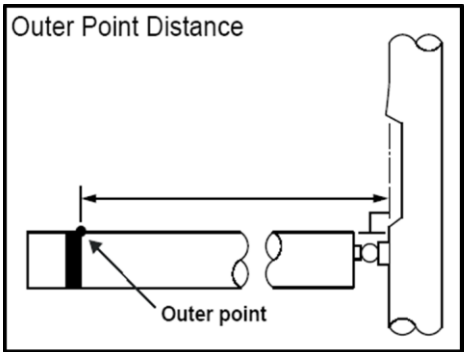


Figure F.2.2

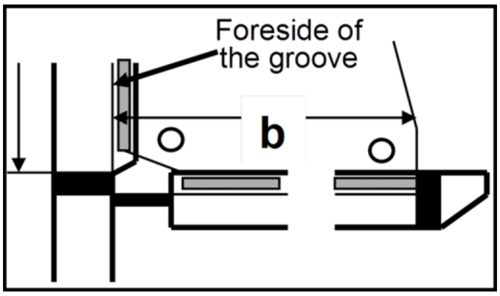


Figure F.2.3

F.3 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. 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. The dimensions of spar sections include the sail track unless otherwise specified (in non-ERS classes like the ACC).

F.4 Curvature (Straightness) of spar

It is a common requirement that spars are "substantially" straight. It is usual to further define this by saying that "a permanent set not exceeding X mm is permitted." This permanent set cannot be determined when the mast is on the boat 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 between the upper and lower points of the mast provides a straight line from which to measure the maximum offset of the "permanent set" which is the ERS “curvature”.

F.5 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. Usually the mast is weighed complete with "fixed fittings". In general, anything which is bolted or riveted or welded to the mast is included under the heading of fixed fittings.

F.5.1 Mast center of gravity measurement

A number of classes specify the lowest acceptable position of the centre of gravity of the mast. A tip weight as specified in the ERS is required by other classes: both ways are covered in the 2017-2020 ERS. In order to carry out the measurement of the location of the centre of gravity, the mast is prepared together with the appropriate fittings and the spar is then supported horizontally at its point of balance. The distance to the heel is then measured.

Determining the CG of a mast only requires a knife edge or inverted angle section on which to balance the mast, so sailors can easily check this themselves.

Prescriptions for CG measurement are shown in figure F.5.1.1. For masts with rigging the shrouds, forestay and backstay are tied to the mast spar as close to the lower point as possible with the lower ends allowed to rest on the ground.

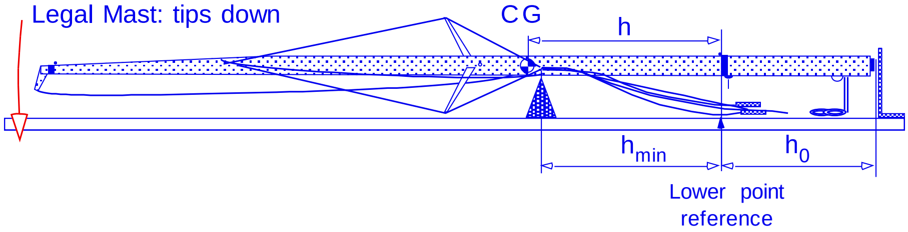


Figure F.5.1.1 *Determination of the mast CG by balancing on a knife edge. The knife edge is set at the minimum permitted distance from the datum point and the mast tip must go down when released.*

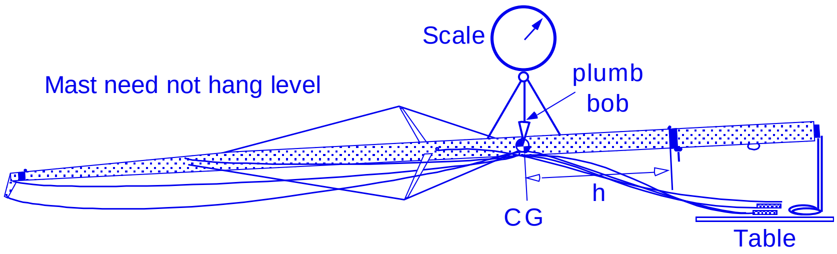


Figure F.5.1.2 *Larger masts can be weighed using a hanging scale, and the CG height determined simultaneously with a plumb bob.*

F.5.2 Mast tip weight measurement

To overcome the problems frequently associated with the measurement of the position of the centre of gravity, especially for bigger masts, the "tip weight" test was introduced. In this test the rigged mast is supported at the lower point and the weight of the spar at its top point taken. Halyards are fully hoisted and their tails are allowed to rest on the ground. Shrouds, forestay and backstay are tied to the mast spar at the lower point with the lower ends allowed to rest on the ground.

In conducting the weight measurement 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 mast or tip weight. The same remarks apply to the halyards.

F.6 Deflection tests

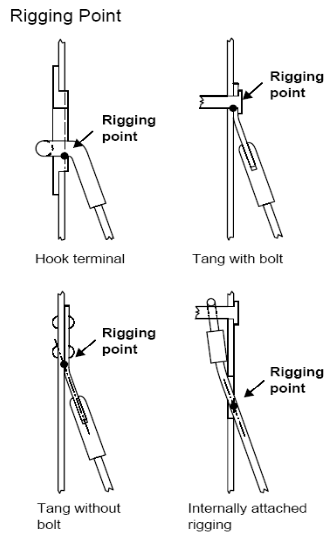
An important feature affecting the performance of the rig is the manner in which the mast bends under load. Some one-design classes require the mast and/or boom to have certain deflections when supported horizontally and loaded with a specified weight.

The test is carried out by supporting the mast at the upper and lower points and fixing a line between them. A point defined in class rules is then found on the spar and the distance from the line to that point measured. The weight is applied and the distance measured again. The deflection is the difference between the two measurements.

The load to be applied is specified in the class rules. An alternative approach, which stabilizes the mast and allows steady application of the load, is the use of an inverted scale with a block and tackle to a fixed point on the floor.

F.7 Rigging points

Shrouds and stays are usually attached to tangs on the outside of the mast, fixed internally or hooked into slots in the spar. The ERS specify a number of distinct situations in order to define the rigging points which are used for measuring the distances (heights) from the mast datum points.



Spinnaker and headsail hoist heights are measured between the datum point and the lower edge of the spinnaker or headsail halyard respectively, when held at 90° to the spar, so in effect are measured to the sheave or block bearing point.

F.8 Poles

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

F.9 ERS Rig measurement in steps

Check the Class rules carefully!

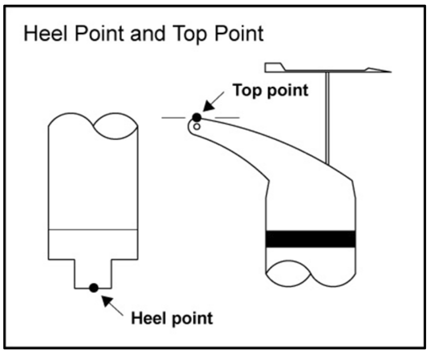
STEP 1: FIND AND MARK the Mast Datum Point

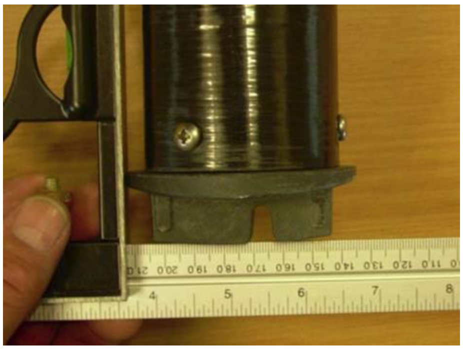
STEP 2: MARK the other Mast measurement Points, in most cases only the upper and lower points.

STEP 3: MARK the Rigging Points, if relevant.

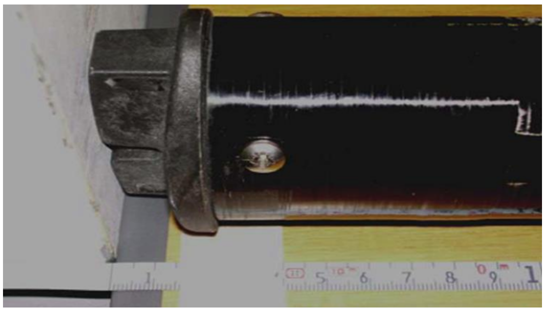
STEP 4: MARK any areas for the mast spar cross section check and the points for deflection tests if any.

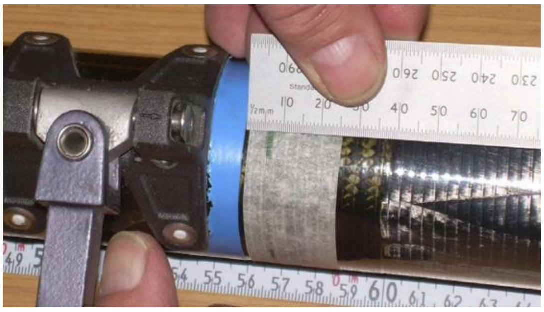
STEP 5: Commence measurement of dimensions



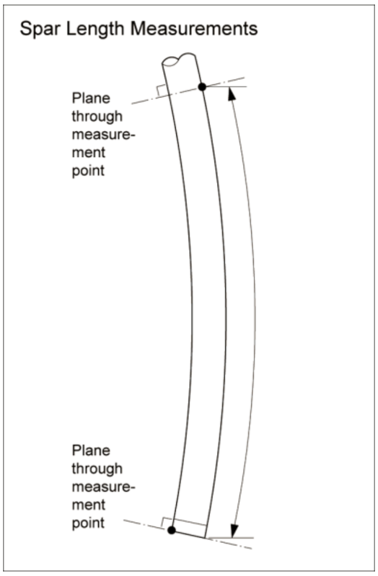


Top and heel points: In many cases, the heel point is also the mast datum point.



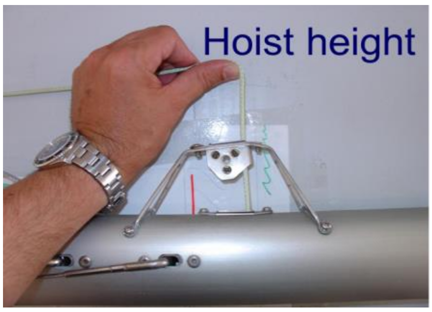


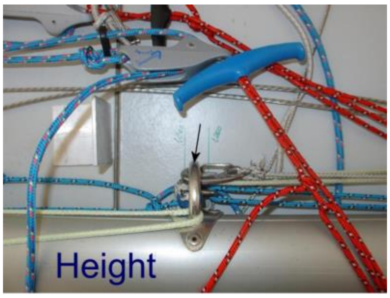
Defining measurement points: lower point from heel point as MDP.



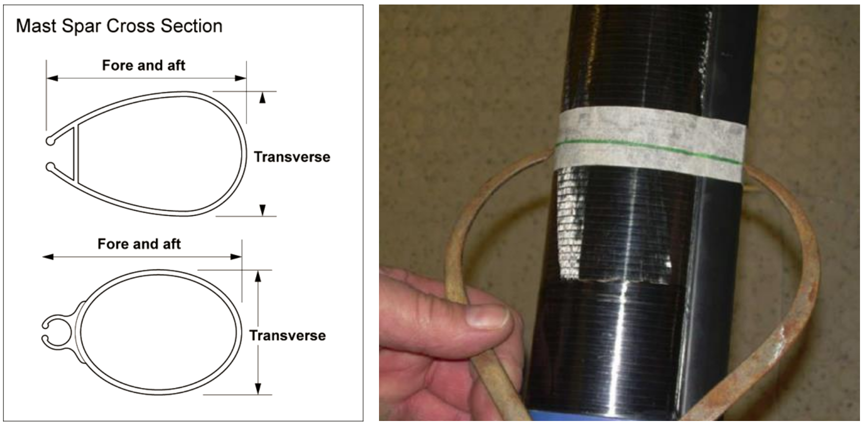
Upper point from MDP. Spar length measurements are to be taken along the spar so any curvature on the spar must be followed closely.

Rigging points: shroud, forestay, trapeze. Heights to be measured from MDP.

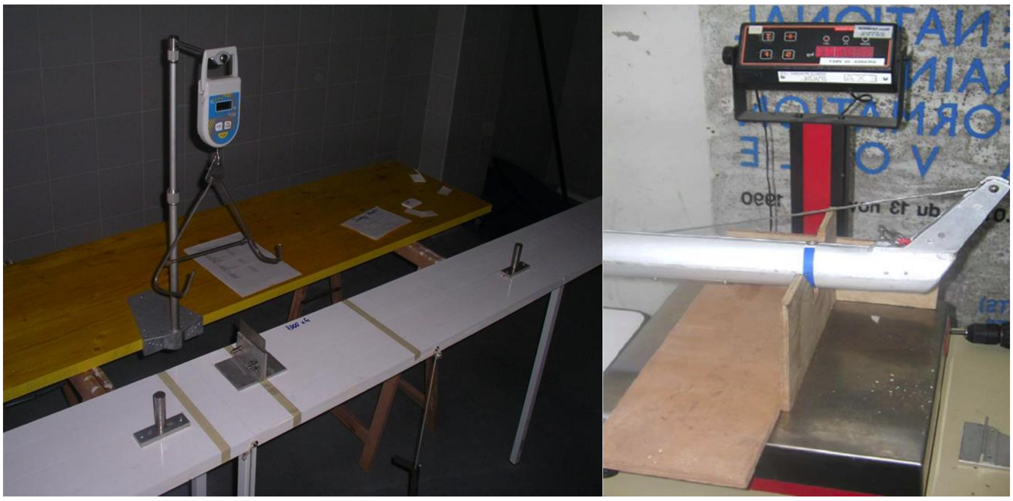




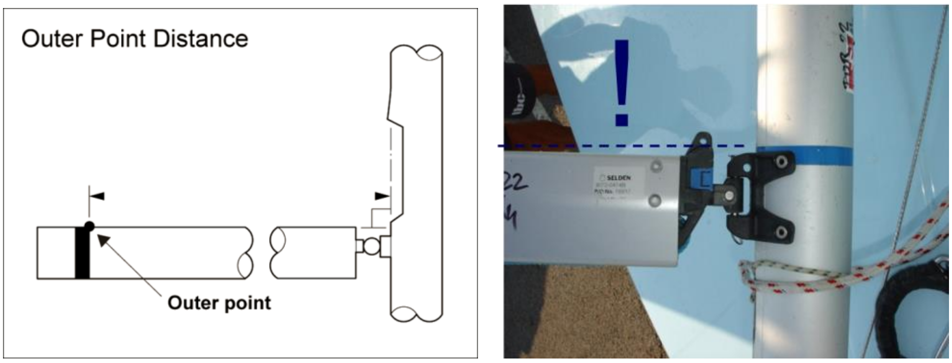
Spinnaker hoist height with the halyard at 90° to the spar.



Spar section measurement.



Mast weight / centre of gravity (left) and tip weight (right) measurement. The centre of gravity may be checked using a knife-edge to balance the mast.



Boom measurement: Outer point distance from mast spar. The lower point defines the lowermost permitted position of the upper surface of the boom: In the example above the boom is improperly positioned with the top of the spar lower than the lower point. Under the ERS, boom measurement has to be done with the boom connected to the mast to minimize errors!

SECTION G. SAIL MEASUREMENT

The ERS 2017-2020 offer a well-developed standard set of definitions for sails, covering terms, measurement points and dimensions so uniformity in measurement methods is possible. A lot of classes follow this system to control:

Sail construction (including materials)

Sail shape (primary and other dimensions)

This section deals mainly with sail measurement according to the current ERS methods.

G.1 Sail Construction

G.1.1 Types of ply

A ply is a sheet of sail material, which can be made up of one or more lamina. 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. The term "ply" also covers window material.

Woven ply is the ply which when torn can be separated into fibres without leaving evidence of a film. A ply which comprises a woven base on which a plastic film has been bonded is considered to be a non-woven laminate.

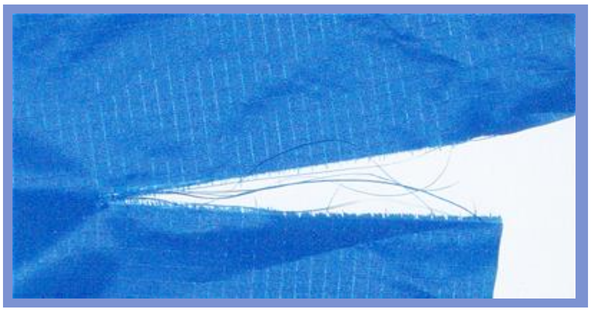


Figure G.1.1.1 *Woven ply which can be torn to show separated fibres*

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. 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.

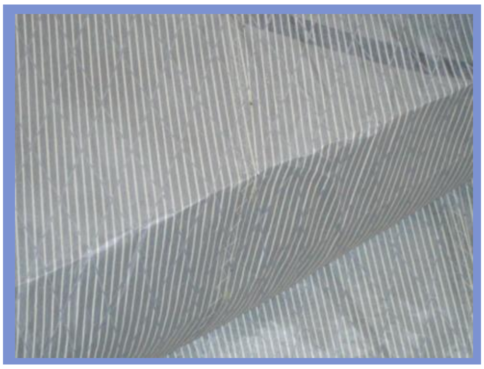


Figure G.1.1.2 *soft sail which can be folded without damage*

G.1.2 Ply weight / thickness

There are a number of classes which specify minimum ply weights. Before discussing the problems associated with such rules, it is necessary to become aware of the different units used to describe ply weight.

These are:
ounces (oz)
ounces per square yard (oz/sq yd)
grams per square metre (g/m^2)

The weight in ounces (Oz) 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 and is the way in which most sailcloth is described in the United States. Table G.1.2.1 and figure G.1.2.1 show the comparison between the three units, and enable conversions to be made from one system to another.

Table G.1.2.1
Cloth weight conversion factors

Ounces	Ounces per square yard	Grams per square metre
Oz	Oz/sq yd	gsm
1 Oz	0.7917 Oz	0.02335 Oz
1.263 Oz/sq yd	1 Oz/sq yd	0.02949 Oz/sq yd
42.828 g/m^2	33.9 g/m^2	1 g/m^2

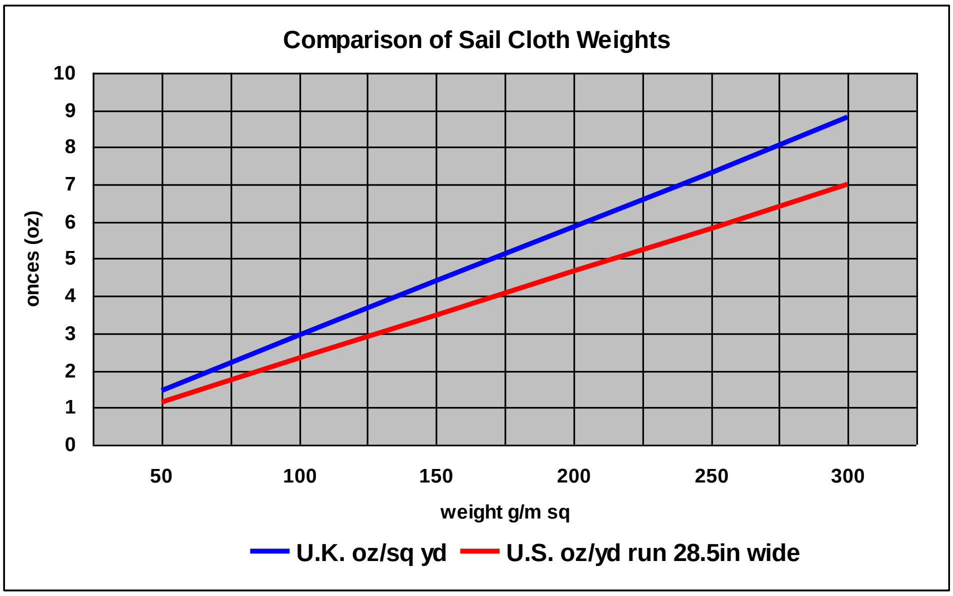


Figure G.1.2.1 *Comparison of sail cloth weights*

Weight of the ply Measurement

To determine the Weight of Ply, one needs an appropriate sample cutter and special certified laboratory scales approved to weigh samples to an accuracy of 0.01%. 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 leveled 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.

Thickness of the ply Measurement

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 G.1.2.2 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%. For spinnaker cloths the change in thickness per g/m^2 is 0.003 mm, which makes it difficult to distinguish between spinnaker cloth types using a micrometre.

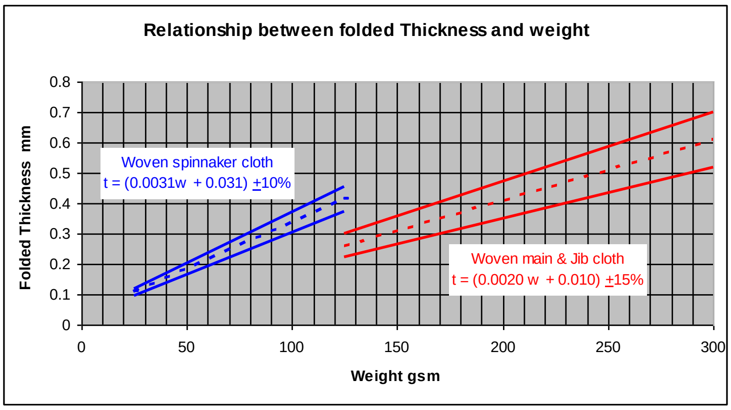


Figure G.1.2.2 *Woven ply thickness vs. weight*

Where class rules control ply thickness, this is usually the minimum thickness. It is thus important that measurement is taken at the thinnest area. If the micrometre 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.

To measure ply thickness, one needs a micrometre and, if the ply has no scrim, a feeler gauge (Figure G.1.2.3).

Figure G.1.2.3 *A digital micrometre of resolution 0.001 mm and feeler gauges for sail cloth thickness measurement*

(i) Before taking any measurements the micrometre measuring surfaces must be carefully cleaned and the micrometre itself zeroed or calibrated using the feeler gauge.
(ii) Always bring the measuring surfaces together slowly and uniformly using the micrometre ratchet when checking zero and when taking measurements.
(iii) Do not scrape the sail cloth with the micrometre 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:

(i) Fold but do not crease the sail.
(ii) Open the micrometre wide enough to enable the jaws to pass over the doubled roll without scraping.
(iii) 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 micrometre reading.

Figure G.1.2.3 *Ply thickness measurement using a micrometre and feeler set.*

G.2 Sail dimensions measurement

ERS H.5.1 gives the conditions for sail measurement, specifying that sails shall:

- be dry
- not be attached to spars or rigging
- unless the **class rules** prescribe otherwise, have all battens removed
- have pockets of any type flattened out
- have just sufficient tension applied to remove wrinkles across the line of the measurement being taken, and
- have only one measurement taken at a time

There are cases where battens are permitted by the class rules to be in place during measurement: jibs with straight leeches and short battens like in the 420 & 470 Classes are one example, but it can also apply to mainsails as in the Finn and Optimist Classes.

The ERS method follows a logical step by step approach to sail measurement. There is no need to specify a single datum point as in spars and hulls, but 3 or 4 corner measurement points, for trilateral or quadrilateral sails respectively. These points are then used for sail edge length measurement, and to define other measurement points on the sail edges themselves. In addition, there are other measurements independent of those points, for items such as batten pockets or reinforcements, and these are taken directly on each item.

G.2.1 Corner measurement points (ERS G.4)

ERS G.4.1, G.4.2, G.4.3, G.4.4 & G.4.5 refer to sail edges “extended as necessary”. Such cases where it is necessary to extend an edge are:

- When there is a cut-out at the sail corner itself, the associated boltrope, or the tabling. See cases 2, 4, 7, 10 and 11 on Figures G.2.1.1 and G.2.1.2

- When the sail edge curvature changes markedly at a point close to a sail corner, a round-off. See cases 1, 3, 6, 8 and 9 on Figures G.2.1.1 and G.2.1.2

The tack point is the intersection of the foot and the luff, each extended <u>as necessary</u>.

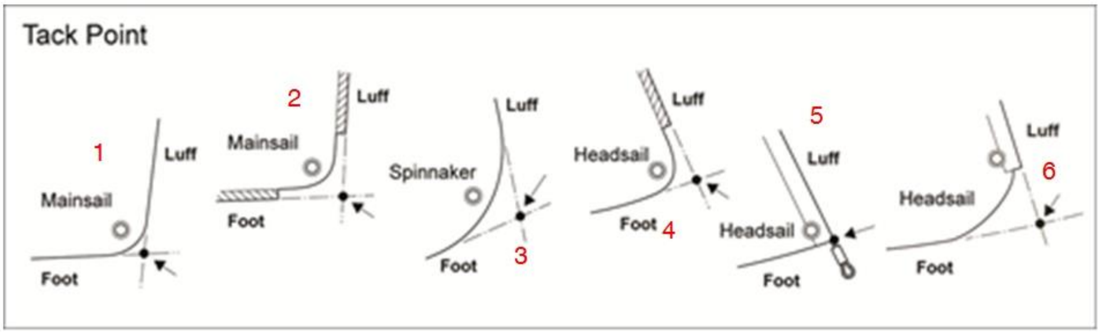


Figure G.2.1.1 *Tack point, ERS definition.*

The clew point is the intersection of the foot and the leech, each extended <u>as necessary</u>.

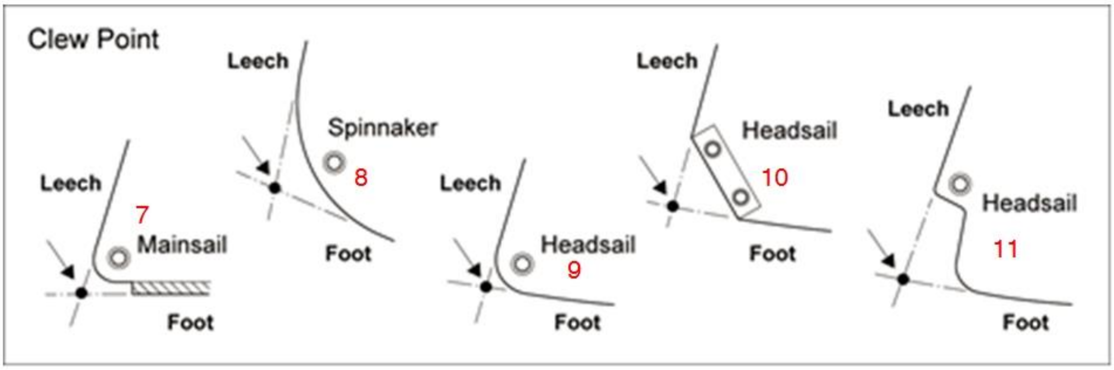
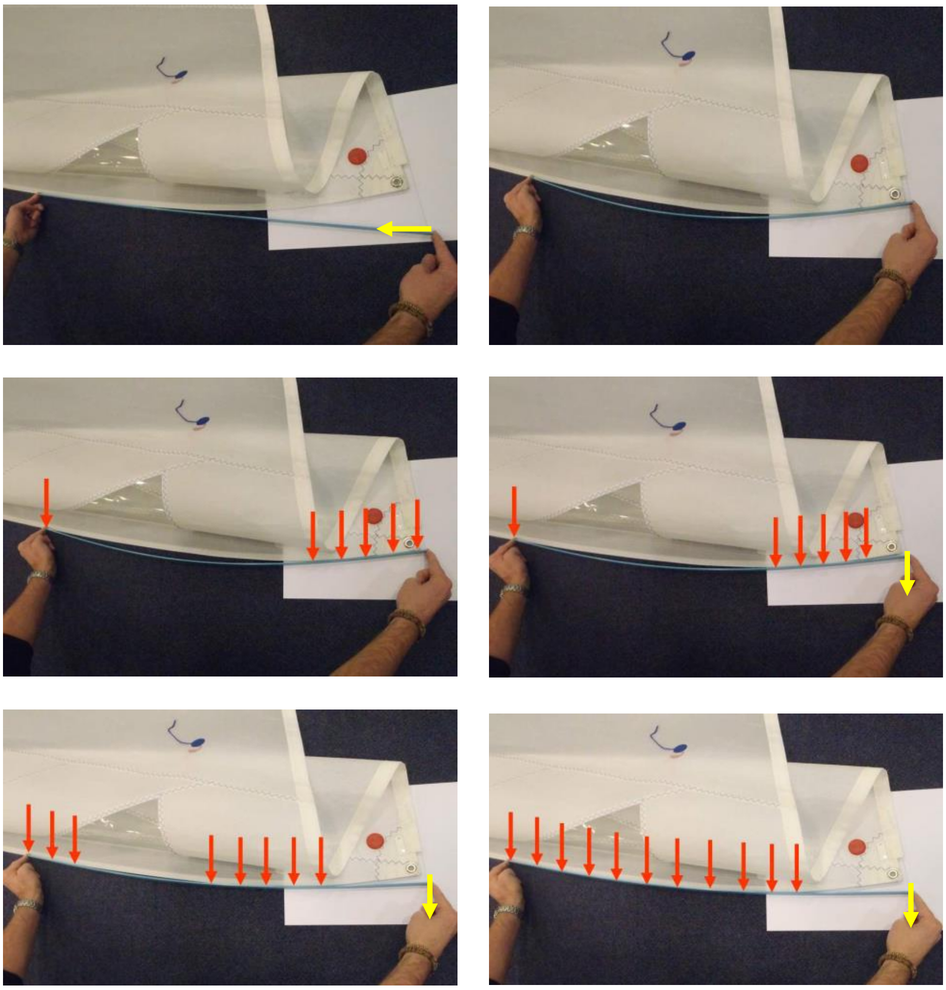


Figure G.2.1.2 *Clew point, ERS definition.*

The 2017 ERS have a new rule H.5.4 which describes the standard method for extending edges:

a) Hold the batten at its very ends with one end approximately where the corner point will be and the other end touching the sail edge being extended.
b) Apply compression only to the batten to produce a uniform curve when required.
c) If the batten does not replicate the sail edge shape exactly, move the end of the batten at the corner away from sail until the longest possible length of the batten touches the sail edge.

Step by step, this method can be described in the following series of photos:



When the line of the extension of the edge is uncertain and not repeatable, leading to inconsistent measurement points, the measurement of the sail should be refused and the certification authority contacted for consultation.

Classes are free to choose if they wish to modify H.5.4 to better suit their needs and their particular sail geometries (H.5.4(f)).

Marking the extension lines on paper taped to the underside of the sail helps to retain the point during measurement (Figure G.2.1.7).

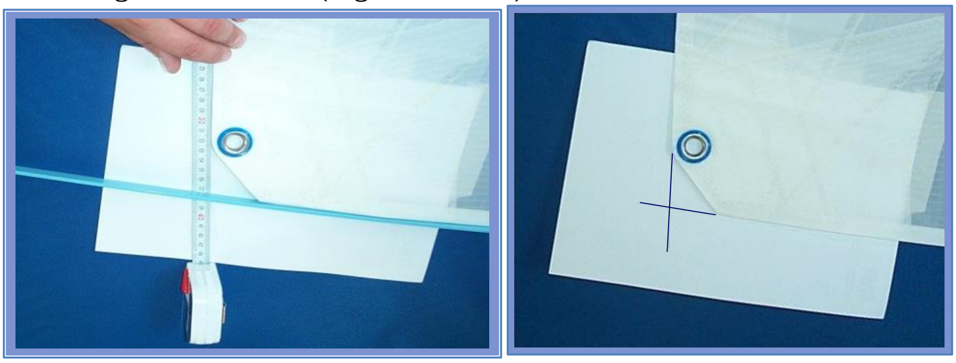
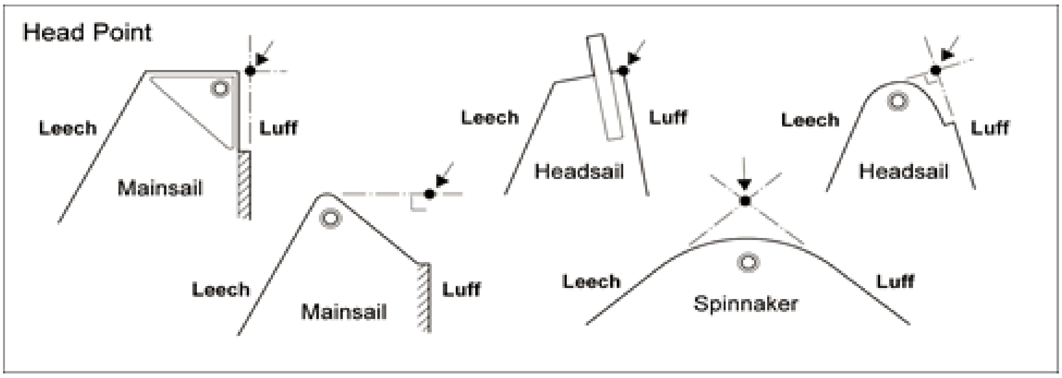


Figure G.2.1.7 *Clew point: sail edge extensions marked on paper.*



The head point on a mainsail is the intersection of the luff, extended as necessary, and the line through the highest point of the sail at 90° to the luff. In this case, any attachments are to be included (Figure G.2.1.9)

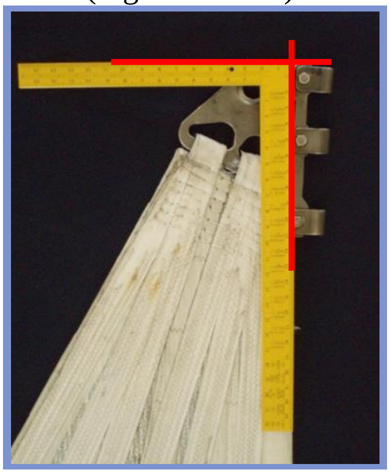


Figure G.2.1.9 *Mainsail head point.*

On headsails, the head point is the intersection of the luff, extended as necessary, and the line through the highest point of the sail at 90° to the luff but in this case excluding attachments (Figure G.2.1.10)

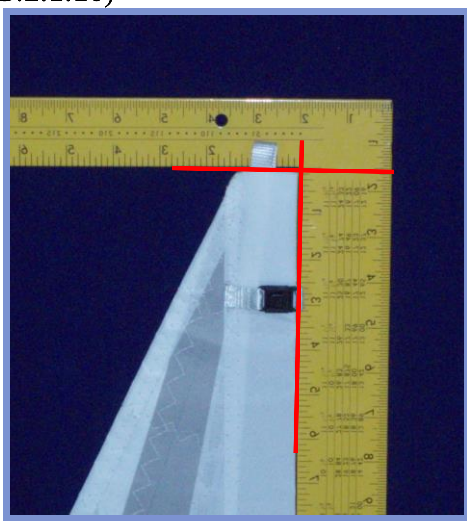


Figure G.2.1.10 *Headsail head point.*

On spinnakers, the head point is the intersection of the luff and leech, each extended as necessary, in the same way as for the clew and tack points.

G.2.2 Sail edge measurement points (ERS G.5)

The half leech point is found by folding the head point to the clew point (Figure G.2.2.1-1) and equally tensioning the two halves of the leech so formed (Figure G.2.2.1-2). The half leech point is the intersection of the fold and the leech (Figure G.2.2.1-3).

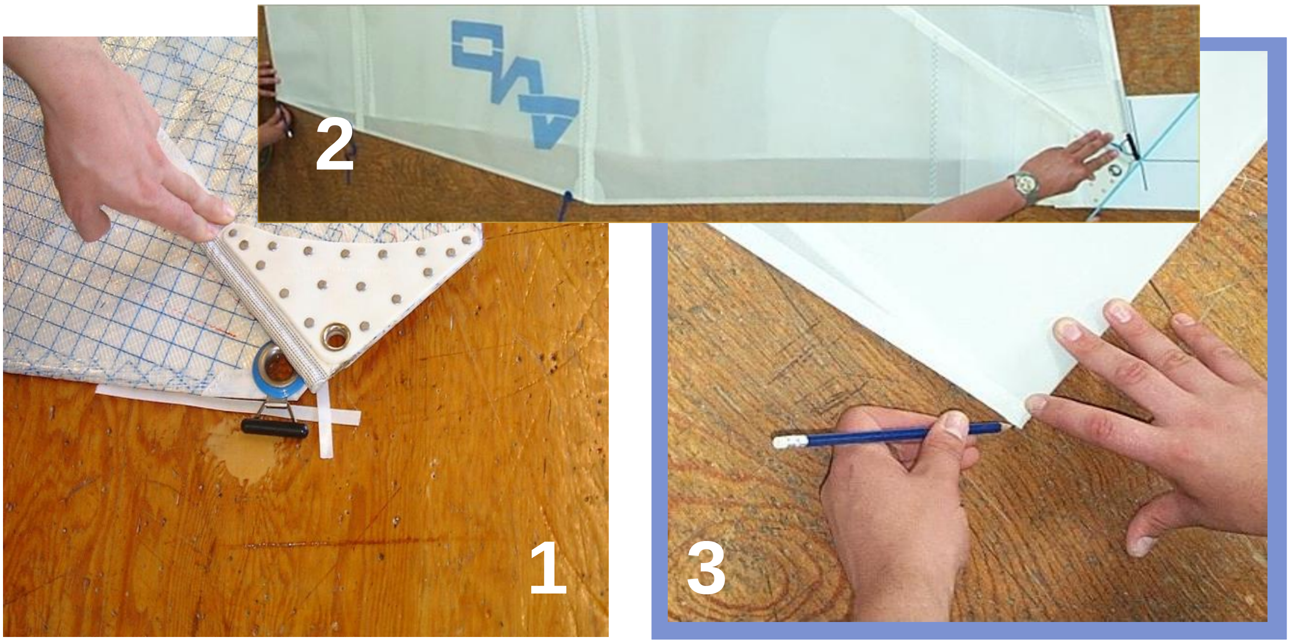


Figure G.2.2.1 *Half leech point.*

The quarter (Figure G.2.2.2) and three-quarter points are found similarly by folding the clew point and the head point respectively to the half leech point. The points are the respective intersections of the folds and the leech.

Figure G.2.2.2 *Quarter leech point.*

For upper point marking, the head of the sail should be flattened and tensioned to remove wrinkles, and then the specified distance measured with a tape from the head point to the leech and marked on the leech. A number of Classes are controlling their mainsail widths at one or more "upper points" and ignore the ERS half and quarter points.

The same technique is used to find and mark measurement points on the luff, using the tack point instead of the clew, and also on the foot, where the mid foot point is found by folding the sail with the clew point on top of the tack point or in the case of spinnakers, one clew point to the other clew point (Figure G.2.2.3)

Figure G.2.2.3 *Spinnaker mid foot point.*

G.2.3 Primary sail dimensions (ERS G.7)

Having defined the various corner and edge measurement points, the next step is to measure primary dimensions such as lengths and widths. Sails are to be flattened as in Figures G.2.3.1 to G.2.3.3 by laying them out on a flat surface and then by folding or flaking them, and with just sufficient tension applied to remove wrinkles across the line of the measurement being taken (Figure G.2.3.4). The latter is especially important in spinnaker measurement, to avoid stretching the sail.

When checking sail leeches for not being convex it is vital to flake the sail, as shown in figure G.2.3.1 as this can change the leech from appearing convex to being concave. It is also important to flake the sail when measuring luff perpendiculars on full jibs see figure G.2.3.6.

Figures G.2.3.1 & G.2.3.2 *Leech flattening before and after flaking.*

Figure G.2.3.3 *Leech hollow before and after flaking.*

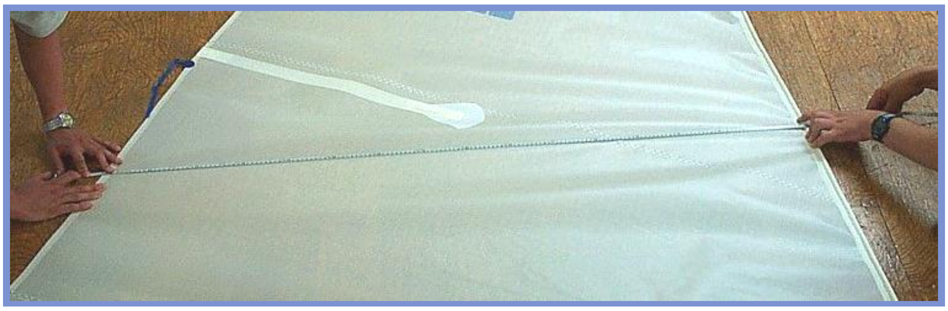


Figure G.2.3.4 *Proper tensioning of sail for wrinkle removal.*

All lengths shall be measured as the straight line distance as defined: for example, leech lengths between the head point and clew point (Figure G.2.3.2 on a headsail), spinnaker foot median between head point and mid foot point Figure G.2.3.7). Corner reinforcements which cannot be "straightened" at the head of the spinnaker may necessitate the taking of two part measurements to an intermediate point, with the sum of these giving the dimension of the defined measurement (spinnaker foot median, Figure G.2.3.5).

The luff perpendicular shall be measured as the shortest straight line distance swung across the sail by a tape from the clew point to the luff as appropriate, including bolt rope if any (Figure G.2.3.6).

Figure G.2.3.5

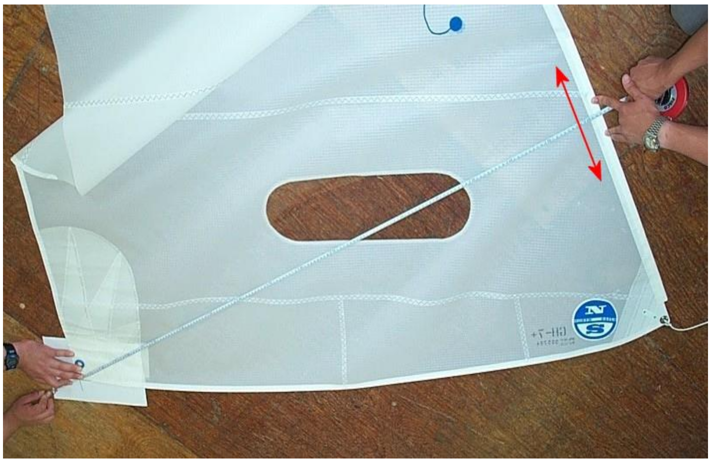


Figure G.2.3.6 *Luff perpendicular.*

Figure G.2.3.7 *Spinnaker foot median.*

Mainsail and headsail widths, except top width, shall be measured as the shortest straight line distance swung across the sail by a tape from the leech point to the luff including bolt rope if any (mainsail half width example in Figure G.2.3.8).

Figure G.2.3.8 *Mainsail half width.*

ERS H.5.2 states that when there is a sail edge hollow and a measurement point falls in the hollow;

between adjacent batten pockets;

between the aft head point and adjacent batten pocket;

between the clew point and adjacent batten pocket

between the tack point and adjacent batten pocket

at an attachment;

the sail shall be flattened out in the area of the sail edge, the sail edge hollow shall be bridged by a straight line and the shortest distance “A” from the measurement point to the straight line shall be measured. This distance shall be added to the measurement being taken (Figure G.2.3.9).

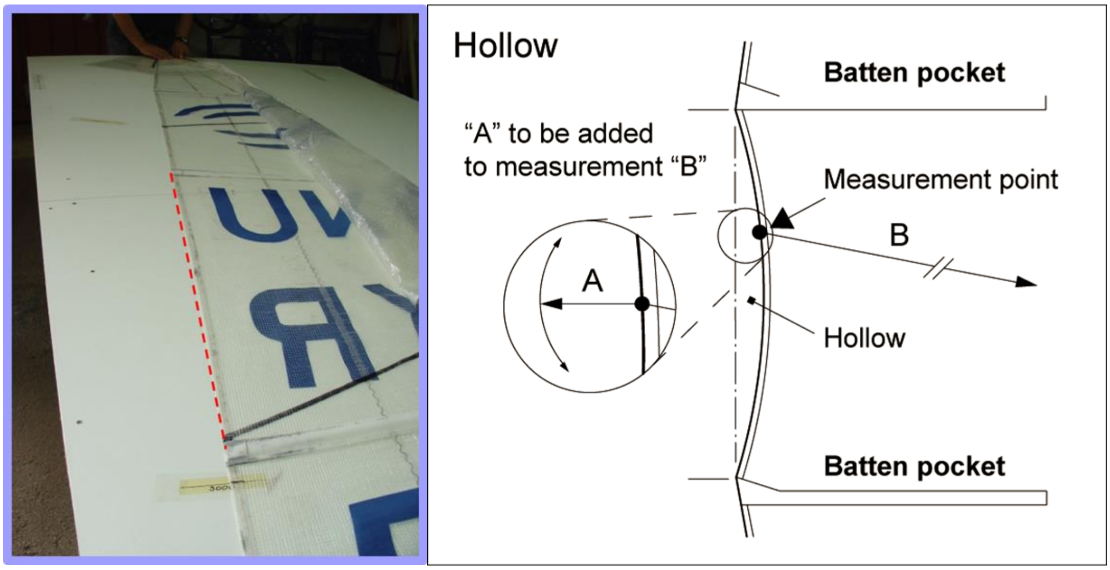


Figure G.2.3.9 *Bridging leech hollows.*

The spinnaker widths shall be measured as the straight line distance between the leech points as defined, for example the spinnaker half width in Figure G.2.3.10 is to be taken between the half luff point and the half leech point.

Figure G.2.3.10 *Spinnaker half width.*

G.2.4 Other Sail Dimensions (ERS G.8)

Other items to be measured include reinforcements (Figure G.2.4.1.a), batten pockets, foot irregularity, seams and attachments.

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 G.2.4.1.b Permitted tabling is not included in the measurement of reinforcement.

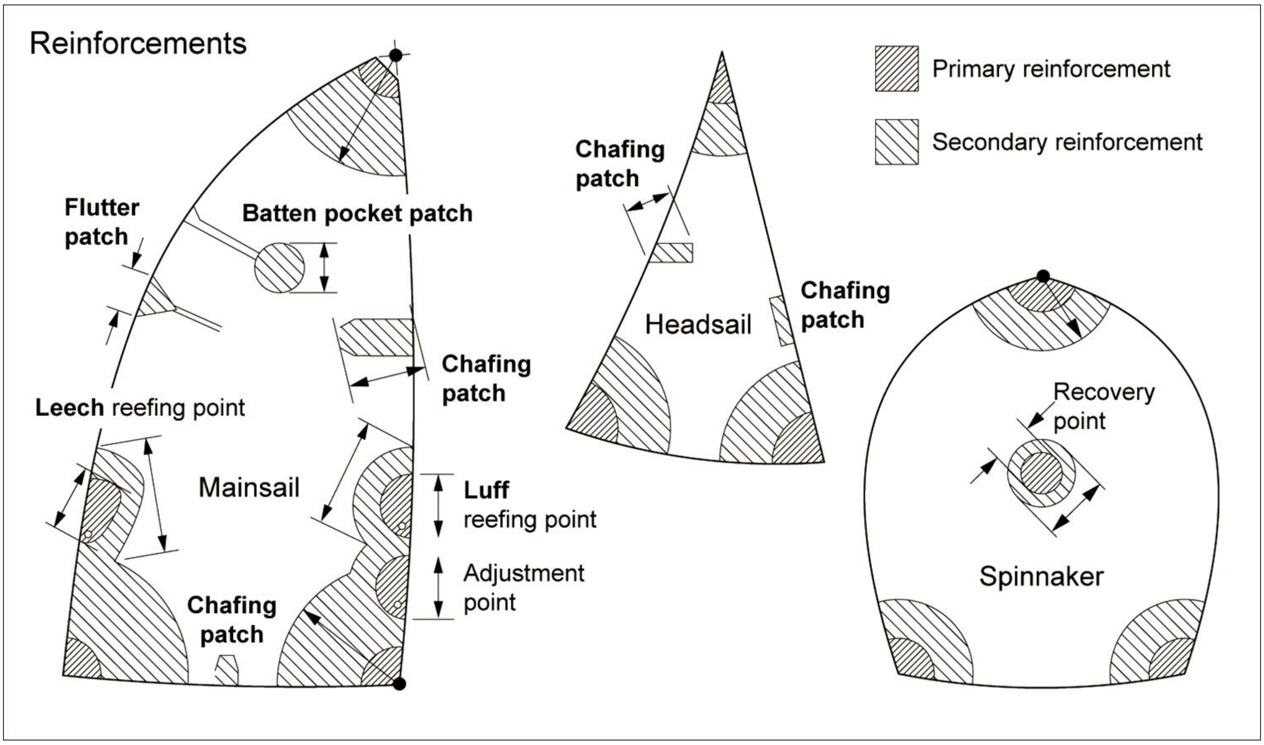


Figure G.2.4.1a *Primary & Secondary reinforcement size.*

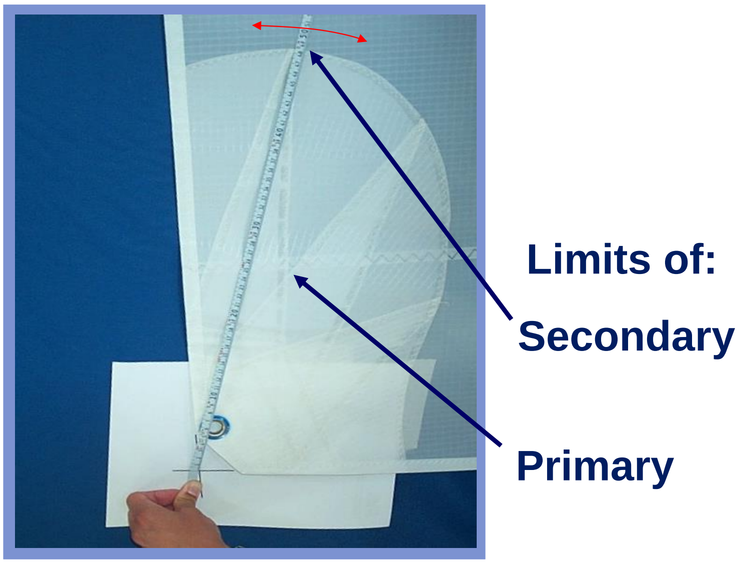


Figure G.2.4.1b *Corner reinforcement size.*

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 (Figure G.2.4.2 chafing patches, Figure G.2.4.3 batten pocket patches). This may not necessarily be continuous across the reinforcement.

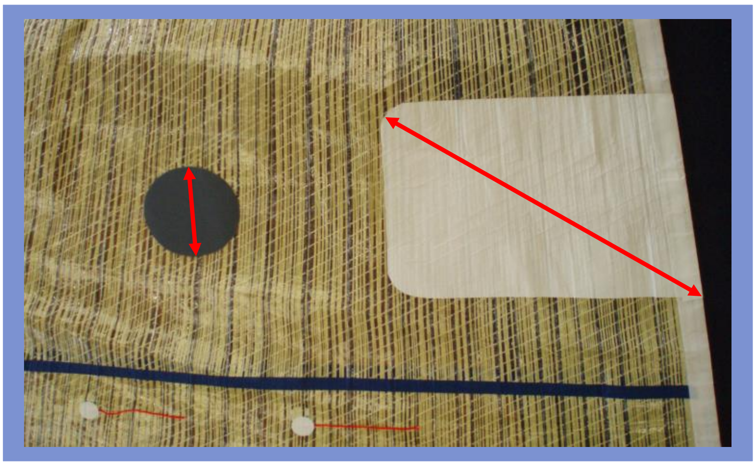


Figure G.2.4.2 *Chafing patch size.*

Figure G.2.4.3 *Batten pocket patch size.*

The inside and outside lengths of a batten pocket are measured ignoring the effect of any elastic or other batten retaining device.

The inside length is the greatest dimension measured parallel to the centreline of the pocket from the sail edge to the inside of the stitching, fold or similar at the inside end of the pocket. The outside length is the greatest dimension measured parallel to the centreline of the pocket, from the sail edge to the extreme end of the pocket material.

Local widening for batten insertion is not included in the measurement of either inside or outside batten pocket width.

The inside width is measured at 90º to the centreline of the pocket, between the inside of the stitching or similar on each side of the pocket. The outside width is measured at 90º to the centreline of the pocket, between the outside edges of the pocket material.

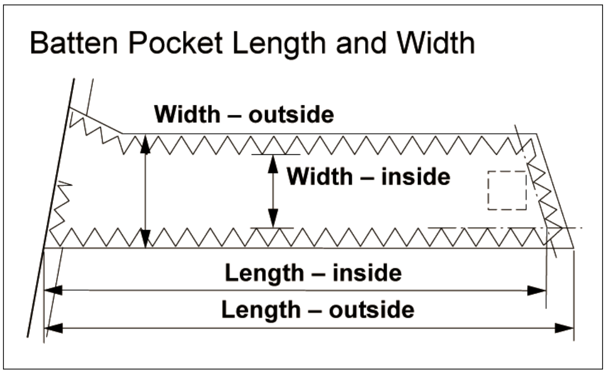


Figure G.2.4.4 *Batten pocket length and width measurement.*

To check the foot irregularity, with the sail flat in the area of the foot, the tack point should be folded over and run down the edge of the foot, and its extensions if necessary, until it reaches the clew point. During this procedure, the greatest dimensional difference between the two parts of the sail edge, measured at 90º to the edges, should be noted. The same procedure should be undertaken, folding over and running the clew point down the edge of the foot until it reaches the tack point. Again, the greatest dimensional difference between the sail edges should be noted. The foot irregularity is the greater of the two noted dimensions (figure G.2.4.5).

Foot irregularity used together with a foot median limitation can help control the shape and size of the foot roach in cases where a deck sweeper headsail design is used by a class: appropriate foot irregularity values can prevent drastic changes in curvature along the foot, and the foot median controls total size of the foot roach.

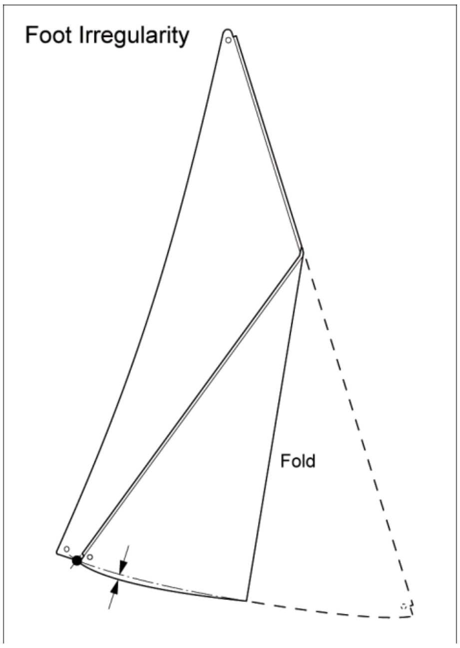


Figure G.2.4.5 *Foot irregularity.*

G.2.5 Additional Sail Controls

Additional sail controls include items such as the colour of the sail (Figure G.2.5.1), additional symbols like a women's rhombus (Figure G.2.5.2), the sail construction (e.g. number of panels) and the presence of valid class royalty tags (stickers, buttons etc., Figure G.2.5.3).

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 supposed to be transferred 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. Usually these items are numbered so it is a good idea to write down the number in the certification mark, provided it has space for notes.

Figure G.2.5.1

Figure G.2.5.2

Figure G.2.5.3

G.2.6 Identification on Sails

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. A number of classes specify that sail numbers shall be sequential and not re issued and in such cases the legality of such sail numbers should be checked.

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 – 1.1 specifies that:

"Every boat of a WS Class shall carry on her mainsail and, as provided in rules G1.3 (d) and G1.3 (e) for letters and numbers only, on her spinnaker and headsail:

- the insignia denoting her class;

  at all international events, except when the boats are provided to all competitors, national letters denoting her national authority from the table below. For the purposes of this rule, international events are WS events, world and continental championships, and events described as international events in their notices of race and sailing instructions; and

  a sail number of no more than four digits allotted by her national authority or, when so required by the class rules, by the international class association. The four-digit limitation does not apply to classes whose WS membership or recognition took effect before 1 April 1997. Alternatively, if permitted in the class rules, an owner may be allotted a personal sail number by the relevant issuing authority, which may be used on all his boats in that class.

Sails measured before 31 March 1999 shall comply with rule G1.1 or with the rules applicable at the time of measurement."

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 but at least it should be taken to mean legible to the

RC and Jury under adverse situations. It also specifies that acceptable typefaces are those giving the same or better legibility than Helvetica (Figure G.2.6.1)

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.

Figure G.2.6.1 *Identification on Sails: Example of Helvetica typeface.*

RRS Appendix G – 1.3 specifies the positioning of identification as follows:

- Except as provided in rules G1.3 (d) and G1.3 (e), class insignia, national letters and sail numbers shall when possible be wholly above an arc whose centre is the head point and whose radius is 60% of the leech length. They shall be placed at different heights on the two sides of the sail, those on the starboard side being uppermost.

  The class insignia shall be placed above the national letters. If the class insignia is of such a design that two of them coincide when placed back to back on both sides of the sail, they may be so placed.

  National letters shall be placed above the sail number.

  The national letters and sail number shall be displayed on the front side of a spinnaker but may be placed on both sides. They shall be displayed wholly below an arc whose centre is the head point and whose radius is 40% of the foot median and, when possible, wholly above an arc whose radius is 60% of the foot median.

  The national letters and sail number shall be displayed on both sides of a headsail whose clew can extend behind the mast 30% or more of the mainsail foot length. They shall be displayed wholly below an arc whose centre is the head point and whose radius is half the luff length and, if possible, wholly above an arc whose radius is 75% of the luff length.

G.2.7 Advertising on Sails

The size and position of permitted advertising on sails is governed by WS Regulation 20, except at events at which the International Olympic Charter applies.

Class rules and the rules of a Rating System may prohibit or limit the right to display Advertising on the boat. If the class rules or the rules of a System do not prohibit or limit the right to display Advertising, it shall be permitted. This does not apply for Olympic Classes, which cannot prohibit or limit in any way the right to display advertising while racing.

Personal Advertising on sails shall be clearly separated from national letters and sail numbers and from Class insignia unless it is part thereof.

Event advertising on sails is permitted only on windsurfers, on each side of the sail, placed between the sail numbers and the boom (wishbone) and aft of the foot median line. Such advertising shall not exceed 0.4 m^2.

Sailmaker’s marks are permitted at all times as follows:

> Boats: One sailmaker's mark, which may include the name or mark of the sailcloth manufacturer and the pattern or model of the sail, may be displayed on both sides of any sail and shall fit within a 150mm x 150mm square. On sails, other than spinnakers, no part of such mark shall be placed farther from the tack point than the greater of 300mm or 15% of the length of the foot.
>
> Sailboards: One sailmaker’s mark, which may include the name or mark of the sailcloth manufacturer and the pattern or model of the sail, may be displayed on both sides of the sail and shall fit within a 150mm x 150mm square. No part of such mark shall be placed farther from the tack point than 20% of the foot length of the sail, including the mast sleeve. The mark may alternatively be displayed on the lower half of the part of the sail above the wishbone (boom) but no part of it shall be farther than 500mm from the clew point.

G.2.8 Certification marks on Sails

When satisfied that a sail complies with all applicable rules, the official measurer can certify it by attaching a certification mark. This is undertaken in different ways in different countries: certification marks usually take the form of a numbered sail button with the MNA logo (figure G.2.8.1), a sticker/label (figure G.2.8.2) or a stamp (figure G.2.8.3) with the details of the MNA and official measurer. In some cases the certification mark may be just a signature but classes should try to avoid this for their sails, as it is next to impossible to verify the identity -and the authority- of the person who signed the sail.

Buttons are small and don’t have the details of the measurer. The serial number is known to the issuing MNA but for inspection purposes it is not easy to see who the measurer of the sails was.

Stamps need good quality ink, and this is not always easy to get. In any case ink will inevitably fade out after some time rendering the certification mark difficult to check or even invisible.

Good quality stickers, made of self-adhesive sail cloth material similar to the one used for sail numbers or sailmaker marks are probably the best solution. For extra security, they may be sewn onto the sail.

Certification marks should always include the date because this is the only way to check if a sail is eligible for grandfathering in case of a specific class rule that applies after a certain date.

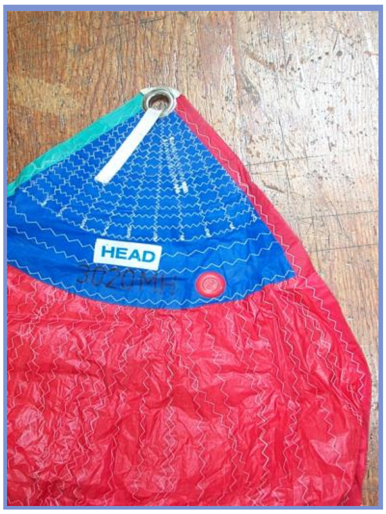


Figure G.2.8.1 *Sail button*

Figure G.2.8.2 *Sail certification stickers*

Certification marks should be at the tack of jibs and mainsails leaving the clew area for event limitation marks / stamps.

Figure G.2.8.3 *Sail Certification Stamp*

Figure G.2.8.4 *WS IHC sticker*

SECTION H. ACCURACY, PRECISION & REPRODUCIBILITY OF MEASUREMENTS.

H.1 Introduction

In order for measurements to be meaningful they must be accurate, precise and reproducible so that they 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 misinterpreting the rules thus measuring in the wrong way to the wrong points, from miss-reading a measurement, incorrectly using measurement equipment, or as a result of incorrect recording of the data.

To avoid misinterpreting the rules the measurer must be completely conversant with the class rules and the ERS if applicable. 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, especially if you get a deviant reading, 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

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

H.2 Basic Standards and Units

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 common in Naval Architecture, the Standard International (SI), i.e. metric units should be used for sailboat measurement, unless specified in the class rules. The units must be clearly stated together with the numerical value, for a measurement to be meaningful.

Basic quantities

Table H.2.1 Fundamental quantities

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.

H.3 Definition of terms

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 and immediate comparison with the mandated value.

In daily conversation a number of terms are often loosely and imprecisely used, so some relevant terms will now be defined:

True value:

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

The average of the measurements is a best estimate of the true value and probably within the standard deviation of the mean of the true value. For practical purposes, when discussing with the jury, the finally found value can be declared to be accurate and within the precision of the true value.

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.

The following types of errors are generally under the control of the measurer and can be minimized by appropriate methodology and equipment. These are errors, in the sense that they are mistakes, which should be corrected:

1) Mistakes in recording or calculating results
2) Reproducibility, determined by methodology and stability
3) Round-off errors, due to poor calculation practices
4) Quantization, due to insufficient resolution of the measuring instrument
5) Incorrect measurement, e.g. LOA parallel to the deck rather than the baseline.

That leaves two primary sources of error in the sense that they are deviations from the true value:

6) Systematic errors, which determine accuracy
7) Random errors, which determine precision

Accuracy:

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

Precision:

Precision is the extent to which a given set of measurements of the same quantity agree with their mean and is characterized by the scatter of successive 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. Precision also depends on the resolution of the measurement device. A measurement can be extremely precise, but not necessarily be accurate.

Reproducibility:

Reproducibility is defined as the closeness of the agreement between the results of measurements of the same quantity carried out under *changed* conditions or at different locations or times. Lack of reproducibility can be due to either systematic or random errors, different measurement tools or protocols.

Round-off error:

This is 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, but the input data must have sufficient significant figures. For example $3 \times 1/3 \approx 3 \times 0.33 = 0.99$!

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. Measurements, and the results, of calculations should only be quoted to the precision of the measurement.

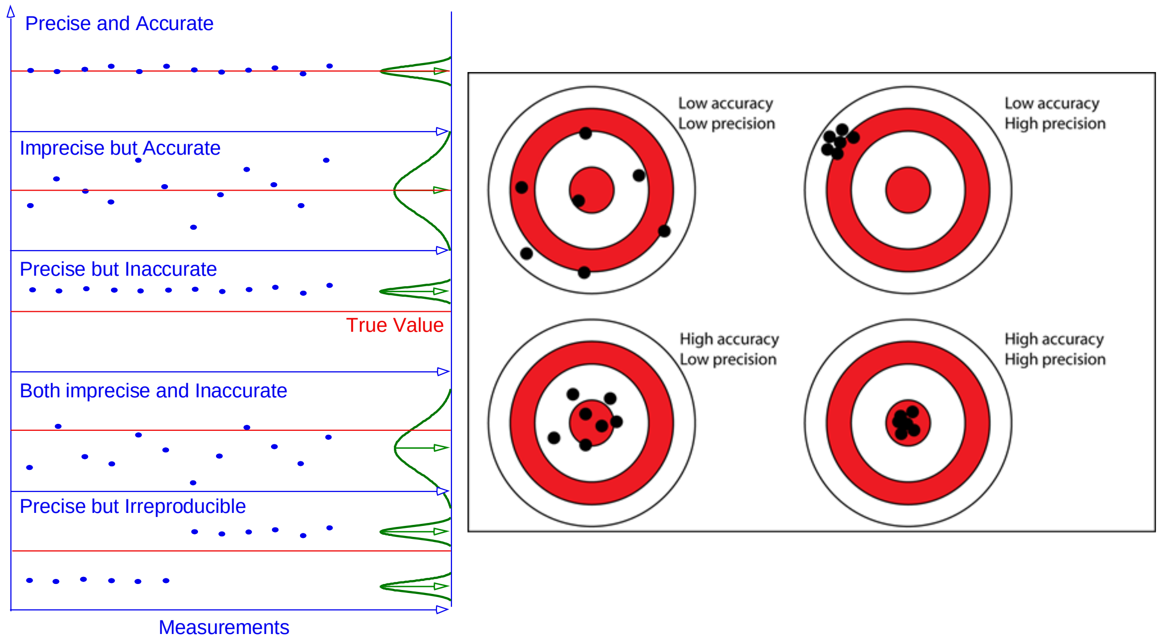


Figure F.3.1 *The difference between accuracy, precision and reproducibility.*

H.4 Errors

Systematic errors

These are errors which are reproducible from measurement to measurement and caused by:

- Incorrect calibration or conditions of use.
- Imprecise definition of the quantity to be measured.
- Faulty methods or procedures.
- Defective or inappropriate instruments.
- Incomplete or approximate equations.
- Bias on the part of the measurer.

Properties:

- Cannot be reduced by averaging, as any given systematic error is reproducible and of constant sign.
- Systematic errors $\boldsymbol{\Delta}$ add algebraically, $\boldsymbol{\Delta = \Sigma \cdot \Delta_i}$.
- Can be corrected later if recognized.
- 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 response of scales. High precision scales require multi point calibration.

Measurement Tape Errors

Off the shelf Class II steel measurement tapes are surprisingly good and can be used for measurement but preferably after comparison with a certified class I tape to confirm their calibration. Every IM should have one class I measurement tape as a reference but generally use cheaper class II commercial tapes for measuring.

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. Some measuring tapes have sliding hooks at their end, to facilitate inside and outside measurements, which are legal for all classes, but create an additional value to the certification error. Precision tapes have their zero offset from the end of the tape. A bent tape (by stepping on it) will also give wrong dimensions.

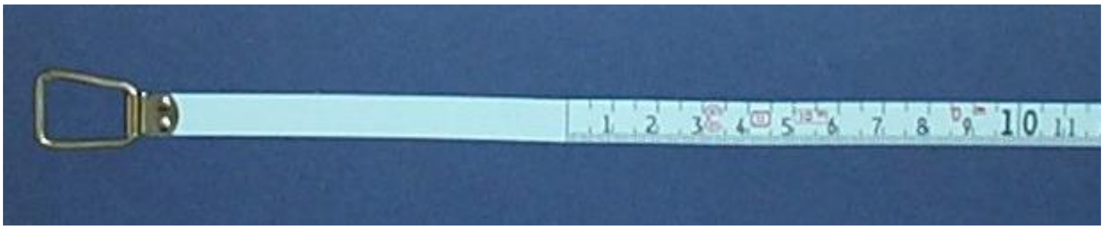


Figure H.4.1 *A measuring tape with an offset zero to eliminate end errors.*

Temperature errors

Measuring tapes, as well as the items to be measured, expand as they get hotter, but unless made of the same material they expand at different rates. Steel has a coefficient of expansion $C_S = 11.6x10^{-6}/°C$, while the coefficient of expansion of aluminium is $C_{Al} = 23.4x10^{-6}/°C$.

Some coefficients of expansion are given in table H.4.2:

Table H.4.2 Thermal Expansion Coefficients

Material	**Coefficient x 10^{-6}/deg C**
Aluminium (6061)	23.4
Brass	18.7
Copper	16.6
Stainless Steel (316)	16
Steel	11.6
Cast Iron	10.5
Polyester-Glass	25 (resin dependent)
PVC	50.4
Lead	29.3

The thermal expansion of wood and plywood depends on the grain direction and humidity but is typically 5 x 10^{-6}/°C. For all combinations of fibres and resins, glass, carbon etc. the coefficients depend on the type of resin and fibres and the direction of the fibres. In most cases these are more or less unknown, so in important cases where there is doubt, try to measure in the morning or evening, when the temperature is close to 20°C.

For example if a 10m long 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 for a deviation in temperature $\Delta T = 20$ degrees C would be $\Delta L = L(mm) \times \Delta T(deg. C) \times C_s = 2.3$ mm while that of the mast would be 4.7 mm, i.e. the mast would appear to be 2.4 mm too long. 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.

Proper Tension

Most precision steel measuring tapes are calibrated at a temperature of 20^0C with a tension of 49.0 N (5kg) applied, and in the absence of a tension being stated on the tape these values should be used for accurate measurement. However, unless supported, the sag can also contribute, see below. Cloth or plastic tapes should not be used for boat measurement.

Sag in tape

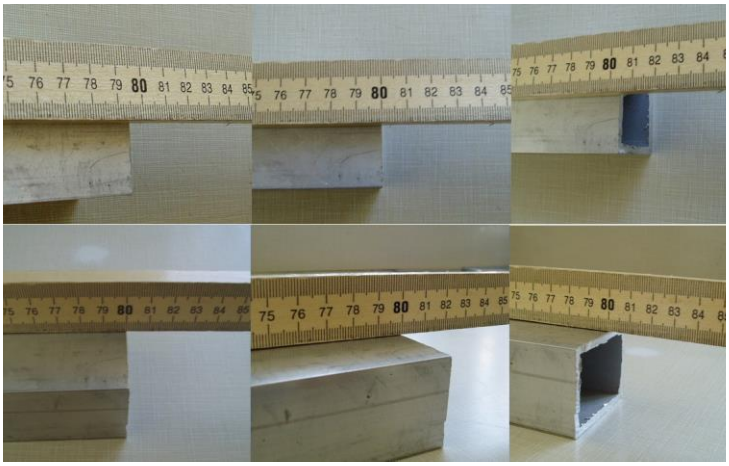
Unless a flexible tape is laid along a straight surface it will always have some sag in it and this will cause an error, however small. The amount of sag and hence the error, depends on the tension T applied and the mass per unit length **λ** of the tape or cord.

For keel rocker measurement use a very light line, i.e. twine **(**or, for boats more than 7 m, another way of measurement like a laser beam or a surveyor's level) as the sag is proportional to λ, the square of the length L and inversely to the tension T.

For mast deflection measurements, where the ends of the line move as the mast bends it is useful to use a somewhat elastic line so the tension remains essentially constant.

Parallax Error

This is a misreading 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.



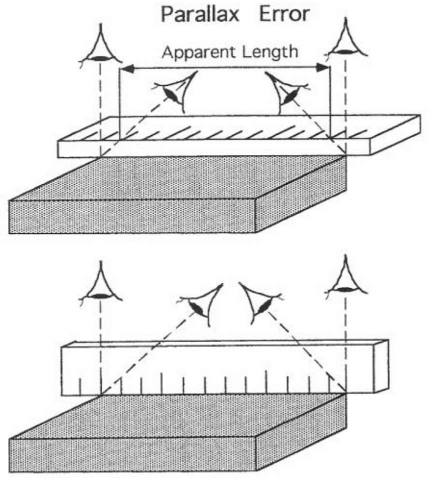


Figure H.4.3 *The parallax error when sighting a non-contiguous scale*

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.

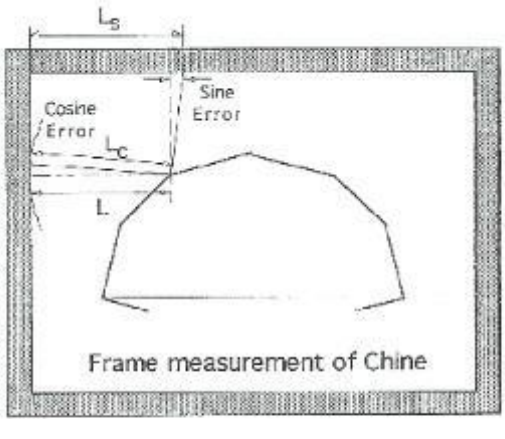


Figure H.4.4 *Sine and Cosine errors*

Measurement Axes errors

Unless specifically required by class rules to be taken in another way, 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 major axes of the hull, which are defined in the ERS as:

MAJOR AXES

The three major axes of the boat at 90^0 to each other – vertical, longitudinal and transverse – shall be related to the baseline and the hull centerplane.

The baseline is as defined in the class rules, and although typically parallel to the DWL, this is not always the case. The Europe class defines how the hull is to be leveled, see figure F.4.5, and although small deviations from the correct level 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.

Wedge gauges

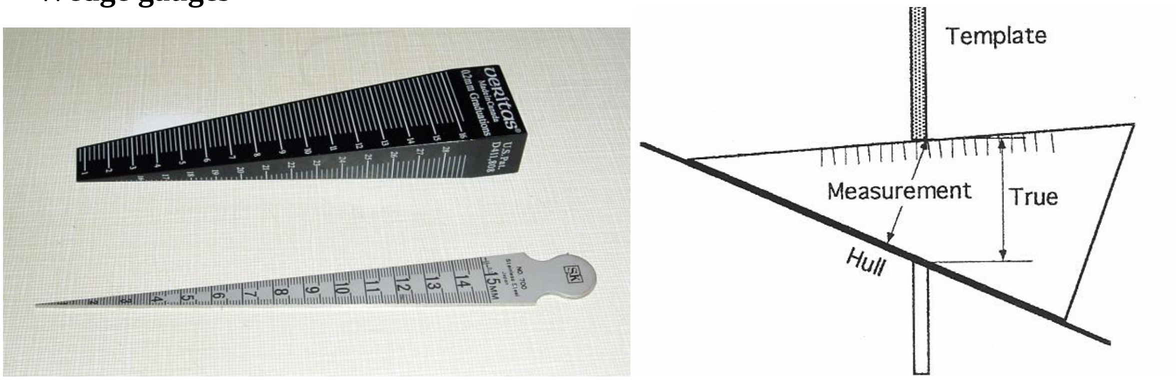


Figure H.4.6 *Two types of wedge gauge and the error in gap measurement.*

Wedge gauges come in two varieties:

- Those that measure perpendicular to one edge, and
- 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 in figure H.4.6. This again is a Cosine error and so unimportant where the template is almost perpendicular to the hull surface, but does become important at the bow sections where the angle is significant. The Yngling class rules state 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.
- The distribution of the data generally follows a Gaussian probability distribution.
- Can be reduced by more precise instruments, better procedure and by averaging.
- A quantitative estimate, the standard deviation **σ**, can be derived from the scatter of a set of measurements.
- Random errors add in quadrature, $\boldsymbol{\sigma^2 = \Sigma\, \sigma_i^2}$
- Random errors limit the precision of the measurement.

It will be seen that taking many readings does reduce the random error of the mean. However, it is much better to improve the technique, i.e. for a Lamboley test to use a photogate, $\sigma = \pm\ 0.0005$ s, to start and stop the timer.

Resolution

Resolution is the degree to which a measured value is 'rounded off' by the instrument. For example a length of 100.74 mm would be recorded as 101 mm when using a ruler graduated in mm. Electronic instruments display the measurement to a given number of significant figures, thus rounding off the result. A display of 101 means that the taken measurement is between 100.501 and 101.499.

Combination of errors

In general one should always try and measure a quantity directly and not as a combination of a number of measurements, primarily because the errors compound.

- Systematic errors **Δ** add algebraically, $\boldsymbol{\Delta = \Sigma \cdot \Delta_i}$.
- For addition and subtraction random errors add in quadrature, $\boldsymbol{\sigma^2 = \Sigma\, \sigma_i^2}$.
- When multiplying or dividing fractional random errors (percentages) add.

H.5 Measurement Techniques and Reproducibility

Technique:

When possible, do not measure a quantity 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, except when the scale is a multi-pad scale specifically designed for this.

Use of precise templates:

Precision templates are often used in order to increase the precision and reproducibility of measurement checks especially during regatta inspection.

- Aluminium hull templates.
- Mylar master to check templates.
- Rudder and centreboard templates.
- Gunwale, rubbing strake gauges.
- Gauges for masts, booms and spinnaker poles.

- Mylar templates for sails.

Record keeping:

Accurate and complete records are essential during measurement and it is often beneficial to have a record keeper keep them while you measure. This facilitates

- Comparison with measurement certificate.
- Record keeping on paper as backup, as well as on a computer.
- Records should be available to measurers on the Internet.

Calibration of tools:

The calibration of all tools should ideally be checked before any important regatta.

- For sailboat measurement SI units and standards are used.
- For the precision required for sailboat measurement the calibration of steel tapes, callipers, etc. are generally not a problem.
- Calibration of weighing scales should, if possible be checked on site against calibration standards of similar mass to the object to be weighed.

H.6 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 if these are the only two vertical forces acting.

The act of weighing measures the force **N** the scale exerts to balance the force of gravity on the object, however, scales are calibrated to read "the mass **m'** 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 latitude to another, so "g" changes) the scale calibration is no longer valid. For accurate weighing the scales must be calibrated (span adjusted) in the location in which they are to be used.

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