IYRU-MYRD
Resolution, Error and Accuracy of Measurements

1 Introduction

The question has been asked 'How should we choose suitable measuring equipment for use during control measurement at a WC regatta when the class rules stipulate minimum/maximum weights for the keel and boat?' No express IYRU policy concerning resolution, error and accuracy of measurements exists, so these notes are made to indicate the rationale behind the general policy which will be used for IYRU-MYRD events.

Where the quantity being measured is performance critical, e.g. keel maximum weight and boat minimum weight, it is inevitable that there will be a significant number of cases where the accuracy of the measuring equipment is called into question both at initial measurement and later at control measurement. It is also of vital importance for a regatta committee to know exactly which procedure it should be using, and for that procedure to be technically correct, when performing control measurement. Thus it is necessary to establish a policy which will indicate the required accuracy and resolution or acceptable error of measurements/measuring equipment.

2 Some General Definitions.

A measurement is a representative value ascribed to what is, for all practical purposes in most cases, an absolute value.

Resolution is the degree to which a measured value is 'rounded'. For example we would normally record a length judged to be approximately 100.7 as 101 when using a rule graduated in whole units and we would round a value of 10.07 to 10.1 when we are required to use one place of decimals. Thus the degree of resolution contributes to the error in a measurement.

Error is the difference between the representative measured value and the absolute value of a quantity.

Accuracy describes the degree to which error is absent.

Zero Error is the error which is present even when the quantity being measured is zero.

3 Discussion

The purpose of the measurement process in the wider context of boat measurement is to determine whether or not certain critical values conform to stipulated minima or maxima.

The certainty of an accurate measurement is of interest to the measurer who signs the measurement form to say the boat conforms to the rules and also to the owner, who may find his boat is the subject of a measurement protest at a later time.

There are several ways in which resolution, error and accuracy impinge on the measurement process and which contribute to the degree of certainty over whether or not a boat is in rating.

3.1 Error in the Measurement Scales

The resolution** of the scale with which the measurement is taken, be it rule, tape, weighing scales etc will affect the reading. An absolute value of 100.5 may be read either as 100 or 101 because the scale is graduated no finer. This represents an 'error' of + or - 0.5%.

Additionally the scale will be subject to an inherent error or inaccuracy.

For example an absolute value of 100 may be measured as exactly 101 by the scale. Thus there is a calibration error of 1%. This error of 1 may exist when the quantity being measured is zero i.e. it may be a zero error. Alternatively it may be a progressive error which is always 1% of the value being measured. In practice the error will comprise some element of each type.

The scope for error of a scale which is graduated in whole units and has a 1% error in its calibration is 1.5% when measuring a quantity of 100 units.

3.2 User Error

The person making the measurements may unwittingly contribute error to the process by making systematic and/or random errors. These are illustrated by the example of not correctly calibrating the 'no load' reading of the weighing scales to zero prior to making measurements (eliminating zero error) and consistently misreading the scale, respectively.

3.3 Lack of Resolution in the Rules

The degree of resolution used to define maxima and minima values stipulated in class rules may also contribute to the uncertainty issue. A quantity limited to a value of 0.3 units may be measured using commonly available scales to a resolution of 0.01. For example 0.295 would be read as 0.30. Should a value of 0.34 then be accepted because, when expressed to the same degree of resolution (number of decimal places in this case) as the value in the class rules, it becomes 0.3?

If that is not acceptable then should an absolute value of 0.3049 be accepted because, measured to the commonly available degree of resolution it is read as 0.30?

** The word 'precision' is sometimes used in this context.

As we have seen it is the value ascribed to the absolute value which is of interest because in most cases it will not be possible to determine the absolute value. Only in cases like determining the number of battens will it be possible to obtain absolute accuracy.

Ideally, the choice of suitable units of measurement and degree of resolution should be considered when the class rules are formalised, so that critical measurements are invariably repeatable at initial and control measurement. Consideration should also be given to whether measured values rounded down to equal a maximum value (or up to equal a minimum value) are acceptable.

In almost all cases of linear measurement, the systematic and random errors of the measurer are likely to be of a higher order than that attributable to the measurement equipment. Apart from encouraging Division Members and Race Committees to employ only the very best available measurers there is little that can be done to eliminate this common source of error. However, at control measurement any measurement which poses a real problem is likely to be re-checked by several people before punitive action is taken.

4 General Policy

4.1 Existing Class Rules

In the absence of any existing express policy, maximum and minimum values in class rules are understood to be absolute limiting values. For example, a maximum value of 20 units means the ABSOLUTE MAXIMUM VALUE is 20 units precisely.

4.2 New and Revised Class Rules

These should contain a section dealing with units of measurement which specifies the number of decimal places to which measurements and calculations are recorded. Values used in calculations should also be dealt with in this section where necessary, viz:

XX.1 Unless specified to a greater number of decimal places measurements and calculated values shall be taken and recorded as follows:

Item	Units	Decimal Places Measurement	Decimal Places Calculation
Length	millimetres	0	0
etc			

XX.2 EITHER OPTION A — Maximum and minimum values shall be taken as absolute limiting values. Measurements shall not be rounded before comparison.

OR OPTION — Measured values shall be correctly rounded to the required number of decimal places before comparison with maximum B or minimum limits.

XX.3 Calculated values shall be correctly rounded to the required number of decimal places before recording.

XX.4 Any previously calculated value used in subsequent calculations shall be the correctly rounded recorded value.

4.2 Linear measurement below 1000mm

Where linear measurements are typically below 1000mm the class rules should specify minima and maxima values to zero places of decimals and measurements should be taken and recorded to zero places of decimals. Measurements in the range below 1000mm may reasonably be expected to be taken to this degree of resolution and highly accurate engineers' rules are readily available graduated in whole millimetre markings.

If it is intended that measured values of 100.49 or 100.049 are not acceptable maximum values of 100.0 and 100.00 then Option A of XX.2 above should be used in the class rules and the maximum value can be stated as 100.

4.3 Linear measurement below 50mm

Measurements below 50mm would normally be taken using a vernier gauge or micrometer and a degree of resolution of 1 or 2 places of decimals is easily satisfied. They are made to a high degree of accuracy and, like rules, may be readily checked using standard gauges.

4.4 Weight measurement

The special case of measuring weight is, in essence, no different from measuring linear quantities. However, commonly available weighing scales have a larger inherent error and lower degree of resolution, relative to the quantity of interest, than linear measuring equipment. For example a digital electronic scale with a range up to 5 kg costs circa £50-£150, has a typical error of + or - 20 grams and a resolution of 10 grams (reads to the nearest 10 grams). Such a weighing scale may be calibrated by use of a standard 5 kg weight costing circa £25 and with an error of -0 to + 0.5 grams. However, the degree of resolution will mean that, when an item is weighed on several scales each calibrated using the same standard, there will be a variation in the measured value.

The cost of weighing scales which will reliably discriminate between 3.9996 and 4.0004 kg is several £K and it is therefore unreasonable to expect measurers and Race Committees to have access to such. During pre-race control measurement, where all competitors have the opportunity to adjust their boats, absolute accuracy of measured value is of less importance than repeatability. Absolute accuracy only becomes of crucial importance when a boat, whose weight is very close to the rule limit is protested when no pre-race control measurement has been carried out. At an event where all boats are control measured prior to the start, provided the same measurement equipment is used consistently for each boat, an equitable approach would be to calibrate the weighing scale at regular intervals using a certificated standard with a high degree of accuracy and require each boat to comply with the minima/maxima values *as measured by that scale*. The degree of resolution of the scale then acquires a much lower significance.

For example when weighing a One Metre class boat:

Assume a 4 kg certificated standard weight
The known error of less than + or - 0.2 grams
It is check measured on scales which have a resolution 0.01 kg (read in steps of 0.01 kg)
The measurement is 4.01 kg and the temperature is recorded
Any boat weighing 4.01 or more is thus acceptable

Later the standard weight is checked measured
The temperature is noted and is different to the earlier figure
The measurement is now 4.02 kg (the scales are slightly temperature dependant)
Boats shall now check measure at 4.02 kg to comply with the rules
Any boat is deemed out of rating.if it is check weighed at 4.01 kg.

How a boat might be found to be out of class when it was first check measured satisfactorily is as follows:

The scales initially measure the standard weight as 4.014 kg
Their restricted resolution permits an indicated measurement of 4.01 kg only
A boats has an absolute weight of 3.992 kg
Thus it is weighed by the scales as 0.008 kg less than the standard weight i.e. 4.006 kg
The restricted resolution of the scales means the indicated measurement is 4.01 kg
The boat appears to conform to the rules
Later the scales measure the standard weight as 4.016 kg
The indicated measurement becomes 4.02 kg

The boat again check measures at 0.008 kg less than the standard weight i.e. 4.008 kg The indicated measurement is 4.01 kg
The boat is, quite correctly this time, identified as being out of rating.

The possibility of a boat being control weighed and found to be out of rating in this way remains a realistic one because of the temperature dependence of some scales. Thus it is emphasised that the use of the very best affordable scales is of utmost importance in addition to making it clear to competitors that, if their boat is exactly on the limit when checked, there remains a chance of circa 1 in 10 that the boat will fail a later control measurement.

In practice it is possible to purchase scales which weigh up to 6 kg with a resolution of 1 gram (read to nearest whole gram) for £300. A calibration certificate is available for an additional £80 but this is considered to be of less value than suitable calibration weights. Use of this grade of equipment would prevent the unfortunate case described above from happening.

5 Acceptable Levels of Resolution and Error in Measuring Equipment

The following are considered appropriate minimum standards.

M'ment range	Capacity of scale	Resolution of scale *	Calibration quantity	Acceptable error in calibration qty
0-50mm	adequate	0.1mm		
50-3000mm	adequate	1mm		
0-4 kg	0-5 kg	0.01 kg	2 kg	0.1 gram/kg
4-9 kg	0-10 kg	0.02 kg	5 kg	0.2 gram/kg
9-40 kg	0-50 kg	0.1 kg	20 kg	0.5 gram/kg
X kg known qty	0-(X+30%)	larger of 0.2% X or 0.01 kg	X + or - 20%	as appropriate from above

* Here a resolution of 1 is taken to mean that the scale is graduated in whole units. Thus the measurement will be within + or- 0.5 of the absolute value where there is no other error.

Effective 11 January 1994

Chairman of the Technical Committee IYRU-MYRD