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REPORT Nº H100-12.1A	Competition pools to FINA standards Practical concerns

Competition pools to FINA standards
Practical concerns

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Reference Documents

FINA Facilities Rules. Other references listed in Appendix 3 of this document

Changes from last issue marked with a sidebar..

Introduction

This document has been prepared to promote discussion on the practical requirements in providing pools for fair competitive swimming. It is based on a number of years experience of measuring competition pools, including the 2012 Olympic Pools at Stratford, London.

It is clear that there are a number of discrepancies and methods of interpreting the existing rules, together with some matters which have not been considered at all. This lack of clarity can lead to significant differences in the lengths actually swum.

As an example to indicate the extent of variation, a 1500 metre course in a nominal 50 metre pool can theoretically have a swimming length which could vary from 1499.07 metres to 1500.87 metres, depending upon the type of pool and the jurisdiction under which it has been certified. (Refer to Appendix 2 for detail of the calculation).

The construction of the London Aquatics Centre has brought the problems into sharp focus and I should start by expressing my gratitude to the contractor, Balfour Beatty, the London 2012 representatives and other professionals from the engineering and architectural disciplines, who have been adamant that the facilities should be constructed to meet not just the letter of the FINA rules, but to encompass the spirit of fair competition. In this they have gone well beyond the normal contractual requirements to check and investigate many matters which have previously been un-noticed or not reported.

The main body of this report outlines the various matters, while the appendices provide a more detailed commentary on specific subjects and the problems inherent in trying to construct and maintain a facility to millimetric tolerances, together with references.

Interested parties

There are a number of groups which have an interest in both the provision and maintenance of competitive swimming pools.

FINA: as the international governing body

National Associations: as the promoting and organising bodies for the sport within their respective countries

Swimming clubs: as the grass roots organisers of local activities

The general public: as the audience at swimming competitions

Pool owners: as the providers of facilities for use by both local and national communities

Designers and building contractors: who have to correctly interpret the requirements and construct the facilities required in a cost-effective way.

Some or all of the matters contained in this document are relevant to all of these groups in different ways. The one overriding consideration is that all of the groups would expect *consistency* and it is this which is presently lacking, both nationally and internationally, and about which this document attempts to stimulate a debate.

Changes

Past correspondence with FINA has indicated that changes to the rules and their application need to be driven by National Swimming Associations, hence the purpose of this document in attempting to promote discussion amongst interested organisations.

The inconsistencies, which have become apparent over a long period of investigation, derive principally from a lack of understanding of technical matters. This is not a criticism of those involved; merely a recognition that the apparently simple matter of providing a given swimming distance is actually technically quite complicated.

Before proceeding further, I should make my personal view on this clear. Regardless of any future changes which may be implemented, times and records already set have to stand, even if the course over which they were set might not comply with any new requirements (or indeed fail to comply with the current regulations when *correctly* interpreted).

Facilities which are found to be non-compliant with the existing rules (correctly interpreted) need to be upgraded if they are to continue to be certified. However, this could place a significant financial or practical burden on the operator and so a reasonable timescale for such work would be required.

Where such changes can be implemented by a simple substitution of existing equipment (even if this was a short-term solution) then there should be little delay. Where changes are needed which require the pool to be closed for a significant period of time then a timescale of some years might be required.

Meetings which have already been arranged should proceed on the basis of the existing certification: it would be unfair and unrealistic to cancel events already being organised. However, pools which did not meet any new rules would need to upgrade before being allocated international events.

Fundamental problems

The critical problem is the one of how far a swimmer has to travel to complete the course in each event. At first glance the existing rules seem clear: the distance must be at least that stated in the length of the event, but the practical implementation of the rules leaves much to be desired. Records can be won or lost by 1/100 second and this time is a swimming distance of about 18 mm. in a 400 metre race, equivalent to just over 2 mm. change in a lane length.

Firstly, there are inconsistencies in the way the rules are written, which leads to inconsistencies in the interpretation.

Secondly, there are fundamental misunderstandings of the terms accuracy and precision when applied to methods of survey measurement, together with little concept of the theory of errors (understandable – probably less than 1% of the population have even the slightest idea).

Thirdly, there are matters which the rules do not consider.

All these factors affect both the ability to achieve the desired aim and the costs of providing the facilities. The latter point has considerable significance. Depending upon past experience different building contractors may have a significantly different understanding of what is going to be required under the contract to build. This could, in some circumstances, fall within "unfair competition" legislation.

The fundamental problem is one of measurement, the practical considerations of constructing pool tanks, moveable bulkheads and the stability of timing pads, but the wording of the present regulations was not drafted with these matters in mind. All of these have a significant affect on the ability of the pool operator to provide AND maintain a pool of appropriate length.

Respect for any rule can only be maintained if the requirements of the rule are practical: where this is not the case then it can be expected that ways will be found to circumvent the intention. This is not to suggest that deliberate flouting of the rules takes place; more that the natural human reaction, faced with something which appears impossible, is to apply a different interpretation to make it achievable.

Items which are overly technical are referenced in the text, but the detailed explanations are placed in Appendix 1. The symbol (*) placed in the text indicates these items.

Precision, accuracy and tolerance

(*) Precision is the ability to repeat something and arrive at the same answer each time (regardless of whether it is correct): accuracy is the ability to arrive close to the correct answer each time. Tolerance is the permitted deviation from the true requirement.

These definitions are frequently misunderstood and thus incorrectly applied. This gives rise to some of the problems found over the years: designs which do not allow for accumulative tolerances; rules which specify some tolerances as being positive or negative only and others as positive/negative; methods of measurement which assume the accuracy of a piece of equipment is the same as its precision.

These matters will be discussed in more detail in the sections which follow.

The Rules

The existing rules need some minor redrafting to make their application crystal clear. This is principally a matter for the National Associations to press FINA. Such redrafting needs to take into consideration all the matters which are currently *assumed* to be dealt with by interpretation of the rules, such as distortion of moveable bulkheads by the attachment and tensioning of lane ropes.

1) The rules need to be clear regarding the precision of dimensions. The existing expressions such as 25.0 metres are sometimes used as a reason to give certified distances to the nearest centimetre. Where a dimension is required to be accurate to a millimetre then the rule should use that precision (…a length of at least 25.000 metres). Where a lesser accuracy is required, such as clear water beyond the outer lane, then a lower precision should be used (…at least 0.20 metres).

Strictly, the words *at least* should be adequate on their own, but it is clear from many examples that misinterpretation occurs due to the lack of precision in the given dimension.

2) The specification of tolerances needs to be consistent and take into consideration the order in which construction and fitting out takes place. Under the current rules a contractor can build a pool which meets the specification (say 25.022 metres long) which allows for two timing pads each of 10 millimetres thickness. The timing pad supplier then delivers timing pads of 12 millimetres thickness (permitted since the tolerance for pads is specified as plus/minus 2mm.) and the pool is immediately too short.

The critical tolerance limit should always be ZERO. The rules need to be worded and interpreted so they deal with the *accumulative* effect of tolerances.

3) The upper tolerance on pool lengths is problematic when moveable bulkheads are installed, especially when more than one has been incorporated. It also causes difficulties when timing pads of a thickness other than that used for the design are supplied.

Although it is preferable for the variations in lane length to be kept to a minimum, it would be better if the existing tolerance of plus 0.03 metres (before installation of timing pads) above the nominal distance was reworded to be *recommended*. (USA Swimming do this). This would permit a small margin of additional length, which would ease constructional difficulties and better accommodate various bulkhead configurations. Note: for competitive swimming with timing pads the additional distance (if any) can be taken up by the timing pad mounting mechanism. (See later comment).

4) The wording of the FINA rules implies that the certification of length is carried out on the completed pool tank before the timing pads have been installed. This is logical in that the contractor building the pool may complete his legal obligations well before the timing pads are available for installation. **Proper consideration needs to be given with regard to dimension checks after the timing pads have been fitted.**

5) There is no rule relating to moveable bulkheads. Considerable temporary distortion has been recorded in bulkheads once the lane ropes are attached. Relocating the bulkhead exactly in the same position once it has been moved is also a cause for concern. Some countries have implicitly acknowledged that bulkheads present a problem and mention them in guidance notes. (See USA Swimming, for example).

Measurement

Various types of equipment are in use in different parts of the world and various techniques have been adopted. Some of these techniques are flawed or based on false premise (mainly due to a lack of understanding on how errors occur and are propagated through a survey).

Whatever equipment is used must be checked in a manner which ensures it is accurate or which enables the correction values to be determined. This includes all ancillary items related to the measurement. **It is not adequate to take the manufacturer's specification as an indication of accuracy for a specific set of equipment.**

(*) Tape measures are problematic in use except where a tape can be run out and fully supported along the side of the pool. They are generally unsuitable for lane measurement.

(*) Handheld laser units (Distos etc) have very limited use for precise distances unless a dedicated unit is used and checked on a fixed reference base at the pool concerned.

(*) Electronic surveying instruments are suitable, but only if the correction constants are known for the specific combination of instrument and target.

(*) All electronic measuring equipment used in a non-contact mode will be at risk of errors introduced by the colour and surface texture of the target surface. Dark blue is a particularly problematic surface which can lead to errors when measuring to centreline markings.

The FINA requirement is for dimensions to be taken above and below water level. Measurements only taken above water level should not be acceptable: this raises questions about length confirmation measurements taken only with a hand-held measuring device unless custom accessories are available to enable checking of underwater distances.

In all cases the various methods of measurement and the equipment needed are detailed and commented on in Appendix 1.

Certification measurements need to be taken by professional personnel who understand and are experienced in the equipment, techniques and conditions. It appears from a study of some of the documents and illustrations available that this is not always the case. There is also some indication that builders may have self-certified their own work.

Timing pads

Timing pads are specified as being 10 millimetres, plus or minus 2 millimetres. This inconsistent use of tolerances has already been commented on. Other sizes (5 mm and 15 mm also seem to be in widespread use although these do not comply with the FINA regulations. Such sizes might be appropriate where a pool tank is found to be significantly out of tolerance when fitted with standard pads.

(*) From inspection, timing pads do not retain their flatness for long. The continual battering they receive from swimmers rapidly induces warps and bends, especially close to water level when the pad is in use on a pool with raised ends and a gutter.

Timing pads often have a slotted fitting giving adjustment along the length of the pool, but no method of ensuring the pad is refitted in the same position. If the fitting sockets on the top of the pool wall are not set at exactly the correct spacing this may induce a twist and tilt into the pad when in position, thus changing the overall lane distance.

Some pads, with frame and supports greater than 12mm. appear to be designed on the basis that they react only when compressed against the pool wall. This means that the swum length will be significantly longer than the length measured to the face of the uncompressed pad.

(*) Measurements should be taken with the pad compressed by its "trigger pressure".

Moveable bulkheads

(*) Booms may be lifting bulkheads, which are restrained by guide slots in the pool sides, or may be traversing bulkheads which can move along the pool length. Both types are at risk of temporary distortion when lane ropes are applied and tensioned (typical loads 2.5kN per rope)

(*) Traversing bulkheads have an additional problem of relocating the bulkhead in exactly the same position as it was placed when certification took place. The fixing sockets and pins normally have significant clearances. In addition, when the bulkhead is lowered into place it may not seat down evenly, resulting in the bulkhead tilting one way or the other and thus changing the lane distances. This can also happen with the lifting bulkhead, but that should be restrained by the guide slots *if the clearances are small.*

Both types of bulkhead will have manufacturing tolerances, which are unlikely to have been taken into consideration when the main pool tank was constructed. Again, these tolerances tend to be treated as plus or minus, rather than minus only. Depending upon the construction methods (or installation methods where the bulkhead as been prefabricated as a one-piece factory unit) some distortions may be present in the completed bulkhead. These are difficult to remove and are unlikely to be in sympathy with any constructional variations of the main pool walls. Thus wide parts of the bulkhead might coincide with small projections in the tiling, stopping the boom from fully moving to the desired position. (There should be adequate room designed into the pool tank, but this doesn't always happen.)

Thus although the main pool walls may meet the required tolerances and the faces of the bulkhead are similarly in conformity, together the distribution of the variations may mean that at some points the required dimensions are not achieved.

The problem is especially difficult to overcome when a combination of lifting and traversing bulkheads is installed to give multiple courses for use at the same time.

Action points

1) FINA needs to clarify all the dimensions and tolerances, to be consistent with each other.

2) FINA needs to make it clear if measured distances are to be rounded off to centimetre values or recorded and interpreted as millimetre values.

3) FINA needs to consider if additional length should be permitted (but not recommended) to ease construction and operating difficulties.

4) Bulkheads need to be considered and regulations made to ensure that they can be used within the spirit of the rules.

5) National Associations need to ensure that certification is carried out only by *independent* parties who are appropriately qualified *and experienced* in the methodology.

6) A mechanism is needed to ensure timing pads are at their "reaction thickness" when measurements are taken.

Reserved matters

1) Checking and recertification of pools which are suspected of being outside the rules.

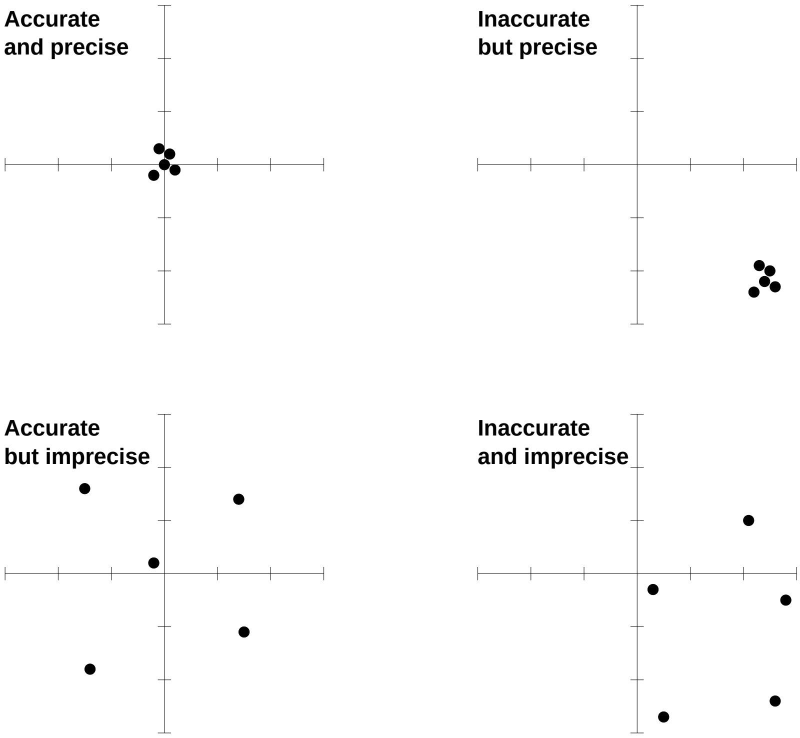
Appendix 1 Technical matters

This appendix provides a separate detailed narrative on various matters, to avoid the main document text becoming overburdened with full technical explanations. The comments contained are not, however, exhaustive since some of the headings could command complete papers in their own right. It is hoped that sufficient information is provided to enable a good understanding of the problems and difficulties and to identify further reading direction.

Precision and tolerance

The following diagram illustrates the differences between accuracy and precision. It can be seen that reliance should not be placed simply on an instrument's specified precision, or indeed on a series of readings, all of which are close to each other. More important is the accuracy achievable and the number of readings required to reach that accuracy.

For a calibrated or fully checked instrument of sufficient precision two readings may be sufficient. In some cases lower precision instruments can be used with special techniques to obtain higher level accuracies, but best practice is normally to use an instrument entirely suited to the task. (See section on measurement methods.)



Checking and calibration

Calibration implies that corrections have to be applied to the readings taken to get an exact answer. Checking implies that the readings taken are accurate within a tolerance.

Equipment which cannot be adjusted to provide true readings (such as a steel tape where the graduations are fixed and unchangable) needs to be *calibrated.*

Equipment which can be adjusted to provide true readings (such as a level, where the set of the bubble can be manipulated) needs to be *checked*.

Some equipment may only be adjustable under laboratory or service conditions. In this case the equipment would be calibrated on major service and subsequently checked during use. Certain limitations may apply.

Specific procedures are generally accepted for the purpose of on-site checking and these should always be applied prior to use of any instrument.

Measuring equipment

This section of the appendix describes the various types of equipment, the limitations in use and the accessories needed to enable accurate measurement.

Wet or dry

All usual measuring equipment (with the possible exception of tapes) will not measure underwater. Where a pool needs to be measured when filled then an appropriate technique is required to transfer the location of the desired point to a position above water where it can be measured. Generally this will be by means of an adapted spirit level or a double-prism offset rod. In the case of a spirit level different adaptations are needed, depending upon whether the measurement is to specific points on the face (ie. 0.8 metres below water level at lane centres and edges) or is determining the most protruding point on the face.

Tape measures

Tape measures have limited use in swimming pool measurement. Linen and fibre/plastic tapes stretch easily and have no accurate use.

Steel tapes need to either be fully supported or hung in controlled catenary. In both cases accurate tension and temperature readings are needed to enable the correct corrections to be applied. It is not practical to use a tape suspended over water since a catenary tape needs to be kept dry (the weight of the tape along its length is taken into consideration during the calculation and a variable water coating would distort this correction). Use of a steel tape is probably limited to approximate check measurements.

Handheld laser measuring devices

With regard to accurate measurement, the description "handheld" is an oxymoron. The devices really need to be securely positioned. Holding jigs are most desirable (see USA Swimming – Measuring and Certifying Competition Pools).

Most of these devices are specified as having a typical accuracy spread of 2-3mm. **This means that an ex-works unit under good conditions (standard temperature, pressure and humidity) and at shorter ranges will achieve that spread when measuring to a Kodak Standard Grey Card.**

Surface texture and colour can have a significant effect (1-2 millimetres) on the distance measured. Dark blues are commonly found to increase the measured length. The devices should therefore always be used with a Standard Card or similar coated board. The thickness of the target needs to be added to the dimension read (see also section "Target types").

These instruments measure a direct line, hence the two positions between which the measurements are taken must be equivalent, so that the line is not angled either horizontally or vertically.

It is difficult to accurately site check these instruments unless a permanent calibration line has been set using a different type of equipment. Errors which develop with time or rough handling may therefore not be detected. A suitable checking line would consist of two vertical plates within the pool hall, set to give a line about the length of the pool and suitably measured by a high-order surveying instrument. The laser device can then be used between these plates and the readings compared with the true distance. The difference recorded would then be the correction constant to be applied to all readings of *similar* length. (This implies that on a 50 metre pool with a bulkhead giving 25 metre lengths then two checking lines are needed.)

Electronic surveying instruments

The term electronic surveying instrument is used to refer to precision equipment which is generally tripod mounted and electronically measures angles (directions) as well as distances. These may be manually operated (total stations or theodolite/measuring head combinations) or automatic instruments (scanners).

The instruments may read to discrete targets or read to any surface if the measuring system is a "non-contact" variety.

Scanners

Scanners record huge numbers of surface points, but need significant processing time to provide a result. Distance measurement suffers from the same constraints as laser rangefinders with regards to surfaces. There is continued discussion regarding methods of calibration: as these units are intended for providing a 3D model of the item being surveyed rather than for specific direct line measurement, calibration methods delivering accuracies of a few of millimetres are normally accepted. This is not appropriate for pool measurement.

For the foreseeable future they are unlikely to prove a suitable tool.

Total stations

Total station instruments may have three sources of error: scale factor, instrument/target constant and cyclic (assuming the correct temperature, pressure and humidity values have been entered into the instrument).

Scale factor would not usually be applicable to swimming pool measurements. It is normally no more than a few millimetres over 1 kilometre and is related to the measuring frequency drift of the instrument electronics. Major service and calibration will identify and enable any scale error to be corrected.

Cyclic error generally occurs only in older design instruments, which the user would identify. The errors take the form of a sine wave of frequency 5 metres and are typically of amplitude 1-4 millimetres. The error curve is usually very uniform and corrections can therefore be established and applied to survey readings with a good certainty.

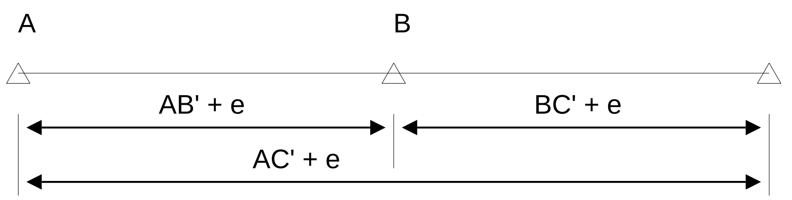
Cyclic errors are at zero when the length measured is a full wavelength. The most commonly used wavelength is 5 metres so they can be eliminated by ensuring the directly measured distances are multiples of 5 metres, which is quite convenient for 25 and 50 metre pools.

To guard against unexpected appearance of cyclic errors it is best practice, when carrying out pre-survey checks, to set the baselines used to multiples of 5 metres.

The most common cause of error is the instrument/target constant. This needs to be determined for **each** target used with the instrument, including surfaces used as targets by non-contact measurement. It can be calculated and the correction applied to each distance measured, or it can be eliminated on a single line by differential measurement. (Line BC is measured as the difference between AB and AC, where A, B, C are colinear). This method effectively cancels out the error constant present in both AB and AC and is the best method for determining the instrument/target constant on site.

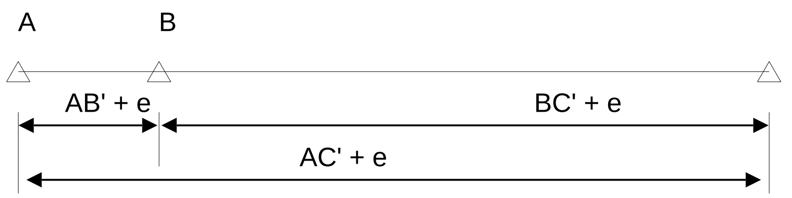
Determining the error constant

The term e is the instrument/target error, which is found by the test.
The constant e is then either subtracted from all readings or set in
the survey instrument to be applied automatically.



AC'+e = AB'+e + BC'+e, hence AC' -(AB'+BC') = e

Eliminating the error constant to measure BC



BC= (AC'+e)-(AB'+e)=AC'-AB'

Note that apparently identical targets and reflector surfaces can have different constants. It is not unusual to find a spread of 2 millimetres across a batch of, say, 10 prisms. Ideally the pre-survey checks should use a single prism and this prism should then be used for all subsequent measurements.

Reference targets

Previous sections of this report have stressed that each *individual* target may give a slightly different result and that it is best practice to use the same instrument and target combination for all observations within a pool: that combination must be proved, by checking, to show that it gives accurate results.

Where the measured lengths in a pool fall mid-way between the acceptable limits then this is not so critical, but where one or more distances fall on the limits then it is essential that no unknown error is introduced into the results.

The description "reference target" is taken to mean both the reflective surface/prism AND the mounting or apparatus to which it is fixed.

The type of target used depends upon the instrument and whether the measurement is taking place to points above or below water level. In all cases the target needs to be rigidly held in place with no opportunity for movement during the measurement. In practice this means that the target or holder must be firmly seated on the face of the wall or timing pad. A single contact point is unlikely to achieve this requirement and hand held survey rods, plumbed up using a circular level bubble mounted on the rod, will not be suitable.

Target types

Targets can be refractive, reflective or inert.

An **inert** target could be the surface finish of the tiling or a Kodak Grey Card. The card is an internationally accepted standard for measuring reflected light intensity. Other inert surfaces may reflect light in a different manner: colour and texture can affect the amount of light returned to the measuring sensor and may introduce a "time delay" effect, which changes the apparent distance. A common effect of this is that a dark blue surface will appear to "soak up" a red laser source and result in the distance appearing to be slightly longer than it really is (typical experiments show around 1 millimetre increase, occasionally more).

Reading direct to the tile face is likely to result in a slightly longer distance than the true value, since the reading is more likely to be to the main face of the tile rather than to the raised non-slip dimples (where the tile is of this form).

Where a card is used the thickness of the target material needs to be considered. There are practical difficulties in using a card in a water filled pool, unless the card is completely sealed to stop water take-up. This, in turn, may affect the reflectivity of the card.

An inert target could also consist of a tape material, such as masking tape, but this can give rise to complications in checking for consistency, particularly if the incident angle of observation varies depending upon where the target is located in relation to the instrument.

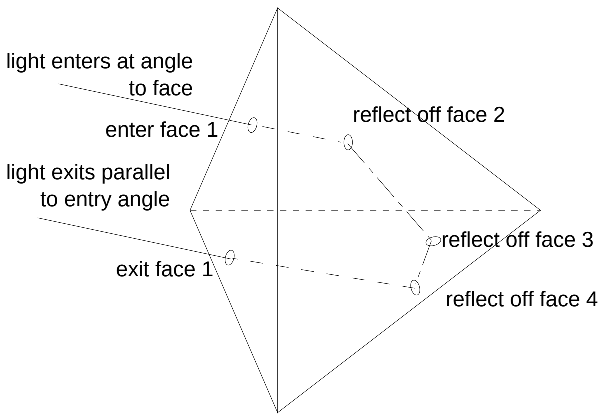
Reflective targets are commonly stick-on plastic consisting of a surface of reflective material backed by an adhesive layer and often with a printed reference cross. They are widely used for general civil engineering and building purposes. Some drop-off of accuracy occurs as the incident angle of observation increases and the threshold at which this becomes significant needs to be determined for each instrument/target combination.

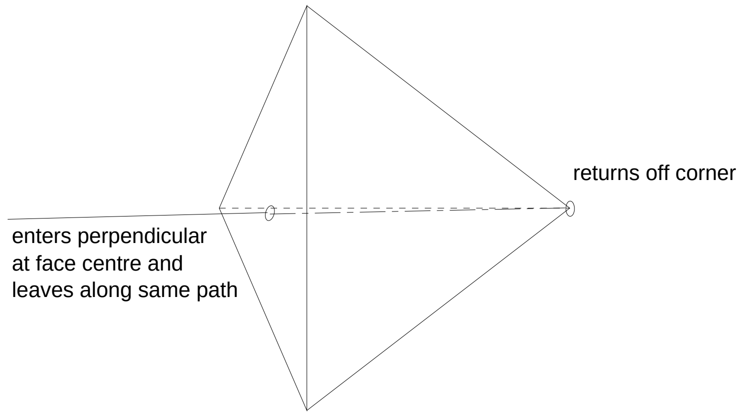
By definition, stick-on targets preclude the use of a single instrument/target combination for all the measurements, so it is essential that all the targets used come from the same roll or sheet and that ones from this source are used for the checking procedure. If used under pool operational conditions the faces need to be kept dry and clear of condensation, since this can give variable readings. (Stick-on prisms are quite liable to have been in long term close proximity with chlorinated water, unlike removable targets).

Refractive targets consist of optical quality (usually!) glass which has been machined and polished to create a true corner cube prism, which is formed by cutting the corner off a cube, with the cut at 45º to each face, (Commonly known as reflectors, but the term refractive is being used here to distinguish between these and reflective materials.)

The mathematical characteristic of such a prism is that all light entering it refracts at the front face (if the prism is not square to the light path), reflects off the three back faces, refracts again as it leaves the front face and returns down a path, precisely parallel to the entry path. Furthermore the length of the path within the prism is identical, regardless of the position at which the light first hit the front face. Thus all the light, and only the light, emitted by the measuring device returns to the device and every path is the same length. This virtually eliminates any external influences and enables a very high quality measurement to be obtained.

Light rays through a corner cube prism





The prism is mounted in a holder, which needs to be included in any checking procedures since the instrument/prism constant derived is dependent upon the reference point of the *target holder.*

Most prism holders are designed for mounting on a tripod or pole to enable ground detail points to be surveyed. They are not especially suitable for measuring to vertical faces. Most have a known distance to the edge or a point at the back so that they can be used in normal survey to a give an offset to objects such as walls. However, this often gives just a single point of contact and may rely on hand holding to an accurate alignment (difficult when the holder has to stand between the target and the instrument).

Better results are obtained when a flat plate mount or block is used, which enables contact onto an area of wall to be achieved. This eliminates the possibility of the measured point falling, say, in the recess between two adjacent tiles or on the area behind the dimpled non-slip face of the tiles.

Bubble levelling

Where the target point is offset from the point to be measured (such as underwater points) then the reference line between the two needs to be truly vertical, although each may be set at a known offset from that line. In this situation it is best practice to take several separate readings to ensure that a true value is obtained.

Defining the vertical line normally means using some form of levelling bubble. An engineering quality spirit level with graduated glass vials should generally enable a vertical line to be defined within about plus or minus 1mm. over a metre length (ie. a 2mm. spread of reading). This is about the best that can practically be achieved and should really be used only for those readings taken at the 0.8 metres below water level mark. This is the position least likely to be used by swimmers for touching, hence any error here is least likely to affect the race result.

Circular bubbles, commonly used on hand held targets and plumbing poles typically have manufacturers accuracy of plus or minus 2½mm (ie. a 5mm. spread of reading). This can be improved if the bubble can be viewed from directly above, which eliminates any parallax effect. However viewing from above requires the bubble to be mounted on top of the pole/target.

This means that items such as plumbing poles are not normally acceptable for precision work.

Offsetting

It is often convenient, when measuring to a target which is not on the point to be measured, to use offset blocks. These lift the object joining the target and the reference face clear of any possible obstructions. This is not necessary if *only* the shortest distance is being determined for racing purposes, but is essential if the measurements are being used to check that the work is within the construction tolerances specified in the building contract.

Depending upon the fixings used, the target may be mounted so that the reading recorded is equivalent to the face of the offset block or at a fixed offset (say 10mm) from it. The design of any such accessory must be such that removal and replacement of the target does not change the relative positioning of the target and the measuring face. The accessory needs to be checked with the instrument being used for the survey, to determine the offset constant, if any.

A common survey method of obtaining the position of a point to which direct measurement cannot be made is to use a double prism pole. This consists of a rod with two prisms attached. The rod is held at an angle so that the tip of the rod can be placed on the point to be measured and readings are then taken to each prism. From those readings the position of the point can then be calculated. To obtain good accuracy this method requires the rod to be absolutely still throughout the measuring sequence (normally by a clamping mechanism, which makes it generally unsuitable for measuring pools). The accuracy is limited since any reading errors may be accumulative rather than cancelling.

Pool equipment considerations

This section deals with the equipment installed in a pool and the implications of interfacing that equipment with the basic pool tank structure. It identifies matters which are not addressed fully, or at all, by the Rules. Some matters raised have clearly been considered by *some* National Associations, since they are referenced in guidance and other notes.

Bulkheads

The rules contain scant mention of moveable bulkheads. Rule FR2.14 deals principally with the marking and safety aspects of bulkheads.

Rule SW 12.5.2 states "Where a moveable bulkhead is used, course measurement of the lane must be confirmed at the conclusion of the session during which the time was achieved." This appears to be quite clear but, given the distortions measured on bulkheads, raises questions about how the lanes have been measured in the past. It would be expected that if a bulkhead has distorted by more than 10mm under the lane rope tension then this should have been detected and reported. (Texas A&M is a rare occasion where a bulkhead positioning problem has been publicly reported, although I have not seen any explanation for the cause).

Both lifting and moveable bulkheads are generally constructed from metal frame units covered with a suitable panelling material. In most cases the frames will be fabricated in sections for transport to site and movement into the pool. Factory completed booms (which may be moulded from GRP) are more likely to be found in outdoor pools due to the handling difficulties in transporting and placing a long, easily damaged object.

The finished structure, by itself and not placed under significant loading, can be considered stable and only likely to show slight flexure when placed in water. The problems arise with respect of two activities; locating the bulkhead in a repetitive manner at the operating positions and side loading of the structure due to lane rope tension.

Location fixings

Each type of bulkhead has different problems with regard to fixings.

For *lifting bulkheads* which raise and lower in sidewall channels the principal problem is clearance between the guides and the permanency of the fixings. Generally this design of bulkhead appears to be less likely to cause significant problems, since it should move only in a vertical plane and thus not affect the lane length.

There will nearly always be a small amount of clearance in the sliding mechanism (although this could be eliminated by a spring loaded pressure pad which always kept the bulkhead tight against one guide).

In most cases the bulkhead guide is installation adjustable to enable correct setting of distance and this is held in place by friction grip bolts. There is a possibility that these can slip over a period, with the result that the bulkhead moves by a few millimetres, thus shortening or lengthening lanes on one side of the pool, relative to the other side. Alternative methods of fixing (more expensive) such as side adjustment screws or serrated locking plates would eliminate this possible source of error.

For *moveable bulkheads*, which traverse along the pool, there are always at least two fixing positions, depending upon the number of pool length configurations which have to be considered.

The usual fixing consists of some form of pin which drops into some form of socket. Where both pin and socket are parallel sided then there will be some clearance play (typically about 2 millimetres). If there is no play then there is a real risk that a small piece of grit getting into the socket will cause the pin to jam and be irremovable.

If the pin and socket are tapered then precise repeat positioning can be achieved, but there is a risk that the interference fit so formed will give rise to a greater frictional load than can be applied by hand, in order to remove the pin.

The alignment and size of the pin guide within the bulkhead is also critical, since an arrangement which makes it easy to reach and operate the pin safely often results in a significant spacing between the guide and the socket set in the pool edge wall. This can result in the pin being inserted out of vertical, thus "throwing" that side of the bulkhead by several millimetres, in an unpredictable manner.

With both types of bulkhead, any play in the fixing enables the end of the bulkhead to deflect from line when lane rope tension is applied. This has a disproportionate effect on the central deflection which occurs, since the ends act as a "free joint" rather than as a restrained one.

Lane rope loadings

There are no given requirements for lane rope tension. Manufacturer guidance is variable and the general consensus appears to be that the ropes are tightened until the tension springs start to open. The amount of tension thus depends upon the ultimate spring strength, the tool used to apply the tension and the perception (or energy level) of the person applying the load.

Typically a loading of some 2.5kN per rope may be applied. Under this sort of loading, a test measurement on a 25 metre boom showed that the following deflections of the boom occurred. Substantial strengthening works on the boom produced only relatively small improvements to the performance, suggesting that a major redesign was required if satisfactory performance was to be achieved.

distance from side wall	measured lane length	lane length with ropes	change under load
0.3	50.028	50.025	-0.003
2.5	50.028	50.017	-0.011
5.0	50.025	50.011	-0.014
7.5	50.027	50.011	-0.016
10.0	50.028	50.010	-0.018
12.5	50.030	50.011	-0.019
15	50.028	50.009	-0.019
17.5	50.028	50.012	-0.016
20	50.028	50.014	-0.014
22.5	50.028	50.019	-0.009
24.7	50.028	50.025	-0.003

The rapid build-up of displacement values is partly due to the pivoting of the boom end about the location pin. This particular bulkhead had access doors below water level at the outer edges. (Note: recent measurements on a 21m. boom of the same manufacture, but after redesign, showed that a maximum delection of 8mm. still occured with lane ropes tensioned.)

A separate report (H2106-1) has been written relating to tests carried out on a moveable boom, where the lane rope tensions were slightly changed. This document is listed under Appendix 3 Other references.

Timing pads

Timing pads normally consist of the measuring surface, some form of edge frame and a fixing mechanism. Comment has already been made on the tolerances given within the FINA rules: the pads are defined as being 10mm. plus or minus 2 mm., which means they can be between 8 and 12 mm. in thickness, but the allowance in pool design is invariably taken as being exactly 10 mm. Pads in common use vary in nominal thickness from 5 mm to 15 mm.

When the frame is considered, the distance between the front face of the pad and the back face of the frame should always be within the permitted dimensions, although this does not always seem to be the case. There is often a strengthening bar at the top, behind the main frame which holds the actual timing pad. This bar can displace the pad forwards, giving a wall to face of pad dimension of around 15mm.

The pad frames are easily damaged, either during use or when stored in an unsuitable manner. Bends in the frame can mean that part of the pad falls well outside the tolerances allowed. On the occasions when worn pads have been inspected, the distance from the most forward point on the pad to the line joining the back top and bottom edges of the frame has been found to be up to 20mm. (on a nominal 10mm. pad).

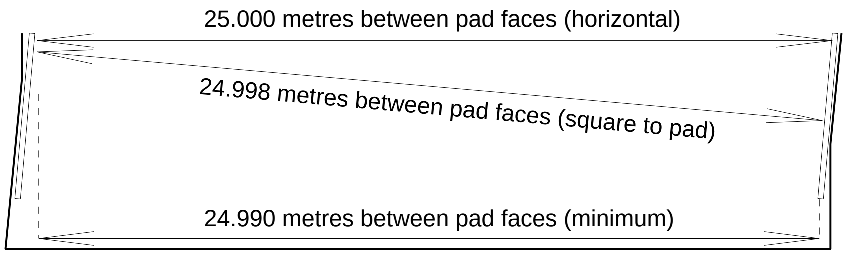
Pads need to be set truly vertical and should really be set square to the pool end wall. (Again, this is not made clear.) There will inevitably be some variation in the straightness of the pool wall. If the pads are set truly vertical and parallel then only one point on the pad is likely to be touching the wall, hence a truly minimum swimming distance will be defined, but the pad will be liable to damage every time it is hit by a swimmer.

If the pad is clamped to be tight to the wall (top and bottom of the pad) the likelihood is that it will not be vertical or square, but it will probably represent the position which least changes the wall to wall dimensions (ie. the measured distance between equivalent points on the end walls will shorten by little more than the pad thicknesses). However, this flexes the pad.

If the pad is clamped tight to the wall at the top only, it is likely that the bottom of the pad will kick out, thus significantly shortening the overall distance near the bottom of the pad.

Pads which are not vertical and square can still give swimming dimensions within the required tolerances, depending upon the shape of the wall upon which they sit. Only in the most extreme circumstances and where the horizontal distances between points on the timing pads is just on the minimum permitted dimension will the minimum distance fail to meet the requirements.

The following diagram depicts the extreme case, with timing pads which are parallel to each other and at a slope of 10mm over the height of the timing pad. The distance between vertical planes set at the foremost point on each is 24.990 metres and the shortest possible distance is just over 24.998 metres, but to utilise this shorter distance a swimmer would have to touch at the top of the pad at one end and at a point 300 mm. below water level at the other end.



On balance, it is probably best if the pads are set square and vertical, since this provides a *constant* length at any position within a single lane. However, this introduces added complications with regard to the construction phase and control of those tolerances. (It is straightforward for a builder to understand that any measured dimension must be greater than 50.000 and less than 50.020: far less easy to picture those dimensions applying to an imaginary plane positioned in a lane which has not yet been defined by visible tiles. Allowing a greater upper tolerance value would make construction work easier).

To avoid spurious readings created by water movement, the pads are set only to record on a significant impact. This is typically a load of about 2kg. When this load is applied the surface of some pads compresses significantly (up to 2mm.) Clearly, a swimmer therefore needs to achieve that compression in order to register the touch. (There are numerous documented instances of a swimmer touching, but not with sufficient force to register).

This potentially increases the lane length by up to 4mm., so the measurement of a course, with pads installed, should therefore have the pads in compression at the measurement point.

This is difficult to achieve during measuring and the exact trigger pressure would need to be known. A straightforward solution would be for the timing pad supplier to also provide a device to plug in to the pad timing socket, to indicate when the correct pressure had been applied, by displaying a light.

Measurement methodology

Types of instrument and targets have already been described, together with comment on any limitations of use. Once the most appropriate equipment has been selected and checked, it is still necessary to adopt a methodology which will enable an accurate result to be obtained.

Equipment which measures distance only needs to be restricted to measuring lane lengths between points selected on a "like-for-like" basis. This will entail measuring at a number of positions for *each* lane.

For the certification of a pool then the use of a hand-held laser device is not best practice, although such devices are suitable for subsequent checks to see if anything has changed.

Total stations have the ability to coordinate positions in three dimensions relative to the instrument location. It would therefore appear that a single instrument set-up part way along one side of the pool could be used to determine the coordinates of all the required points on the end walls and thus calculate the lane lengths.

However, this method will multiply any residual errors in the distance measuring (because the observations to each end are added together, hence the answer contains 2 times any residual).

It also results in a very significant variation in horizontal angle between points observed on the nearest and furthest lanes, which may also introduce small systematic errors. Furthermore, when the pool is filled with water at operating temperature there may be high humidity. The near lane observation lines will not pass over water at all; those to the far lane will pass almost wholly over water. Any refraction problems will therefore be different for each line.

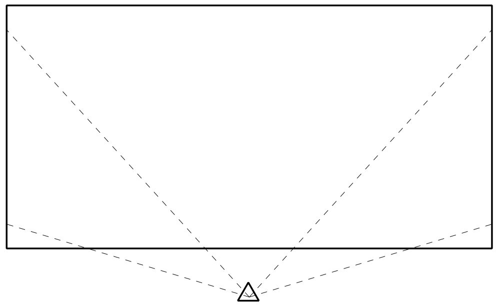
It is much better to use one, or two, set ups at each end of the pool and observe to the opposite end from each. This way any residual errors are minimised since the lane distances are calculated by subtraction of the individual observations. This method minimises any horizontal angular variations and also ensures that all lines pass over similar distances of water, so refraction problems *should be consistent*. (NOTE: on two occasions I have found significant problems due to humidity and it has been necessary to de-humidify the air down to an acceptable level).

The choice of one or two set-ups at each end depends partly upon the pool shape (long and narrow or short and fat) and partly upon whether problems such as refraction are expected. Using two set-up positions at each end reduces further any horizontal angle variations and enables an overlap of readings to be taken, thus providing further reassurance.

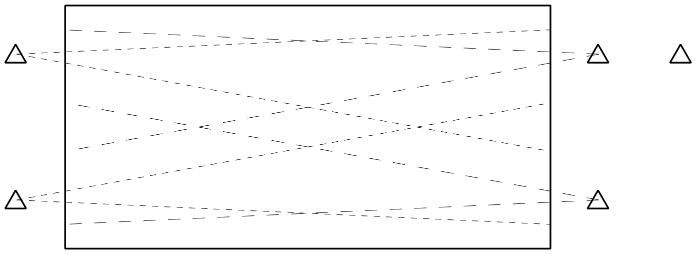
During checking, tripods and tribrach baseplates **must** remain set and untouched with just the instrument and reference target being moved. Prior to any pool observations, all available distances and angles between the tripods should be measured so that the "control network" can be assessed for accuracy. It is good practice to incorporate the three set-up checking procedure as the initial part of this work. (Positions A and B will be two of the set-ups to be used for the pool observations, with set-up C being behind one of these locations, assuming the pool is filled.)

Where a lane needs to be measured because a record has been broken then two instrument positions should be used, central on the lane concerned. If the certified length of the lane is known to be significantly greater than the minimum required then a hand-held laser, which has been checked against a known and appropriate on-site baseline, may be suitable for checking the swum length. Measurements should be taken from both ends of the lane. If there is a significant difference between the observed distance and the certified distance, then a full measurement with an electronic survey instrument ought to be carried out.

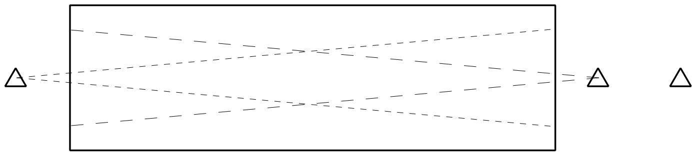
Single set-up, not recommended



Quadruple set-up, best practice



Double set-up, suitable for narrow pools



Appendix 2 Specific calculations

1500 metre length

The following calculation does not refer to specific facilities, but uses the referenced documents to show how two different pool lengths *could* be calculated under the approved regulations in the countries concerned.

Pool A

1) 10 lane pool tank with no bulkhead, originally certified under USA Swimming Rule 103.3.1 (guidance notes, part 2.1)

2) two timing pads, each of 8mm. thickness. This meets the FINA requirement FR3

3) Lane ropes attached and tensioned up to fixed sockets set in end walls.

Item 1 & 2)	overall length of measured pool with pads in place	50.029
Item 3)	pool ends are rigid	0.000
	Actual lane length	50.029
Course of 30 lengths		**1500.87**

Pool B

1) 10 lane pool tank with moveable bulkhead originally certified as being exactly 50.020 long, with bulkhead sat down central on locking pins, no timing pads or lane ropes installed. This meets the FINA requirement FR3.

2) Two timing pads, each of 12mm. thickness. This meets the FINA requirement FR3

3) Lane ropes attached and tensioned up to 3kN, in accordance with suppliers instructions

Item 1)	overall measured length of pool	50.020
Item 2)	overall thickness of pads	-0.024
	clearances due to wall irregularities	-0.004
Item 3)	take up of slack in locking pins	-0.002
	boom deflection in lane 5	-0.021
	Actual lane length	49.969
Course of 30 lengths		**1499.07**

Difference in swimming distance **1.80 metres**

Both pools A and B appear to comply with the interpretation of the relevant regulations. (I have not been able to identify any documents which show pools have been permanently de-certified following any checks made. The conclusion must be that when a check is made which apparently shows a pool to be short, then the measurement is treated as "spurious" and a new reading is taken in a manner which enables that pool certification not to be challenged).

However, note that the USA Swimming Measurement Certification form only asks for the pool to be measured to an accuracy of 5mm. It would therefore be possible for the lane length to be 50.034 giving an overall distance of 1501.02 metres, as the recorded lane length would be rounded down to 50.03 metres.

The calculation does not take into consideration use of any timing pads which exceed the approved thickness. This could shorten the 1500 metre course by a further 0.2 metres.

Appendix 3 Other references

During the preparation of this report the following documents (amongst others) have been referenced:

FINA Facilities Rules FR2, FR3
http://www.fina.org/H2O/index.php?option=com_content&view=category&id=88:facilities-rules&Itemid=184&layout=default

This is the definitive document for international swimming facilities. All other documents should be in agreement with these rules. (National organisations may exercise some local relaxations for sub-national competitions.)

ASA Guidance on measuring pools
http://www.swimming.org/asa/facilities/pool-length/

The UK national association, the ASA, provides guidelines which clarify the interpretation of FINA rules, as used in the UK. This gives the pool tank dimensions for a 50 metre pool as being between 50.020 and 50.030 metres long (incorrectly! - it means 50.000 and 50.030).

USA Pool certification documents
http://www.usaswimming.org/DesktopDefault.aspx?TabId=1756&Alias=Rainbow&Lang=en-US

This document is a very thorough presentation of guidelines for certifying pools. Much of it is good commonsense and very helpful. It mentions bulkheads and possible difficulties. The sample certificate specifically asks that the surveyor declares that he is not employed by the pool contractor (ie. no conflict of interest).

The section on total station use does not follow best practice and could give rise to significant errors. It also asks for an instrument of 2mm. accuracy and a certification to within 5mm. By comparison, for a handheld laser unit it asks for ½mm accuracy.

Harlow certificate of length
http://www.harlowpenguins.com/pool2.htm

This document shows the certificate for Harlow pool, England. The length dimensions are given only to the nearest centimetre, so it is unclear if the pool exceeds or is short of the required dimensions in millimetres. Only one dimension was given for each lane, with no indication of the lengths below water level. It appears that the pool is certified for single 10mm. touchpads.

The pool was measured with a hand-held Disto, by two persons who both appeared to be employed by the pool fitting out contractors. The professional qualification quoted was sub-degree level.

Swimming World article on Texas A&M pool being short
http://www.swimmingworldmagazine.com/lane9/news/19650.asp?q=Texas%20A&M%27s%20Triin%20Aljand%20Clips%20NCAA%2050%20Free%20Record

This article documents a rare example of a bulkhead fault being identified (on two separate occasions, so presumably adequate remedial actions were not taken) resulting in records not standing. For this pool it appears that an independent survey was carried out on a regular basis. What is not clear is how the bulkhead position was recorded as having changed by 40mm. in the course of a few days.

Masters swimming Ontario length certification
http://www.mastersswimmingontario.ca/pdf/fm.pool.length.pdf

This document is the standard form used in Ontario, Canada. It requires the pool to be measured using only a steel or a fibreglass tape. The only condition is that the tape used must be longer than the pool.

H2106-1 : Movable booms in competition pools :Investigation into distortions due to lane rope tensions

http://www.SCSsurvey.co.uk/guidance.htm