Skip Thompson's Pool Measurement Howto

Overview

USMS specifies that pools used in competition be measured to an accuracy of 1 cm for all lanes used in competition. The two methods allowed are the steel tape and the laser. Both are described.

Steel Tape

For the highest accuracy obtainable with a steel tape, five corrections are required:

1. *Standardization* – The true length of a tape will not exactly match the length marked on the tape. The Bureau of Standards offers tape standardization services. They will determine the true length of a tape for a specified temperature, tension and support condition. They will also determine the coefficient of thermal expansion. The support conditions are either *unsupported* (i.e. held at the ends only) or *supported throughout* (i.e. laying on the pool deck beside the water).
2. *Temperature* – A tape changes length in response to changes in temperature.
3. *Tension* – A tape changes length in response to the force applied at the tape endpoints. There is a device to measure this force that consists of a clamp and a spring scale.
4. *Sag* – An unsupported tape will sag and assume the shape of a catenary. The measured length will be longer than the true length.
5. *Slope* – If the measurement is not made perpendicular to the pool wall but across a diagonal, the measured length will be longer than the true length. Usually a visual sighting is enough to render this correction negligible but the user should be aware of it.

Corrections

The following formulas give corrections, C, to make to the measured length, L, to compensate for these effects:

1. Standardization: $C = L * (L_S/L_N - 1)$ where:
   - L = measured length (what you or your assistant read off the tape when you're measuring a lane),
   - L_N = nominal length (what the hardware store claims the total tape length is),
   - L_S = standardized length (what the Bureau of Standards reports the total tape length to be).
2. Temperature: $C = L * (F_t - F_s) * C_e$ where:
   - F_t = pool water temperature when measurement is made, in °C,
   - F_s = standardized temperature in °C (usually 20°C/68°F),
   - C_e = coefficient of thermal expansion (approximately 12e-6 $°C^{-1}$ for steel).
3. Tension: $C = L * (T_f - T_s) / (A * E)$ where:
   - T_f = measured tension, in N (what your fish scale reads as you measure the lane),
   - T_s = standardized tension, in N (what the Bureau of Standards used when they checked your tape),
   - A = cross sectional area of the tape (approximately 8e-7 m^2 for a typical tape).
   - E = Young's modulus of elasticity (approximately 200e9 N/m^2 for steel).
   - Here, N stands for *Newtons*, the metric unit of force. 1 lb = 4.45 N.
   - The term $A*E$ is about 160000 N for a typical steel tape.
4. Sag: $C = - (w*g)^2 * L^3 / (24*p^2)$ where:
   - w = mass density of tape in kg/m (0.006 is typical),
   - g = acceleration of gravity (9.8 m/s^2),
   - p = force applied to the endpoints of the tape (in N).
5. Slope: $C = L * (\cos\Theta - 1)$ or approximately $C = - h^2 / (2*L)$ where
   - Θ = the horizontal angular deviation from parallel to the lane centerline,
   - h = the horizontal displacement of the tape across the lane.

Example

To illustrate the calculations and to give a feel for the magnitude of the corrections, assume the tape was standardized for 20°C, tensioned to 40 lb, supported and had a nominal length of 50 m. However, the paperwork that came back from the Bureau of Standards reported the length to be 50.010 m with a coefficient of thermal expansion of 15e-6 $°C^{-1}$.

When the water temperature was 30°C (86°F), a pool measured out to 50.020m, but the tape was tensioned only 10 lb and it was unsupported. Moreover due to obstacles, the tape was offset by 0.5m at one end compared to the other end. The corrections are:

1. Standardization: 0.010 m
2. Temperature: 0.008 m
3. Tension: -0.041m
4. Sag: -0.009m
5. Slope -0.002m

The adjustments add up to -0.034m or -34 mm. The corrected length is therefore 49.986 m. The pool cannot be certified for long-course competition.

Considerations

The lengths of the pools to be measured are 25 yd, 25 m and 50 m. Since it is convenient to work with one set of units and since the conversion of yards to meters is exact, the length 22.860 m is used instead of 25 yd.

Since a tape deforms with use, it should be checked periodically with a known length to insure accuracy.

One source of error cannot easily be eliminated, but care should be taken to minimize it. A tape is suited for measurements only when used horizontally. To properly tension the tape, the measurement can only be made at the top of the pool wall. This location is usually rounded for safety reasons so the exact location of the pool wall is a matter of judgment.

The pool wall should be evaluated to see how vertical it is. This can be done with a 2 ft or longer level; an additional correction should be applied if the wall is not vertical.

A support, to be discussed in the section on lasers, can be used to surmount this difficulty.

Laser

The alternative to the steel tape is the laser. Handheld models are now available in the $300 price range that measure to an accuracy of 3mm up to 100m with the push of a button. The laser cannot be used submerged so this presents a complication. It is overcome by the construction of a support for the laser at one pool end and a target at the other end.

All pool configurations can be dealt with in one design. There are the various pool configurations that are encountered.

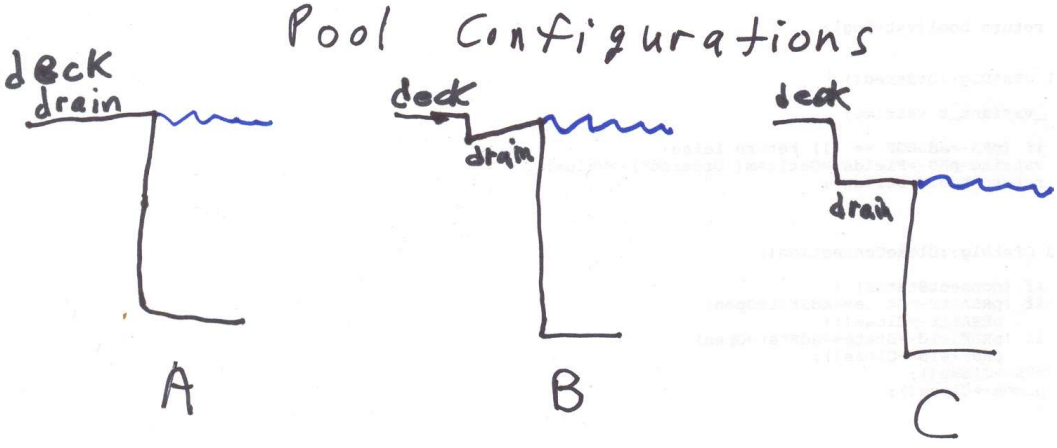

Figure 1.

Configuration A is used for some university pools, B is used in many outdoor pools and C is found in many older indoor pools. All pools have the same basic design with a drain at the top of the pool wall. There may or may not be an offset of the deck from the pool wall and the top of the pool wall may or may not be below the level of the deck. To

deal with these configurations, two supports are needed: one for the laser and one for its target at the other end. Here is a design for both.

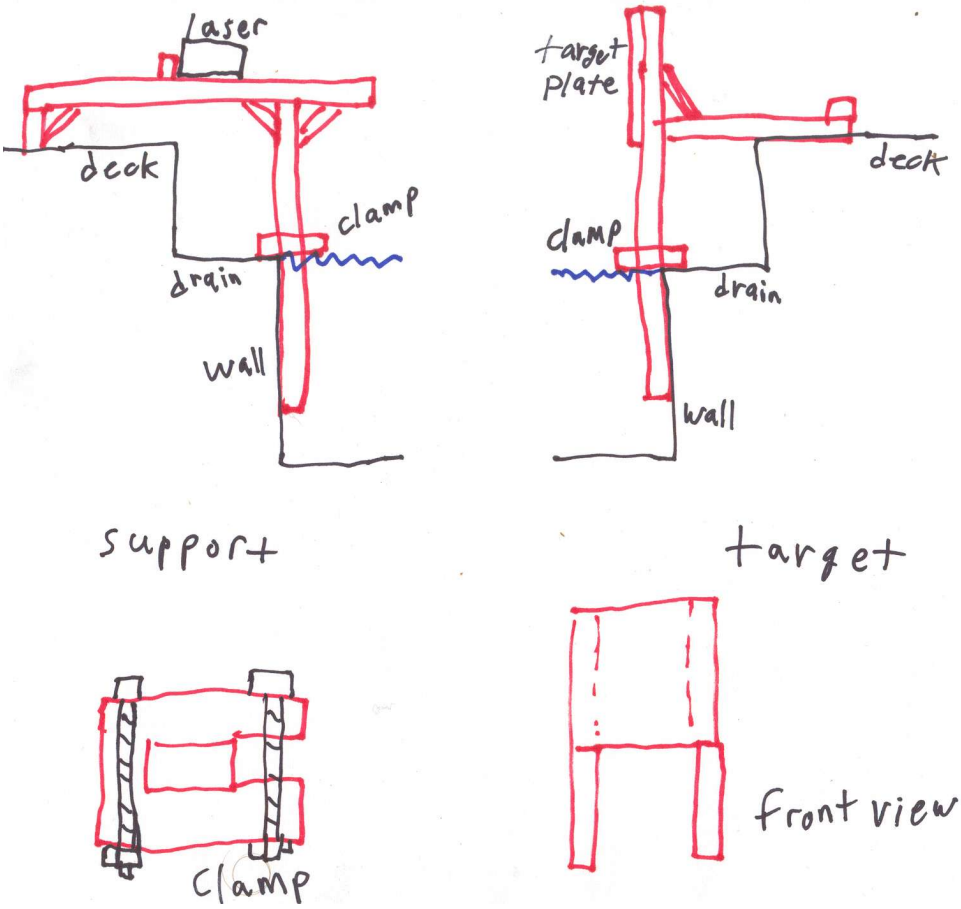

Figure 2.

The target and support can be constructed from materials as simple as 2x4 lumber and plywood. All wood pieces should be coated with at least 2 coats of satin polyurethane for waterproofing. The dimensions of the support are:

- Height of laser above the deck: 8 inches
- Distance of end of laser support piece from the wall: 16 inches.
- Distance of the vertical piece below the deck: 24 inches.

The vertical pieces must be long enough to extend a significant distance down the pool wall. The joint between the vertical and horizontal pieces must be rigid so the vertical piece is plumb when the laser level bubble is centered. Two braces are used at this joint to ensure alignment.

The target is 16x16” and is of natural wood color. This color is recommended by the manufacturer for highest accuracy and best performance. Its vertical pieces also extend 24 inches below the pool deck and the horizontal piece extends 16 inches back from the pool wall.

Note that the height of the laser is at 1/2 the height of the target so that the laser's beam is centered on the target. The back of the laser is offset from the pool wall by the thickness of the target and its vertical support piece so that no offset calculations are required.

A clamp is used to keep the support and target from falling into the pool and to hold them in the proper alignment. The same correction for slope applies as with the steel tape so that efforts to keep the target perpendicular to the laser beam are advised.

The laser accuracy is not affected by temperatures in which pools would be measured (0 to 40°C). The unit will not take readings in fog, snow or rain which interferes with the beam. In sunlight the beam cannot be seen. There are two options: One is to used a sight or align the laser by eye to take a reading. The other is make the measurements in twilight or darkness when the beam can be seen. Indoors there is no problem seeing the beam.

In 2005, Leica sold the Leica Disto Lite 5 for $379 list. The unit is accurate to 3 mm up to 100m. It used 2 AA batteries and could make up to 10,000 measurements on one set. Since then they have introduced a version 6 with improved features, lower price and higher accuracy. Other helpful equipment includes spare batteries; a pen, paper and clipboard to record measurements; and small levels for the target support. Suitable levels can be obtained for about $3. A telescopic sight is available for making measurements in the daylight on outdoor pools.

Conclusion:

Both the steel tape and laser are allowed but the laser is superior in ease of use and accuracy. Handheld lasers continue to become more affordable and a more attractive option.

Editors Note: Somehow the above document reached the desk of Mr. Griffiths, and he responded with a few criticisms and suggestions in the slightly edited email, below.

From: "Bob Griffiths" <email redacted>
Date: January 28, 2010 12:20:51 PM EST
To: "'Fred Pigott'" <email redacted>
Subject: RE: Pool measurements

Thanks Fred.

The article portion on using a steel tape is useful. Saves me looking up all the corrections. It does need to go into how to measure points on the wall.

The article on laser measuring is basically OK as far as the theory goes. It lacks a discussion on precision based on methodology. The largest potential sources of error are not discussed: the verticality of the frame and its placement. The proposed wooden rigs will probably not give the precision needed.

The variation in straightness of the proposed wooden vertical legs, particularly in a damp, immersed, environment would not give me much confidence. The most important parameter in the measurement is the verticality of the legs! The range of measurement required for a pool is 0.8 m below to 0.3 m above the water line – total of 1.1 m = 3.609' = 3' 7 5/16". If the leg is off vertical by ½ degree the potential error in location of the measuring point is 0.03 ft (about 3/8 inch). Applied at both ends this could total 0.06 ft or about ¾ inch!

The best 4 ft long carpenters levels ($50 or so at Home Depot) are accurate to about 1 in 2000 or about .03 degrees (1.7 minutes of arc). If these were used as the vertical leg the potential length error at each end would be about 0.6 mm or 2/100 inch. Using regular carpenters levels could result in errors of 4 mm at each end (about 5/32 inches at each end). Really cheap levels could result in considerably more error.

In all cases the level should be used to set the vertical leg vertical, not a horizontal portion of the rig horizontal and relying on the constructed right angle for the vertical to be accurate. Tilting the laser to read to the target, best with some sort of leveling screw, does not introduce any significant error.

I'd suggest replacing the vertical legs of the rig with 4 ft long aluminum precision levels. The "clamp" should be set so that 0.8 m (2' 7 ½") is below the water surface and with a mark set 0.3 m (1 ft) above. The laser can be set to read from beside the level.