Kayak Review Info (p.1)

Sea Kayaker
Magazine

In 1986, *Sea Kayaker* magazine established a standard for reviewing kayaks that has never been equaled. The reviews included measuring the hull to provide a basis for an objective assessment of performance characteristics. The number crunching may be confusing for many readers, but it is worth making an effort to understand the various terms involved.

The information presented here on *Sea Kayaker*'s web site is intended to augment the information provided by the reviews published in *Sea Kayaker* magazine. Here you'll find a list of the terms used in our numerical assessments of the kayaks we review. We also have a supplement for each kayak review (starting with those published in the June 2004 issue) that include tables of measurements, computer-calculated hydrostatics and metric conversions.

For the full kayak reviews, please visit the *Sea Kayaker* store's Back Issues area to order specific issues of *Sea Kayaker*.

Tech Talk

Following is a list of terms and figures we use in measuring the kayaks reviewed in *Sea Kayaker* magazine

MEASUREMENTS

(These are taken for each kayak reviewed in *Sea Kayaker*.)

Length overall: The length of the kayak from bow to stern, not including the rudder if present.

Beam: The maximum width of the kayak.

Volume: The space occupied by the entire kayak including the cockpit's interior space as if closed off by a cockpit cover.

Cockpit size: The width and length measured inside.

Cockpit heights: Measured to the inside, at the lower edge of the coaming.

Height of the seat: Measured at the lowest point. The height of the seat is a significant factor in the kayak's stability. With a foam seat or a foam pad, a bit of compression is allowed for.

Weight: The weight of the kayak as measured by *Sea Kayaker*. The weights we list often differ from the weights given by the manufacturer because of variations in the construction of individual kayaks.

HYDROSTATICS

Hydrostatics are computer-generated figures that are derived from a three-dimensional mathematical model of the kayak, created by *Sea Kayaker* from the boat to be reviewed. The hydrostatics describe the relationship of the kayak to the water it sits in. As the load in a kayak varies by its weight and distribution, so does a kayak's hydrostatics. For the hydrostatics (and for the stability data described below) we have established a standard for the weight distribution. The center of gravity of our theoretical 150-pound paddler, in a seated position in the kayak, is 10 inches above and 10 inches forward of the lowest point of the seat, approximately where the "sit-bones" of the pelvis would settle. The center of gravity of the theoretical 100 pounds of cargo is horizontally located at the kayak's center of buoyancy, so it does not change the fore-and-aft trim of the kayak. It is vertically located at an approximated center of the kayak's cross-sectional area, roughly where the cargo's center of gravity would be if the kayak were completely filled with a theoretical material of uniform density.

The hydrostatics and the stability data are calculated by the Nautilus computer program from New Wave Systems (www.newavesys.com).

Waterline length: The waterline length refers to the part of the kayak hull that meets the water's surface. If the kayak has a long sloping bow and/or stern, its waterline length will be shorter than its overall length. Waterline length is a critical element in establishing the maximum speed of the kayak. The greater the waterline length, the greater its potential for a top-end speed. Kayaks are displacement hulls—that is, they move through the water rather than skim across its surface as a planing boat does. The top speed of a displacement hull is roughly determined by the waves it creates. At maximum speed, the hull creates a wave at the bow and at the stern with a trough in the middle. Since a wave of a given distance between crests travels at a particular speed, the hull can only be as fast as the wave it creates, known as the wave of translation. Increases in speed are possible but only with dramatic increases in the energy applied to propelling the hull forward.

Waterline beam: This refers to the maximum width of the hull area that meets the water's surface. Since most kayaks have rounded or sloped sides, the waterline beam is usually less than the overall maximum beam. The waterline beam also has an impact on the efficiency in converting effort into speed. Narrower beamed boats have less distance to push the water aside and therefore create less resistance to forward motion.

The beam also has an impact on stability: The wider the boat, the more stable it will feel when you're sitting with the kayak on an even keel.

Draft: The vertical distance between the surface of the water and the deepest part of the hull.

Prismatic Coefficient: The "prism" refers to a shape that has a a cross-section identical to the widest part of the immersed hull and a length equal to the kayak's waterline length. The prismatic coefficient, or PC, is the ratio of the displacement of the kayak to the volume of the prism. A kayak that displaces 45% of the volume of the prism has a PC of 0.45. The PC is useful as a measurement of how fine or full the ends of the kayak are.

A kayak with a high PC has more volume in its ends. This increases the wetted surface, creating more drag from friction between the hull and the water. This is a significant factor in the efficiency of the hull at low speeds. At high speeds, the full ends create a long wave of translation, so a kayak with a higher PC has a potential for a higher top speed (for the application of a given amount of effort).

A kayak with a low PC has less volume in its ends. The slender ends have a lower wetted surface, contributing to more efficiency at low speeds. At higher speeds, the fine ends don't create a bow wave as far forward as a kayak with a high PC. The shorter wave of translation results in a lower top speed, but the kayak with a lower PC will have a smaller wetted surface and will therefore be easier to paddle at average cruising speeds.

Wetted Surface: This is the area of the hull's surface that's in contact with the water. At low speeds, those typical of cruising kayakers, the friction of the water against the hull is the principal factor that determines how fast a paddler will go for a given level of effort. The less the area, the less the friction, and the more efficient the hull will translate effort into forward speed. Kayaks that have the waterline length and high PC to provide the potential for high speed have comparatively large wetted surfaces. They require more effort to paddle at slower speeds.

Center of buoyancy. If you were to push down on the bow, it would sink deeper and the stern would rise. The opposite would happen if you depressed the stern. If you were to press down at a point near the middle of the kayak that would sink the bow and stern equally, you'd be at the center of buoyancy. Kayaks with a center of buoyancy forward of a kayak's measured mid-point are said to be fish form—wider at the head than at the tail. Those with a center of buoyancy aft of the measured center are called swede form. Fish-form kayaks have more buoyancy forward to lift the bow over oncoming waves and resist "pearling" (diving down) when surfing down a wave face into the trough between waves. Swede-form kayaks can be less "sea kindly" but have a greater potential for speed. Flat-water sprint kayaks have swede-form hulls. A kayak with its center of buoyancy at the measured middle of the boat is called symmetrical.

The center-of-buoyancy percentage figure given in each kayak review describes the location as a percentage of the overall length, measured from the bow. A percentage under 50% is fish form, at 50% is symmetrical and over 50% is swede form. The center of buoyancy changes with the load a kayak is carrying. We provide a figure for the kayak carrying a 150-pound paddler and 100 pounds of gear, distributed to maintain the trim of the kayak.

(NOTE: The following hydrostatics—block coefficient, effective waterline length, and pounds-per-inch immersion—are not included in the print reviews in the magazine, but are included here as supplemental information. Visit our Kayak Reviews under the Resources link in our tool bar.

Block coefficient: The "block" refers to a rectangular solid with a width equal to the maximum width of the kayak's immersed hull, a length equal to the waterline length and a depth equal to the draft. The block coefficient is a ratio of the volume of the immersed portion of the hull to the volume of the block. The block coefficient correlates with a kayak's tracking ability, but it is listed here because it is a factor in the resistance prediction calculations described later.

Effective waterline length: Waterline length is an important part of the equation in predicting speed/resistance figures. Variations in the shape of the waterline however, especially at the bow, can create different wave-forming characteristics. Some of these differences are accounted for with the prismatic coefficient, but we've added another measurement to refine the accuracy of the predictions. If a kayak has a very sharp bow, often accompanied by a concave curve in the waterline, the formation of the bow wave occurs farther aft than it would on a boat with a fuller bow and convex waterlines. The effective waterline length is derived from the plotted curve of areas for a kayak. Any narrow extensions at the bow are subtracted from the waterline length, leaving an effective waterline length that more accurately describes the formation of the wave of translation.

Pounds to immerse one inch: As you load cargo aboard a kayak, it settles deeper in the water. The pounds-to-immerse-one-inch figure shows how much weight it would take to push the kayak an additional inch deeper in the water. A kayak with flaring sides and a raked bow and stern is going to create a larger "footprint" in the water as it is loaded and will take more weight to sink another inch than a kayak that has more vertical sides and ends.

SPEED VS. RESISTANCE

The two sets of numbers provided in each kayak review (Winters/KAPER and Broze/Taylor) offer two mathematical predictions of resistance at six given speeds. The resistance is listed in pounds and is shown to hundredths to differentiate figures we had previously rounded to tenths. Speeds are listed at one-knot increments, with the exception of the listing at 4.5 knots. With most kayaks, the transition from 4 to 5 knots marks the transition between skin friction being the most significant factor and wave-induced drag being the most significant factor. A fit paddler can maintain a cruising speed at 3 pounds of drag. Only a few can work against 5 pounds of drag for long distances. Paddlers who don't have the strength or the need to paddle at high speeds should consider kayaks that work well within their typical speed range. Paddlers who spend most of their time at cruising speeds of 3 to 3 1/2 knots should focus their attention on boats with a low wetted surface and low PC.

Over the years, *Sea Kayaker* has presented several ways to provide objective measurements of a kayak's potential for speed. The initial idea for measuring how much force was required to move a kayak thorough the water at a given speed was to tow a kayak with a line tied into a scale. The force measured by the scale would be recorded along with the speed at that moment. While the idea is sound in theory, it is difficult on a practical level.

Water conditions in the out-of-doors have a number of variables—temperature, waves, currents, etc.—that make it difficult to take consistently accurate measurements. Fortunately, the early kayak tests included towing tank tests conducted by BC Research (www.vizonscitec.com) at their Ocean Engineering Center. The tests were conducted in a 220-foot-long tank in a controlled environment that provided the accuracy required to detect the significant differences between kayaks. The kayak reviews including the tank tests were published from Fall '86 through Spring '87. While towing-tank tests are the preferred way of assessing resistance to travel through the water, they are prohibitively expensive.

When the kayak tests were reestablished in our Winter '93 issue, the Speed-vs.-Resistance figures were calculated by a relatively simple formula provided by Richard Spilman, a naval architect.

Residual resistance = $21.541\ (V/\sqrt{L})^4 - 58.373\ (V/\sqrt{L})^3 + 59.124\ (V/\sqrt{L})^2 - 25.828\ (V/\sqrt{L}) + 4.12$
Frictional resistance $=[0.00871 + 0.053/(8.8+L)]S*V^{1.825} + 0.04$

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Total resistance = Residual resistance + Frictional resistance
V = Speed in Knots
L = Waterline length in feet
S = Wetted surface in square feet

Later improvements were made to the formula by Matt Broze of Mariner Kayaks (www.marinerkayaks.com) and John Winters (www.greenval.com/jwinters.html), a kayak and canoe designer working with QCC Kayaks (www.qcckayaks.com). Broze's calculations use a series of graphs—the Taylor Series—that were derived from tow-tank testing of ship models. Winters' figures are calculated by the KAPER program, a computer program he developed for predicting resistance. The updated formulas incorporate more of a kayak's hydrostatics and are adjusted to make the results predicted more closely coincide with the results measured with the data gathered from the 12 kayaks that were tested in the towing tank.

Keep in mind that these Speed-vs.-Resistance figures are derived from standardized tests based on a constant straight-line force applied to the kayak. In actual use, kayaks are propelled by an intermittent force applied on alternate sides of the kayak. The act of paddling a kayak generates yaw: the bow swings back and forth, away from the side where the paddle blade is in the water.

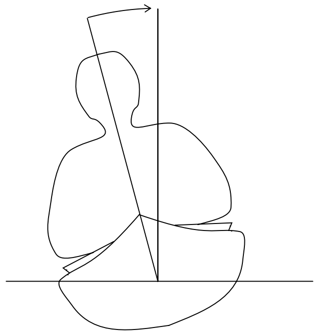
The towing tank tests were conducted both in flat water and in waves. The results recorded in waves showed dramatic differences between kayaks. While this might seem to be worthwhile data, the performance of the kayaks in waves was closely tied to the relationship between the wavelength in the tank and the length of the kayak. Selecting a few arbitrary standard wavelengths as standards would have given some kayaks an advantage and others a disadvantage.

Most of the towing tank trials were run with rudders retracted (if present). (No kayaks equipped with skegs were tested.) In the trials run with rudders deployed, it was noted that the rudder created a significant amount of drag. *Sea Kayaker* decided not to use the figures recorded with rudders. Since rudders (and skegs) help counter yaw and can be very effective in keeping a boat on course while the paddler focuses on straight-ahead paddling, the benefit of rudders in real-life conditions could outweigh the disadvantage of the drag they create.

Righting Moments (Fixed weight)

The graph depicting Stability Curves includes four curves. The two lowest curves describe the stability of the kayak with a 150-pound paddler and a 250-pound paddler with no cargo in the kayak. The two higher curves have the same paddlers in place but with 100 pounds of cargo aboard. The cargo has the effect of increasing the kayak's stability because the righting moment (the force acting to right the kayak) is based on the center of gravity of the paddler, the kayak and the cargo combined. Since the cargo's center of gravity is lower than that of the paddler (10 inches above the lowest point of the seat), the combined center is lower than that of the paddler in the kayak alone.

In *Sea Kayaker*'s tank tests, stability was measured by putting the kayak in a long, water-filled tank and attaching the bow to an apparatus that used a scale to measure the righting force. Concrete weights were used to simulate the weight of the paddler. It was a long and arduous process, made progressively less pleasant in the summer months by the growth of algae in the tank. When we switched to using a hull-design computer program, we could acquire the stability data with more accuracy and less effort.



Righting Moment:
A "moment" is a measure of force applied to a lever arm. Just as a torque wrench applies a rotational force measured in foot pounds, a hull exerts a rotating force to resist leaning.

In each review, the test paddlers assess the kayak's initial stability—how stable it feels while sitting at rest (without listing) on the water. The secondary stability is the force with which the kayak resists setting the kayak on edge. On the graph, the initial stability is represented by the rise of the curve from the zero point. The steeper the curve, the higher the primary stability. The secondary stability is represented by the upper part of the curve, but only by the portion to the left of the apex. The higher the apex, the more resistance you would feel when setting the boat on edge. The farther the curve's apex is to the right, the greater degree of heel you could apply to the kayak before the righting force is diminished.

To the right of the curve's apex, the kayak enters angles of heel that present diminishing amounts of righting force for increases in angle. While a kayak can be balanced at these angles, the slightest movement can cause them to capsize. When we used the water tank to measure righting forces beyond the apex of the curve, we were lucky to get the kayak to balance at all and had to be ready to catch it if it suddenly started to roll.

If the apex of the curve is broad, the kayak will enter the area of instability gradually and not catch a paddler by surprise. A sharply peaked curved indicates a kayak that may suddenly and unexpectedly capsize.

The stability characteristics that the graph provides are static—that is, they represent how the kayak would respond to a paddler sitting in the kayak motionless, spine and hips locked. In practice, we respond to every motion of the kayak. Our hips may be locked into the kayak, but our spine flexes. While the graphs provide some objective data useful in making some comparisons between boats, they do not take into account the dynamic factors presented by a kayaker responding to the motion of the boat in the water.

In a few cases, kayaks have had stability curves that start at the zero point and scarcely rise above the baseline before sloping downward. While this represents a lack of static stability, our reviewers did not capsize immediately upon getting aboard. The subtle adjustments to balance they made while sitting in the kayak made it possible to have the subjective feeling of a functional degree of stability. **SK**