Hull Speed[1]
How Fast Can A Boat Go?

When underway a boat generates a considerable amount of kinetic energy (E), defined as $E = ½mv^2$, where m = mass in kilograms and v = velocity in meters per second. Note that kinetic energy is proportional to mass but increases with the *square* of the boat speed.

For example, *Myeerah*, a 27-meter boat weighing 268,000 pounds has a mass of 121,820 kilograms. At six knots (11 km/hr) it travels 3.055 m/sec, generating kinetic energy of 568,470 Joules; but at 12 knots (6.11 m/s) the energy is 2,273,900 Joules.

This energy is imparted to the medium through which the boat travels, normally water, but in the case of an icebreaker, ice. The result is a wave that travels outward—and underneath—the boat. The velocity of that wave is $\nu = \sqrt{(g\lambda/2\pi)}$, where λ is the wave length (say, crest to crest) in meters and g is the gravitational constant ($9.8\ m/s^2$). Thus, a boat traveling so as to generate a wave with a 6 meter length will find that the wave travels sternward at 2.6 m/s (9.36 km/hr). One would see the transverse rollers that come from under the stern moving sternward at 9.36 km/hr absolute (ground speed), and at v + 9.36 kmh relative to the boat's stern.

If the boat has, say, a waterline length of 20 meters, there will be three crests along its length—one is the bow crest, the others are "echos" from the bow crest. This includes the forward motion of the boat: as the crests move sternward at 2.6 m/s the boat is advancing at 3.06 m/s. The first crest will arrive 5.66 meters behind the bow, the second at 11.32 meters, the third at 16.98 meters. Subsequent crests are seen as the wake at the stern.

These crests add to the water resistance ("drag") and slow the boat as waves under the boat create frictional forces.

Measuring Hull Speed

In effect, the boat is not outrunning its wake, so it experiences continuing water resistence. This drag is minimized when the wave length is equal to the length of the boat at the waterline, i.e, $\lambda = L$, or, stated differently, when the boat is advancing at velocity $v = \nu$, i.e., the wave velocity equals the boat's speed. In this case there will be two wave crests along the hull: the bow wave and the other at the stern.

---

[1] We use the MKS system of units: **M**eters (distance), **K**ilograms (mass), **S**econds (time); this is also called the Standard International system (SI). In this system, velocity is meters per second (m/s) or kilometers per hour (kmh) and energy is in Joules. One alternative is the "English" PFS system, which uses **P**ound (weight), **F**oot (distance), and **S**econd (time) as the units. Velocity is feet per second or miles per hour, energy is in dynes.

Recall the definition given above of the wave velocity: $\nu = \sqrt{(g\lambda/2\pi)}$. *Hull speed* is achieved when $\lambda = L$, in which case $v = \nu$ and hull speed is $v = \sqrt{(g/2\pi)}\sqrt{L} = 1.25\sqrt{L}$ meters per second (using the MKS system with $g = 9.8m/s^2$ and L in meters).

Converting v in meters per second to knots[2] (nautical miles per hour) gives hull speeds of

Hull Speed Definitions

$v = 2.43\sqrt{L}$ knots in the MKS system (L in meters, $g = 9.8m/s^2$)

$v = 1.34\sqrt{L}$ knots in the PFS system (L in feet, $g = 32.15\ ft/s^2$)

Consider *Myeerah*: With a length of 78.4 foot (23.76 meters) at the waterline, her hull speed is 11.9 knots ($= 1.34\sqrt{78.4} = 2.43\sqrt{23.76}$) or 13.7 statute miles per hour.

Exceeding Hull Speed

Hull speed is a theoretical speed that can be exceeded, but only at great fuel inefficiency an engine wear. For example, military vessels are designed to exceed hull speed by using multiple high powered engines. A 400-foot naval destroyer has a hull speed of 26.8 knots, but reports put its top speed at over 40 knots!

Effective speeds can also be increased by hull design. Hull speeds are designed for displacement boats. Boats with semi-dispacement hulls designed to give lift will exceed hull speeds somewhat, and boats with planning hulls easily exceed hull speed by riding on the bow wave.[3]

When a displacement boat exceeds its hull speed it is outrunning its bow wave. The effect is to raise the bow wave significantly as the bow rides up. At the same time the second crest is emerging behind the stern, allowing the stern to squat in or near a trough as it tries to run uphill over its bow wave.

[2] One nautical mile is 6080 feet or 1.15 mile statute miles A knot is, therefore, 1.15 statute miles per hour.

[3] A single-engine 36-foot Hinckley Classic Picnic Boat has a hull speed of 8 knots but a top speed of 25-30 knots.