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

The concept of *hull speed* has been created to define the fastest efficient speed of a displacement vessel.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, or 11 kilometers per hour (kmh), it travels 3.055 m/sec, generating kinetic energy of 568,470 Joules J). At 12 knots (6.11 m/s) the energy is 2,273,900 Joules, equivalent to almost 2200 BTUs!

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 $\nu = \sqrt{(g\lambda/2\pi)}$ m/s, where λ is the wave length[2] (say, crest to crest) in meters, g is the gravitational constant (9.8 m/s^2), and ν is in meters per second.

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 kmh). One would see the transverse rollers that come from under the stern moving sternward at 9.36 km/hr. 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 absolute (sea surface speed, and at v + 9.36 kmh relative to the boat's stern. The second crest is at 11.32 meters, and the third at 16.98 meters. Subsequent crests are seen as the wake at the stern. See Figure 1.

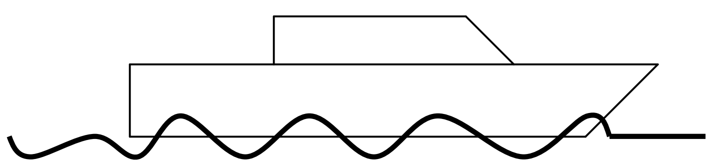

Figure 1
Boat speed less than hull speed

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[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. An 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.

[2] This is the deep water equation for wavelenth. Shallow waters give lower lengths.

Measuring Hull Speed

In effect, the boat experiencing wake drag is not outrunning its wake. This drag is minimized when the wave length is equal to the length of the boat at the waterline, i.e, when $\lambda = L$, 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 only two wave crests along the hull: one at the bow and the other at the stern, as in Figure 2.

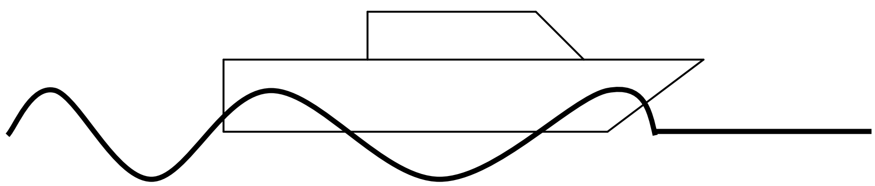

Figure 2
Boat speed equals hull speed

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 $v = \nu$. Thus, hull speed is $v = \sqrt{(g/2\pi)}\sqrt{L} = 1.25\sqrt{L}$ meters per second (using the MKS system with $g = 9.8 m/s^2$ and L in meters). Converting v in meters per second to knots[3] (nautical miles per hour) gives hull speeds of

Hull Speed Definitions

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

$v = 1.34\sqrt{L}$ knots in the PFS system (L in feet, $g = 32.2\ ft/s^2$)

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 and 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! This is achieved by

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

massive horsepower driving the boat up on to of its bow wave. Through sheer power a displacement hull is forced to plane.

When hull speed is exceeded the boat rides as in Figure 3. The wavelength exceeds the boat length, the bow wave rises because the water can't get out of the way fast enough, and the boat loses support at the stern. As a result the boat squats as it runs uphill against its bow wave, dramatically increasing water resistence.

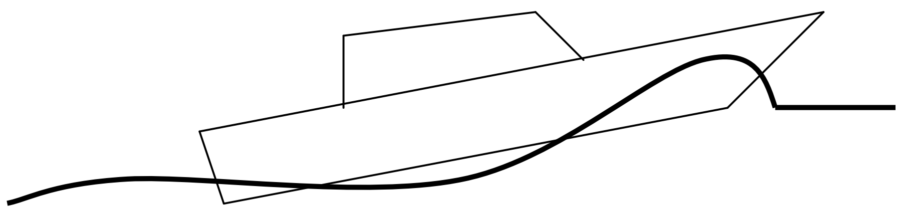

Figure 3
Boat speed exceeds hull speed

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 (such as *Myeerah*) will exceed hull speeds somewhat, but any small gains in speed are at considerable cost. Boats with planning hulls easily exceed hull speed by riding on the bow wave. For example, A single-engine 36-foot Hinckley Classic Picnic Boat has a hull speed of 8 knots but a top speed of 25-30 knots. At cruising speed the bow wave is under the mid-point of the boats length.